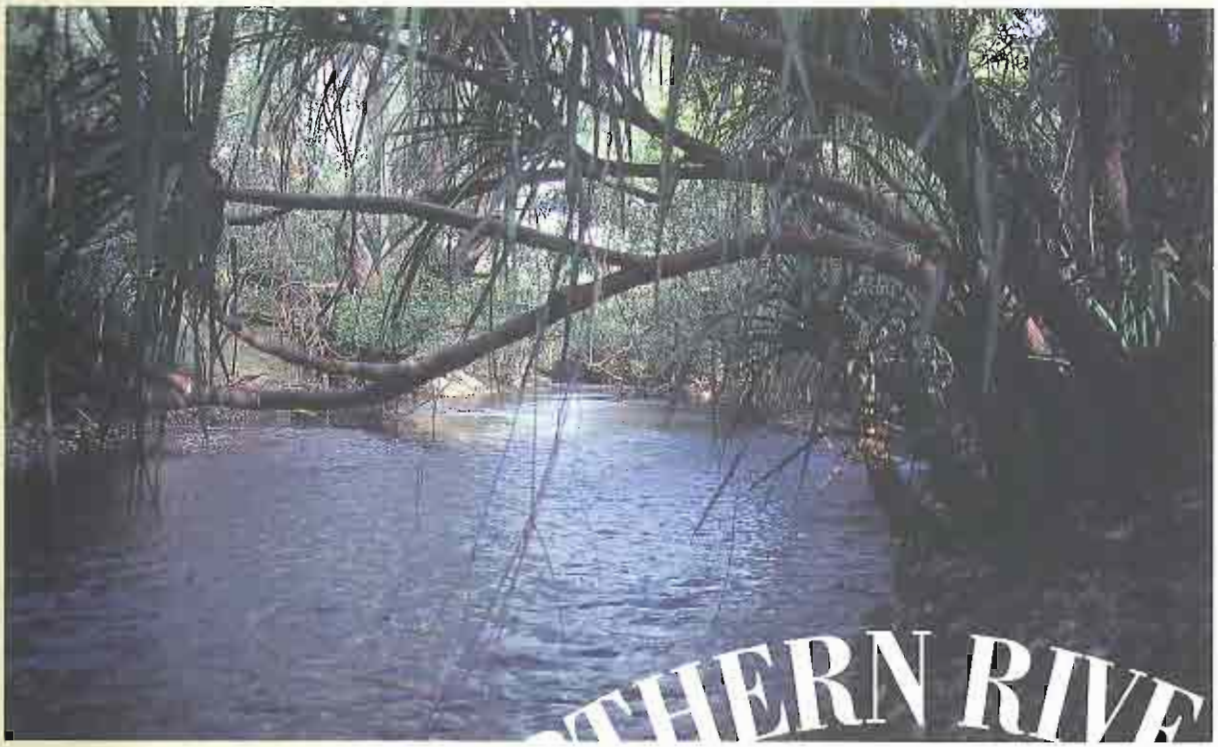
WATER
AND RIVERS
COMMISSION



THE STATE OF THE NORTHERN RIVERS

WATER AND RIVERS
COMMISSION

HYATT CENTRE
3 PLAIN STREET
EAST PERTH
WESTERN AUSTRALIA 6004

TELEPHONE (08) 9278 0300
FACSIMILE (08) 9278 0301

Cover Photograph: A pool on the Carson River in the Timor Sea Drainage Division within an area of vine thicket.

THE STATE OF THE NORTHERN RIVERS

A report designed to inform the community of the state of Western Australia's rivers in the Indian Ocean, Timor Sea and Western Plateau drainage divisions

WATER
AND RIVERS
COMMISSION

Published by the

WATER AND RIVERS COMMISSION

HYATT CENTRE
3 PLAIN STREET
EAST PERTH WA 6004

TELEPHONE (08) 9278 0300
FACSIMILE (08) 9278 0301

Publication No. WRAP 10
Water Resource Allocation and Planning Series
ISBN 0 7309 7388 3

Tidal mudflats and floodplain of the Lower Ord River.

STREAMLINE Abstract

This report describes the State's northern rivers according to river types based on length, flow regime and the type of vegetation cover in the areas they arise from and flow through. The report briefly covers the history of land and river management and pressures affecting these environments. It identifies key forms of degradation found in some rivers and the measures that are needed to restore degraded rivers and to protect those rivers that remain unspoilt.

Rivers; habitat; vegetation; biota; ecosystems; flow; erosion; siltation; dams; salinisation; eutrophication; pollution.

Title page photograph: The Berkeley River near its mouth.
(For acknowledgment of photographs see inside back cover.)

Printed on recycled stock: Monza Satin 100% recycled.

December 1997

FOREWORD

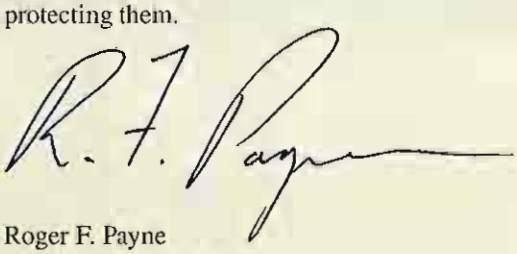
WHILE MANY PEOPLE may be aware of the general environmental pressures facing the rivers of Western Australia — such as salinity and nutrient enrichment — a comprehensive picture of the condition of the State's rivers has not been available. In June 1992, the Western Australian Water Resources Council published a report on the state of the rivers of the South West. It covered the rivers of the South West Drainage Division, one of the four surface water hydrology divisions into which the State has been divided. This present report covers the other three, namely the Indian Ocean, Timor Sea and Western Plateau drainage divisions.

The State of the Northern Rivers Report is not intended to be solely a detailed scientific work. Rather, the report provides commentary on the status of our northern rivers to help develop a greater public awareness and understanding of the condition and importance of those rivers.

This report describes the rivers according to river types based on length, flow regime and the type of vegetation cover in the areas they arise from and flow through. The report briefly covers the history of land and river management and pressures affecting these environments. It identifies key forms of degradation found in some rivers and the measures that are needed to restore degraded rivers and to protect those rivers that remain unspoilt.

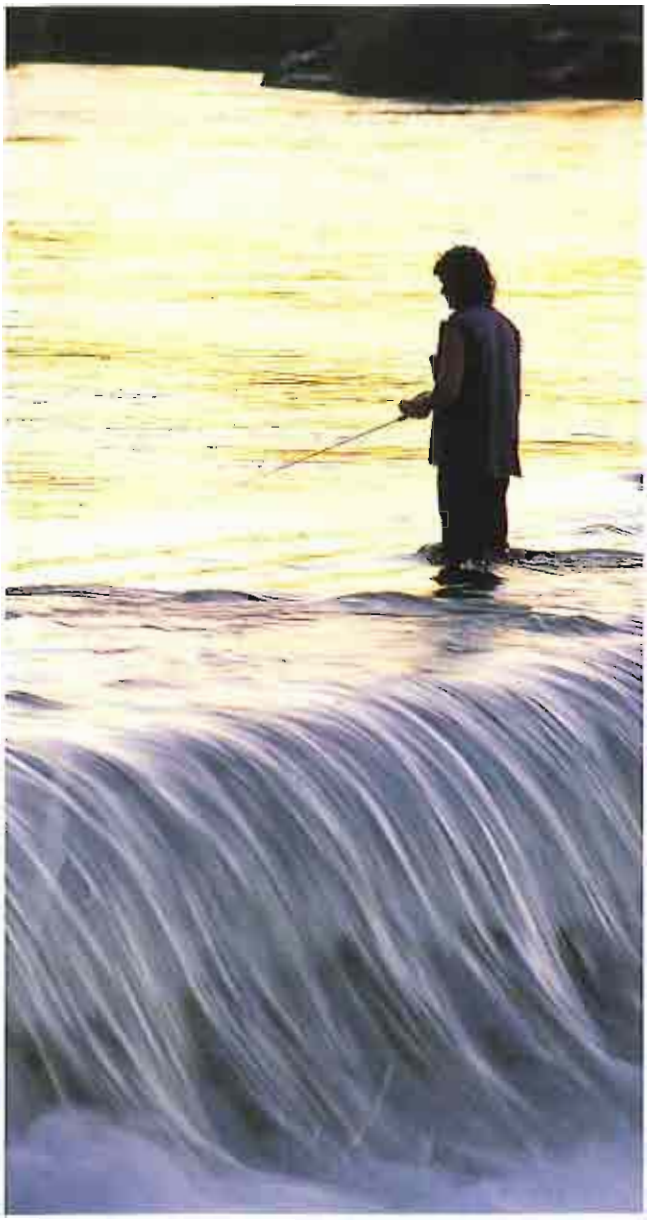
The illustrations and maps in this report show clearly the degradation occurring in many of our rivers. They also show the great range and beauty of our national riverine heritage, and demonstrate that there is much left that is worth protecting.

The task of ensuring that the rivers of the State are well managed and protected is the responsibility of the Water and Rivers Commission, which was formed in January 1996. Ultimately, however, much of the responsibility lies with the owners and managers of the land through which our rivers pass, and all of us who live within catchments that contribute to their flows. As we become aware of the plight of our rivers, there is a need for each and every resident of Western Australia to play their part in preserving and protecting them.



Roger F. Payne
CHIEF EXECUTIVE

CONTENTS



TABLES

Fishing at Ivanhoe Crossing, Kununurra: Beware of crocodiles (facing page).

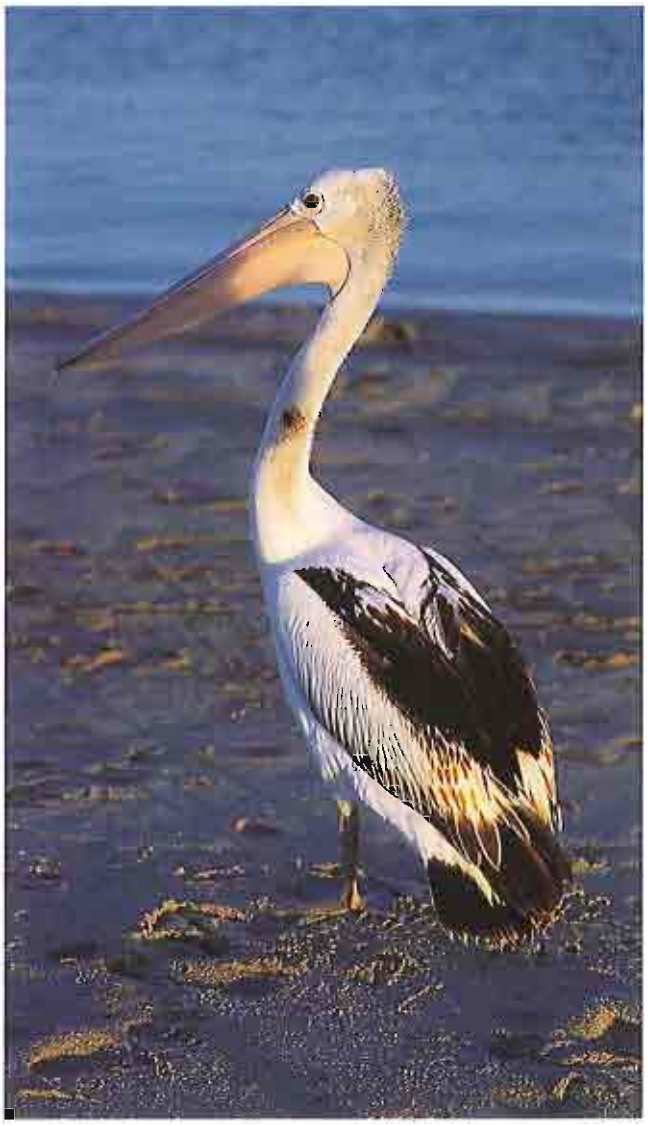
Canoeing on the Murchison River.

FIGURES

ACKNOWLEDGMENTS

THIS REPORT IS partly based on a study and draft report by Esther Skitmore and Associates to the Western Australian Water Resources Council, and on reports by Peter Williams and Luke Pen to the Australian Heritage Commission. The report was written primarily by Jillian Harris, and the figures prepared by Gerry McCourt, under the direction of Peter Williams of the Policy and Planning Division of the Water and Rivers Commission.

Special acknowledgment is due to Donna Forcellati for word processing, Glyn Kernick for layout and design, and to all the photographers whose collective work comprises the most important and graphic component of the document.



Australian Pelican
at the mouth of
the Murchison River.

INTRODUCTION

THIS REPORT briefly describes the state of all the rivers of Western Australia outside the South West Drainage Division or Region. It covers the other three surface water drainage divisions into which the State has been divided, namely the Indian Ocean, Timor Sea and Western Plateau divisions, as shown in Figure 1. Except for the north of the Timor Sea Drainage Division, most of the area covered is arid and rivers are ephemeral, flowing only following infrequent heavy rainfall events. Despite this, the rivers are vital components of the landscape and constitute a rich and varied riparian zone and wildlife habitat.

Much of the report is about the state of the land and what is happening to fix land degradation problems. This may seem strange for a report that claims to be about rivers, but rivers are a part of the landscape. Their health is intimately linked with the health of the land. Efforts to repair the land have positive impacts upon the rivers.

The report is written in a series of short sections, each containing numerous figures, tables and illustrative photographs. The aim was to produce a document that provides ready access to information on specific topics and areas, and to present a clear, easily assimilated and readily understood picture of the current situation.

The report is partly based on a consultant's study commissioned in 1993 by the Western Australian Water Resources Council, the results of which are contained in an unpublished report. It is partly based, also, on a study by the Water and Rivers Commission, contributing to the Australian Heritage Commission's Wild Rivers Project, aimed at identifying all rivers in pristine and near-pristine condition throughout Australia.

The State of the Northern Rivers is a companion document to *The State of the Rivers of the South West*, published by the Western Australian Water Resources Council in June 1992.

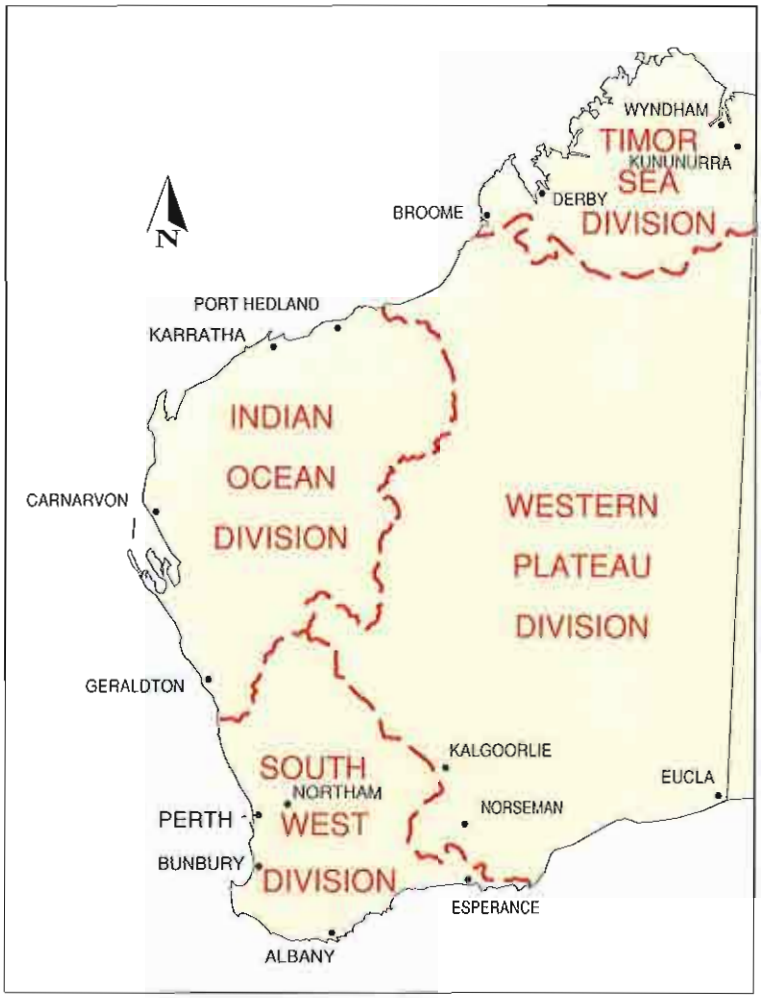


Figure 1: Drainage divisions of Western Australia.

THE LIE OF THE LAND

Indian Ocean Drainage Division

The Indian Ocean Drainage Division covers an area of 518 000 square kilometres. About two thirds of the division lies within an extensive Precambrian shield, sub-divided into a series of fractured rock provinces. The remaining third makes up a wide coastal plain, of which a small portion comprises the northern extremity of the Perth Sedimentary Basin, and the remainder the Carnarvon Sedimentary Basin (Figure 2). Drainage in the north of the division centres around

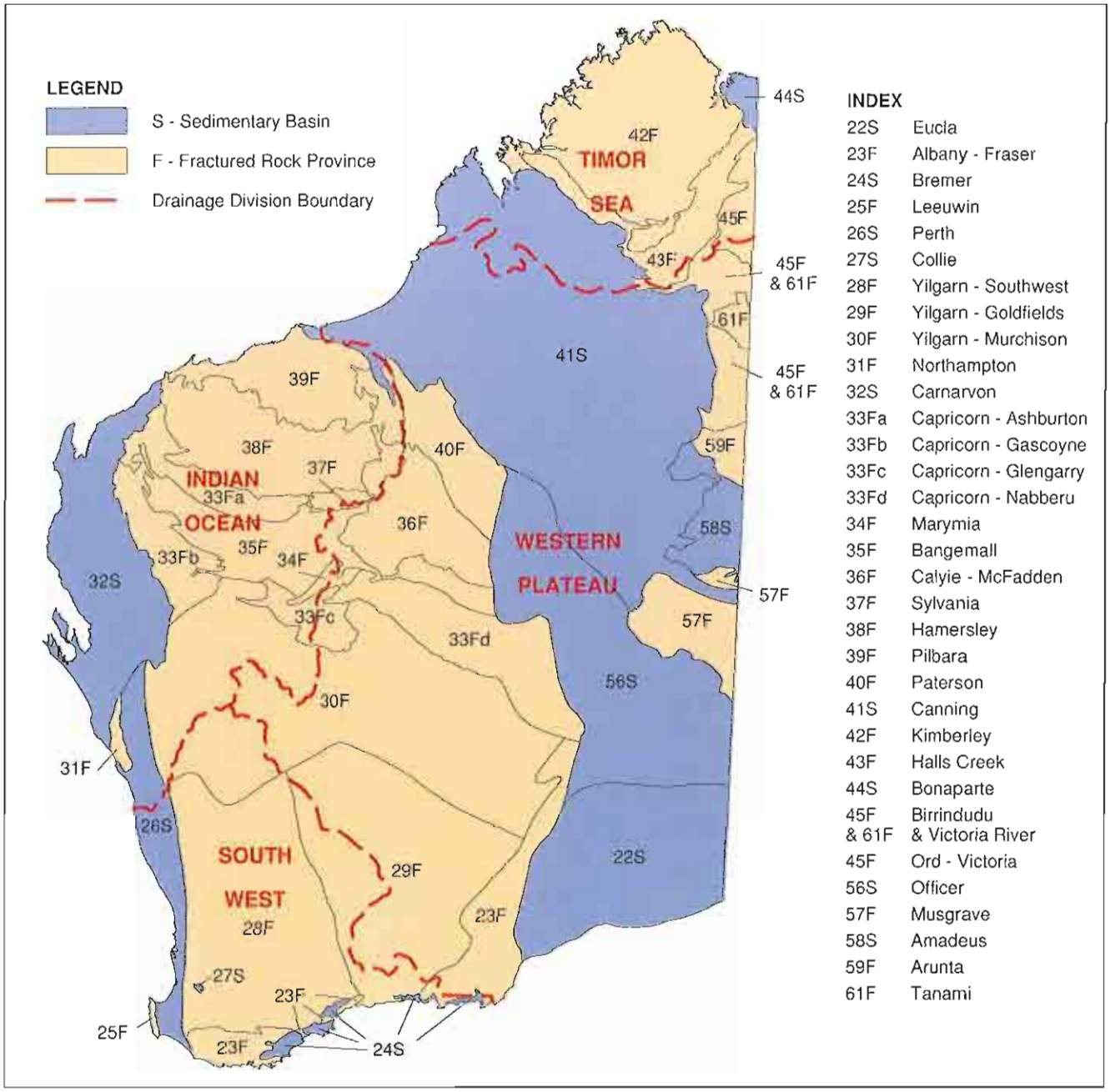
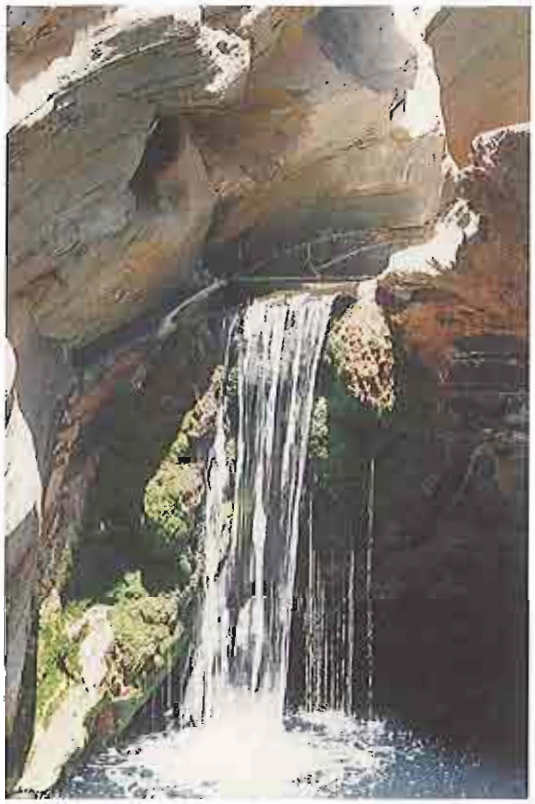


Figure 2: Geological provinces of Western Australia.



The Millstream Spring feeds Millstream itself, shown here, and a series of pools along the Fortescue River (above).

Waterfalls, such as this in the Karijini National Park, are a feature of the Indian Ocean Drainage Division (top left).

Rivers cut through the ranges, forming spectacular gorges, such as Kalbarri Gorge on the Murchison River.

the Hamersley and Chichester ranges (Figure 3). Rivers have cut through the ranges, often forming spectacular gorges, then cross the wide coastal plain to the ocean. Many of the division's rivers disappear before reaching the ocean, into coastal lagoons such as Lake MacLeod, into large expanses of tidal flats, or simply into the deep coastal basin sediments.

The climate of the Indian Ocean Drainage Division is semi-arid to arid. The northern portion is sub-tropical with most rain resulting from cyclones. Rainfall averages between 250 and 400 mm a year, arriving mostly between January and March. September to November is the driest period (Figure 4). Streamflow reflects the rainfall. It is highly variable, erratic and occurs for only short periods of time. The southern portion of the division has a Mediterranean climate, with most rain falling between May and August. Generally rainfall is below 250 mm, except in the extreme south where it reaches about 500 mm. The central portion of the division is too far south to experience much from cyclonic rains, and too far north for rainfall resulting from winter depressions. As a result it experiences extended periods of drought.

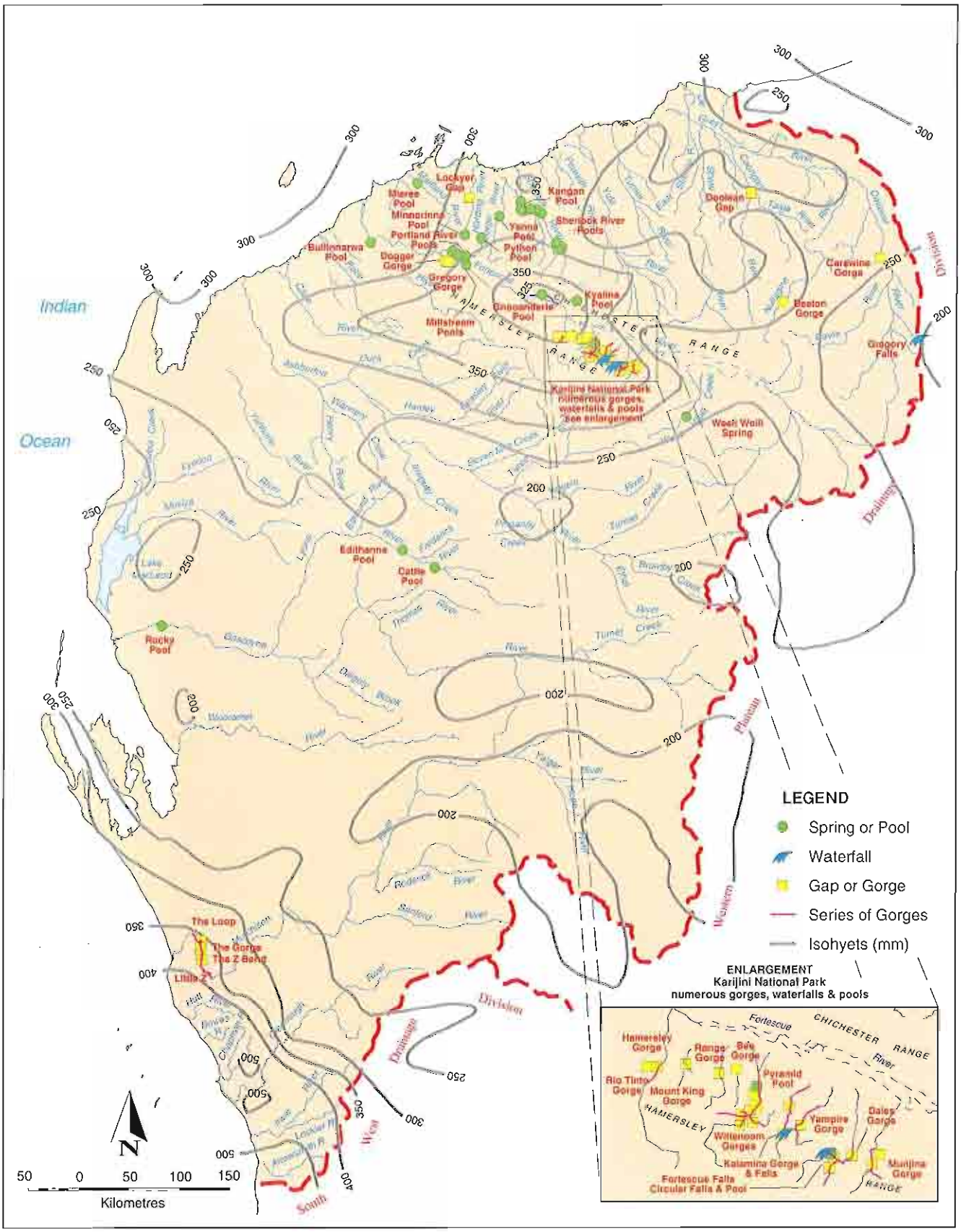


Figure 3: Indian Ocean Drainage Division — River system and major riverine landform features.

