State of the Pallinup River and the Beaufort Inlet

Water and Rivers Commission

Natural Heritage Trust

Water and Rivers Commission
Water Resource Management Series
Report No WRM 37
March 2003

Acknowledgments

This report was prepared by Kaylene Parker, Steve Janicke, Travis Drysdale, Joanne O'Connor and Lea Barber for the landholders along the Pallinup River, the Gnowangerup Land Conservation District Committee (LCDC) and the Water and Rivers Commission. The Water and Rivers Commission and the Natural Heritage Trust provided the funding.

Thank you to those landholders who walked along the river and gave us an historical account of the river from their local knowledge. A special thank you to Penny Moir, who helped collect and identify many of the plant species, and to the Albany Herbarium for their assistance and encouragement in identifying the plant specimens. Thanks also to the volunteers, Susan McCabe for organising the community walk and canoe trip for the bottom of the river and Beaufort Inlet. Thank you also to Steve Newbey, for guiding the project's direction and his insight into the Pallinup River, and to Cindy Stevens of the Department of Agriculture.

Thanks to Ben Boardman for the technical review of water quality data for the Beaufort Estuary and to Clare Taylor for discussions on the Pallinup river channel geomorphology.

Marg Wilke edited and prepared the final version.

Reference details

The recommended reference for this publication is: Water and Rivers Commission 2003, *State of the Pallinup River and Beaufort Inlet,* Water and Rivers Commission, Water Resource Management Series, No WRM 37.

ISBN 1-920687-89-0

ISSN 1326-6934

Cover photograph: Chillinup Crossing during the flood of 1982 [taken by Arnold Black].

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Purpose of this report

The purpose of this report is to provide a basic understanding of the river so that an integrated and coordinated approach to on-ground waterways management on a local scale, may be developed. The report provides:

- a record of river condition;
- an indication of problem areas;
- an overview of management issues;
- technical aspects of river and estuary function;
- a mechanism to increase community knowledge of waterways management issues; and
- a mechanism for recording and prioritising on-ground work.

How to use this report

The 'State of the Pallinup River' report was prepared for the Water and Rivers Commission, community groups and the landholders in the Beaufort Inlet catchment.

Section 1 describes the scope of the study, lists the aims and objectives of the project and outlines relevant context of the information contained in the report.

Section 2 describes the catchment, giving an overview of the environment and provides information on the natural resources, heritage and land tenure within the catchment.

Section 3 describes the state of the waterways in the catchment, in particular, the Pallinup River main floodway and the Beaufort Inlet. This includes vegetation condition, channel erosion, sedimentation, water quality and other ecological aspects of the river.

Section 4 discusses river management issues in general and presents recommendations.

Section 5 contains additional information and references.

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Executive summary

The Pallinup River drains from just south of Broomehill, past Gnowangerup and Borden, and eventually discharges to the Beaufort Inlet, near Wellstead on the South Coast of Western Australia.

This report provides the Water and Rivers Commission, community groups, Landcare groups and landholders with general and specific information on the Pallinup River and Beaufort Inlet. In this report, the Pallinup River, refers to the main trunk and not the entire drainage system. The information was gathered from a foreshore survey of the river and data collected through other environmental projects. The survey was conducted to determine the condition of the river and to map and prioritise management issues.

The Pallinup River is currently showing signs of degradation similar to other rivers in Western Australia. In particular, the riparian vegetation is degrading due to stock access, salinity, erosion, high nutrient levels and weed invasion. There is evidence that the quality of the water in the rivers is deteriorating and Beaufort Inlet is also showing signs of extreme nutrient enrichment. The banks of the river are eroded and sedimentation of the river pools is a major issue. This qualifies most of the foreshore, particularly in the upper reaches as C grade.

There are however sections of the Pallinup River in good to excellent condition with a few reaches where foreshore vegetation is graded as A and more commonly B. The Pallinup River has many spectacular reaches and is a unique environment on the South Coast.

Considerable works have been undertaken by landholders to protect and restore the Pallinup River. Most of the river is fenced, however many sections of the fences were lost during the 1955 and 1982 flood events.

There are considerable areas of the river that require revegetation, particularly sections graded as C and D.

The results of the survey indicated that:

- A significant portion of the Pallinup River is fenced, with landholders planning to undertake further fencing. Many unfenced reaches have received some degree of protection due to the adjacent landuse being continuous cropping.
- The Pallinup – North Stirlings revegetation program was completed in 2001 and has been a good example of a well-managed project that targeted waterways and remnant bush to ensure their protection.
- Future management of the Pallinup River will require a 'whole of catchment' approach, where landholders recognise that they are in a catchment, and therefore, all play a part in the health of the waterways. Catchment wide activities are not addressed in this report.

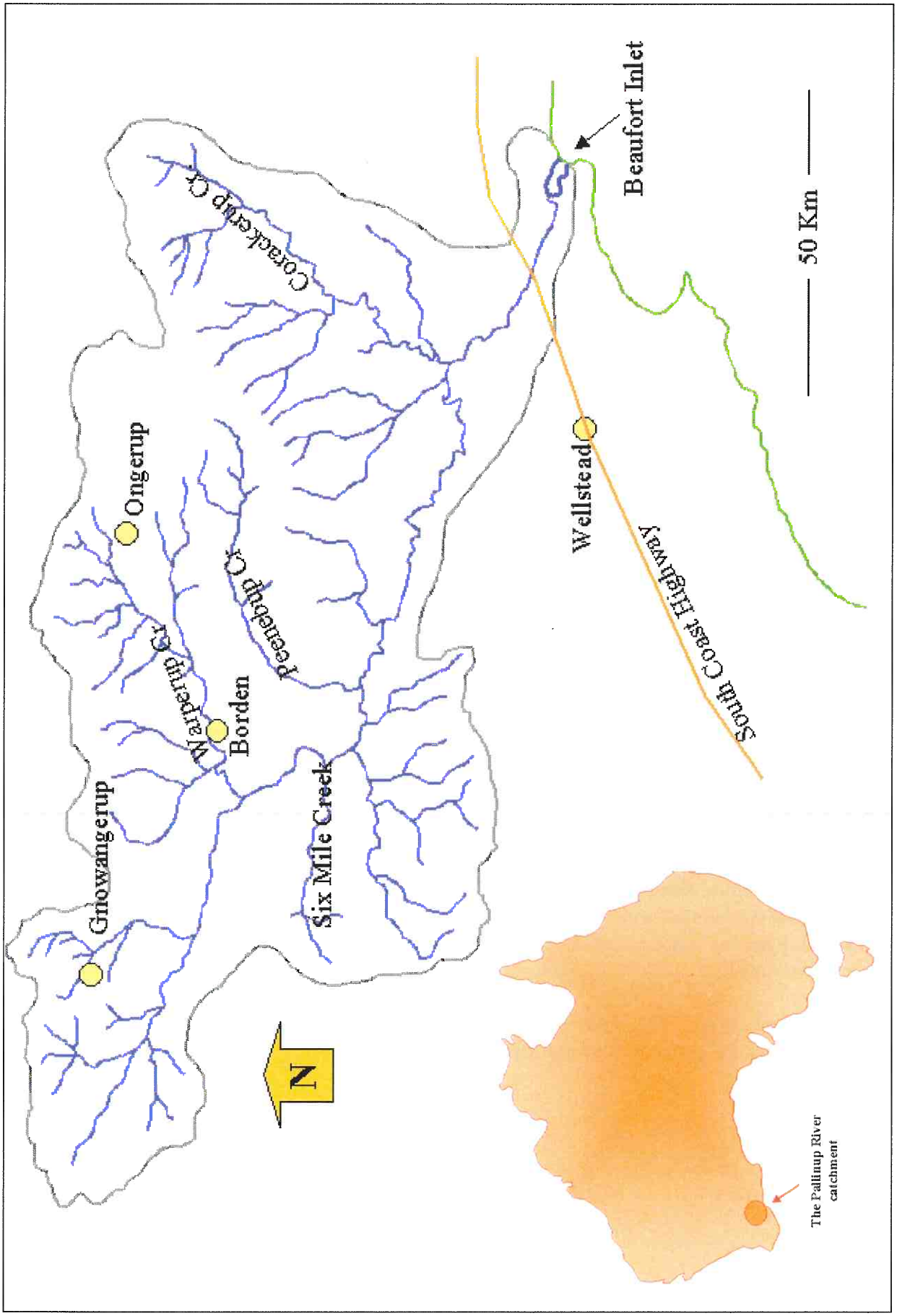

Figure 1. The Pallinup River catchment

1 Introduction

1.1 The study area

The Pallinup River is located on the South Coast of Western Australia, north-west of Albany. The headwaters of the river are near the town of Broomehill. The river extends through the shire of Gnowangerup to the Boxwood Hill and Wellstead districts, before reaching the Beaufort Estuary. The river survey covered the entire length between Beaufort Inlet and the Gnowangerup – Tambellup Road. Other towns in the catchment are Borden and Ongerup. The river reaches were walked to obtain a detailed and unbiased picture of the floodway.

This study focuses primarily on the main corridor of the Pallinup River. There are a number of large tributaries, the Warperup, Corackerup, Six Mile and Peenabup creeks, that have similar structure and management issues. Some studies have been done for these tributaries and the information resides with the Water and Rivers Commission, the Department of Conservation and Land Management and the Western Australian Department of Agriculture.

1.2 The aim, objectives and goals of the study

The aim is to work together to protect and restore the Pallinup River.

The broad objectives of the 'State of the Pallinup River' report are to:

- describe the Pallinup River, including Beaufort Inlet and to define the key environmental issues relevant to their future management;
- provide a benchmark against which the local community's future work to protect the river can be evaluated;
- provide a document upon which a River Action Plan and a Management Plan can be developed; and
- document important technical information for future funding and project submissions.

These objectives were to be achieved by conducting a desk top study of current knowledge and carry out an on-ground survey of the river corridor.

The Pallinup River and Beaufort Inlet at a glance

Catchment area	4800 square kilometres (km^2)
Length of the main channel	200 kilometres (km)
Estimated mean annual flow	25 000 Megalitres (Ml)
Discharge point	Beaufort Inlet
Nutrient levels in river	Nitrogen and phosphorus high
pH in river	Median 8.4, low variability
Dissolved oxygen levels	Generally adequate
Temperature of river	10 – 24°C, a warm system
Nutrient levels in estuary	High, regularly eutrophic
River salinity	High at low flow, brackish, sometimes fresh during floods
Distance of estuary from Albany	110 kilometres to the NW
Area of estuary	6.5 square kilometres
Length of estuary	14 kilometres
Volume of estuary	6 500 000 Megalitres for an average depth of one metre
Estuary vegetation	Lower: Good condition, upper: disturbance on east bank

The short term goals for these studies were:

To determine the condition of the river floodway by:

- describing the form of the river and its characteristic features;
- assessing the state of the over storey, understorey and species regeneration;
- determining the extent of actual or potential threats of weeds;
- identifying erosion and sedimentation hot spots and their likely causes;
- evaluating the status of large woody debris (fallen timber) and its function in the river; and
- identifying the character of and threats to the river pools.

To define the river process and management issues by:

- determining the relative importance of degradation issues;
- evaluating current discharge and water quality data;
- comparing the impacts of uncontrolled grazing and the absence of stock;
- assessing the adequacy of existing fencing to control stock access;
- determining the relevance of the Unallocated Crown Land boundary;
- forecasting the future impact of the inevitable major floods;
- identifying opportunities for agricultural diversification that are 'river friendly';
- capturing historical river information to understand the changes that are taking place;
- assessing risks to river crossings; and
- identifying opportunities to protect and rehabilitate riparian areas of special value.

To raise community appreciation and awareness of the Pallinup River by:

- summarising the findings of the survey in a State of the Pallinup River report;
- revealing the unique and picturesque features of the river;
- encouraging discussion about the future of the river;
- considering the social value of the river as a 'natural asset' worth protecting;
- linking the Pallinup River, Beaufort Inlet and farming activity with the national; and
- International recognition of the Fitzgerald Biosphere and the Stirling Ranges as having world heritage value.

1.3 Background to the study

A priority strategy of the South Coast Regional Land and Water Care Strategy (SCRIPT, 1997) is to "develop a strategic network of healthy, well-vegetated riparian corridors and improve and protect the water quality of rivers, estuaries and wetlands". In response, the Water and Rivers Commission initiated a project to develop River Action Plans for specific South Coast catchments, funded by the Natural Heritage Trust and the Water and Rivers Commission.

The Commission targeted the Pallinup River system as it has important ecological, economic and cultural and historical values. The Gnowangerup LCDC felt that little was known about the Pallinup River. Information was scattered and kept separately by various agencies and community groups. The State of the River report is an opportunity to collate relevant information pertaining to the river, in one document.

The waterways of a catchment can be thought of as a 'thermometer' of the quality of land management and landuse being undertaken along its fringe. Changes can be subtle – slowly taking place over many decades, or they can be catastrophic – happening within a few days, usually as a result of one of those rare, but inevitable extreme floods. Over time, the next generation have less first hand knowledge of the original condition of the river and may accept the existing situation as

normal. An interesting analogy can be found in Ernestine Hill's book, Water into Gold, published in 1937. It deals with the opening up of the Murray Darling River system to economic development. Between the glowing descriptions of those efforts in that optimistic age, are observations by people living along the river that all might not be as rosy as first thought. The author records observations that we now know were the precursor to the difficult environmental and economic issues that are a major concern today, salinity, deteriorating water quality, degrading riverbanks and excess water extraction. Although the Pallinup is a small river system compared with the Murray Darling, it can likewise fall victim to the same neglect of its environmental and social values.

The Pallinup River is showing signs of ongoing degradation including loss of riparian vegetation, erosion, sedimentation and weed invasion. Floods have significantly disturbed the flood plain and the pools. The disturbances include the formation of secondary channels, head-cuts and severe erosion across farmland. In addition, catchment changes including rising groundwater levels and nutrients draining from the catchment, are impacting on the Beaufort Inlet. There are however considerable amounts of on-ground works that have been completed along the waterways including fencing, revegetation, construction of creek crossings and erosion control. Although, there are still sections where on-ground works are required to ensure the long-term protection of the river.

The State of the River report aims to encourage a more coordinated approach to protect the Pallinup River. The assessment information contained in the report is important for catchment planning activities to ensure that the protection of the river and estuary is linked to whole-of-catchment natural resource management issues.

The objectives focus on the Pallinup River, its tributaries, wetlands and the estuary, and the requirements for successful future management. A management plan needs to recognise the issues confronting the waterways and outline a process for accomplishing, monitoring and evaluating them. It should also define what constitutes, 'Best Management Practices' (BMPs) in the catchment, for environmental, social and economic benefit.

A more detailed plan should include mapping ground works that have been completed and identifying specific management recommendations for future on-ground restoration works at a local and catchment scale. It should be relevant to all stakeholders including the local authorities, State agencies and community groups, as well as landholders.

This report is intended to encourage a more coordinated approach to protect the Pallinup River. Recognising the difference between the 'activity of planning' and 'planning the activity' is important to ensure that time, effort and money are not wasted and that the work can be extended well into the future.

An Action Plan addresses the condition of the riparian vegetation, weed location and landscape characteristics outlined in this report. The 'State of the Pallinup River' report is, in one sense, a forerunner of a fully-fledged River Action Plan, however, an effective plan is best developed by the catchment community.

1.4 River and estuary values and issues

"If you've got something as outstanding as the Pallinup River, even in the hard times it gives you something to take your focus off the hard times and sort yourself out a bit. I'm sure that when you've spent a day being close to something that's quite pristine and beautiful the problems diminish down to about a tenth of what they were. There's no two ways about it in my mind, areas like this really need to be preserved simply for the sake of our mental health".

Source: Charlie Hick,
Stories of the Beaufort Inlet (WRC, 2002)

Apart from a few bridges and river crossings, the Pallinup River is largely hidden from those who do not live along its banks. Occasionally, when driving over a bridge, a visitor may get a quick glance at the Pallinup, often when the flow is low and the channel sediments are exposed.

Because an overall view of the Pallinup river is hard to achieve, a comprehensive river management plan has not been developed. However the associated changes to the picturesque Beaufort Inlet have not gone unnoticed and this has led to efforts to gain a better understanding of what is happening in the river environment.

Over the years, many people have visited the Inlet to relax on its tranquil, virtually undisturbed banks. It has been famous for camping and fishing, and provided a place to relax and enjoy a truly unique part of the world. To date there is evidence of significant blooms of microscopic organisms known as phytoplankton and pico-plankton. Low oxygen conditions in the water column are known to have caused large numbers of fish to die in what is more commonly known as a 'fish kill'. It is easy to overlook that the transformed catchment upstream of this pristine environment may be having a detrimental effect on the long-term quality of the estuary.

"The last time I was there I was pretty disgusted. It really is degraded and I really don't know why because its not as though there is a lot of people pressure there...Every time that we had a flood further up river there seemed to be a noticeable burden of silt going into the river."

Source: Bill Moir,
Stories of the Beaufort Inlet (WRC, 2002)

The observed degradation of the Pallinup River system is the result of relatively rapid land clearing within the Pallinup catchment. Early pioneers and the Government at the time were unaware of the long-term effects of their actions. Some of their descendants now work this land, and are witnessing the gradual change in the river condition. They would not be aware of how the Pallinup once looked, and it would be easy for them to accept the current state of the river as acceptable.

The erosion of foreshores and invasion of weeds and feral animals are some of the more pressing issues along the river and the inlet. Water quality in our rivers is declining with many streams carrying excessive loads of nutrients, and algae is growing prolifically in some reaches. Despite these aspects of the impact of development, the Pallinup River has many inherent values. These are summarised in the following table.

