ESTUARIES AND COASTAL LAGOONS OF SOUTH WESTERN AUSTRALIA

ESTUARIES OF THE SHIRE OF RAVENSTHORPE AND THE FITZGERALD RIVER NATIONAL PARK

Environmental Protection Authority
Perth, Western Australia

Estuarine Studies Series
Number 7
July, 1990

'A Contribution to the State Conservation Strategy'

Other published documents in the Estuarine Studies Series
By E.P. Hodgkin and R. Clark

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An Inventory of Information on the

Estuaries and Coastal Lagoons of South Western Australia

ESTUARIES OF THE SHIRE OF RAVENSTHORPE

AND THE

FITZGERALD RIVER NATIONAL PARK

By Ernest P. Hodgkin and Ruth Clark

Culham Inlet, December 1988 Photo: Land Administration. WA.

Environmental Protection Authority

Perth, Western Australia

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COMMON ESTUARINE PLANTS AND ANIMALS

Approximate sizes in mm.

Plants
- A Rush - *Juncus kraussii*
- B Samphire - *Sarcocornia* spp.
- C Paperbark tree - *Melaleuca cuticularis*
- D Seagrass - *Ruppia megacarpa*
- E Diatoms 0.01

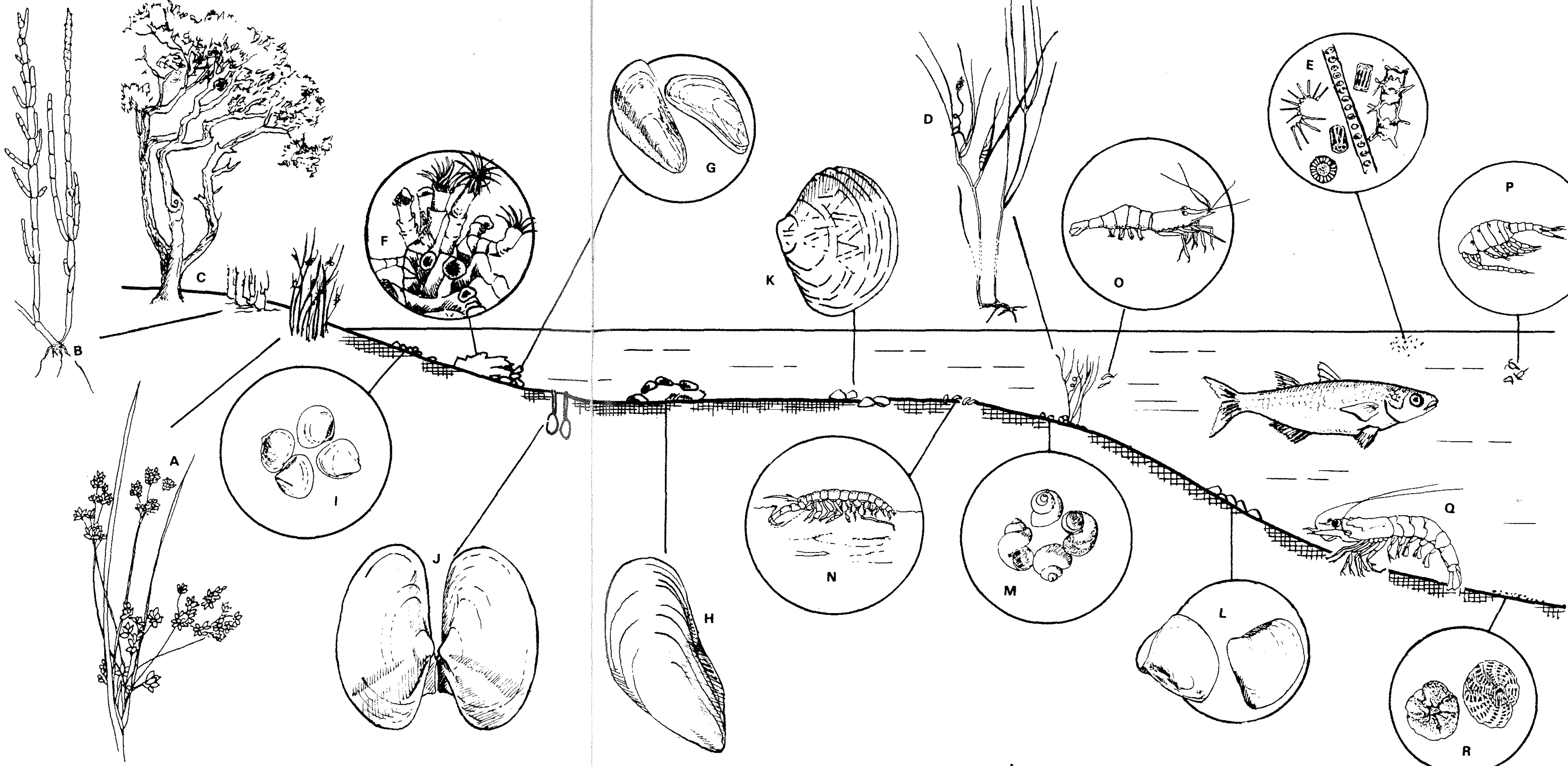
F Tubeworms - *Ficopomatos enigmaticus* 20

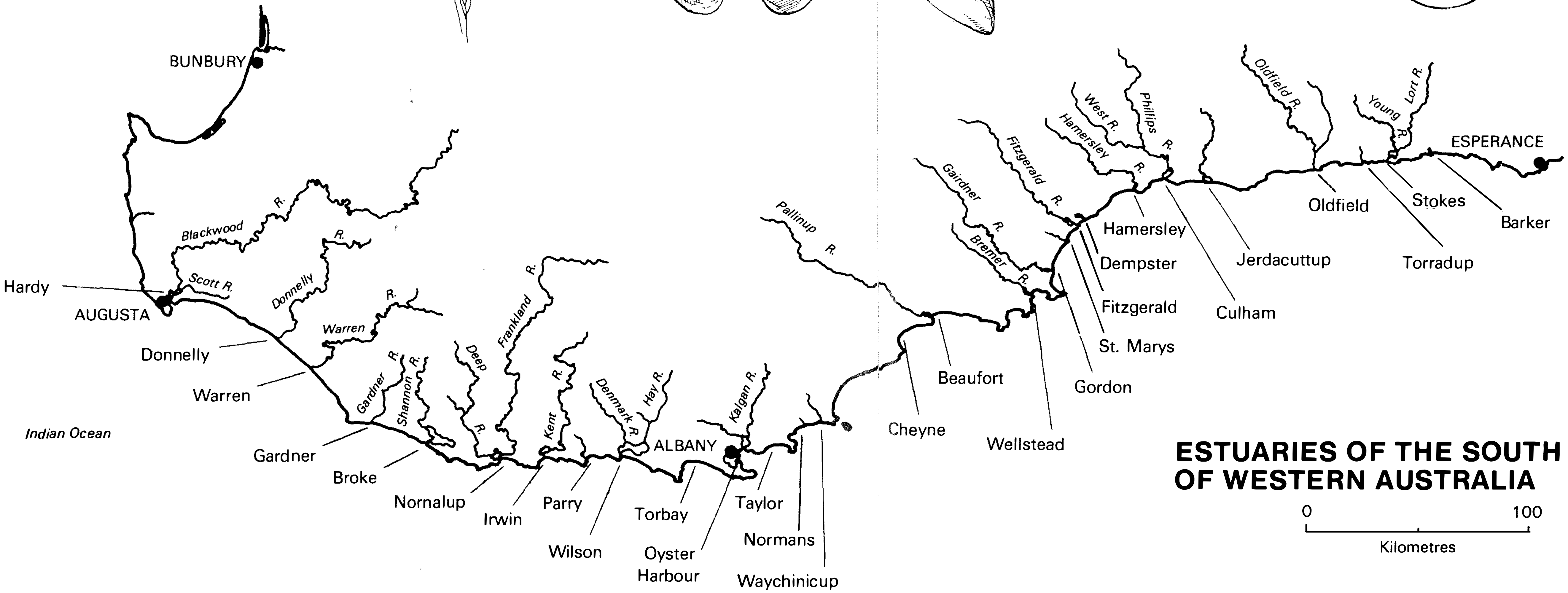
Bivalve molluscs
- G Estuarine mussel - *Xenostrobus securis* 30
- H Edible mussel - *Mytilus edulis* 100
- I *Arthritica semen* 3
- J *Sanguinolaria biradiata* 50
- K Cockle - *Katelysia* 3 spp. 40
- L *Spisula trigonella* 20

Gastropod molluscs
- M Snail - *Hydrococcus brazieri* 4

Crustacea
- N Amphipod - *Corophium minor* 15
- O Shrimp - *Palaemonetes australis* 40
- P Copepod - *Gladioferens imparipes* 2
- Q King Prawn - *Penaeus latisulcatus* 100

R Foraminifera 0.02





ESTUARIES OF THE SOUTH COAST OF WESTERN AUSTRALIA

Hon. R. J. Pearce, M.L.A.
Minister for the Environment

FOREWORD

I welcome this study of the estuaries and coastal lagoons of the Shire of Ravensthorpe.

It is the seventh in the series of studies of estuaries of the south west to be published by the Environmental Protection Authority for the State Conservation Strategy.

Like its predecessors, this study provides information for conservation and management decisions and highlights the need for further investigation. Each is a unique system whose management presents particular problems for the State, the Shire and CALM, which manages those in the Fitzgerald River National Park.

There is ample evidence that most of the areas studied were typical tidal estuaries less than 6,000 years ago, but they are no longer estuaries in the usual sense of that word.

Those in the National Park are only briefly and rarely open to the sea. They are shallow and, like inland salt lakes, they often become dry. There is generally little river flow to them and it is only the occasional floods that result from downpours in the catchments that break the bars.

Outside the park, Culham Inlet and the Jerdacuttup Lakes no longer have any connection with the sea, although they both can be flooded by the big rivers that flow into them. They have been closed salt-water lagoons for hundreds, perhaps thousands, of years. The Culham Inlet bar probably last broke naturally in 1849 but it was again at risk of breaking in 1989 after heavy rains and catchment clearing which increased runoff from the land.

Management criteria are very different from those that apply to the more typical estuaries of higher rainfall areas of the South West. Fish populations are only recruited from the sea, or the rivers, when they flood and break the bars and, though popular with recreational fishermen, the estuaries are seldom fished commercially.

They provide important habitats for northern migrants which visit them regularly and large flocks of waterbirds feed on the abundant small fish and other organisms.

The estuaries offer beautiful scenery, though the best views have to be sought on foot, or by boat during floods. All are part of Western Australia's natural heritage which the Government aims to conserve. I commend this study to all who are concerned for the welfare of these systems.

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CONTENTS

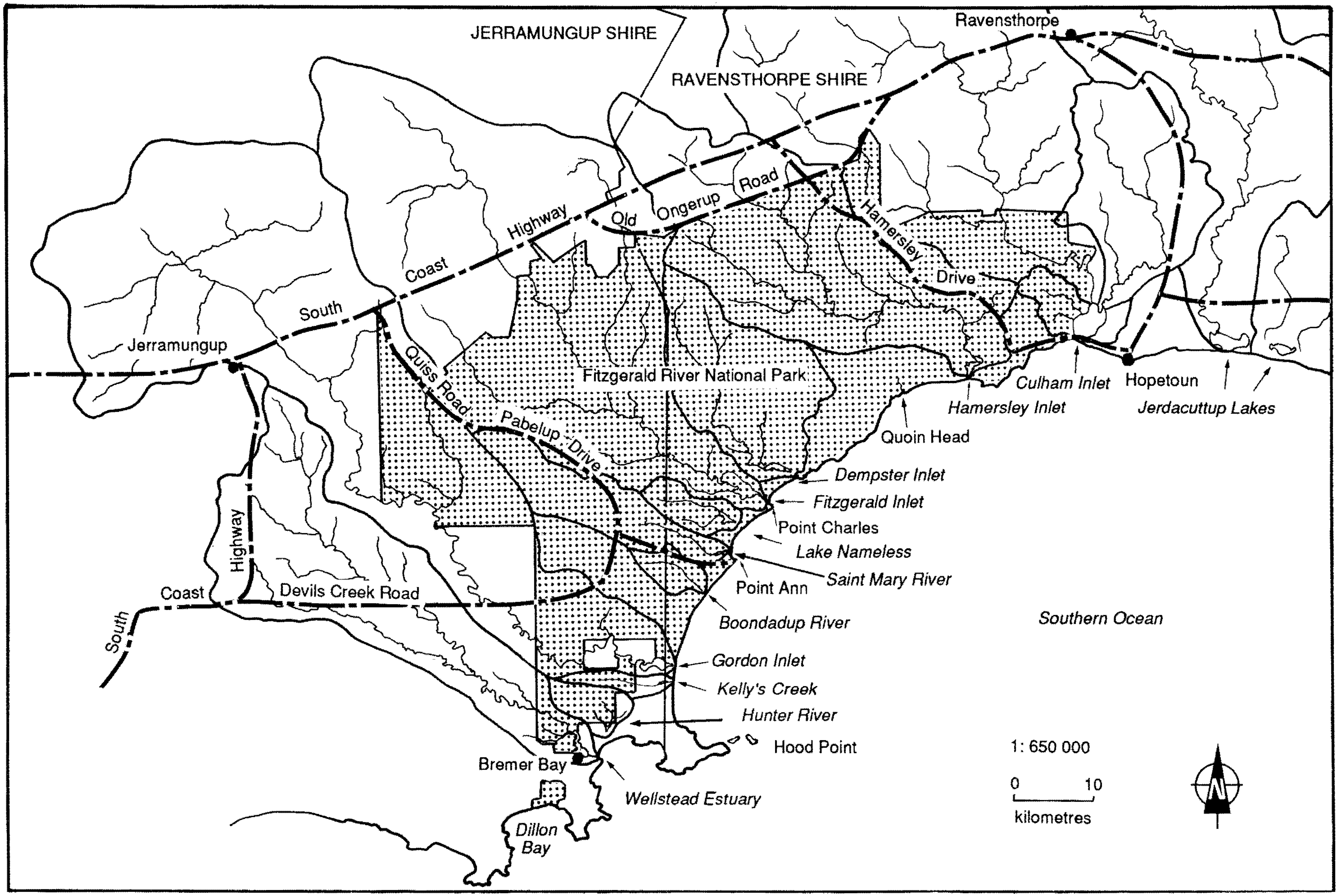

Figure 1.1 The lower catchments of the estuaries of the Ravensthorpe Shire and the Fitzgerald River National Park

1 INTRODUCTION

The coastal water bodies of the Shire of Ravensthorpe differ from most estuaries of the south coast in a number of respects. They are no longer estuaries in the conventional sense of the word and probably forfeited their claim to that term 3000 years ago or more. The Inlets of the Fitzgerald River National Park can at best be described as 'temporary' or 'transient estuaries' that are seldom open to the sea. They are coastal lagoons which are now so shallow that although they are flooded by river water in winter they are often dry in summer. But for the sea bars most would only hold a skim of tidal water at any time; Hamersley Inlet alone has any depth, about 1.5 m below sea level.

Oldfield Estuary on the eastern boundary of the Shire and Gordon Inlet on its western boundary are similar in the above respects. These are discussed in numbers 4 and 5 respectively in this Estuarine Studies Series (Hodgkin and Clark, 1988 & 1989).

Outside the Park, Culham Inlet and the Jerdacuttup Lakes are closed coastal lagoons, 'fossil estuaries' that no longer have any connection with the sea. Only 4000 years ago Culham Inlet was wide open to the sea and had a rich marine fauna similar to that in Princess Royal Harbour today, and it may have continued to be estuarine for some time after. A 10 m high, stable dune separates the Jerdacuttup Lakes from the sea and there is no clue as to when it was last estuarine. Both lagoons absorb the flow from large rivers and flood to a depth of 3 m but are sometimes dry in summer.

Several small coastal water bodies which are still sometimes open to the sea, or have been in the recent past, are discussed in Chapter 9. They include a creek at Quoin Head, Boondadup River near Point Ann, Kelly's Creek, and 'Lake Nameless' now blocked from the beach by a kilometre wide stable dune. Their story is an integral part of the evolutionary history of our south coast estuaries and may give clues to the future of the others. From Lake Shaster in the east to the Jerdacuttup Lakes a number of saline lakes are separated from the sea by a belt of low coastal dunes. Most have small catchments and are not likely to have been estuarine, at least in the Holocene.

Rainfall is low, about 500 mm at the coast falling to 400 mm north of South Coast Highway, evaporation is high, about 1700 mm, and river flow is only sufficient to break the estuary bars at intervals of several years following above average rainfall such as that of May 1988. Rainfall is seasonal with most rain falling in winter, and runoff probably much more so; however summer cyclonic rains sometimes precipitate 100 to 200 mm in a few days and cause flash floods that may break the bars.

River water is saline and when it evaporates the little water that remains in the estuaries becomes too saline for all but a few marine or estuarine animals to survive, though these may be abundant. Populations of Sea mullet and a few other species of fish are recruited from the sea when the bars break and may flourish for months or years until the water becomes too saline. Black bream and several small fish come down with the flood waters from river pools and at times are very abundant. Commercial species are netted by professional and recreational fishermen.

Large parts of the river catchments of all the Inlets (not Jerdacuttup) lie within the National Park, or in still uncleared bush nearby, and the St. Mary River and Dempster Inlet catchments are entirely within the Park (Figures 1.1 1.2 1.3). The Fitzgerald, Hamersley and Phillips river catchments extend into farm land which has only recently been cleared; most of it was released for farming progressively from the late 1950s through the 1960s. The volume and rate of river flow and the mobilisation of sediment will have increased as the result of clearing, as is shown by studies in Stokes Inlet (Hodgkin and Clark, 1989). But there are no hard data to show what effect it has yet had on sedimentation in the Park Inlets, or indeed on the many pools in the rivers. Outside the Park, land along the Steere River tributary of Culham Inlet and along the Jerdacuttup River has been extensively cleared.

The **Fitzgerald River National Park** (FRNP) was declared in 1973 and enlarged along its northern boundary in 1989. It now covers an area of 3280 km^2, from the coast 30 to 40 km inland to the Old Ongerup Road and from Culham Inlet in the east to Gordon Inlet in the west, with an extension to Wellstead Estuary. It is a remarkable area in many respects, not least because of the diversity of plant life of which 125 of the 1750 known species are endemic to the Park and its immediate vicinity, but also for the spectacular scenery with cliffs and gullies carved in the many coloured spongolite rock. The recently published FRNP Draft Management Plan provides much information about the Park (Moore, 1989) and the South Coast Region Draft Management Plan (CALM, 1989) about the wider south coast region. 'The Bush Comes to the City' (Anon, 1989) and 'Trembling Horizon' (Thomas, 1989) tell the story of the internationally recognised Fitzgerald Biosphere Project. This includes the Park, which is regarded as its core area, and the surrounding agricultural 'Zone of Co-operation' of the Project.

History In 1868 the Dunn brothers took up a lease at Cocanarup on the Phillips River where they built a homestead and shepherded sheep through the surrounding bush. James Dunn discovered payable gold in 1899 and production began soon after at a number of mines. The population of the new town of Ravensthorpe grew from 500 in 1900 to 3000 in 1909. Copper replaced gold as the principal mineral mined in the Phillips River Mineral Field. The ore was exported from Hopetoun first by wagon and then by rail after the railway was completed in 1909. A fall in the price of copper in 1913 caused many mines

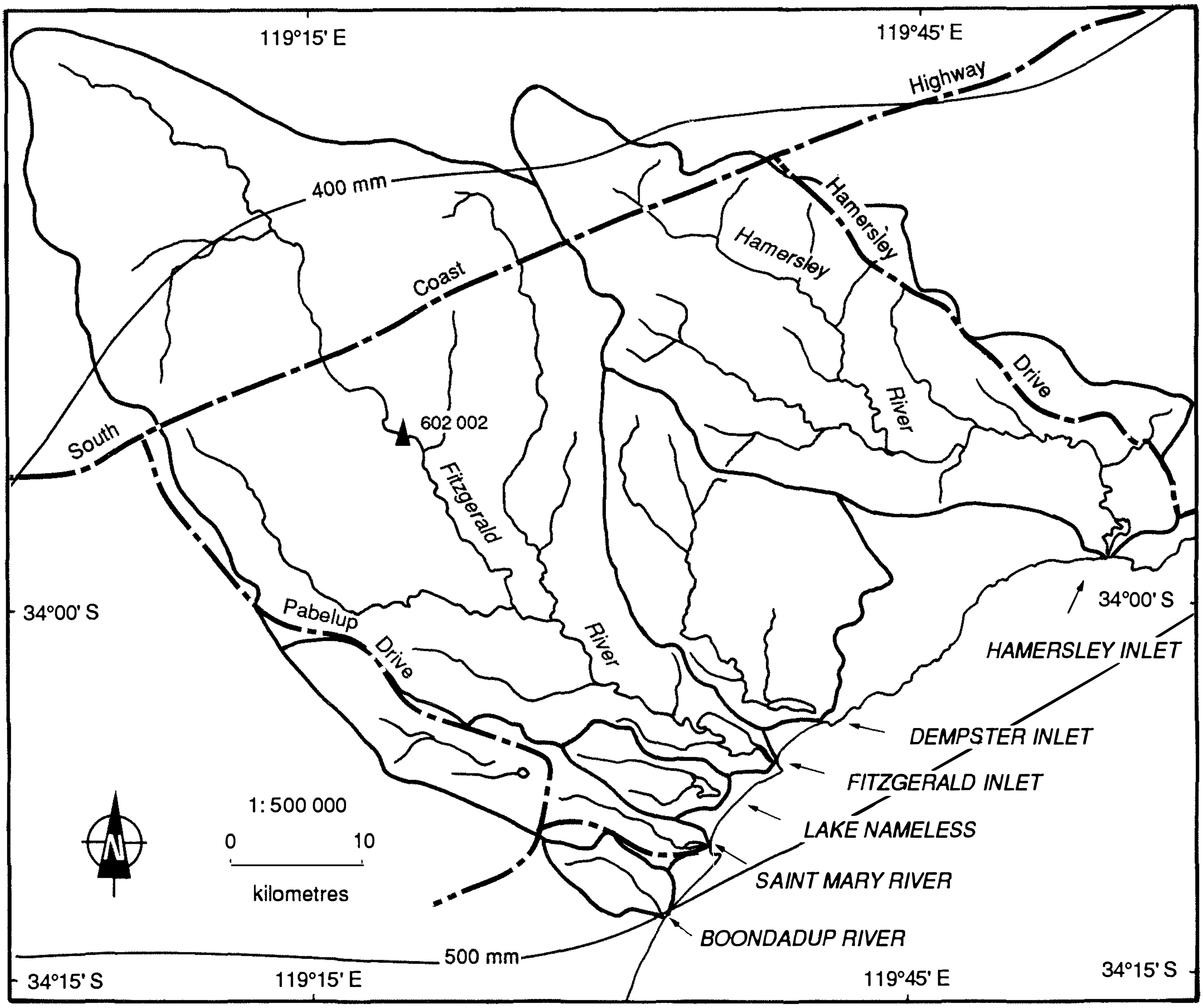

Figure 1.2 Catchments of Boondadup and Saint Mary rivers, Lake Nameless, Fitzgerald, Dempster and Hamersley inlets. Mean annual isohyets (mm).

to close. Small scale mining began again in the late 1950s. Accounts of the history of the area will be found in Archer (1979) and Bignell (1977).

In 1849 A.C. and H. Gregory sailed to Doubtful Island Bay to investigate the report of coal 'on the East Fitzgerald' and found a small outcrop of low quality coal. The sequel to this was the proposal to mine for montan wax in 1970 which lead to action to establish the National Park. Spongolite was quarried at Twertup from 1967-73, but this was abandoned because of the poor quality of the stone for building purposes. The mine buildings are now the study centre for the Fitzgerald River National Park Association.

John Wellstead of Bremer Bay established the Quaalup property on the Gairdner River in 1858 and some years later the family opened a lambing station near where the Fitzgerald River flows into the Inlet, where the ruins of a stone building still stand.

The Overland Telegraph Line was constructed east-west through the Shire from 1875-1877. After the line was abandoned the track continued to give access to off road vehicles through the Park until recently closed to prevent the spread of dieback. Apart from this most tracks through the Park were opened by beach, rock and estuary fishermen. The No. 2 Rabbit Proof Fence, which ends on the south coast at Point Ann, was erected in 1904-5 and only abandoned in the 1950s and 60s after the introduction of myxomatosis. The No.1 fence, begun in 1903, ended at Starvation Boat Harbour 40 km east of Hopetoun.

John Septimus Roe, the first Surveyor General, named the Fitzgerald River and Inlet after Governor Charles Fitzgerald R.N. (1848-55), the Phillips River after Samuel Pole Phillips, Roe's son-in-law, Culham Inlet after 'Culham', Phillips's 'Culham' estate at Toodyay, and the Hamersley River and Inlet after Phillips's partner. Sandiford (1988) gives the Aboriginal names of these and other localities of the area.

1.1 THE ESTUARIES – LOCATION AND ACCESS

Access to the estuaries is from South Coast Highway; Fitzgerald, Dempster and St. Mary Inlets through the National Park via Quiss Road 20 km east of

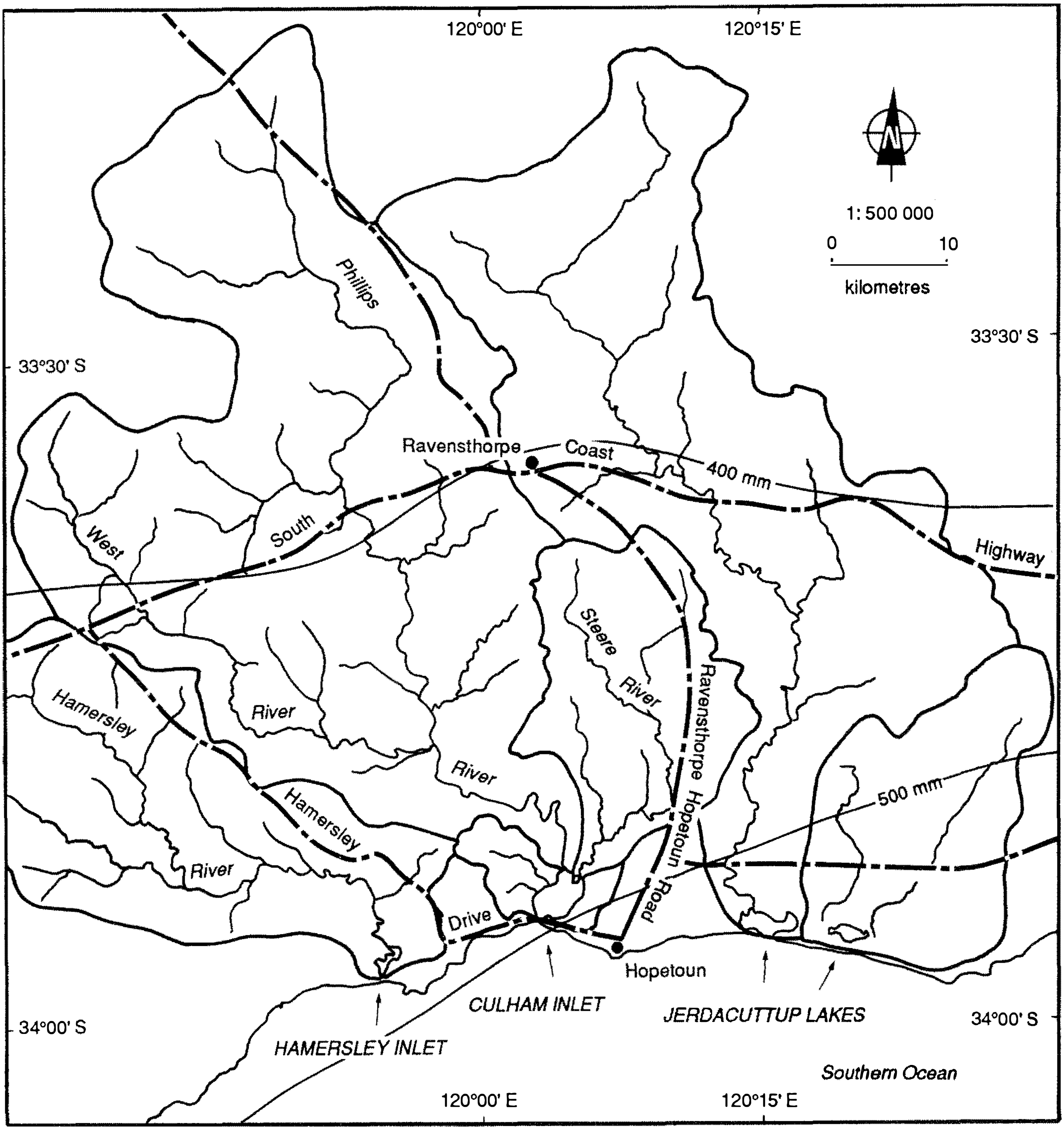

Figure 1.3 Catchments of Hamersley and Culham inlets and Jerdacuttup Lakes.

Jerramungup; Hamersley Inlet and Culham Inlet from Ravensthorpe and Hopetoun (Figure 1.1). Grid references are to maps 2829 Hood Point, 2830 Cocanarup and 2930 Ravensthorpe on the 1:100 000 topographic map series published by Natmap.

There is hotel and motel accommodation at Ravensthorpe, a hotel at Hopetoun and caravan parks at both towns. On the western side of the Park there are hotels and caravan parks at Jerramungup and Bremer Bay.

Fitzgerald Inlet is the largest estuary in the Park with an area of 7 km^2, 4 km of river reaches and a 1 km long narrow channel from the lagoon to the sea. It opens at the western end of a 5 km long bay across a wide, east facing sandy beach that is sheltered from the south west by Point Charles. The beach is only 1 to 1.5 m above sea level and the floor of the lagoon appears to be at about sea level so that the water is probably never more than 1 m deep, though the river and channel are deeper and always hold water. Spectacular cliffs in the spongolite rock border much of the shore of the lagoon.