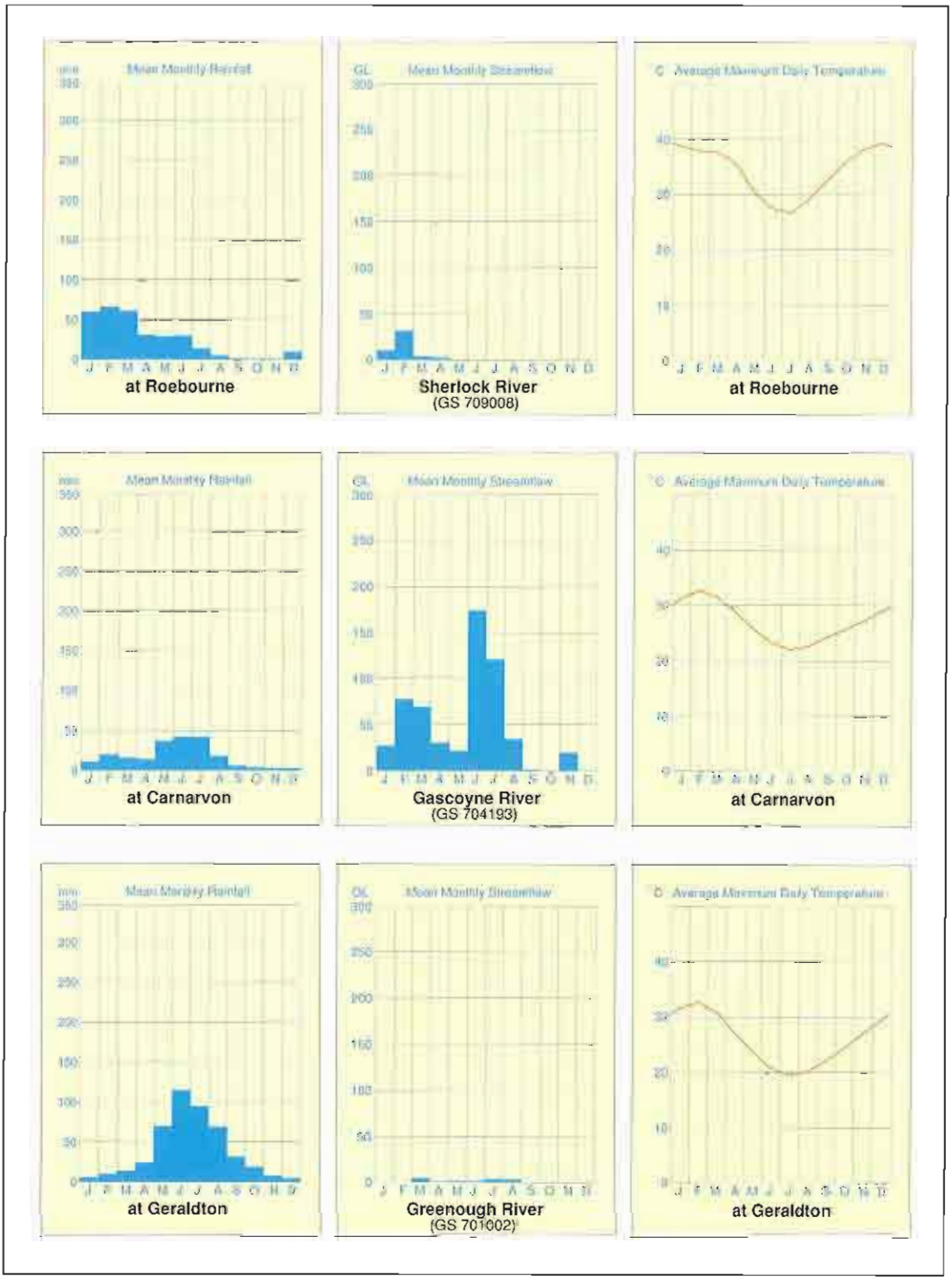


Figure 4: Indian Ocean Drainage Division — Monthly rainfall, streamflow and temperatures.

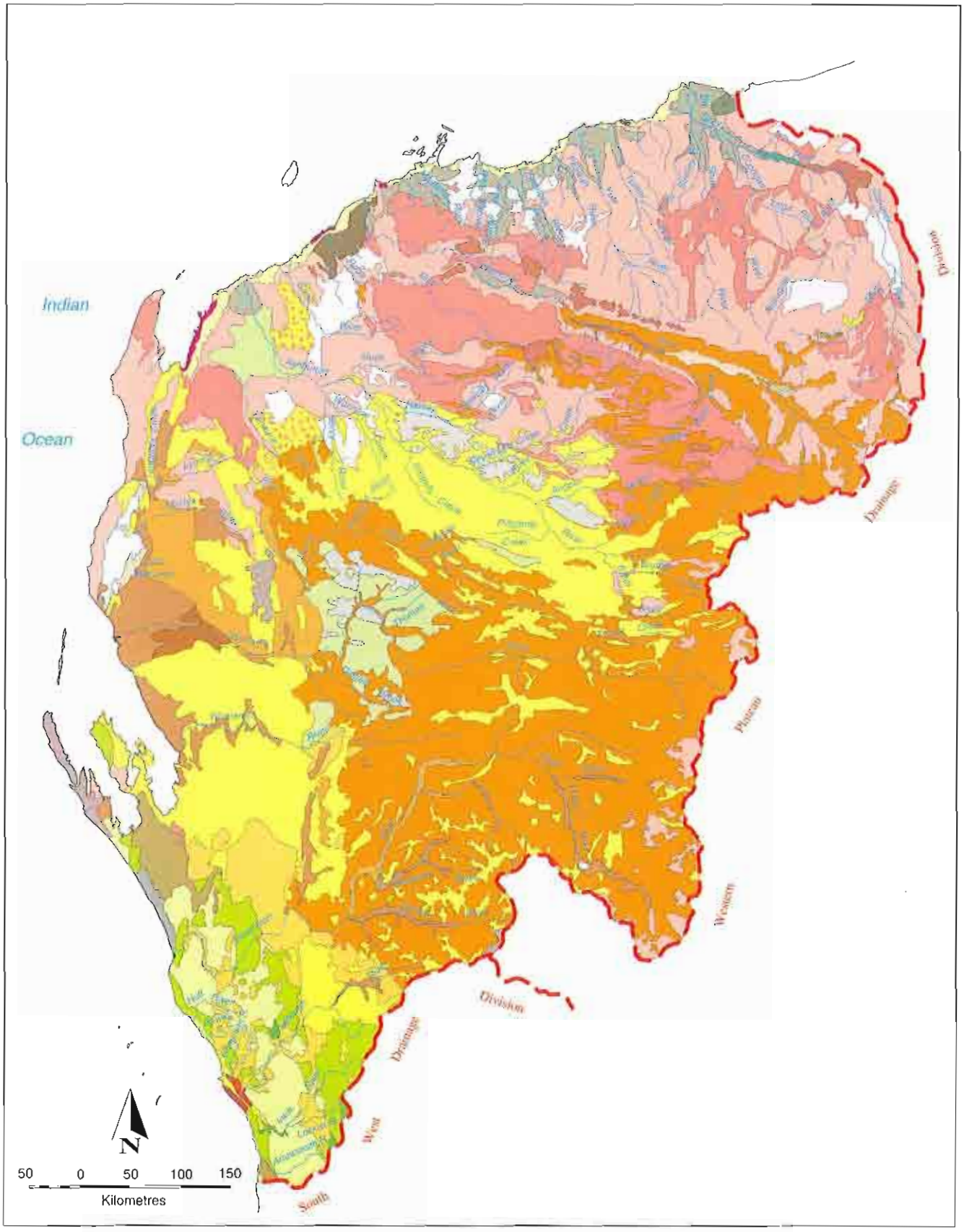
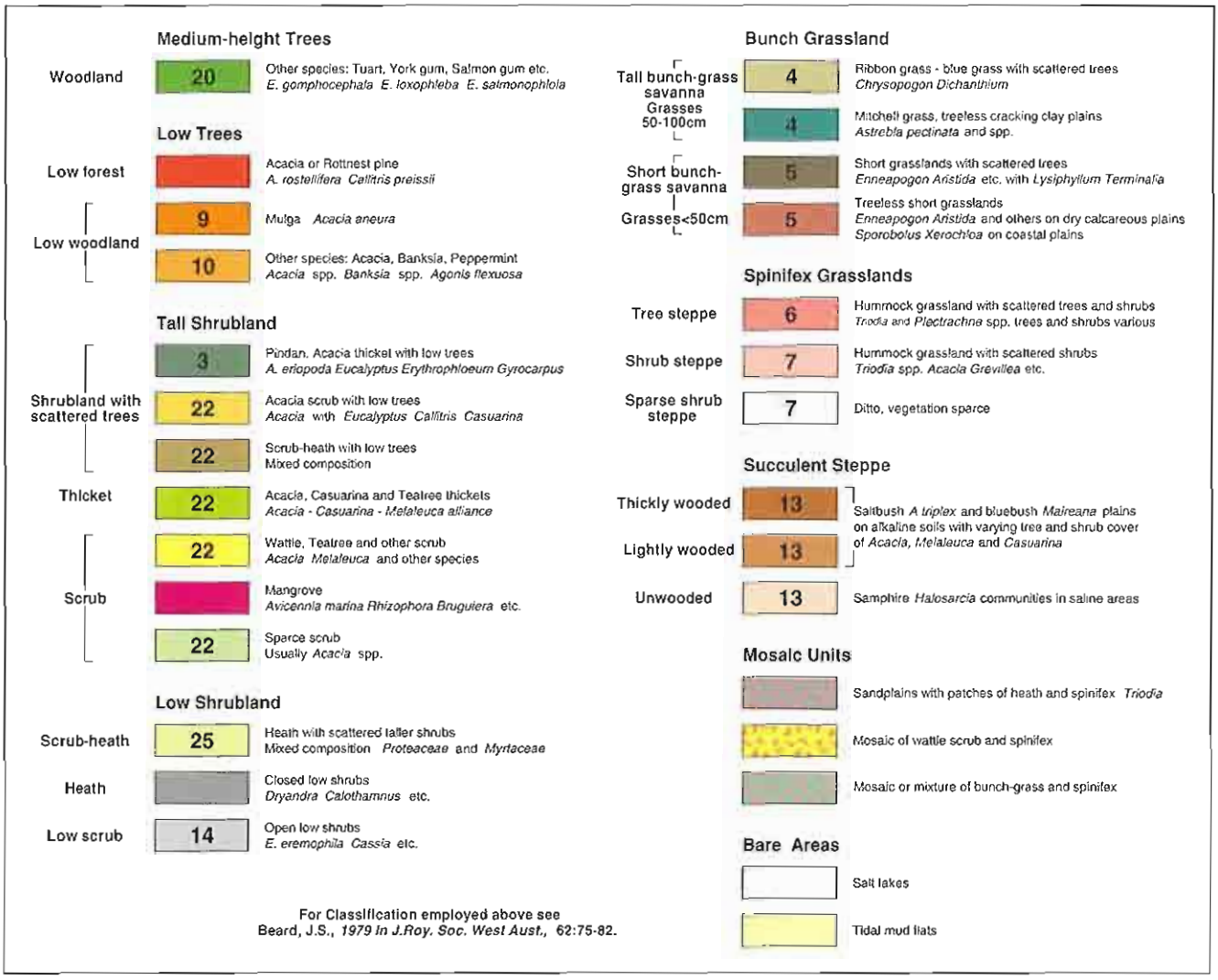


Figure 5: Indian Ocean Drainage Division — Vegetation (after Beard).



The original natural vegetation is shown in Figure 5. Mulga (*Acacia aneura*) low woodland and scrub (9) covered 38.5% of the division, with other Acacia low woodland and scrub (10) a further 14% (Table 1). Tree and shrub steppe (spinifex with scattered eucalypts or shrubs) (7) covered 31%. Other vegetation types found include: short bunch grass savanna (5); samphire and saltbush communities (13); Acacia-Casuarina thickets and scrub (22) and scrub-heath (25).

The rivers of the division are very much either in drought or flood. Rivers such as the Sherlock can have three years without any flow followed by flooding. The variability of these rivers is (at a regional scale) as high as anywhere else in the world.

A pool on the Fortescue River below Millstream.

Table 1: Indian Ocean Drainage Division — Vegetation areas (after Beard).

Legend	Vegetation area	Rainfall range (mm)	Approximate original coverage of division (%)
(5)	Short bunch-grass savanna, with or without trees	300-350	4
(7)	Tree and shrub steppe; spinifex with scattered eucalypts or shrubs	200-350	31
(9)	Mulga (*Acacia aneura*) low woodland and scrub	200-250	38.5
(10)	Other Acacia low woodland and scrub	200-300	14
(13)	Halophytes: samphire and saltbush communities	250	2.5
(14)	Dwarf scrub of Cassia and Eremophila	200-250	2.75
(22)	Acacia-Casuarina thickets and scrub	250-500	3
(25)	Scrub-heath	250-600	4.25
	Playa lakes, mainly bare mud and salt	250	Neg.

Table 2: Indian Ocean Drainage Division — River types.

T12	Short to medium length rivers originating in areas of Acacia-Casuarina thickets (22) and scrub-heath (25).
T13	Longer rivers originating in areas of mulga low woodland and scrub (9), flowing through other Acacia low woodland and scrub (10) and to the coast, sometimes through Acacia-Casuarina thickets and scrub (22) and/or scrub-heath (25).
T14	Short to medium length rivers flowing through the same mulga (9) and other Acacia low woodland and scrub (10), but flowing into near coastal playa lakes (-) or disappearing into coastal sands without reaching the sea.
T15	Longer rivers flowing from areas of mulga low woodland and scrub (9) and sometimes dwarf scrub of Cassia and Eremophila (14) through tree and shrub steppe (7) to the coast.
T16	Medium length and longer rivers flowing from the tree and shrub steppe of the Pilbara (7) and through areas of short bunch-grass savanna (5) along the river valleys and in coastal regions.

The rivers of the division can be divided into five types, based on their length, flow regime, and the type of vegetation they arise from and flow through. Table 2 presents details of the river types, and Table 3 provides data on examples of each of them. Many of the division's rivers feature spectacular gorges, such as the Murchison (through Kalbarri National Park); the Robe (within Karijini National Park); the Harding (Lockyer Gorge); the Fortescue (Hamersley Gorge) and the Oakover River (Carawine Gorge). Rivers such as the Fortescue, Gascoyne and Sherlock also feature several pools (see Figure 3), some of them are spring fed from groundwater aquifers, such as Millstream and the Fortescue Pools.

A variety of amphibians and reptiles live in the rivers. These include tortoises, river lizards, skink lizards, frogs, crocodiles, pythons and other snakes, but comparatively few fish. Of the fish that do inhabit the division, some have extremely restricted distribution. The golden gudgeon, for example, is only found in the Gascoyne and Murchison rivers. The Fortescue grunter is only found in the Ashburton, Fortescue and Robe rivers. The invertebrate aquatic fauna of the division is poorly surveyed and documented.

Spinifex with scattered eucalypts and shrubs covers almost a third of the Indian Ocean Drainage Division.

Table 3: Indian Ocean Drainage Division — Representative examples of river types.

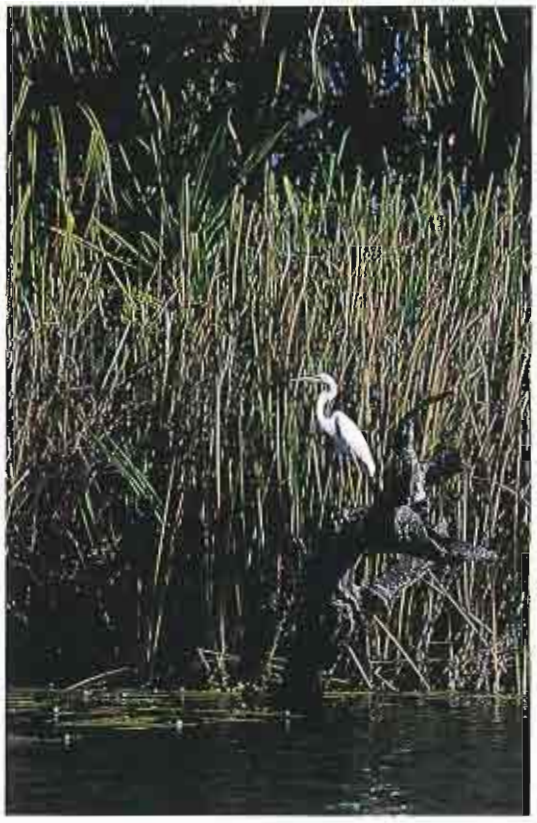
River	Type	Catchment area (to mouth) (km^2)	Extends inland from coast (km)	Rainfall range (mm)	Traverses vegetation area (see Table 1)	Mean annual flow ($m^3 \times 10^6$)	Run-off (mm)	Mainly flows during period	Maximum instantaneous recorded flow (m^3/sec)
Chapman River	T12	1 160	100	300-500	(22); (25)	20	13	May-Oct	133
Murchison River	T13	82 300	550	200-400	(9); (10); (22); (25)	161	2.4	Mar-Sept	1 080
Minilya River	T14	5 008	200	250	(9); (10)	48	1.4	Mar-July	419
Ashburton River	T15	70 200	600	200-350	(9); (10); (7)	500	6	Dec-June	3 070
De Grey River	T16	49 600	450	200-300	(7); (5)	1096	18	Jan-April	4 870

Minilya River (Type T14) flows through low woodland and scrub into Lake MacLeod.

Timor Sea Drainage Division

The Timor Sea Drainage Division (Figure 6) covers an area of 277 000 square kilometres. About half comprises the Kimberley Fractured Rock Province, a quarter comes within the Canning Sedimentary Basin and the remaining quarter is divided between the Halls Creek, Bonaparte and Ord-Victoria Fractured Rock Provinces (see Figure 2). Rainfall varies from about 350 mm along its southern border to over 1400 mm in the rugged remote north-west coastal area. The climate is tropical with a wet season from November to March, and a long dry season from April to October. September and October are the driest months (see Figure 7). Rainfall results from a series of monsoonal depressions, tropical lows, cyclones and thunderstorms originating over the Timor Sea to the north, the distance they penetrate inland depending on their strength and severity. The break in season and annual quantity of rainfall is highly variable. The whole drainage division experiences very high evaporation rates, from about 2800 mm per year in the extreme north to over 4000 mm in the south.

The geological record shows that about 20 000 years ago the region was experienced a very dry period. The sea was about 100 metres below its present level, and the shoreline 200 kilometres further out than it is today.



The Great Egret is widespread on coastal wetlands throughout Australia. It is, however, the only egret that frequents inland waterways in Western Australia.

Windjana Gorge on the Lennard River.

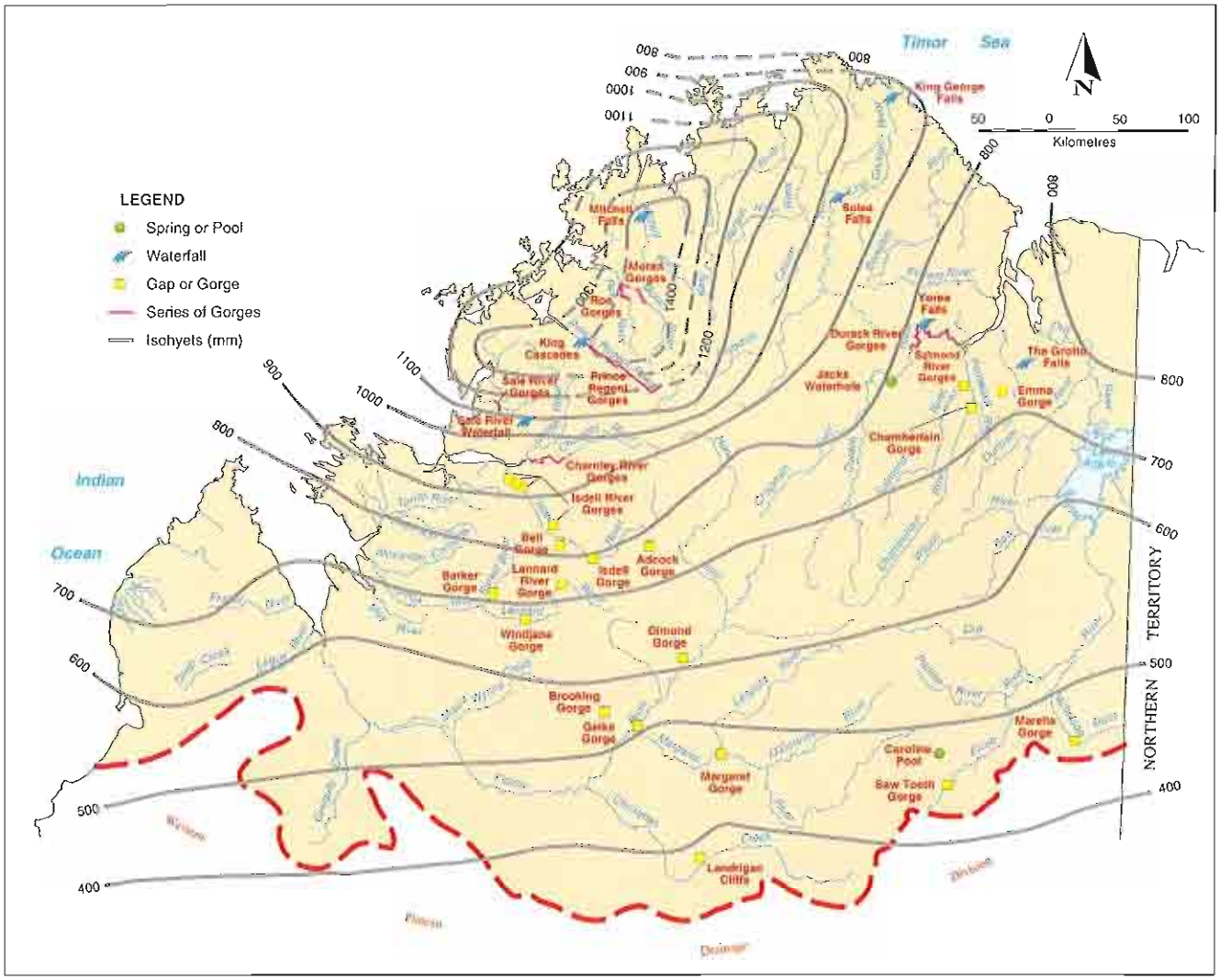


Figure 6: Timor Sea Drainage Division — River system and major riverine landform features.

Spectacular electrical storms are common in the Timor Sea Drainage Division. They bring much needed rain, but also fire, and their intensity can result in severe erosion where soils have been left unprotected.

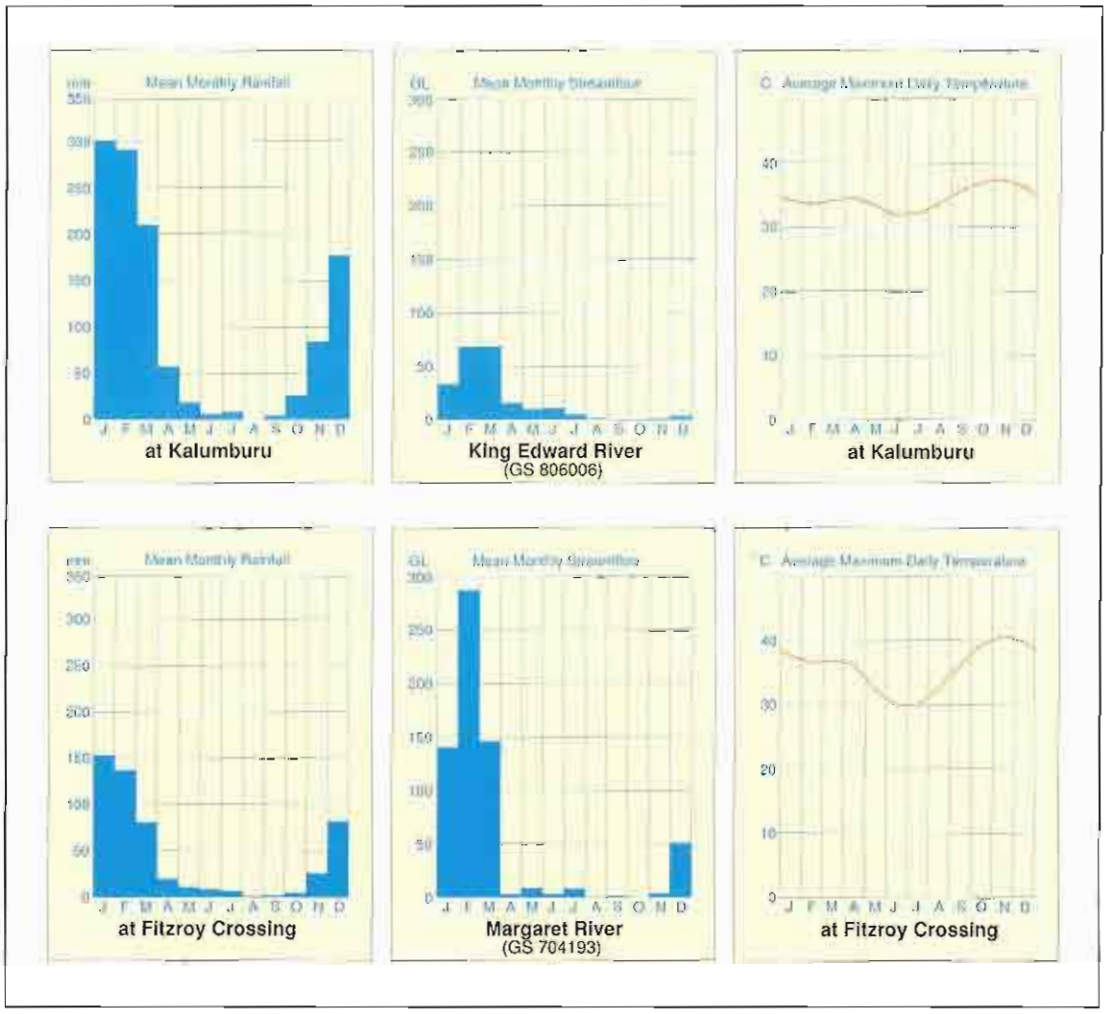


Figure 7: Timor Sea Drainage Division — Monthly rainfall, streamflow and temperatures.

In the Kimberley streamflow generally occurs over the wet summer months, with little or no flow for most of the long dry winter. Although streamflow is irregular, all major rivers do flow every year. However, only a few in the extreme north-west flow year round. Peak flows are very high by world standards, and flooding as a result can be extensive. In general, the rivers and streams rising in the drier southern part of the division are more seasonally variable than those of the north. Five major types of rivers are recognised (see Table 5). Spectacular gorges and waterfalls are common. Geike Gorge on the Fitzroy River, Windjana Gorge on the Lennard River and Mitchell Falls on the Mitchell River are perhaps the best known.

Walcott Inlet, into which flow the Calder, Charnley and Isdell rivers.

Mitchell Falls on the Mitchell River.

Flooding along the Fitzroy River at Camballin in 1962.