The scenic and well-vegetated lower reaches of the Pallinup have potential for attracting the attention of travellers who have an interest in the environment. The opportunities may take the form of walk or hiking trails, canoeing, scenic vantage points, unique flora, bush tucker, locations of historical and cultural importance. In addition, rising awareness of landcare issues and the future of our agricultural areas means that the Pallinup is in a good position to demonstrate a wide variety of best management practices into the future. This will become important if regional branding of products, linked to good environmental management, becomes an attraction for marketing in the future.

Aesthetics

The Pallinup already has an advantage with its backdrop being the spectacular Stirling Ranges. Visitors from interstate and overseas have remarked that this is a magnificent and unique area.

The current information suggests that the Pallinup River is at a turning point where a practical and ongoing management plan has the potential to not only protect areas of natural beauty, but to lead to an aesthetically pleasing farming environment.

Alternatively, neglect will inevitably lead to a- more degraded landscape with little appeal to travellers or residents.

The Water and Rivers Commission is responsible for coordinating the management of the State's waterways. The Commission, in partnership with local community groups, initiated the project to assist with the development of a River Action Plan. The Natural Heritage Trust funded this initiative.

Table of values

Uniqueness	Economic	Special features	Cultural	Opportunities
The river is a naturally saline system with low flows often having a salinity close to that of seawater.	Economic activity in the catchment is dominated by traditional farming ventures, sheep and grain cropping.	The catchment on occasion receives snowmelt water from the Stirling Range making it unusual for Western Australia.	The river was a significant dweling place for aboriginal peoples and an important thoroughfare between the inland and coastal areas.	Eco-tourism and recreation in the scenic rocky reaches or the lower river of the Beaufort Inlet.
Beaufort Inlet is on the Register of the National Estate Database as it is located in one of the world's most outstanding botanical areas.	Commercial fishing occurs in Beaufort Inlet, but some on farm aquaculture ventures are being trialed.	Picturesque dolerite cliffs at Boxwood Hill and spongolite cliffs at Beaufort Inlet.	The Beaufort Inlet is a popular camping and fishing area requiring a sound management plan if its values are to be adequately protected.	The river channel appears to be robust and should respond well to erosion and sediment control through a management protection plan. This would favour the natural re-excavation of the in-filled pools.
There are known rare and endangered native plant species along the river valley, contributing to its biodiversity value.	There are three towns within the catchment and two near the catchment divide.	Freshwater springs and pools in the Pallinup floodway, alongside the normally highly salne river flow.	Old staging post ruins near the Magitup river crossing.	

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2 Catchment and community context

Three quarters of the Beaufort Inlet catchment is in the Pallinup-North Stirlings sub-region. About 85% of the overall Pallinup catchment itself is cleared, mainly in the upper catchment. The Pallinup River is one of the longer rivers in the South Coast Region. The river is a naturally saline system, but there has been some speculation that the general salinity levels have increased over time. The extensive clearing has also exposed the sandy topsoils that are being eroded, leading to the sedimentation of the river. Following the flood in January 1982, an estimated 100 000 tonnes of sediment was dumped into the Beaufort Inlet. Nutrient pollution is widespread, which is a suspected consequence of the extensive use of fertiliser.

2.1 Physiography

The landscape of the Pallinup River catchment is extremely worn down, in a geological sense, however slight tilting, due to large-scale movement of the continental margin on the southern coastline, has resulted in short southward flowing rivers with some rejuvenated head-ward erosion. The waterways of the upper Warperup Creek are a good example. The average bed slope of the river is gentle, being approximately 2.8 metres of fall per kilometre, although there are shorter reaches that are quite steep, with up to 11 metres of fall per kilometre.

The most obvious feature in the landscape is the precipitous Stirling Range that dominates the southern boundary watershed. Elsewhere the landscape is gently undulating, with low hills where the bedrock, mainly granite-gneiss, has been exposed. The lower reaches of the Pallinup have incised into this basement rock forming steeper sided valleys. The river empties into the Beaufort Inlet, which is closed to the sea by a sand bar, for most of the year.

2.2 Geology

The bulk of the Pallinup River catchment lies on the old continental rocks of the Yilgarn Craton. The lower reaches cut into what is known as the Biranup Complex. The complex consists of deformed, banded gneiss (rock of a similar composition to granite, but modified by heat and pressure). Good examples of this rock can be seen in the small quarry alongside the Hassell Highway about a kilometre west of the Marra Bridge.

The Stirling Range Formation, overlying or thrust against the Archaean Yilgarn Craton, is mildly folded and thrusted (Smith, 1997). The rocks of the Stirling Ranges consist of sandstone, quartzite and shale. Recently, traces of tracks left by ancient small creatures have been found in these rocks. Dolerite dykes are common across the catchment on the Yilgarn Craton, and are referred to as the Gnowangerup dyke swarm (Myers, 1995). The major east to north-easterly trending dykes have a fine-grained igneous texture. The dykes dip steeply to the south and vary from several metres to tens of metres thick (Dodson, 1997).

The soft sedimentary rock found outcropping along the South Coast is commonly called the Pallinup siltstone. A good example of this can be seen in the high and fragile cliffs adjacent to Beaufort Inlet. Spongolite, a similarly friable rock, formed from marine sponges, can also occur in conjunction with the Pallinup siltstone.

A more detailed description and map of the geology of the area can be obtained from the Department of Minerals and Petroleum Resources. A series of explanatory notes was produced by the Geological Survey of Western Australia. The relevant notes are Mount Barker-Albany SI/50-11, 15 and Bremer Bay SI/50-12.

2.3 Soils and hydrogeology

For a detailed summary of the soils and hydrogeology of the catchment refer to the Department of Agriculture, which is a custodian of relevant data sets. Information may also be available through the Rapid Catchment Appraisal or RCA report being prepared by the Department of Agriculture in 2003.

2.4 Climate and rainfall

The Pallinup River catchment is hot and mostly dry in summer, except for summer storms and very occasionally, intense cyclone activity, that may advance as far as the South Coast. The climate is of a Mediterranean type. Average temperatures generally

vary from approximately 10°C in mid winter to over 30°C in summer. At times the winter temperature reaches as low as 2°C and in summer as high as the mid forties. Average annual rainfall is 370 millimeters (mm), varying from 360 mm in the north-east to 500 mm in the south-west coastal parts. The average annual Class A pan evaporation varies from 1720 mm in the north-west to 1580 mm in the south-east. The Stirling Range has a definite influence on the average rainfall to the immediate north, creating a minor rain shadow, effectively drawing the 400 mm rainfall boundary southward. Immediately south of the ranges the average rainfall is approximately 500 mm. Intense summer storms have, in recent decades, caused powerful floods that have had a significant impact on the river floodway.

2.5 Wetlands

(Information from Kevin Hopkinson, Wetlands Officer, Water and Rivers Commission)

Wetlands are an integral part of the catchment hydrological system and although they are not the focus of this report, their contribution to the ecological health and diversity of the catchment is very important.

In the Pallinup-Stirlings subregion, there is a broad system of lakes north-west of the Stirling Range including a series of floodplain wetlands associated with the Pallinup River. The Middle and Upper Pallinup Wetland group includes wetlands on broad floodplains on the middle and lower Pallinup River and major tributaries. A narrow corridor of remnant vegetation occupies the valley floor of the river in many sections, but in others the river is heavily salt affected and eroded, placing the wetlands in the degraded C or D classes.

The North Stirlings Wetland Group includes large areas of internal drainage in the south-west corner of the Pallinup catchment, known as the Balicup wetland suite. This group of wetlands are remnants of an ancient watercourse believed to be a former channel of the Pallinup River. Rising sea levels filled the valley with marine sediments and created the chain of basins found today. The wetlands include many, mainly dry and intermittent, lakes and some permanent lakes including Tom South, Munrillup, Horse Shoe, Balicup, Anderson, Cheepanup, Camel and Salt lakes.

Nearly all of the private land is cleared with most of the lakes retaining only a degraded narrow fringe of remnant bush. As a result, most wetlands range between lower C and D grade with only those within or on the edge of the more substantial nature reserves classified B grade (including Anderson and Camel).

The Balicup Lake system is, however, extremely significant and considered to be of national importance, and is listed in the National Directory of Important Wetlands in Australia. Lakes Cranbrook, Anderson and Camel are monitored by the Department of Conservation and Land Management. All three are hypersaline but vary in their level of flooding and extent of fringing vegetation. Most wetlands in the catchment are at risk from salinity and waterlogging.

The Kojaneerup suite, on the west side of the lower Pallinup catchment, is a type of wetland where the watershed is not as clearly defined and the boundary wetlands are likely to be more strongly linked to the Kalgan River catchment than the Pallinup. Several of the larger (unnamed) wetlands of this suite are considered regionally significant, due to the valuable fringing remnant vegetation, habitat and refuge they provide for water birds and other fauna.

These wetlands are large, open-saltpans that lie south/south-west of the Stirling Range and are fed by surface water. They have formed on alluvial fans at the base of the ranges and have small drainage lines flowing into them from the range lowlands. Surrounding vegetation is commonly samphire, sedgelands, salt paperbark (*Melaleuca cuticularis*) and yate (*Eucalyptus occidentalis*). Water quality ranges from naturally brackish to increasingly saline, due mainly to saline groundwater discharge. A unique feature of these systems is the gypsum sediments that have precipitated from the groundwater and underlie the basin.

2.6 Aboriginal heritage

On the scale of the history of the western world, the settlement of the Pallinup catchment, by European immigrants, is a very recent event. The Aboriginal settlement is vastly older though much of the detail is lost in the mists of time and only sensed through brief notes and jottings of early pioneers and the recollections of events and stories passed down to descendants of those original inhabitants.

Here and there are subtle reminders that indicate people have lived in the landscape for centuries, but perceiving these signs usually requires a trained eye or knowledge handed down from parents to children. The meaning of many place names is also obscure though some are generally accepted. For example 'Martinup' refers to the thigh bone of a kangaroo, a cut that was considered a great delicacy. 'Ongerup' is the place of the young kangaroo" (from *"The fruit of the country"*, Merle Bignell). Aboriginal people referred to the lower river as 'Marra', meaning 'hand' (from comments by Graham Miniter), reflecting the branching pattern of the major tributaries such as the Corackerup.

The notes of John Eyre, a young European explorer, and later Ethel Hassell, an early settler in the Jerramungup area, suggest a dynamic culture existed along the South Coast prior to the arrival of settlers. The Aboriginal communities of the South Coast built no large monuments, paved no roads and forged no machinery. Their consumer goods were sourced from the local environment and were quickly absorbed back into the landscape – unlike our plastic bags, bottles and aluminum cans. There were no weeds, nor use of artificial soil conditioners or pesticides. Their use and management of the natural environment was sustainable. The climate and vegetation dictated what the environment looked like making any change relatively slow.

For these reasons the indigenous culture was considered, by many settlers, to be underdeveloped, even non-existent, simply a hand-to-mouth issue of survival. More recently it has been revealed that the richness of the aboriginal culture was in its relationships, not its edifices or by-products. The sadness of the culture was its fragility in the face of a more aggressive approach to the subjugation of the landscape to other ideals. For this reason the signs and places of the old culture are a precious and valuable heritage resource, worthy of respect and protection. Many of these places are associated with the rivers, creeks and wetlands of the catchment.

It has been recorded that the Pallinup river and the Inlet supported important camping grounds and afforded movement between the inland areas and the coast. The river was the old 'highway'. The area between the Marra Bridge and the estuary was an important camping and fishing ground (from comments by Graham Miniter) Despite the river being saline there were, and still are, a number of water holes along the floodway that supplied drinkable water. Some of these springs and soaks – especially in the upper catchment – have since become salty, but others still contain fresh water.

2.7 European heritage – first impressions

Edward John Eyre walked to Albany along the South Coast in the winter of 1841. He was twenty-six years old and was accompanied by a young Aboriginal named Wylie. He encountered the Beaufort Inlet and Pallinup River on the third of July 1841. He states in his journal of the expedition:

"July 3: Upon commencing our journey today I found our route was much intersected by deep ravines and gorges, all trending to the larger valley below, and where I had no doubt a large chain of ponds, and probably much good land would have been found.

After proceeding four miles and a half, we were stopped by a large salt-water river (probably the mid to upper Beaufort Inlet) which seemed to be very deep below where we struck it and trended towards a bight of the coast where it appeared to form a junction with the sea. Many oysters and cockles were on its shore.

This was the largest river we had yet come to and it gave us much trouble to cross it, for wherever it appeared fordable, the bed was so soft and muddy, that we dared not venture to take our horses into it. By tracing it upwards for eight miles we at last found a rocky shelf extending across, by which we crossed. At the point where we crossed, it had become only a narrow rocky channel; but there was a strong stream running and I have no doubt, higher up the water might probably have been quite fresh. Its waters flowed from a direction nearly of west-northwest and appeared to emanate from the high rugged ranges behind King George Sound.

The country about the lower or broad part of the river as far as I traced it, was rocky and bad; but higher up, there was a good deal of grass, and the land appeared improving. In the distance the hills seemed rocky and more grassy and might probably afford fair runs for sheep. Upon the banks of the river were a few casuarinae and more of the tea-tree and bastard gums, than we had seen before upon any other watercourse".

The Western Australian Surveyor General, Septimus Roe had explored the upper Pallinup River in the mid 1830s. On the first expedition he was accompanied by the first Governor, James Stirling. Merle Bignell records in "*The Fruit of the Country*", that the party encountered plentiful grassy plains, but that the river was dry (November) with occasional pools of extremely salty water. For this reason the river was called the Salt River for many years.

2.8 Land tenure and landuse

There was no rapid settlement of the South Coast after Eyres reconnaissance and by the late 1800s the region was only sparsely inhabited by newcomers. By the first two decades of the twentieth century, land allotments had been surveyed in the upper catchment and the process of clearing the natural vegetation started. In earlier years sandalwood cutters operated along the river. A few trees can still be found, here and there. By 1995 the estimated population of the Cranbrook, Gnowangerup and Tambellup Shires was 3648.

During the early 1900s surveyors divided the land and a crown land reserve was established along the river floodway. Although this boundary was fenced in many reaches, subsequent floods forced landholders to shift their fences back to higher ground. Some of the old 6"x 6" wooden boundary marker posts can still be found along the river.

Much of the upper catchment was cleared by the 1950s. Sheep, cattle and grain crops formed the main farming activities, and still do today. Canola is a more recent addition to the agricultural scene. Some landholders are taking a long-term view and experimenting with re-establishing sandalwood trees as a commercial venture. It is in this context that the discussions about river management need to stress the need for achieving and maintaining stability in the riparian environment of the river and its tributaries. The river drains the landscape, but it is not just a drain.

3 State of the Pallinup River

3.1 The geomorphology of the river

The geomphological structure of the Pallinup River is described in this section. The geomophology deals with the actual structure, shape and development of the river valley and channel, through erosion and sedimentation processes. The survey showed, that overall the channel structure is stable, but the smaller scale features of ecological significance have been degraded. For example, in many reaches the riparian zone is highly degraded, bare, weed and sediment filled. There are segments of the channel where the foreshore vegetation is in B Grade condition with a few reaches that rate an A (see foreshore vegetation condition for an explanation of these grades). The indications suggest that the river could benefit by better protection and management of the floodway and that it should respond well to such measures. Sheep and cattle have taken a heavy toll on the fragile native vegetation inside and alongside the main channel. The fact that the river is a saline system does not mean that it is of no environmental value. The nature of the waters flowing along the river is not the only factor that determines the health of the river corridor.

3.2 The river

3.2.1 Floodway structure and stability

This section describes the physical environment of the Pallinup River floodway. There are four factors that are relevant to the future management of the river, these are:

1. The structure of the floodway.
2. The way the river has responded to past catchment development.
3. Community expectations and demands placed on the river environment.
4. Longer-term climatic changes, which will play an extremely important role in determining the long-term hydrological changes.

The Pallinup River has not been actively interfered with. Engineered areas are mostly crossings, although a few reaches, with wider floodplains, have artificial drains in place and some small tributaries have been

Overall condition summary

Structural feature	Upper reaches	Lower reaches
Bed	Clay, periodic rock bars.	Extensive rocky pavement.
Meanders	Stationary, destabilised chutes on bends.	Stationary.
Pools	Mostly infilled with sediment, current depth perhaps 20–25% of former depth. Fresh sediment slugs common at the upper end of pools.	Increase in the number of shallow rocky-based pools. Scoured pools appear generally deeper than in the upper reaches (~ 50% of former depth).
Floodway banks	Little understorey, healthy mature sheoaks, but not much regeneration. Some large flood scours.	Steeper valley sides, extensive sheoak growth, young and mature, oxalis extensive. Old and some large flood scours are more common than upstream.
Low flow channel	Eroding banks prevalent, fallen trees, banks of woody debris.	Large revegetated sediment plumes with some long sediment slugs moving slowly downstream.
Headcuts (waterfalls)	Uncommon, occasional incised slots in clay bed.	Uncommon in alluvial bed, with rocky rapids becoming more common downstream.
Minor tributaries	Generally degraded ditches. The junction with larger tributaries generally degraded.	Contributing sediment (probably proportional to catchment area) No obvious hot spots.
River crossings	Generally well sited and designed.	Generally well sited and designed, some abandoned crossings.

enlarged. The major crossings are bridges designed to stand above the peak heights of major floods. Most other crossings are low and follow the cross-sectional shape quite well, making them less of a liability during floods. While fringing vegetation still exists, it is poor in native understorey cover and high in annual weeds and grasses. This means that the soil surface is fragile and easily moved by flood flow. This report suggests that river managers give serious thought to the future condition of the Pallinup and take up opportunities to enhance beneficial natural processes that shape the river.