The Inlet lies between 119°34' and 119°39' East and 34°04' and 34°06' South. The mouth is at grid reference: Hood Point 420235. Access is via Quiss Road and Pabelup Drive through the Park. These are gravel roads. From Pabelup Drive the road to Colletts Camp at the mouth of the Inlet is unsurfaced and not suitable for 2WD vehicles. The Park 4WD tracks may be closed to traffic following heavy rain. Alternatively access from the west is off South Coast Highway 30 km south of Jerramungup via Devils Creek Road and Pabelup Drive.

Hamersley Inlet occupies a valley cut by the Hamersley River through the contorted rocks of the Mount Barren Beds. The narrow upper reaches of the estuary zigzag through a gorge between steep slopes and cliffs to the narrow lagoon where much of the shoreline is rocky and deeply indented. Coastal dunes border part of the southern shore and constrict the mouth which opens at the western end of a small sandy beach. The lagoon is deeper than the other Inlets, it holds water longer, and provides a more favourable environment for estuarine and marine animals. The catchment of the river lies mainly within the Park and only a small part of the headwaters is in cleared agricultural land.

The Inlet lies between 119°54'30" and 119°55'30" East and 33°57' and 33°58' South. The mouth is at grid reference: Cocanarup 685380. It is at the eastern end of the Park, 22 kilometres west of Hopetoun. Access is by a gravel road off Hamersley Drive (gravel) from Culham Inlet to Old Ongerup Road (40 km west of Ravensthorpe). A Shire reserve borders the eastern shore of the Inlet and a camp site is being developed there.

Dempster Inlet is only 4 km north of Fitzgerald Inlet and its mouth opens at the NE end of the same bay. It is a long, shallow lagoon lying east-west in a narrow valley in the Mount Barren schists and the slope of Mid Mount Barren rises steeply from its northern shore. The coastal dunes on the western shore of the inlet channel confine it to a deep, narrow gutter against the rock of the eastern shore. The mouth faces south with no protection from the south west. The two small rivers that flow to the Inlet have only shallow riverine reaches that hold little water in summer.

The Inlet lies between 119°37' and 119°40' East and 34°04' and 34°05' South and the mouth is at grid reference Hood Point 461258. It lies within a proposed wilderness area (CALM, 1989) and the only vehicle access is along the beach from the mouth of Fitzgerald Inlet.

Saint Mary River flows into a small, shallow lagoon with a narrow channel to the sea which opens at the south end of Point Charles Bay in the shelter of Point Ann. The whole catchment is within the Park. The estuary lies between 119°33' and 119°34' East and 34°10' South and the mouth is at grid reference 373167. Access is by Point Ann Road (gravel) off Pabelup Drive through the Park and a 4WD track to a proposed camping area on the Inlet shore.

Culham Inlet. Two rivers, the Phillips and Steere, flow into this large, shallow lagoon on the eastern flank of East Mount Barren. The sea bar has not broken since about 1920 when it was breached artificially; it is now over 4 m above sea level at its lowest point and has more the character of a foredune. The Phillips River is part of the system for 7 km upstream from the Inlet and always retains water; this is saline and may be about one third to several times the salinity of sea water. The smaller Steere River is also part of the system for about 2 km. Much of the catchments of the Phillips River and its tributary the West River are in the Park or in other uncleared bush, but both extend into cleared land north of South Coast Highway. The east bank of the Inlet and the Steere River are farm land.

The Inlet lies between 120°03' and 120°05' East and 33°53' and 33°55' South and the bar is at grid reference 275422. It is 7 km west of Hopetoun on Southern Ocean West Road (gravel). Access to the riverine reaches of the Phillips and Steere rivers is via bush tracks off John Forrest Road which leaves the Ravensthorpe Hopetoun Road 9 km north of Hopetoun.

Jerdacuttup Lakes. The open water and paperbark tree swamps of the Lake system extend for 15 km along a shallow depression behind the coastal dunes. The large western lake is separated from the sea by a densely vegetated foredune, 1 km long, 8-10 m high and only 50 m wide. The Jerdacuttup River enters the western lake through a swamp which restricts river flow to the lake, but during floods the water then backs up the river and over Springdale Road. Two small streams drain to the smaller eastern swamps. The river rises north of Ravensthorpe and has a large catchment with cleared agricultural land on the coastal plain within 20 km of the Lakes.

The lakes lie between 120°14' and 120°23' East and 34°03' and 34°05' South, adjacent to Southern Ocean East Road between 10 and 25 km east of Hopetoun. When the water level is high, reaching the road, small boats can be launched to the western lake 13 km from Hopetoun. Access to the riverine part is from the Springdale Road crossing.

1.2 GEOLOGICAL HISTORY OF THE ESTUARIES

The estuaries have only come to have their present form in very recent times geologically. Only 20 000 years ago sea level was more than 100 m lower than it is now and the rivers flowed out across the continental shelf, which is here more than 50 km wide. There were valleys and perhaps lakes where the estuaries are now. They were only flooded by the sea during the Holocene (the last 10 000 years) when the ice caps melted and sea level rose rapidly. The sea came to its present level about 6000 years ago, and for some time may have been about 2 m higher than it is now.

At first the estuaries were always open to the sea; they were tidal and sea water flowed into them. Extensive Holocene shell beds in all the Inlets are clear evidence of marine conditions only 4000 years ago. They were also deeper than they are now, probably with channels through the spongolite to hard rock. Sediment from the catchments and from the beaches has progressively shallowed the lagoons and reduced their volume. Growth of the bars has reduced exchange with the sea to the brief and infrequent periods when the bars are open. The Culham Inlet bar has only broken naturally once or twice in the last 150 years. The Jerdacuttup Lakes were probably an estuarine lagoon 6000 years ago and the Jerdacuttup River would have flowed to the sea. 'Lake Nameless' may also have been an estuary during the Holocene.

Coastal dunes were formed during previous interglacial periods when sea level was about the same as at present. The last high sea level was 125 000 years ago when it was probably slightly higher than it is now. The sand has subsequently cemented to Coastal Limestone along much of the coast. Blowouts, such as those at Hamersley and Dempster Inlets, have exposed the limestone in places. The ocean beaches were formed during and following the Holocene rise in sea level from sand eroded from the dunes and from the sea bed. Finer sand was blown up into new dunes or added to the older dunes and has been stabilised by vegetation. The new dunes have further constricted the mouths of the Inlets. In many places, as at Culham and Jerdacuttup Inlets there is limestone in the shore and in offshore reefs parallel to the shore. Unfortunately it is not known when this sand was hardened to rock, though it seems logical to conclude that it is Holocene in origin.

2 CATCHMENT CHARACTERISTICS

The Hamersley Inlet, Culham Inlet and Jerdacuttup Lakes catchments are largely within the Shire of Ravensthorpe, though the Phillips River extends into the Shire of Lake Grace. Much of the Fitzgerald River catchment is in the Jerramungup Shire and its source is in the Shire of Kent. Fitzgerald Inlet, Hamersley Inlet, Culham Inlet and the Jerdacuttup Lakes all have large catchments which extend north and east of the National Park (Figure 1.1). The northern watersheds of these rivers are poorly defined where they traverse areas of internal drainage on the plateau. Dempster Inlet and Saint Mary Inlet have smaller catchments entirely within the Park.

There was little clearing in the catchments until the 1950s, except around Ravensthorpe and Hopetoun, but since then extensive areas of the upper catchments of the Fitzgerald, Hamersley, West and Phillips rivers have been cleared and there has been further clearing in the catchments of the Jerdacuttup and Phillips rivers since the 1987 data summarised in Table 2.1.

Table 2.1 Catchments of estuaries and coastal lakes in the Shire of Ravensthorpe. Total and cleared areas, as at January 1987. Estimated mean annual discharge and runoff to the estuaries and lakes.

	Catchment area (km^2)	Cleared area (km^2)	Percentage cleared	Mean annual discharge to estuary ($X10^6 m^3$)	Runoff (mm)
Fitzgerald Inlet	1611	628	40	8.0	5.0
Hamersley Inlet	838	158	19	4.2	5.0
Dempster Inlet	335	0	0	<1.3	<3.8
Saint Mary	169	0	0	<0.6	<3.8
Culham Inlet	2307	1019	44	13.8	6.0
Jerdacuttup Lakes	1818	902	50	10.9	6.0
Boondadup	38	0	0	<0.1	<3.8
Lake Nameless	50	0	0	<0.2	<3.8

East of Hopetoun there is a considerable area of internal drainage within 20 km of the coast, not only to the Jerdacuttup Lakes but also to a number of smaller coastal lakes of which Lake Shaster is the largest. There are also areas of internal drainage in the Park, especially to 'Lake Nameless' which has no outlet to the sea.

2.1 LANDFORMS, GEOLOGY AND SOILS

Chapman and Newbey (Mss.) recognise five major landforms in the Park associated with different rock and vegetation types (Figure 2.1). These are: **Upland** on the sandplain overlying granite in the north, and valleys in this; **Plain** on the softer spongolite rock; **Gorges** cut in the spongolite; **Ranges**, the Mount Barren ranges, showing different features on the schists and quartzites; **Coastal Dunes** with both limestone rock and sand. The soils, vegetation, and erosion hazards associated with these landforms are tabulated by Moore et al. (1989).

UPLAND The upper parts of the catchments of the Fitzgerald and Hamersley rivers lie on the gently undulating sandplain that covers the hard granitic and gneissic Archaean rocks of the Yilgarn Block at about 300 m above sea level. The rivers then traverse an area south of South Coast Highway where the valleys have cut down through the sandplain to the underlying bedrock, which is exposed in the river beds where they cross the Highway.

PLAIN Within 20 to 30 km of the coast the Pallinup Siltstone (spongolite) of the Plantagenet Group rocks forms a wide plain with little relief. Spongolite is a relatively soft rock formed from marine sediments which were deposited in the late Eocene sea (40 million years ago) over the irregular surface of the hard Precambrian rocks. It is a horizontally bedded rock composed of clays, sponge spicules and a sparse, fossil fauna. It has been quarried for building stone at Twertup in the Park and 22 km SW of Ravensthorpe.

GORGES These are cut in the spongolite, the upper surface of which has been hardened (indurated) by oxides making it more resistant to erosion than the underlying rock. Wind and water have eroded the softer rock leaving cliffs and steep slopes that wall the river valleys. Some of the gorges are narrow, gouged 50 m deep and 200 m wide through the Plain; in others the cliffs surround wide valleys, as along the Fitzgerald River and around the Inlet. Flat topped mesas such as Roe's rock are remnants of the plain protected by the hard capping. These spectacular features of the landscape, 100 m above present level, indicate the level to which the Eocene sea rose. The Werillup Formation of the Plantagenet Group is a thin layer of grey and black clay with lignite and montan wax under the spongolite. It is exposed in the Fitzgerald River near its junction with the Suseta River.

RANGES Proterozoic schist and quartzite rocks of the Mount Barren Beds form the coastal range of hills from East Mount Barren to Mid Mount Barren, between Culham Inlet and Dempster Inlet, and rise to over 300 m. These hard sedimentary rocks have been much deformed by pressure, as can be seen in cliffs along the Phillips River upstream from Culham Inlet and in the Hamersley River gorge. The Phillips River lies in a fault in the range and the Hamersley River cuts a zigzag course through it to Hamersley Inlet, also in faults. Dempster Inlet lies in a valley in schist on the flank of Mid Mount Barren. Schist outcrops again at Point Charles and Point Ann on a coastline otherwise dominated by dunes. Inland from Point Charles the Mount Bland - West Mount Barren hills are quartzite. Wide 'wave-cut' benches at about 80 m are prominent features of the seaward face of the eastern range. They are believed to be relics of a former higher sea level and were noted by Clark and Phillips (1953) in their study of the south coast and 'thought to result from a Pleistocene marine transgression' (Thom et al.,1977) but possibly from the earlier Eocene high sea level.

DUNES South and west of Dempster Inlet the curve of the coast is formed by coastal dunes up to 2 km wide, interrupted by the cliffs of Point Charles and Point Ann. They only cover a small part of the catchments, but to a large extent determine the character of the estuaries by narrowing their connection with the sea. The dunes have a core of Coastal Limestone of late Pleistocene age overlain on the seaward side by dune sand which, if not bound by vegetation, forms blowouts of mobile sand. Beach and dune sands are a mixture of silica sand eroded from the land and calcareous sand derived mainly from the breakdown of marine plants and animals.

The loose sandy soils contain different proportions of these, some being predominantly siliceous, others mainly calcareous. The Coastal Limestone has been formed by solution and redeposition of some of the calcareous material (lithification).

The Fitzgerald and Hamersley rivers rise on the sandplain of the Upland and traverse the other landforms, but the small catchments of Dempster Inlet and Saint Mary Inlet lie entirely within the Park and drain mainly the belt of spongolite rock within about 30 km and 15 km respectively of the coast. Dempster Inlet itself is in a valley cut in the schists of the Mount Barren Beds and this rock is exposed on the bare southern face of Mid Mount Barren.

East of the Fitzgerald River National Park the catchments of Culham Inlet and the Jerdacuttup Lakes lie in different landscapes. The Phillips River, and its tributary the West River, rise on sandplain north of South Coast Highway, but much of the catchment and that of the Steere River is in rugged hilly country of the mineral rich, Archaean volcanic and sedimentary rocks south of the Ravensthorpe Range. The lower reaches of the rivers are in more gently undulating country. The Jerdacuttup Lakes are fed

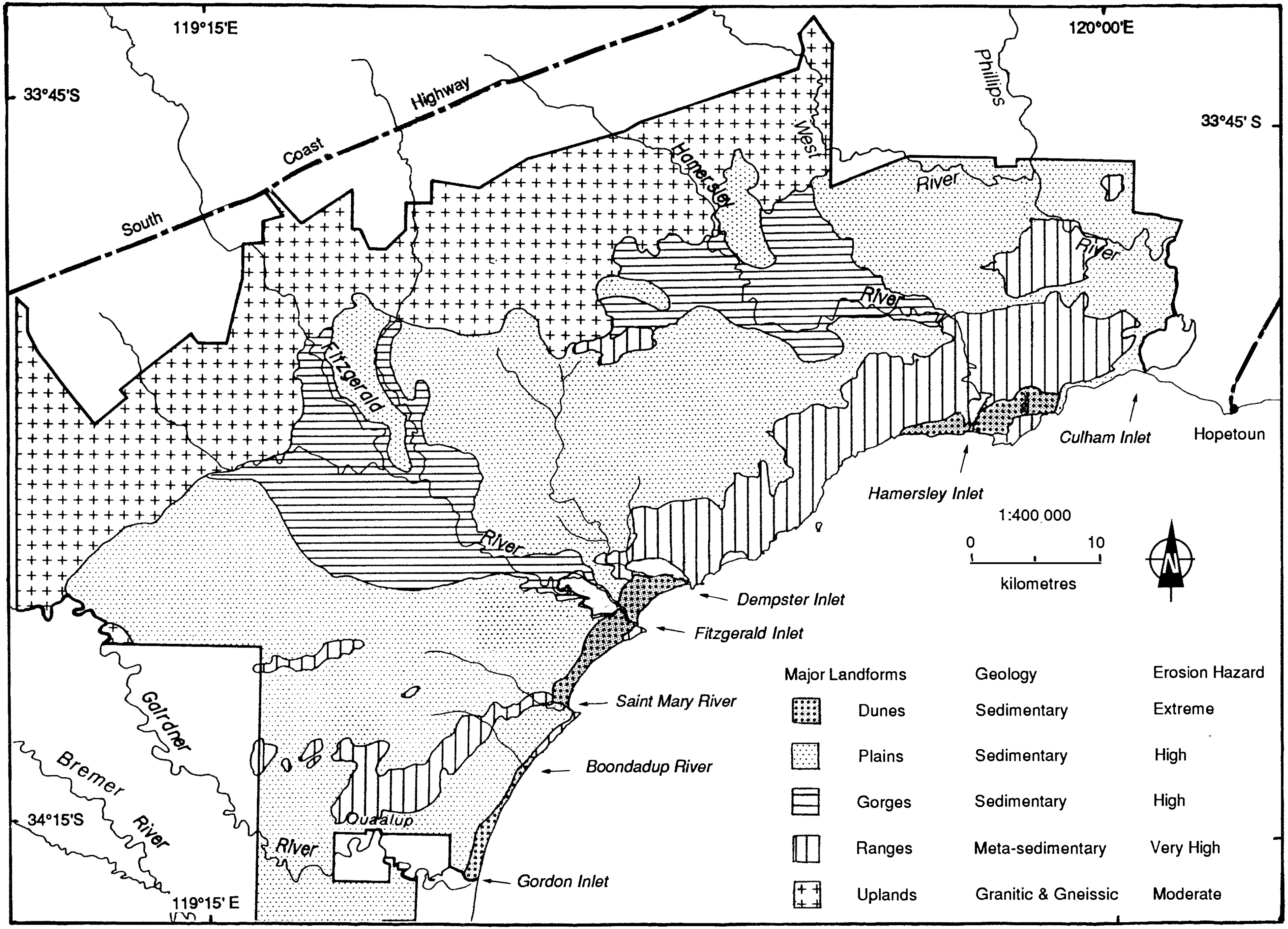

Figure 2.1 Major landforms in Fitzgerald River National Park. (redrawn from Chapman, A & Newbey, K in Moore *et al*, 1989)

by the Jerdacuttup River which rises north of Ravensthorpe and drains the eastern face of the Ravensthorpe Range. The eastern and southern part of the catchment is mainly undulating sandplain with outcrops of granitic rock north of the lakes.

The soils of all the catchments are mainly hard setting loamy soils with yellow clayey subsoils and poor sandy soils along the coast.

The geology of the area is described and mapped by Thom et al. (1977), Thom et al. (1984) and Thom and Chin (1984). Clark and Phillips (1953) studied the geology and coastal features of the area.

2.2 RIVERS

River flow is seasonal and there is often no flow for much of the year, though Chapman and Newbey (Mss.) observed some flow in the Phillips River throughout 1983-84. The dry river beds have a string of pools often with a dense growth of shrubs and trees between them. The smaller pools may dry in summer but larger pools, many a kilometre or more long, can be several metres deep and always hold water. Flood waters may flow several metres deep and scour the channels. River water is saline, seldom less than a quarter sea water salinity, and evaporation increases this greatly in shallow pools. Nevertheless some permanent pools support a number of plant and animal species including Black bream and three other species of fish.

Table 2.1 lists catchment areas, also areas of cleared land measured from 1987 Satellite images. The headwaters of the larger rivers are on flat land on the plateau, from which there is seldom much flow, and the precise location of the watersheds cannot be drawn accurately. Similarly the upper half of the Saint Mary Inlet catchment is a shallow basin from which water probably rarely flows to the river.

The **Fitzgerald River** flows in a north west - south east direction from its headwaters in Lake Magenta Nature Reserve 80 km from the coast and 300 m above sea level. It is the only river flowing into Fitzgerald Inlet. Between the Nature Reserve and the Fitzgerald River National Park boundary the river flows in a narrow strip of reserve and Vacant Crown Land through cleared farm land. Twertup Creek (15 km long from the west) and Sussetta River (35 km long from the north) join the river in the Park, 25 km from the sea, but both rise in farm land outside the Park.

The **Hamersley River** also rises on the edge of the plateau just north of South Coast Highway, 50 km from the Inlet and 300 m above sea level. Outside the Park the river flows through farm land, none of it reserved but some still not cleared. It has carved a valley through the Archaean granite to where it discharges onto the spongolite plain at about 100 m. There it takes a meandering course, sometimes cut deep into the soft rock and with 30 or more pools in the river bed. A number of small tributaries join the river, one from Mt. Drummond, before it carves a gorge through the hard rocks of the Mount Barren Beds from which several small valleys enter it and the Inlet.

Culham Inlet Two rivers, the Phillips and the Steere, flow into Culham Inlet. The Phillips River, and its tributary the West River, rise in sandplain north of South Coast Highway, but much of their catchments and that of the Steere River are in rugged hilly country of mineral rich, Archaean volcanic and sedimentary rocks south west of the Ravensthorpe Range. Most of the catchment south of South Coast Highway is natural bush, but much of the area north of the Highway and east of the Steere River is cleared agricultural land. The southern part of the Steere River catchment is in more gently undulating country much of which is farmed.

The **Jerdacuttup River** rises in Archaean granite country north of Ravensthorpe at over 300 m, some 60 km from where it discharges into the Jerdacuttup Lakes. It follows a tortuous course along the eastern side of the Ravensthorpe Range and then across the coastal sandplain. There are many pools in the river bed, some over a kilometre long and 5 m deep in places. South of Jerdacuttup North Road the river is in a narrow reserve through farm land. There has been extensive recent clearing in the northern part of the catchment so that three quarters of the catchment of the Lakes is now cleared.

The small catchments of **Dempster Inlet** and **Saint Mary Inlet** are entirely within the Park. The greater part of each catchment is in the spongolite plain with the harder rock of the Mount Barren ranges only near the coast.

RUNOFF and RIVER FLOW There are now no gauging stations on any of the rivers in the area though Station 602002 operated at Jacup on the Fitzgerald River from 1974 to 1986 (Figure 2.2). Extrapolating from this data and from the Pallinup River gauging station data (602001), runoff to the estuaries averages about 6 mm from cleared catchments but probably less than half that from bush land in the Park. Bush fires cause a temporary increase in runoff; it is estimated (from Satellite images) that by 1986 some 186 km^2 of the Park had been recently burnt. In December 1989 lightning strikes started fires which burnt about 1500 km^2 of the Park; then in January 1990 heavy rain caused floods that carried much ash and other debris and broke the bars of all the Park estuaries.

Table 2.1 shows estimates of mean annual flow to the estuaries, based on assumed rates of runoff of 6 mm from cleared land and 3.8 mm Park land. However such means are of little significance from the point of view of the response of the estuaries because river flow varies greatly from year to year. As will be seen from Figure 2.2 most of the flow is flood flow following brieg heavy rains. In 1976 94% of the

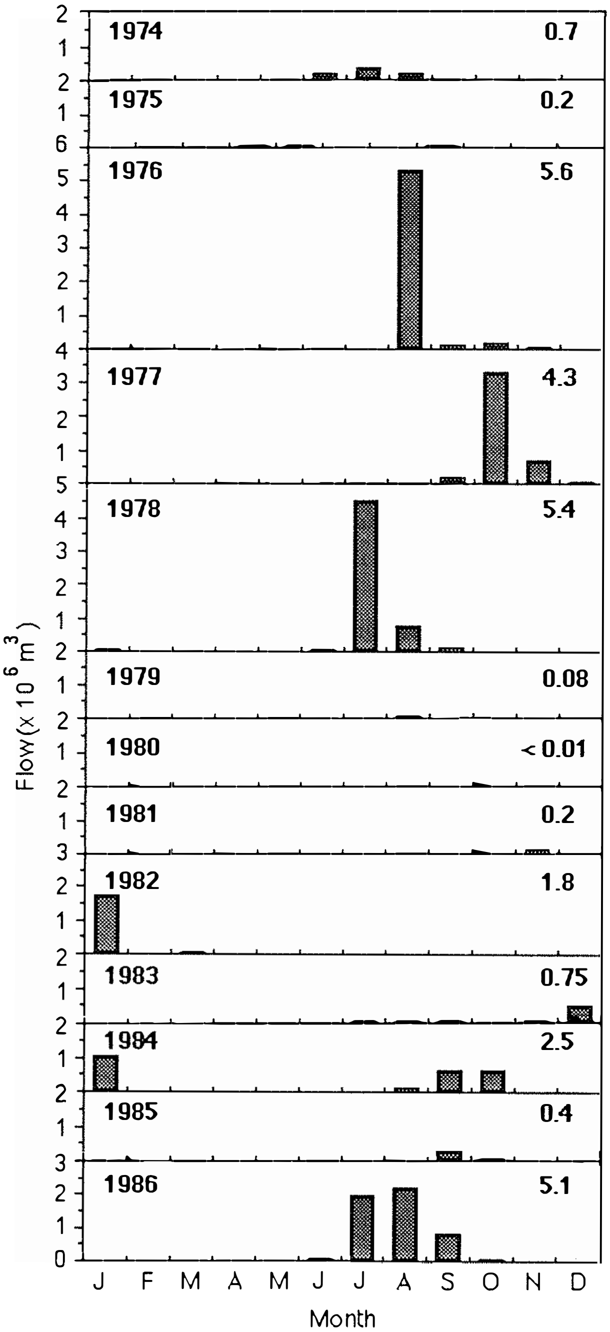

Figure 2.2 Monthly flows at Jacup gauging station 602 002 on the Fitzgerald River between 1974 and 1986. Yearly totals on right. (Water Authority of WA)

year's flow was in August, more than half of it in one day. There was almost no flow in the three years 1979-1981. Flood flow following sustained above average flow is probably the main cause of the bars breaking. High flow in the Fitzgerald River in 1976 and 1977 was followed by flood flow (6 X 10^6 m^3) in July 1978 causing the bar to break. All the estuary bars broke following the record rains of May 1988. Heavy rain of 100 mm or more can cause a rapid rise of water level in an Inlet in a few days and be sufficient to break the bar if there is already water in it. The 75 mm of rain that fell in the Culham Inlet catchment on 28-29 January, 1990 caused the Inlet water level to rise 360 mm over the next 10 days. This rain falling on the recently burnt Park catchments caused flood flow that broke all the bars.

Floods also transport large volumes of sediment such as the estimated 100 000 tonnes of sediment scoured from the Pallinup River channel in the 1982 flood (Hodgkin and Clark,1988). Some of this sediment is deposited in the river valleys, as in the alluvial terraces along the Fitzgerald River, but much is carried down to the Inlets together with trees and other vegetation as occurred in the 1963 (?) flood.

There are no dams on the rivers. The only dams are on farms in the upper parts of the catchments.

SEDIMENT TRANSPORT There are no data on sediment transport, however it is evident that large amounts of coarse and fine sediment are washed down to the estuaries, principally during major floods. Some of this comes from cleared areas of the upper catchments but it is also scoured from the river channels. Evidence from Beaufort Inlet and Stokes Inlet shows that catchment clearing has greatly accelerated the rate of sedimentation in the estuaries (Hodgkin and Clark, 1988 &1989).

WATER CHEMISTRY All river water is saline, where it flows from cleared catchments and within the Park, but salinity varies from almost fresh to greater than sea water salinity. The salinity (TSS) of strongly flowing water at Jacup appears from PWD records to have been between 3 ppt* and 8 ppt, though with some much higher figures. Too few samples have been taken of water flowing into the estuaries for any reliable estimate to be made of the salt load contributed by river water to estuary water. In September 1989 surface water in the Jerdacuttup River was 5 ppt, in the Steere River 7 ppt, in the Phillips River 15 ppt, and 4 ppt in Saint Mary River in October.

NUTRIENTS Of 51 samples of river water taken by Chapman (Mss.) in the Park in 1983-84 and analysed for Total Phosphorus, 45 showed concentrations of 10 µg/L or less and the highest was 60µg/L. A few samples taken later at the road crossings have shown much higher levels, up to 250 µg/L in the Hamersley River, and it is clear that at times there are high nutrient levels in runoff from cleared land. However without more extensive data these are an unreliable indication of nutrient input to the estuaries.

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* parts per thousand, 1 ppt = 1000 mg/L TSS

2.3 COASTAL FEATURES

Three radically different types of shore along the 150 km coastline of the Shire influence the character of the estuaries. From Oldfield Estuary to Culham Inlet the open, south facing coastline is dominated by low Pleistocene dunes which have trapped a series of saline coastal lakes between them and granitic rock inland. The dune line is interrupted by the granitic headlands which shelter Mason Bay and Starvation Boat Harbour from the south west. There are also a few small outcrops of granite shore rock near Hopetoun. Limestone reef rock is exposed at Oldfield Estuary and at intervals from Mason Bay to Culham Inlet, with wide reef platforms at Twelve Mile Beach near the Jerdacuttup Lakes and near Culham Inlet. These probably represent former beach lines.

From Culham Inlet to Dempster Inlet the coastline is rocky with jagged cliffs and narrow wave cut benches in the quartzites and schists of the Mount Barren Beds, very different from the rounded shore rocks of granite coasts. The rocky shore is only interrupted by short stretches of dune sand and rock, the largest of which forms the small bay east of Hamersley Inlet, the only significant estuary along this stretch of coast.

Westwards from Dempster Inlet to Gordon Inlet the sandy coastline backed by Pleistocene and recent dunes faces first south east and then east. This is interrupted by two rocky (schist) headlands, Point Charles and Point Ann, which shelter the mouths of Fitzgerald Inlet and Saint Mary River respectively from south westerly wind and swell. Inland from the dunes the landscape surrounding the Inlets is dominated by flat topped hills with deep valleys and cliffs cut in the spongolite rock. Quartzite is exposed in the Mount Bland - West Mount Barren range of hills from which the Boondadup River drains.

2.4 RAINFALL

Mean annual rainfall ranges from about 400 mm in the upper catchment (423 at Ravensthorpe and 450 mm at Jerramungup) increasing to 500 to 600 mm at the coast (504 at Hopetoun, 626 at Bremer Bay), but the extremes are much greater (Table 2.4). This is mainly winter rainfall but there are occasional summer storms usually with about 100 mm both at the coast and inland (200 mm in February 1955) and these distort the monthly means, as will be seen from the difference between the means and medians in Figure 2.4.

2.5 LAND OWNERSHIP AND USE

The Fitzgerald River National Park covers an area of 3280 km^2 from its western boundary in the Shire of Jerramungup to the Phillips River and Culham Inlet in the east. The catchments of Dempster Inlet and Saint Mary River are entirely within the Park. The Fitzgerald, Hamersley and Phillips river catchments extend north of the Park into land that has been cleared for agriculture since the 1950s and 1960s. This comprises about 40% of the Fitzgerald River catchment and nearly 20% of that of the Hamersley River (Table 2.1). There are reserves, and other uncleared land, along most of the major rivers and some of these are recommended as reserves to be managed by CALM because 'no Department or agency is formally responsible for day-to-day management' of them (CALM, 1989).