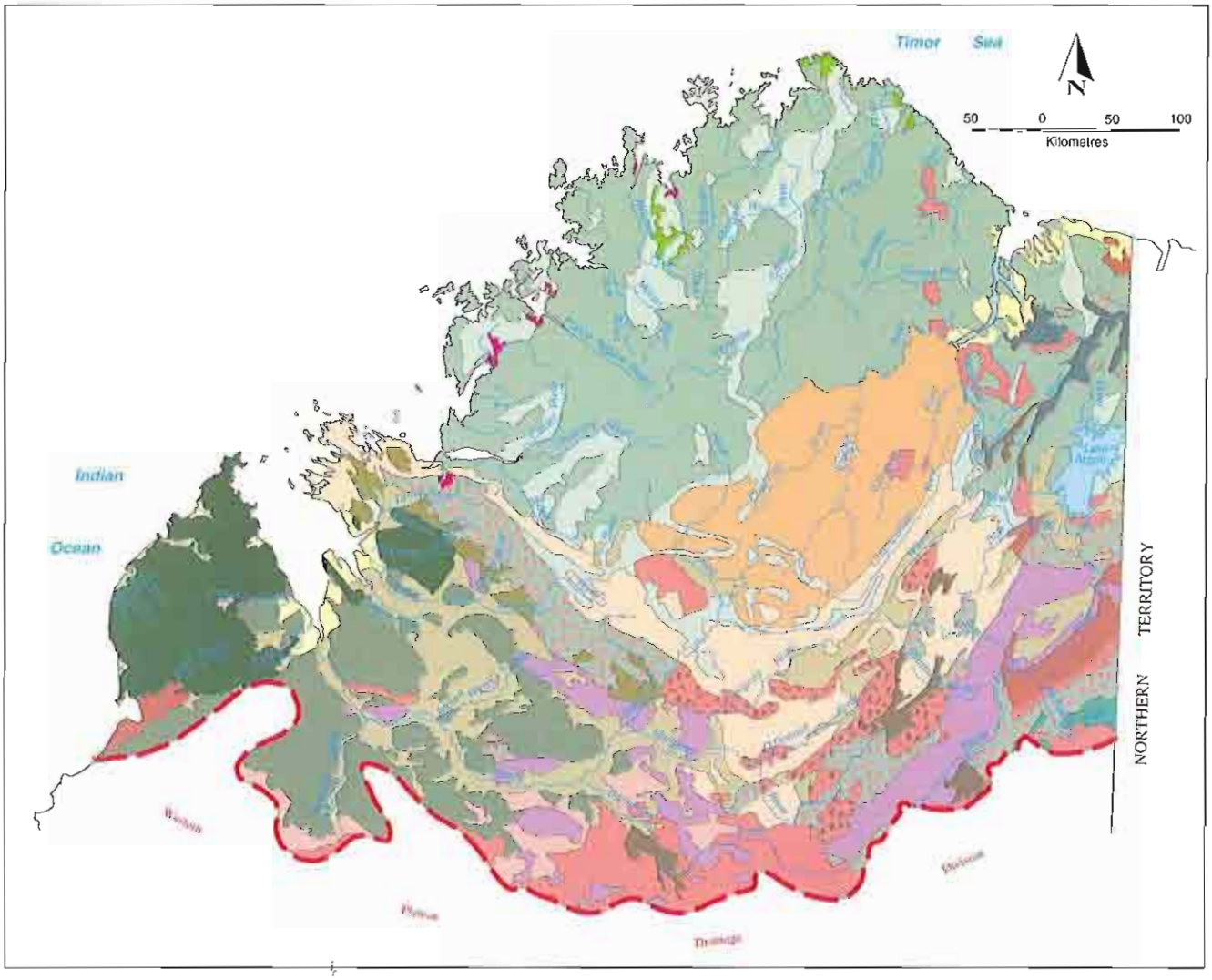
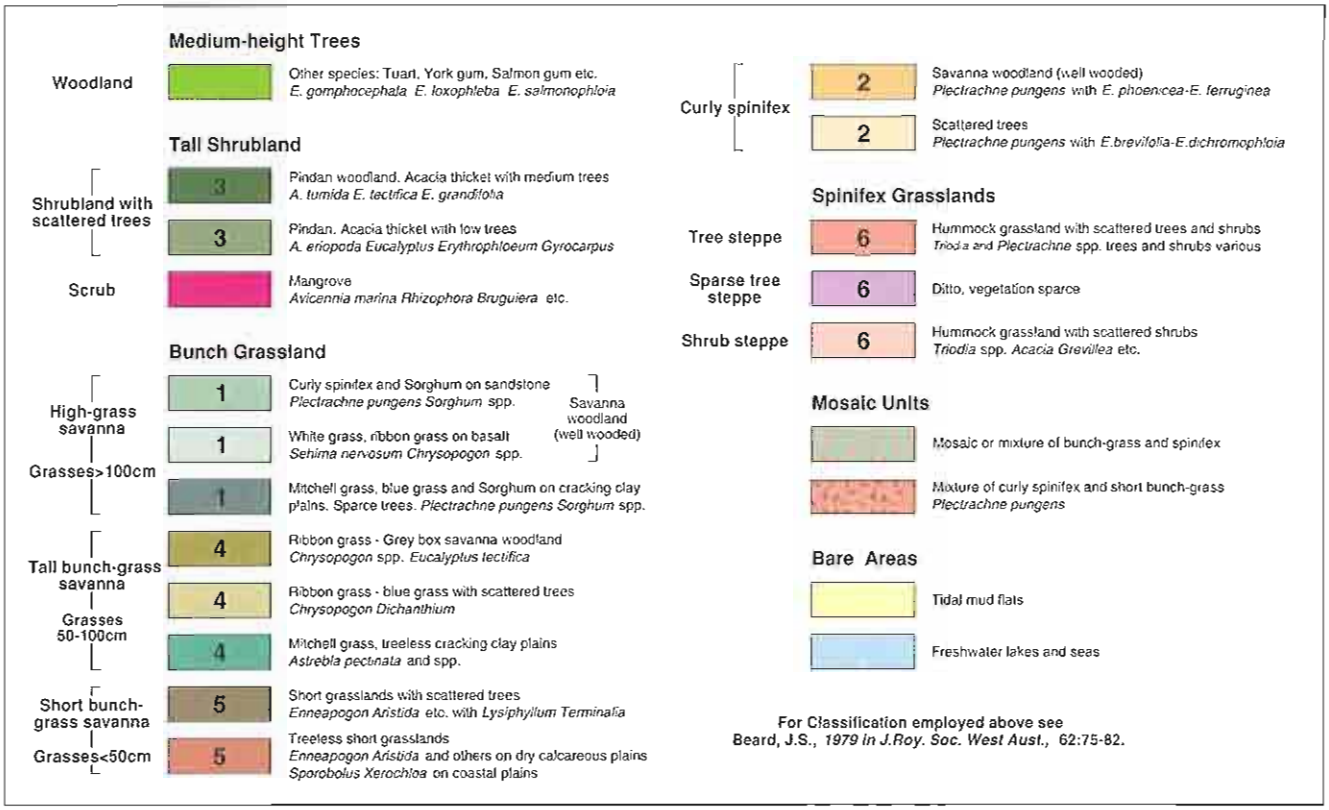


Figure 8: Timor Sea Drainage Division — Vegetation (after Beard).

Lily flower in the Everglades, Lake Kununurra.

Table 4: Timor Sea Drainage Division — Vegetation areas (after Beard).

Legend	Vegetation area	Rainfall range (mm)	Approximate original coverage of division (%)
(1)	High grass savanna woodland	700-1500	38
(2)	Curly spinifex savanna woodland and tree savanna	500-800	29
(3)	Pindan (Acacia thicket with scattered trees)	500-800	12.5
(4)	Tall bunch-grass savanna, with or without trees	350-800	5.5
(5)	Short bunch-grass savanna, with or without trees	350-700	5
(6)	Semi-desert spinifex steppe	350-800	10



Almost 40% of the Timor Sea Drainage Division is covered by high grass savanna woodland (1). Curly spinifex savanna woodland and tree savanna (2) make up a further 29%. Pindan (3) (Acacia thicket with scattered trees) and semi-desert spinifex steppe (6) also cover notable areas. Other vegetation types present are tall (4) and short (5) bunch-grass savannas (Figure 8 and Table 4). A notable vegetation type found in small isolated patches in the extreme north of the division is known as vine thicket, thought possibly to be a remnant of rainforest that once covered the area in a much wetter geological period.

Kimberley vine thickets, thought to be remnants of rainforest that once covered the region, surrounded by high grass savanna woodland.

Table 5: Timor Sea Drainage Division — River types.

T17 Short to medium length rivers originating in, and keeping within, the Northern Botanical Province's high grass savanna woodland (1) and flowing north to meet the rugged coastline.

T18 Longer rivers originating in curly spinifex savanna woodland and tree savanna country (2) and flowing north through the high grass savanna woodland (1) to the coast.

T19 Shorter rivers flowing solely within pindan (3).

T20 Longer westward flowing rivers traversing a number of vegetation areas including curly spinifex savanna woodland and tree savanna (2), semi-desert spinifex steppe (6), tall bunch-grass savanna (4) and pindan (3).

T21 Longer northward flowing rivers traversing an even wider variety of vegetation areas from semi-desert spinifex steppe (6), through short bunch-grass savanna (5), tall bunch-grass savanna (4), curly spinifex savanna woodland and tree savanna (2) to high grass savanna woodland (1).

Table 6: Timor Sea Drainage Division — Representative examples of river types.

River	Type	Catchment area (km^2)	Extends inland from coast (km)	Rainfall range (mm)	Traverses vegetation areas	Mean annual flow ($m^3 \times 10^6$)	Run-off (mm)	Mainly flows during period	Maximum instantaneous recorded flow (m^3/sec)
Prince Regent River	T17	3150	100	1 400	(1)	790	263	Dec-May	-
Drysdale River	T18	12 200	300	800-1 000	(2); (1)	2 150	176	Dec-May	N/A
Fraser River	T19	N/A	50	600	(3)	N/A	N/A	Dec-Mar	-
Fitzroy River	T20	88 900	450	400-800	(2); (6); (4); (3)	14 200	93	Nov-May	12 200
Ord River	T21	46 100	350	450-800	(6); (5); (4); (2); (1)	3 940	116	Nov-April	30 800

The Kimberley has several animal species that are not found further south in Western Australia. These include the Black Necked Stork, Saurus Crane, Lotus Bird and some species of large native rodents, finches, parrots and sandpipers, plus a number of invertebrate species. The rivers contain 40 principal species of fish, of which 16 are endemic to the region. Some of these fish and a number of frogs have interesting adaptations that enable them to survive in the harsh environment. Some bury themselves in the mud as inland waters dry up, and remain dormant until the next downpour. Other species, such as the Spangled Grunter, can swim long distances in flash floods, and have been found many kilometres from the nearest river, following a trickle of water in a wheel rut.

CROCODILES

Two species of crocodile are found in the Kimberley, the saltwater crocodile and the smaller freshwater crocodile. The latter has undergone a population explosion since the Ord River Dam was built. It is estimated that Lake Argyle is home to at least 25 000 of them.

The saltwater crocodile has not fared so well. Between 1940 and 1970 about 25 000 were killed for their skins. In 1977–78 surveys indicated that there were only about 2 000 mature individuals remaining. To improve their chances of survival, the Ord River and Parry Lagoons Nature Reserves were created, taking in the Lower Ord River's extensive tidal waterways and vast areas of mangrove swamps and mudflats. The main breeding area is along the King River near Wyndham, which has been fenced off by the Department of Conservation and Land Management to keep out cattle and feral donkeys which trample the vegetation and destroy the crocodiles' breeding habitat. It is proposed to make this area into another nature reserve.

Mudflats and tidal creeks provide habitat for an abundant wildlife.

A large saltwater crocodile.

Western Plateau Drainage Division

The Western Plateau Drainage Division is the largest of Australia's surface hydrology divisions. It covers 32% of the total area of the continent and 56% of Western Australia. The whole division is basically an area of uncoordinated internal drainage with almost no major riverine landform features. The information below, relating to the Western Plateau, refers to that portion of the division that lies within Western Australia.

The whole division is hot and arid. Rainfall varies from less than 150 mm a year up to about 350 mm. Rain in the northern part of the division results from tropical summer cyclones. These systems occasionally extend as far south as the goldfields area around Kalgoorlie and the Nullarbor Plain. On such occasions the systems of salt lakes fill and overflow, resulting in the flooding of large areas. More commonly, infrequent rainfall in the southern part of the division occurs as a result of passing winter cold fronts extending up from the Great Australian Bight. The area experiences extreme heat in summer and near zero winter nights. Evaporation exceeds rainfall throughout the division by a factor of about ten. It ranges from 2800 mm near the south coast up to 4500 mm in the middle of the Great Sandy Desert.

Just over half of the division is covered with tree and shrub steppe (7) (spinifex with scattered eucalypts or shrubs). Mulga (9) (*Acacia aneura*) low woodland covers about 20%. Other vegetation types include bluebush plains (12), samphire and saltbush communities (13), mixed spinifex and heath (15), dry woodlands (20), mallee (23), desert oak (8) and pindan (3) (Figure 10 and Table 7). Ephemeral vegetation responds to heavy rain by flashing through rapid life-cycles. Vast carpets of wildflowers are a common sight after heavy rain.

Occasionally the Nullarbor is subject to massive and spectacular flooding, as shown in this 1975 photograph.

Drought is a frequent occurrence, causing lake beds to dry out and form hard, cracked surfaces.

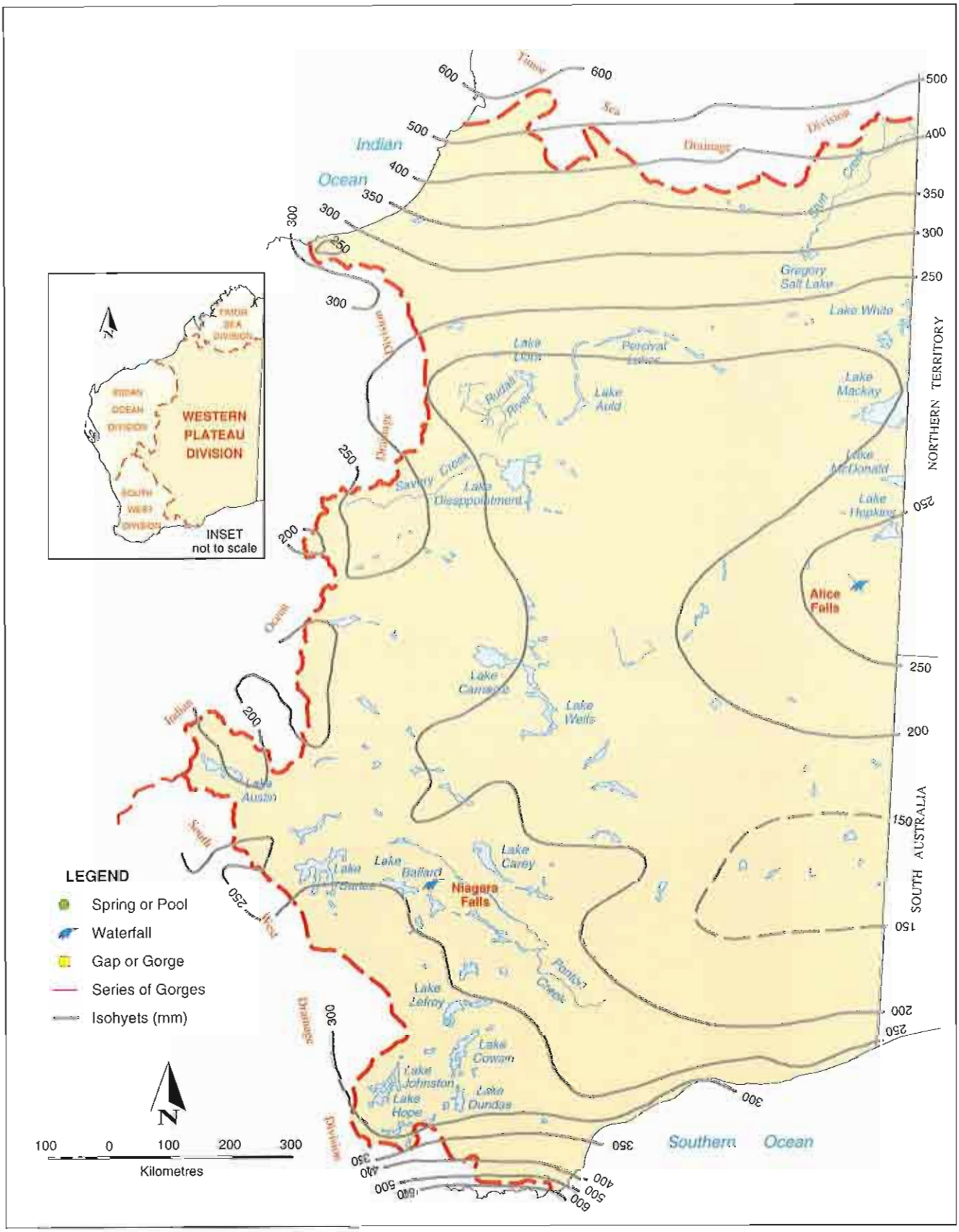


Figure 9: Western Plateau Drainage Division — River system and major riverine landform features.

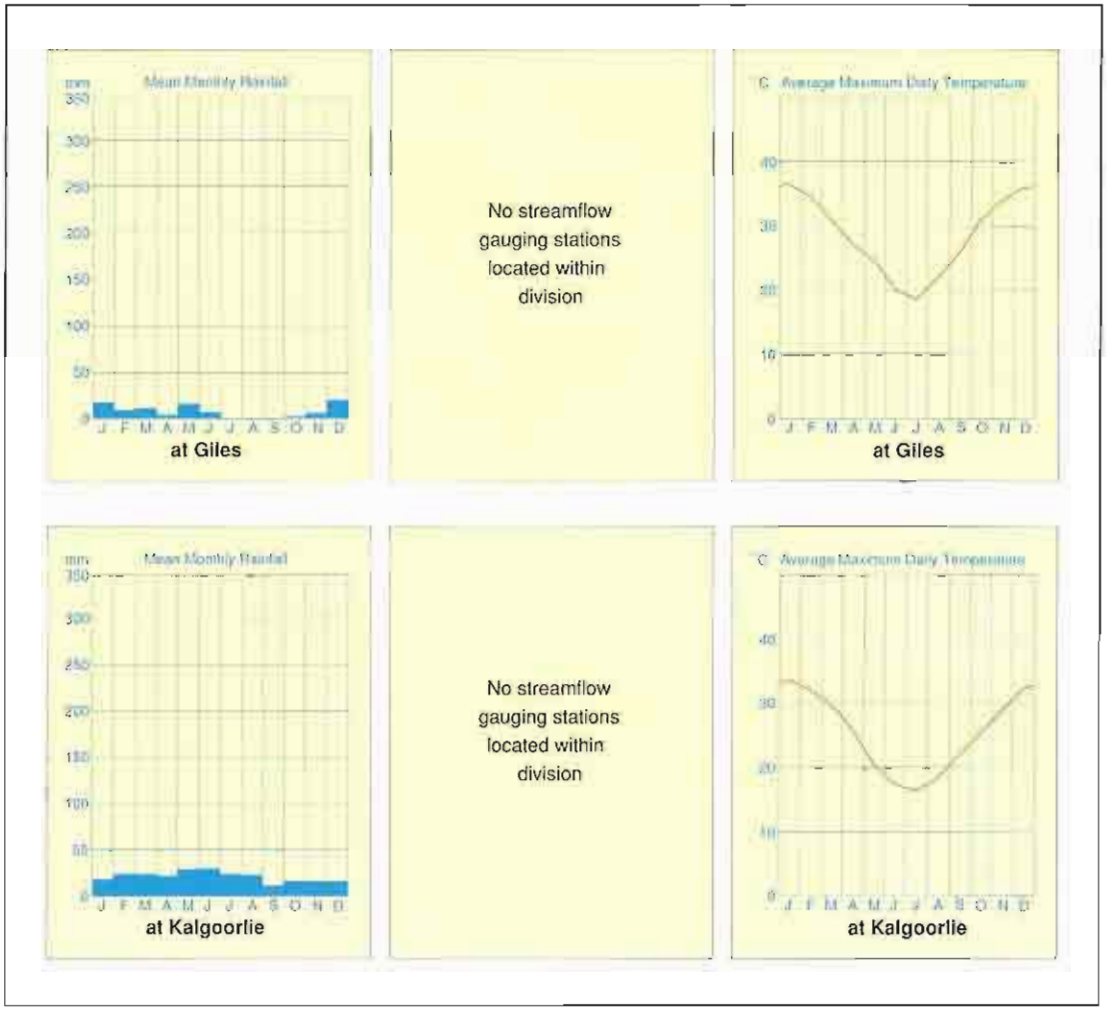
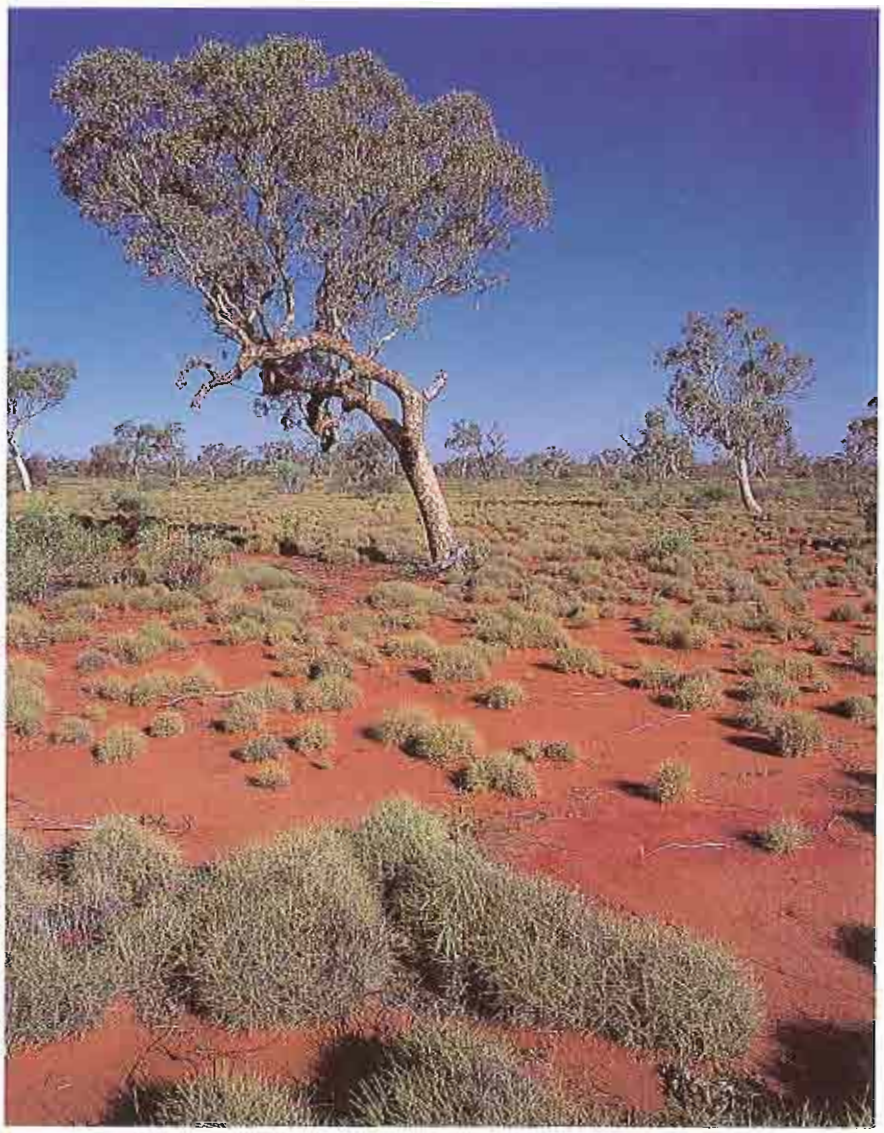


Figure 10: Western Plateau Drainage Division — Monthly rainfall and temperatures.

The Western Plateau Drainage Division has a particularly rich reptile fauna.



Spinifex with scattered eucalypts covers over half the Western Plateau, including the Great Victoria Desert pictured here.

After heavy rain, colourful wildflower carpets cover large areas.

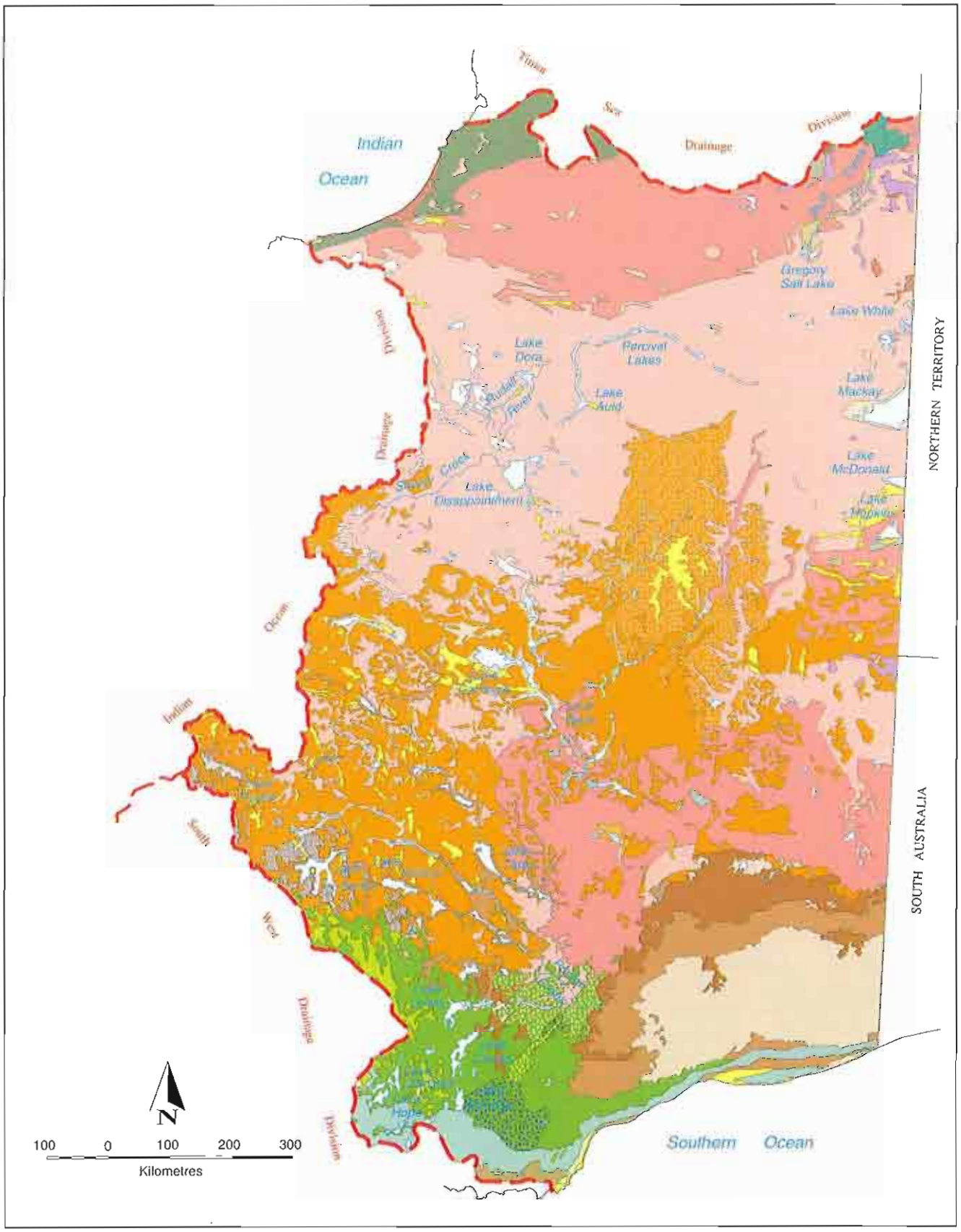


Figure 11: Western Plateau Drainage Division — Vegetation (after Beard).