The evidence that has been collected so far, also suggests that the Pallinup River has been excessively and unnecessarily degraded over a relatively short space of time, less than 100 years. It is suspected that following widespread clearing of the catchment and the reduction of natural vegetation in the floodway, the streams being highly susceptible to massive erosion episodes as soon as significant floods occurred. Such a flood occurred in 1955 and appears to have been the main culprit for major modification to the river channel. The removal of vegetation from a river or creek often leads to increased erosion. Observations on other rivers on the South Coast suggest that the scale of damage caused by these large floods would have been much less if the reparian zone had remained uncleared and ungrazed. The impacts are still evident today and the signs suggest that degradation is ongoing.

There are, however, some encouraging signs; first, many landowners are concerned about the future of the river and would like to see it remain as is, or improved. Secondly the remaining foreshore tree cover is generally healthy, with signs that, given an opportunity, regeneration of the major tree species can occur. Thirdly a number of riparian areas are still in very good condition, although these are mainly in the lower, rockier, reaches.

Less favourable signs suggest that the river may be unlikely to stay as it is, although some pockets will be more persistent than others. For example, sediment movement into pools, bank erosion, weed incursion and feral animals are putting pressure on the remaining areas of native vegetation and the aquatic environment.

Improvements in the quality of vegetation along the river will also benefit the Beaufort Inlet which receives the waters of the Pallinup, and is in one sense still a part of the river. This diverse and intriguing estuary supports large numbers of water birds and aquatic fauna. The Beaufort is however experiencing large sediment influxes and nutrient enrichment, with corresponding eutrophication of its waters.

The assessment method

Approximately 50 km of the upper reaches of the river (from the junction with the Martinup Creek to Chester Pass Road) were assessed, on the ground, between mid October and early November, 2001. Before this, aerial photographs were used to identify key locations and features. Foreshore condition information was gathered, but closer attention was paid to the channel structure and its stability, than for the rockier lower half of the river.

The information collected during this part of the assessment, included the basic 'form' of the river, the condition of the foreshore vegetation, weed infestation, the state of the river channel as well as the amount of foreshore fencing protection along the river corridor.

Photographic information was gathered during the course of the assessment and now provides a unique historical record of the state of the Pallinup River. This will enable assertions about the progress and health of the river to be more objectively assessed in future decades. The photographs were also scanned and stored electronically on CD. Accurate GPS location references for each photo point ensure that the sites can be relocated to within 5 metres.

Areas of remnant riparian vegetation that were in very good condition (refer to the foreshore condition assessment) were observed and specific native species information was collected. Historical information also has been collected as well as general points of interest.

No detailed erosion and sedimentation audit was undertaken for the lower half of the river, however general observations were made relating to channel form and environmental issues. A sequential photographic record of the dominant channel was made for one section of about 12 km in length, with GPS reference and other photographs taken by property. These capture the general nature of the reaches. Much of the channel length is rocky and therefore has a stable base.

Overall river style of the Pallinup River

The well-defined main channel of the Pallinup River is about 180 km long, stretching from near Broomehill at the top end to Beaufort Inlet, which starts about 12 km upstream from the sand bar separating it from the ocean. For convenience, the Lower Pallinup River (some 85 km) was defined as the river downstream of Chester Pass Road and the Upper Pallinup the part extending upstream of Chester Pass Road. A ground survey recorded the structural features of the lower river and was carried out in September-October 2000 and the upper parts were assessed in October-November 2001.

The surveyed part of the upper river extended from the Gnowangerup-Tambellup Road to Chester Pass Road. Along this section and as far as O'Meehans Road, downstream the river has a relatively constant and, low average slope, of 1.25 m of fall per kilometre. The channel structure is uniform, with many medium to large river pools and rocky outcrops. The broader floodway often has a distinct meandering, low flow channel contained within its banks. In a number of places it is easy to be fooled into considering that this low flow channel is the river proper, but it only handles annual floods. Significant tributaries are the Warperup and Jackitup Creeks.

The river below O'Meehans Road has three zones of varying average slope, determined by the coastal geology. Some valley sections are steep sided with gorge-like features in places, but there are also reaches that are similar to those found along the upper parts of the river. There are also several significant tributaries including the Peenabup and Corackerup creeks.

Trickles and floods

For much of the year the flow in the riverbed is not much more than a small stream of salty water. Pools provide the dominant water containment areas in the floodway, at any particular time.

The stream gauging record (from near Chillinup) does not reveal which parts of the catchment contributed most strongly to the river flow during high discharge periods. For example during the recent, December 2001, flood there was no evidence of high water levels in the channel upstream of Jackitup Creek, but significant volumes had entered the river from tributaries downstream, filling the floodway. This was consistent with the spatial distribution of the main storm event across Gnowangerup, Jerramungup, Ongerup and Wellstead, but only the resulting high flows were gauged at Chillinup.

The flood of 1955

The flood of 1955 is still recalled by landowners along the river and was perhaps the most significant flood to impact on the structure of the Pallinup. Bill Moir provided useful insights about the changes that have taken place along the river. According to Bill, the upper catchment, around Tambellup contributed more of the flood waters in 1955 than the coastal tributaries, but the reverse was true of the 1982 flood event. The rainfall

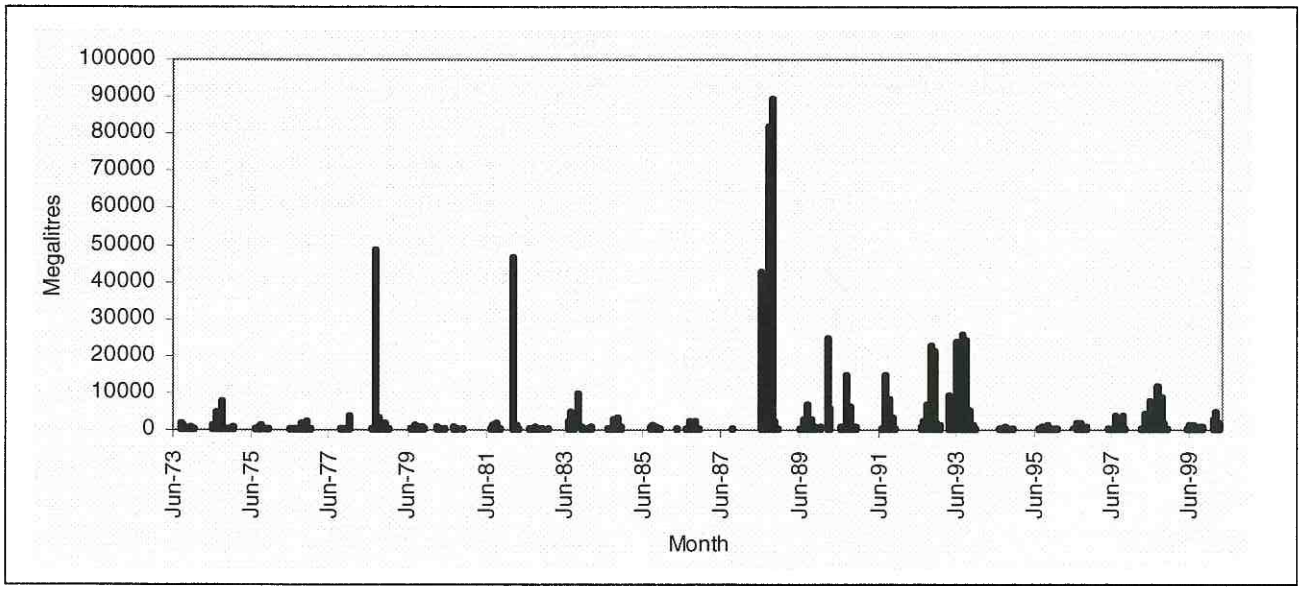


Figure 2. Monthly discharge at the Bull Crossing gauging site, below the Chillinup Road crossing, between 1973–1996

distribution isohyets show that in 1955 very high falls occurred over the entire catchment, but were actually greater nearer the coast. However as these areas were largely uncleared and the upper catchment cleared it is indeed likely that the upper catchment contributed the larger part of the flow.

The following rainfall figures were recorded near the Tambellup-Gnowangerup Road crossing as follows.

6 February 1955	63 pts (16 mm)
15-18 February 1955	656 pts (167 mm)

In 1955 there were two interesting rainfall events in the South West, but only five gauging stations with any record, the highest being on the Murray and Warren rivers.

The first event was cyclonic, covering the whole of the South West from Geraldton to Collie and to Esperance. The dates were 14-18 Feb 1955, in accord with the above figures for the Pallinup. The rainfall across the South West was substantial with the heaviest being at Marradong, which recorded 268 mm, but there were many over 100 mm.

The second event was a winter flood in the lower South West that was not a single event, but continuous rain – effectively for weeks on end. The peak seems to have been on 23 August 1955, but the two interesting periods of rain seem to be, the seven days from 17-23 August and thirteen days, 11-23 August. This certainly is not how we generally think of floods (i.e. usually a 72 hr event at worst). It implies that weeks of continuous light rain can cause floods just as well as a single three-day event.

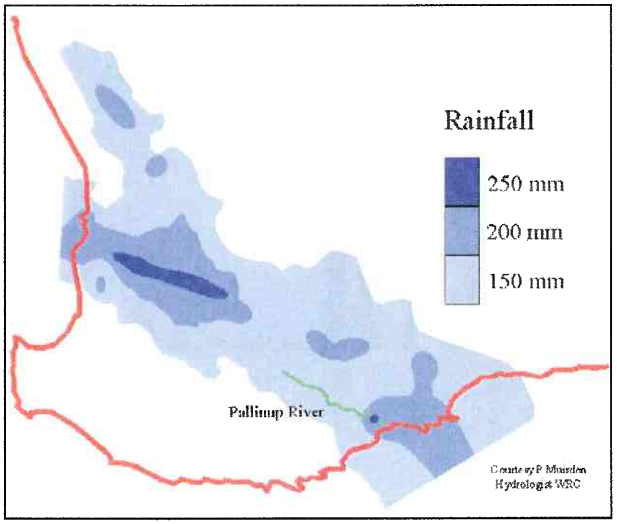


Figure 3. Rainfall Isohyets for the SW 14-18 February 1955

By comparison, Margaret River had 126 mm over seven days and 192 mm over thirteen days, but only 62 mm maximum in a three-day period. Below are rainfall figures for other towns on the South Coast.

	February (14-18)	August (17-23)
Katanning	183	66
Jerramungup	198	38
Esperance	77	53

(Information courtesy of Peter Muirden, Hydrologist WRC)

The flood of 1982

This flood, although not registering as a high peak discharge event on the hydrograph record shown in figure 2, was also considered significant. The total monthly discharge does not reveal the high water mark or the short-term intensity of the flood event. On the other hand the floods that occurred in 1988 contributed large monthly discharges, suggesting a longer duration for the higher flows.

Michael Lance supplied the following rainfall data, recorded near the Tambellup- Gnowangerup Road crossing;

21 – 22nd January 1982 850 pts (216 mm)

Bill and Amelia Moir recorded the following rainfall at their farm "*Salisbury*".

21 – 22nd 1982 655 pts (163 mm)

The Upper Pallinup River – the nature of the river

The most obvious feature of the Upper Pallinup River is its broad relatively shallow floodway, containing a distinct low flow channel. Periodically the low flow channel widens into a broad pool. Many of these pools are believed to have been much deeper in the past, but infilling with sediment has made them quite shallow, typically less than a metre deep.

At intervals the floodway widens further and floodwaters can spill out to hundreds of metres in width. These areas in which streamline fences are at risk and major erosion scour is a possibility, have distinct management requirements. The ultimate management goal in these areas is to allow floodwaters to pass through, but to keep the soil and vegetation intact.

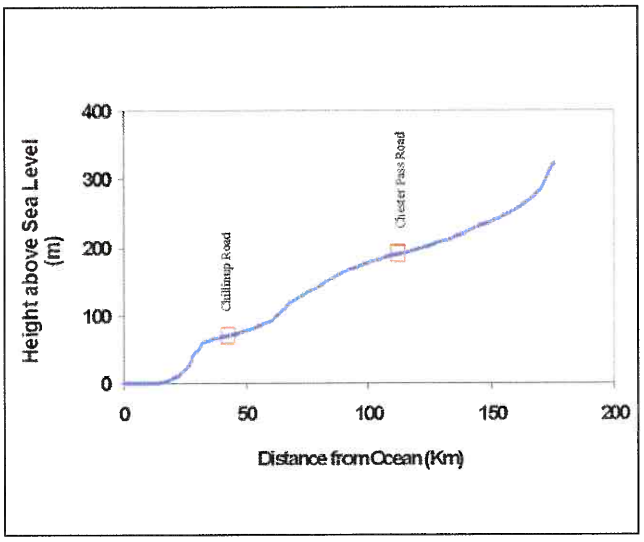


Figure 4. The longitudinal altitude profile of the bed of the Pallinup River

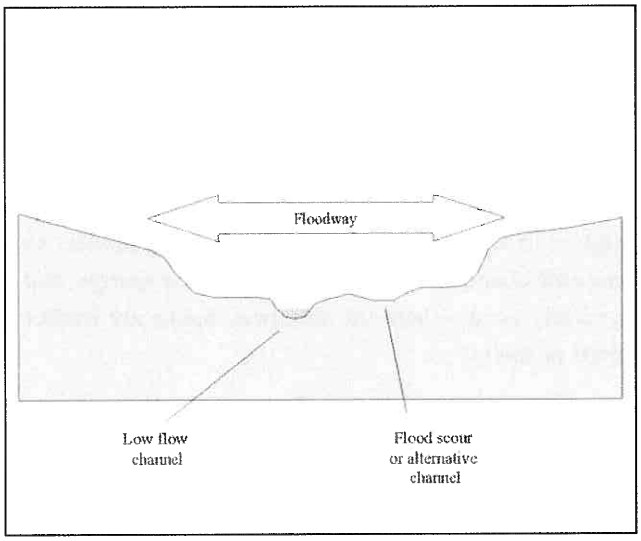


Figure 5. Stylised cross section of the Pallinup River floodway

Figure 6. The typical broad floodway with low flow channel

Figure 7. A more distinct low flow channel lies within the main floodway with sediment deposits and samphire regeneration

The floodway topography viewed from its bank, is determined by the river planform, which is in turn determined by the depth to bedrock, the weathering profile and the long-term flow regime. The planform at this scale, varies from a sinuous single channel to a single channel with a secondary floodway thatis often higher in the floodway, broader and shallower, to multiple channels (two or three) which are narrow, and typically occur where the floodway banks are further apart or lower.

The plan-form of the Pallinup River can be termed sinuous (winding) and passively meandering (pers. comm. Clare Taylor). This means that the broad floodway channel weaves its way through the landscape with few tightly looping bends. The bends that exist are relatively stable in terms of their location and are not aggressively migrating across the landscape over time, as for some rivers. The sinuosity appears to be strongly influenced by the local geology. For example, bends occur where the bedrock outcrops. Rocky outcrops become more frequent and extensive in the downstream direction. A consolidated clay base is also exposed quite frequently.

Within the broader floodway, the low flow channel is distinct and generally sinuous, although periodically it becomes more highly meandering (looping). Its size varies considerably from 3–15 m in width. In a few places this dominant channel is well incised (deepened). In places there is also evidence of older (paleo) channels, which may still convey flows during major floods.

Depositional features generally consist of fine to coarse clean sand sheets on the floodplain, irregular hummocks in alternate channels, plugs at the upstream end of pools and lateral sand bars in the pools.

The evidence suggests that massive quantities of sediment have been introduced into the system in the recent past and that this is now a significant influence on channel form at the reach scale. The loss of deep pools will also have had a major influence on the type and quantity of aquatic plants and animals present.

River pools

An important feature of the river is its sequence of pools. These are broad, open reaches 150 – 1500 m in length and up to 50 m in width. At the time of the survey, the river was at base flow and pools were quite shallow, varying in depth between a half and two metres, but generally less than 1 m deep. The bed appeared to consist of loosely deposited sediments forming a grey ooze in the top layers. Distinct sediment plumes entering at the upstream ends of the pools are common (Figure 8 opposite), but can also be found along the length of pools.

Some landowners commented that they could remember or had heard that particular pools were originally perhaps five or more metres deep. As a comparison pools in well vegetated reaches of the Kalgan and Oldfield rivers have been plumbed to depths of 7 m and in one case 11 mThis page has been left blank intentionally (unusual though). An experiment to probe the sediment depth, along a cross section of one medium-sized pool at low water level, revealed a layer of soft sediment over two m deep overlying a firm base. The pool could have regularly contained water to a depth of 3 – 4 metres. From a habitat perspective the pools are particularly significant and can be thought of as summer refuges for aquatic and terrestrial fauna. Water salinity at low flow is high (cf seawater), but after storm flooding this can be greatly reduced for a period of time.

Older sheoak trees line the pool banks, enhancing the canal-like appearance of the channel. In places sediment infilling has caused the pool to completely disappear and allowed the bed to become colonised with samphires and young sheoaks. Sheoak saplings, up to 1.5 m in height, show signs of having been heavily grazed by stock and kangaroos.