In the upper parts of the Steere River and Jerdacuttup River catchments there is a large area of native bush in the Ravensthorpe mineral field. This includes the Kundip Nature Reserve, but most of the area is Vacant Crown Land (VCL) and the draft South Coast Region Management Plan (CALM, 1989) recommends its classification as a conservation reserve. The southern part of the Steere and Jerdacuttup river catchments is largely farm land and more land is now being cleared in the northern part of the Jerdacuttup catchment. A reserve (A31760), Parks and Protection of River and Foreshore, gives protection to a long stretch of the Jerdacuttup River valley from Jerdacuttup North Road almost to Springdale Road. However the deep river valley

Table 2.4 Mean annual highest and lowest, monthly and annual rainfalls at three rainfall stations. (Commonwealth Bureau of Meteorology)

	HOPETOUN P.O. 1901-1984 009 557	JERRAMUNGUP (GAIRDNER) 1963-1986 010 792	RAVENSTHORPE P.O. 1901-1983 010 633
Mean annual	504 mm	451 mm	423 mm
Lowest annual	315 mm (1912)	255 mm (1969)	234 mm (1940)
Highest annual	764 mm (1971)	617 mm (1978)	736 mm (1951)
Highest monthly	200 mm Fb (1955)	176 mm Nv (1971)*	179 mm Fb (1955)
Highest two monthly	268 mm Jn/Jly (1916)	250 mm Jn/Jly (1978)*	221 mm Fb/Mr (1955)

*Highest monthly rainfall recorded at Jerramungup was in May 1988, 289 mm and two monthly in May/June 1988 was 350 mm.

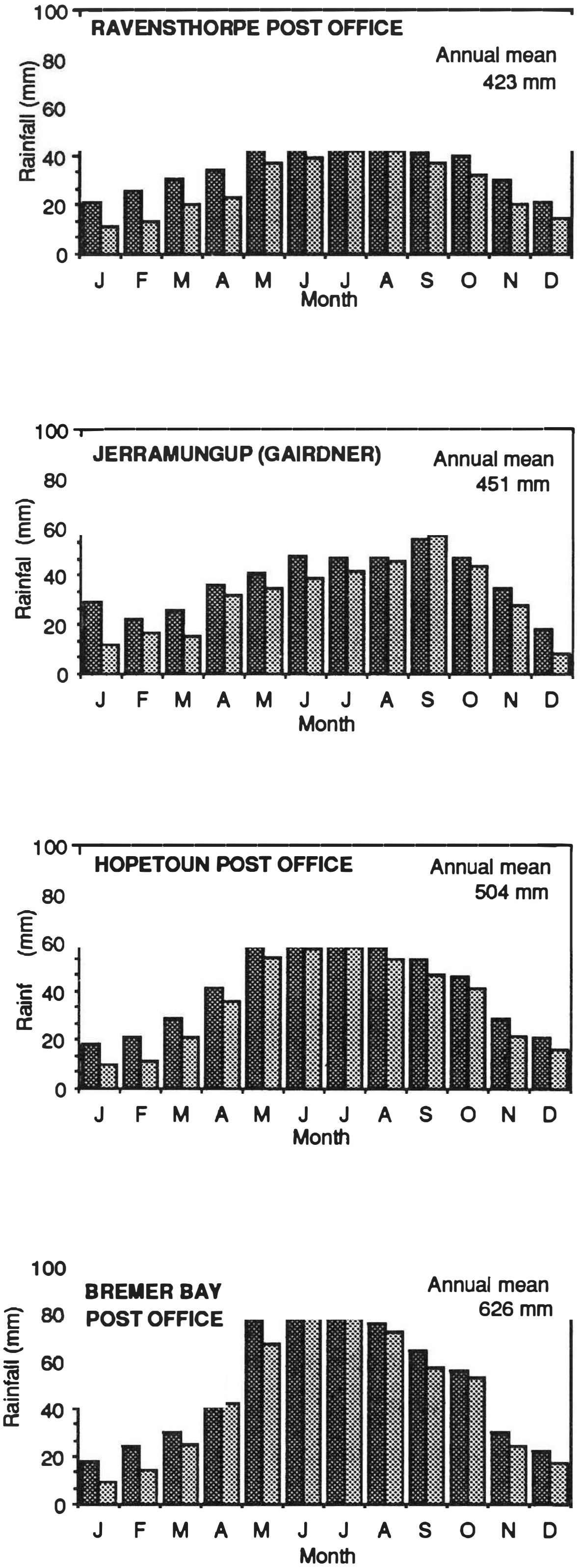


Figure 2.4 Mean and median monthly rainfall for inland stations: Ravensthorpe Post Office, 010 633, (1901-1983) and Jerramungup (Gairdner), 010 792, (1963-1986) and coastal stations Hopetoun Post Office, 009 557, (1901-1984) and Bremer Bay Post Office, 009 654, (1885-1986) (Commonwealth Bureau of Meteorology).

between the road and the Jerdacuttup Lakes is unvested VCL although it is part of the Lakes system which is in the Jerdacuttup Lakes Nature Reserve.

2.6 VEGETATION

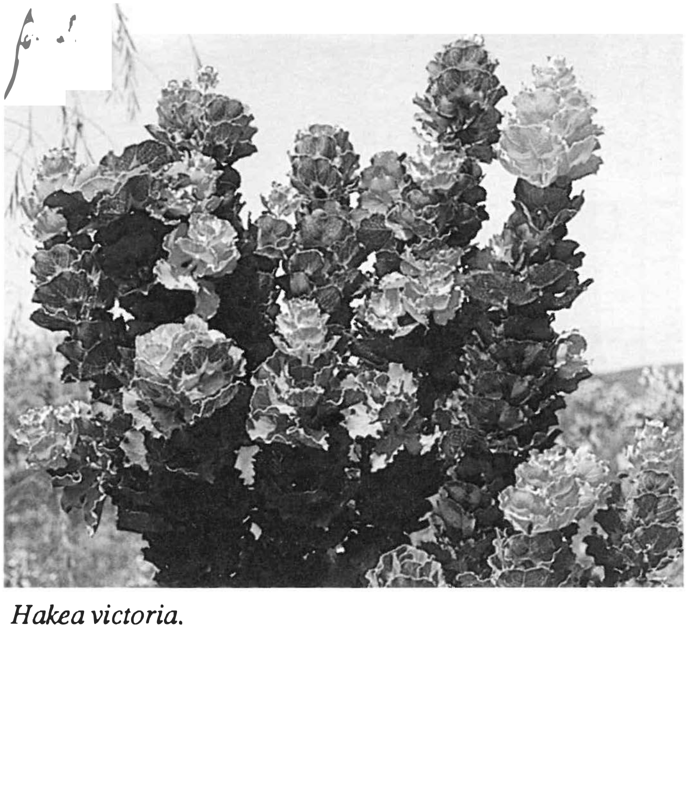
The National Park is noted for the great diversity of the native vegetation. Over 1750 plant species have been identified of which 75 are endemic to the Park and another 50 are restricted to it and the surrounding region. Many are rare. The distinctive *Hakea victoria* is widespread within the Park, but patchy, and is sparse outside.

The fungal dieback disease (*Phytophthora*) has been found at several places in the Park. It attacks a wide variety of plants and its spread could be disastrous not only for the vegetation but also for populations of possums and honeyeaters especially which depend on flowering plants for their food.

In the Park different vegetation types are associated with the five major landforms (Figure 2.1). The soils, vegetation and erosion hazards associated with these landforms are tabulated by Moore et al. (1989).

UPLANDS The undulating sandplain carries an open mallee dominated by *Eucalyptus redunca* or *E. tetragona*. The granite bedrock is often exposed on valley slopes which are vegetated by shrublands and low woodlands dominated by species of *Acacia*, sheoaks (*Allocasuarina*) and Proteaceae.

PLAINS The shallow sandy to sandy clay soils with a shallow soil A horizon are dominated by very open shrub mallee with a variety of species of *Eucalyptus* (*E. incrassata*, *E. leptocalyx*, *E. uncinata*). Where the A horizon is deeper *E. decipiens* is the dominant species, often occurring with *E. tetragona*. *Banksia baxteri* scrub is common on the deepest sands. There are patches of denser woodland in poorly drained depressions with loamy soils.



Hakea victoria.

GORGES The sandy loam soils of the gorge floors are dominated by open mallee of either *E. conglobata* or *E. incrassata*, with low forest of Moort (*E. platypus* var *platypus*) dominant on clay soils. On the shallow soils of the gorge slopes *E. gardneri* low woodland is dominant. Swamp Yate (*E. occidentalis*) woodland is dominant along the river flats.

RANGES The well drained skeletal soils of the Quartzite ranges carry a scrub dominated by either *Banksia oreophila* or *Adenanthos venosus*, with *Regelia velutina* shrubland common in the eastern coastal areas. Open mallee is dominated by a variety of *Eucalyptus* species including the distinctive *E. sepulcralis*. The skeletal schistose soils are vegetated by shrubs of *Allocasuarina trichodon* and *Banksia media*, with *E. incrassata* shrub mallee common on deeper soils.

The Ravensthorpe Range with its varied rock and soil types has a rich flora including several eucalypt species endemic to the area. Common woodland and mallee species are *E. annulata*, *E. nutans* and *E. transcontinentalis*, *E. leptophylla* and *E. leptocalyx*.

COASTAL DUNES There are annual and ephemeral plants on the frontal dunes and the steep slopes of the dunes carry a dense, low, wind-pruned heath. These give way to dense stands of *Melaleuca lanceolata* and *Melaleuca nesophila* in more stable areas. In the lee of the dunes there are dense thickets of Peppermint (*Agonis flexuosa*), the Open Shrub Mallee (*Eucalyptus angulosa*) and Coastal Moort (*E. platypus* var *heterophylla*).

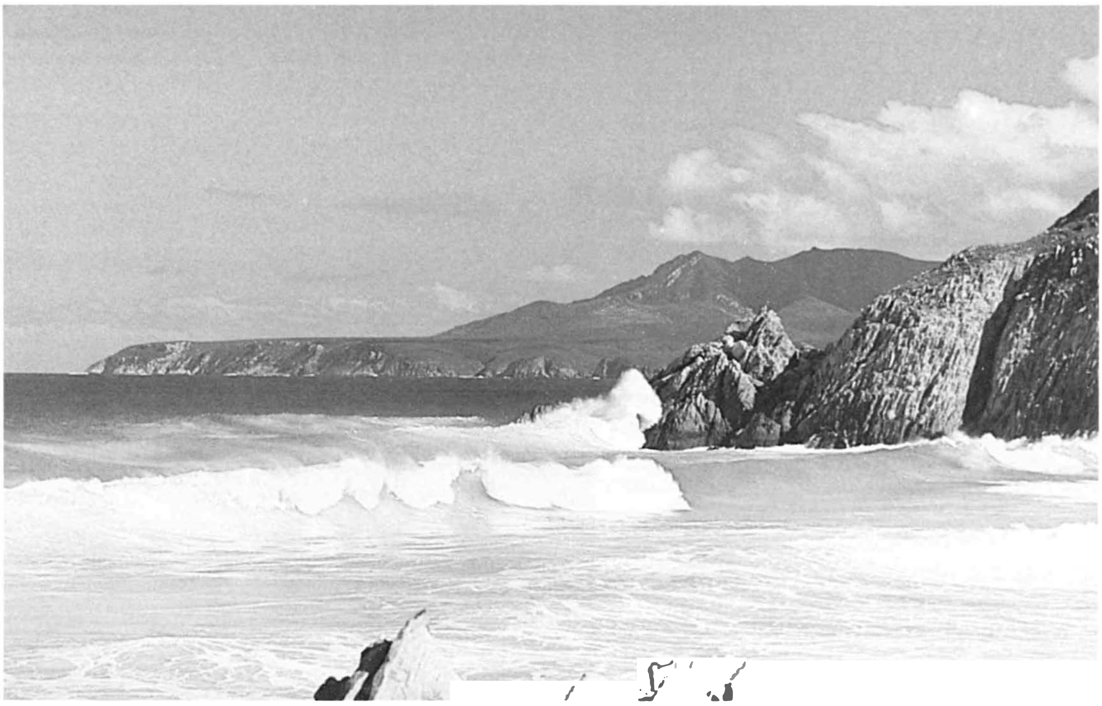
3 FITZGERALD INLET - PHYSICAL FEATURES

Fitzgerald Inlet is the largest estuary in the Park, but like its near neighbours on either side, Dempster and Saint Mary Inlets, it is now so shallow that often the only remaining water is in a deep gutter near the mouth and in the riverine reaches of its single tributary, the Fitzgerald River. The Inlet lies in a valley in the Pallinup Siltstone and around the margin of the lagoon there are spectacular red and yellow cliffs nearly 40 m high in this soft spongolite rock. The narrow inlet channel winds for 1.5 km through the coastal dunes to the ocean at the western end of a 6 km long beach where the mouth is sheltered from south westerly winds and swell by Point Charles (Figure 3). The bar, which is part of the beach, is low so that the lagoon seldom retains more than about a metre depth of water.

3.1 LANDFORMS

RIVER The river winds for about 4 km through an area of deltaic sediments before discharging into the lagoon. Former meanders of the river through the delta now hold samphire swamps. The river widens from 10 m to over 100 m before discharging into the lagoon. For the last 2 km it flows against a cliff on the south side and a curving spit on its north bank that partially cuts off the western segment of the lagoon (Figure 3.1). The spit is high (10 m) and well vegetated at the river end but descends to a samphire swamp where it ends in the lagoon.

LAGOON This is nearly 6 km long, 1.5 km to 2 km wide and has an area of 7 km^2. There are cliffs or steep slopes round most of the margin. The beaches



Thumb Peak and wave-cut bench. View from Quoin Head.

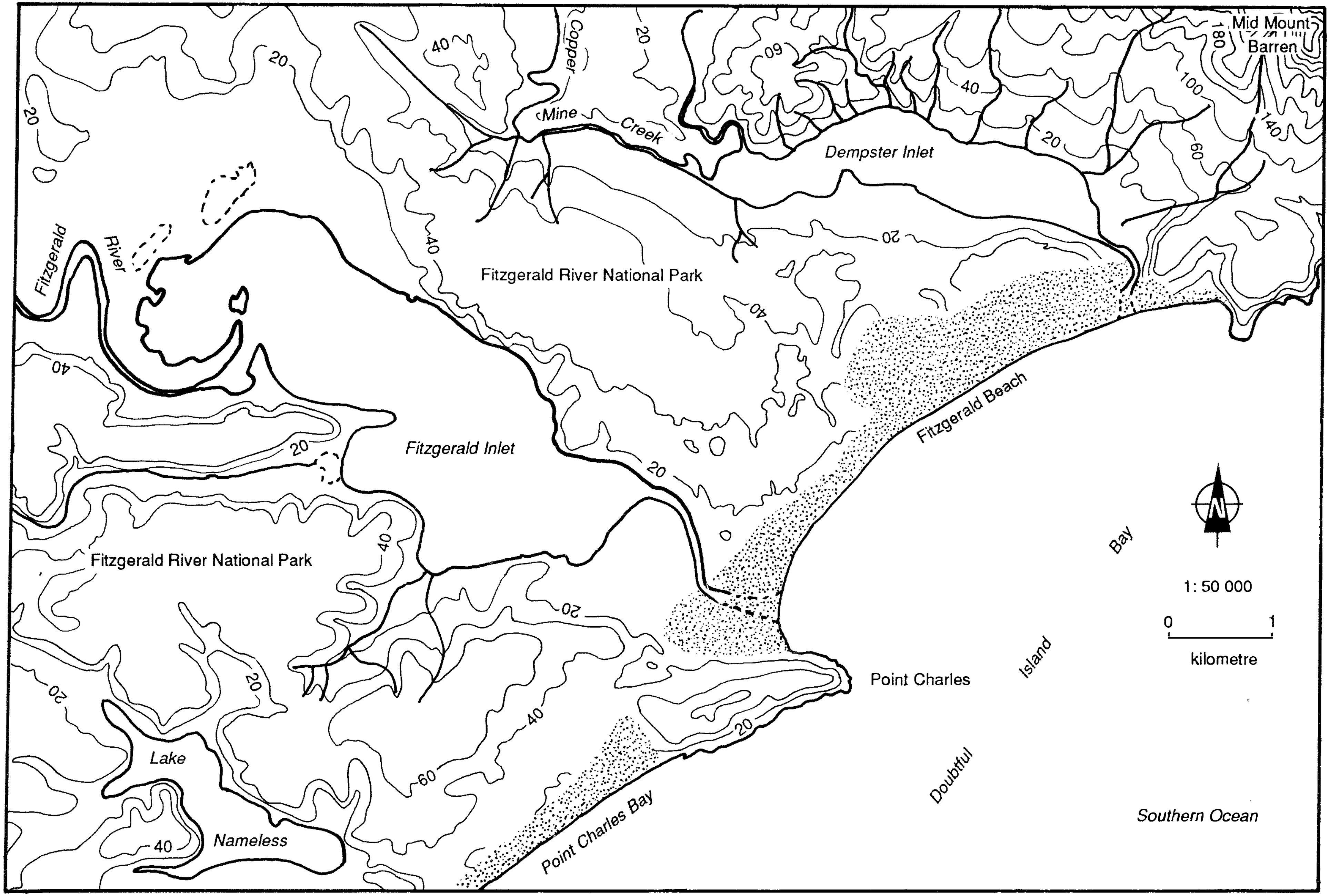


Figure 3 Fitzgerald and Dempster inlets, Lake Nameless. Topography of the surrounding area. Contours in metres.

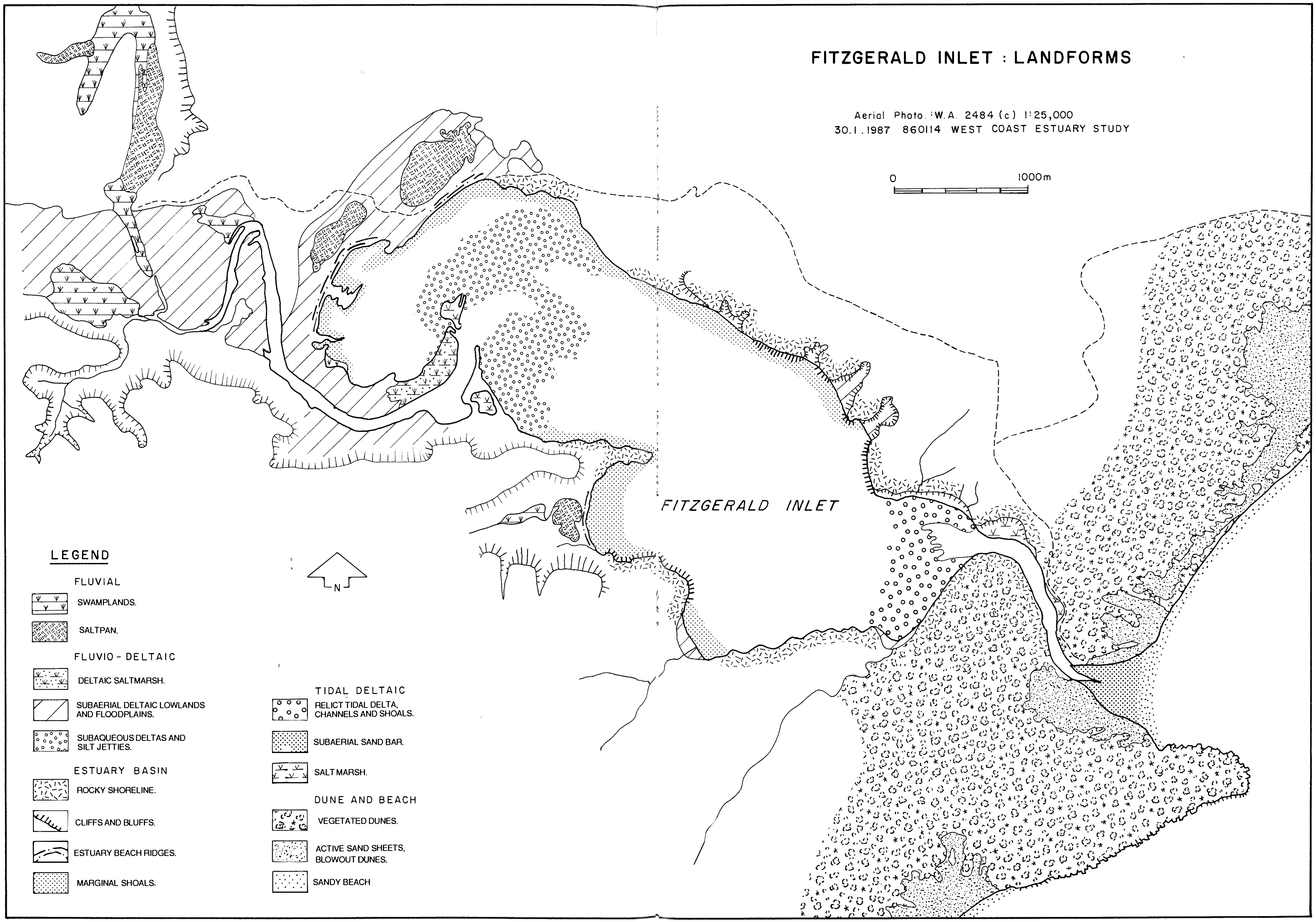


Figure 3.1 Fitzgerald Inlet. Landforms. (I. Eliot & D. Milton)

are narrow and there are only small patches of swamp. It is flat bottomed, at about mean sea level (MSL), so that even when full it is probably a maximum 1.5 m deep, but deepens within 500 m of the inlet channel. Following a flood (about 1963) many tree stumps lay scattered over the lagoon floor for many years, but most of these have now disappeared. Two shallow salt pans at the river end were once part of the Inlet but are now cut off from the lagoon by sand ridges; they are sparsely vegetated.

INLET CHANNEL The channel is about 1.5 km long from the lagoon to the beach. It is 50 to 100 m wide, shallow at the lagoon end and along the margin in wider parts, but is scoured to 5 m deep in the narrowest part. The dunes which border it are unconsolidated sand, but are well vegetated except on the southern shore near the beach. A narrow samphire flat along the northern shore widens near where the channel opens into the lagoon.

3.2 THE BAR

The inlet channel discharges onto the beach in the shelter of Point Charles. The bar is often only about 1.5 m above sea level and waves break over it, but it is reported to build up higher at times and vegetation may grow on it. It is built of a fine white silica sand (Figure 3.2) which becomes saturated when the estuary water level is high and the bar is closed; it is then a quicksand in which numerous vehicles have been bogged in recent years. Bignell (1977) notes: 'It has been claimed that . . . horses pulling a cumbersome wagon heavy with posts sank out of sight' when the overland telegraph line was being built.

The bar breaks infrequently, following heavy rain in the catchment, and generally only stays open for a few weeks. It is said once to have remained open for 18 months and to have had abundant fish and shellfish in it at the turn of the century. A flood broke the bar in about 1963 and it broke again in 1971. It broke in July 1978 and was still open in January 1979 (rainfall in June 1978 121 mm in Jerramungup, 144 mm at Hopetoun). It broke in 1988 (between July and September) after record rains in May and again in January 1990 when heavy rain followed the December 1989 fires, but did not stay open long on either occasion.

Runoff from the catchment is estimated (from the Jacup data, Table 2.2) to be 5 mm and the mean annual inflow to the estuary 8 X 10^6 m^3 (Table 2.1), a flow that must vary from nothing to perhaps 30 x 10^6 m^3. The flow necessary to break the bar will depend on its height and the volume already present in the Inlet. After two dry years, a flow of 7.65 X 10^6 m^3 at Jacup in August 1976 failed to break the bar, but after the two wet winters of 1976-77 the July 1978 flow of 6.0 X 10^6 m^3 broke the bar (Figure 2.2).

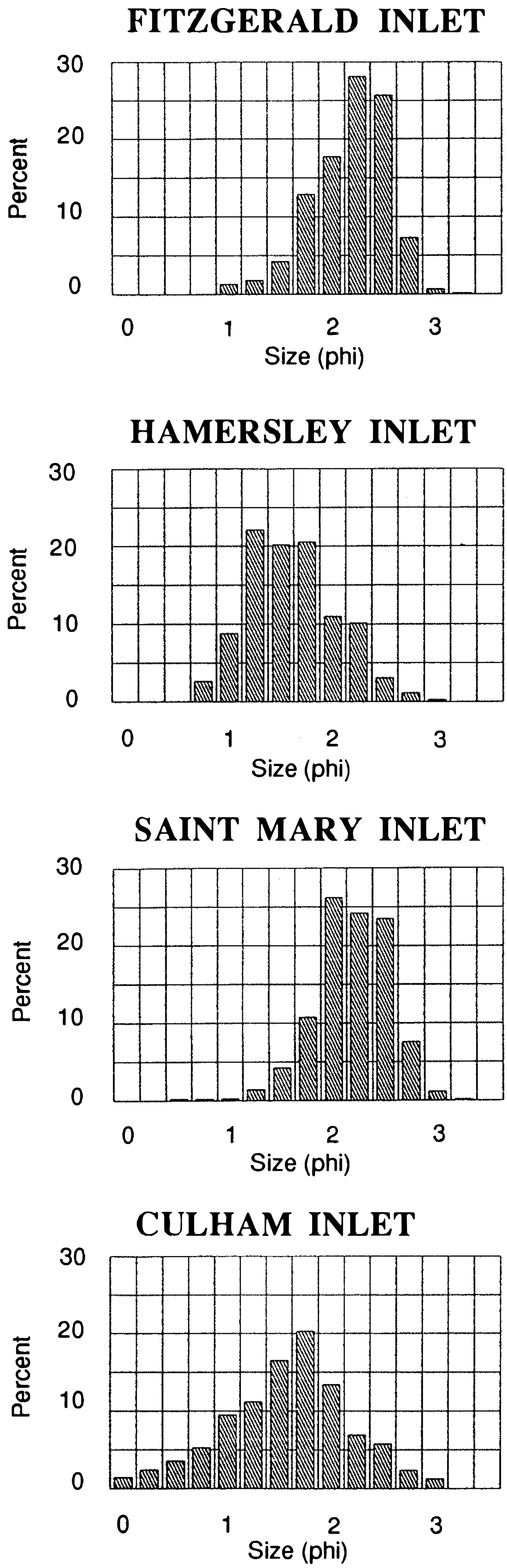


Figure 3.2 Sand size distributions from the bar crests at Fitzgerald, Hamersley, Saint Mary and Culham inlets. Sizes are in phi units. (Bill Wilson) -1 phi = 2 mm, 3 phi = 0.125 mm.

3.3 WATER DEPTHS

There is seldom more than about 1 m of water in the lagoon and it is often dry, except close to the inlet channel. The river reaches probably have a maximum depth of about 2 m and shallow sand flats. The inlet channel is scoured 3 to 5 m deep in the narrow part.

3.4 BOTTOM SEDIMENTS

Sand along the shoreline gives way to sandy mud further from the shores. There is muddy sand along the shallows of the inlet channel and in the adjacent samphire swamp. The lagoon bed was reported to be a mass of shells. A short core taken by Hassell (1962) near the western end of the lagoon showed 2% coarse sand,89% sand, 9 % clay.

3.5 WATER CHARACTERISTICS

There are few salinity records from the Inlet. Presumably it may sometimes be as low as 5 ppt (a figure sometimes observed in river flow) when first filled by winter rains, but it becomes progressively more saline as the water dries up in summer and figures in excess of 200 ppt have been recorded even in the inlet channel. Sea water seeps through the bar into the channel and waves wash over the bar, but the volume is only sufficient to retain water in the channel; this was 95 ppt in April 1977 and in February 1989, nearly three times sea water salinity.

4 HAMERSLEY INLET - PHYSICAL FEATURES

Hamersley Inlet lies in a deep valley carved through hard, quartzite and dolerite rock of the Mount Barren Beds rock. The upper reaches of the estuary zigzag in a gorge between steep slopes and cliffs in the contorted schist (Figure 4). The lower lagoon basin is excavated in a fault valley and the shoreline is rocky and deeply indented. Coastal limestone and dune sand border a short length of the southern shore near the mouth. The mouth opens at the western end of a small sandy beach through a short inlet channel between rock on the west and dune on the east. This dune is reported to have been caused by a fire early this century.

Hamersley Inlet differs from other estuaries of the Shire in that the lagoon floor is about 2 m below sea level. In consequence it holds water longer than other Inlets and provides a more favourable environment for estuarine and marine animals which sometimes flourish for several years. However the Inlet does dry up from time to time and the water level varies over periods of years as well as seasonally.

The Hamersley River is the only river flowing to the Inlet; its catchment lies mainly within the Park and only 20% is in cleared agricultural land in the headwaters.

Fitzgerald Inlet with spongolite cliff. Photo: Stuart Chape.