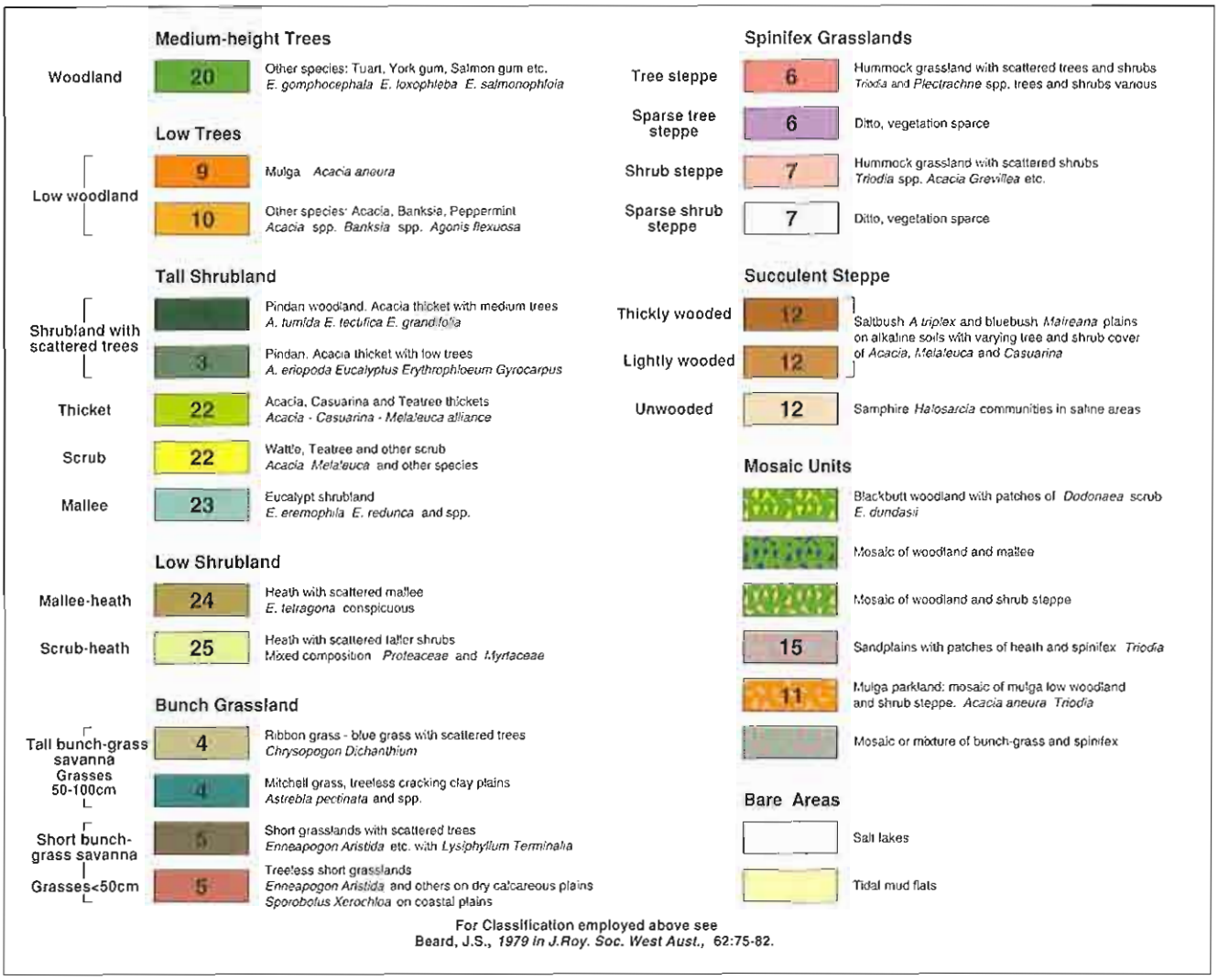


Table 7: Western Plateau Drainage Division — Vegetation areas (after Beard).

Legend	Vegetation area	Rainfall range (mm)	Approximate original coverage of division (%)
(3)	Pindan (Acacia thicket with scattered trees)	300-600	1.25
(7)	Tree and shrub steppe; spinifex with scattered eucalypts or shrubs	200-500	51
(8)	Desert oak; spinifex with groves of Casuarina	200	1.5
(9)	Mulga (*Acacia aneura*) low woodland and scrub	150-200	20
(11)	Mulga parkland; spinifex steppe with patches of mulga	150-200	6
(12)	Bluebush plains — treeless, lightly or thickly wooded	150-250	9
(13)	Halophytes; samphire and saltbush communities	200-300	2.25
(15)	Intermediate sandplains; mixed spinifex	250-300	0.5
(20)	Mixed dry woodlands	250-350	5
(23)	Mallee	250-600	2.5
-	Playa lakes, mainly bare mud and salt	150-200	1

Table 8: Western Plateau Drainage Division — River types.

T22	Short ephemeral watercourses within mixed dry eucalypt woodlands (20).
T23	Short ephemeral watercourses within samphire and saltbush communities of halophytes (13).
T24	Ephemeral watercourses within tree and shrub steppe, spinifex with scattered eucalypts or shrubs (7).
T25	Ephemeral watercourses within mulga low woodland and scrub (9).

The Western Plateau Drainage Division has very few watercourses, as can be seen in Figure 9. However, there are four different types (Tables 8 and 9). Most are short and all are ephemeral, flowing very infrequently and only for short periods of time following heavy rain. They usually disappear in flat lands or shallow lakes. The soil is sandy and porous in many areas, and this results in any surface water rapidly seeping away. Groundwater varies from fresh in the Canning Basin, to mostly brackish or saline elsewhere.

There has been no gauging of watercourses within the division. It is therefore not possible to present data on the mean annual flow, run-off and maximum instantaneous flow in Table 9 below. Also, it cannot be stated that the watercourses flow mainly during any particular period. Flow follows cyclonic rainfall events that could occur at any time of year.

The division has a rich reptile fauna. The fauna of the central desert region is richer than that of any other desert in the world. After heavy rains, the playa lakes, which cover about 1% of the division, fill with water and support large waterbird populations. The Goldfields Region has a blended fauna of arid zone and South West Division species. On the Nullarbor, 32 mammal species were counted at the time of first European settlement. However, a survey in 1984 failed to find 10 of these.

Table 9: Western Plateau Drainage Division — Representative examples of river types.

River	Type	Catchment area (km^2)	Extends inland from coast (km)	Rainfall range (mm)	Traverses vegetation areas (1)	Mean annual flow ($m^3 \times 10^6$)	Run-off (mm)	Mainly flows during period	Maximum instantaneous recorded flow (m^3/sec)
*	T22	10-50	5-25	250-350	(20)	N/A	N/A	Episodic	N/A
**	T23	N/A	5-25	200-250	(13)	N/A	N/A	Episodic	N/A
Sturt Creek	T24	30 000	300	300-400	(7)	N/A	N/A	Episodic	N/A
Ponton Creek	T25	N/A	150	200-250	(9);(7);(20)	N/A	N/A	Episodic	N/A

Notes:

* Short unnamed watercourse among those draining into Lakes Hope and Johnson.

** Unnamed ephemeral watercourse draining into or interconnecting the chains of salt lakes (Lakes Raeside, Carey etc.)

Episodic flows follow infrequent cyclonic rainfall events that occur at any time of year.

N/A — Not Available

POOLS AND BILLABONGS

In arid areas, river pools and billabongs are the main source and refuge of the rivers' aquatic life. Billabongs are rich cauldrons of food. They are far more productive than the main stream of the river. They are a reservoir of water and fertility, providing a haven for life and *recharge area* for the surrounding rivers and landscape. In billabongs, nutrients are cycled, pollutants are removed, and a wide range of organisms breed and have nursery areas.

Changes to a river's health will often first be noticed in the pools and billabongs. They are damaged or destroyed by sedimentation, direct filling, building dams that cut off or reduce inflow, and other changes in an area's hydrology. Spraying mosquitoes in river pools and billabongs has a detrimental effect on other life forms living there. Often we have no idea what we are losing when river pools and billabongs are destroyed. Our knowledge of them, and the species they contain, is generally poor.

Pools and billabongs are rich cauldrons of aquatic life. Our understanding of them, however, is relatively poor.

THE WAY THINGS WERE

Before 1829

AUSTRALIA IS AN ANCIENT CONTINENT. The landscape we see today is the product of millions of years of geomorphic activity and weathering. The country that European settlers and explorers found after colonisation in 1829 was in dynamic equilibrium. The Aboriginal occupants had established a balance with the land and its plants and animals. They had lived here for at least 40 000 years (some recent estimates put it at over 100 000 years), during which time they and the land had grown and changed together.

Aboriginal use of the land and wildlife was not without impact. In particular, their use of fire affected the landscape (see box). However, European exploitation was, and still is, more intrusive and far more damaging than the Aboriginal exploitation of Australia. Many of the adverse effects of this European impact were originally the result of ignorance.

Australian Aborigines lived in harmony with the land. Their stories, songs and ways of life were integrally linked to the rhythms of the seasons. Although their way of life involved seasonal migration, they were not nomadic. They 'belonged' to particular places or 'country'. They took responsibility for caring for and protecting different places.

Rivers and water held an obviously important place in traditional Aboriginal life. Generally speaking, tribal boundaries followed (and still follow) catchment boundaries. Occupation tended to follow rivers, especially in rugged, arid and inaccessible areas. Literally all water sources such as soaks, springs, rock holes and billabongs have Aboriginal sites associated with them. Where water is more abundant, the sites become more dispersed. They still, however, occur within a corridor of easy access to the river. The significance of rivers and watercourses is enshrined in Aboriginal culture.

Many of the sheltered overhangs and caves near watercourses show evidence of long term Aboriginal occupation.

FIRE

Fire was used as a management tool by the Aboriginal people long before European settlers arrived in Australia. Aboriginal use of fire undoubtedly altered the landscape. It was their main influence on the environment during the very long period they lived here before European settlers arrived. The Aborigines used fire to increase productivity, encourage new plant growth, and to make hunting and access easier.

To what extent Aborigines changed the land before European settlement is a matter of conjecture. Traditionally, they burnt the country in strips. Areas burnt in previous years would act as fire breaks. In this way, the burnt areas were never extensive. The country was a patchwork, with different areas burnt at different times. Aborigines concentrated burning practices on land that provided good food supplies. The less productive and more fragile land would have been burnt less frequently, and therefore suffered less impact.

Almost certainly, the vegetation, and therefore the fauna, was altered by Aboriginal fire management practices. The extent of this change is unknown. It is believed that with frequent burning, forest tends to become more open woodland, woodland tends to become savanna, and savanna tends to become grassland. Prevention of fires in modern times has resulted in shifts in vegetation systems in the other direction.

With the arrival of European settlers, burning practices changed. The impact of fires increased substantially because the new settlers burnt less frequently, hence the fires were of greater intensity. The settlers had little or no appreciation of bush-fire management and did not understand the role that fire played in regenerating the Australian bush.

Other factors contributed to the change in burning practices. The fires lit by traditional Aborigines often damaged infrastructure built by the settlers (fences, houses, other buildings and stock yards). As a consequence, the settlers discouraged the Aborigines from lighting fires. The decline in the Aboriginal population following white settlement, along with the limiting of traditional Aboriginal lifestyles to remote areas, also reduced the amount of traditional burning carried out.

Fire regimes in the rangelands have been dramatically altered since the arrival of pastoralists. Current research is looking at traditional Aboriginal fire practices.

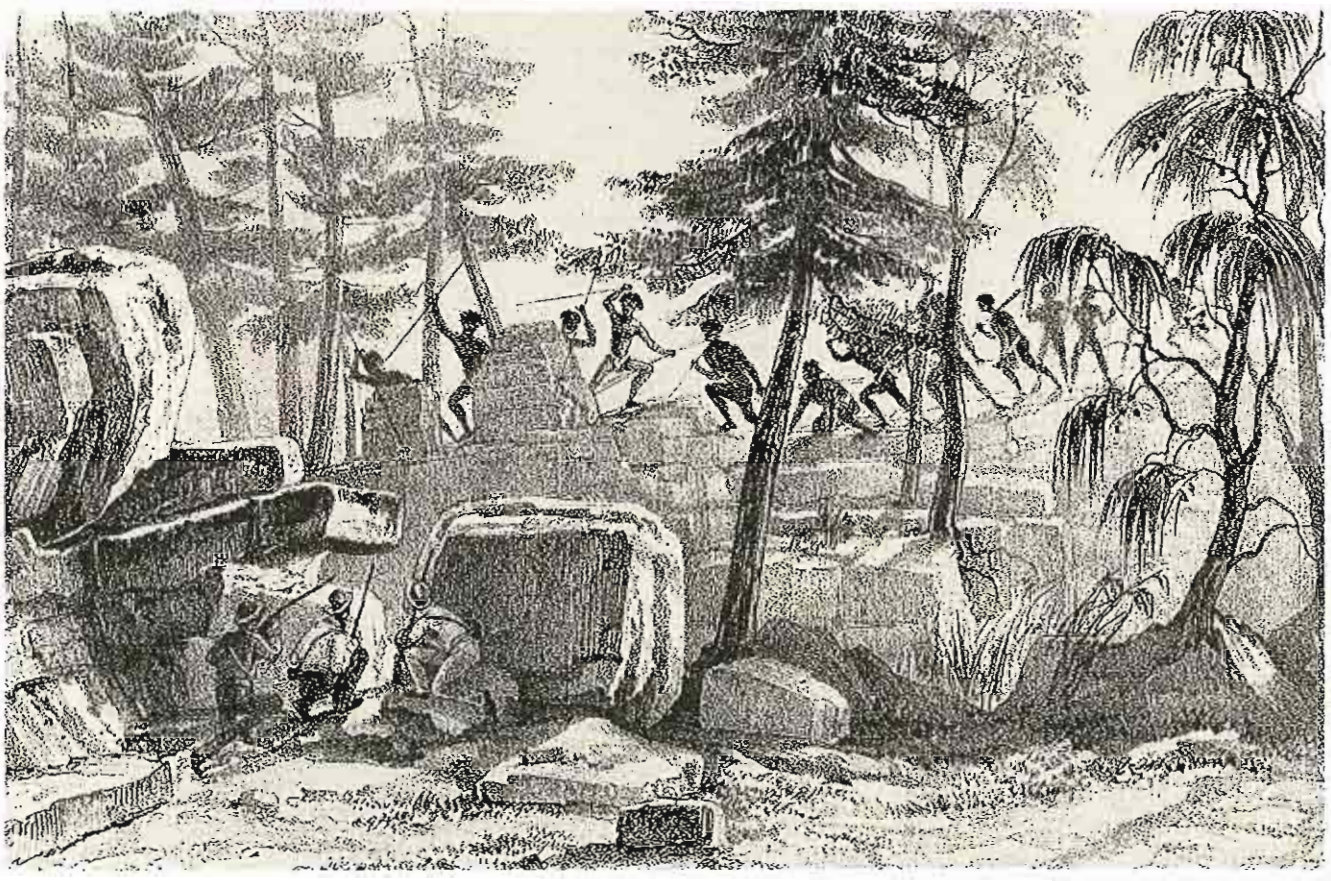
Regeneration after burning.

The arrival of European stock

THE EARLY SETTLERS BELIEVED that the north-west and interior of Western Australia held flowing rivers and mountain ranges, and great promise of fertile land. The land they found, however, was deceptive and harsh, and vastly different to that which they had known in Europe. The new arrivals did not understand the basic climate of the area. They reported simply what they saw, taking no account of the fact that it may be a 'good season' and that there were just as many, if not more, 'bad seasons'. The glowing reports that many early explorers took back to the settlements led to pastoralism spreading into the more remote parts of the State (Figure 12).

Sheep grazing was established in the fertile valleys of the Greenough, Irwin and Murchison rivers in 1840. FT Gregory discovered a large tract of land suitable for pasture north of the Murchison around the Gascoyne River. Other explorers, including Captain George Grey, Ernest Giles, Egerton Warburton and John Forrest gradually moved further inland, most of them searching for the vast sea that many believed lay there. They reached the reluctant conclusion that most of inland WA was unsuitable for settlement. However, Balladonia Station was established on the edge of the Nullarbor in 1881 and the sheep grazing frontier continued to move inland until about the end of the century. In addition to the search for better pastures, it was gold that took settlers and explorers into the more remote parts of the State.

Cattle arrived in the Kimberley overland from Queensland in 1884, brought by the Duracks and the McDonalds. Thereafter, sheep numbers there dwindled and cattle numbers increased. Cattle numbers rose dramatically until 1918 (to about 673 000 head). They dropped during the depression but rose again to reach around 800 000 in 1975. Sheep numbers peaked at 307 000 in 1941. In the Pilbara sheep numbers peaked in the 1930s at 1.6 million. The turning point was 'the big drought' of 1935–42. Today there are less than 100 000.



Captain George Grey's 1839 exploration party in conflict with Aborigines.

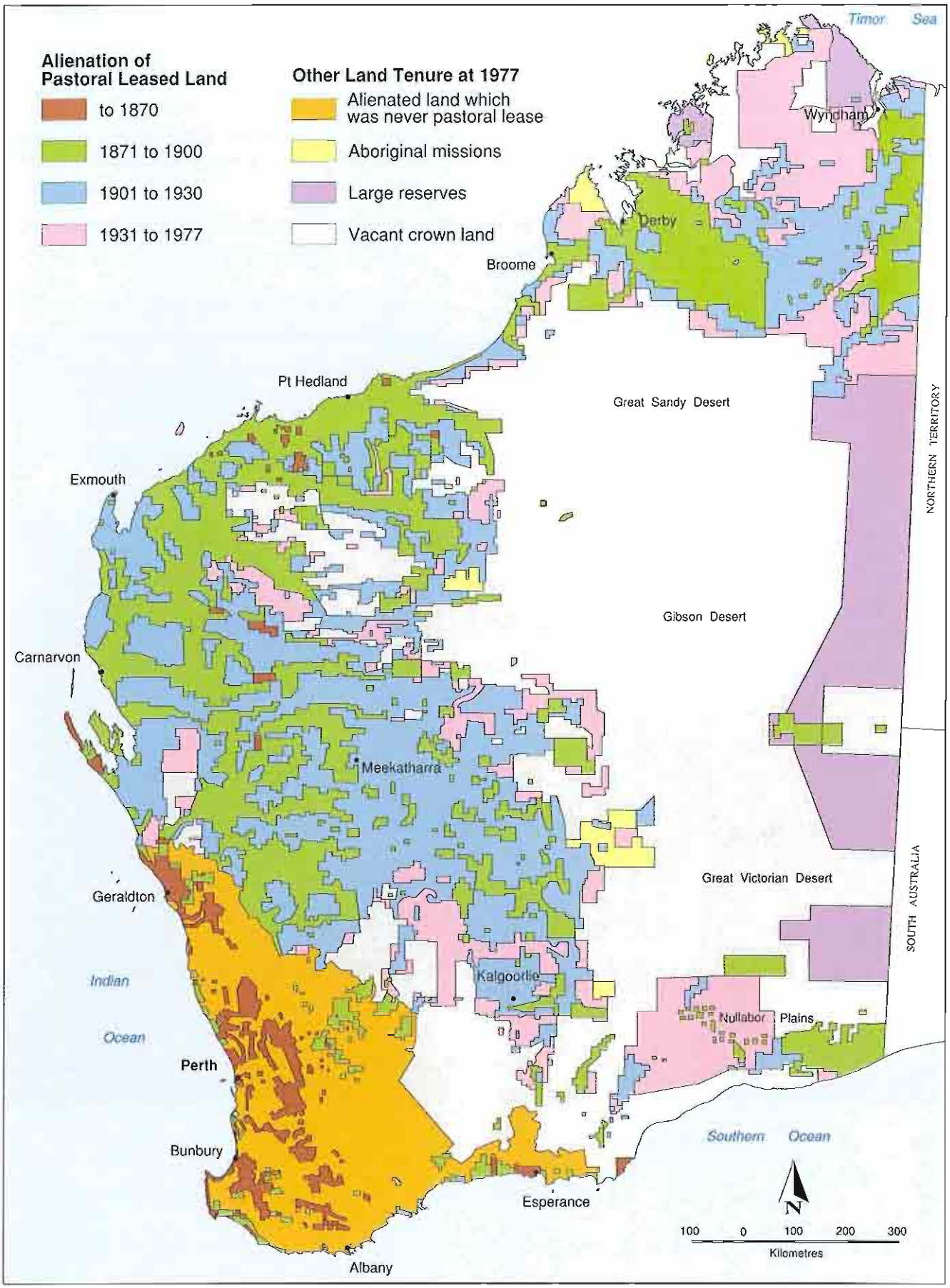


Figure 12: The spread of pastoralism.

FIRST IMPRESSIONS

'A most beautiful country that must be as well watered as any region in the world.'

Captain George Grey, describing the Kimberley in 1837.

'... came to a fertile plain (along the Sherlock River) of at least 20 000 acres of arable land, equal to Greenough Flats ... this fine tract of country ... would support a larger population than is at present in the whole colony of Western Australia.'

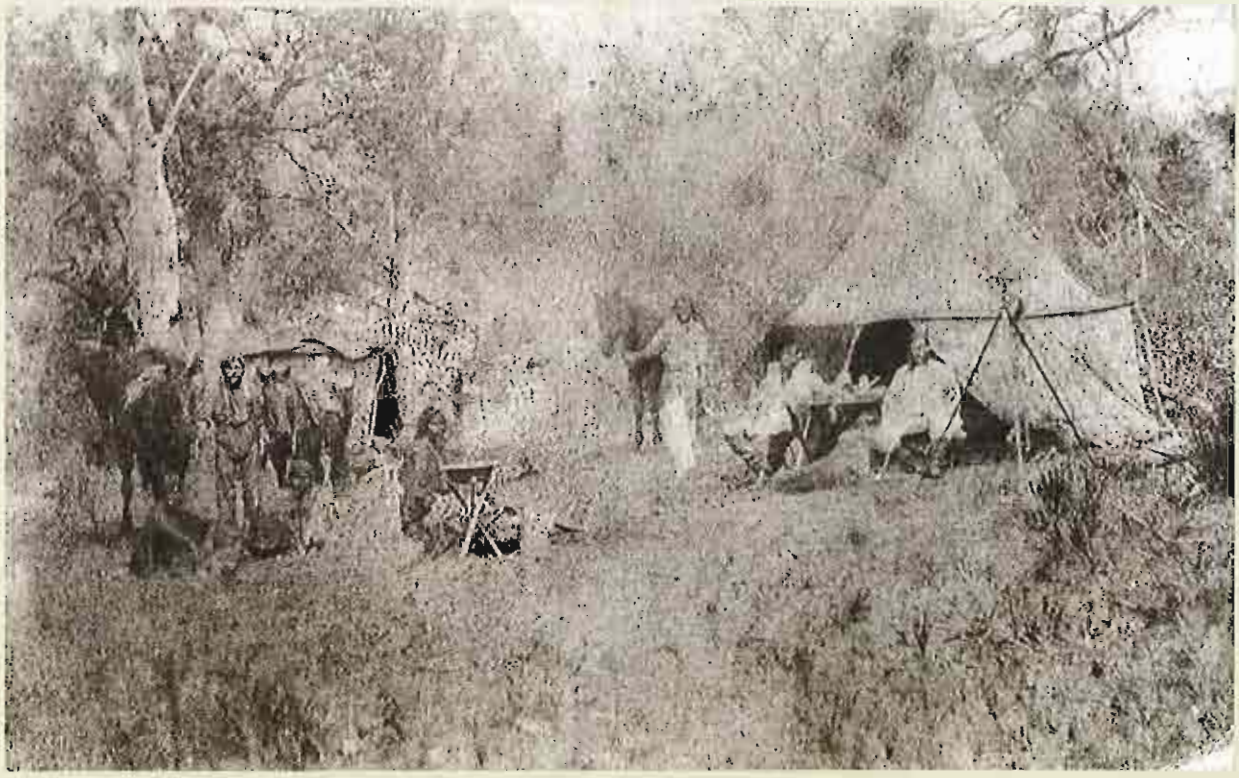
FT Gregory, 'North West Expedition', 1861.

'... we saw 60–80 000 acres of good feeding country ... one mounted shepherd could look after 10–15 000 sheep, the plains being so extensive and unencumbered.'

Walter Padbury, 'Expedition to Nicol Bay', 1863.

'... an area of some 20 million acres of good, well-watered country suitable for pastoral purposes ...'

Alexander Forrest, describing the Kimberley in 1879



Alexander Forrest's party exploring the Kimberley in 1879.

CHANGES TO THE RIVERS

Pastoral land use

EUROPEAN SETTLEMENT AND LAND USE has wrought vast changes to the Western Australian landscape. Among these changes, and integral to them, have been changes to the rivers. Many but not all of these changes have been incidental, rather than planned or intentional.

With the arrival of Europeans and their stock, the number of animals grazing the pastoral areas increased dramatically. Not only were there the sheep, cattle and horses that the pastoralists brought with them. In addition, the water supplies from bores and wells developed for the stock were also utilised by the native kangaroos and wallabies, resulting in an increase in their numbers.

Grazing pressure and degradation of the native vegetation became most severe along the water-courses and across the alluvial plains on either side. Continuous uncontrolled heavy grazing over a comparatively short period of time destroys the vegetation and exposes the underlying soils. Thus large areas become predisposed to erosion from the very high intensity rainfall common throughout most of the Indian Ocean and Timor Sea drainage divisions. Both sheet and gully erosion are widespread and severe, particularly next to river and stream courses.

The introduced animals, many with hard hooves, have a greater propensity to cause damage once the vegetation has been removed by grazing. Before their arrival, no such animals had trodden the ancient Australian landscape. Cattle, sheep, horses, donkeys, goats — largely free of predators and in high numbers — have, on occasions in the past, been left uncontrolled and allowed to graze and destroy the vegetation surrounding pools and water holes, trample the surrounding soils, foul the shallow waters, and cause them to disappear through erosion and evaporation.

Today there are less than 100 000 sheep in the Pilbara, but numbers have been as high as 1.6 million in the past.

Cattle first arrived in the Kimberley rangelands in 1884, brought overland from Queensland.

Much of the land degradation that has occurred was clearly evident within the first 20 years of settlement, particularly in the Kimberley. The Duracks and McDonalds certainly noticed that the country was starting to deteriorate within that period of time.

To quote Mary Durack, speaking in the 1940s:

> 'Sixty years ago pioneer pastoralists came to this country and established their herds here. Few of them made any pretence at building homes where families could be reared. As time went on the holdings were merged and came under the control of large companies which administered them from a distance ... the economy of the country has been strained to breaking-point by a policy of taking everything out of it and putting little back.'

[Mary Durack, quoted in JK Ewers (1962) *With the Sun on my Back,* Angus and Robertson Ltd, Sydney, NSW. p 125.]

In the past many pastoralists seemed to expect the land to continue to provide, regardless of the intensity of use. However, such attitudes must be viewed in the context of the Australian society of that time. Things are changing, pastoralists today are much more aware and pro-active in sustainable rangeland management.