River pool spacing along the Pallinup appears to have a pattern to it, not unlike traffic bunching up along a highway. The reason for this is uncertain, but it is likely to reflect the underlying geological features influencing the river flow. Figure 9 opposite shows the number and approximate spacing of the most significant river pools, between Beaufort Inlet and the Gnowangerup-Tambellup Road. By comparison the Oldfield river has a quite different distribution, with major pools denser in the middle reaches. Approximately one third of the length of the Pallinup main channel consists of these pools. Several pools are accompanied by a secondary channel, this suggests that their occurrence is not just dependent on confined floodway flow. Focussed flow through deeper and narrower sections produces higher stream power and therefore the capacity to create a

Figure 8. A medium-sized pool on the Pallinup showing an encroaching sediment plume at the upper end

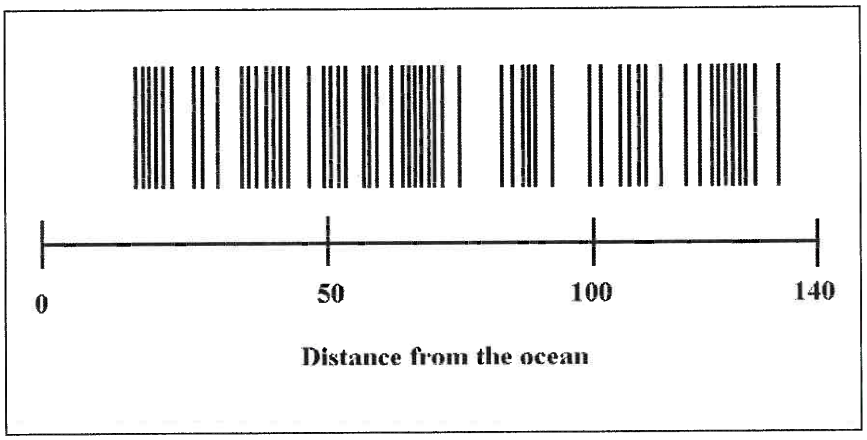


Figure 9. The distribution of primary river pools along the Pallinup River

pool. Many Pools in the lower reaches have a broad shallow, rocky bed.

Solid and weathered rock outcrops of gneiss and dolerite, are common downstream of pools. This is evidence that the formation of pools is determined by local bedrock topography. The pools can develop where bedrock lows occur. The many smaller seasonal pools still play an important ecological role.

When there is flow, water is slowed and impounded by obstacles, such as rocks and logs. These obstacles also focus the water flow and produce deep scour holes. Rather than being a nuisance, impoundment of water enriches the river environment and makes habitat opportunities for a greater variety of small native creatures, such as fish and macro-invertebrates that inhabit these preferred areas. Infilling of the river pools will have significantly reduced the water storage capacity of the river and the diversity of aquatic habitat.

The condition of the river pools provides a potential way to monitor the long-term geo-morphological changes in the river. If erosion is being controlled and sediment movement reduced then reinstatement of deeper pools should be a logical outcome. This is of course likely to be a long-term monitoring option.

The flood fringe

Pasture boundaries follow the floodway topography and the high water mark of past floods. There are the remains of old abandoned fences lower down in the

floodway, which suggest that they were erected at a time when the flood extent was unclear.

A number of old and deteriorated wooden survey pegs were also found along the upper reaches. These defined the corner points for the property and Unallocated Crown Land (UCL) boundaries. The UCL boundary of the Upper Pallinup is very narrow and loosely follows the low flow channel within the floodway, not the fringe of the floodway. The boundaries were surveyed during the late 1890s and early 1900s. Because the UCL boundary only conforms to the low flow channel it is not a useful environmental demarcation between the active floodway and adjacent farmland. It is simply a property boundary.

One of the strong Statewide recommendations for bringing waterways management into the 21 Century is that stock should not have uncontrolled access to the active part of flood-ways and that vegetation in these areas must be preserved and managed to allow for stable natural river processes. Because of the non-functionality, in a protective sense, for most of the Pallinup UCL boundary, such measures depend more strongly on the goodwill of landowners to achieve improvements to the quality of the floodway that is part of their property.

Erosion of river banks and beds

Bank erosion was found to be active along the entire length of the upper river valley. However banks along the broader and straighter pools, appeared less erosion prone, probably due to the adequate cross-section having a high flood flow capacity and the path of fastest flow, remaining in mid channel. Nevertheless bank erosion is particularly severe and widespread with trees being frequently undermined and roots exposed.

Localised erosion points are particularly common in the wooded areas of the floodway where the low flow channel meanders tightly or divides into multiple channels. These areas act as riffles during high flows. Meander cut-offs or chutes are very common and occur where flood flow takes a short cut across a bend. Nearly all bends, large and small, show this tendency and a few sites have a very high erosion risk in the event of the next major flood.

Generally the chute areas have insufficient understorey vegetation to slow the flow and this makes them unstable and particularly susceptible to massive soil loss. Bank and chute erosion provide a steady supply of sediment to the system. The Dalyup River floods (Esperance) of summer 1999 and 2000 provided ample evidence of the sort of extensive damage that can occur when pasture replaces native trees and ground cover. Remnant erosion features of the 1955 and 1982 flood, having the same form, can be seen along the Pallinup Valley.

Together with bank erosion, active bed deepening is also occurring in some reaches of the Pallinup, and this is characterised by small head-cuts (waterfalls) and knickpoints (changes in slope) in the compact clay base. However this type of erosion is not particularly extensive, nor considered a serious issue because any headward erosion is limited by the frequent, rocky bars – however headward erosion may be more critical along tributaries.

Large woody debris

Large woody debris (LWD) consists of fallen trees and large branches and is common within the floodway, but not dense and appears to be highly mobile. The evidence for this is the many flood accumulations both within the dominant channel and across the broader flood-ways. The major pools, on the other hand, contained little in the way of fallen trees suggesting that woody debris passes through these areas readily, during floods. Where the floodway is well-wooded and the dominant channel is a reasonable size, larger logs are common along the banks and appear to be reasonably well-anchored in position.

In a highly vegetated waterway, logs do not move as readily since water velocities are more moderate. A doubling of water velocity can increase the force on a log by nearly four times. Removal or loss of vegetation from a waterway will contribute to increasing the average velocity of water. The erratically distributed heaps of LWD deflect flow and create pockets of local erosion, however removal of dead timber would also promote higher water velocity and aggravate erosion on a larger scale.

Fallen timber is an important habitat and refuge for organisms living in the aquatic environment. Removal of LWD, by fire or mechanically, would significantly shift the balance of life in the stream and decrease the overall bed and bank stability. Localised bank

Figure 10 A–C. A comparison at the same sites showing the effect of high velociy floods on floodway vegetation and sediments between early February and late December 2001

destabilisation appears to be strongly linked to loss of groundcover vegetation particularly those native species, such as sedges and rushes, that overhang the banks.

Regeneration of vegetation

During the survey a comprehensive photographic record was made along the channel. One month after the ground assessment was completed heavy storm rainfall in the north-eastern parts of the catchment led to significant flooding along the river below the junction of the Warperup Creek. A few sites were revisited and photographed from the same vantage points. This provided a rare opportunity to compare, in detail, parts of the channel immediately before and after the impact of the flood flow that ran at between 3 m and 4 m in depth.

One of the questions asked during the course of the survey was: "What effect do high velocity floods have on tree regeneration and samphire colonisation within the floodway?" The impacts on partial and complete samphire cover were of particular interest. The photographs in Figure 10 (A-C) compare the same sites between early November and late December 2001. The arrows on the photographs indicate the estimated peak flood depth to be at or near the top of the floodway bank suggesting a depth of at approximately 4 m in mid channel.

Photographs at site A show that young sheoak trees can handle severe flood velocities, even when totally immersed, at least for short periods of time, between one to two days. The large dead tree trunk on the left of the photograph remained in place, but annual grasses have been damaged or stripped away, except where they formed a denser mat.

Photographs at site B show scattered samphire badly damaged or covered by sediment. The denser, connected patches of samphire remained intact.

Photographs at site C suggest significant removal of sediment to a depth of perhaps 0.3 - 0.4 m, mid channel. This sediment would be deposited further downstream in areas where the velocity slowed. For example the samphire beds at the base of the right bank remained intact and trapped sediment. The stand of young sheoaks in the centre background remained intact but are leaning noticeably downstream.

The structure of sites B and C suggests that these reaches may have consisted of long pools, before clearing in the catchment.

Comparison with 1972 Aerial photographs – good signs!

Aerial photographs from November 1972 were compared with those taken in October 1996 photographs. An example is shown in Figure 11 opposite.

The main observations arising from the comparison were:-

1. Many of the major flood scour and depositional features, seen today, appear to have been present in 1972. This suggests that they are a product of earlier floods (probably 1955) rather than the more recent 1982 flood. Subsequent floods can of course maintain or aggravate such features.

2. Increases in the general density of floodway vegetation, in some places, are observable and since there is a lack of understorey this would suggest increased size and density of the tree canopy cover as the trees age. It is also an encouraging sign for the health of the trees. There are many areas, however, where trees have disappeared, particularly along the edge of paddocks adjacent to the river.

3. Ground cover and understorey condition could not be assessed from either set of photographs.

4. The aerial photographs suggest that in 1972, many river pools had already been filled in with substantial amounts of sediment. Again this implies that the large quantities of sediment seen in the pools today are remnants of floods prior to 1972 and the most likely candidate is, again, the 1955 flood. Estimating the amount of sediment movement down the system and its rate of progress, is difficult and was outside the scope of the survey.

5. A few areas have lost fringing vegetation to pasture and crops but these do not appear to be extensive.

Stream crossings

Stream crossings, along the Pallinup, both major and minor, appeared to be generally well sited and designed. There are many compact clay or rocky bed areas

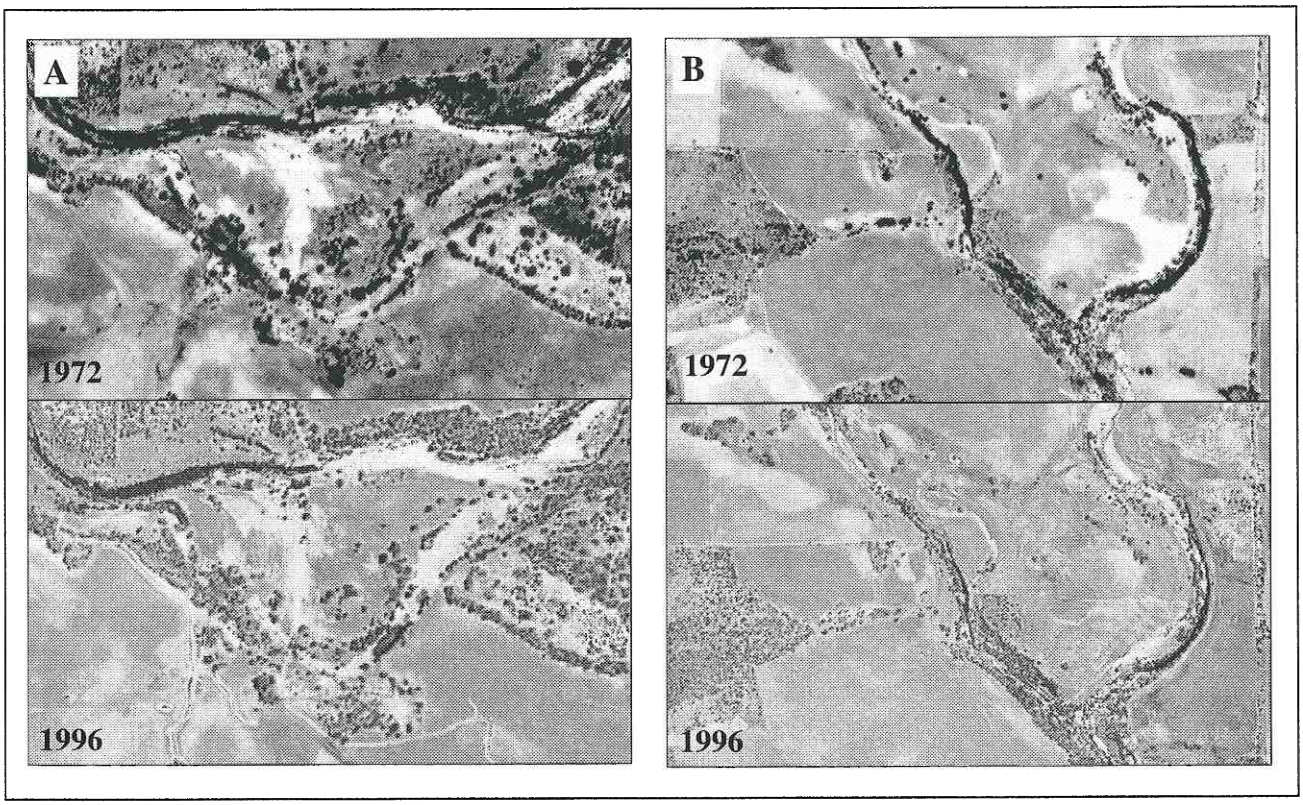


Figure 11. Aerial views of two reaches of the Pallinup between 1972 and 1996

suitable for crossings and apart from the lower reaches of the river the approach banks are not too steep. The flood history of the river has prompted many landowners to keep their crossings low, away from bends and well-armoured with rock. The Magitup Road concrete causeway appears to be particularly well designed and effective.

Westrail plan to upgrade the rail-bridge near the Gnowangerup-Tambellup Road. The old timber pylon structure, thought to be possibly 100 years old, is to be replaced by a large box culvert design (pers. comm.. Westrail Officer,). The decision to use culverts stems from a preference to be able to control the invert level (bed base) of the crossing. The current pylon bridge, thought to be the original from the early 1900s, has worked well but has deteriorated badly. The bridge was overtopped by the 1914 and 1955 flood events. Photographs exist, of floodwaters flowing over the top of the bridge. The age of the bridge suggests that it was well designed with respect to the channel cross-section and the discharge capacity of the upstream catchment.

The lower Pallinup River – The nature of the river

A good portion of the lower reaches consist of steeper-sided valleys where farm boundary fences are located well above the peak flood levels, although there are signs that in some areas, this was not always the case. These areas are rocky and therefore resistant to erosion, nevertheless excessive sediment load from upstream, still poses a threat within the floodway. There are substantial broad reserves along the valley and it is in these areas that near pristine vegetation communities can still be found. The primary threats to the river environs are weeds and sediment slugs.

Erosion

Common features along the lower river floodway are the old erosion scours and large deposits of sediments that formed the banks and ridges running parallel with the channel. These are most likely remnants of the 1955 flood and have been reworked by the 1982 flood. The scours would have contributed large quantities of sediment to the system. Their form is consistent with those newly created in 1999 and 2000, on the Dalyup River west of Esperance.

Much of the bank erosion along the dominant channel is a result of reworking of the large sediment dunes deposited in the floodway in past decades. In many places these have become recolonised with sheoaks and acacias.

The old erosion scours do not appear to have been reworked to any great extent. Figure 12 photographs are typical of the lower reaches of the river and the rocky nature of much of the channel is a distinct feature. The encroaching flood sediment deposits demonstrate the main threat to the pool structure. Denser foreshore vegetation is characteristic of the lower reaches however C Grade foreshore can be seen in Figure 12B.

Sediment

As previously mentioned, the large sediment slugs and hummocks (some now well vegetated) were deposited in the floodway during past floods, but water depths in pools appeared deeper on average, than in the river above Chester Pass Road. Some spot measurements using a steel spike indicated that sediment plumes within the low flow channel and adjacent banks were at least 2 m deep and unconsolidated. The samphire re-colonising the sediment slug in figure 10, is not necessarily evidence of a stable channel since these sand bars may be moved by a sufficiently powerful flood. However as observed in the upper river, the samphires may provide some stabilising influence during moderate and short duration events. In some cases various tree species were also seen to be recolonising these sediment plumes. The exact source of the sediment was not obvious but would logically be the large flood scours upstream. This sediment will eventually reach the Beaufort Inlet. The problem is not that of sediment movement along the river but the rapidity and scale of the process.

The stability of the largest sediment deposits can only be tested when the next large flood occurs. The deposits are being eroded by normal flows, releasing sediment steadily down the river. The usefulness of local knowledge was highlighted during the assessment of the lower parts of the river. For example, Bill Moir indicated that in the Nalyerup Creek, near Borden in 1955, a lot of sediment could be seen moving down the creek as a result of the flooding.

According to Bill, the river did not have the large sediment plumes in it before 1955 but there was a large dumping of sediment during the flood. The tributaries were apparently significant sources for the sediment that can now be seen lodged along the river. Although this report focuses on the main trunk of the river system, in reality the river is the total network including all the minor channels feeding into it. The significance of these tributaries is perhaps overlooked because they are often dry and only flow for short periods of time.

The others major sediment source would have been the floodway fringe. Bill recalls that much of the land had been cleared in the upper catchment by 1955 and more clearing occurred lower down after this.

The 1955 floodwaters originated in the headwaters of the river, around Tambellup, whereas the 1982 flood was fed more from the coastal tributaries. The 1982 flood deposited an estimated 100 000 tonnes of sediment into the Inlet (Hodgin and Clarke, 1988).

The recent, and much smaller, December 2001 flood reached to within several metres of the top of the Marra Bridge on the Hassell Highway, and was fed largely from the tributaries coming from the northern and eastern parts of the catchment.

Floodway vegetation

Some interesting observations have also been made about changes to the riparian vegetation. Bill Moir notes that in the past, samphire did not grow in the river as it does these days, although it was prevalent along Six Mile Creek. He also noted that before the 1955 flood, the river was dominated by fewer large trees, there was not much understorey and it consisted of melaleucas, sedges, rushes, some hakeas and also 'poison'. This type of environment sounds similar to that which can be seen in one of the few remaining well-preserved corridors, the Corackerup Creek.

The fencing along the lower river was set well back to prevent stock moving into these less accessible river areas. This has meant that the steeper valley sides in the lower reaches have wide reserves of native vegetation and have been preserved in A Grade condition. These areas should feature strongly in a management strategy to maintain a high level of protection.