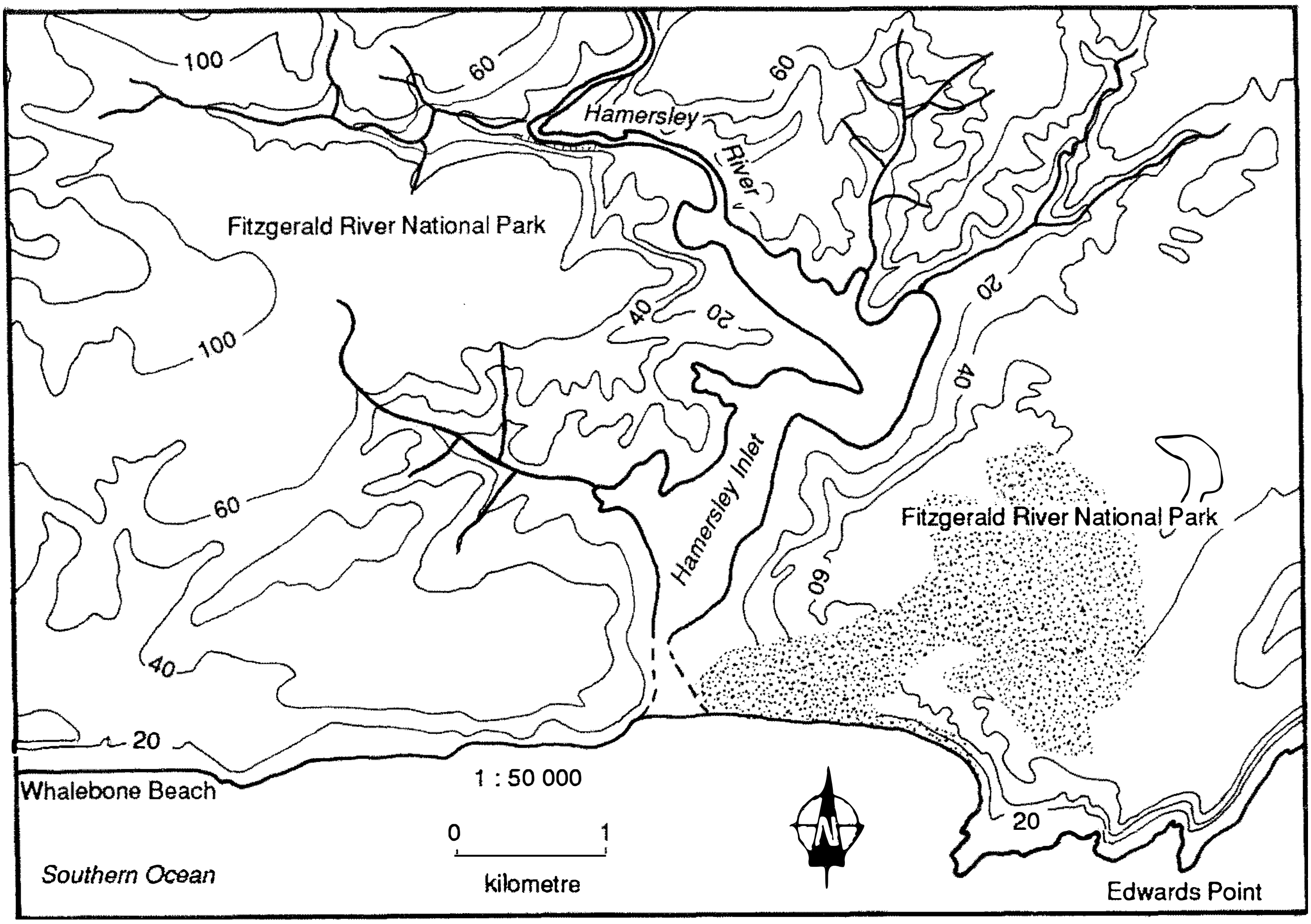
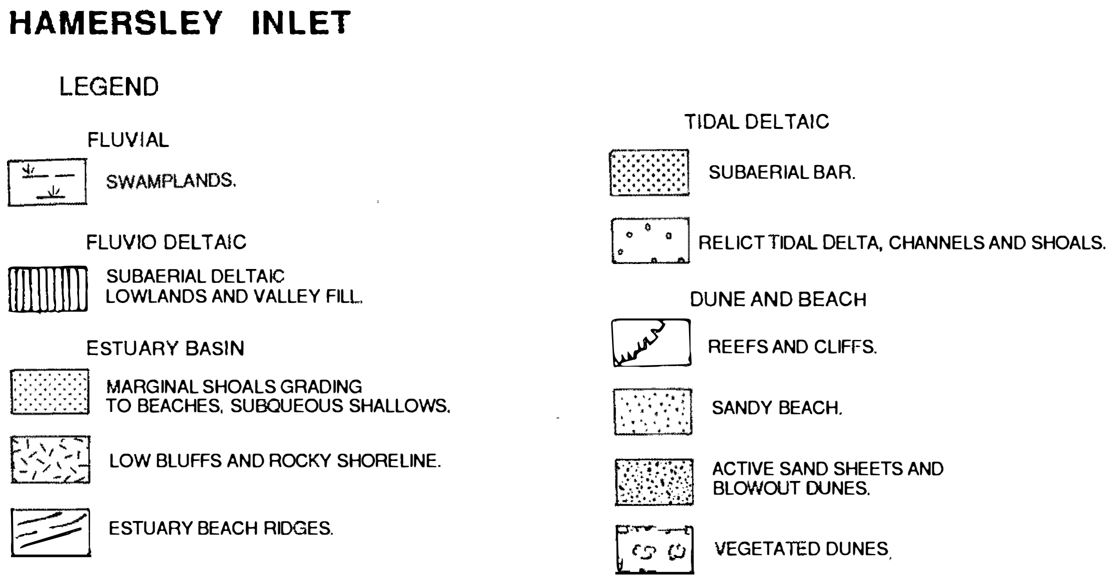


Figure 4 Hamersley Inlet. Topography of the surrounding area. Contours in metres.

4.1 LANDFORMS

The estuary is about 7 km long from a rock bar in the narrow river valley to the mouth at the southern end of the lagoon where it opens to the sea through a short inlet channel (Figure 4.1). The mouth is at the western end of a shallow, 2 km long south facing bay. There it gains some shelter from south westerly swell by a rugged shore platform of interbedded schists and quartzites on the west of the mouth. This rock extends part way across the mouth in the beach and there is limestone reef rock in the beach to the east. A large blowout in the dunes immediately east of the mouth encroaches to within 150 m of the Inlet shore.



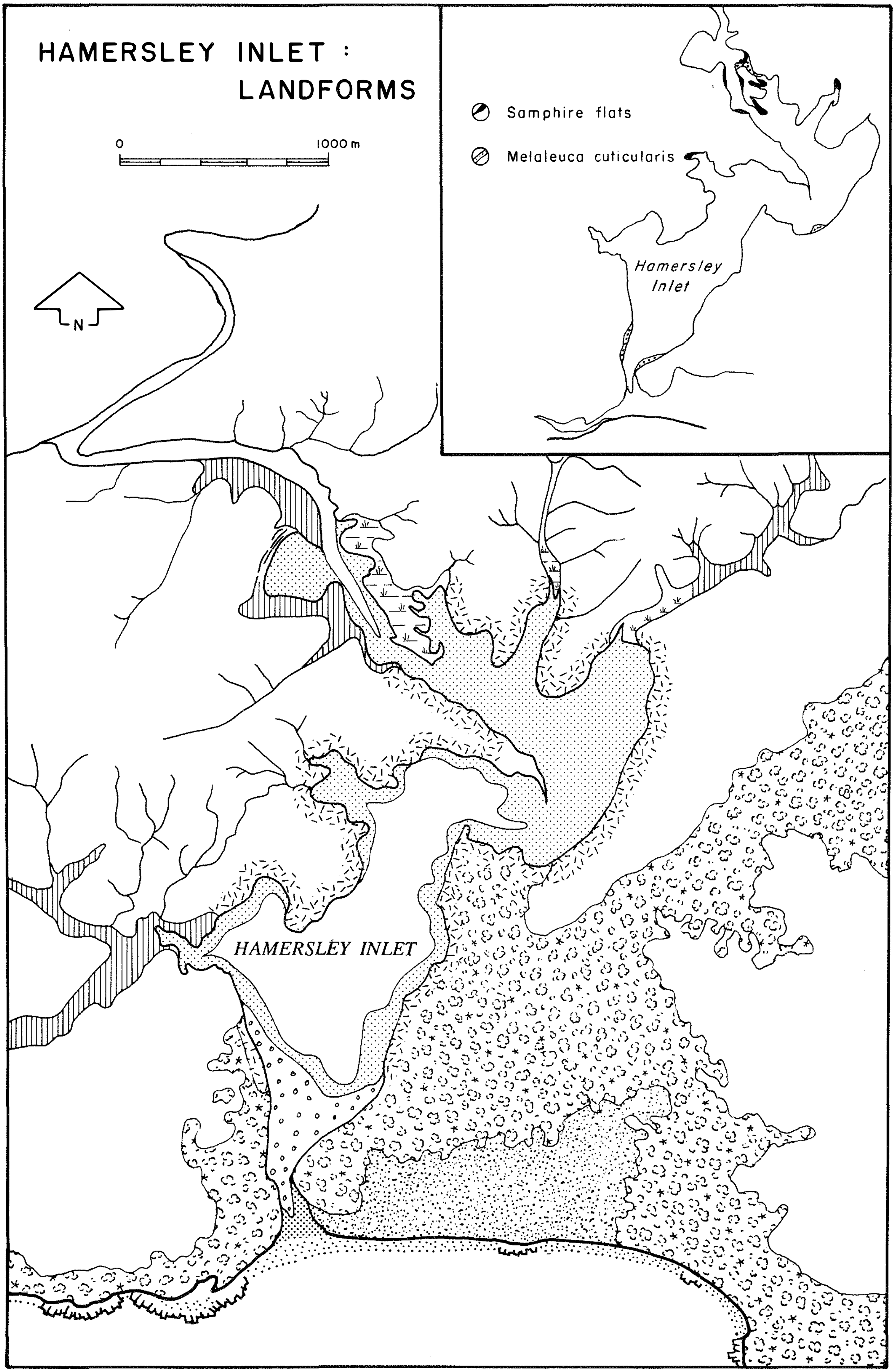


Figure 4.1 Hamersley Inlet. Landforms. (I. Eliot & D. Milton)

RIVER For 2.5 km the riverine reaches wind through a narrow valley in the Mount Barren Beds. Most of the shoreline is rock which rises steeply to over 80 m and is cliffed in places. Rock bars in the river bed break the channel into three pools when the water level is low, but when flooded it is navigable in a small boat its whole length. There is a shallow bay on the western shore before it opens into the lagoon and on the eastern shore of its channel the river has built a delta with samphire and paperbark flats which extend into a long silt jetty.

LAGOON The lagoon is about 4 km long and only 0.5 km wide, with an area of about 2.3 km^2. Near the mouth it is 2 m deep below MSL and shallows gradually upstream and to the wide marginal shoals. The upper arm of the lagoon is narrow in a NW-SE direction from where the river first widens out into it. When the water level is low the silt jetty cuts off small shallow salt lakes in bays at the mouths of two creeks that enter from the north. The peninsula on the western shore is rock with a pebble beach of moderately rounded pebbles.

The 3 km long lower arm of the lagoon turns abruptly to the south west. The tortuous northern shore and part of the southern shore is rock (quartzite and schist). Nearer the mouth the southern shore is cut in the steep northern slope of an old dune which overlies the hard rock and at about 1 km from the mouth shell beds of Pleistocene age are exposed in the steep slope. Here the shore is sandy and slopes gently from the dune to the deeper part of the basin. Near the mouth a dense stand of paperbarks fringes the shoreline.

INLET CHANNEL Near the mouth the basin narrows to a short inlet channel 150 m wide and 500 m long. A flood tide delta fills the seaward end and slopes down into the basin. Rock (quartzite and schist) borders the western shore of the channel and extends to the beach, though covered with sand in places. The eastern shore is dune sand, only loosely bound by the vegetation.

4.2 THE BAR

The mouth of the estuary is closed by a sand bar about 300 m wide built of off-white, moderately well sorted, medium to fine grain sand; 70% quartz and 30% calcareous skeletal remains (Figure 3.2). The bar builds up to about 2 m above sea level and probably more after prolonged closure. On the seaward side sand often covers quartzite rocks which are continuous with the rocky shore west of the mouth and when the bar breaks the outflow exposes the jagged rock which is about a metre above sea level. The bar breaks at its west side over the rocks, which must reduce the scouring action of water flow, but the break probably works eastwards when flushing strongly across the whole width of the bar. At times storm waves wash over the bar and lower it without breaking it.

The bar breaks infrequently and only remains open for a few weeks; 6 weeks in 1978. Clark and Phillips (1953) say: 'The estuary has remained closed since 1915 . . . and although it has been more or less filled several times since then, it has not been open to the sea'. Other reports say the bar broke about 1923 and then not until 1955. Since then it has broken in 1971, November 1977, August 1978, 15 August 1986, May 1988 and January 1990. There are no long term rainfall records for the Hamersley catchment, but records from Hopetoun and Ravensthorpe indicate that the 1955 break may have followed 200 mm of rain in February and 100 mm in April (at Hopetoun). The 1971 break probably followed heavy rain in November (Hopetoun 150 mm, Ravensthorpe 180 mm) after soaking autumn rains. The 1977, 1978 and 1986 breaks followed heavy winter rain. The 1988 break followed three weeks after the record rain of early May (330 mm at Hopetoun) and the January 1990 break came soon after the heavy rain that followed the fires of December 1989. Late winter or spring breaks appear to be the usual pattern. The occasional heavy summer rains are generally absorbed by the dry catchment soils and are unlikely to break the bar unless estuary water level is already unseasonally high.

4.3 WATER DEPTHS

At its deepest point near the bar the lagoon floor is about 1.3 m below MSL and at 3 km from the bar about 0.7 m. The maximum depth in the lagoon when the water tops the bar is thus about 3 m. The lagoon may hold water favourable to animal life for several years, but sometimes dries out in summer leaving only a patch of shallow hypersaline water along the lower arm of the lagoon (as in January 1968, April 1977 and even in July 1983). Pools in the river section of the estuary are up to 4 m deep and still hold water when the lagoon dries.

The bar broke on 2 August 1978 and remained open until about 14 September and when seen on 19 October the water level in the lagoon was only 20 cm lower than in August. By April 1979 evaporation had lowered the water level another 1 m. When the water level is low, as in April 1979, sea water seeps through the bar into the estuary and fresh water seeps from dunes on the eastern shore near the mouth. Such seepages probably add little to the volume of the estuary.

4.4 BOTTOM SEDIMENTS

River sediment has filled the Pleistocene valley of the estuary with sand and clay eroded from the catchment and has built the river deltas and filled the shallow bays. The margins of the lagoon are rock or sand, changing to silty sand in the deeper parts. Bosses of calcareous dune rock are exposed at low water on the eastern shore at 1.5 km from the bar and there are Holocene shell deposits.

4.5 WATER CHARACTERISTICS

SALINITY Surface water in the lagoon is often less than sea water salinity, generally between 15 and 50 ppt (Table 4.51), and it is evident from the live and recently dead fauna sometimes found in the estuary that the water may stay within this range for prolonged periods. However grossly hypersaline salinities have been found when the water was drying up. There is probably seldom significant stratification in the shallow open water of the lagoon, but deep water in the riverine part may be stratified with surface water of 5 ppt flowing from the river over bottom water of more than 50 ppt. When the water level is low sea water seeps through the bar into the Inlet and fresh water seeps from the dunes, however the volumes are only sufficient to maintain some water in the deepest part of the Inlet as it dries up.

Table 4.51 Hamersley Inlet. Records of salinities (ppt), S - surface, B - bottom.

		kilometres from the bar						
		Bar	1	2	3	4	5	6
29/4/77	S	34	-	158	-	-	-	-
20/7/78	S	-	13	-	-	4	-	-
2/8/78	S	17	-	16	-	-	-	6
	B	17	-	50	-	-	-	60
19/10/78	S	26	-	-	-	24	-	-
	B	-	-	-	-	60+	-	-
4/4/79	S	50	-	-	-	-	-	-
28/10/79	S	45	-	-	-	-	-	-
25/5/82	S	-	-	-	175	-	-	-
23/7/83	S	-	220	-	-	-	-	-
14/5/89	S	-	54	-	-	-	-	-
	B	-	54	-	-	-	-	-
24/10/89	S	21	-	-	-	-	-	18
	B	-	-	-	-	-	-	30

WATER TEMPERATURE This is likely to be similar to that in other coastal waters of the south coast, ranging from about 12°C in winter to 25°C in summer, but greater in shallow water.

OXYGEN The water of the lagoon is probably always saturated with oxygen but the deep water of the river will be depleted of oxygen when it is stratified.

NUTRIENTS The few samples tested have shown concentrations of 40 to 70 µg/L Total Phosphorus.

5 DEMPSTER INLET - PHYSICAL FEATURES

Dempster Inlet is the least accessible of the estuaries and information about the behaviour of the bar and persistence of water in the Inlet is sketchy. It is an elongate lagoon lying east-west in a valley carved in the Mount Barren schist which is exposed along the shoreline. In this respect it resembles Hamersley Inlet and is different in character from Fitzgerald Inlet which is in the softer spongolite rock and surrounded by cliffs. However, like Fitzgerald, the lagoon is filled with sediment to about sea level and it is often dry in summer. The mouth opens to the exposed, northern end of an open beach 5 km from the mouth of Fitzgerald Inlet (Figure 3). This is a more exposed position and the bar builds up to 2 m above sea level and retains this depth of water when the Inlet fills.

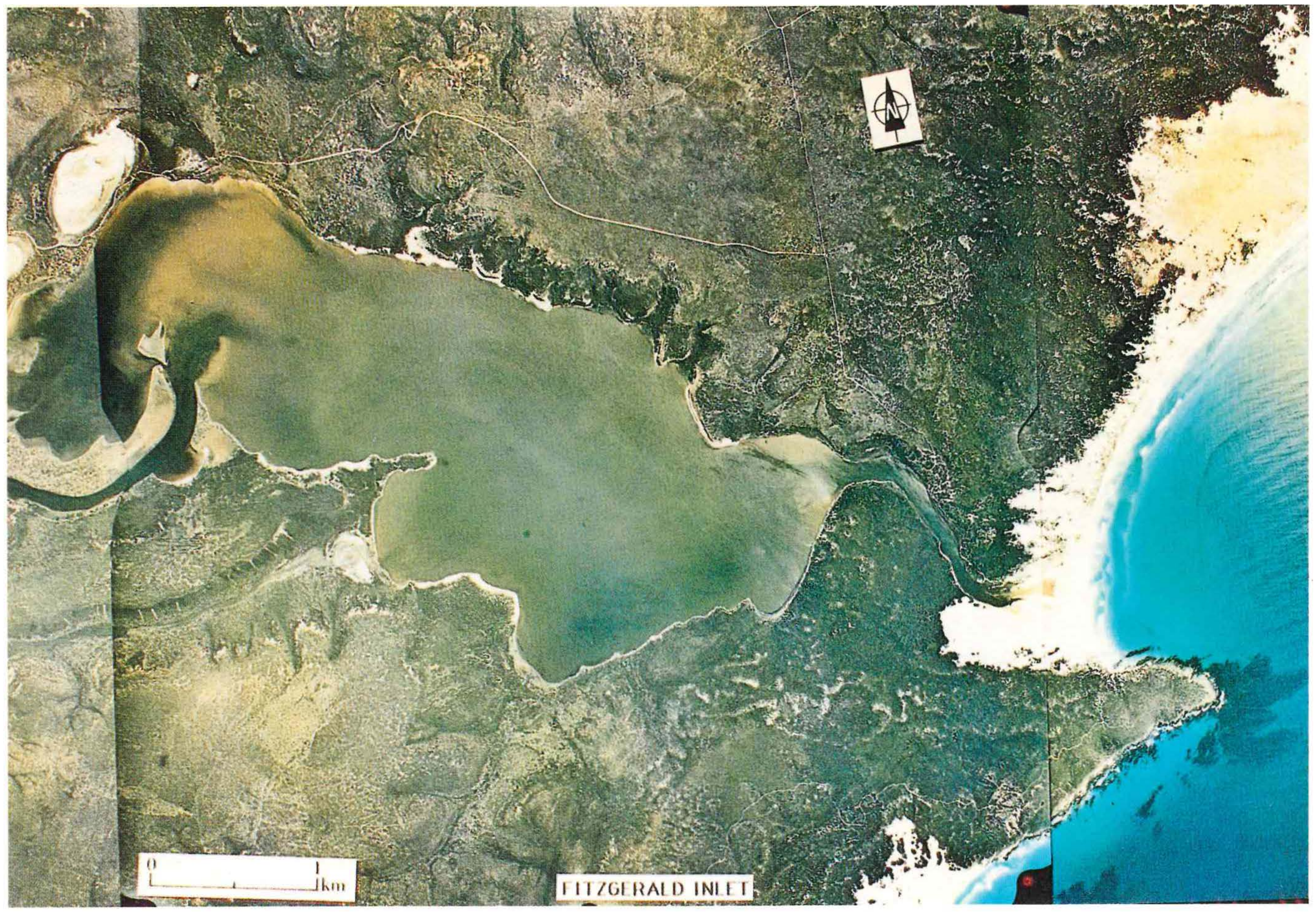
Coppermine Creek flows into the lagoon at its western end from an alluvial valley in the spongolite. An unnamed creek enters nearby from the north from a valley at the junction of the spongolite and schist. The creeks may hold shallow water for about 1.5 km even when the lagoon is dry, but this becomes highly saline. It is evident that much sediment, coarse and fine, has come from the creeks to fill the lagoon basin.

5.1 LANDFORMS

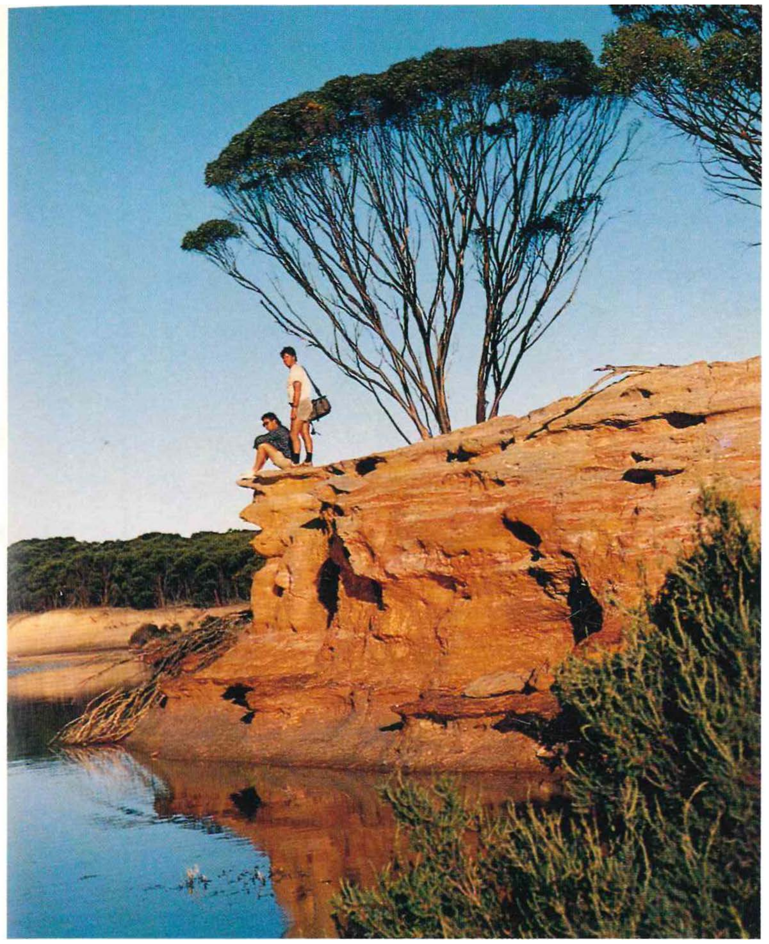
The estuary is nearly 7 km long from the sea to the end of the riverine reaches. On the northern shore of the lagoon the land slopes up to the steep, bare rock face of Mid Mount Barren. Several gullies discharge to this shore and have built small deltas into the lagoon. The easternmost of these creeks discharges to a wide samphire flat which is inundated when the Inlet is full. A wide blowout from the sea beach approaches within 300 m of the southern lagoon shore (Figure 5.1).

RIVERS Coppermine Creek has a nearly straight channel between gentle slopes in the schist for 1.5 km. Near the lagoon a meander of the river has left a wide shallow area on the north bank before narrowing again. It is shallow, but floods have scoured a slightly deeper channel where the creek discharges into the lagoon. The northern creek winds for 1.5 km through steeper slopes in the schist and appears to have scoured a rather deeper channel which also extends into the lagoon.

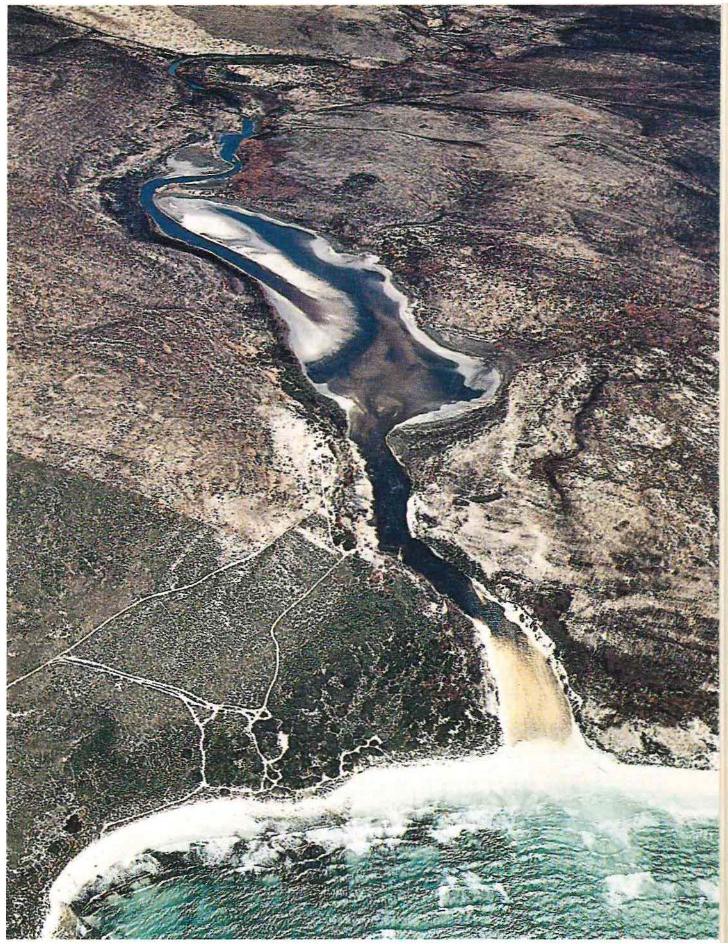
LAGOON The lagoon is 4 km long from the river mouths to the inlet channel, only 400 m wide in the upper arm and 700 m wide in the seaward part. It is less than 1 km wide and 2.3 km^2 in area. It has a flat muddy bottom and narrow sandy shores from which the land rises steeply though to no great height. The river deltas and a flood tide delta at the seaward end are slightly higher than the general level of the shallow basin. Schist is exposed along the northern shore and patchily along the southern shore. Dune limestone and mobile sand reach the southern shore



Fitzgerald Inlet, January 1987. Mosaic air photograph.



Fitzgerald Inlet. Spongolite cliff on the river.

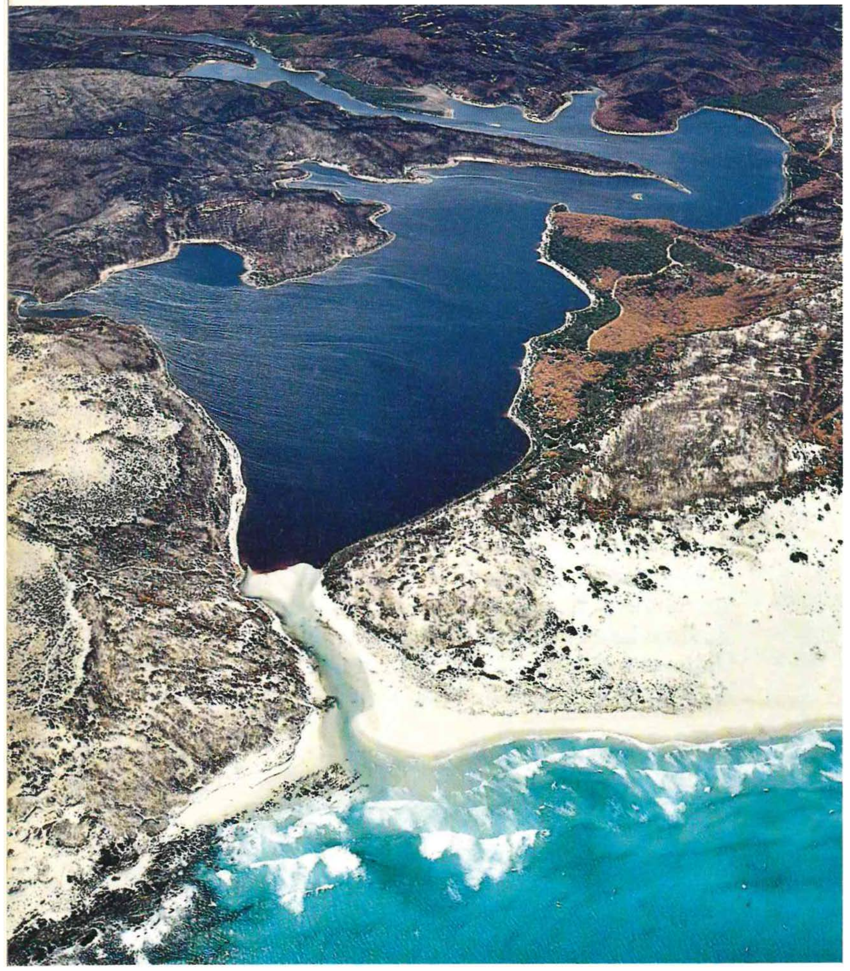


Saint Mary Inlet, February 1990.