Mary Durack

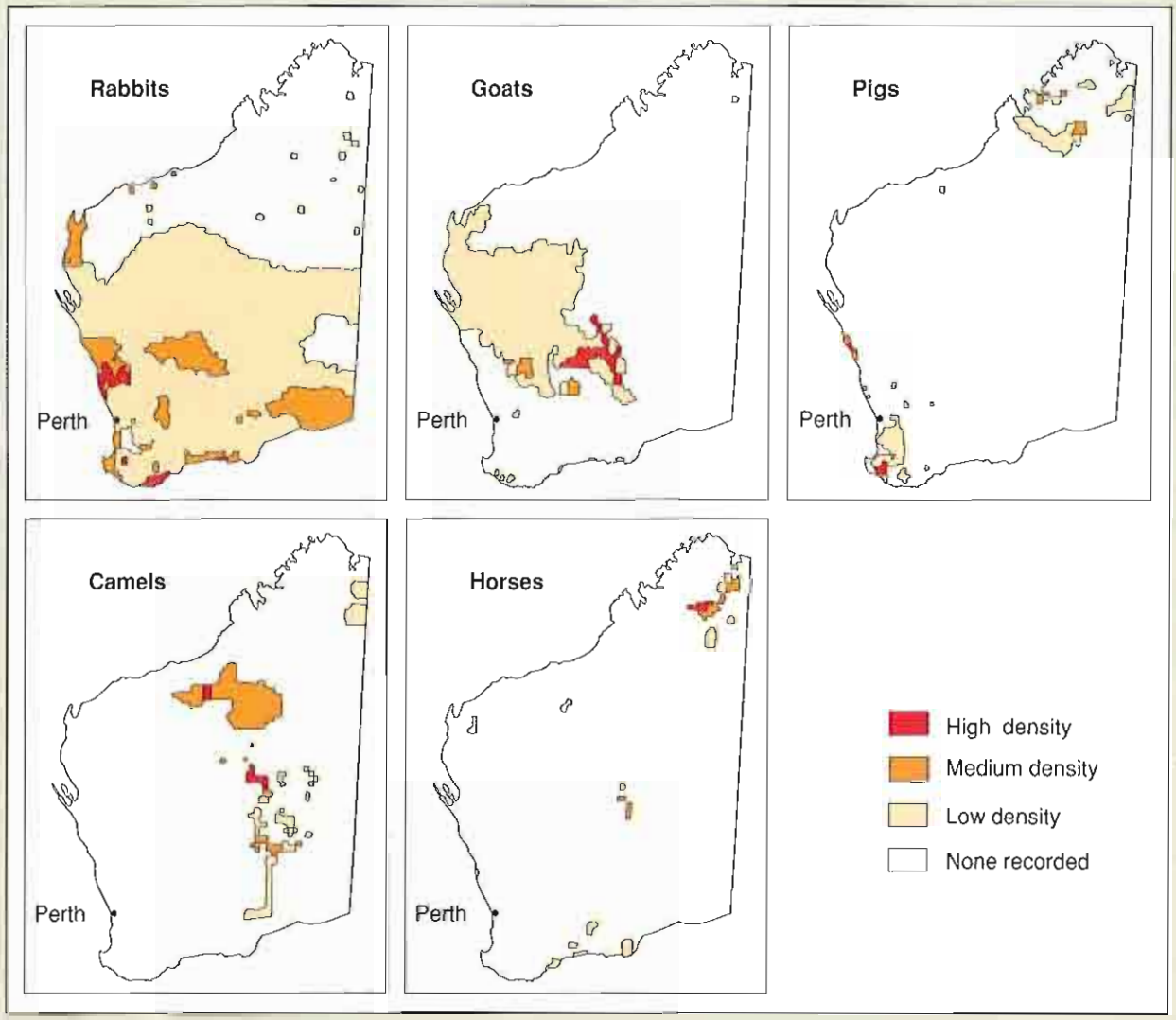
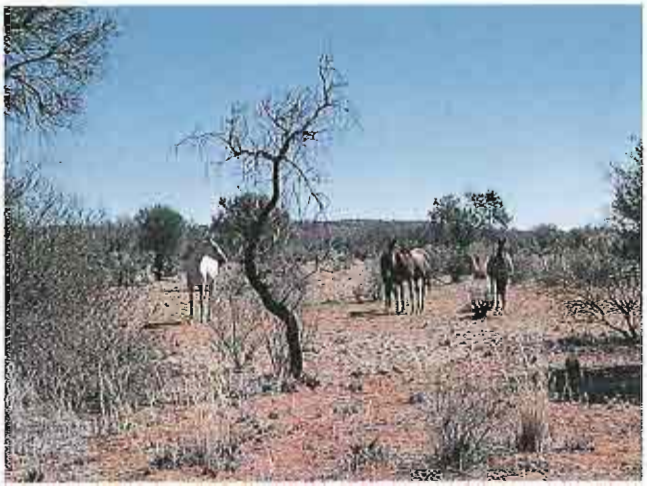


Figure 13: Distribution and concentration of feral animals. (Based on Australian Bureau of Statistics, *Australia's Environment*, Canberra 1992, and reproduced in Western Australia's State of the Environment Report, December 1992.)

FERAL ANIMALS

The problem of land degradation due to grazing pressure has been exacerbated by feral animals. A number of animals introduced by Europeans for stock (goats and pigs), for transport (horses, donkeys and camels) and for other purposes (rabbits, cats and foxes) have escaped or been released into the wild, and learnt to survive and to multiply. The distribution and concentration of some of them is shown in Figure 13. Their greatest concentration is generally along the rivers, their source of food and water. Feral goats and feral donkeys probably are the most significant in terms of river degradation. Horses foul waters and erode river banks and around pools. Pigs can destroy riparian vegetation, damage crops, foul river pools and root up river banks. Although camels have soft pads and therefore do not compact the soil, they reduce vegetation cover and damage water holes. The main concentration of feral camels is in the Oakover River catchment. Rabbits have caused major land degradation and consequently impacted on rivers through sedimentation. They are widespread south of the Tropic of Capricorn, and extend along the coastal margin to Exmouth. There are also isolated pockets near Newman, Roebourne, Port Hedland and the De Grey River.



Wild horses in the Hamersley Range (above).

A feral boar sighted near Fitzroy Crossing in the Kimberley Region (above right).

Rabbits are widespread south of the Tropic of Capricorn.

Since 1972 Agriculture Western Australia (formerly the Department of Agriculture) has surveyed rangeland condition. A 1972 report stated that 30% of the Kimberley rangelands were in very poor condition, a further 45% were fair, and only about a quarter could be described as being in good condition. As far as was known at the time, the situation was similar in the pastoral areas of the other two divisions. Trends that have been noted since, have been an improvement in condition and an increase in the carrying capacity in a few of the areas of good potential, but a substantial deterioration of the poor country. In 1992 it was reported that the number of grazing animals was at the lowest this century.

The present condition of the natural vegetation throughout each of the three drainage divisions is shown in Figures 14 (Indian Ocean), 15 (Timor Sea) and 16 (Western Plateau). Three intermediate conditions (good, fair and poor) are shown, sandwiched between 'essentially undisturbed' and 'cleared of virtually all natural vegetation'.

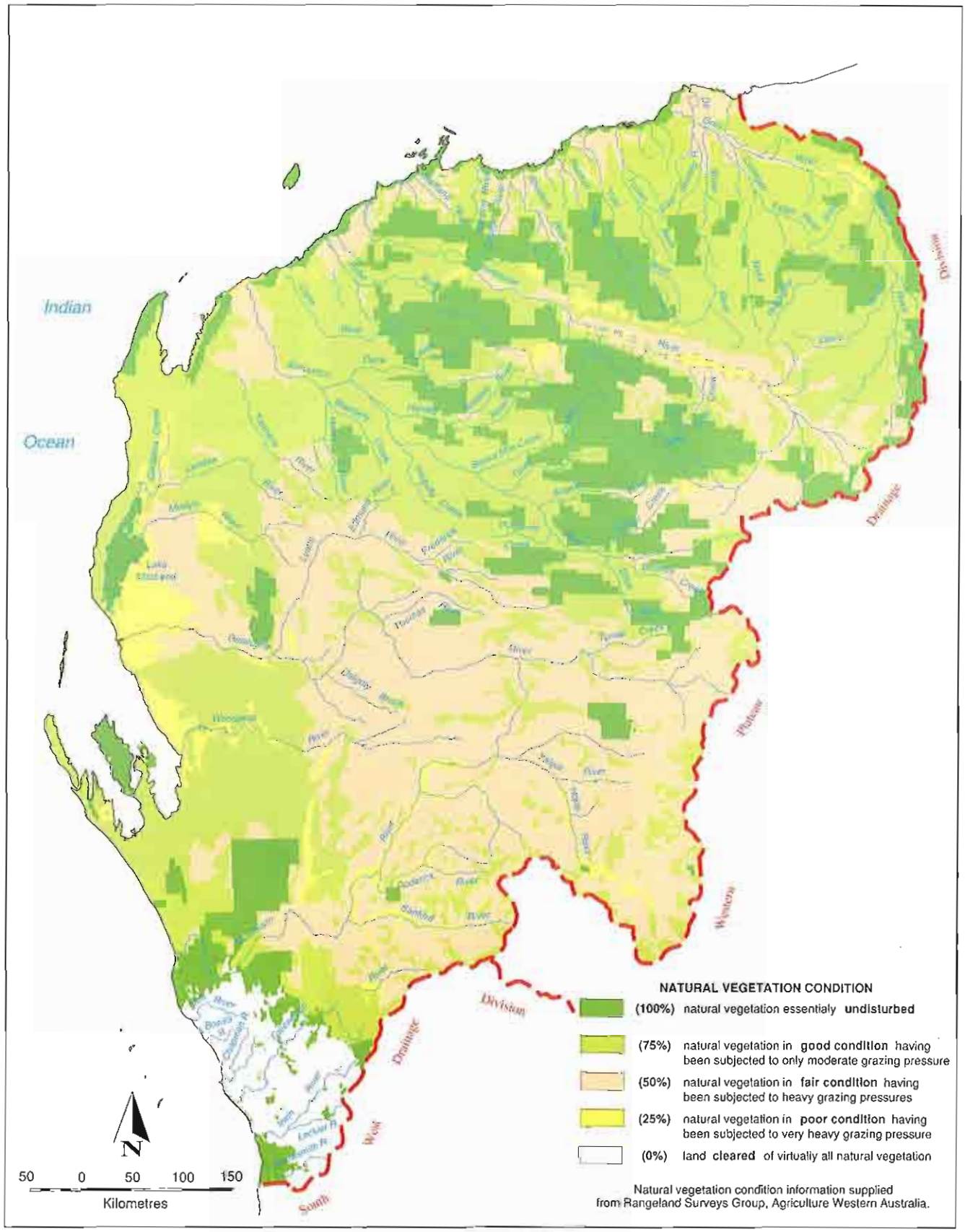
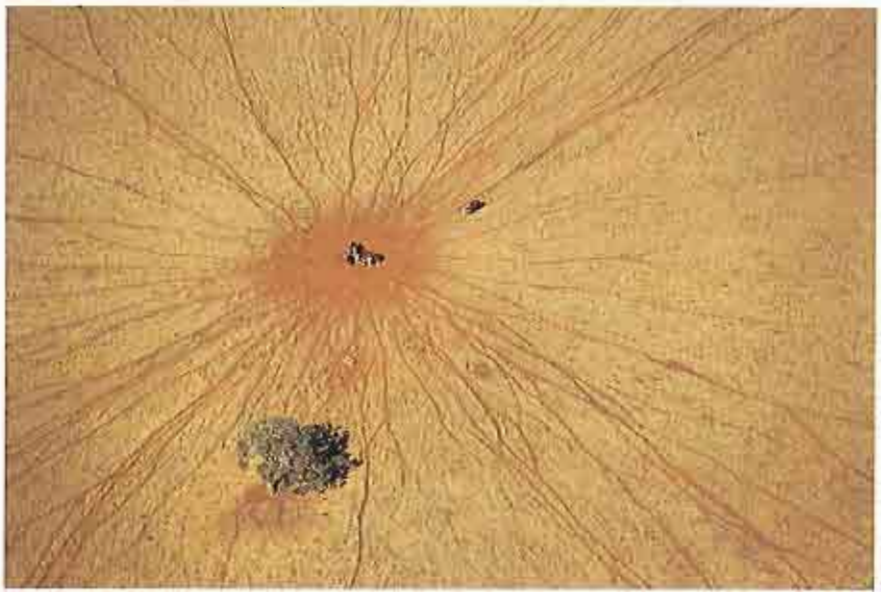


Figure 14: Indian Ocean Drainage Division — Natural vegetation condition.

Watering points developed by pastoralists have enabled the Red Kangaroo population to increase throughout the Indian Ocean and Western Plateau division rangelands.



Overgrazing and trampling has led to the demise of natural water holes to the cost of local native fauna.

The Burrowing Bettong was once widespread on the mainland, but its distribution is now restricted to a few islands off the Western Australian coast.

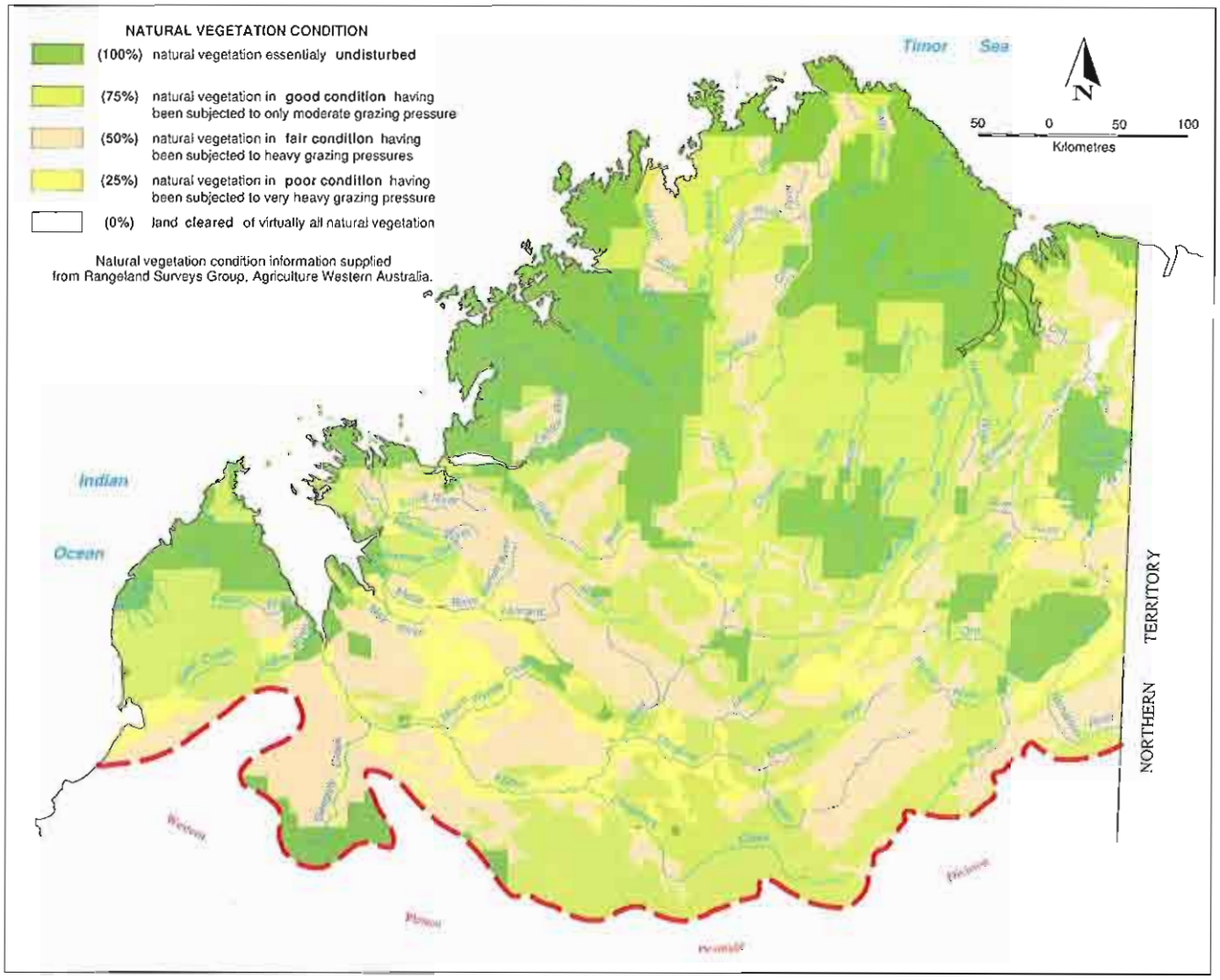


Figure 15: Timor Sea Drainage Division — Natural vegetation condition.

Clearing for agriculture

THERE ARE ONLY A FEW comparatively small areas within the three divisions that have been completely cleared. At the southern extremity of the Indian Ocean Drainage Division, from the Hutt River to the Arrowsmith River, excluding the upper reaches of the Greenough River Catchment, where the rainfall exceeds about 400 mm annually, there is an area cleared for agricultural purposes. There is a similar but smaller area at the southern extremity of the Western Plateau Division, to the north of Esperance.

Clearing in these areas, as in the agricultural areas of the South West Drainage Division, increases stream salinity. This results from the pastures and crops that have replaced the original natural vegetation using less of the incident rainfall, causing groundwater tables to rise, bringing to the surface and into the stream courses, salts that are stored in the soil in large volumes. The process was described in greater detail and illustrated diagrammatically in the report on the *State of the Rivers of the South West*. It has not been reproduced in this report as

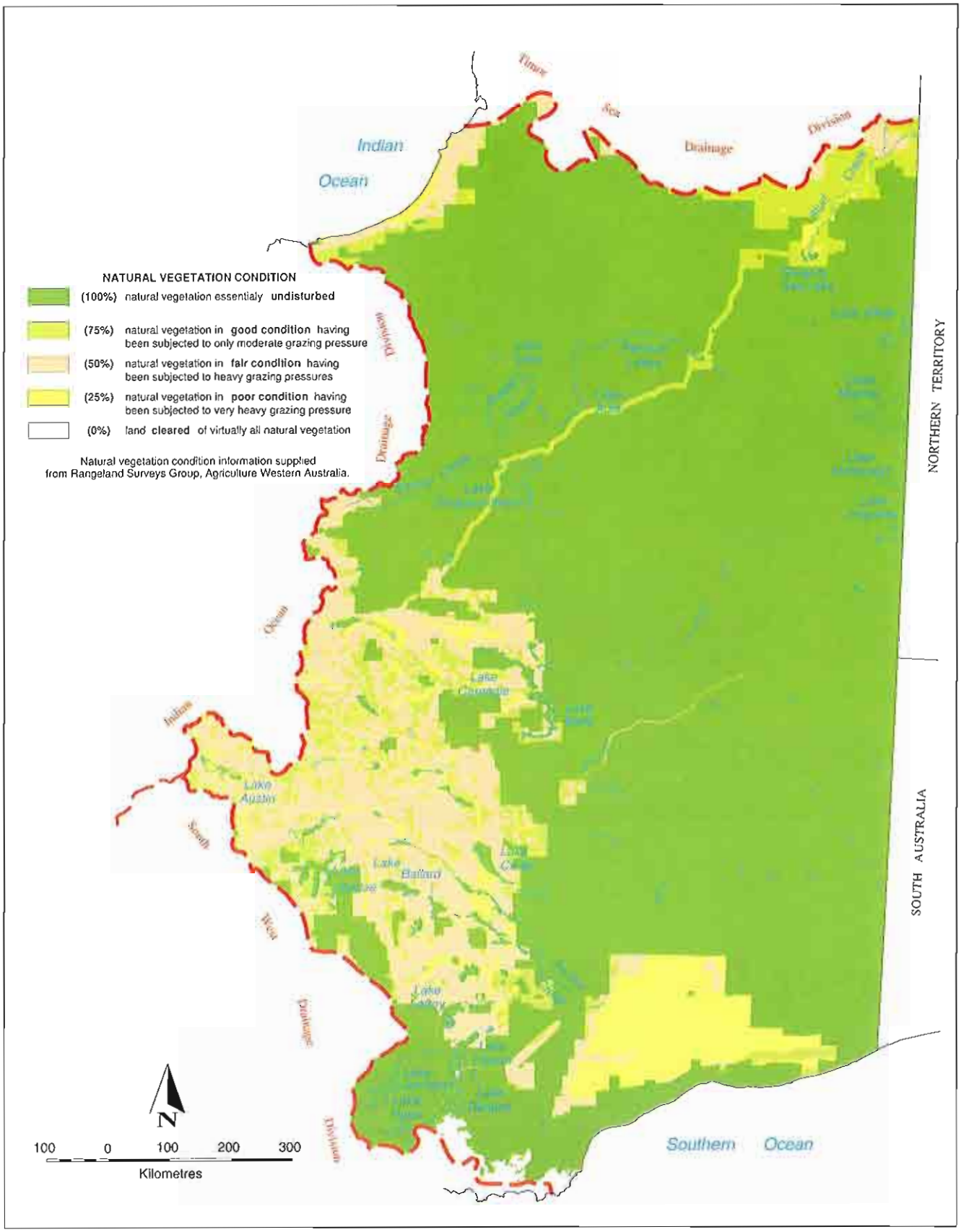
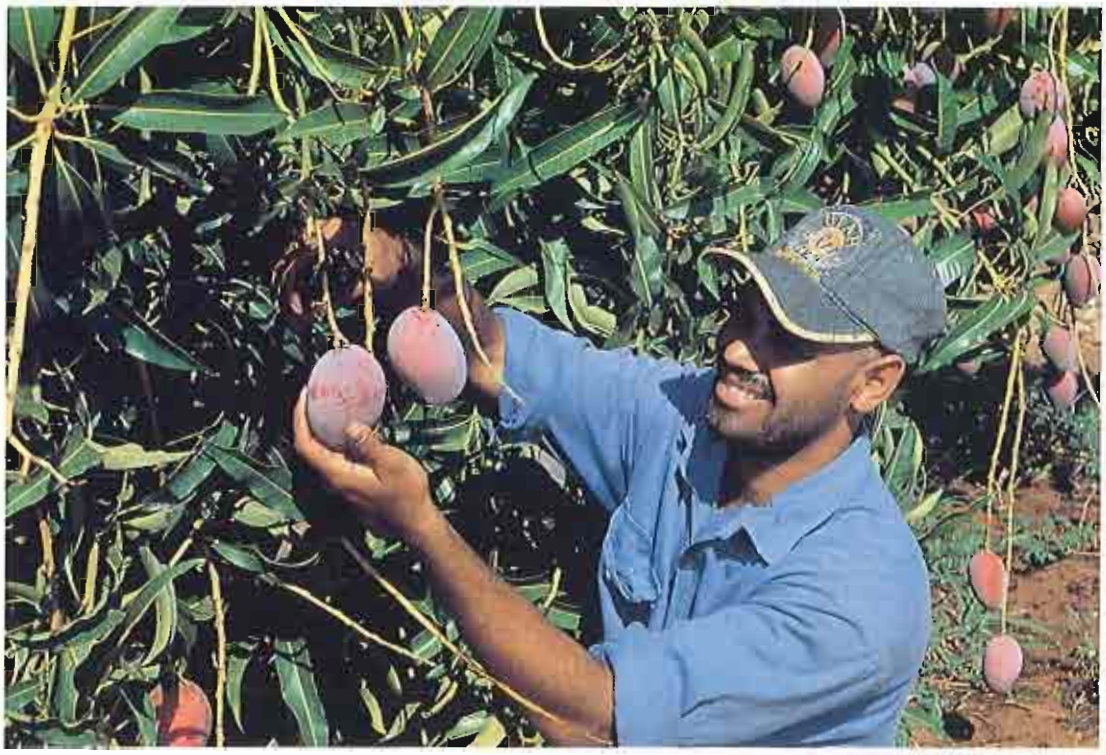


Figure 16: Western Plateau Drainage Division — Natural vegetation condition.



Horticulture is an important industry in Carnarvon and Kununurra, supplied with water from the Gascoyne and Ord rivers respectively.

the problem is not widespread in the other three divisions. It is only rivers in the Greenough and Murchison river basins (701 and 702) that are affected. The rivers in these two basins all have very high salinity levels.

The other areas where the natural vegetation has also been removed and replaced are in the few areas of intensive horticulture. There is a small area near Broome, where local groundwater is used to irrigate a few hectares of melons, mangoes and small experimental areas of cotton. There is an important horticultural industry at Carnarvon. Bananas and tomatoes are the main crops, although tree crops such as mangoes, avocado, pawpaw, grapefruit, mandarins, peaches and nectarines are rapidly growing in size and importance. They are irrigated by groundwater from aquifers fed by, and near the mouth of, the Gascoyne River.

The main horticultural area in the Timor Sea Drainage Division is the Ord Irrigation Area which is supplied with water from the Ord Dam (Figure 17). The irrigation area presently covers about 15 000 hectares, but it is proposed to increase considerably in size, extending to the Carlton Plain further downstream, the Weaber Plain, and over into the Keep River Plain extending across the border into the Northern Territory. The main crops are fruit and vegetables, and a sugar industry is currently being developed. Cotton was a significant industry on the Ord in the 1960s and early 1970s, but the industry folded due to problems with insect pests. Pesticides were used heavily in the 1960s and 1970s, although the level of organochlorides in sediments has gradually decreased over time. Monitoring by the Water and Rivers Commission in 1997 detected organochlorides in the waters of the irrigation drainage system and the rivers. These organochlorides are less persistent in the environment than those used in the 1960s and 1970s, though they are still of concern. A management strategy is being enacted jointly by Government and landholders to improve the situation.

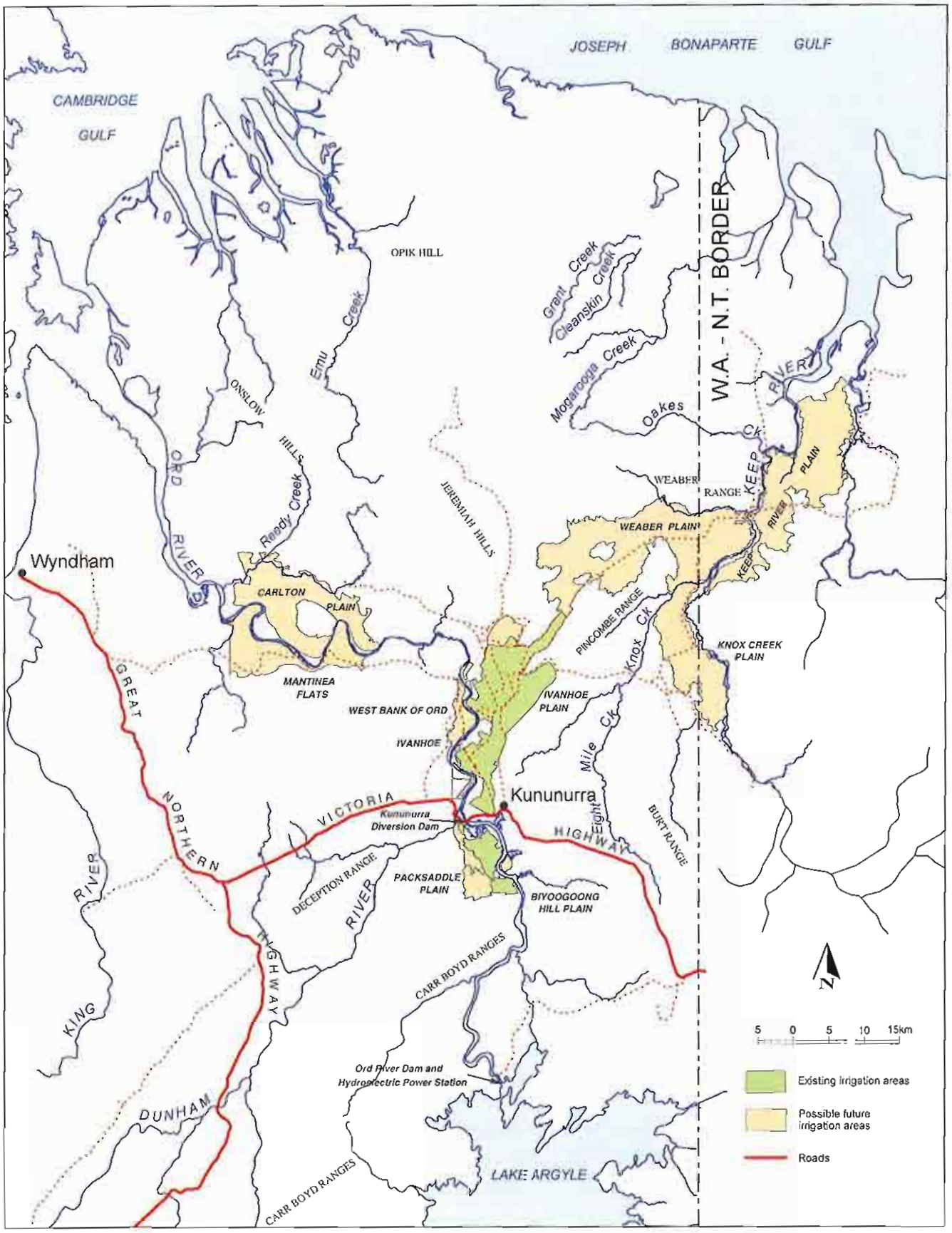


Figure 17: Development of the Ord River.

Introduction of weeds

THE INTRODUCTION OF exotic weed species has had a comparatively small but deleterious effect in the rangelands and, indirectly, on the rivers that drain them. Weeds tend to displace native plants, and native animal species that are unable to adapt to the new species and use them for food or shelter. In addition, introduced plants, especially grasses, may significantly increase the risk and effects of fire.

Noogoora Burr is found along the Fitzroy and Ord rivers, and large areas are quarantined and sprayed to prevent its spreading from the Kimberley to areas where sheep are run. Mesquite was originally introduced as a fodder plant, but the cultivar used reverted to a form that grew large thorns, making it useless to cattle.