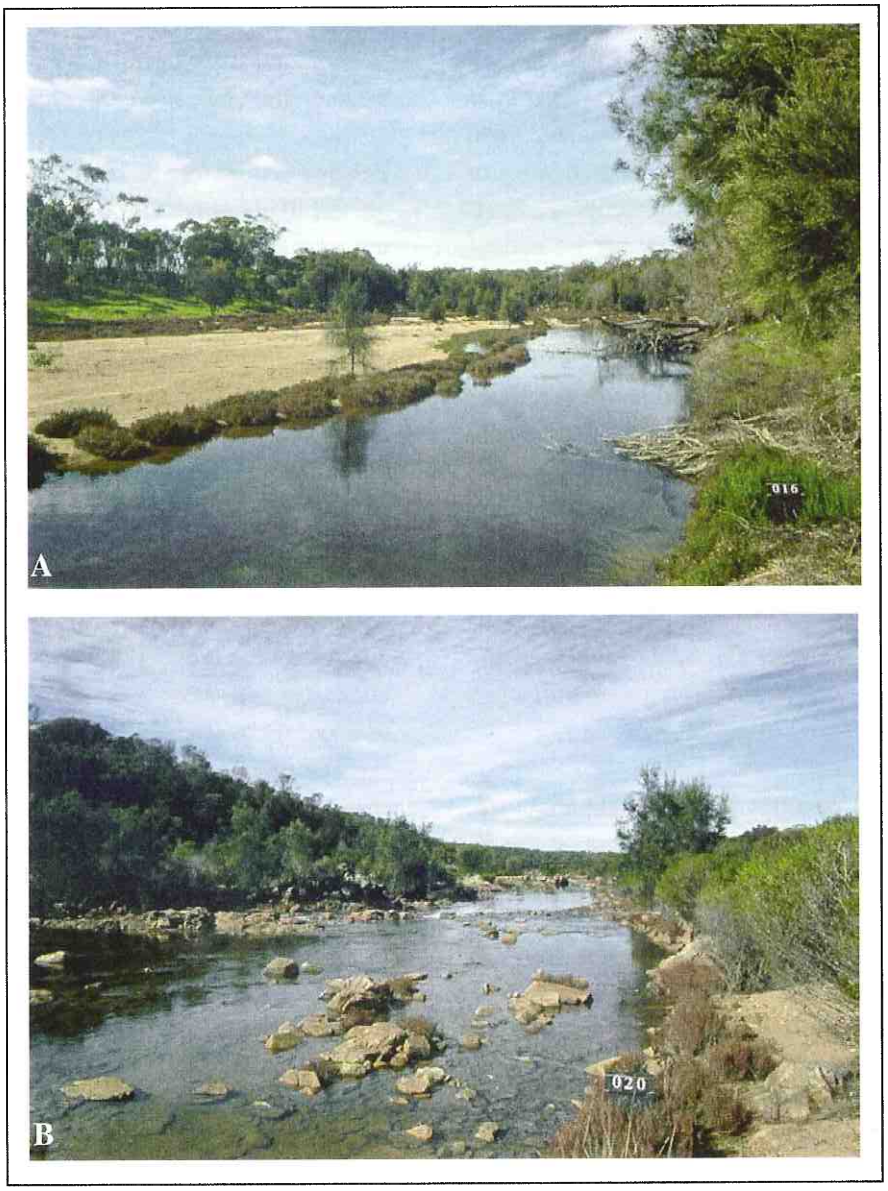


Figure 12 A & B. Typical reaches of the lower Pallinup River

Management issues related to the structure of the floodway

The following discussion considers management matters relevant to the structure and stability of the channel. General management issues and recommendations are discussed more fully in section 5 of this report.

The planform of the Pallinup River floodway was described as passive meandering, suggesting that the river floodway is basically robust. This is particularly true of the rocky floodway in the lower reaches. However, massive amounts of sediment have been introduced to the system from destabilization of the channel banks, tributaries and topsoil loss. Active erosion of banks indicate that the stability of the soil surface in and adjacent to the floodway and in the tributaries, is one of the primary management concerns. In places, and quite commonly, the floodway broadens. These areas are easily identified and parts of these river flats are at risk of significant erosion scour from powerful floods.

The nature and condition of the vegetation that armors the bed and banks is therefore the number one concern for the overall ecological integrity of the river system. A sufficiently powerful flood in the upper catchment has the potential to further degrade the river.

The 2000–2001 survey provided a more detailed assessment of the floodway condition of the Pallinup River, than existed previously. The information is essential to review existing waterways management practices that have developed over a hundred years or more, and to consider opportunities for improvements needed to protect the river and allow for its natural environmental function.

An important aim of river care is to promote community acceptance of a more generous allowance of foreshore space, for natural river processes. The river appears to be in a poor state, but it is not a lost cause. Degradation often proceeds incrementally, 'death by a thousand cuts' as it were. This process continues where there is no general community consensus about what should be protected and how it should be done. Such a consensus on how to manage the river can be developed by the catchment community through a Waterways Management Plan.

Many of our South Coast rivers, the Pallinup included, suffer as a result of being 'out of sight, out of mind'. Feedback from the community, over the years, suggests that many people have little idea about how our river ecology works. In fact these saline rivers have an ecological character that can be considered unique. The potential for tourist development, regional branding and general marketing of good environmental management is something that catchment groups might consider in the development of a useful waterways management plan.
A reluctance of landowners to relinquish land area to natural processes is the sticking point for many waterways care and management programs, and perhaps the underlying concern is loss of income or the effort required. Until this is fairly and realistically addressed, degradation will outrun conservation.

The foremost management recommendation of the Waters and Rivers Commission, for river foreshores, such as the Pallinup, is that they should be fenced to control, if not totally exclude, stock.

The underlying reason is simply to protect native vegetation and to encourage natural regeneration. The fact that several large floods have stripped a lot of vegetation from the main channel is not a reason to believe that vegetation is not appropriate in the floodway, rather it is the single most important river feature that limits erosion and sedimentation. Vegetation is a powerful control of flow velocity above ground, and bank strength below ground.

Fencing is therefore recommended where major floods are not likely to take it out and the area of farmland is not seriously compromised. In broader reaches of the Pallinup River floodway major floods impact large distances from the dominant channel. Fencing for stock exclusion can and does conflict with farming requirements. The question becomes, can the remnant native vegetation be protected and natural regeneration encouraged by any other means. If continuous cropping ocurrs for a few years in adjacent areas, there is a window of opportunity to get tree species established.

A innovative vegetative design may allow floods to be controlled and erosion 'hot spots' to be protected. The main goal is to allow floodwaters to pass through, but to leave the soil and vegetation in place. Removal of the remnant vegetation, within the floodway, by excavation, fire or further clearing, is not recommended. This will inevitably accelerate erosion and release sediment, increasing the already high risk of further destabilisation during major flooding. Realignment (not removal) of large woody debris should be considered where local erosion is being caused by deflection of the flow.

Unallocated Crown Land

Fencing the existing Unallocated Crown Land boundary is inappropriate for most of the upper reaches. Successful protection of the river will therefore depend on the goodwill of landowners to protect the floodway so that it can function in a stable manner. Relocation of the UCL boundary to a more suitable location, through buy-back of farmland is an option for consideration.

There remains the risk of a truly major flood event, one that would be characterized by high storm rainfall over a large part of the catchment. An idea that is sometimes promoted is that a river will function more effectively if the channel is cleared and excavated. In reality, the most efficient size for a channel is dictated by the long-term flood pattern not by an excavator. A channel may be too large or too small for the various flows that it receives. If a channel is artificially enlarged, the shaping forces will act to fill it in, clogging the system with sediment in some places and eroding it

in others. Erosion is not necessarily an indication that a channel is too small and is in the process of enlarging. Loss of bank stability may be a cause. Either way, very little advantage will be gained for the expense. The Pallinup River already appears to be an efficient conveyor of water from the landscape.

Foreshore vegetation and condition

The waters of the Pallinup River run through the Avon, Roe and the Eyre Botanical Districts (Beard, 1979). The floodway vegetation is best understood in context with the botanical regions of the area. These are described briefly below.

Avon Botanical District

This district covers much of the wheatbelt region. The predominant vegetation communities include Wandoo, Yate woodland (*Eucalyptus wandoo, Eucalyptus occidentalis*). Blue Mallet (*Eucalyptus gardneri*), can appear on rises. A sparse understorey consisting of woody species overlay sedge swards and small shrubs. The district is 93% cleared (SCRIPT report, 1997) and farming has led to the clearing of almost all the woodlands.

Eyre Botanical District

There are three systems in this district: The Qualup, Jerramungup and Stirling Range. Included in the Jerramungup systems are the Peenebup and Dedalup creeks, tributaries of the Pallinup.

There is a combination of mallee and mallee heath with mallee, sometimes with areas of Yate woodland in the valleys. The communities are quite complex and are dependent on the soil types. Seven communities were distinguished by Beard (1979) granite outcrops, broom bush (*Melaleuca uncanata*) thicket, heath, mallee heath, casuarina heath, Moort (*Eucalyptus platypus*) thicket and Sclerophyll woodland.

The Pallinup system

The Pallinup system occupies lightly dissected gently undulating country in the upper basin of the Pallinup and its tributaries. The most common community is the mallee but there are communities of mallee heath on rises. The valleys are home to Eucalyptus woodlands.

The mallee heath is characterised by Tallerack (*Eucalyptus tetragona*) and is usually associated with a dense understorey of Melaleuca species. Mallee consists of *Eucalyptus reduca, Eucalyptus uncinata* in association with other species such as *Eucalyptus flocktoniaea, Eucalyptus gardneri* and *Eucalyptus occidentalis*. Low lying areas along the landscapes support patches of yate woodland with paperbarks where it is swampy.

Yate and York gum woodland occurs in the larger valleys along the Pallinup and its tributaries. Yate tends to be dominant on the lower ground and York gum on the upper slopes. Sheoak (*Casuarina obesa*) grows prolifically in the riverbed of the Pallinup and river gum (*Eucalyptus rudis*) and Yate on the banks.

Aquatic fauna

(Information taken from - Romanowski, N. 1998, *Aquatic and Wetland Plants.* Sydney: UNSW Press.)

There has been no long term monitoring programs for aquatic flora, that is macrophytes, phytoplankton or algae in the Pallinup River, although various snapshots have been undertaken. Some aquatic plants, sampled during the foreshore survey (WRC, unpublished) are described below.

Cotula coronopifolia, a plant with small yellow button flowers. This species is found in areas that are frequently inundated, sometimes for long periods. It is an important plant for wading birds, particularly ducks and swans. It is also common in brackish to very saline waters. It is a valuable habitat plant – provides shelter underwater for a wide variety of animals and it also prevents erosion in shallow, disturbed areas.

Nardoo (Marsilea sp) is another macrophyte found in waterways. It looks like a four leaf clover, but has a long single tap root, and floats on top of the water. It grows in seasonally flooded swamps and along creeks, is very drought tolerant, dying away in arid conditions, but growing back rapidly with rains. The sporocarps were originally used by indigenous people, for food (Nardoo).

Water Ribbon (*Juncaginaceae, Triglochin* sp) were also found in the Pallinup River. These have tuberous roots that were also a source of food. The seeds germinate readily in the autumn in shallow water and the small plants survive the winter. This plant is very important for habitat for native fish and macroinvertebrates, and as food for wading birds. The plants will survive dry conditions by putting down underground rhizomes and

tubers. They will only flower when they are flooded.

Terrestrial river fauna

Bandicoot, Quenda *(Isodon obesulus)*
The Bandicoot is a threatened species in WA, but can be found in the Pallinup environs. They like to live where there is a reasonably dense understorey and a source of water. Their diet consists of bulbs, worms and insect larvae. The bandicoot is under threat due to the lack of suitable environments to live. Predators such as foxes and cats put pressure on the population.

Echidna, Spiny anteater *(Tachyglossus aculeatus)*
The echidna belongs to a group of mammals known as Monotremes with the only other member of this group being the platypus. The echidna is toothless and feeds on a diet of ants and termites. Using their forepaws and snout they are able to dig into ant and termite nests and use their long sticky tongue to catch the bugs. When they are disturbed their first instinct is to protect their soft belly, to do this they either dig into the ground or curl into a ball showing only their spines. To see these shy creatures you need to be on the look out for fresh digging or droppings (identifiable by their cylindrical shape and evidence of ant remains), then sit quietly and if the animal is still about it may come out. Echidna populations are known to be affected by foxes.

Tammar Wallaby *(Macropus eugenii)*
Since the reduction of habitat due to farming the Tammar Wallaby's populations are now very restricted making it essential to keep areas such as the Pallinup in good condition.
The tammar wallaby needs areas of thick vegetation which provide protection from feral cats and foxes.

Western Pygmy Possum *(Cercartetus concinnus)*
These mini possums are able to live in a range of habitats however clearing for farming and urban development has reduced much of their range. They also come under threat from feral cats and foxes. The pygmy possums diet includes insects and nectar.

Honey Possum *(Tarsipes rostratus)*
Honey possums are nectar and pollen feeders, these tiny marsupials require a year round source of flowers to survive. They live in areas that have large numbers of plants such as banksias, grevillias, dryandras, eucalypts and melaleucas. Many plants have adapted so that the honey possum and other small mammals are the major form of pollination.

Native Fish

Fish found in the Pallinup River include *Galaxias maculatus* (spotted minnow), *Leptatherina wallacei* (western/Swan River hardyhead), *Pseudogobius olorum* (Swan River goby), *Gambusia holbrooki* (mosquito fish), *Acanthopagrus butcheri* (black bream). (Morgan, unpublished).

The Spotted Minnow *(Galaxias maculatus or Galaxias truttaceus)* is a small fish that is found in a variety of habitats, but is most common in still or slow-flowing waters, mainly in streams, rivers and lakes within a short distance from the sea. They can survive in water with a salinity up to 50 ppt (Allen, 1989). The fish migrate up tributaries, when spawning and deposit their eggs along the banks, where they develop. Hatching will take place after another flood. Spotted minnows feed on many water dwelling and air born insects.

The Western Hardyhead *(Atherinosoma wallaceri)* is found in south-western Australia from the Pallinup River to the Moore River. Wallace Hardyhead (also commonly known as Western Hardyhead) are small, silvery fish that tend to swim around in schools. The fish is generally an olive-green colour with silvery sheen on its sides and belly. It is normally seen in schools near the surface or around the shoreline vegetation and log debris. Spawning occurs during spring and summer. Their diet consists largely of insects and small crustaceans (Allen, 1989).

The Swan River Goby *(Pseudogobius olorum)* is found throughout the South West as far north as the Murchison River. They are a brown or tan with narrow darker brown blotches. The belly is silvery white and the dorsal fins may have irregular dark stripes. This species is also commonly known as a blue spotted goby as it has a black or blue spot on the dorsal fin. They live in streams, ponds and can also live in brackish water. The goby is usually found over mud bottoms, sometimes among weeds or adjacent to rocky areas.

The goby spawn in spring, the female depositing approximately 150 eggs under a rock or other similar object. The eggs are then nurtured by the male during incubation which is approximately four days after which time the larvae are swept into the estuary where they feed on plankton until old enough to travel back

upstream. They have a diet of insects, crustaceans and algae (Allen, 1989).

Aquatic macroinvertebrates

Macroinvertebrates consist of worms, snails, crustaceans (prawns and marron) and insects (such as mayflies, stoneflies, beetles and bugs). Many aquatic macro-invertebrate species are found in the Pallinup River.

Macroinvertebrates play an important role in the ecology of the river system. In the upper catchment, macroinvertebrates are responsible for shredding larger particles including bark, leaves and other detritus that falls into the waterway. Further downstream, macroinvertebrates such as worms, gilgies and marron take small particles of organic matter from the sediment and digest them further.

Algae that grow on the rocks is 'scraped off' by snails and limpets. There are also predator species of macro-invertebrates including the dragon fly, adult beetles and stonefly larvae that prey on smaller animals. The survival of aquatic macroinvertebrates is strongly linked to the quality of the water they live in, as it is for larger animals such as fish. Macroinvertebrates are sensitive to changes in the physical and chemical conditions of the water, including salinity, flow and temperature. The most important habitat feature in a stream is the vegetation, including logs that fall in the stream to form snags, branches that over hang to create shade and microclimates, bark and leaves. This forms the basis of a food web and protective environment for macroinvertebrates in our waterways. Vegetation removal can impact on food availability, light penetration, water flow, sediment levels, and temperature of the water.

Protection of foreshore vegetation is vital to ensure the protection of the ecological attributes of our river system. Removal of riparian vegetation upstream can have serious consequence on downstream macroinvertebrates that rely on the input of organic matter to the system. Macroinvertebrates have been sampled in the catchment as part of the National Rivers Health Program. Appendix 1 summarises the results of a macro-invertebrate 'snapshot', collected by the Department of Conservation and Land Management in the spring of 1997, at a number of river sites.

3.2.2 Foreshore survey assessment

The Pallinup River was surveyed using the Stream Foreshore Assessment and Survey Technique developed by Pen and Scott. This straightforward technique grades the condition of the foreshore as A, B, C or D, with A being a pristine foreshore to D a highly degraded foreshore (Figure 13). Pen and Scott's technique further breaks down these grades i.e. A1, A2, A3, B1, B2 and so onto provide a more detailed assessment especially at a reach or paddock scale. The method gives an estimate of the current relative proportions of native plant and weed species and also an assessment of bed and bank integrity.

The survey was undertaken by Kaylene Parker, Steve Janicke, Lee Barber (Landcare trainee), Travis Drysdale (Landcare coordinator), Joanne O'Connor (volunteer), Penny Moir (community representative).