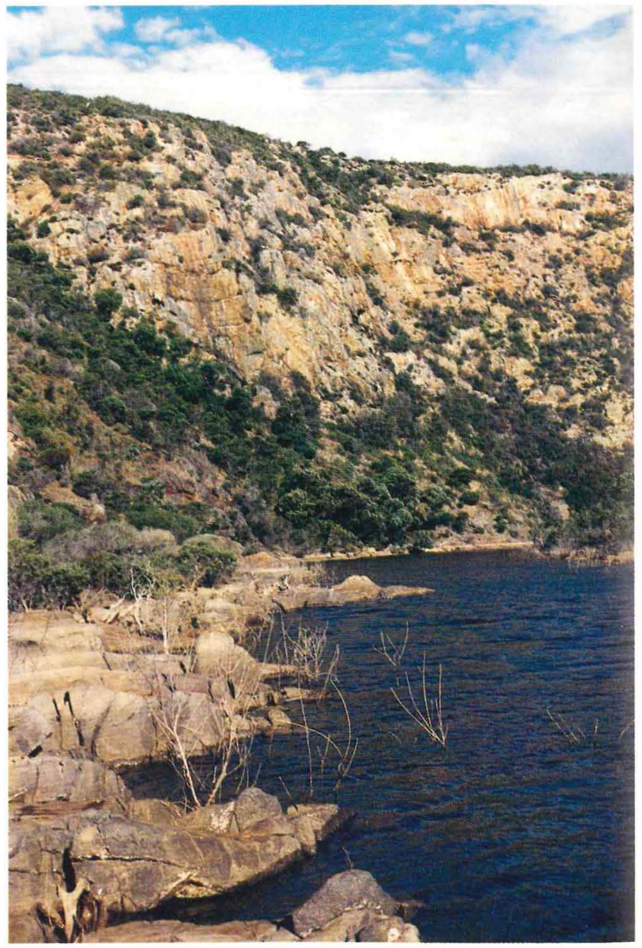
Air photographs by Department of Land Administration, WA.

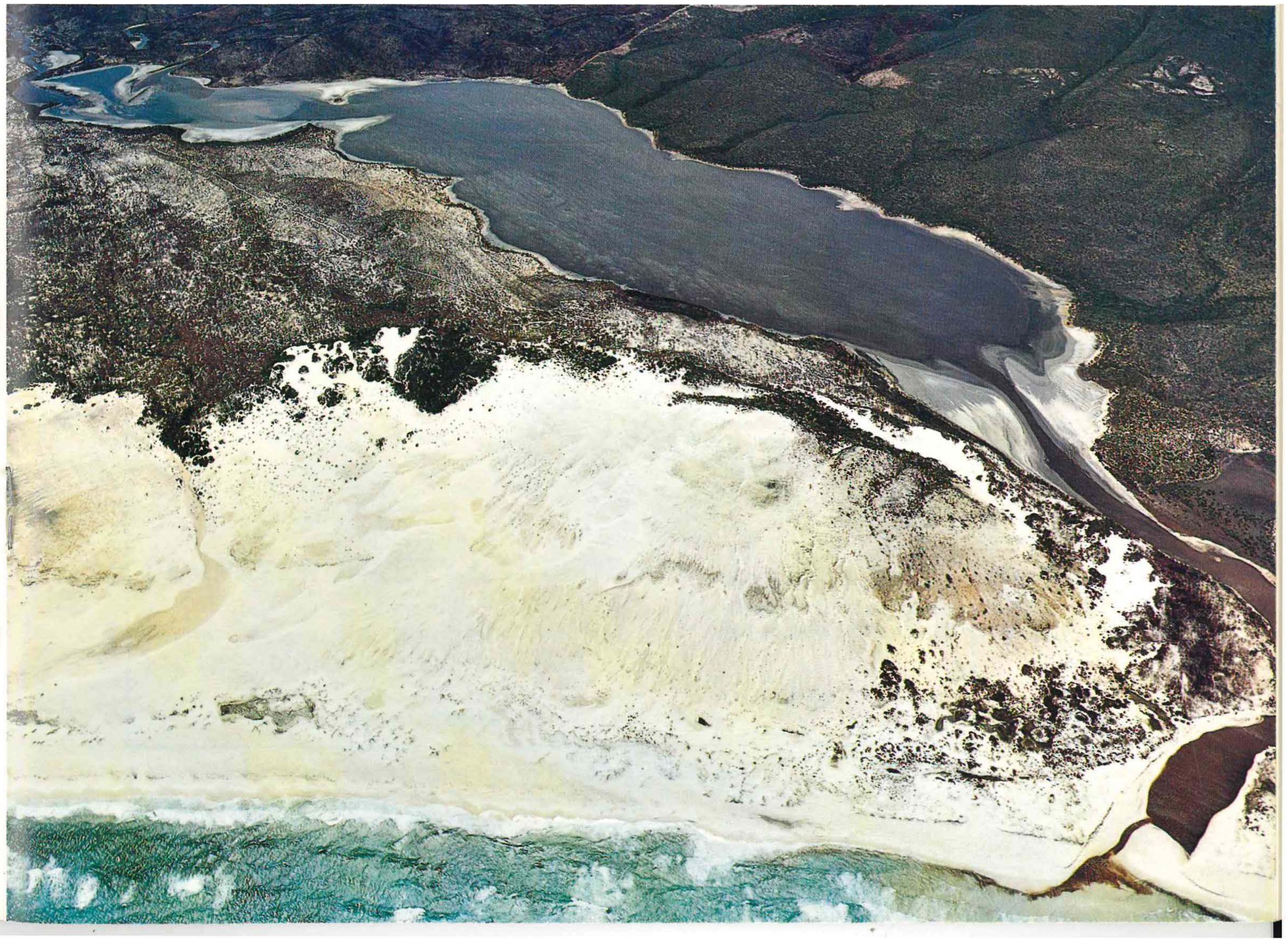
Dempster Inlet, February 1990.

Hamersley Inlet, February 1990.



Hamerlsey Inlet gorge.





near the mouth and about 2 km from the mouth fresh water drains from the limestone to a small swamp. This is probably the Taylor Spring of some maps.

INLET CHANNEL The inlet channel curves for 700 m from the lagoon to the beach. It is narrow (25 to 50 m) and is scoured to 5 m deep below the level of the lagoon but shallows both into the lagoon and to the bar. On the northern shore there is first a wide beach ridge, at about 2 m above sea level, which bars the samphire swamp in the mouth of a small creek. Seawards from this, almost to the beach, the shoreline is a steep rock face with the schist exposed at the water line. The southern shore is a steep, well vegetated sand slope.

5.2 THE BAR

The bar is part of the beach, here about 2 m above MSL, but it may build up higher after prolonged closure. It is reported to break infrequently and probably does not stay open for more than a few weeks. It broke following the heavy rains of November 1971, in 1988 (between July and September) and in January 1990; no doubt also at other times of which there is no record. As at Fitzgerald Inlet the bar sand may become quicksand when saturated.

5.3 WATER DEPTHS

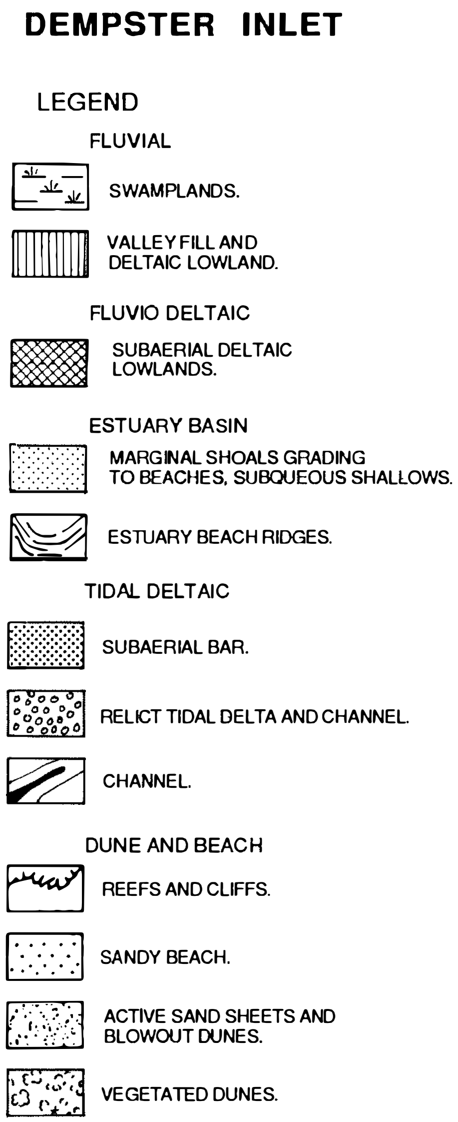
The lagoon can hold nearly 2 m of water when full but it is often dry except for the pool in the inlet channel which is scoured to nearly 5 m in the narrowest part. It has an almost flat bottom at about MSL, slightly deeper in the seaward 2 km than in the narrower, upper arm which is shallowed by deltaic sand. At the seaward end a low flood tide delta is also exposed when there is still some water in the central basin.

5.4 BOTTOM SEDIMENTS

The shores are sandy and some of the sand is coarse and sharp with patches of gravel which suggest recent erosion from the shore rock. Beyond the shore the basin sediment is sandy mud and mud. Two short cores taken by Hassell (1962) from the southern shore showed 65% sand with silt and clay. At about 1.5 km from the mouth on the southern shore there are abundant mollusc shells both on the shore, where some are cemented in, and under the mud of the basin. These are marine species, principally cockles (*Katelysia scalarina*, *K. rhytiphora*, *Fulvia tenicostata*), oysters (*Ostrea angasi*) and scallops (*Chlamys asperrimus*). This is probably a Holocene deposit similar to those in other estuaries of the south coast.

5.5 WATER CHACTERISTICS

The lagoon seldom holds water for more than a few months and the salinity must change rapidly from 10 ppt or less following heavy rain to brine, both in the lagoon and in the rivers as they dry up. However some invertebrates (e.g. the bivalve *Spisula trigonella*) sometimes have time to grow to maturity in the lagoon and well grown Sea mullet have occasionally been caught in a pool in Coppermine Creek. The salinity of water in the inlet channel is less extreme because it is deep and sea water seeps into it through the bar; the surface water was 55 ppt in February 1989 although the lagoon was almost dry.



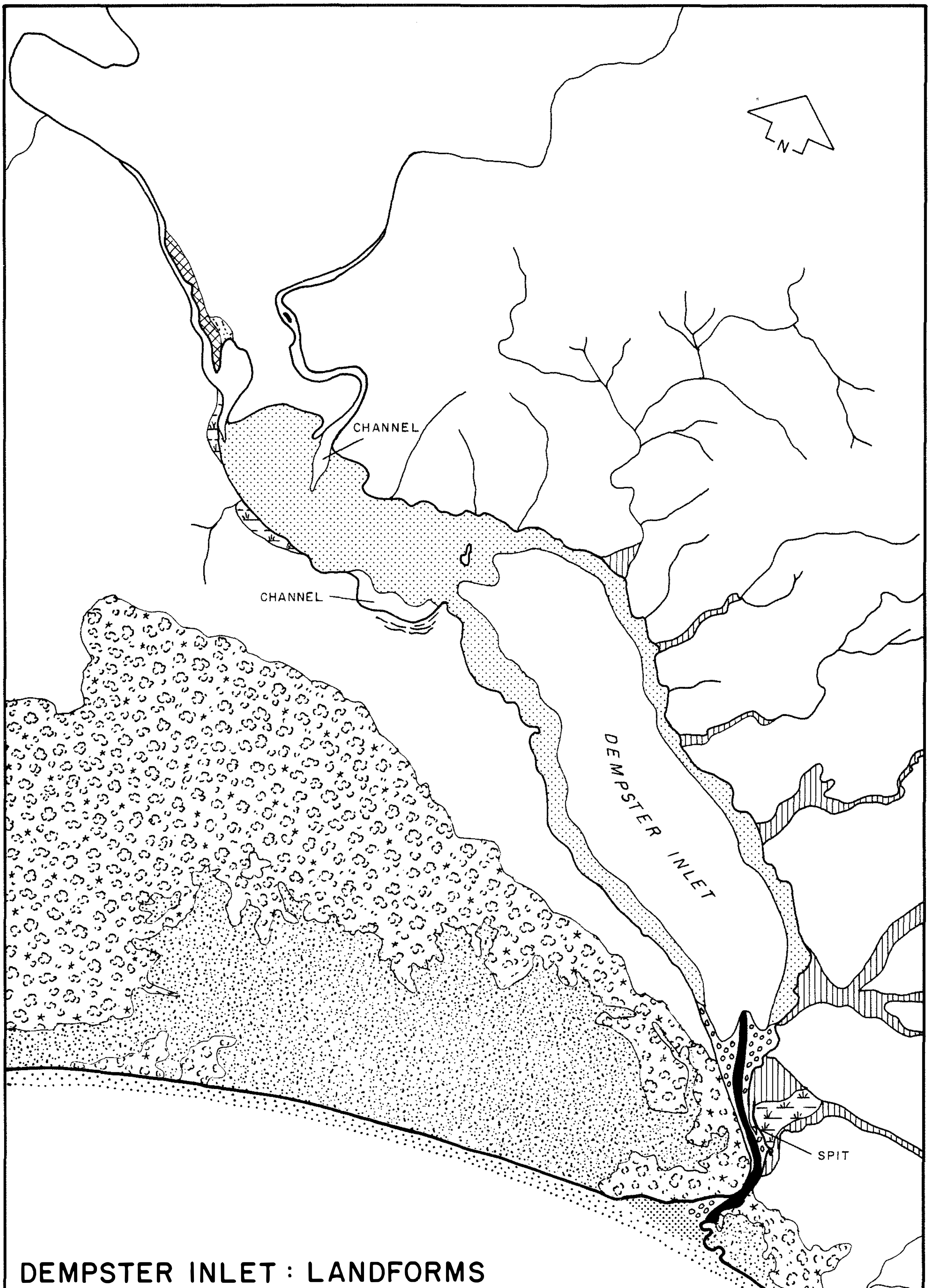


Figure 5.1 Dempster Inlet. Landforms. (I. Eliot & D. Milton)

6 SAINT MARY INLET - PHYSICAL FEATURES

Saint Mary Inlet is the smallest of the four estuaries of the Park with a lagoon barely 1 km long and 250 m wide. The riverine part and the inlet channel are each about 700 m long. The estuary lies east-west in a valley between the spongolite on the south and quartzite and coastal limestone on the northern shore. As at Fitzgerald and Dempster Inlets, the valley has been filled with sediment to about sea level and the estuary is often dry in summer. Most of its small catchment drains from the spongolite within 15 km of the coast. The mouth opens onto the beach at the southern end of the 7 km long Point Charles Bay (Figure 6). There it faces east in the shelter of Point Ann which is the end of a ridge of schist along the coast to the south. Rock also outcrops in the beach. The bar is part of the beach and in this sheltered situation it is low so that it only retains about 1 m depth of water in the shallow lagoon.

Saint Mary River flows to the Inlet in a steep rocky valley with several pools, the last nearly 1 km long, and discharges to the Inlet through a densely vegetated swamp. Small tributary creeks also flow direct to the northern rocky shore of the Inlet.

6.1 LANDFORMS

RIVER From the swamp the riverine part of the estuary has a narrow channel against the steep ridges of schist on the north bank and a narrow flat on the south bank to the gentler slope of the spongolite hillside. The channel continues for 700 m into the lagoon where the river has built a sand spit on its northern side (Figure 6.1).

LAGOON The southern shore of the lagoon has a narrow sand flat with samphire and other marsh plants backed by paperbark trees against the hill slope. There is no sand flat on the steep north shore, except where the schist gives place to limestone near the inlet channel. There a small sand flat with beach ridges and a swamp fills the mouth of a gully in the contact between the limestone and schist.

The lagoon is filled with sediment to about MSL. It appears (from air photos) to be slightly deeper on the north side than on the south where the river has deposited a delta.

INLET CHANNEL This is 700 m long and 50 m wide at the narrowest part to 100 m wide between the dune slopes near the mouth. Limestone is exposed along the upper part of the south shore, and is

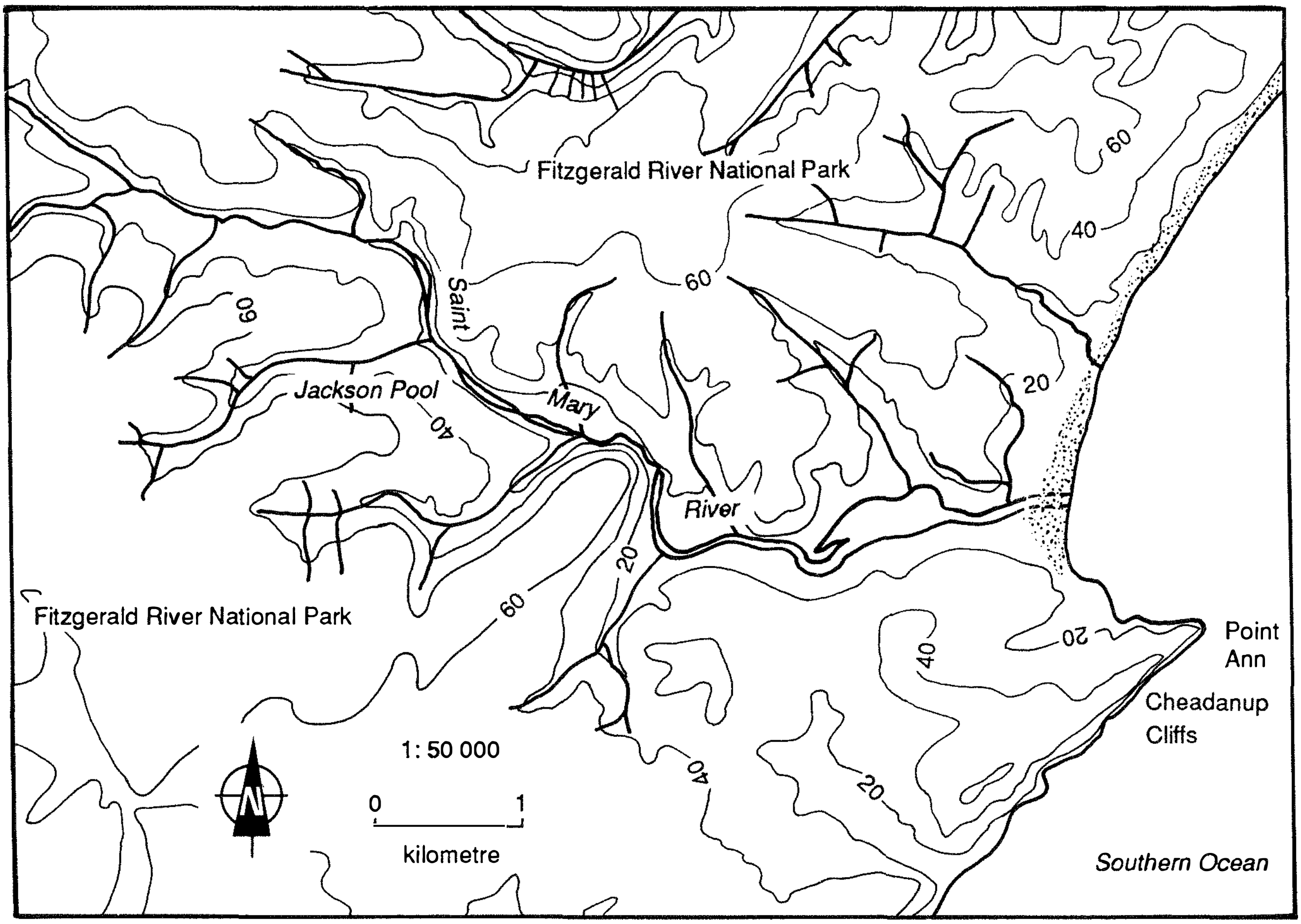


Figure 6 Saint Mary Inlet. Topography of the surrounding area. Contours in metres.

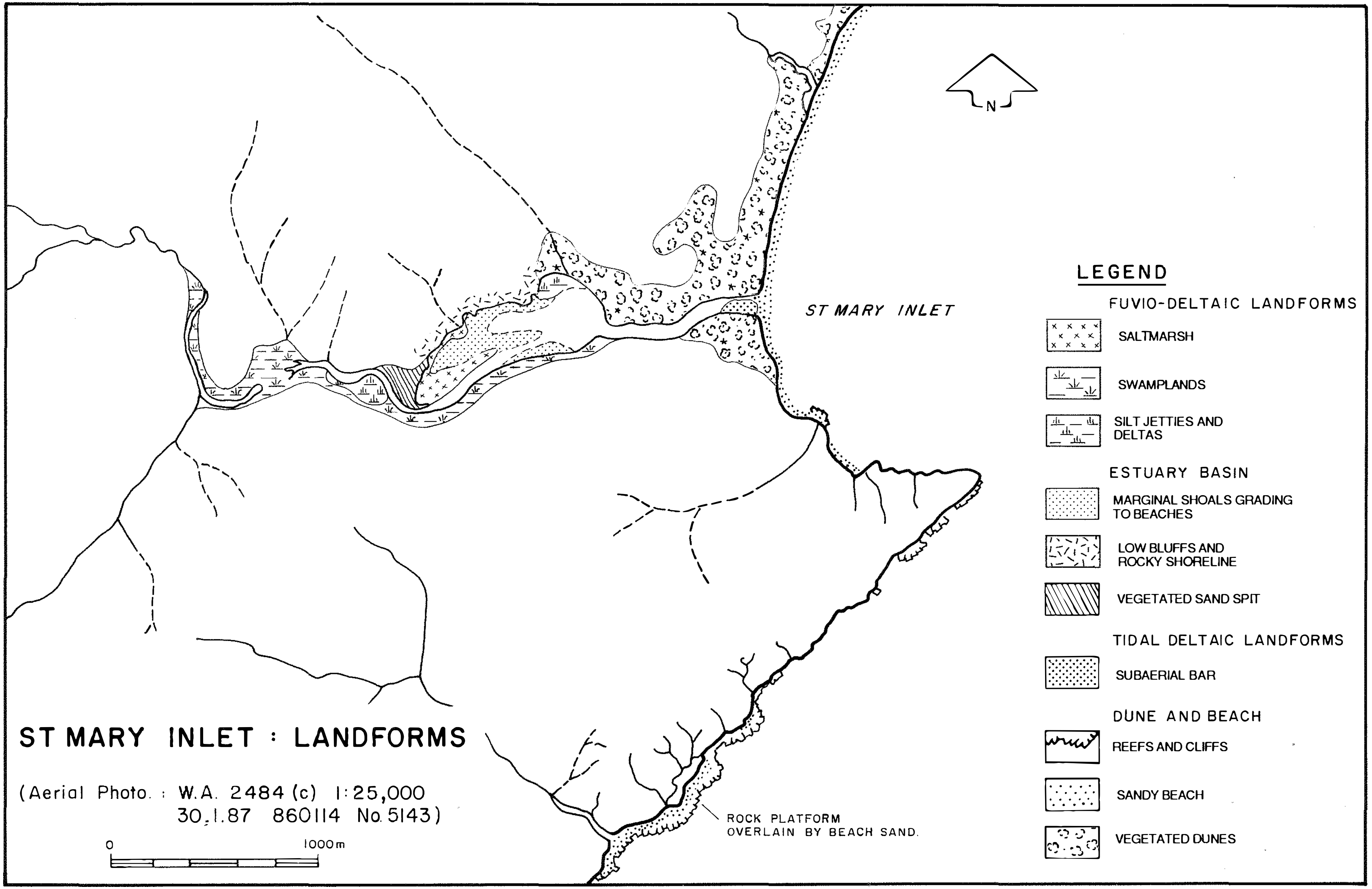


Figure 6.1 Saint Mary Inlet. Landforms. (I. Eliot & D. Milton)

replaced by spongolite where the channel opens out into the lagoon. On the north shore the dune is collapsing below a hard cap along much of its length. Beach sand fills the seaward end of the channel for 200 m which then deepens somewhat until it opens out into the lagoon.

6.2 THE BAR

The bar is part of the sea beach, here only about 1.5 m above sea level. Waves wash over it and carry sand into the channel shallowing it for about 200 m from the dune line. The bar sand is a well sorted, mainly fine sand (Figure 3.2). The bar broke following the heavy rain of May 1988 and again in January 1990. It probably behaves similarly to the Fitzgerald Inlet bar, breaking infrequently and only staying open briefly.

6.3 WATER DEPTHS

The estuary is shallow throughout. The lagoon floor is at about sea level and the riverine reach and inlet channel are only a little deeper. In consequence it often dries out completely although there is generally some water in the inlet channel. The river pool above the swamp appears always to hold water.

6.4 BOTTOM SEDIMENTS

The narrow shelf of limestone and spongolite on the south shore of the inlet channel and lagoon is submerged when the Inlet is full. Elsewhere a narrow sandy shore, with patches of coarse sharp sand and gravel, surrounds the sandy mud of the central basin.

6.5 WATER CHARACTERISTICS

The salinity of the water probably varies from less than 10 ppt following heavy rain to brine as the water dries up. The only records are 64 ppt in October 1971, 56 ppt in April 1977, 30 ppt in October 1989 in the lagoon, and 96 ppt in the inlet channel in February 1989 when there was very little water in the lagoon. River water is almost fresh (4 ppt in the pool on 26.10.89) so salt water must come mainly from the sea when the bar is open. Sea water seeps through the bar when the water level is low. It is evident from the presence of shells of recently dead molluscs that the water is sometimes between about 25 and 50 ppt for a year or more.

The catchment is entirely within the National Park and river water is unlikely to be significantly nutrient enriched or polluted in any way. Samples taken 22.2.89 when the water level was low showed Total Phosphorus 90 µg/L near the bar and 20 µg/L in shallow water in the lagoon.

7 CULHAM INLET - PHYSICAL FEATURES

Culham Inlet is a large lagoon that abuts the steep slopes of East Mount Barren on the eastern edge of the Fitzgerald River National Park (Figure 7). It is now cut off from the sea by a stable foredune and is no longer an estuary. The last time the bar is known to have broken naturally was in 1849, but it was broken artificially about 1920. Abundant shells of Holocene marine molluscs testify to the Inlet having been an open estuary within the last 4000 years. Cockle shells (*Katelysia scalarina*)from the eastern shore of the Inlet have been radiocarbon dated at 3660 ±185 years before present (shell collections by G. Kendrick, dating by Curtin University, courtesy of Dr. P. Playford). Several species of *Katelysia* are abundant in the shallows of Princess Royal Harbour and small numbers settle sporadically in many estuaries east of Albany.

Limestone is exposed patchily along the ocean beach following winter storms and may extend under the foredune/bar. On either side of the bar region broken limestone shelves extend 600 m seawards with sand between them. What appears to be an old shoreline joins the extremities of these shelves.

The lagoon is so shallow that it often dries up completely though it may hold water for several years, as in 1988 and 1989, and be 2 m or more deep because of the high bar. The Phillips River, the western tributary to the Inlet, is deeper and always holds water for 7 km from the lagoon. The eastern Steere River is shorter and shallower.

River water is saline and salinities are similar to those in Fitzgerald Inlet, less than half sea water in winter and brine as it dries up. When the salinity is favourable there can be an abundance of the few species of fish and other salt tolerant 'estuarine' fauna such as Black bream, some hardyheads, gobies and their invertebrate prey. However, in the absence of any sea water access there are none of the marine species of fish or bottom fauna that invade estuaries of the Park when the bars are open. The Inlet is an important feeding place for great numbers of waterbirds when there is water in it.

7.1 LANDFORMS

The mouth of the Inlet is now closed by a stable foredune across which a road (Southern Ocean West Road) has been built along the Inlet side. At either end of this the dunes widen and to the east they form a belt up to 20 m high and a kilometre or more wide. They also widen to the west, but a low swampy area in the south west corner of the Inlet near the Park Ranger's cottage suggests that this is possibly the location of an old flow channel to the sea at Barrens Beach (Figure 7.1). From the western shore of the Inlet the land slopes up to East Mt Barren and the Eyre Range with exposed Proterozoic rock and a wide area of rock and sand eroded from them. Two

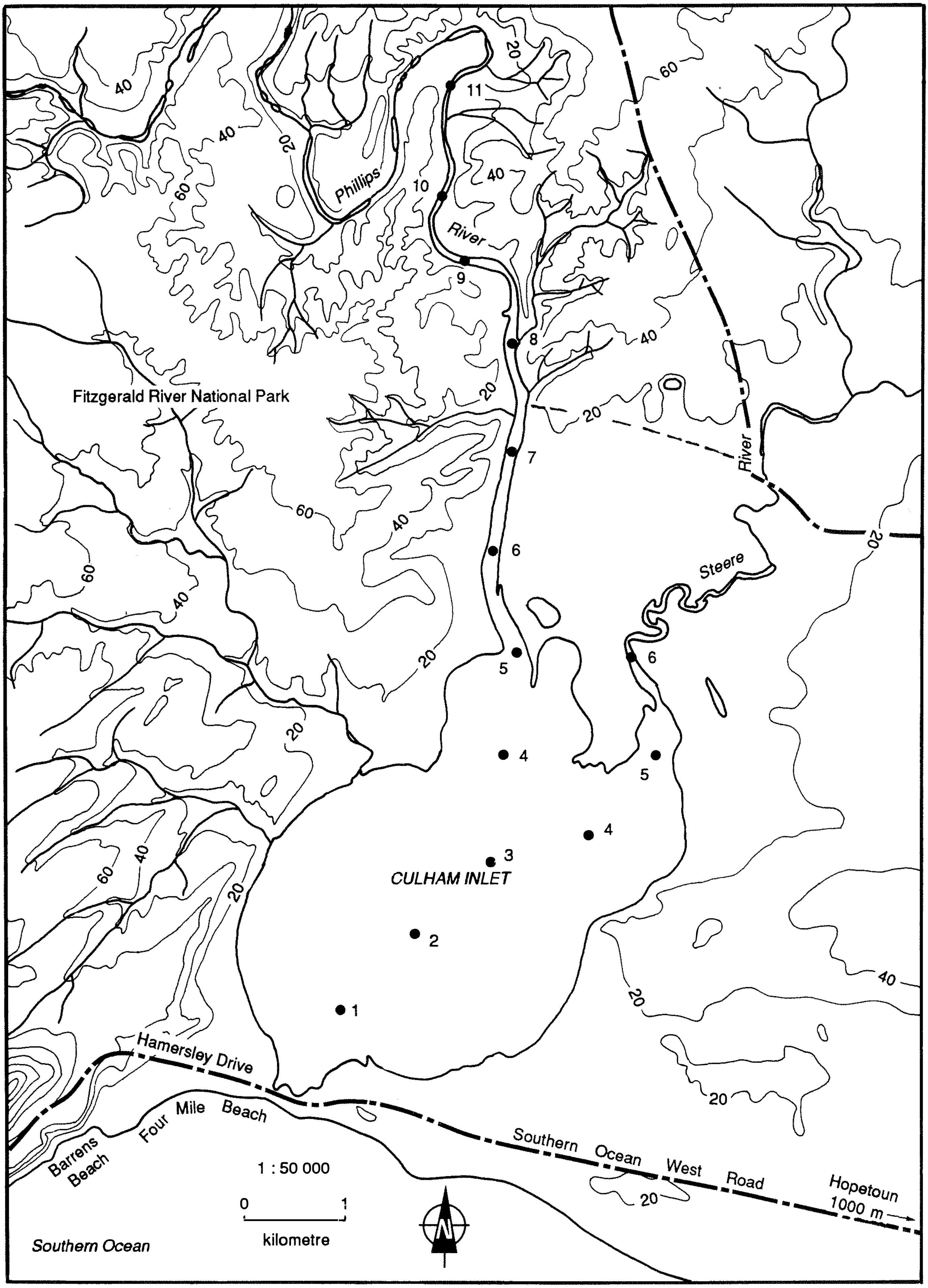


Figure 7 Culham Inlet. Topography of the surrounding area. Contours in metres. Distance upstream in kilometres.