Noogoora Burr

Mesquite thicket

Mining

MINING HAS THE POTENTIAL to affect rivers in a variety of ways including water harvesting and the disposal of wastes. Mining operations and their impact on the environment are now covered by mining agreements reached with the State and monitored by the Departments of Resources Development and Environmental Protection. Iron ore is the major industry in the Pilbara Region of the Indian Ocean Drainage Division, and manganese is also mined there. The Argyle Diamond Mine is the largest operation in the Timor Sea Drainage Division. In the Western Plateau there is extensive gold and nickel mining, most of it concentrated in the Eastern Goldfields. Existing mine sites, known large mineral deposits and potential sources are shown in Figure 18.

Mine process water is generally contained, decontaminated on site and often recirculated. Dewatering of mines can have an impact on the environment by lowering water tables or by creating permanent flows where previously there were none. However, impacts are generally fairly local, and there are no known instances of major or extensive adverse impacts on local fauna or flora.

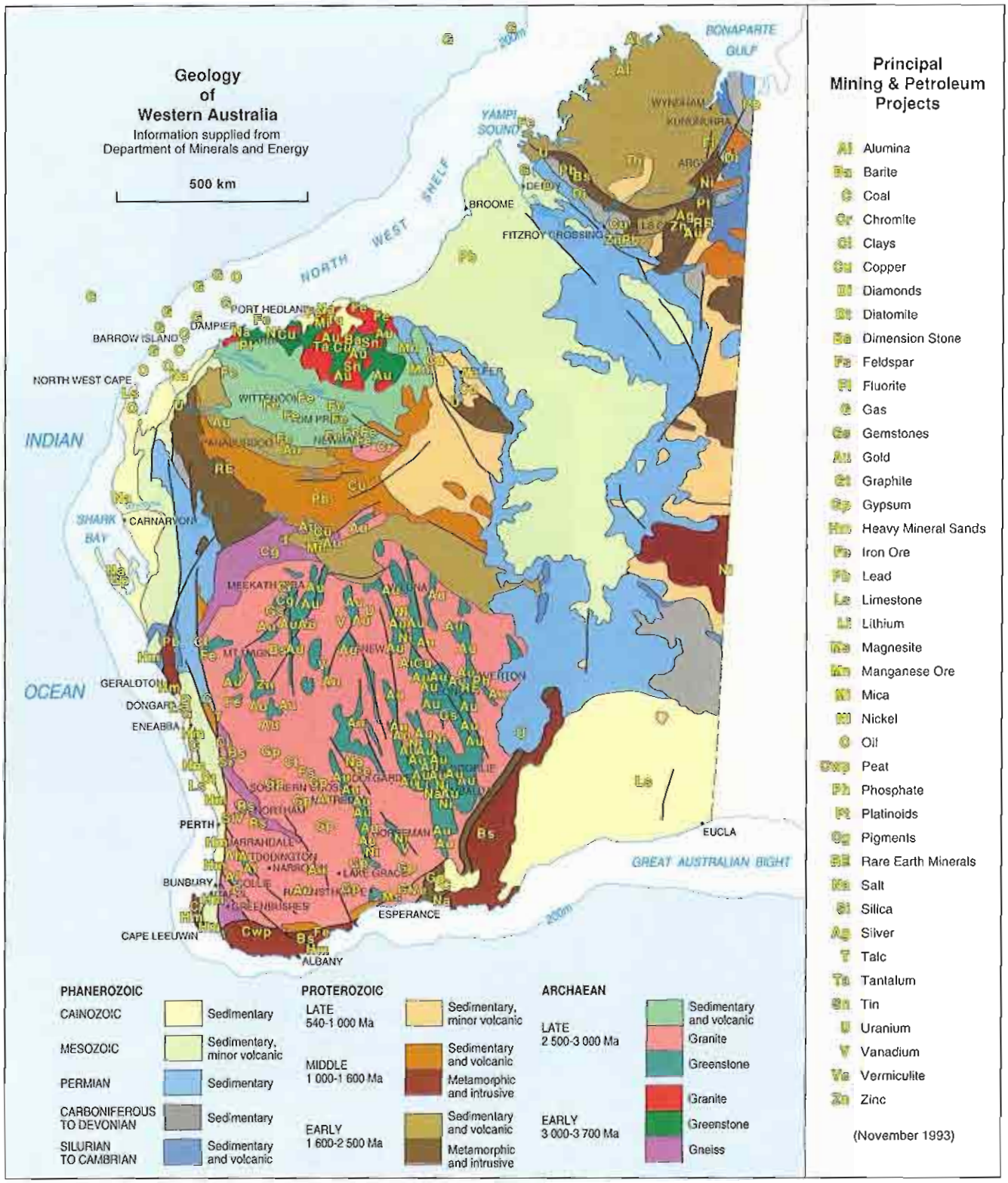


Figure 18: Mine sites and mineral deposits.

Roads and tracks

ROADS OFTEN REQUIRE CUTTINGS and embankments, and have impervious surfaces which increase run-off, all of which frequently results in the channelling of water causing erosion. Even minor tracks lead to destruction of vegetation, as the soil is ploughed up or loosened by traffic, leading to erosion, deep ruts, and alternative alignments a few metres away. The cycle can be repeated several times, depending upon the traffic load and the fragility of vegetation and soils. Roads are comparatively few and far between throughout the three divisions and generally do not cause major problems. However, there is a significant problem in some areas, such as in the flat mulga country of the coastal flood-plains in the Pilbara, and ways of minimising such impacts are being sought.

Road construction can alter drainage patterns resulting in erosion, if not carefully planned.

Dams

THERE IS ONLY A comparatively small number of dams outside the South West, within the other three drainage divisions of Western Australia. The reason for this is partly the size of the demand, partly the technical difficulties involved in developing surface sources, and partly the availability of groundwater as alternative and less costly sources. Major dams and diversion structures are listed in Table 10.

Table 10: Major dams and diversion structures.

Division	River	Structure
Indian Ocean	Harding River	Harding Dam
	Fortescue River	Ophthalmia Dam
Timor Sea	Fitzroy River	Fitzroy Barrage
	Uralla Creek	17 Mile Dam
	King River	Pipehead Dam
	Moochalabra Creek	Moochalabra Dam
	Arthur Creek	Arthur Creek Dam
	Ord River	Ord Dam
	Ord River	Kununurra Diversion Dam
Western Plateau		

Dams have major effects on rivers:

- they radically change the downstream flow regime, and can prevent any flows for a number of years. When flows do occur by overtopping, or if water is released, they can be quite different from the normal flow regime in terms of temperature, oxygen content, silt load etc.;
- they prevent passage of fish and invertebrate fauna and sometimes floral species, in both directions;
- they create reservoirs which can become completely new (micro) environments, particularly in arid regions like those under consideration.

The structures on the King River and Moochalabra Creek are only small, constructed for the purpose of supplying water to the town of Wyndham. Arthur Creek, a tributary of the Dunham River south-west of Kununurra, also has a small dam, built as part of a private irrigation development scheme that is not presently operating. Fitzroy Barrage is a low structure that facilitates the diversion of a very small portion of the huge flows of the Fitzroy River to another small dam on Uralla Creek, and to a private irrigation scheme that is also not presently in operation.

Harding Dam was built by the Public Works Department in the early 1980s as a source of water supply to the West Pilbara. The dam, 35 metres high and 380 metres in length, impounds 80% of the run-off from its 1071 square kilometre catchment area. It has had a significant effect on the pools in both branches of the comparatively short length (40 kilometres) of river downstream, and on their surrounding vegetation.

OPHTHALMIA DAM

Ophthalmia Dam, on the Fortescue River, was built by the Mt Newman Mining Company in 1981 to supply water to the town of Newman and the Mt Whaleback Mine operations. The building of the dam coincided with climatic changes and annual flows into the dam have varied from considerably below, to a little above the long term average. The dam has spilled several times, but generally only for brief periods. The most significant impact of the dam is on the moderate flood events which occurred every five years and were considered sufficient to maintain the floodplain vegetation. Lack of flow data, however, makes it difficult to determine the distance to which this impact occurs downstream of the dam.

Significant deterioration in vegetation health on the Fortescue River floodplain and that of some of its tributaries on Ethel Creek and Roy Hill stations have led to several investigations by state agencies. Research is coordinated by the Pilbara Iron-ore Environmental Committee chaired by the Department of Resources Development. The investigations have shown that the environmental problems experienced on these stations are the result of a combination of issues.

The longstanding severe landscape degradation in the form of almost complete loss of perennial vegetation cover and soil erosion (mainly scalding) is considered to be due largely to historical overgrazing and climatic changes[1]. A large scale rehabilitation programme, involving paddocking, de-stocking, cultivation and reseeding, by BHP on Ethel Creek station has proved highly successful. Perennial vegetation has returned to much of the previously degraded area and the land is now in far better condition.

The earlier reported[1] widespread stress and death of trees (mainly *Eucalyptus coolabah*) largely reflect the change in annual flows within the river resulting from both climatic changes and Ophthalmia Dam.

Recent above average rainfall events have, however, seen remarkable recovery in many of the previously affected areas. The more recent concern about the death of *Acacia aneura* (mulga) on Roy Hill Station has been found to be related to many factors other than Ophthalmia Dam. The main causes are old age, fire, climatic changes, grazing and changes in local hydrological flow patterns due to infrastructural development.

[1] Payne A. L. & Mitchell A. A. 1992, *An Assessment of the Impact of Ophthalmia Dam on the Floodplains of the Fortescue River on Ethel Creek and Roy Hill Stations* (Technical Report 124), Department of Agriculture Western Australian, Perth.

Cumbungi rushes proliferating along the Lower Ord due to river flow controls.

ORD RIVER DAM

When the Ord River Dam was built in 1971, it created Lake Argyle. With a storage volume of 10 760 million cubic metres, it is the second largest reservoir in Australia.

The dam has changed the whole of the Ord River (see Figure 17). Downstream the river has changed from a seasonal to a perennial river. This has caused a significant change in the riverine flora. Exotic species are slowly colonising the area and taking over from the native flora. This has obvious implications for fauna that utilise the fringing vegetation. The Lower Ord no longer floods regularly, as it once did. As a result, silt is building up, causing the river to get wider and shallower. This will change the physical and biological characteristics of the river.

The salinity of the Ord has also changed markedly since the construction of the dam. Before the dam was built, the tidal influence extended up the river as far as Ivanhoe Crossing. The river was salty as far as Goose Hill. With the change to perennial flow brought about by the dam, the tidal influence has diminished and the water is now fresh. This has implications for some species, such as barramundi and freshwater crocodiles.

The huge reservoir formed by the dam is a major new wetland. Birdlife in the area is probably more prolific now than it was before the dam was built. It is estimated that there are now 25 000 freshwater crocodiles in Lake Argyle. Before the dam, the area probably only supported a few hundred.

Ord River Dam, completed in 1971, was built to supply water for irrigation.

Erosion and sedimentation

Heavy rainfall on bare soils results in a network of eroded channels as shown here in the upper reaches of the Hahn River, a tributary of the Fitzroy.

While dams, mining, roads and tracks, and introduced floral species (weeds) have all resulted in river degradation in the Indian Ocean, Timor Sea and Western Plateau drainage divisions, by far the most serious cause of degradation is removal of the natural riverine and catchment vegetation resulting in soil erosion and sedimentation. In the South West this has caused salinisation which is the drainage division's most serious form of degradation and Western Australia's most serious environmental problem. Erosion and sedimentation are widespread throughout the Indian Ocean and Timor Sea divisions and the problem is growing in magnitude. Like salinisation, it has a momentum of its own and will require the expenditure of considerable time and effort before progressive deterioration can be halted and the position begin to improve.

Large areas of the Indian Ocean and Timor Sea divisions are predisposed to soil erosion because of their susceptible, often fine textured soils, and the highly intense rainfall that is experienced. Some areas are not so disposed, such as the spinifex covered hard rocky soils on the Hamersley and Chichester ranges in the Pilbara. To this predisposition has been superimposed very intensive grazing pressure over wide areas, destroying the vegetation and exposing the fragile soil structure and stability to the impact of the northern tropical storms. The broad pattern of land use throughout the three drainage divisions is shown in Figure 19. It can be seen that nearly all the Indian Ocean, two thirds of the Timor Sea and significant portions of the Western Plateau drainage division are subject to pastoral activity.

In the Kimberley (Timor Sea Division) sheet and gully erosion is widespread, particularly in the Ord and Fitzroy river catchments, stemming from the vegetation degradation shown in Figure 15. In the drier areas of the Indian Ocean and Western Plateau divisions overgrazing and consequent death of saltbush has led to widespread erosion. Saltbush is an incredibly hardy perennial with deep roots that hold the soil together. The broad picture was presented in Figures 14 and 16.

Intensive grazing pressure over many years has denuded the land over large areas, such as this portion of the Ord River catchment.

Lake Argyle, with a storage capacity of 10 760 million cubic metres, is the second largest reservoir in Australia.

Large portions of the Murchison and Gascoyne river regions are degraded. In the Pilbara degradation is widespread on the extensive coastal floodplain areas. The Ashburton and Cane rivers are two of the most degraded catchments and parts of the De Grey River catchment have also experienced similar decline.

Sheet erosion, acting on broad areas of denuded soils, and gully erosion, where the water is concentrated into channels which are continuously cut deeper and deeper, are both common. Both are exacerbated by stock trampling and tend to occur around pools and billabongs where stock usually congregate. Once erosion starts to occur, particularly in the form of gullying, it is very difficult to stop. Areas of sheet erosion can be held by revegetation, but the forces of water involved in gully erosion are huge, gullies can become very deep and wide, and sometimes major artificial structural works are the only practical remedy.

As the watercourses grow in size and strength, gully erosion can develop to huge proportions.

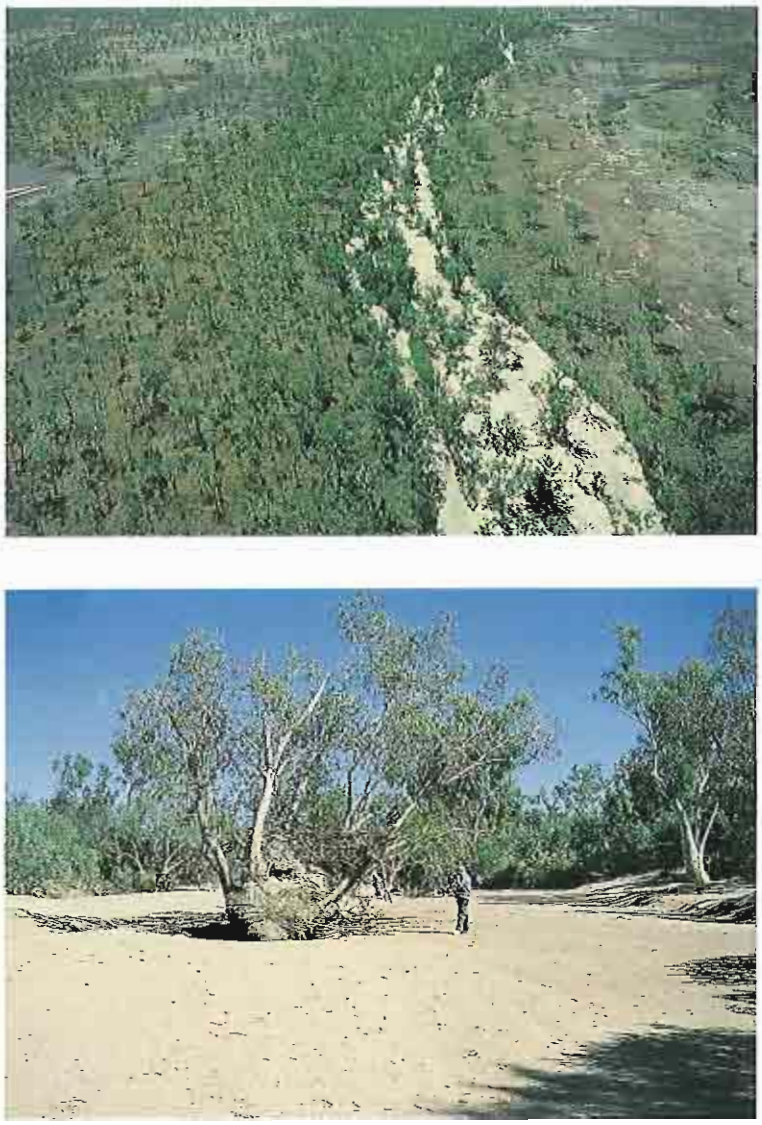
The soil that is eroded has to end up somewhere. It muddies the rivers as they flow. It is deposited and lines the river banks and fills the precious pools. It is deposited in estuaries and in any artificial reservoirs that are formed.

The deposit of sediment in the pools has a number of detrimental effects. First, the finer sediments smother the bottom gravels in which a variety of creatures feed, breed and shelter. As it deepens, it smothers the stream-bed flora and fauna and buries organic waste matter, preventing access to a food source and cutting down the water's oxygen supply. Logs and branches that fall from the fringing vegetation, and which would normally become a home or shelter to other species, also become buried. As the sediment builds up, the pool becomes shallower and the temperature of the water rises, often aided by the removal of the fringing vegetation and the shade it provided. This increased temperature makes a dramatic difference to the pool's ability to support life as the oxygen demand increases while dissolved oxygen concentration decreases.

As the pool becomes completely filled, it no longer slows the stream down; it allows what remains of the bottom-dwelling flora and fauna to be swept downstream. Pools can get scoured out to some extent in big floods, especially the large rocky pools, but they are generally subsequently refilled over periods of lower and slower flows.

Over the 25 years since the Ord Dam was built and its reservoir, Lake Argyle, was formed, sediment has been deposited at the rate of 24 million cubic metres a year, reducing the useable storage by 600 million cubic metres, a little over 10% of the original volume. The figure of 24 million cubic metres a year is very close to that estimated at the time of construction. However, it had been hoped that the withdrawal of badly degraded portions of the catchment from pastoral use, and the regeneration programme that has been carried out, would have reduced the rate. This does not appear to have worked, and it is believed that while sheet erosion has been reduced, this has been off-set by an increase in gully erosion. Further work is necessary to determine the sources of the sediment and measures necessary to regain control. In order to safeguard the potential of other Indian Ocean and Timor Sea drainage division rivers for future water supply purposes, it is essential that natural erosion control mechanisms are not lost.

The Fortescue River in flood carrying a huge sediment load.



Robinson River from the air and on the ground, choked by the sediment that has been deposited along most of its length.

Generally rivers have become degraded in pastoral lease areas subjected to heavy grazing pressure. Where the land use has not been unfavourable, such as in national parks, Aboriginal reserves, nature conservation and various other forms of Crown reserves, and in areas of vacant Crown land (VCL) (Figure 19), the rivers and riparian zones remain in good to excellent condition. Figures 21, 22 and 23 give an indication, based on the land use, and on the reported degradation of the natural vegetation and general rangeland condition as surveyed by Agriculture Western Australia, of the probable state of the riparian zone.

The condition of the rivers is shown as very poor, poor, fair, good and excellent. These descriptions correspond, approximately, to a previously developed system of grading the condition of river foreshores or riparian zones, as shown in Figure 20. The system was originally developed for and is being used progressively throughout the South West Drainage Division. However, it has been found suitable for use elsewhere in the State, though the original natural riparian zone vegetation depicted in Figure 20 will obviously vary from region to region.

In the Indian Ocean Drainage Division, as can be seen in Figure 21, there are no entire rivers in excellent condition, only a few of the upper tributaries of rivers draining the Chichester and Hamersley ranges. The Gascoyne, Wooramel and Murchison rivers and all of the smaller rivers to the south of the Murchison, from the Hutt to the Arrowsmith River, are in poor to very poor condition. The Ashburton River is good overall, but deteriorates where it crosses the coastal plain. The condition of the Fortescue River is very mixed, ranging from excellent to very poor.

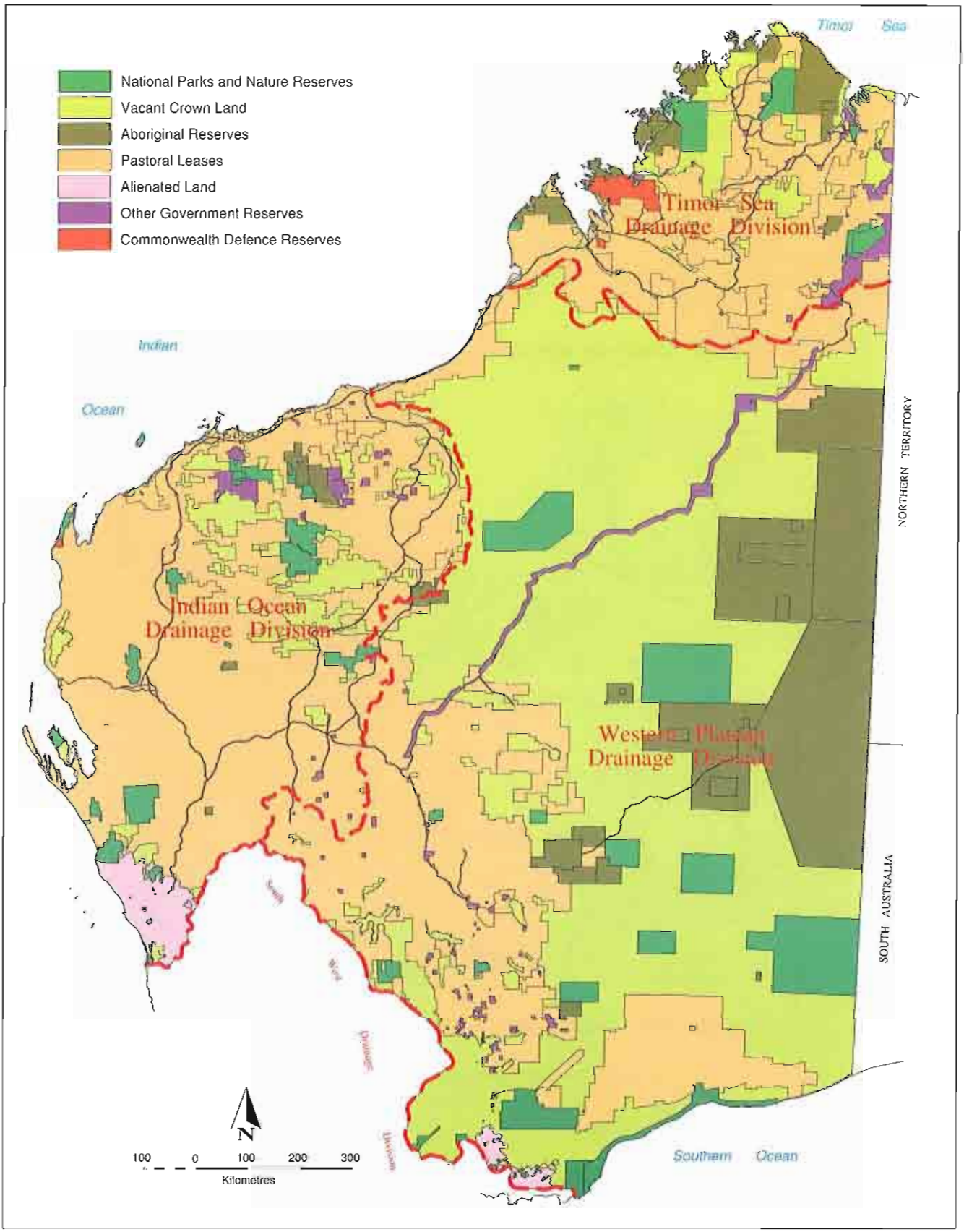


Figure 19: Land use.

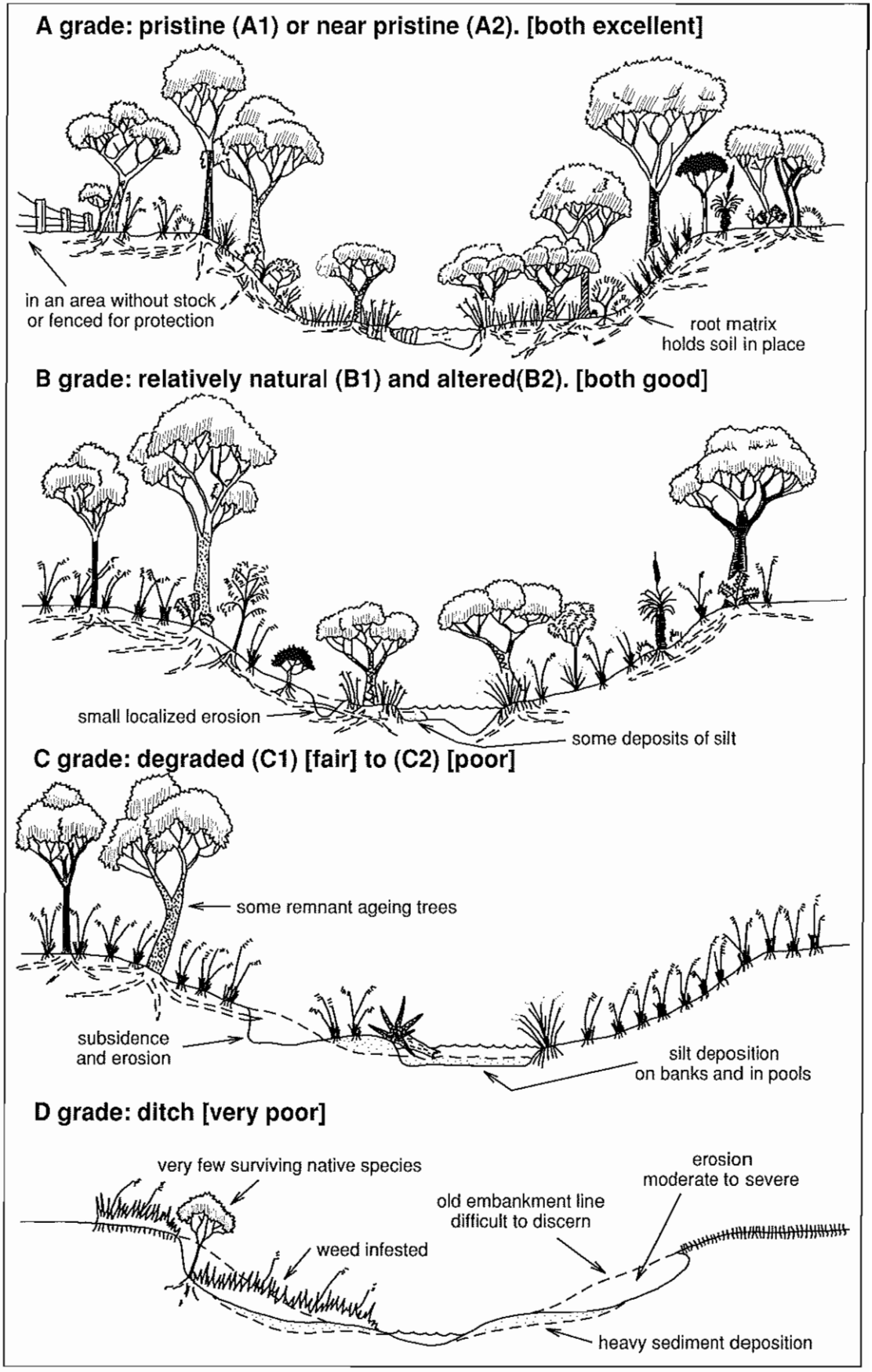


Figure 20: Riparian zone condition gradation system. [River foreshore condition divided into four main stages or grades, following general process of river valley degradation, pristine (A1) to ditch (D).]

A gorge in the Hamersley Range, through which runs one of very few streamcourses in the Indian Ocean Drainage Division that are still in good condition.