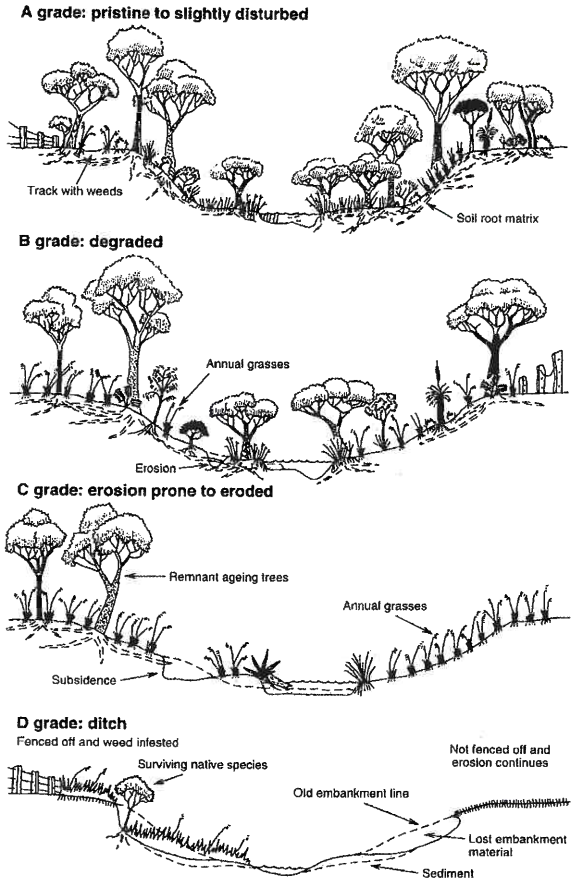
The survey used a systematic ground inspection and aerial photographs of the properties, and recorded the following information:

- foreshore condition (A1, A2, A3, B1, ...D3);
- fencing status (existing and proposed);
- crossings (design, location, survival of floods);
- revegetation (present);
- presence of weed species; and
- channel bank stability.

In the course of the upper river assessment, particular attention was paid to the geomorphological structure of the river in an attempt to understand its structure, particularly erosion and sedimentation features and the changes that are occurring over time.

Stream Foreshore Assessment Survey

The condition of the Pallinup River floodway was assessed using the simple condition categories defined below. Figure 14 shows a pictorial view of the vegetation structure typical of each category. Each location was assessed and the information recorded.



A Grade: Pristine, embankments are entirely vegetated with native species. With grades A2 and A3 native vegetation still dominates, weed density is increased.

B Grade: Degraded, weed infested. Weeds have become a significant component of the understorey vegetation. Native species remain dominant. With grades B2 and B3 weed infestation increases and there is a reduction of native species.

C Grade: Erosion prone, trees remain possibly with some large shrubs. The understorey is weed dominant mainly annual grass. Most of the trees will be of only a few resilient long-lived species and their regeneration will be below replacement level. With C2 and C3 soil erosion has begun due to the effects of wind or water. With C3 subsidence into the river valley has occurred.

D Grade: Ditch, eroding. No significant fringing vegetation remains and erosion is out of control. Undermined and subsided embankments are common, as are large sediment plumes along the river channel. Any remaining trees are likely to be undermined.

Figure 13. The stages of river degradation

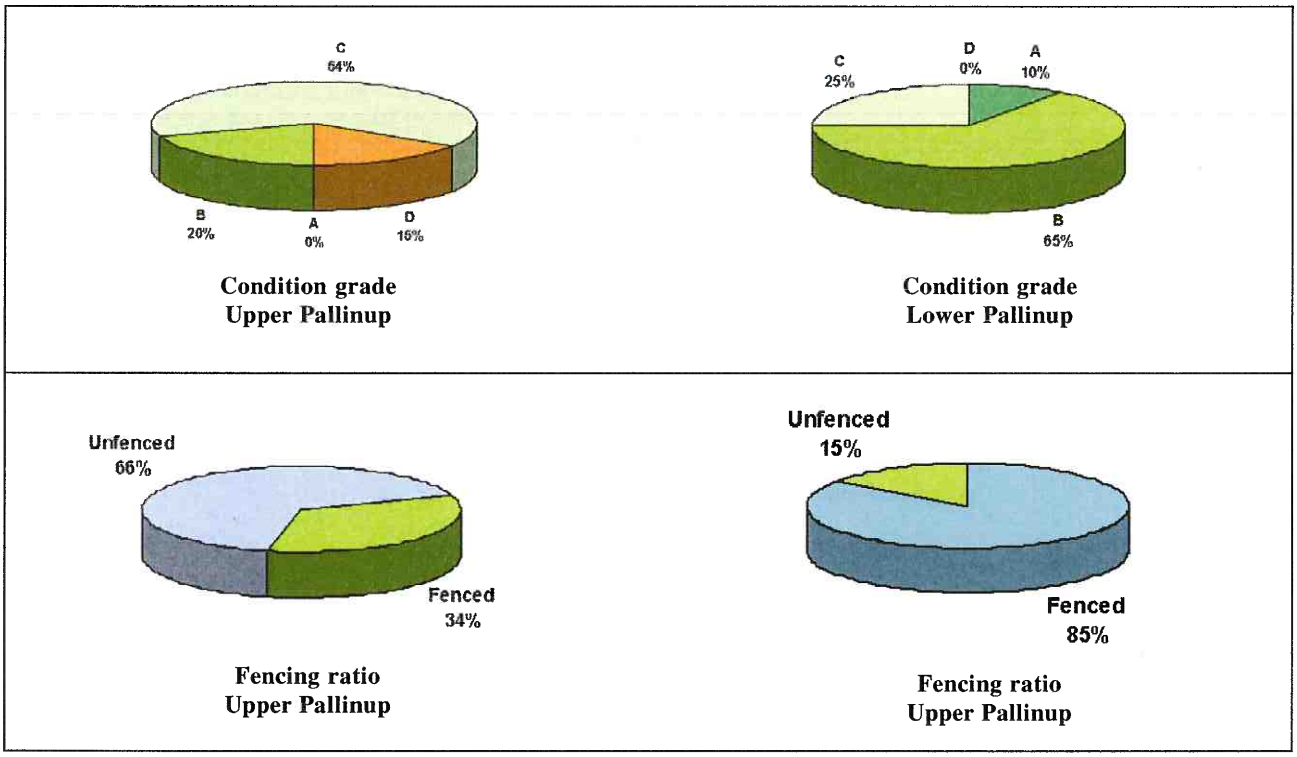
Figure 14. Pictorial stages of river degradation

Summary of the riparian status of the Upper and Lower Pallinup River

UPPER PALLINUP	Comment	Status
Fencing	Where fences have been placed above the high water mark stock control is most effective. Fences are safe from floodwaters and the remnant vegetation is noticeably healthier with new growth visible, and riverbanks have been stabilised.	The Upper Pallinup River (the reaches above Chester Pass Road) are approximately 34% fenced, however quite a bit of the 66% remaining unfenced has cropping activity adjacent to the river and stock incursion is not a problem in these areas.
Riparian vegetation	The majority of the Upper Pallinup Foreshore vegetation is considered C Grade, consisting of *Casuarina obesa* trees over an understorey dominated by weeds. Samphire is more prevalent where stock is excluded and provides erosion protection on the waters edge.	The Upper Pallinup is under stress through grazing pressure. The subsequent sedimentation is a major concern for the whole river system. By maintaining the foreshore vegetation and excluding stock landholders will be able to minimise these impacts. No reaches qualified as A Grade, although a few small pockets approached A3. **Foreshore Vegetation Condition** A grade < 1% B grade 20% C grade 63% D grade 16%
Weeds	Well-established native vegetation will resist weed incursion. Areas of the foreshore that were fenced from stock and free from disturbance showed lower weed impact. The further from crop, the fewer weeds.	The foreshore vegetation of the Upper Pallinup is largely dominated by weeds. The native understorey is being out competed by several species. Areas of disturbance are most prone to weed colonisation.
Erosion / Sedimentation	The riverbanks that are well vegetated with native species and have an adequate width of foreshore vegetation, are better stabilised to withstand the force of strong flows and limit sedimentation.	Large amounts of sediment have entered the river system. The evidence for this can be seen as large plumes in pools and throughout the floodway. Aquatic vegetation is being smothered and the former deep pools are now well filled. There is also the eventual threat this may place upon the Beaufort Inlet once the sediment is deposited.
LOWER PALLINUP	**Comment**	**Status**
Fencing	Where fences have been placed above the high water mark stock control is most effective. Fences are safe from floodwaters and the remnant vegetation is noticeably healthier with new growth visible, and riverbanks have been stabilised. Where the river valley becomes steeper, fences are set further back from the channel. A history of floods taking out fences has resulted in landholders being more cautious with placement.	The Pallinup River below Chester Pass Road (Lower Pallinup) currently has approximately 85% fenced. As for the upper river cropping provides some degree of relief from stock pressure although this is likely to be unpredictable or intermittent.
Riparian Vegetation	The majority of the Lower Pallinup Foreshore vegetation is considered B Grade, consisting of *Casuarina obesa* trees over an understorey dominated by weeds. Bank erosion and sedimentation are evident.	The Lower Pallinup is under stress through grazing pressure, but not in all reaches. Sedimentation is a major concern for the whole river system and large sediment slugs stretching over a kilometre were observed. By maintaining the foreshore vegetation and excluding stock landholders will be able to minimise these impacts.The lower reaches of the river have areas of A Grade bush, perhaps not A1 perhaps A2 in small sections and definitely A3 areas worth noting.

Summary of the riparian status of the Upper and Lower Pallinup River (continued)

LOWER PALLINUP (continued)	Comment	Status
Riparian Vegetation (continued)		**Foreshore Vegetation Condition** A grade 10% B grade 65% C grade 25% D grade 0%
Weeds	Well-established native vegetation will help reduce weed infestation. Sour sob is prolific in those parts of the floodway where there are dense sheoak groves. Areas of the foreshore that were fenced from stock and free from disturbance showed lower weed impact. The further from crop, the fewer weeds were observed.	The foreshore vegetation of the Lower Pallinup varies, but is largely dominated by weeds where farmland is close to the river. The native understorey is being out competed by several species. Areas of disturbance are most prone to weed colonisation.
Erosion / Sedimentation	Riverbanks that are well vegetated with native species and have an adequate width of foreshore vegetation are better stabilised to withstand the force of strong flows and limit sedimentation. Much of the lower channel bed is very rocky and this means that bed erosion is not a problem.	The banks of the Pallinup River have contributed large amounts of sediment to the river system. The evidence for this is numerous large bank scours, indicating major flood activity. Also there are the corresponding large sediment plumes within the floodway, many of which are currently well vegetated, though possibly loosely consolidated. Aquatic vegetation is being smothered and the deep pools are filling in, although sediment is flushed through the rockier reaches. This material is the most immediate and eventual threat to the Inlet, particularly the upper parts.



Figures 15. Graphical summary of fencing and foreshore condition for Pallinup River above Chester Pass Road

3.2.3 River fauna

See Hodgkin, E.P. and Clark, R. 1988 for a summary.

3.2.4 Water quality

Median water quality values at a glance

	Salinity mS/cm	Temperature °C	pH	Nitrogen mg/L	Phosphorus mg/L
1973–1998 Lower river	27	16	8.4	1.3	0.06
1998–00 Mid-upper river	36	18	8.3	1.5	0.07

Figures are for flowing waters only.

The table above gives a brief overview of some of the main characteristics of waters in the Pallinup River.

This water quality review summarises data collected from the Pallinup River catchment. Steam gauging data (discharge and water samples) have been collected consistently at the lower end of the river since 1973. This data provides an excellent assessment of the hydrographic response of the river to storms in the catchment and is sufficient to provide reasonable estimates about the average frequency of moderate to large floods. In addition, further water quality data has also been collected at various sites in the upper catchment and at the Beaufort Inlet, during 1998–1999. This was a part of the NHT funded *"Water Resources Assessment and Enhancement, South Coast"* (WRA&E) project. Monitoring of the water quality of the Beaufort Inlet has also been undertaken since 1998 under the South Coast estuarine monitoring program.

The monitoring program and its results are intended to help the community and the Water and Rivers Commission to understand the condition of the river, and therefore to be more informed about management issues.

The role of stream data

There is an increasing amount of water quality data on rivers and streams draining catchments of the South Coast of Western Australia.

It is generally accepted that due to widespread clearing of vegetation, for agricultural purposes, water quality has become severely compromised. For example, extensive areas of the catchment are affected and many waterways have increased salinity and nutrient levels, with resultant algal growth.

It is assumed, through anecdotal evidence and experiences in other Western Australian catchments, that the loads of sediments and nutrients carried by rivers in this region have increased dramatically. However, except for areas such as the Wilson Inlet and Albany Harbours catchments, the condition of the waterways of the South Coast had not been well quantified. Gaps in our knowledge have been steadily filled from the late 1990s.

A reliable set of indicators of water quality, that are easily understood by the community, are needed to monitor improvements in the Pallinup River over time.

An overview of surface water hydrology of the Pallinup River catchment

For most of the year, the aquatic environment of the Pallinup River and its larger tributaries consists of a string of permanent or semi-permanent pools (section 3.2). There are also saline seepage areas, rocky outcrops, salt encrusted bare clay scours and sediment slugs.

Freshwater pools can be found along sections of the Pallinup River, south of Chester Pass Road.

Vegetation, particularly *sheoaks, samphire* and *acacias*, are dominant along most of the floodway, often colonising large sediment deposits in mid channel. Some highly saline trickle flow may occur through summer and summer storm events can create spectacular floods such as occurred in 1955 and 1982. In winter, flows are generally low to moderate and confined to a smaller channel within the floodway. Pools swell with water and in some years, such as 1988, significant winter floods can occur.

The area of the catchment is 4800 km^2 and rainfall varies from about 500 mm /year in the south coastal areas to less than 400 mm /year in the northern parts of the catchment. The northern side of the Stirling Range is in a rain-shadow that draws the 400 mm isohyet further south. Most of the rain falls in the cool winter months although significant storm events and river discharge can occur in summer along with the occasional cyclone. On average less than 2% of rainfall is converted to flow at the lower end of the river (1973–1996).

The Pallinup River catchment has one interesting, and virtually unique feature for Western Australia, in that it is periodically the recipient of snow-melt waters from the Stirling Ranges, although this contribution is very small indeed. Both saline and fresh creeks are known to flow from the Stirling Range National Park.

Figure 16 shows the annual discharge estimates at the Bull Crossing gauging station, near the Chillinup Road, between 1974 and 1996. Values range from less than ten Gigalitres (Gl) to around 250 Gl /year. (A Gigalitre is the amount of water that would cover one square kilometre to a depth of one metre).

Figure 17 enables you to estimate the percentage of time that the river discharge exceeds a particular value (chosen on the vertical axis). This graph also gives clues to how efficiently the catchment supplies, both groundwater and surface runoff to the river.

It has been observed that flows out of the Pallinup River only exceed 0.1 cubic metres per second (100 litres per second) for approximately 40% of the time and that very low flows are the most common condition. This suggests that the ground water leakage into the river is not great. Storm water is more rapidly released after storm events, compared with some of the other major rivers on the South Coast.

For example the Kalgan River, on the other side of the Stirling Ranges, exceeds a discharge of 0.1 cubic metres per second for approximately 94% of the time (HYDSYS analysis of the flow data set). It is consistent with the comments of some landholders, that runoff from the Pallinup landscape is fast and furious, because of the widespread 'heavy' clay soils.

Many small creeks, for example Chelgiup Creek, a tributary of the Kalgan, and Coramup Creek at

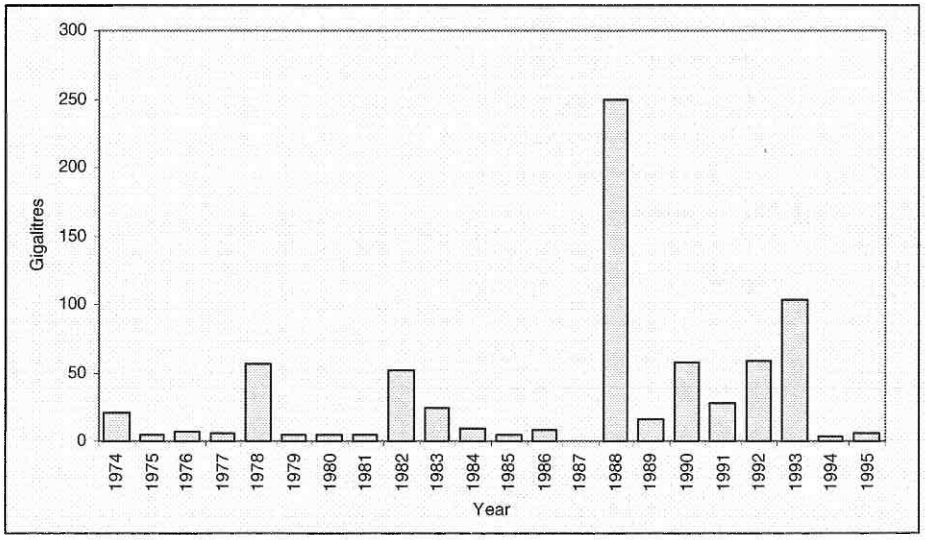


Figure 16. Annual discharge at Bull Crossing gauging site

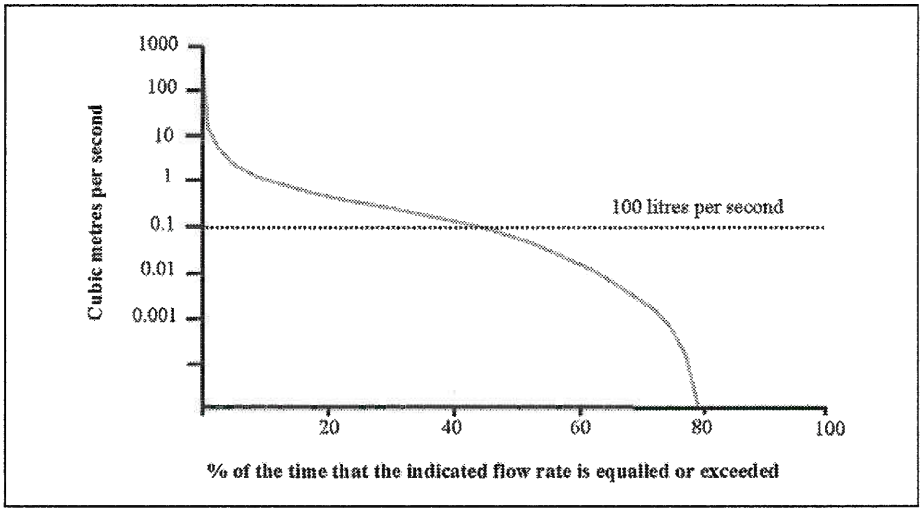


Figure 17. The durage of flows

Esperance have a steady flow all year round, comparable to the Pallinup, only ceasing to flow in particularly dry years. The catchment soils act as sponges releasing the stored water more consistently as baseflow. For this reason the hydrological response of clearing in the catchments of the South Coast may varying in subtle ways.