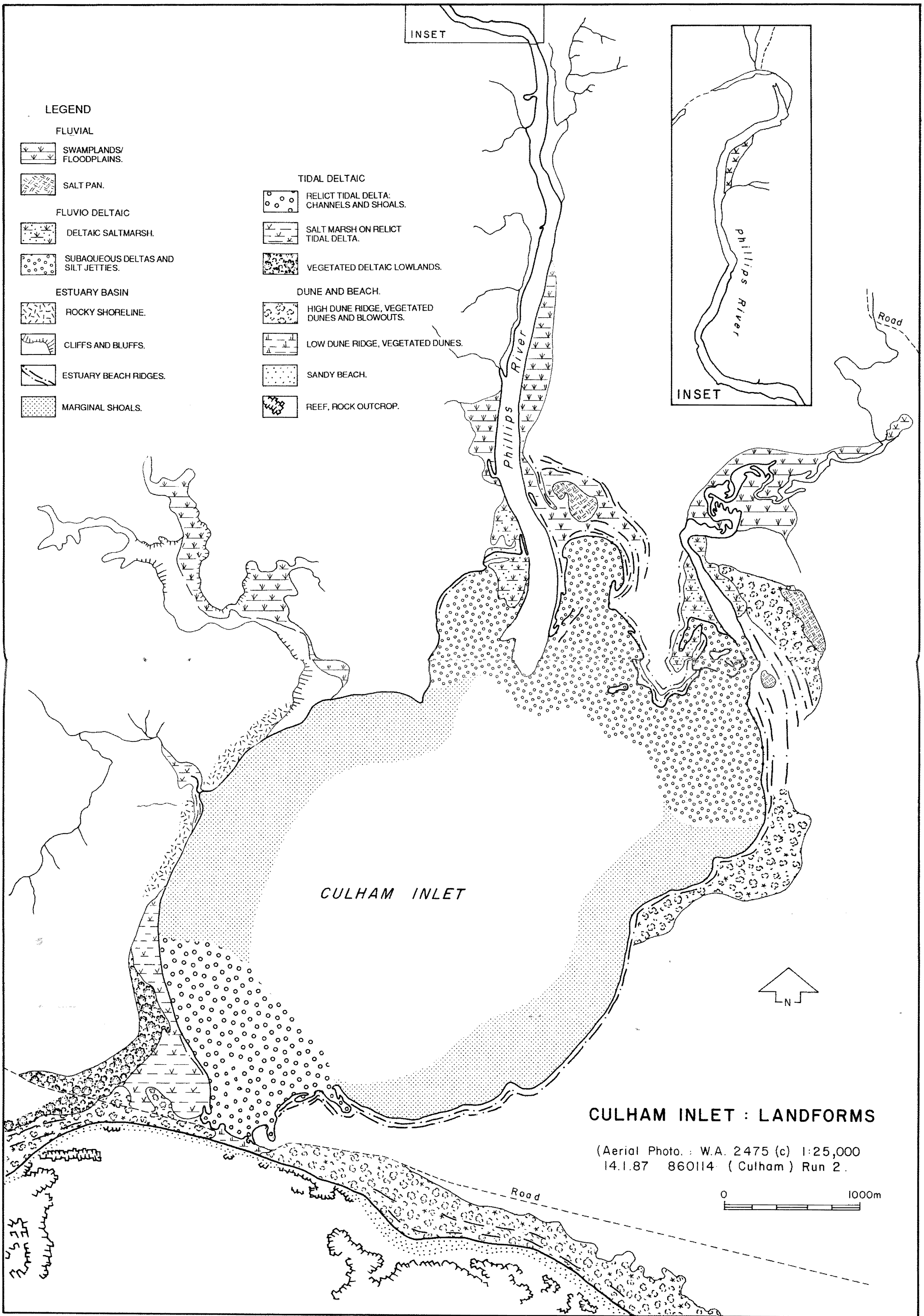


Figure 7.1 Culham Inlet. Landforms. (I. Eliot & D. Milton)

small streams flow from this area to the western shore. On the east of the Inlet a wide low lying area of Quaternary coastal dune sand abuts the Inlet, but with a low cliff mid way along the shore. There are one or two Holocene beach ridges in places along the northern, eastern and southern margins of the estuary.

The Phillips and Steere rivers discharge to the northern shore of the Inlet through a wide area of deltaic sand and gravel about 2 m above the level of the lagoon bottom. This incorporates extensive shell beds of marine and estuarine species of molluscs, probably mainly of Pleistocene age. There are also wide marginal terraces of predominantly cemented, fossiliferous Pleistocene sands in the lagoon with a thin veneer of Holocene sediment with abundant mollusc shells.

RIVERS The Phillips River lies along a fault line through the Quartzite rocks of the Mount Barren Beds and in the upper reaches the banks are cliffed to 20 m or more. It is, or was, 'estuarine' for about 7 km from the Inlet to a sharp bend in the river at Pitchie Ritchie (local name), and for some distance further upstream when flooded. There is open water at all times from that point to where the river discharges into the lagoon. The water is 4 m deep (below MSL) against the cliffs, but has sandy shallows in the upper reaches. The Steere River has a meandering course across a low lying alluvial plain and Inlet water only backs up to near the road crossing about 2 km from its mouth. The lower parts of the river deltas are flooded when the Inlet is full of water.

LAGOON The lagoon is oval in shape, approximately 3 km x 4 km with an area of 11.3 km^2. It is a shallow pan that is often almost dry in summer. At its deepest part near the bar the bottom is at about MSL and from there it slopes gently to the shorelines and to the river delta area. The lagoon narrows to a width of 500 m close to where the dune now closes what appears to have been the former mouth of the Inlet. Through the middle of this area there is a shallow gutter perpendicular to the bar which appears to have been dug, rather than being a natural feature.

7.2 THE BAR

The bar is now a foredune about 500 m long and 30 - 40 m wide at its narrowest point and 4 - 5 m above sea level. It carries an open dune vegetation, but there are tracks across it to the beach. The road is built along the Inlet side of the dune close to the water's edge. The lowest point on the road is 1 km further west near the turnoff to Barrens Beach, at which point it is only about half a metre above mean sea level. In 1986 the Inlet water almost reached the level of the road there, then following the heavy rains of May 1988 water covered the road to a depth of 0.9 m and in August 1989 there was 1.6 m of water over the road. The Inlet water was then 3.2 m above MSL and water was seeping through the dune to the beach.

The bar is subject to erosion and storm waves expose patches of hard limestone reef rock in the sea beach at the eastern end of the bar in winter, to be covered again with sand in summer. It would be valuable to know the extent of this reef rock and whether it underlies the beach along the whole bar region.

The bar is reported to have been open in the 1870s after winters of very heavy rain (E.H. Dunn in Archer, 1979). Gregory (1849) records the bar breaking in April 1849 after continuous heavy rain:

> 20 April 1849. At daylight the [Phillips] river was rising rapidly. . . The river continued to rise during the day, and at sunset was 7 feet above the usual level.
> 21st. The water during the night having found a passage through the sandy bar at the entrance to the estuary, it sank five feet. . . We attempted to cross the entrance to the estuary, but found the current too strong to admit the horses swimming across the principal channel although we succeeded in crossing the smaller ones, and reached a sandbank in the centre of the stream.
> 23rd. Made a successful attempt to cross the mouth of the inlet . . . Having completed our observations we returned along the beach, recrossed the entrance of the estuary, and reached camp at 4h, p.m.

Accounts differ about attempts to break the bar in the first two decades of the 20th century, with conflicting dates between 1917 and 1920. The Public Works Department was approached for permission to open the bar in February 1918 to start a fishing and fish curing business (Fisheries Department files). The years 1913 to 1920 were years of above average rainfall at Ravensthorpe and Hopetoun. Mr. Harry Thomson, who was a child at Hopetoun at the time, reports that in the winter of 1920 the Inlet filled and his father and local farmers, with eight horses and a scoop, dug a channel from the Inlet to the sea at the narrowest point. The bar broke during the night 'with a roar' and the water cut through the dunes, emptying the Inlet and leaving 'stinking black mud'. When sea water washed back in it covered only a small area on either side of the narrow channel from the break into the lagoon. The bar is variously reported to have remained open for a few weeks up to three months.

The Ravensthorpe miners are said to have broken the bar in 1906, but it did not stay open for long. Another report says that the bar broke in 1918 at its eastern end and the water flowed out over rocks so that the Inlet did not drain completely. Inlet water is also reported to have 'trickled out' in 1955.

7.3 WATER DEPTHS The lagoon appears to have a nearly flat floor at about 1 m below MSL, sloping gently to the beaches. There was about 4.5 m of water in the deepest part in the centre in August 1989, making the bottom there about 1.5 m below MSL. The Phillips River is considerably deeper in places, 8 m or more near the cliff at 7 km.

7.4 BOTTOM SEDIMENTS

The estuary is filled with a veneer of Holocene sands, silts and clays which in some places have become cemented to calcrete. There are extensive sub-fossil shell beds around the margin of the Inlet.

7.5 WATER CHARACTERISTICS

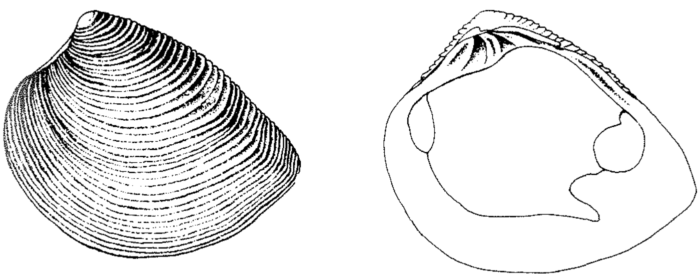
SALINITY River water is saline, the Phillips River perhaps about 10 ppt when flowing and the Steere River probably half that, but surface water at Pitchie Ritchie was only 4 ppt on 22.10.89. The lowest salinity we have observed in the lagoon was 17 ppt when the Inlet was flooded in September 1989, after 33 ppt in May 1989. As the water evaporates the water often becomes much more saline than sea water. Salinities observed in the riverine reaches of the Phillips River range from 12 ppt to 50 ppt with one record of about 70 ppt (October 1973), when Black bream were reported to be blind. The river water may be stratified: 23 ppt surface, 36 ppt at 4 m (5.10.889); 12 ppt surface, 16 ppt at 7 m (22.10.89).

WATER TEMPERATURE This is likely to be similar to that in other coastal waters of this part of the south coast, ranging from about 12°C in winter to 25°C in summer, or more in shallow water.

OXYGEN The shallow water of the Inlet is probably always saturated with oxygen, but the deeper river water may lack oxygen when the water is stratified.

NUTRIENTS Lenanton and Edmonds (pers comm) found very high levels of total nitrogen and total phosphorus in stagnant hypersaline water in the Inlet and in the Phillips River, but nitrate and phosphate levels were low. When there was deep water in the Inlet in May 1989 Total Phosphorus was 30 µg/L.

Chapman (1985) found consistently low levels of Total Phosphorus in the West River in 1983-84 (<0.01 mg/L). Most records from the Phillips River were 0.01 with 0.03 in June and 0.06 in October, these high levels were presumed to coincide with recent applications of superphosphate on nearby farms. The data suggest that high concentrations are short lived. We have no records from the Steere River where levels may be higher because of drainage from nearby farm land.



Katelysia scalarina.

8 JERDACUTTUP LAKES - PHYSICAL FEATURES

The Jerdacuttup River discharges into lakes and swamps trapped behind high, well vegetated coastal dunes that are 10 m high and only 60 m wide at the narrowest part (Figure 8). The lakes are a coastal lagoon system which is gradually shrinking as samphire and paperbark swamps encroach on the areas of open water. However there is no evidence to show whether the lakes have been open to the sea in the 6000 years since the Holocene rise of sea level, as seems probable, and when they were last estuarine. Reef rock outcrops at intervals along the sea shore, but again there is no evidence of the age of this rock.

The lake water is saline, but so too is the river water, and becomes increasingly so as the water evaporates. The water level varies by about 5 m from when it floods the swamps and surrounding land, following wet winters like those of 1986-89, to when the lake is almost dry.

The Jerdacuttup River is part of the system and is navigable by small boats for 8 km from Springdale Road to where it disappears into a dense paperbark and samphire swamp that blocks passage from the river to the lake for 500 m and retains water in the river as lake water recedes.

8.1 LANDFORMS

The lakes and swamps lie in a shallow depression parallel to the sea between the coastal dunes and sandplain to the north. The large western lake is 3 km long and 1 to 1.5 km wide and has about 3.8 km^2 of open water to the wide band of samphire and paperbark swamp surrounding it (Figure 8.1). The swamp extends another 3 km eastward, beyond which swamps and one larger lake (about 1.5 km^2) and many small shallow lakes extend for a further 8 km along the coast. The multiple curving lines of paperbark trees show where the swamps have progressively grown out into the lakes greatly reducing the area of open water. There are small outcrops of granite (migmatite) on the northern shore of the swamp.

The RIVER follows a meandering course south for 8 km from Springdale Road. From less than 10 m near the road it widens to about 150 m at 7 km. The first 2 km has high sandy banks on the eastern side and for 3.5 km on the west. Then there are river flats on the east and flat grazing land on the west. There the banks are only 2 - 3 m above water level and are bare and eroded by cattle. From 6 km there are wide areas of swamp on either side with paperbark (*Melaleuca cuticularis*) and Yate (*Eucalyptus occidentalis occidentalis*) trees and the river disappears into a dense woodland swamp dominated by the same trees. On the eastern side of the swamp, below a steep granite slope, there is a pool that must formerly have been part of the river and into which water seeps from the river. An old meander joins the river from

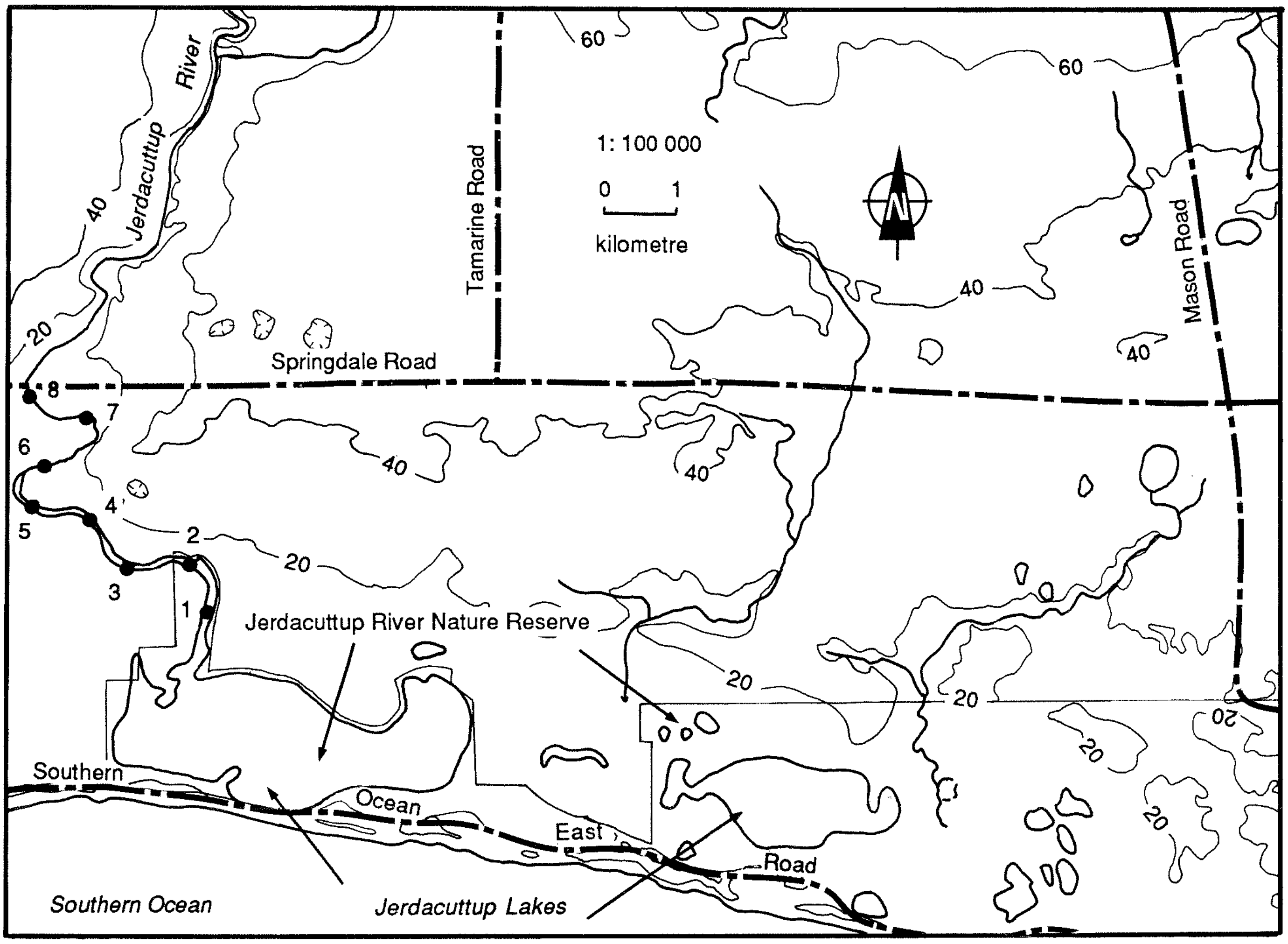


Figure 8 Jerdacuttup Lakes. Topography of the surrounding area. Contours in metres. Distance upstream in kilometres.

JERDACUTTUP LAKE

LEGEND

FLUVIAL

FLOODPLAIN.

FLUVIO DELTAIC

SWAMPLAND WITH 'HERBACEOUS' VEGETATION.

ESTUARY BASIN

LACUSTRINE BEACH RIDGES.

VEGETATED LOWLANDS.

MARGINAL SHOALS/ PAPERBARKS.

MARGINAL SHOALS/ SAMPHIRE.

DUNE AND BEACH

VEGETATED DUNES INCLUDING PARABOLIC DUNES.

VEGETATED FOREDUNES INCLUDING BLOWOUTS.

BEACH.

REEFS AND CLIFFS

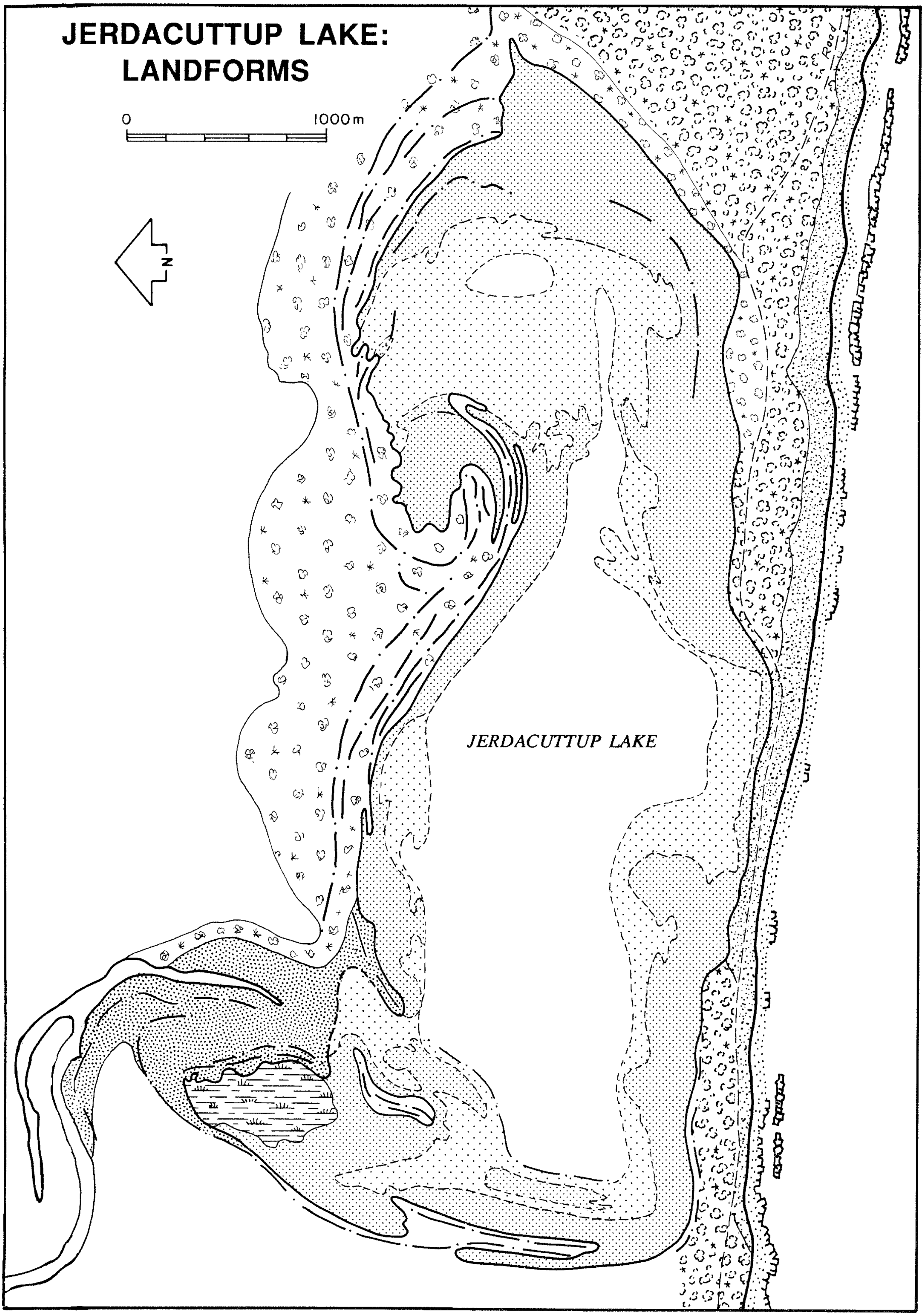


Figure 8.1 Jerdacuttup Lake. Landforms. (I. Eliot & D. Milton)

the east at 6.5 km. There are small outcrops of granite near Springdale Road and at 7 km on the east bank. A sharp bend near 1.5 km has exposed an alluvial deposit with pebbles over rock (spongolite) on the east bank. A spring below the escarpment at the next bend feeds a freshwater swamp with tall rushes (*Baumea articulata*).

8.2 THE 'BAR'

For a kilometre the coastal dune is only 60 m to 120 m wide and about 12 m high. It is well vegetated with trees and shrubs but appears to be unconsolidated sand, unlike the higher and wider dunes to east and west which are dune limestone. Limestone reef rock is exposed at water level intermittently along the sea shore here and along the whole length of the lake system, in some places with two lines of reef 100 m apart. While this 1 km stretch of dune is clearly the site of the former bar it is not possible to say when the lakes were last estuarine, whether during the last 6000 years, as seems probable, or much earlier.

8.3 WATER DEPTHS

When flooded, with water over the coast road as in the winters of 1986,87 & 89, there is about 5 m of water in the centre of the lake and 2 m over the samphire fringe. In January 1990 the water level in the lake was 3.3 m above MSL. All this water may be lost by evaporation after years of low rainfall leaving the lake dry. The river always holds water, with 3 to 4 m on the bends when flooded and probably only 1 to 1.5 m less at other times.

8.4 BOTTOM SEDIMENTS

The lake has a muddy bottom, becoming more sandy towards the margins, and the river has sand in shallower and mud in deeper parts.

8.5 WATER CHARACTERISTICS

Samples taken from the lake show that the water can vary from almost fresh when full (5 ppt at the surface and 8 ppt at 4 m on 23.10.89) to brine when it dries out. It only becomes much greater than sea water salinity (35 ppt) when the water level falls below the samphire fringe and there is still 2 m in deeper parts of the lake. Records of flowing river water at Springdale Road are about 6 ppt, with less than 2 ppt in September and October 1989. The few records from the river suggest that it is seldom more than half sea water salinity and often less. It was 15 ppt in April 1977 but in October 1973 it had been about 70 ppt and Black bream were developing blindness (Fisheries Dept. files).

9 OTHER RIVERS AND COASTAL LAKES

A creek at Quoin Head and two streams west of Point Ann all break to the sea periodically. A small landlocked ephemeral lake drains to the sea through Kelly's Creek south of Gordon Inlet and the larger 'Lake Nameless' between Fitzgerald Inlet and Saint Mary River no longer has an outlet to the sea. Quoin Head is reached by a bush track off Hamersley Drive and Telegraph Track. Access to Boondadup River is by a bush track along the coast from Point Ann. The only vehicle access to Kelly's Creek is along the beach from Gordon Inlet. 'Lake Nameless' is in a dieback quarantine area and can only be reached by driving along the beach from Saint Mary River, thence on foot over the dunes to the lake.

Two small creeks flow from East Mount Barren to Mylies Beach, Mylies Creek at the western end and an unnamed creek, 'Newlands Creek', further east (access is from Hamersley Drive). Strong flow from the heavy rain of May 1989 scoured the channel of Newlands Creek making it estuarine for a short distance from the beach and the January 1990 flood opened up both creeks. Black bream have been caught in Newlands Creek.

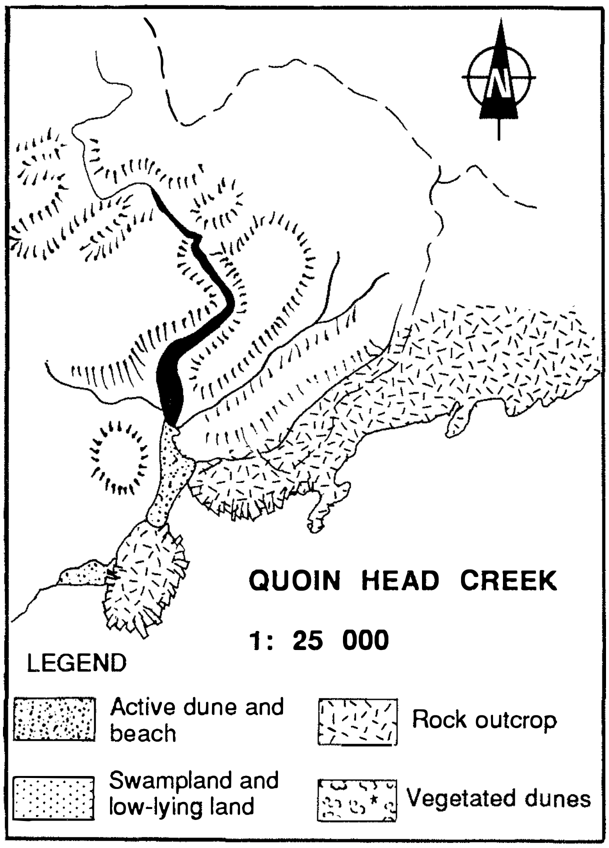


Figure 9.1 The estuary of Quoin Head Creek.

A number of coastal lakes east of the Jerdacuttup Lakes have small catchments and most are well separated from the coast by dunes. They are unlikely to have been estuarine during the Holocene, however they would repay further investigation, especially two small lakes in interdune depressions near Starvation Bay.

9.1 QUOIN HEAD CREEK

The deep valley here is one of a number of gullies cut in schist and quartzite along the precipitous coast between East Mount Barren and West Mount Barren (Figure 9.1). However this is the only one that is estuarine, although only temporarily. The mouth of the valley is choked by a sandy beach which forms a low bar (1 - 1.5 m above MSL) that holds back water in a 300 m long, narrow pool. When the pool scours to the sea, sea water flows back into it. The water is saline (40 ppt in May 1989) and Yelloweye mullet up to 50 cm are reported to have been caught in it. There are reported to be oyster shells in the creek which would indicate earlier more marine conditions. Samphire flats form narrow borders along the margin of the pool beyond the rocky mouth. The attached green alga *Polyphysa peniculus* was growing in the green water when seen in May and crab burrows (probably *Leptograpsodes octodenatus*) were found in the shore.

9.2 BOONDADUP RIVER

West of Saint Mary Inlet two small streams hold long pools where they flow to the sea. The smaller, 2.5 km SW of Point Ann, lies in a gully in the coastal strip of schist. It holds a narrow pool 250 m long that discharges across a sandy beach in the mouth of the valley. About 4 km further west the larger Boondadup River flows from the north slope of Mount Bland, with a waterfall where it drops to the spongolite plain across which it flows before winding through the foredunes. The catchment covers 36.5 km^2 of bush within the Park.