Thus, there are no well preserved examples of any of the five types of rivers of the division (T12 to T16) as described in Table 2. All T12 rivers at the southern extremity of the division are generally in very poor condition as a result of widespread clearing. The Murchison River, a representative of type T13, is mixed; excellent in appearance as it passes through Kalbarri Gorge and the Kalbarri National Park (see photo on page 3), but only fair to very poor in its upper reaches. The Wooramel and Gascoyne, the other T13 rivers, are both only fair to very poor.

The three examples of T14 rivers, the Minilya, Lyndon and Yannarie rivers, are good in places but with some extensive poor and very poor sections or reaches. The Ashburton, one of only two representatives of type T15, is generally good, with a few excellent tributaries but also a few only fair ones, but is in poor condition over the final 120 or so kilometres as it crosses the coastal plain. The other T15 river, the Fortescue, is very mixed with a considerable portion in the very poor category. A few of the type T16 rivers are as near as they get to being well preserved in this division. The Robe River is mainly good and excellent at its upstream end, the Yule River similar. However, all drop down to only fair or poor as they cross the coastal plain to the ocean.

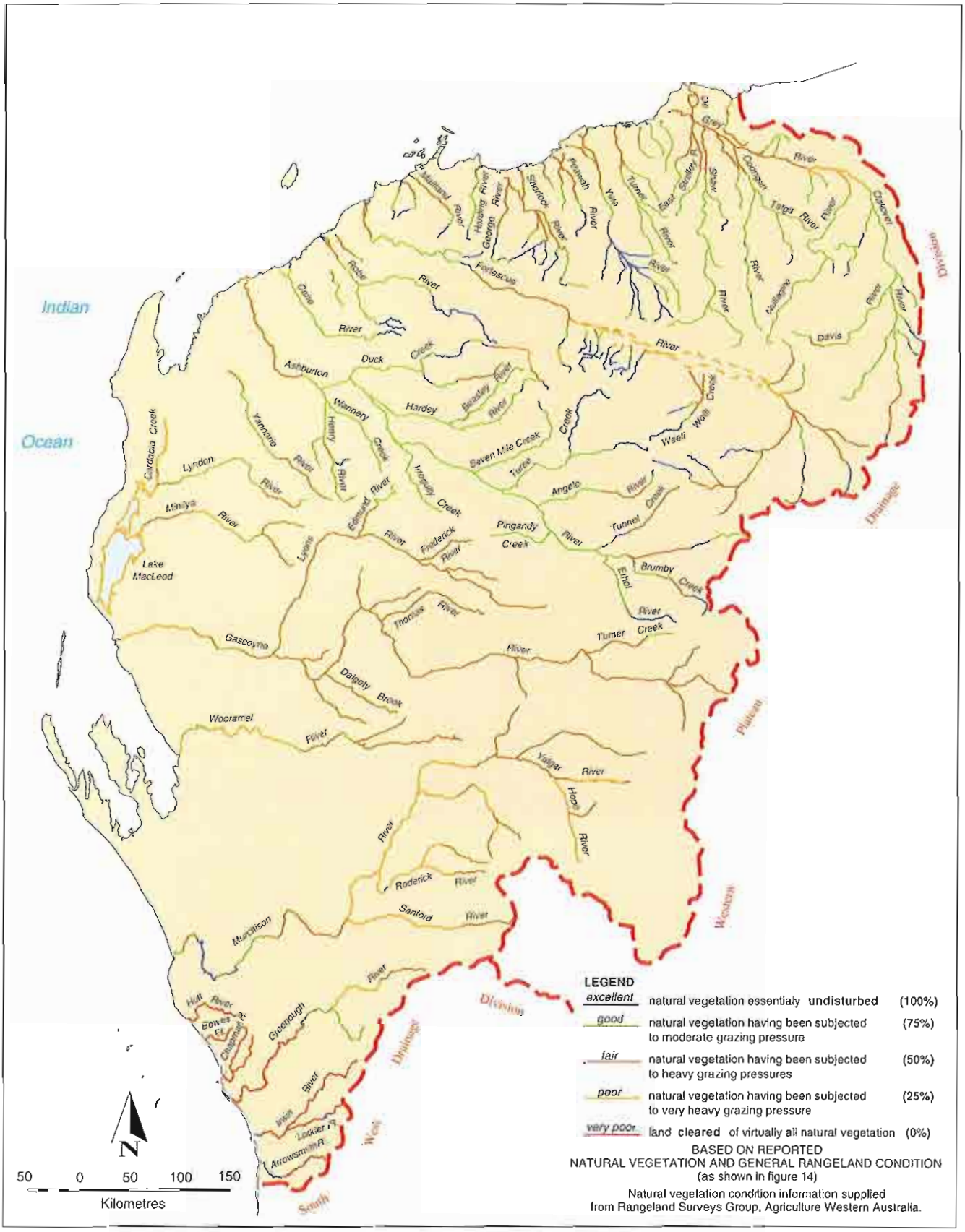


Figure 21: Indian Ocean Drainage Division — Probable state of riparian zones.

Erosion scars developing on an upper tributary of the Durack River.

Erosion along Christmas Creek, a tributary of the Fitzroy River.

Overall, the rivers of the Timor Sea Drainage Division are in much better condition than those of the Indian Ocean, as shown in Figure 22. The two largest rivers, the Fitzroy and the Ord, are only fair to poor, but most of the remainder are still in good condition and quite a number are excellent.

The Ord River (T21) is the sole representative of its type as listed in Table 5, thus there are no well preserved examples. The Fitzroy River (T20) is one of only a few, and the largest example of its type. All the others, such as the May, Meda/Lennard and Robinson rivers are in a similar poor condition, and therefore there are no well preserved examples of T20. A number of the type T19 rivers are in good condition, the best being those draining the Dampier Peninsula, flowing westwards to the Indian Ocean north of Broome.

Most of the type T18 rivers, including the Drysdale; King Edward/Carson; Mitchell; Calder; Charnley and Isdell rivers, are in good condition, with some excellent portions and a few reaches that are only fair. All type T17 rivers are in good or excellent condition.

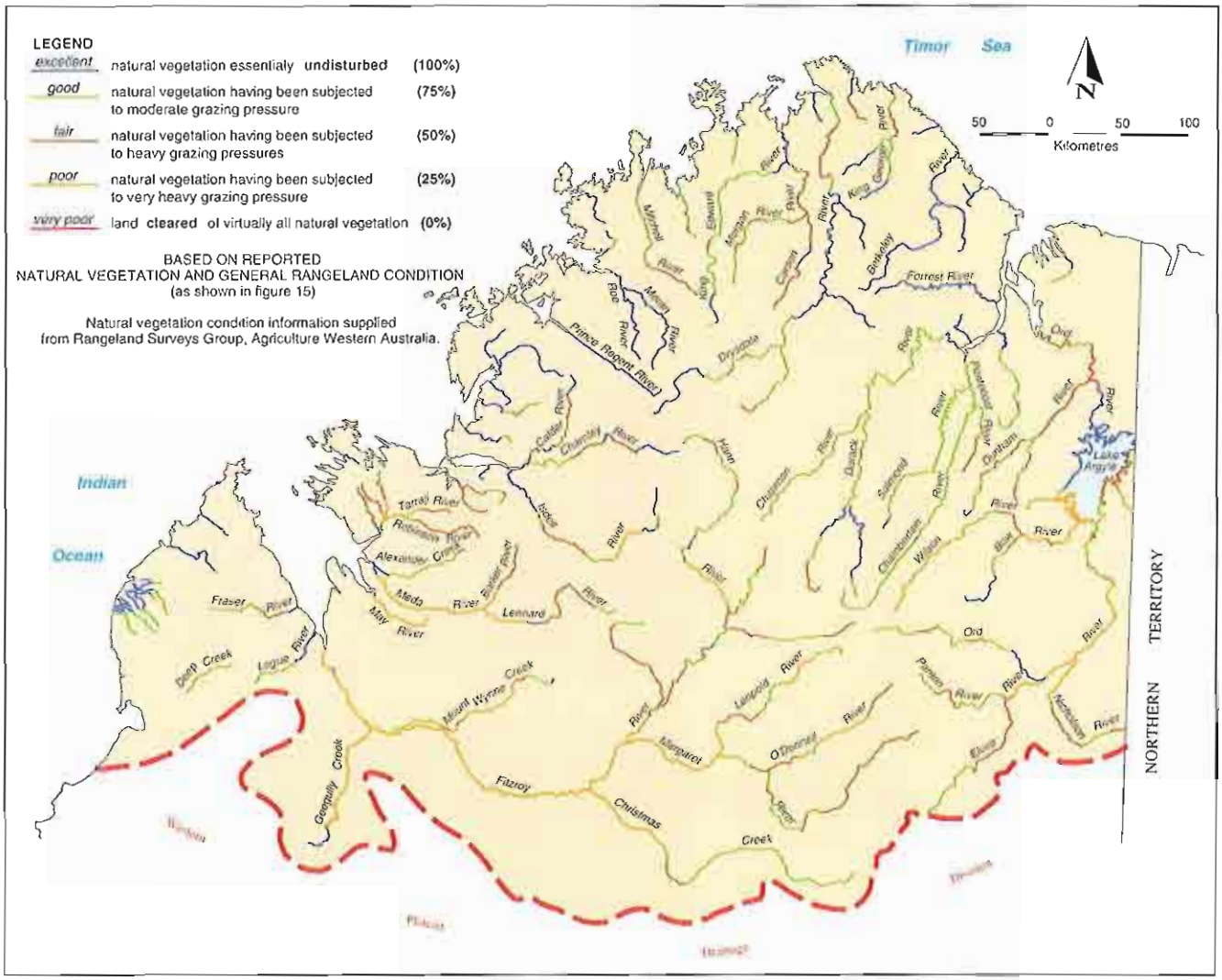


Figure 22: Timor Sea Drainage Division — Probable state of riparian zones.

Scouring in the upper reaches of the Isdell River catchment area.

The Western Plateau Drainage Division as shown in Figure 23 has very few watercourses of any size. Sturt Creek located just to the south of the Timor Sea Drainage Division is in generally poor condition. What small watercourses there are to its south, as far as the Great Australian Bight, are essentially undisturbed and in excellent condition. The two major watercourses to the west of the Great Sandy Desert, the Rudall River which flows into Lake Dora and Savory Creek which flows into Lake Disappointment, are both in excellent condition overall. Ponton Creek is in generally excellent condition, but the watercourses joining the two major strings of salt lakes to its north-east are in poor condition. There are several short ephemeral watercourses in the south-west of the division, in the Lakes Johnston, Hope and Dundas areas, that are in excellent condition.

The river types as listed in Table 8 for the Western Plateau Drainage Division is stretching the concept to the limit, and perhaps beyond, for this vast arid area of highly ephemeral watercourses. In general, any watercourse of significant length constitutes a sole representative example of its type. All of the very few that exist are unique, and thus warrant great care and consideration.

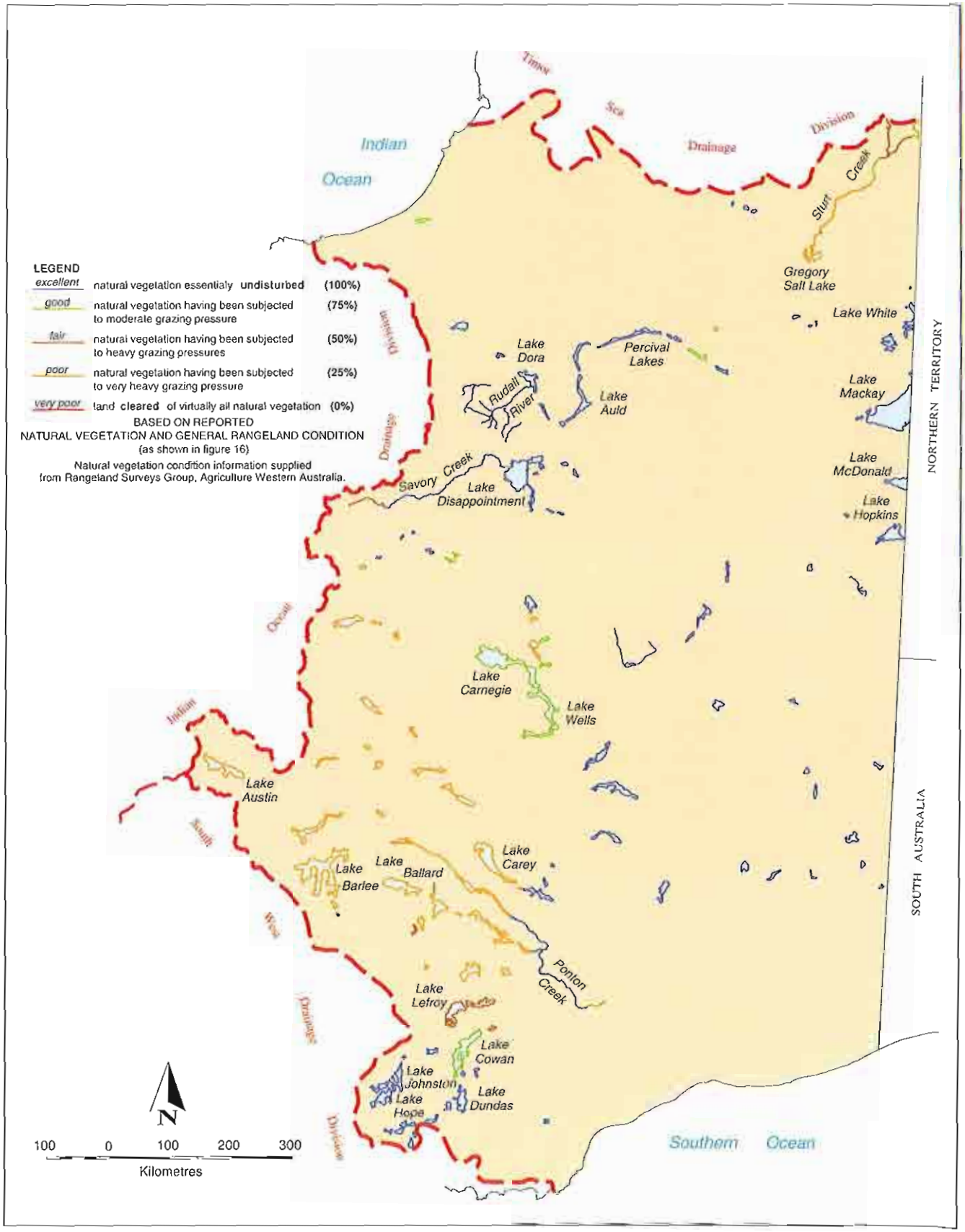


Figure 23: Western Plateau Drainage Division — Probable state of riparian zones.

THE BEST OF WHAT REMAINS

'A thing of beauty is a joy forever
Its loveliness increases; it will never
Pass into nothingness.'

John Keats

BEAUTIFUL RIVERS, as well of being of great practical use and aesthetic appeal to human beings, have huge intrinsic value. However, while a river may never pass into nothingness, at least as long as the hydrologic cycle continues to function on this planet, it can, become severely degraded and lose much of its loveliness.

The Water and Rivers Commission has participated in a national study funded by the Commonwealth Government, aimed at identifying all Australia's 'wild' rivers, i.e. rivers that remain in a pristine or near-pristine (excellent) condition. Wild (pristine or near-pristine) rivers have been defined as 'those rivers which are undisturbed by the impacts of modern technological society. They remain undammed and exist in catchments where biological and hydrological processes continue without significant disturbance. They occur in a variety of landscapes, and may be permanent, seasonal, or dry watercourses which flow only occasionally.

The rivers were first provisionally identified by means of a Geographic Information System (GIS) study and review, similar in method to but at a much larger scale and in much greater detail than that presented in Figures 21, 22 and 23 in the previous chapter. They were then the subject of field inspection and verification. During this phase the categories at the top (well preserved) end of the scale shown in Figure 20 were further refined.

Rivers assigned to Category A1 (pristine) have had no alterations to their watercourses or to their catchments since European settlement. There has been no significant:

- clearing or other alteration to the landscape;
- road or track construction;
- increased fire frequency;
- introduction of foreign plants or animals;
- introduction of plant diseases.

Rivers assigned to Category A2 (near-pristine) have had no significant changes to their natural ecosystems, despite some past or present human activity within their catchments. However, there may be:

- some seldom-used minor foot and vehicle tracks;
- some increase in fire frequency;
- very limited introduction of plant or animal species;
- minor evidence of grazing, but no soil exposure.

Rivers assigned to Category B1 (relatively natural) are still essentially dominated by native species throughout their catchments, and though they have been changed to some extent, it is considered that with the removal of grazing pressure, they would quickly return to a near-pristine state. They may be experiencing:

- some, but not extensive problems of erosion and sediment deposition;
- relatively constant use of tracks;
- some loss of vegetation as a result of grazing;
- increased fire frequency.

Rivers assigned to Category B2 (altered) have been significantly changed in one or several ways. There may have been:

- fairly heavy grazing;
- regular use of fire, degrading some plant communities;
- a moderate number of fairly heavily used vehicular tracks;
- some unnatural bare patches, sheet erosion and gullying;
- considerable sediment deposition in river floodways, but mainly on point bars.

Rivers in this category have been degraded to such an extent that it would not be possible or practical to return their catchments to a near-pristine state. However, with appropriate rehabilitation measures and proper management, they could be made stable, healthy functioning ecosystems.

Hunter River, a river in pristine condition.

Rivers assigned to Categories C and D have been very extensively and radically changed by post-European settlement land use. They have been subject to all or most of the following:

- areas completely cleared or subject to heavy grazing pressure, particularly on sedimentary plains and along watercourses;
- frequent fires and related damage;
- many frequently used stock and vehicle tracks;
- many bare patches, sheet and gully erosion;
- river channels and floodplains heavily silted and eroded;
- trampled river banks and fouled billabongs;
- widespread infestation of weed species;
- impoundments and regulation of river flows.

Though rivers in this category would be capable of being rehabilitated to a considerable extent, it is considered that they could never be returned to anything approaching their undisturbed state.

While there is a distinct theoretical difference between rivers in Category A1 and those in Category A2, there is not between A2 and B1. Also, there is a distinct theoretical difference between rivers in Category B1 and those in B2, but there is not between B2 and C. Rivers in Category A1 are unmodified and have not been changed in any way, as far as is known, since the time of European settlement. All the rivers in A2 and B1 have been changed, and from the best of those in A2 to the worst of those in B1 there is more or less a continuum. The dividing line between B1 and B2 is drawn on the basis that rivers in Category B1 would revert to a wild state, if the land uses causing change were to be removed. In contrast, in the case of rivers in Categories B2 and C, if the land uses causing alteration or degradation were to be removed, the river conditions would improve, but they would not be able to return to near their original undisturbed state. These rivers have been radically and permanently changed.

Table 11: Remaining pristine, near-pristine and relatively natural rivers.

	DRAINAGE DIVISION		
	Indian Ocean	**Timor Sea**	**Western Plateau**
A1 Pristine		Prince Regent River	Rudall River
		Mt Page Creek	Herbert Wash
		Doubtful River	
		Mt King Creek	
		Hunter River	
		Scott Creek	
		Cape Whiskey Creek	
		Helby River	
		Lyne River	
		Thompson River	
A2 Near-pristine		Jinunga River	Savory Creek
		Gibson Creek	Ponton Creek
		Glenelg River	
		Ashburn Creek	
		Wade Creek	
		Londonderry Creek	
		Stewart River	
		Bulla Nulla Creek	
		Salmond River	
		Walmar Creek	
B1 Relatively natural	Upper Yale River	Lawley River	
	Upper Robe River	Placid Creek	
	Sherlock River tributary	Berkeley River	
		King George River	
		Sale River	
		Roe River	
		Calder River	
		Forrest River	
		Charnley River	
		Moran River	
		King Edward River	
		Pentecost River	
		Chamberlain River	

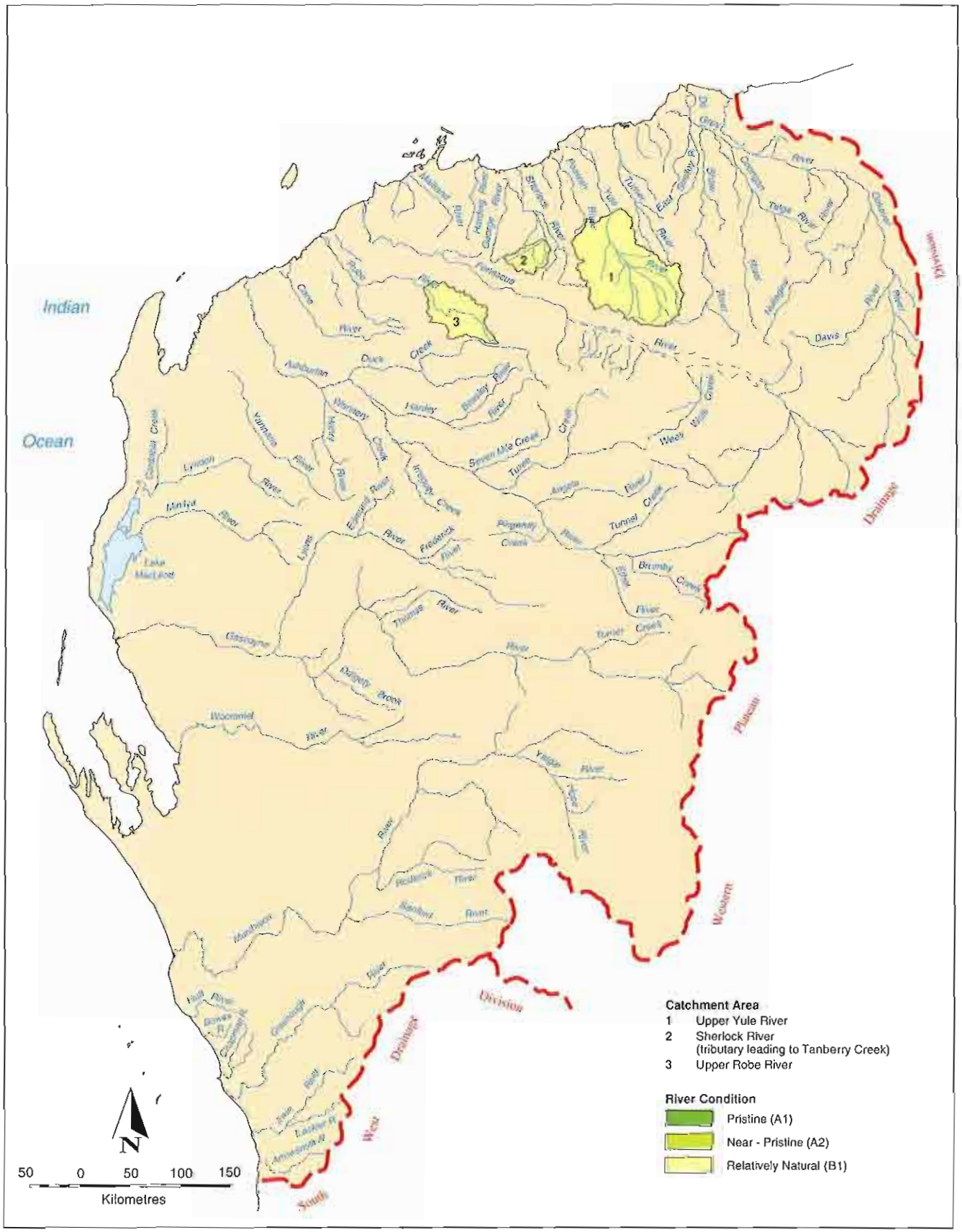


Figure 24: Pristine, near-pristine and relatively natural rivers remaining in the Indian Ocean Drainage Division.

Charnley River Gorge.

Rudall River, a pristine river in the Western Plateau Drainage Division.

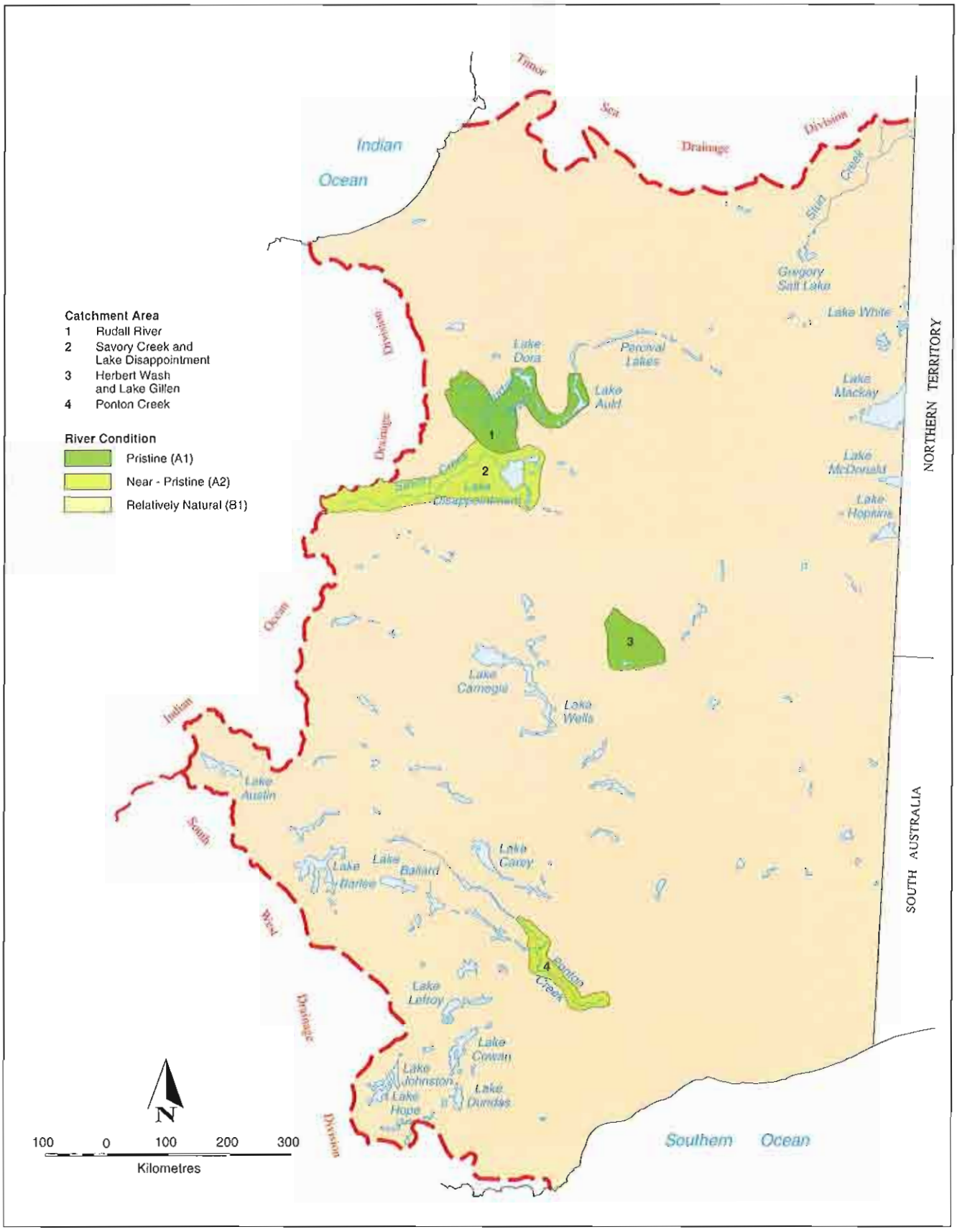


Figure 25: Pristine, near-pristine and relatively natural rivers remaining in the Western Plateau Drainage Division.

King George River
Falls in the dry season.

The rivers of the Indian Ocean, Timor Sea and Western Plateau drainage divisions that have been found in each of the three top categories A1 (pristine), A2 (near-pristine) and B1 (relatively natural) are listed in Table 11 and shown in Figures 24, 25 and 26.

There are no pristine (A1) or near-pristine (A2) rivers in the Indian Ocean Division; only the upper reaches of the Yule and Robe rivers, and a tributary of the Sherlock River can be found in the relatively natural (B1) category.