Water quality in the Pallinup River catchment – Water Resources assessment results

The principle aim of the monitoring program conducted in 1998–2000, was to describe the basic chemical and physical nature of surface water in the main channel and what enters from the larger tributaries. The quality of the water is important for the biota living in and around the floodway. It is also a reflection of what is happening across the broader landscape.

Figure 18 shows rainfall in the catchment during the monitoring period, which commenced in September 1998 and continued through to October 1999. Overall there were fifty-three days in which water quality in the catchment was sampled (weekly to monthly depending on the season). Most flows would have been representative of ground-water discharge rather than surface storm water runoff.

Pallinup water temperature

Temperature regulates ecosystem function directly by influencing the rate of metabolic activity of aquatic organisms. Small changes in ambient water temperature can affect the growth rate of an organism and its reproductive cycle. Seasonal changes are therefore involved in triggering these factors. In rivers like the Pallinup, high summer temperatures combined with lengthening days and low water levels may trigger more ecological activity in and about the river pools, providing summer and drought refuge habitats. The relatively cool water in deeper and shaded areas would be especially important for many species, to ride out the long hot and dry periods. There has been little investigation of the impacts of seasonal changes on the ecology of rivers such as the Pallinup.

A number of factors can alter the average temperature of river waters, for example the level of shading from fringing vegetation, turbidity, depth, cooler discharges from groundwater storage or the formation of haloclines (saline bottom layers) in deep or still pools. In the Pallinup loss of large trees along banks has exposed important areas, such as the pools, to greater levels of incident solar radiation that may, in turn, have increased the average summer temperature of pool water. Infilling with sediment, apart from reducing pool capacity, also may contribute to raising the average temperature of the remaining water.

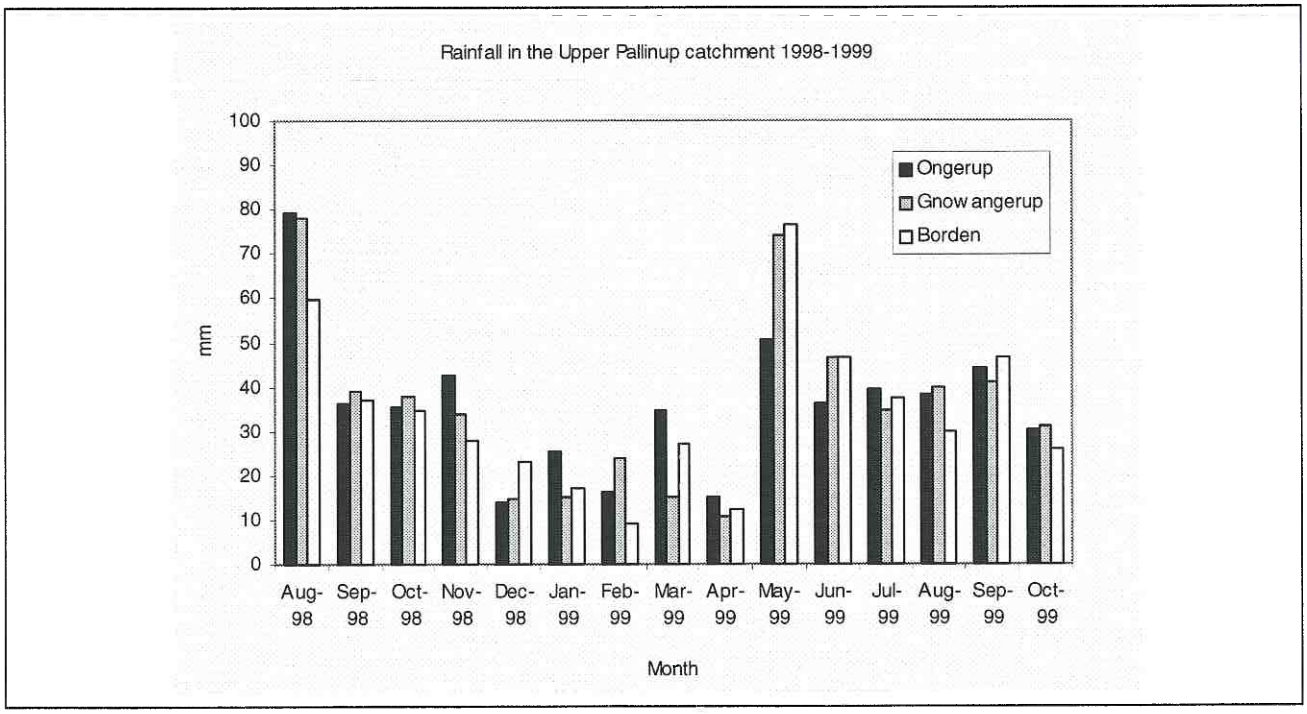


Figure 18. Rainfall in the catchment during the sampling period illustrates the seasonal pattern for the area

Monitoring showed that the temperature of the water in the Pallinup catchment varied from just below 10 °C in winter, up to 30 °C in summer, when water levels were lowest. Although the extremes of temperature were similar between flow and no-flow situations the median temperature during flows was approximately 5 °C less than the median of the no flow conditions. It is probably a fair conclusion that flowing water in the catchment rarely gets much above 24 degrees, simply because of the lower air temperatures and evaporative cooling during and following periods of rainfall. Generally, the Pallinup River and its ephemeral tributaries can be classified as warm water systems.

Oxygen levels

The level of oxygen in water reflects an equilibrium condition between oxygen-consuming processes (decay of organic matter, respiration) and oxygen producing processes (input/loss from the atmosphere, photosynthesis). The quantity of oxygen that can be held in water varies with temperature.

The 1992 ANZECC guidelines suggested that oxygen/water concentrations consistently below 6.0 mg/L, may be of environmental concern. Since there have been other indicators of potentially eutrophic conditions in the Pallinup River, such as the occurrence of turbid and even 'stinking' waters or hydrogen sulphide in pool sediments, this figure may be quite applicable. The concentration of dissolved oxygen also varies between the day and night. Flowing water is aerated to a greater extent, particularly where it is agitated by flowing around or over rocks, or woody debris. Low values of oxygen in flowing water may be of more concern than in river pools under no-flow conditions.

The table below shows the number of oxygen measurements that were below the 6.0 mg/L level. The last column shows the possible percentage of time values fall below the critical values, based on the sample data. For example, with a total of 277 samples (n) and 25 measurements less than 6.0 mg/L this means that water in the Pallinup River catchment contains less oxygen than the ANZECC limit, for up to nine percent of the time. The character of the river pools, in summer, would account for much of this. Rehabilitation to help moderate conditions in the summer refuge pools, is therefore an important facet of river management.

In general the levels of oxygen in surface water in the Pallinup River catchment were high enough to sustain aquatic life, even in pools when they were still and warm. The low oxygen levels were detected in the main channel and lower tributary sites between September and March. Two very low values occurred in the Cowellelup reference pool in June and one at the Fairdale reference pool in May. Oxygen levels less than 4 mg/L were detected on only five occasions.

A number of quite high (10–14 mg/L) DO concentrations in the waters of the Pallinup River were a feature given the relatively high temperatures of the waters. Observations of active aquatic plant and algae growth are probably related to these high values.

Salinity

Salinity is often measured on the basis that the electrical conductivity of water increases with salt concentration. Electrical conductivity (EC) is used as a 'de facto' measure of the total concentration of inorganic ions (salts) in the water. Since electrical conductivity varies with temperature, measurements are converted to the values they would have at a standard temperature of 25°C.

Oxygen values obtained during site visits

System	Number of measurements	Samples with less than 6.0 mg/L oxygen	Possible period (% time) over which Pallinup water contains less than 6.0 mg/L oxygen
Pallinup Main Channel	88	10	11%
Sub-catchments	87	6	7%
Cowellelup reference pool	51	4	8%
Fairdale reference pool	51	5	10%
TOTALS	277	25	9%

This standard conductivity is also called Specific Electrical Conductivity or EC(25). The units used in this report are milli-Siemens per centimeter. (mS/cm) Multiply this by 100 to convert to milli-Siemens per metre (mS/m).

Since 1973 flow and salinity data have been collected at Bull Crossing near the Chillinup Road. There is no strong indication of a trend in salinity levels over that period, but the data does suggest a good deal of variability from one year to the next (Figure 18).

Most of the time, salinities in the river have been below that of seawater (52–53 mS/cm) with occasional values as low as the marginal to brackish range (2–5 mS/cm). A spot measurement at the peak of the December 2001 flood registered 1.5 mS/cm, which is quite fresh (although it was muddy). Low annual median values are associated with high peak flow years, such as 1988, 1992 and 1993.

Although concerns regarding salinity have increased in Western Australia generally, because of the threat to agricultural production, increased salinisation is also a concern for natural saline aquatic systems. The view that, "it is naturally saline therefore more salt won't make a difference", is not a good environmental management paradigm. The Pallinup River is a naturally saline system, with salinities generally above 10 mS/cm. High salinities were noted by early pioneers, however increases in the average salinity can be a problem for the health of the waterways. Other related changes would include increased waterlogging, changes to the wetting/drying cycle, increased base flows, loss of freshwater pools, loss of fringing vegetation and increases in salt scalds. There is evidence of a change towards a more samphire dominated system (pers. comm. Bill Moir) and the loss of yate trees results in less shading of the river, hence increased water temperatures and evaporation.

A useful specification of what constitutes acceptable levels of stream salinity is complicated by the fact that the salinity can vary considerably between low flow and storm flow. It is more important now to answer two questions:

1. How much has salinity variation changed since agriculture started in the catchment?
2. can it be influenced by improved land management practices? It may seem strange to be concerned about these issues given that the water is so saline. However, because of these extreme conditions, any increase is just as likely to place a serious stress on the ecological balance of the waterways, as in a fresh water system.

Salinity in the river environment can also be related to other degrading factors. A survey of the channel stability and foreshore vegetation condition in 2000/2001 revealed that sedimentation may in fact be the most serious influence on the aquatic environment of the Pallinup. Salt scalded areas become prone to erosion and the relative impact of evaporation will therefore be increased in shallower pools. Figure 18 shows the proportion of salinity readings for various levels, for all sites sampled. The graph shows that salinities are high, but with some brackish flows. Salinity increases noticeably with evaporation over the summer months.

Figure 19 reveals that water salinity, in the Pallinup, is extremely variable from year to year with the variable rainfall and catchment discharge characteristics strongly influencing salinity at any point in time. There is little evidence of a trend, even when various statistical analyses are applied to the data, adjusting for flows and sample timing.

Salinities at the Bull Crossing gauging site varied from less than 10 mS/m to more than 70 mS/m in the period 1973 and 1996 with approximately 25% of the readings greater than the conductivity of seawater. The most frequent values were between 30-40 mS/cm.

The median value for the measurements was 27 mS/cm. Adult sheep can tolerate up to 22 mS/cm, although they would probably be disgruntled. The extent to which this spread of values has changed over the past century, is unknown.

Figure 20 (courtesy of Alan Seymour, Dept of Agriculture) shows the estimated ground water salinities for depths below four metres. It can be seen that the ground-water salinity is not uniform across the catchment.

The data from the Six Mile Creek site (Magitup) shows much higher values than the other tributaries, which might be expected given the higher groundwater salinity in the area (Figure 21). The highest main channel values

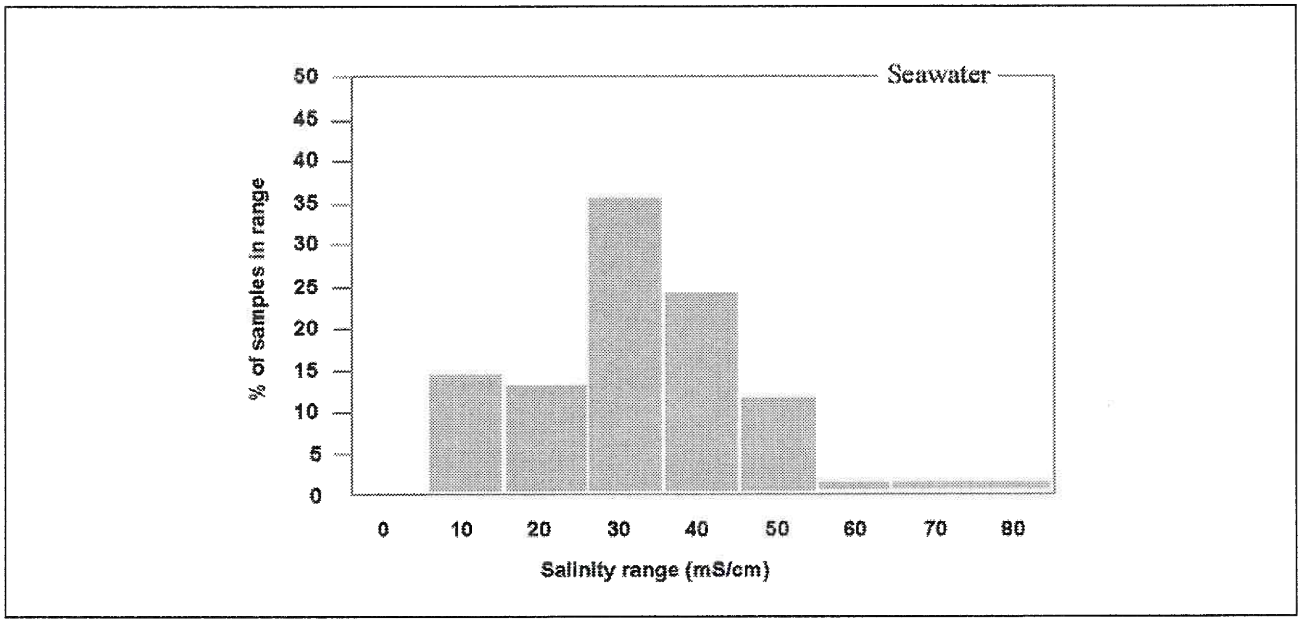


Figure 18. The distribution of salinities (EC) measured between 1998 and 2000 for all sites along the river

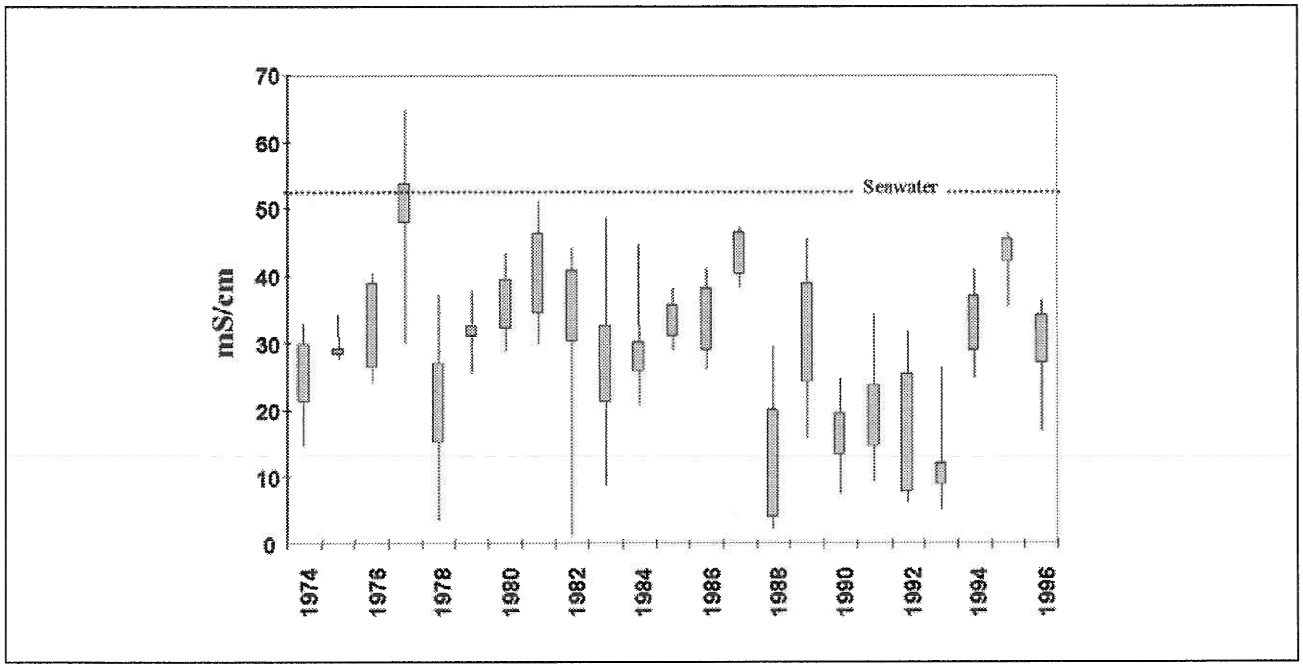


Figure 19. Salinity changes in the Pallinup River, over time. The 'whiskers show the maximum and minimum values and the boxes show the range of the middle 50% of the values (inter quartile range)

were recorded at Magitup, which is adjacent to the same high salinity groundwater region. Warperup Creek drains from an area of higher saline groundwater however the range of salinity values at the lower end of its catchment, though they were higher than for other sites, were considerably lower than for Six Mile Creek. Understanding the various spatial, as well as temporal influences that act on different parts of a catchment can help us to be more precise about what may or may not be acceptable for the future management of the system.