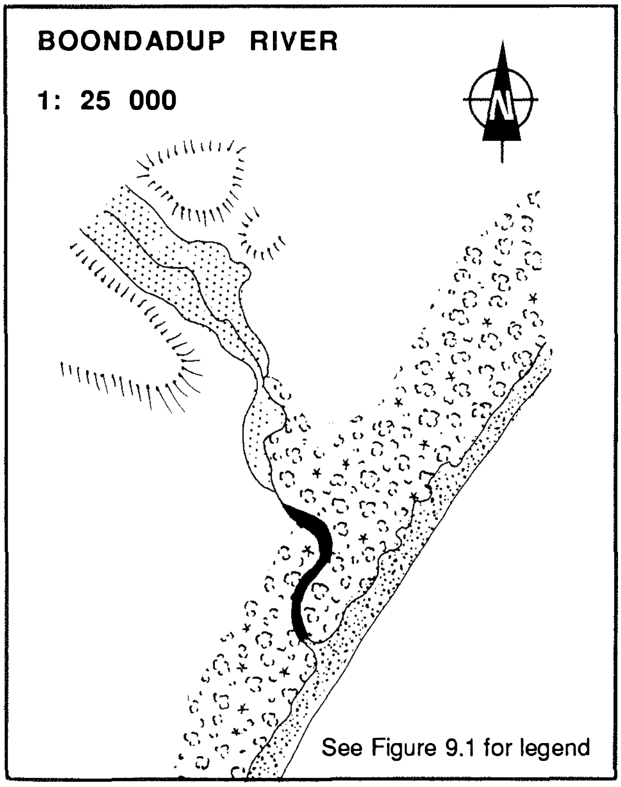


Figure 9.2 The estuary of Boondadup River.

The river is estuarine for about 700 m and is up to 10 m wide (Figure 9.2). The banks are low where the river has cut a broad valley in the spongolite, but high where it winds through the dunes. Paperbarks make a dense growth along the banks through the dunes and more sparsely in the open valley. When seen in February 1989 the mouth was choked for 50 m with beach sand blown up to over 2 m above sea level. The water in the river was 2 m below sea level and only 1 m deep, but there was evidence of higher water levels with stranded marine debris to the height of the bar. The bar is reported to break infrequently, but when it does sea water and driftwood are carried in for some distance. The river water was tannin stained swamp water of 5 ppt salinity.

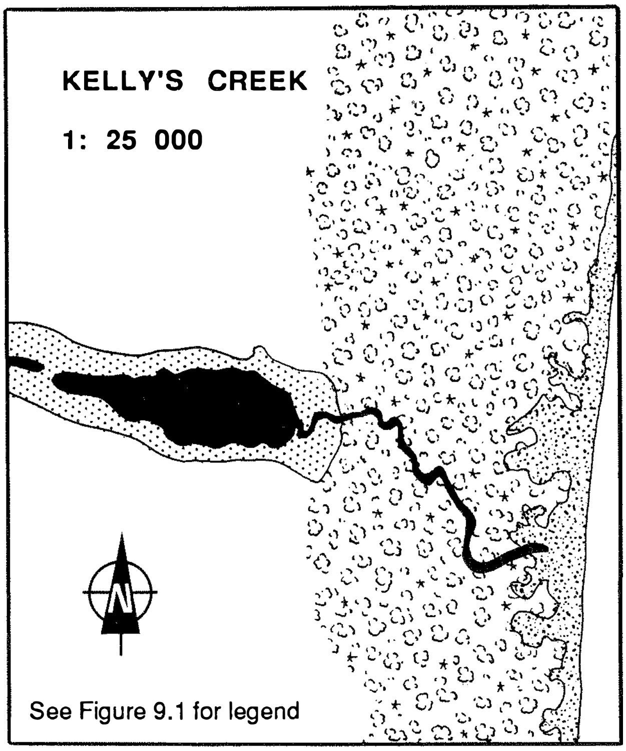


Figure 9.3 Kelly's Creek.

9.3 KELLY'S CREEK

This creek discharges onto the low, east facing Tooregullup Beach 2 km south of Gordon Inlet (Figure 9.3). The creek drains from a small salt lake in a valley in spongolite behind the 1 km wide coastal dunes through which the stream follows a meandering course. It is nowhere more than about 5 m wide. The creek flows to the sea across the low beach from time to time and sea water floods back into it. Sea mullet and Black bream are reported to be caught in the creek and the estuarine bivalve mollusc *Sanguinolaria biradiata* was found in it when visited in May 1987. The salinity of the tannin stained water was then 42 ppt.

9.4 LAKE NAMELESS

Lake Nameless– it has no name – is now a salt lake with no connection with the sea and the former channel is blocked by established dunes a kilometre wide (Figure 9.4). However the location of the former 500 m wide channel is evident from the longitudinal dunes that fill it, in contrast to the higher, lithified dune landscape on either side. The lake lies in a branching valley in the spongolite plain with cliffs and steep slopes similar to those around Fitzgerald Inlet. The catchment covers an area of 50 km^2 of bush within the Park. Apart from the lack of an outlet to the sea the lake is similar in most respects to Fitzgerald Inlet and Saint Mary River on either side; smaller than the one and larger than the other. It would be interesting to know whether this former estuary is of Holocene or late Pleistocene age.

The water level varies several metres as evidenced by the border of salt marsh plants and dead *M. cuticularis* similar to those described below (Section 10.2). When seen in February 1989 there was shallow hypersaline water (190 ppt) in the centre of the lagoon surrounded by a wide area of muddy sand.

10 ESTUARINE VEGETATION

All the estuaries reviewed here experience cycles of flooding, evaporation of the water, increasing salinity, and often drying up altogether; cycles sometimes of twelve months, often over years or decades. These expose the flora and fauna to environmental extremes beyond the ability of most to sustain life throughout the cycle. Nevertheless the estuaries are at times very productive, as evidenced by the great quantities of fish sometimes caught and the number of waterbirds seen feeding in them. However there are no data to assess their productivity or records of the succession of plants and animals that contribute to it at the various stages in the cycles. Studies of the ecology of the Coorong in South Australia are of interest in this connection, especially one on the effect of changes in salinity on the fauna and flora (Geddes and Butler, 1984).

The following records relate to observations made during brief visits and are far from being adequate accounts of the plant life, the primary producers, or of the animal life they support (Chapter 11).

10.1 AQUATIC PLANTS

The attached aquatic vegetation is generally restricted to rather sparse growths of the seagrass *Ruppia megacarpa* and the stonewort *Lamprothamnium papulosum* while hydrological conditions are favourable, i.e. while there is clear shallow water within a salinity range of perhaps 10 to 70 ppt. The

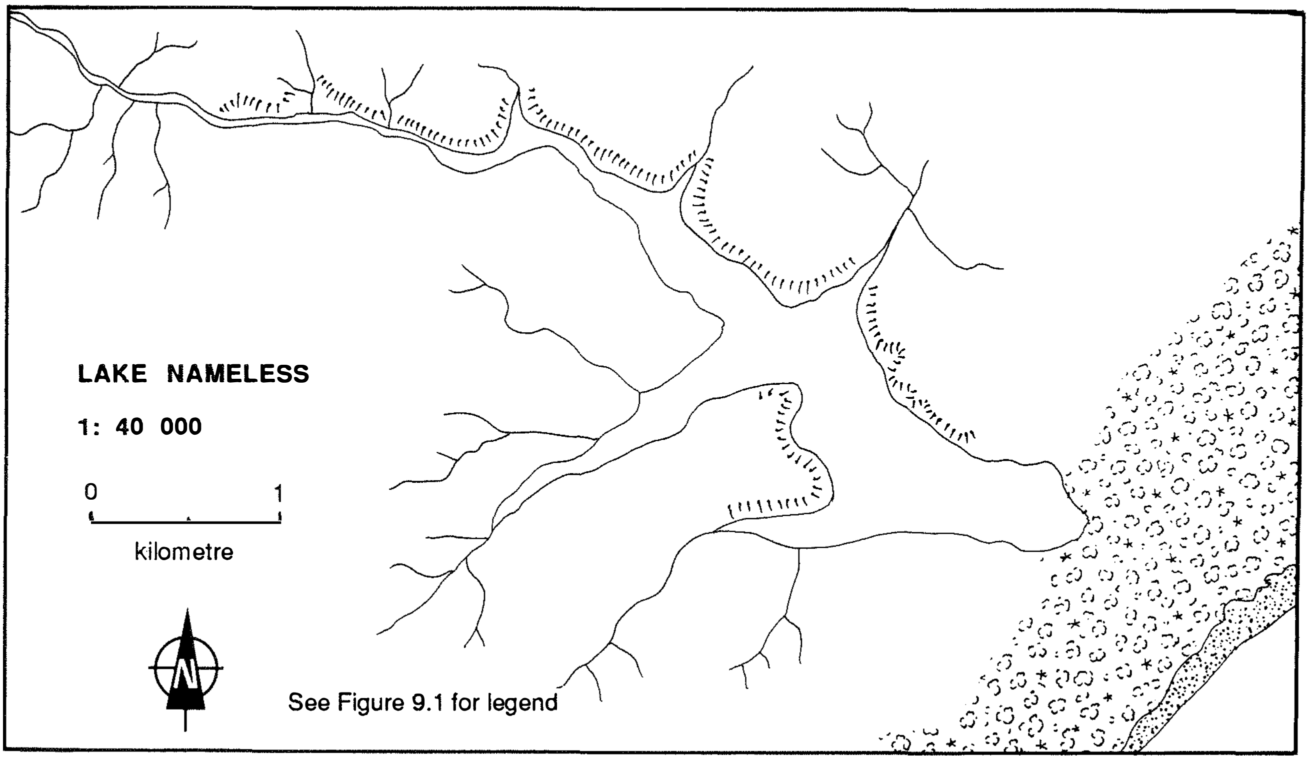


Figure 9.4 Lake Nameless.

Flood level marked by algae on the rock at Dempster Inlet

relative sparsity of these plants here, as compared with estuaries in higher rainfall areas, is probably also partly attributable to light limitation by resuspended sediment from the shallow muddy bottoms and by brown tannin stained water. In October 1989 the shallow water (0.7 m) of Saint Mary Inlet had a dense stand of fruiting *Ruppia* overgrown by a filamentous green alga. Dense *Ruppia* stands are also reported in Jerdacuttup River and sometimes in the Lakes. The small green alga *Polyphysa peniculus* is sometimes common in shallow water of the estuaries. Rich growths of planktonic algae sometimes turn the water green and such blooms often coat the dry marginal rocks and vegetation with a deposit that clearly records the water level reached before a bar breaks.

10.2 SALT MARSH AND FRINGING VEGETATION

Hamersley Inlet is the only estuary where a detailed study has been made of the marginal vegetation, by J. M. Chambers in January 1987. Here the steep rock slopes that surround the greater part of the Inlet and gorge leave only a narrow strip of sand or rock subject to inundation. The sand, and crevices in the rock, support the salt marsh community shown in Figure 10.21. On the eastern side of the Inlet this community is often backed by *Melaleuca lanceolata* and *M. nesophila* before being replaced by a dense eucalypt woodland on higher ground. On the western shore these paperbarks are generally absent and the salt marsh blends into dense mallee scrub dominated by *Eucalyptus platypus heterophylla*. There are small salt marshes in coves in the valleys and on narrow flats (Figure 4.1) and these are dominated by *Sarcocornia quinqueflora* and *Suaeda australis* rather than the salt marsh community of steeper slopes shown in Figure 10.21. A stand of the salt water paperbark *Melaleuca cuticularis* dominates a narrow strip of sandy eastern shore within a kilometre of the mouth where fresh water seeps from the dune, and there is small dense stand at 2.5 km. There is a small strip of *M. cuticularis* on the western shore near the mouth and it grows sparsely along the steeper shores of the estuary. Table 10.21 lists plants collected along the southern shore of Dempster Inlet in February 1989.

Table 10.21 Plants collected along the southern shore of Dempster Inlet, February 1989.

Cynodon dactylon (couch)	*Halosarcia lepidosperma*
Sporobolus virginicus (grass)	*Suaeda australis*
Gahnia trifida	*Carpobrotus* sp.
Lepidosperma sp.	*Melaleuca cuticularis*
Juncus kraussii	*Melaleuca nesophila*
Juncus pallidus	*Melaleuca* sp
Atriplex cinerea	*Wilsonia humilis*
Halosarcia indica subsp *bidens*	

The other estuaries of the Park, and Lake Nameless, show similar patterns of marginal vegetation, modified by the different contours of the surrounding land. Where the muddy sand of the margins slope gently into the lagoons there is generally a succession of salt marsh plants dominated by *Suaeda australis*, the samphires *Sarcocornia* and *Halosarcia* (Chenopodiaceae), or *Wilsonia humilis*

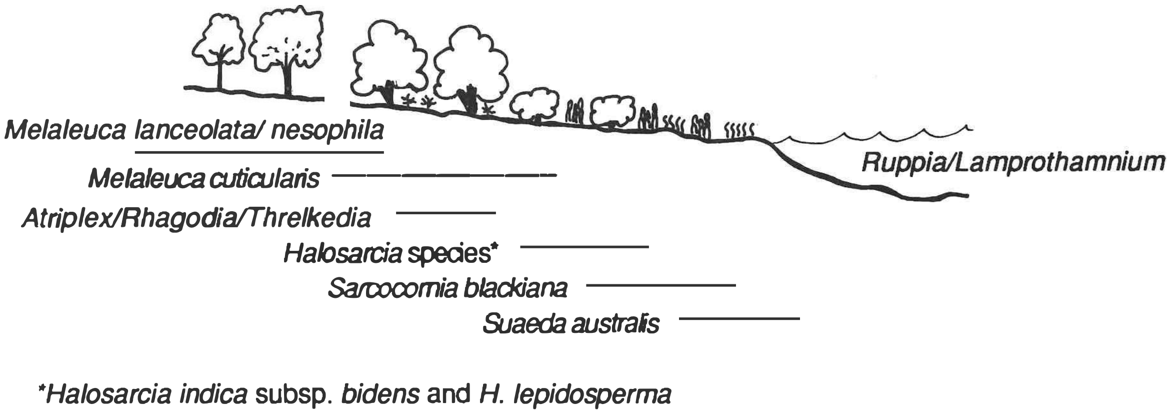
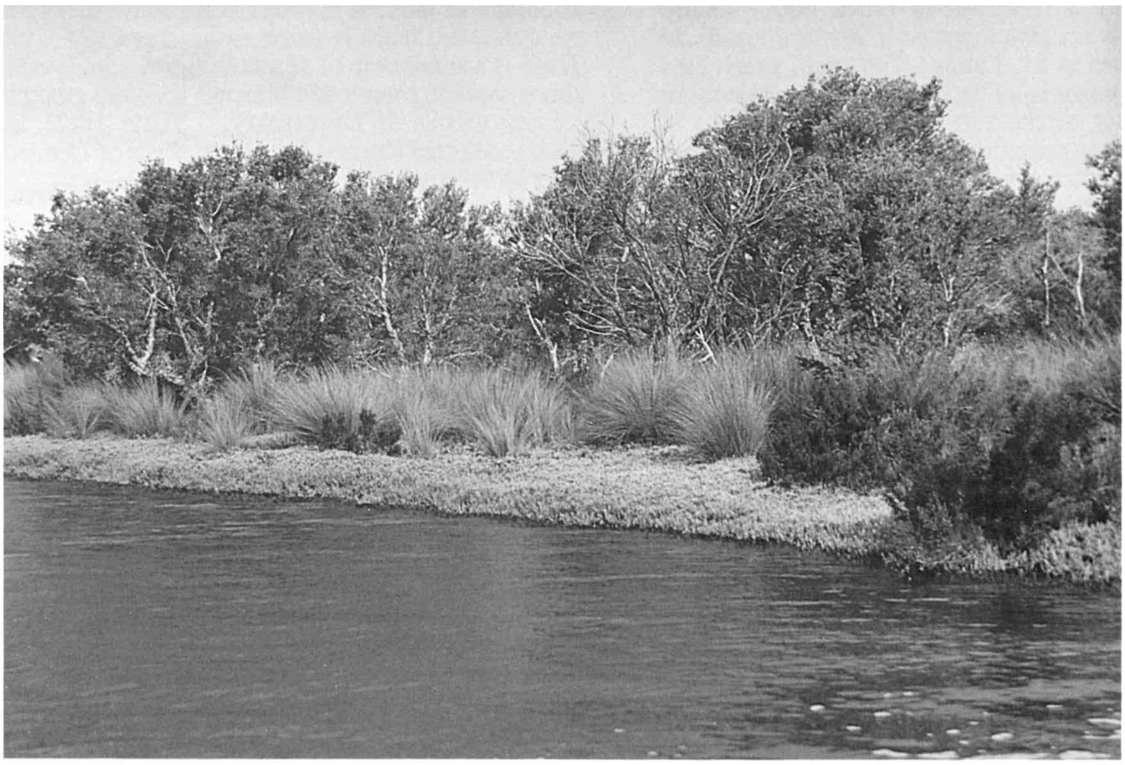


Figure 10.21 Hamersley Inlet. Salt marsh fringing vegetation transect up the estuarine banks. (J.M. Chambers)

(Convolvulaceae), often interspersed with and progressively overshadowed by *Melaleuca cuticularis*. Elsewhere these plants may cover wide flat areas which end abruptly with a drop to the muddy bottom, e.g. samphire swamps near the mouth of Fitzgerald Inlet, *Wilsonia* swamps in Saint Mary Inlet, and the wide *Melaleuca cuticularis* and samphire swamps that surround the Jerdacuttup Lakes. They may be accompanied by a variety of other salt tolerant plants such as those found in similar situations in Beaufort and Gordon Inlets (Hodgkin and Clark,1988).

These are plants which tolerate inundation with salt water, which continue to grow on the salty soil when the water retreats, and propagate rapidly on the return of favourable conditions. The vertical extent of the salt marshes is largely determined by changes in water level and the accompanying wide range of salinity experienced in the shallow basins. There are often narrow bands of dead paperbark trees (*Melaleuca cuticularis*) along the Inlet margins, sometimes with seedlings only a metre or two high, often with tall trees that may have been dead for decades. These reflect changing water levels that have provided favourable conditions for growth over periods of years or decades before again becoming unfavourable when the water retreated. Such dead paperbarks 'possibly hundreds of years old' were seen by geologists Clark and Phillips (1953) at Dempster Inlet and are figured by them (Text Fig. 2).



Fringing vegetation at Saint Mary Inlet, *Wilsonia, Halosarcia, Gahnia, Melaleuca.*

There are a few small swamps with very different vegetation, such as the dense swamp where nearly fresh water drains from Saint Mary River into the Inlet. On the south shore of Dempster Inlet fresh water seeps from the coastal dune into a small swamp (Taylor Springs) where there is a dense cover of *Baumea articulata*, some *Typha* and other freshwater species behind the paperbark and samphire that fringe the lagoon. A spring on the east bank of the Jerdacuttup River also has a dense *Baumea* swamp.

No detailed study has been made of the marginal vegetation of Culham Inlet and the Jerdacuttup Lakes. Superficially it is similar to that of the Park Inlets. Culham Inlet has a narrow fringe of *M. cuticularis* and samphire that widens to a swampy area on the river delta shores. Along the south eastern shore this fringe is backed by a dense stand of Coastal Moorts (*Eucalyptus platypus heterophylla*) most of which died following inundation with salt water in 1988 and 1989, as also did the sparser Yates (*E. occidentalis occidentalis*) and shrubs of *Melaleuca tenella* and wattle. Except where it widens into the river delta the Phillips River has only a narrow fringe of salt tolerant vegetation along its steep banks.

The Jerdacuttup Lakes are surrounded by dense salt marsh of *Melaleuca cuticularis* and samphire which has progressively invaded the open water. This was inundated to a depth of nearly 2 m in September 1989. The vegetation of the Jerdacuttup River appears to reflect a generally fresher water environment, with the sedges *Scirpus nodosus*, *Baumea juncea* and *Gahnia* sp. growing close to the water's edge and a stand of Yate (*Eucalyptus occidentalis occidentalis*) with *M. cuticularis* in the swamp at the south end. Nevertheless *M. cuticularis* forms a fringe along much of the river banks.

10.3 TERRESTRIAL VEGETATION

On higher ground not subject to prolonged innundation, where the soil water is fresh or nearly so, the salt marsh plants are replaced by thickets of less salt tolerant plants such as *Melaleuca lanceolata* and *M. nesophila*, with a greater diversity of understorey plants, and sometimes by dense mallee woodland of *Eucalyptus platypus heterophylla*. Chapman and Newbey (Mss.) report at length on the terrestrial vegetation of the Park.

The bars are colonised by species which tolerate salt spray, windblast and burial by sand; especially *Scaevola crassifolia*, *Arctotheca populifolia* and *Cakile maritima*. On the dunes these are progressively replaced by *Spinifex* and the taller shrubs and trees with increasing distance from the shore and with the shelter of swales and stable dunes. (Figure 10.3)

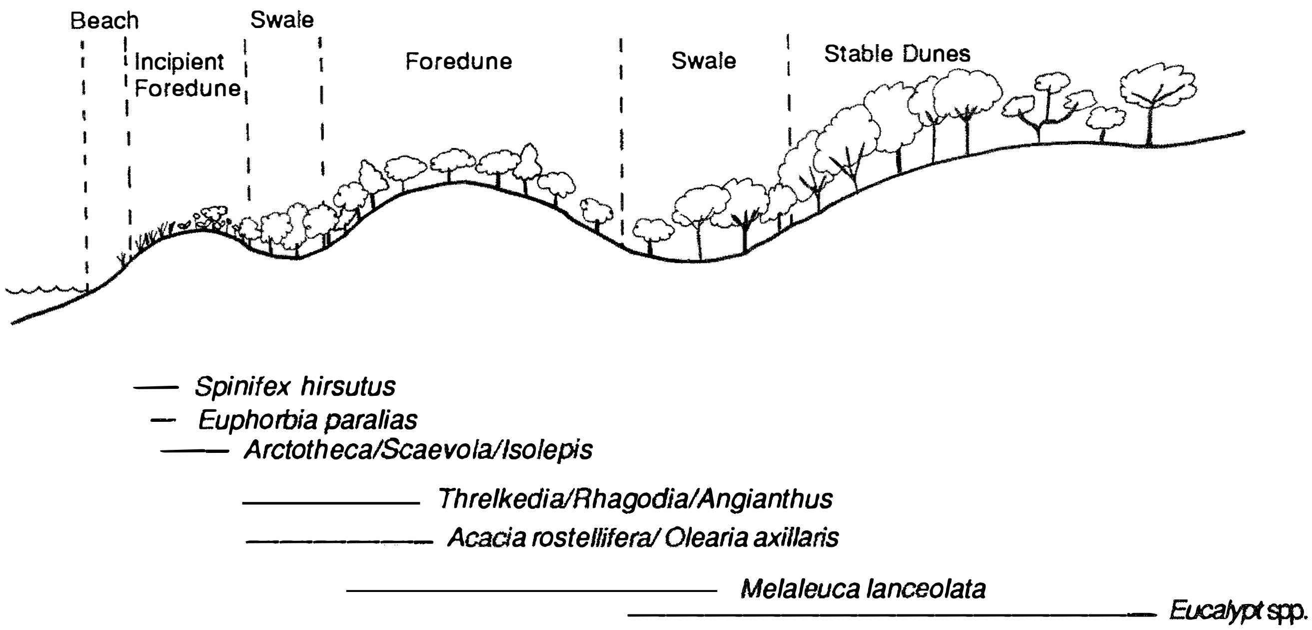


Figure 10.3 A typical dune transect. (J.M. Chambers)

11 ESTUARINE FAUNA

11.1 PLANKTON

A plankton haul in Hamersley Inlet in October 1989 (21 ppt salinity) showed large numbers of the common estuarine copepod *Gladioferens imparipes* and small medusae of the genus *Australomedusa* found in salt lakes in eastern Australia. A daylight haul in the Phillips River (16 ppt salinity) produced quantities of the same medusa and fish larvae.

11.2 BOTTOM FAUNA

Table 11.21 lists the known mollusc fauna, principally from collections made by J. Wallace in April 1977, supplemented by sporadic collections mostly of shells of recently dead animals found as the waters were retreating. The list is probably not complete but does indicate the composition of the mollusc fauna of these temporary estuaries, though not relative abundance or how the fauna changes as water evaporates and salinity increases. Other fauna are identified in the text below and in Table 11.22.

The fauna is a mixture of a few 'estuarine' species, a considerable number of 'marine affinity' species, and salt lake species of inland ephemeral waters. Estuarine species, species which are believed to be confined to estuaries, include the small snail *Hydrobia* and the small bivalve *Arthritica*, both of which were found in the closed waters of Culham Inlet, and *Hydrobia* in the Jerdacuttup River. Another estuarine snail, *Hydrococcus*, was found in Saint Mary Inlet. The estuarine shrimp *Palaemonetes australis* was present in the estuarine reaches of the Fitzgerald, Steere and Jerdacuttup rivers, also the Amphipod *Melita* sp. in Fitzgerald and Jerdacuttup rivers.

Marine affinity species, species which also live in sheltered marine environments, are recruited from the sea as larvae when the bars break; though they die as the water evaporates they sometimes have time to reach maturity. Settlement in the estuaries depends on larvae being present in sea water when the bars are open. They include such large bivalve molluscs as *Pinna* and *Pholas* that burrow in sandy mud in water near the estuary mouths. The cockles *Katelysia* spp. and *Fulvia* and sunset shells *Sanguinolaria* burrow in the littoral sandy shoals. A smaller bivalve, *Spisula trigonella* sometimes appears in vast numbers throughout the lagoons. The tube worm *Ficopomatus enigmaticus* is a marine affinity species that settles on rocks on the Hamersley Inlet shoreline.

Salt lake species include the small snail *Coxiella* which is often abundant; it tolerates a wide range of salinity and survives drying by closing the shell opening with a horny operculum. Brine shrimps are sometimes present and the small ostracod crustaceans are often abundant; they produce drought resistant eggs which are carried from one location to another on the feet of waterbirds. The larvae of salt lake species of chironomid midges are sometimes common.

Clark and Phillips (1953) quote Dr. D. Serventy as saying that 'between 1915 and 1920 Hamersley Inlet contained large quantities of oysters and fish . . .' and there are other reports of large numbers of shellfish in the estuaries early this century. It may be that some of the shell beds in these Inlets represent relatively recent influxes of marine affinity species, however most of the shells are clearly much older and so far all datings have been more than 3500 years old.

The results of a survey in Hamersley Inlet in 1987 (Table 11.22) show how impoverished the benthic fauna can be even though the salinity (29 ppt) was

Table 11.21 Species of Mollusca collected in the Saint Mary (SM), Fitzgerald (FZ), Dempster (DE), Hamersley (HM), Culham (CU) and Jerdacuttup (JC) Inlets. Live animals or shells of recently dead animals.

		SM	FZ	DE	HM	CU	JC
GASTROPODA:							
Hydrobiidae:	*Coxiella striatula*	+	+	+	-	-	-
	Hydrobia buccinoides	-	-	-	-	+	+
Hydrococcidae:	*Hydrococcus brazieri*	+	-	-	-	-	-
Nassariidae:	*Nassarius burchardi*	+	-	-	+	-	-
BIVALVIA:							
Mytilidae:	*Mytilus edulis planulatus*	+	-	-	+	-	-
Pinnidae:	*Pinna bicolor*	-	+	-	+	-	-
Pectinidae:	*Chlamys asperrimus*	-	-	-	+	-	-
Leptonidae:	*Arthritica semen*	-	+	-	-	+	-
Cardiidae:	*Fulvia tenuicostata*	+	+	+	+	-	-
Mactridae:	*Spisula trigonella*	+	+	+	+	-	-
Sanguinolariidae:	*Sanguinolaria biradiata*	+	+	+	+	-	-
Veneridae:	*Katelysia* spp.	-	+	-	+	-	-
Pholadidae:	*Pholas australasiae*	-	+	+	+	-	-

Table 11.22 Bottom fauna at Hamersley Inlet, April 1987. Survey by J.L. Shaw and G.M. Cliff, identified by M. Platell and D.H.D. Edward.

SPECIES	BAR	1.5 km	2.5 km	4 km	8 km
POLYCHAETA:					
Capitellidae:					
Capitella capitata	+++	+++	+++	+++	++
Pectinariidae:	-	++	-	+	-
CRUSTACEA:					
Amphipod	+	-	-	-	++
INSECTA:					
Chironomidae:					
Dicrotendipes	+++	-	-	++	++
Tanytarsus ? barbitarsus	+++	-	-	-	-
Polypedilum sp.	++	-	-	-	-
Sediment type	sand *Ruppia*	fine black mud	thick clay	black clay	sticks coarse grey sand
Depth (m)	-	0.5-1.5	0.8	0.5-1.2	-

then near that of sea water, the water deep and fish plentiful.

Table 11.23 lists the species of Foraminifera found by Hassell (1962) in the surface sediment of Saint Mary Inlet.

Table 11.23 Foraminifera of Saint Mary River. (Hassell, 1962)

Vertebralina striata	*Elphidium poeyanum*
Elphidium crispum	*Sigmoilina schlumbergeri*
Robertina sp.	*Elphidium macellum*
Bolivina punctata	*Halplophragmoides canariensis*
Rotalia beccarii	*Elphidium articulatum*
Discorbis araucana	*Triloculina tricarinata*
Discorbis rosacea	*Quinqueloculina seminula*
Elphidium artica	*Heronallenia translucen*

11.3 FISH

After the Inlets become too saline or dry the fish populations have to be recruited from the sea when the bars break or from the rivers they flow. Only four families of fish breed in the estuaries and saline rivers: Sparidae (Black bream), Atherinidae (Hardyheads), Galaxidae (Minnows), Gobiidae (Gobies). They are the only fish recorded from pools in the tributary rivers (Table 11.31) and the only fish taken in the two closed systems, Culham Inlet and the Jerdacuttup Lakes. The other fish listed in Table 11.32 are marine species. The list represents only limited sampling and no doubt other species enter the estuaries from time to time, and probably also Saint Mary and Dempster Inlets.