In the Western Plateau Division there are two rivers in pristine (A1) condition, Rudall River together with the Broadhurst-Auld Lakes System, and the Herbert Wash and Lake Gillen System. In addition, there are two rivers in near-pristine (A2) condition, Savory Creek and Lake Disappointment to the south of Rudall River, and Ponton Creek in the Eastern Goldfields. There are no relatively natural (B1) rivers.

The South West Drainage Division has no pristine (A1) rivers, five or six near-pristine (A2) and three or four in relatively natural (B1) condition. These, however, are outside the scope of the report. They are only mentioned to give perspective to the great wealth of the fourth and last division in terms of well preserved and beautiful rivers.

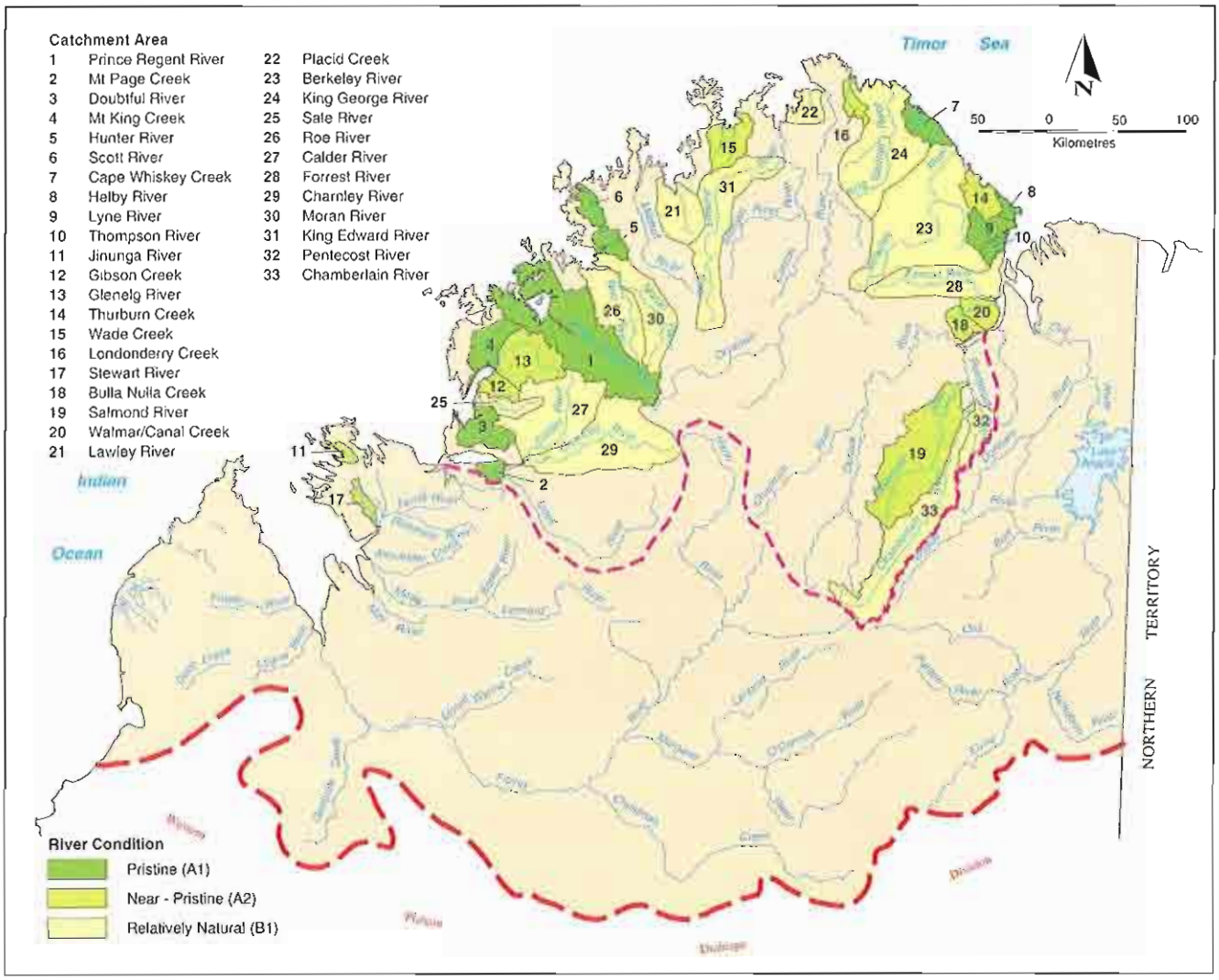


Figure 26: Pristine, near-pristine and relatively natural rivers remaining in the Timor Sea Drainage Division.

In the Timor Sea Drainage Division there are 10 pristine (A1), 10 near-pristine (A2) and 13 relatively natural (B1) rivers as listed in Table 11. The largest of the pristine rivers, the Prince Regent, is one of the most spectacular and beautiful, and possibly the best preserved river in Australia. The other nine pristine rivers are all considerably shorter in length and smaller in catchment area.

All rivers in the near-pristine (A2) and relatively natural (B1) categories have been disturbed/modified/degraded solely as a result of past or current pastoral activity within portions of their catchments. The position is not a static one. Continued pastoral activity in some sensitive areas, with grazing heavily concentrated along stream-courses, and the increasing frequency of burning, is bringing A2 rivers down into the B1 category, and B1 rivers down into the lower B2 altered and C degraded categories. On the other hand, the removal of pressure on rivers in the B1 relatively natural category would, it is believed, allow time and the natural regenerative healing processes to raise their status back to A2 near-pristine.

The rivers of the north-west Kimberley, flowing to the ocean from Walcott Inlet to the western arm of Cambridge Gulf (to the north and west of the dotted line in Figure 26), together constitute a priceless natural heritage, a river system and area of outstanding beauty. It contains rugged gorges, many rapids and spectacular waterfalls in the wet season. The area's hydrology and hydrologic processes have resulted in:

The upper reaches of the Prince Regent River, one of the most spectacular, beautiful, and possibly the best preserved river in Australia.

i. outstanding examples of physiographic features and landforms;

ii. outstanding representatives of terrestrial, fresh-water, coastal and marine ecosystems and communities;

iii. areas of superlative and exceptional natural beauty;

iv. important habitats for in-situ conservation [savanna woodlands, mangrove, vine (tropical rainforest) thickets], with a still complete natural flora, fauna and biological diversity.

The region's attributes, in these four areas, clearly demonstrate its heritage value by international standards.

The region's ruggedness, remoteness and difficulty of access have been the main factors in its preservation to date. It is subject to two main threats: the provision of new and better facilities of access, and the pressures of pastoral and other activities.

The region contains all of about a dozen, and portions of about half-a-dozen pastoral lease areas. Some of these are no longer utilised and have reverted to the Crown. Those remaining need to be carefully managed to ensure their impact on the surrounding sensitive environment is acceptable.

MOVES TOWARDS REHABILITATION

Regeneration

THE REGENERATION OF DEGRADED rangelands is a vital step in improving the condition of the land and the rivers that flow through them. In the past decade, there has been a dramatic increase in the amount of regeneration work carried out. Much of it revolves around controlling grazing pressure and stock access. This is done by reducing stock numbers (de-stocking), fencing to control stock movements and prevent access to sensitive or degraded areas, and controlling feral animals. When this has been achieved, seeding for re-vegetation can be carried out.

The Brucellosis Tuberculosis Eradication Scheme (BTES), during the course of which cattle have been almost completely removed from some areas, has had beneficial impact on rangeland condition. For example, degraded areas on Warrawagine Station on the De Grey River have been de-stocked under this scheme. It has large areas of tussock grassland and is flat alluvial country. The land is potentially very productive, although it has been overgrazed in the past. It is such areas that have most benefited from the BTES. A large section of the De Grey River frontage has been fenced off to control cattle, and there are plans to carry out trial revegetation.

On Ethel Creek Station on the Fortescue River, revegetation cultivation has been carried out very successfully. The station had over 20 000 hectares of degraded and eroding country. The soils on Ethel Creek that are degraded are cracking clay and other alluvial types. These areas are now de-stocked. In some areas, the river channels have caved in. These are being repaired by revegetating. This mainly involves using graders to build trench banks on contours. The banks are quite small. They provide ponds and intercept water flow. Direct seeding is also being undertaken.

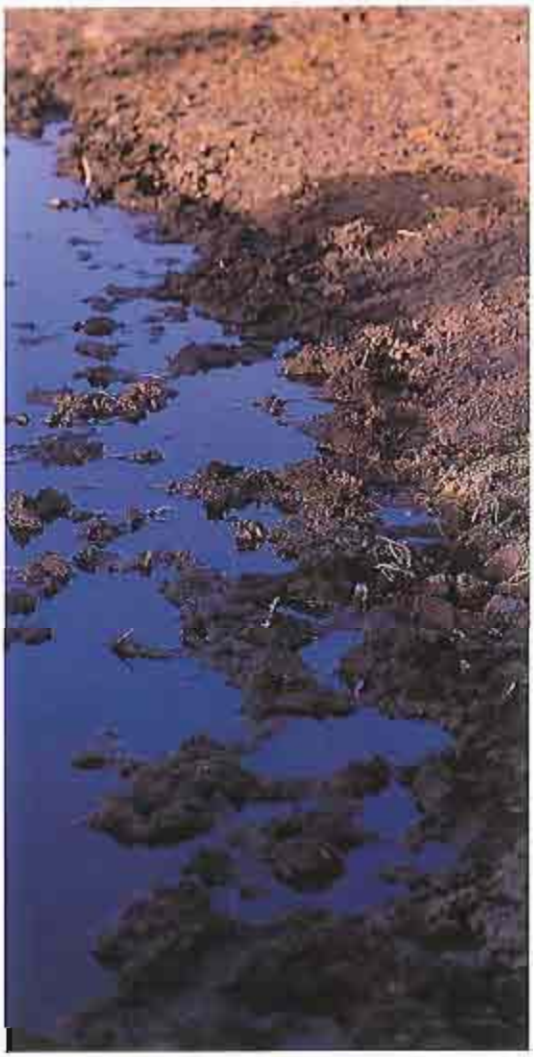
Fencing river frontages to prevent stock access to river banks drastically reduces or entirely eliminates such problems as destruction of riparian vegetation and bank erosion. On Coolawanya Station, for example, a large section of river frontage has been fenced off, thus preventing stock access to the Fortescue River. On Roy Hill Station stock numbers in river paddocks have been reduced, with positive effects on the river's health. In other areas, these changes are not yet happening. In the Ashburton area, for example, a lot of the country has been fenced, but very little, if any, of the river frontage has been fenced off. The river is still being used as a water source.

In the West Kimberley, large sections of the Fitzroy River frontage have been fenced. Much of this work has been facilitated by the West Kimberley Land Conservation District Committee, which has been instrumental in improving land management practices and influencing the use of degraded land in the area, particularly along the Fitzroy River frontage. Since 1983, a number of programmes have been implemented.

The fencing on the Fitzroy has benefited the rare Purple crowned Fairy Wren. The fences have successfully excluded stock. This has enabled riparian vegetation to regenerate, re-establishing and extending the wren's very particular type of habitat.

Over most of the State, Land Conservation Districts, with their own Land Conservation District Committees (LCDCs), have been formed by local people to care for the land, working under the WA *Soil and Land Conservation Act 1982*. A total of 137 LCDCs were formed between 1982 and 1994. They cover all of the pastoral land in the State and 80% of the agricultural land (Figure 25).

Stock are being reduced in number and their quality improved under the Brucellosis Tuberculosis Eradication Scheme.



The rivers are being fenced off to prevent stock damaging the banks and the fringing vegetation.

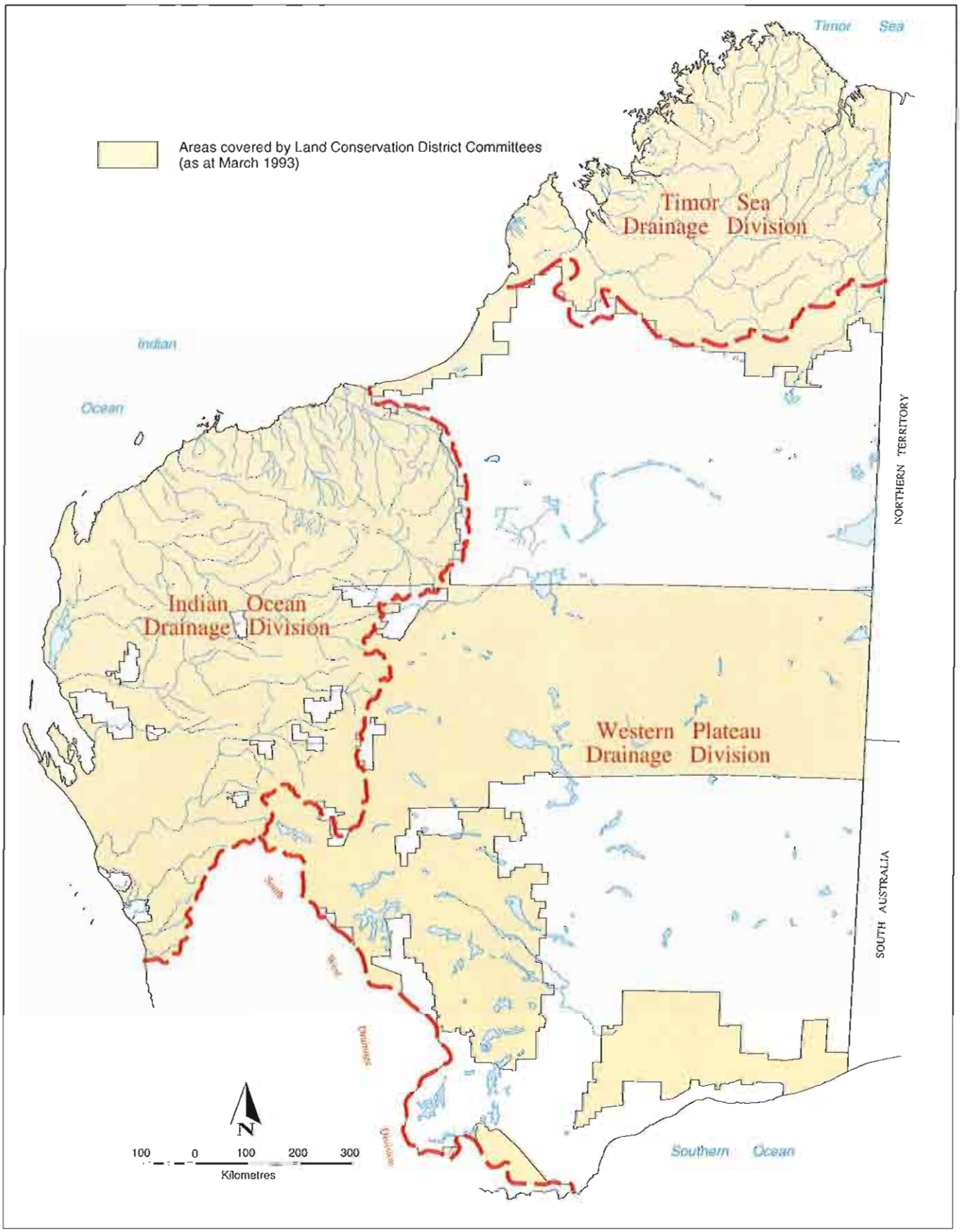


Figure 27: Areas of the State covered by Land Conservation District Committees.

Controlling feral animals

WITHOUT ADEQUATE CONTROL of feral animals, such as goats and donkeys, it is not possible to achieve acceptable stocking rates and to ensure that pastoral activities do not degrade rangelands and adversely impact rivers. Feral animal control requires continuous and coordinated effort. The ability of feral animals to survive in rugged, remote country means that controlling them can be expensive. Without continuous effort, numbers build up quickly and rival or even exceed sheep and cattle numbers. There have been many efforts to control feral animals in the past. These have met with varying success, although none has been totally successful and no feral animals have been completely eradicated. However, feral donkeys have been eradicated from some pastoral stations south of the Leopold Ranges in the Kimberley. To date, the most successful programme is probably the current feral goat eradication programme.

Feral goats were declared vermin in 1928. Before then, they were popular livestock for early settlers and miners, providing meat, milk and, from some breeds, mohair. When the miners moved on, or attempts to produce mohair commercially were given up, many herds were abandoned. Others went wild due to lack of supervision. Goats are extremely hardy and quickly adapt to life in the wild. They are most common in rocky or hilly country in the semi-arid rangelands. The population tends to concentrate around rivers, as they are a prime source of water and food. Goats trample riparian vegetation and foul the water.

Before the feral goat eradication programme began, it was estimated that sheep, which were being managed by the pastoralists, formed only 39% of the grazing biomass. The other 61% was composed of kangaroos and goats, over which the pastoralists had no control. On some stations in the upper Gascoyne, goats contributed up to 50% of the grazing pressure.

Over 1.4 million feral goats were removed from the rangelands between 1991 and 1995.

Between July 1991 and June 1997, over 1.75 million feral goats were removed from the rangelands. It is estimated that between July 1990 and June 1993, there was a 25% decrease in feral goat numbers. In the three years before that (i.e. 1987–1990) there was a 64% increase. It is predicted that, with the programme in place, the feral goat population will decrease by 20% each year. Without the programme, the population would increase by 18% each year.

The feral goat eradication programme covers 13 LCDs. The pastoral industry identified the need for such an initiative and started things moving in 1991. Approximately $1.25 million is currently being spent on this programme annually. There is an 85% participation rate in the programme, which is now coordinated by Agriculture WA.

Achieving control of feral animal numbers will facilitate natural regeneration of the rangelands, helping to ensure a viable and sustainable future for the pastoral industry and the rangeland resource. It will also benefit the condition of the rivers that run through the presently degraded areas.

Surveys and monitoring

RANGELAND CONDITION SURVEYS and monitoring are an important part of any revegetation and restoration effort. Initially rangeland surveys identify the areas which are most degraded and most in need of rehabilitation. In 1972 a full scale assessment was initiated on behalf of the Pastoral Appraisement Board. The assessment came about as a result of the work carried out by the Department of Agriculture in the Gascoyne River catchment area, and from the seriousness of badly eroded areas in the Fitzroy Valley. Since then a number of rangeland surveys covering various areas have been carried out. As part of the assessment process, a rating scale was developed for land erosion and pasture condition. The categories good, fair and poor were delineated. These are the categories shown in Figures 14, 15 and 16.

Long term monitoring, detecting change in either direction over time, is achieved by means of the establishment of permanent assessment plots. At least once a year, these plots are photographed and the vegetation in them assessed. The information collected is kept for future reference. Many individual pastoralists and LCDCs now undertake annual monitoring. This enables pastoralists and Agriculture Western Australia to assess the impacts station management and grazing strategies are having on the land.

Monitoring the rangelands, with pastoralists and Agriculture Western Australia working in close cooperation, is a vital component of rehabilitation.

Diversification

Some rangeland station owners and managers are considering, and being encouraged to diversify their operations. This can assist in maintaining or increasing economic rates of return, while at the same time lowering stocking rates.

One pastoralist in the Indian Ocean Drainage Division is growing rock and water melons and using them as stock feed. This has achieved a considerable reduction in grazing pressure. On the Beverley Springs Station in the Kimberley, the cattle were removed under the Brucellosis Tuberculosis Eradication Scheme. The station is in an area of reliable rainfall and suitable soil, so the lessee decided to grow sesame seed as a crop. In the first year, 1994, 50 tonnes of sesame seed was produced, and that figure was doubled in 1995. Without cattle trampling and fouling waterways, the health of the rivers will improve.

Others are looking at the viability of a variety of crops, such as stone fruit and table grapes. The potential depends largely on proximity to markets, although in many areas there is the advantage of being able to produce crops at different times to more traditional suppliers. A good quality and reliable water supply is generally essential. Natural resources, such as quandong, sandalwood, emus and kangaroos, also have potential as alternative sources of income.

Depending on their location and natural attributes, some stations have great potential to profit from the increasing tourism market. The presence of natural features, such as ranges, gorges and rivers, on the station or in the vicinity, draws visitors to the area. A fine example is the El Questro Station in the Kimberley, which has been developed into a major luxury tourist facility.

The Pilbara Development Commission Tourism Advisory Committee is promoting and assisting stations in the Pilbara to develop station holidays. Two stations are now running station stays, and others are considering it. It has proved very popular and successful. These station stays are considered to be true eco-tourism, in that they provide income from the natural assets of the land without intrusive land use.

A tourist development on El Questro pastoral station in the Kimberley next to the spectacular Chamberlain River Gorge.

On Wooleen Station 680 km north of Perth, tourism has been developed as a means of increasing income while reducing the number of sheep. It is estimated that by the end of 1997, sheep numbers on the station will be down to 8000, compared with 14 000 in 1993.

Carrying fewer sheep will allow the rangeland to recover, so the remaining stock will be in better condition, as will the land and rivers.

While the expansion of tourism has many benefits, it can also have a number of adverse side effects. River systems and coastal areas are particularly susceptible to tourism pressures.

Tourism can result in an increased number of roads and tracks which, if not carefully controlled and sensitively designed, can result in erosion and increased river sediment loads. Tourist boats, the only way of reaching the rugged north-west Kimberley Coast, and their sewage and bilge waters, also present significant hazard potential. Arrangements need to be made for safe disposal of all waste material well away from the rivers.

LOOKING TO THE FUTURE

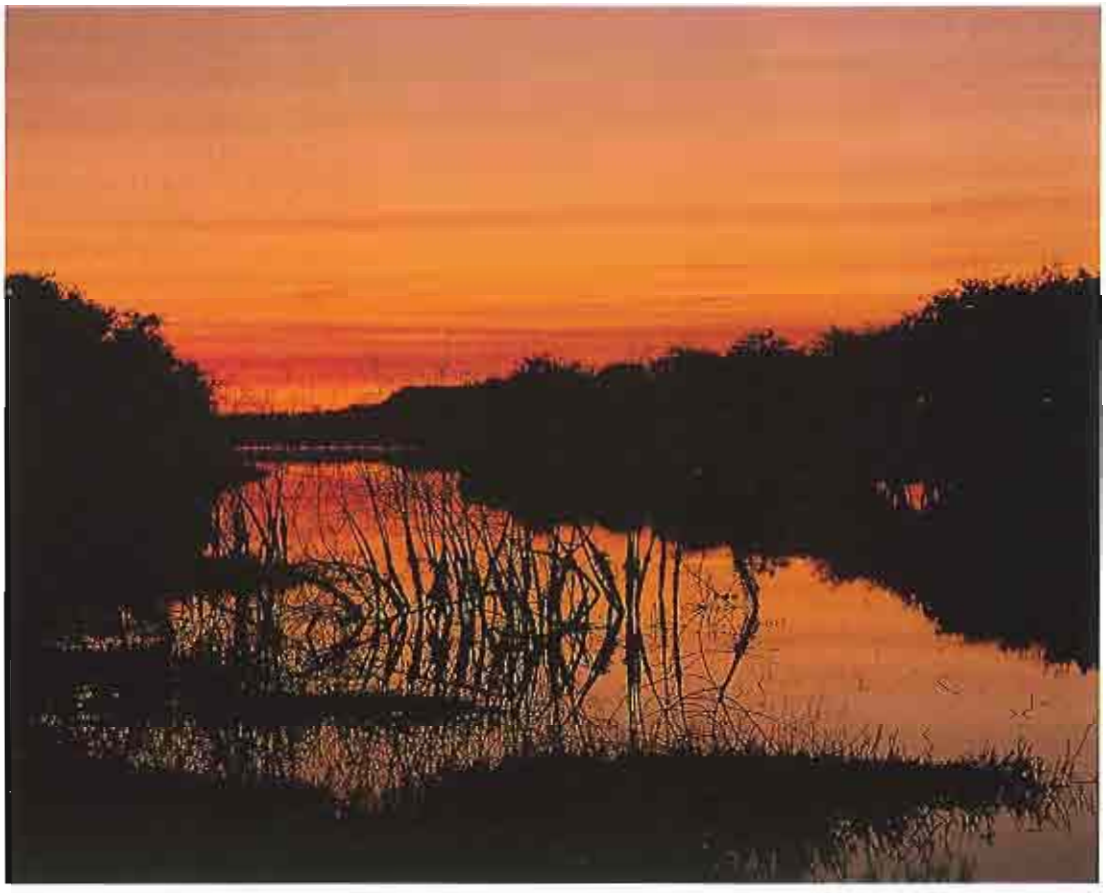
THINGS ARE CHANGING in the rangelands. Much has already changed. The early days of getting in, making a quick dollar and leaving are gone. Pastoralists today are interested in maintaining their stations for future generations.

We know much more about the land, its rivers and wildlife. We know much more about its carrying capacity. We know much more about managing the land. We are getting better at working together and sharing information.

All of these things speak of positive implications for the rivers of the North West. Undoubtedly, the rivers and the land through which they flow have suffered since Europeans first arrived. Their condition is far poorer. But things are on the turn.

There is still much work to be done. More people need to be involved in doing that work and more money needs to be spent but wisely. Some people still need to let go of damaging old ways of doing things. It is important, also, that all Western Australians develop a greater understanding of the people who live and work on the rangelands.

We need to work together. Our land and rivers depend on it.



Dawn at Marglu Billabong, Parry Lagoons, Ord River floodplain, Kimberley Region.

Sources of photographs

Page	
Front Cover	Luke Pen
Title Page	Luke Pen
(ii)	Simon Neville — ECOTONES
(iv)	Dennis Sarson — LOCHMAN TRANSPARENCIES
(v)	Simon Neville — ECOTONES
(vi)	Simon Neville — ECOTONES
3TL	Alan Hill
3TR	Luke Pen
3B	Simon Neville — ECOTONES
7	Luke Pen
9T	Agriculture Western Australia
9B	Alan Hill
10T	Simon Neville — ECOTONES
10B	Peter Howard
11	Jiri Lochman — LOCHMAN TRANSPARENCIES
13T	Peter Williams
13BL	Peter Williams
13BR	Public Works Department
14	Simon Neville — ECOTONES
15	Peter Williams
17T	Simon Neville — ECOTONES
17B	Simon Neville — ECOTONES
18L	Agriculture Western Australia
18R	Marie Lochman — LOCHMAN TRANSPARENCIES
20	Agriculture Western Australia
21T	Simon Neville — ECOTONES
21B	Simon Neville — ECOTONES
25T	Simon Neville — ECOTONES
25B	Luke Pen
26	Alan Hill
27L	Agriculture Western Australia
27R	Luke Pen
28	Battye Library
30	Battye Library
31	Agriculture Western Australia
32T	Simon Neville — ECOTONES

Page	
32B	Battye Library
34TL	Agriculture Western Australia
34TR	Agriculture Western Australia
34B	Agriculture Western Australia
36T	Jiri Lochman — LOCHMAN TRANSPARENCIES
36C	Jiri Lochman — LOCHMAN TRANSPARENCIES
36B	Jiri Lochman — LOCHMAN TRANSPARENCIES
39	Agriculture Western Australia
41T	Agriculture Western Australia
41B	Agriculture Western Australia
43	Agriculture Western Australia
45	Simon Neville — ECOTONES
46	Peter Williams
47	Peter Williams
48T	Peter Williams
48B	Peter Williams
49T	Luke Pen
49B	Public Works Department
50T	Luke Pen
50B	Luke Pen
53	Alan Hill
55T	Agriculture Western Australia
55B	Peter Williams
57	Peter Williams
60	Peter Williams
63T	Peter Williams
63B	Jiri Lochman — LOCHMAN TRANSPARENCIES
65	Peter Williams
67	Peter Williams
69T	Agriculture Western Australia
69BL	Simon Neville — ECOTONES
69BR	Simon Neville — ECOTONES
71	Agriculture Western Australia
72	Agriculture Western Australia
73	Peter Williams
74	Simon Neville — ECOTONES