These marine species only breed in the sea, they enter the estuaries during the brief and infrequent times when the bars are open and flourish while conditions are favourable. As Inlet water evaporates they retreat

Table 11.31 Fish caught in the Gairdner (Ga), Fitzgerald (Fz), Hamersley (Hm), Phillips (Ph) and Jerdacuttup (Jc) rivers. (Chapman, A, 1985)

	River systems					Observed ranges	
	Ga	Fz	Hm	Ph	Jc	TSS* g/L	Length (mm)
Spotted minnow *Galaxias maculatus*	-	+	+	+	+	13-28	20-100
Hardyhead *Atherinosoma* sp.	-	+	+	+	-	4-20	11-43
Blue Spot goby *Pseudogobius olorum*	-	+	+	+	+	4-54	10-56
Black bream *Acanthopagrus butcheri*	+	+	-	+	+		<70

*TSS = Total Soluble Salts = salinity parts per thousand.

Table 11.32 Commercial and non-commercial estuarine and marine species of fish caught in Fitzgerald (FZ), Hamersley (HM), Culham (CU) and Jerdacuttup (JC) Inlets. (R.C.J. Lenanton & G.M. Cliff - WA Fisheries Department, Prince, et al, 1982)) + present, - not caught.

Commercial		FZ	HM	CU	JC
Sillaginidae:	King George whiting *Sillaginodes punctatus*	-	+	-	-
Arripidae:	Western Australian salmon *Arripis truttaceus*	-	+	-	-
Sparidae:	Black bream *Acanthopagrus butcheri*	+	+	+	-
Mugilidae:	Yelloweye mullet *Aldrichetta forsteri*	-	+	-	-
	Sea mullet *Mugil cephalus*	-	+	-	-
Pleuronectidae:	Elongate flounder *Ammotretis elongatus*	-	+	-	-
	Long snouted flounder *Ammotretis rostratus*	-	+	-	-
Monacanthidae:	Six-spined leatherjacket *Meuschenia freycineti*	+	-	-	-
Non commercial		**FZ**	**HM**	**CU**	**JC**
Galaxiidae:	Minnow *Galaxias truttaceus*	+	-	-	-
	Common minnow *Galaxias maculatus*	+	+	-	-
Gonorynchidae:	Beaked salmon *Gonorynchus greyi*	-	+	-	-
Atherinidae:	Elongate hardyhead *Atherinosoma elongata*	+	+	-	+
	Silverfish *Leptatherina presbyteroides*	-	+	+	+
	Wallace's hardyhead *Leptatherina wallacei*	-	+	+	+
	Atherinid sp.	+	+	-	-
Gobiidae:	Blue spot goby *Pseudogobius olorum*	+	+	-	+

to the deeper riverine reaches and die out progressively in the increasingly salty water (Lenanton, 1984). It will be noted that Hamersley Inlet has the larger number of species and while this is partly because of more frequent sampling it probably also reflects the deeper water and more continuously favourable salinity there than in the shallower and more ephemeral Inlets, Fitzgerald, Dempster and Saint Mary.

The Sea mullet is the most common of the marine species and generally the longest to survive when the estuaries dry up. It spawns over at least six months and immature stages are present in coastal waters for many months, longer than most other marine species (Lenanton, 1984). Sea mullet appear to survive the longest and tolerate a wide range of salinity from fresh (<3 ppt) to 75 ppt and are sometimes found in pools upstream from the estuaries.

The Inlet waters can be very productive and Black bream and Sea mullet especially are often present in great abundance following flooding and while the salinity remains favourable. At such times they are netted by professional fishermen and also by recreational fishermen. Hamersley Inlet and the deep water of the Phillips River are especially popular. Black bream are caught in Culham Inlet, but snags round the margin make it unsatisfactory for netting. Black bream were introduced into the Jerdacuttup River in 1935 and they are also caught in the Jerdacuttup Lakes.

Chapman (Mss.) who sampled the river pools (Table 11.31) notes that Black bream and hardyheads are more dependant on deeper, less saline, more permanent pools than the minnows and gobies which also live in small ephemeral pools. Black bream and the Swan River goby are common throughout saline waters of the south west. In Western Australia the two galaxiids listed are only found between Albany and Esperance although *Galaxias maculatus* is widely distributed elsewhere in southern Australia. Chapman also reports that the introduced Mosquito fish (*Gambusia affinis*) has not been found in the Park rivers although present in the Pallinup River and warns against the potential for this exotic species to spread into Park rivers because it withstands salinities up to 13 ppt.

11.4 BIRDS

Birds are the most mobile fauna of the estuaries and, often flying in large flocks, they move from one Inlet to another to take advantage of favourable conditions, where the water is of appropriate depth, where salinity is not too great, and where there is an abundance of prey. For this reason while Table 11.4 clearly shows the great diversity of waterbirds that visit the Inlets it does not present a reliable picture of bird species and numbers that favour individual estuaries, rather it represents the condition of the estuaries at the time of the surveys and the frequency with which surveys were made. For example the 200 Shelduck recorded in Dempster Inlet is not a measure of its value to waterbirds, only that conditions were not favourable on the few occasions when it was visited; it is the least accessible of the Inlets.

Black Swans and some ducks feed mainly on water plants, but most waterbirds feed on the benthic fauna or on fish and are uniquely adapted for feeding in particular depths of water. Some, like the stilts, prefer to peck for their prey in the sandy shallows, others stretch their necks to shovel through mud in deeper water, as do Grey Teal, while Musk Ducks dive to feed on the bottom in deeper water. Deep water favours cormorants and other birds which swim in search of fish. When the food supply is rich and the water levels ideal the favoured species are present in their thousands, as when 44 000 Banded Stilt were seen on Culham Inlet in October 1986.

Some species are more tolerant than others of the high salinities experienced following evaporation of the water and most ducks, particularly the Chestnut Teal, are well adapted to cope with such conditions (Chapman and Newbey, Mss).

Table 11.4 Waterbirds observed at Saint Mary River (SM), Fitzgerald (FZ), Dempster (DE), Hamersley (HM) and Culham (CU) Inlets and Jerdacuttup Lakes (JC). (A. Chapman, B. Newbey, RAOU). Figures show the highest numbers recorded.

Common name	Scientific name	SM	FZ	DE	HM	CU	JC
Great Crested Grebe	*Podiceps cristatus*	-	-	-	12	15	-
Hoary-headed Grebe	*Podiceps poliocephalus*	3	27	#	12	85	#
Australasian Grebe	*Trachybaptus novaehollandiae*	-	-	-	2	+	-
Australian Pelican	*Pelecanus conspicillatus*	-	14	-	10	12	-
Darter	*Anhinga melanogaster*	-	1	-	2	-	-
Great Cormorant	*Phalacrocorax carbo*	1	-	-	100	-	-
Pied Cormorant	*Phalacrocorax varius*	-	-	-	60	-	-
Little Black Cormorant	*Phalacrocorax sulcirostris*	1	1	-	300	620	-
Little Pied Cormorant	*Phalacrocorax melanoleucos*	4	1	-	40	37	-
White-faced Heron	*Ardea novaehollandiae*	3	20	-	40	5	-
Great Egret	*Egretta alba*	-	-	-	3	11	-
Eastern Reef Heron	*Egretta sacra*	1	-	-	-	1	-
Rufous Night Heron	*Nycticorax caledonicus*	-	-	-	4	-	-
Black Swan	*Cygnus atratus*	12	168	7	30	30	100
Cape Barren Goose	*Cereopsis novaehollandiae*	-	-	-	-	5	-
Australian Shelduck	*Tadorna tadornoides*	20	1800	200	100	158	250
Pacific Black Duck	*Anas superciliosa*	6	10	-	20	400	250
Grey Teal	*Anas gibberifrons*	10	50	-	103	237	4000
Chestnut Teal	*Anas castanea*	100	26	-	100	60	10
Australian Shoveler	*Anas rhynchotis*	-	-	-	-	6	350
Maned Duck	*Chenonetta jubata*	-	5	-	1	-	20
Musk Duck	*Biziura lobata*	2	6	-	500	34	40
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	-	-	-	2	-	-
Eurasian Coot	*Fulica atra*	-	-	-	200	35	1000
Pied Oystercatcher	*Haematopus longirostris*	-	2	-	1	-	-
Sooty Oystercatcher	*Haematopus fuliginosus*	-	-	-	3	-	-
Hooded Plover	*Charadrius cucullatus*	6	2	-	4	-	-
Red-capped Plover	*Charadrius ruficapillus*	16	8	-	4	-	-
Black-winged Stilt	*Himantopus himantopus*	2	-	-	#	7000	-
Banded Stilt	*Cladorhynchus leucocephalus*	800	150	-	-	44000	-
Red-necked Avocet	*Recurvirostra novaehollandiae*	215	13	-	24	4	-
Common Sandpiper	*Tringa hypoleucos**	1	1	-	3	2	-
Greenshank	*Tringa nebularia**	1	-	-	1	7	-
Sharp-tailed Sandpiper	*Calidris acuminata**	-	22	-	-	-	-
Red-necked Stint	*Calidris ruficollis**	34	87	-	-	-	-
Silver Gull	*Larus novaehollandiae*	6	180	#	5	54	#
Pacific Gull	*Larus pacificus*	1	1	-	1	-	-
Caspian Tern	*Hydroprogne caspia*	1	2	-	1	-	-
Crested Tern	*Sterna bergii*	-	-	-	1	1	-

* denotes migratory bird; present in greater numbers in spring and summer, most depart in autumn. All other birds are sedentary or vagrant. # denotes present but no numbers recorded.

12 DISCUSSION

It will be evident from the foregoing accounts that there are large gaps in our knowledge and understanding of these unusual ecosystems. We know little of their evolution from deep, open estuaries to shallow, often closed lagoons; of the processes of erosion and sedimentation that are still at work in them; the effects human activities have had, and continue to have, on them; of their flora and fauna and their ecology generally. This information is of great scientific interest and it is basic to deciding how they should be managed and for what purpose. A brief discussion of these aspects is appropriate here but a full consideration must await treatment elsewhere.

HISTORY This Study began with the statement that there are no longer any estuaries in the Shire of Ravensthorpe in the conventional sense of the word. The Park Inlets are 'temporary estuaries', coastal lagoons that are only intermittently open to the sea; and Culham Inlet and the Jerdacuttup Lakes are 'fossil estuaries', closed lagoons with no connection with the sea, their only claim to estuarine status a historical one.

'The key to full understanding of the present nature of Australia's aquatic environment is knowledge of past events' (De Deckker, 1986) and in Section 1.2 we tried to interpret the evolution of the estuaries on the basis of limited observational data and extrapolation from what is known about other estuaries of the south west (e.g. Hodgkin, 1978; Hesp, 1984; Hodgkin and Kendrick, 1984). The processes of sedimentation and erosion which have transformed them from open estuaries to closed lagoons are still at work today, some modified by human activities, and an understanding of them is essential for management. Extensive studies of the sedimentary history of NSW estuaries have shown how they have changed and are changing physically and ecologically (Roy, 1984). In the estuaries of the south west there is abundant evidence waiting to be studied which can provide a valuable understanding of their evolution: the lagoon sediments, their depth, nature and rate of accumulation; the extensive shell beds; the structure of the bars and dunes and of the onshore and nearshore limestone reefs.

Major episodic events are likely to dominate sedimentary and erosive processes; more so here than in areas of higher and more uniform rainfall. The occasional downpours of 100 mm or more cause floods that are the main factor in sediment transport. They wash soil from the catchments, they scour the river channels and the riverine reaches of the estuaries and dump sediment in the lagoons, and when the bars break they scour the gorges through the narrow inlet channels. *But what effect has clearing in the catchments had on sediment transport to the estuaries, shielded though they are by long stretches of river through virgin bush?*

Storms erode the ocean beaches and may help to break the bars, but regrowth of the bars and erosion and sedimentation round the margins of the lagoons probably result from more continuous and well understood processes. *But what effect do the great changes in water level and the extreme salinities have on sediment stabilisation and the normal processes of salt marsh growth and encroachment into the lagoons?*

ECOLOGY The conventional concept of an estuary is of a place where fresh water and sea water mix tidally in the sheltered environment of a river mouth; a place with an abundance of plant and animal life that provides rich feeding grounds for fish and waterbirds. Estuaries support important commercial and recreational fisheries and are nurseries for many species of fish taken in coastal fisheries. They are havens for waterbirds and here especially for migrants that feed in southern waters during the northern winter. *How far are these concepts applicable to the systems discussed here? What is their function ecologically, and what part have they in the wider coastal ecosystem?*

Fresh water and sea water only mix in the estuaries intermittently, at intervals of years, and generally only for brief periods while the bars are open. They experience great changes in water volume and level, and extremes of salinity from nearly fresh to many times that of sea water, cycles sometimes of years or decades, and they often dry up altogether. Most species of plants and animals can only sustain life over a narrow range of salinity and few species live in the waters of these estuaries. Very few species, such as the seagrass *Ruppia* and the snail *Coxiella*, survive over the wide range experienced and recover when the lagoons are flooded again. Most others must be recruited from the sea or from saline river pools. The permanently closed systems are now essentially salt lakes, but unlike most inland salt lakes are fed by rivers with permanent pools.

When the bars break large numbers of fish are recruited from the sea and while the salinity is favourable there is often an abundance of plant and animal life. The estuaries can be very productive and support rich fisheries for a few years, but few fish return to the sea and their contribution to coastal fish populations is negligible. Floods bring large numbers of Black bream and other river fish to the lagoons and these survive and multiply over a wide range of salinity.

The estuaries are also important waterfowl habitats and at times support large numbers of waterbirds, including migrants. Although there are often long periods when there is little or no water and food in individual estuaries such conditions are rarely synchronous throughout the area and flocks fly from one lagoon to another to take advantage of transient favourable conditions. There has been considerable loss of wetlands in the south west during the last half century and it will be a tragedy if these wetlands are also lost through neglect or over exploitation.

Unfortunately there are no data to assess their productivity or records of the changing populations of plants and animals which contribute to it at the various stages in the cycles. The changing salinity is probably the dominant ecological factor, but it may be that 'the ability to tolerate wide fluctuations of combinations of environmental factors rather than extreme levels of each factor determines which plants [and animals] will grow in saline lakes' (Brock, 1986) and in these estuaries. There is also the chance factor of what species are available for recruitment when the lagoons are flooded and the bars break.

13 MANAGEMENT

The Inlets provide some of the most spectacular and most accessible scenery of the Park, especially when flooded. But large areas of bare mud and sand are not usually conceived as being attractive scenically however beautiful may be the surrounding cliffs of Fitzgerald Inlet, or the rocky gorge of Hamersley Inlet. The riverine reaches can be peaceful places for boating and canoeing but there is seldom enough water for such pastimes to be enjoyed in the lagoons, with the notable exception of Hamersley Inlet. They are attractive wild places for the few who enjoy adventure in our diminishing natural environment and the tracks to them are increasingly used by people with a wide variety of interests, besides the fishermen who pioneered many of them. The Inlets are part of our natural heritage and they are of great scientific interest.

Hamersley Inlet is a beautiful place with spectacular scenery in the gorge. The recent construction of a gravel road to the Inlet, and the proposed camping area, have made it much more accessible and it will now come under greater pressure. It is to be hoped that visitors will show more respect for the natural features than is often the case, and especially for the fragile coastal vegetation along the shores.

SEDIMENTATION Here, as elsewhere in this southern region of low and intermittent rainfall and river flow, the principal long term management concern is with regard to sedimentation. Estuaries are traps for sediment of both terrestrial and marine origin. River deltas and flood tide deltas have built into the lagoons and sediment has filled these Holocene river valleys to sea level. The Hamersley lagoon alone now has any depth (1.5 m) below sea level, perhaps the marine contribution has been less there than in other Inlets as suggested by the small flood tide delta.

Transport of river sediment results mainly from flood events which erode dry topsoil and scour accumulated sediment from river beds. In 1875 Nicolay (quoted by Bignell, 1977) observed how floods had mobilised large quantities of sand and filled the Fitzgerald River bed near the Inlet. The Fitzgerald, Hamersley, West, Phillips and Jerdacuttup rivers all have their headwaters in cleared land but flow through the Park or other uncleared land for some distance before discharging into the Inlets. However it is not known what effect clearing has yet had on the rate of sedimentation. Observations in Fitzgerald Inlet suggest that a flood in the 1960s brought down a quantity of sediment comparable to the 100,000 m^3 carried to Beaufort Inlet by the Pallinup River in the January 1982 flood (Hodgkin and Clark, 1988). The catchment had recently been cleared, but there is no evidence as to the source of the sediment, whether from the headwaters of the river or perhaps from the river channel as the result of more rapid flow. Sedimentation has increased greatly in Stokes Inlet following clearing in the catchment (Hodgkin and Clark, 1989). Extensive burns such as those of December 1989 no doubt also increase sediment loss from the Park catchments.

The Fitzgerald River National Park Draft Management Plan states the following management objective: *Ensure that, as far as possible, activities both inside and outside the Park do not harm the quality and quantity of the Park's water resources.* It recommends that relevant bodies: *encourage land use practices upstream of the Park which do not lead to further deterioration in water quality or changes in quantity.* 'Quality' here probably refers principally to salinity and plant nutrients, but the sediment load is at least as important for the future of the rivers and estuaries. Sediment transport from cleared catchments can be reduced by tree planting and by retaining native vegetation along the margins of the rivers and streams. There are linear reserves along the Fitzgerald River from the Park to Lake Magenta, but 'no Department or agency is formally responsible for day-to-day management' of them and they appear to be largely uncared for. It is important that they become the responsibility of CALM as recommended in the South Coast Region Draft Management Plan and that stock be excluded from them. Where possible similar reserves should also be established along the other rivers.

THE BARS Management of the bars has been an important consideration in respect to other estuaries examined in this series of Studies. So far there has been no interference with the natural course of events in the Park estuaries and there does not seem to be any occasion to do so. Relevant recommendations in the Fitzgerald River National Park Draft Management Plan are: *Do not construct new structures or facilities on sand bars which periodically open to the sea*, sometimes at long intervals. Such structures should not be built lower than 1 m above the level of the tops of the bars anywhere around the estuaries. *Do not use machinery or other human-induced means to open bars of any of the Inlets in the FRNP, unless it can be shown to be desirable by competent scientific authorities.* There is little to gain by opening the bars prematurely and even if the bars could be kept open artificially the water in the lagoons would be very shallow. The more prolonged opening of Gordon Inlet and Wellstead Estuary bars allows a more diverse fauna sometimes to persist longer there than in other Park Inlets, but both now have massive flood tide deltas and the lagoons are shallow. Hamersley alone might occasionally benefit, but at the risk of an increased input of marine sand.

The only controversial situation is that of Culham Inlet where the road from Hopetoun to the Park is built along the bar. The bar was broken in about 1920 when it was topped by Inlet water and in 1988 it was proposed to breach it when Inlet water flooded the road and prevented vehicle passage. Such floods have been infrequent, perhaps once every 25 years, though increased runoff from the cleared catchments will probably make them more frequent.

In 1920 there was no road across the bar and its slow regrowth to its present size cannot have inconvenienced anyone seriously. Now if the bar were to break the 100 to 200 m wide gap would probably take years to rebuild naturally or be difficult and costly to rebuild artificially. If the bar were to remain open, an unlikely event, the Inlet would be very shallow.

At the time of writing the level of the road is being raised, a pipe laid under it at a height which will retain about 2 m of water in the Inlet but not allow it to flood the road. This might not be sufficient to prevent flooding the road and possibly breaking the bar following a series of years of above average rainfall and downpours such as that of May 1988. The bar is also under threat from the sea. Recent winter storms have caused serious erosion of the beach and exposed rock at the eastern end of the bar region. This may be only a temporary situation because of unusual storms, but the situation should be watched.

EUTROPHICATION We have seen no evidence of excessive nutrient input to these estuaries although relatively high levels of total phosphorus have sometimes been recorded in river water. This in contrast to the eutrophic Beaufort Inlet where nutrient levels are high and there are frequent phytoplankton blooms (Hodgkin and Clark, 1988). There 84% of the catchment is cleared. The attached aquatic plants *Ruppia* and *Lamprothamnium* are sometimes abundant in the Inlets, when the salinity is favourable, but the only time an excess of algal growth was observed was in Saint Mary Inlet in October 1989 when the *Ruppia* was heavily laden with a filamentous green alga. The Saint Mary River catchment is entirely within the Park.

FISHERIES The Inlets sustain small fisheries for a limited period after the bars break or the lagoons are flooded and until the water becomes too saline; generally longer in the riverine reaches. The Fitzgerald River National Park Draft Management Plan recommends that commercial fishermen be given access to Gordon Inlet and Hamersley Inlet and allowed to transport catches through the Park subject to certain conditions. Saint Mary, Fitzgerald and Dempster Inlets would be closed to commercial fishing. Recreational fishing would be permitted in all waters of the Park except Dempster Inlet, subject to Fisheries Regulations. Outside the Park net fishing is prohibited in the Phillips River, from 4.2 km upstream from Culham Inlet, and in the Jerdacuttup River (Fisheries Dept. WA., 1988), but netting is permitted in Culham Inlet and the Jerdacuttup Lakes.

All the Inlets have been fished by licensed fishermen, where legal, and here, as elsewhere, the interests of professional and recreational fishermen are sometimes in conflict. Professionals wish to harvest a resource before it disappears through natural causes and amateurs want access to an undiminished supply of fish. This conflict will be resolved progressively as commercial fishermen leave the industry and are not replaced. However it is relevant to note that surveys of coastal fisheries have shown that recreational fishermen can take considerably more fish than professionals. Professionals are often more selective in their catches and take principally mullet and bream of legal size. With improved access to the estuaries there is the danger of over exploitation of the limited stocks, especially by some visitors who, unlike experienced fishermen, have little feel for the need to conserve the resource. This is but one aspect of increasing people pressure and more intensive use of resources which must concern anyone involved in management. Any substantial increase in the use of motor boats on Inlet waters could be detrimental to fish populations, to the ecosystems generally and to their survival as the wild and peaceful places that is one of their main attractions.

RESPONSIBILITY FOR MANAGEMENT At present the Park Inlets are Vacant Crown Land (VCL) and no organisation is responsible for their management. The Draft Management Plan recommends vesting Fitzgerald, Saint Mary and Dempster Inlets in the Park, alternatively as marine parks but as closed waters (i.e. closed to netting), and vesting Hamersley and Gordon Inlets as marine parks open to commercial fishing (commercial fishing is not permitted in National Parks). Culham Inlet is an anomalous situation, the Inlet is VCL but the Phillips River is in the Park. A narrow strip of the eastern and southern shores of the Inlet are an A Class recreation reserve (No.34998) vested in the Shire. The Jerdacuttup Lakes are in a Nature Reserve (A 40156) managed by CALM. However the vulnerable riverine part, to Springdale Road, is in a narrow strip of unvested VCL; much of this is not fenced and the banks are eroded by stock. It is part of the Lake system and it should be managed with the Nature Reserve.

Ultimately the successful conservation and management of an environment depends on the public being alert both to its natural worth and its value to the community. It depends on people appreciating the resource they are using and understanding the impact they have on it, whether this be to its benefit or to its detriment and to the advantage or disadvantage of other users. They must be aware of what the environment has to offer them and attentive not only to what they can gain from it but also to what they can contribute to its continued wellbeing. This is as true of the estuaries and their hinterland as of any other natural resource. CALM has accepted responsibility for providing "information, interpretation and education as part of a regional and local community approach" (Moore et al., 1989) and other bodies such as the Fitzgerald River National Park Association and the Fitzgerald Biosphere Project Inc. are assisting the process. We hope that this Study of coastal waters of the Ravensthorpe Shire will also help towards an appreciation and understanding of them, of their place in the wider south coast environment and of their value to the community.

14 FURTHER INVESTIGATION

While detailing what is known about these estuaries and coastal lagoons this Study also shows how little we really know about them and highlights the need for further research. They look deceptively simple but the complex processes at work in them are still not well understood, an understanding that is essential to planning their effective long term conservation and management. Several avenues for further research are discussed above (Section 12) and some more specific suggestions are made here.

The almost total absence of data on river flow to any of the estuaries makes it difficult to interpret their dynamics and the behaviour of the bars in response to rainfall and to know what effect clearing in the upper catchments has had on volume and rate of flow. The only data is the 1974-1985 record from Jacup on the Fitzgerald River (Figure 2.2). It is important that at least one of the rivers should be gauged, both where it leaves the cleared land and where it discharges to the estuary. Records should be kept of the opening and closing of the bars, of the depth, salinity and temperature of water in the Inlets and of river flow in relation to rainfall.

There are no data on sediment transport and the effect clearing has had on the rate of sedimentation in the Inlets. Experience in Beaufort Inlet and Stokes Inlet suggests that the sedimentation rate has increased greatly, though here much of the increased load may have been retained in river channels where they meander through the Park and river reserves. It is hoped that the Stokes Inlet sediment study can be extended to one or more of the Park estuaries. The effect of extensive fires, such as those of January 1990, on runoff, nutrient loss, and sediment transport to the estuaries also needs to be evaluated.

The increased salt load following clearing is of more concern with respect to the ecology of the rivers and river pools than of the estuaries, which gain much of their salt load from the sea. Both the rivers and the estuaries are vulnerable to the effects of increased nutrient inputs and it is to be hoped that a systematic study of the river and estuary nutrients can be undertaken to measure the levels and identify the sources of nutrients.

The Draft Management Plans stress the need for further studies of rare and endangered species of plants and animals. While recognising the importance of these in respect of the terrestrial flora and fauna it is clear that the need of the endangered estuaries is for broad based ecological studies to understand the sequence of events in them and their role in the wider coastal ecosystem. Such studies will help to interpret their conservation value and identify management problems.

The estuarine vegetation presents obvious problems of great ecological interest that as yet have received little attention. The composition of the marginal flora as it relates to changing water levels and the salinity of both the free water and the soil water is of particular interest. There are evident differences between the dominant salt marsh plants of the various estuaries that would reward study and help towards understanding their ecology.

Knowledge of the fauna is also still superficial. Fauna lists are certainly incomplete and little is known about how the few invertebrate species that colonise the estuaries respond to the flooding and subsequent evaporation of the water, with the associated extreme changes in salinity. Small invertebrate animals are the principal food of most fish and waterbirds and studies on their biology would be a valuable contribution to understanding these unique 'estuarine' ecosystems. There has been much study of marine species of fish that invade estuaries, but as yet little is known of the biology of Black bream, the principal catch of recreational fishermen and the only species fished that lives permanently in the estuaries and river systems.

It will be obvious from what has been said in this report that there are still large gaps in our knowledge of these unique coastal ecosystems and that there is scope for much further study of them, for observation and scientific research, by amateurs and professionals. Such study can contribute greatly to our knowledge and understanding of them and of how they should be managed for the benefit of the systems themselves and for those whose responsibility it is to care for them, for the people who use and enjoy them, and for the community generally.

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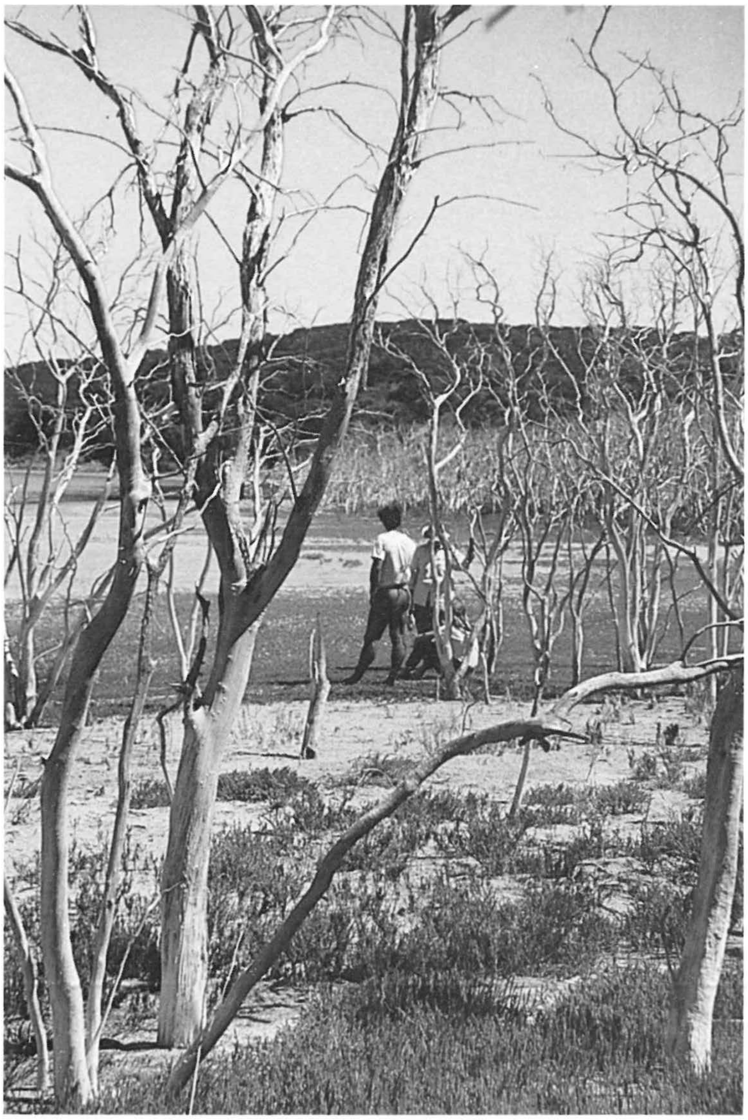

Sarcocornia, Suaeda and dead *Melaleuca* at Lake Nameless.

Jerdacuttup Lakes, December 1988. (Land Administration, WA)

Lake Nameless, February 1990. (Land Administration, WA)