The main channel data (Figure 21) shows a slight decrease in overall salinity at O'Meehans Road and Sandalwood Road compared with sites further upstream. Peenabup Creek recorded the lowest overall values. Camballup is at the top end of the catchment. The geology of the landscape lower in the catchment combined with increasing rainfall and groundwater discharge, towards the coast, may account for this 'freshening'. The effect has been noted in other South Coast Rivers such as the Blackwood and Oldfield Rivers (Water and Rivers Commission data sets).

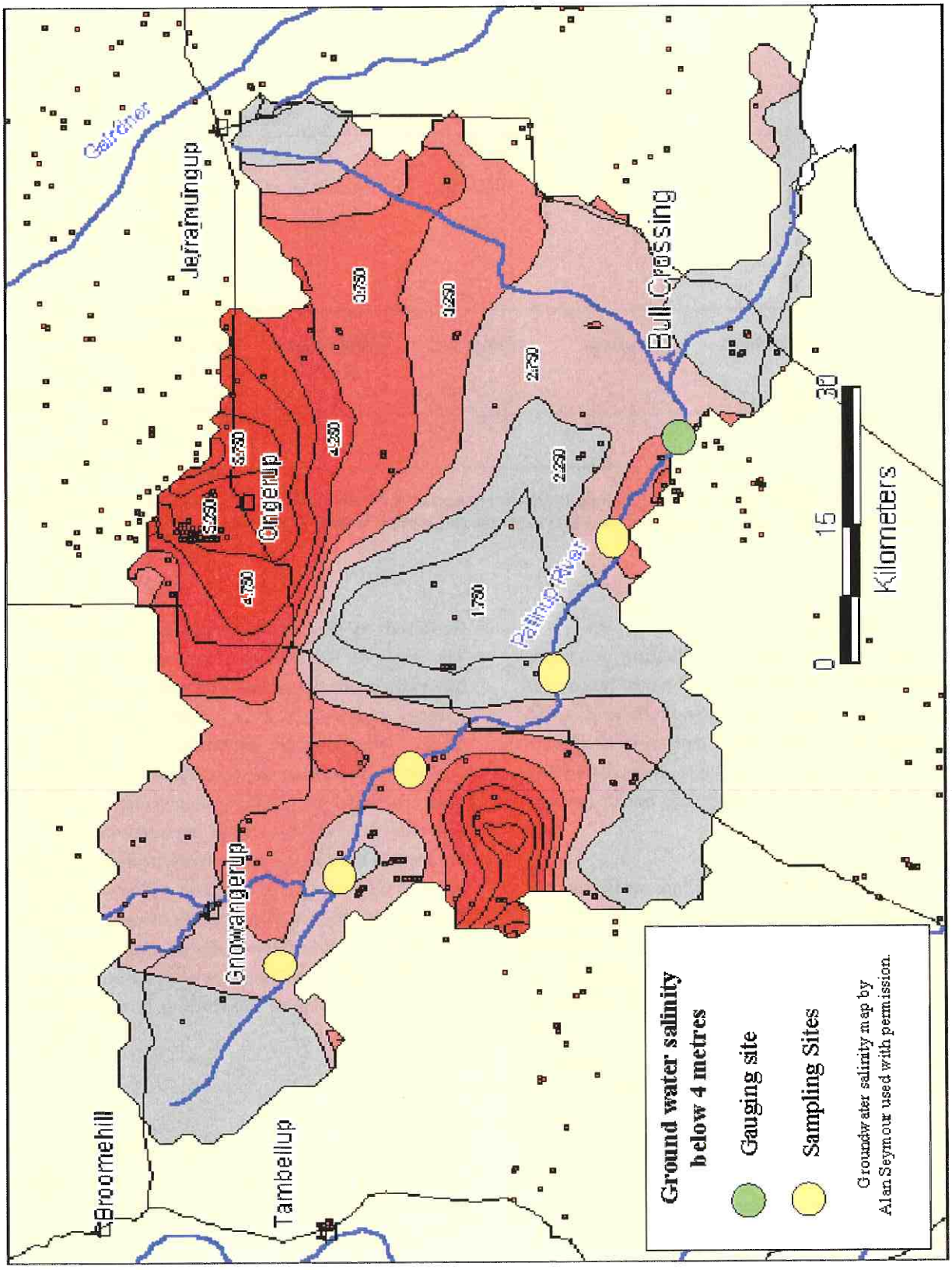


Figure 20. Groundwater salinity > 4 metres depth in the Pallinup catchment

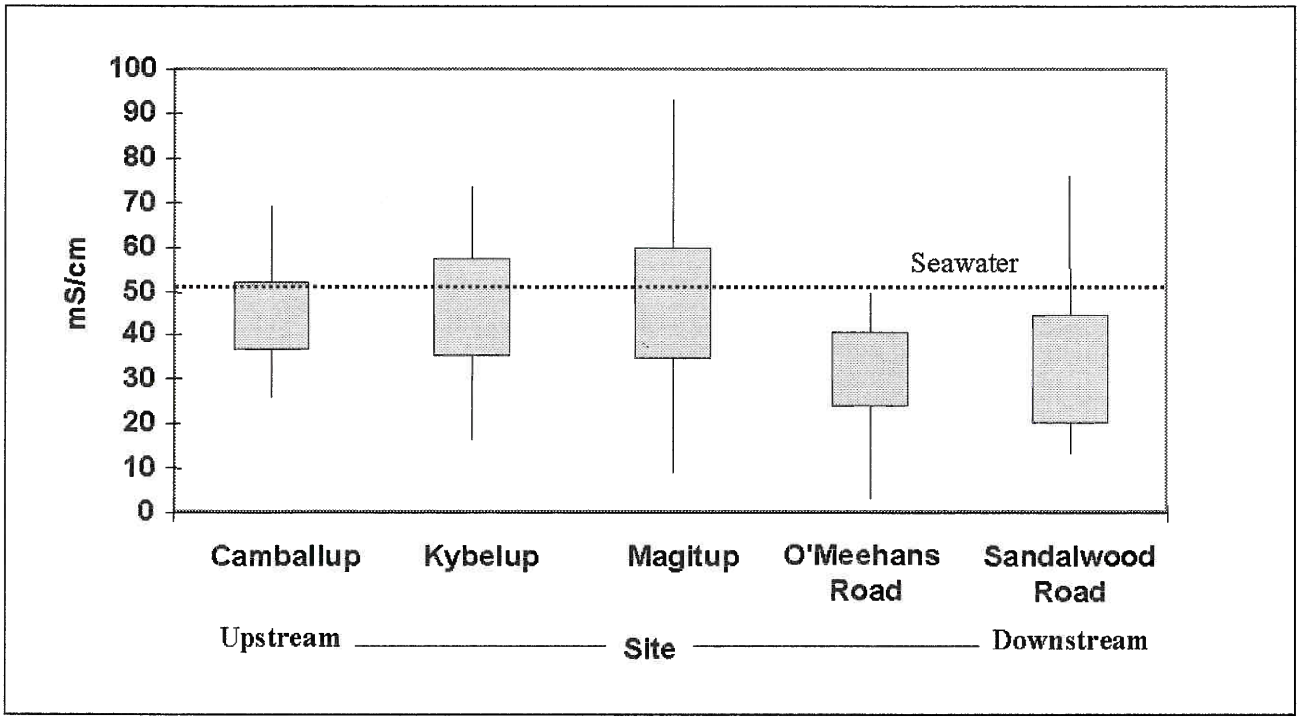


Figure 21. Salinity range for samples collected along the main channel of the Pallinup River (The 'whiskers' extend from the maximum to the minium values and the boxes show the range of the middle 50% of the measurements)

Acidity and Alkalinity

pH is a measure of the acidity or alkalinity of water and it influences many chemical and hence biological processes. Values range from 1 (extremely acid) to 14 (extremely alkaline). Generally the pH of freshwater is around the neutral value of 7, but this varies depending on the geology of the catchment and hence the soil composition.

Waters with pH below about six are rare unless there is input of natural acidic substances, for example in peaty soils. Other influences are acidification of soils by application of agriculture fertilisers, acid rain and acid leachate from mines discharged to a waterway. Potential acidification of soils in the Pallinup catchment would most likely to be a result of fertiliser application. Currently however the average pH of Pallinup waters (Figure 22) is well above 7 with no values recorded below pH 6.5 and some values greater than pH 9.

The median value for all samples was pH 8.4 and this level is characteristic of many of the South Coast rivers. It can be seen from figure 22 that pH does not vary greatly over time and space. The ANZECC guidelines (1992) indicate that in many waters the pH is controlled (buffered) by the carbonate-bicarbonate content.

The soils of the Pallinup are shallow so there is relatively good contact between water and bedrock. The geology is dominated by weathered Pre-Cambrian granite underlying the catchment. The soils may also contain contain calcareous (lime) material in lower horizons, which means that water in contact with these soils for any length of time becomes alkaline. It is known that marine waters are very strongly buffered to a pH of approximately 8.2. The saline waters of the Pallinup also show a narrow range of values suggesting a high degree of buffering. For example during 1998-2000, the median pH value for all measurements made was 8.35 with 50% of the reading lying between 8.1 and 8.4.

Turbidity

Turbidity is caused by suspended material in water such as fine clay, silt, phytoplankton, bacteria or organic detritus. Particulate matter may come from point sources such as sewage outfalls, industrial wastes and stormwater drains, but most of the fine sediment load in catchment tributaries comes from stream bank erosion and the catchment top soils.

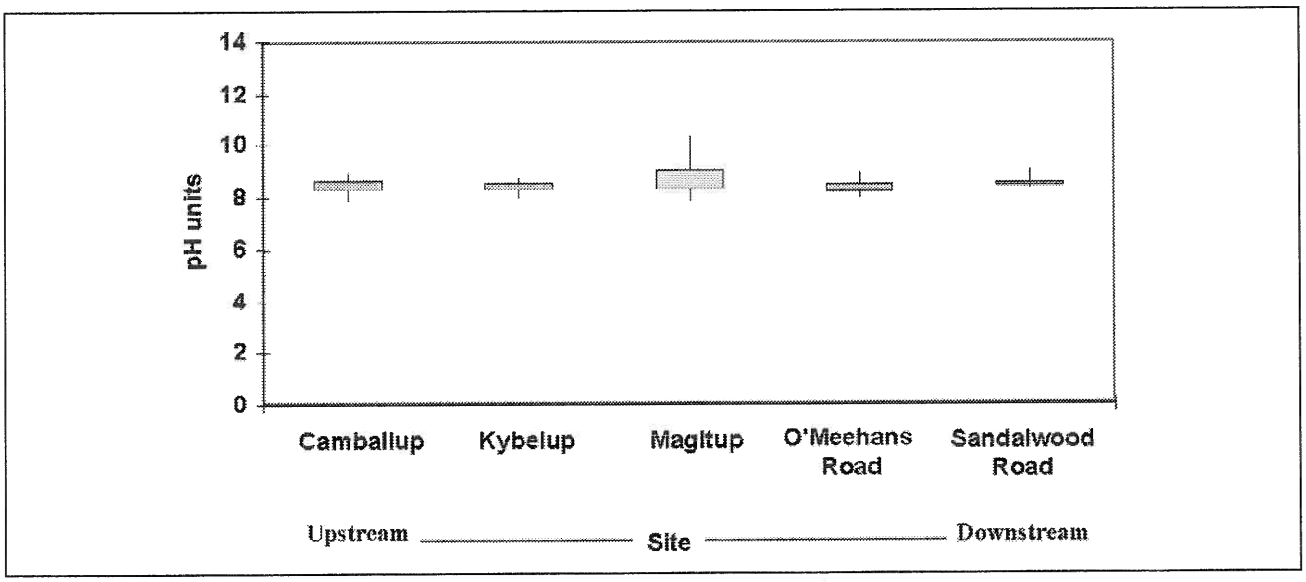


Figure 22. The variation in pH values along the Pallinup River (1998–2000)

Widespread clearing of catchments can cause significant increases in turbidly, especially in steep areas. In still waters turbidity may reflect mostly phytoplankton abundance or, in windy conditions, stirred up sediments. Turbidity measurements do not differentiate between the types of suspended material.

High turbidity affects aquatic ecosystems both while in suspension and when the suspended material settles out. After floods, fringing vegetation may be covered with fine sediment giving it a dusty appearance. While in suspension, sediment cuts down the underwater light levels and therefore affects aquatic plant growth and temperature. As it settles, fine clays and silts can smother bottom organisms and their habitats. The quantity of suspended material in flowing waters is highly dependent on the rate of flow, with large increases associated with storm flows.

The difficulty in describing critical levels in Australia, is that our dryland streams are naturally high in suspended material. The 1992 ANZECC guideline recommended that in relatively clean waters turbidity should remain below 10 NTU's. In still, poorly mixed waters, the ANZECC (1992) recommendation is 4.5 NTU's. NTU stands for Nephelometric Turbidity Unit and is a relative measure of the degree of 'cloudiness' of the water.

Many turbidity values for the Pallinup sites were close to 10 NTU, which is moderately low. There appears to be little difference between sites on the main channel and the sites representing the major sub-catchments although there is a suggestion that the main channel was slightly more turbid over the sampling period. Other observations made during site visits indicate increased turbidity was possibly due to microscopic algae. The stability of the river banks will be most strongly reflected in turbidity values during storm events.

Nutrients

Nitrogen (N) and phosphorus (P) are two essential elements for the growth of living things. High concentrations of N and P are linked to excessive growth of nuisance plants in water bodies. Most of the nutrients present in a catchment are stored in its soils. Natural levels of N and P are determined by the amounts released from the bed-rock material by weathering processes, fixation of atmospheric N by some plants and leaching. Human activities such as sewage disposal, fertiliser application and industrial effluent's have added to the store of nutrients in catchment waterways. Land clearing may have mobilised the natural store of nitrogen through increased runoff and sub-surface flow.

The evidence suggests that there has been an increase in the export of nutrients from catchments to waterways, although the process of transfer of nutrients is not sufficiently understood to define best management practices that will prevent further enrichment.

The overall effect on river pools and estuaries is that excess nutrients and warm temperatures trigger algal blooms or excessive aquatic plant growth. Once these conditions subside the algae dies and sinks to the

bottom to decay. This organic matter is decomposed by bacteria that consume oxygen during respiration. Combined with insufficient mixing of the water body, the deeper waters can become anoxic and unable to support fish and aquatic macro-invertebrates. These conditions are common in Beaufort Inlet and are discussed in that section of the report dealing with the water quality of the estuary.

Worldwide increase in levels of algal growth in waterways, both microscopic and macroscopic, suggests that the issue is of broad concern to environmental health. It has also been noted nevertheless, that higher levels of nitrogen in water can be found in relatively pristine streams in Australia (ANZECC water quality guidelines 1992)

Nutrients can so stimulate the growth of certain plants that they can come to dominate an aquatic system, often to the exclusion of other species groups. Such systems are said to have become 'simplified ecosystems'. They typically contain high populations of very few species. This loss of biodiversity, is a form of environmental degradation. Once such simplified ecosystems begin to control the natural cycling of nutrients, it may become very difficult to shift the balance and problems can become persistent and recurring.

Exotic nuisance plants include water hyacinth, salvinia and hydrocotyle. These types of aquatic weeds are introduced into waterways systems and can alter the nutrient cycle. They are not likely to become a problem in the Pallinup River because of the extremes in environmental conditions. More likely are problems with macroalgae and phytoplankton such as cyanobacteria. The most threatened parts of the Pallinup are the permanent pools and the estuary.

Relatively little is known of natural N and P levels in semi-arid river systems, and of the natural nutrient status and processing within perennial pools in these ephemeral river systems. A wide range of nutrient concentrations has been reported for Australian rivers and streams. It is important to know how persistent high concentrations are and what influences them.

Nitrogen (N)

Nitrogen in catchments is present in several different forms. In the WRAE monitoring program, only the total amount of nitrogen present in each water sample, was measured. This measure is known as the Total Nitrogen (TN). Most forms of nitrogen are soluble and therefore relatively mobile being easily lost in solution with storm runoff, or leached with rainwater as it infiltrates the soil profile and is carried to groundwater. Nitrate (NO_3) is generally the most important fraction in rivers. Nitrogen is also returned to the atmosphere through various processes.

During dry weather, organic nitrogen (N incorporated into plant and animal tissues) in the pools may be the dominant fraction, because of the growth and the uptake of available N in new plant tissue (phytoplankton remember are plants).

Leaching of nitrogen compounds may be important in the arable areas of the Pallinup because in these areas most soil N is present as the highly soluble, and therefore mobile, nitrate.

Fertiliser use has frequently been linked to N enrichment in waterways. This is particularly a problem when crops have a high demand for nitrogen fertilisers. Canola, an increasingly important crop in the Pallinup region, is known to have high nitrogen requirements (100kg/ha) because high soil nitrogen status is essential to its establishment and good early growth. The loss of nitrogen from arable areas in the sub-catchments may occur during storms (surface runoff) and shallow ground water flows that discharge to small tributaries or directly to the main channel.

Figure 23 compares the ranges of TN values for sample sites along the Pallinup main channel. Only samples taken during flows are represented however as these were considered a better indicator of dynamic nutrient transport through the catchment. The median value for samples in flow conditions was 1.6 mg/L and for nil flow conditions 3.9 mg/L, suggesting local instream nutrient cycling is a significant influence during periods of no flow.

It is common for a layer of higher salinity water to collect at the bottom of pools and estuaries, especially in summer. This process is known as stratification and is known to be associated with the release of nutrients from sediments. The shallowness of the Pallinup Pools makes it less likely that stratification is a major influence.

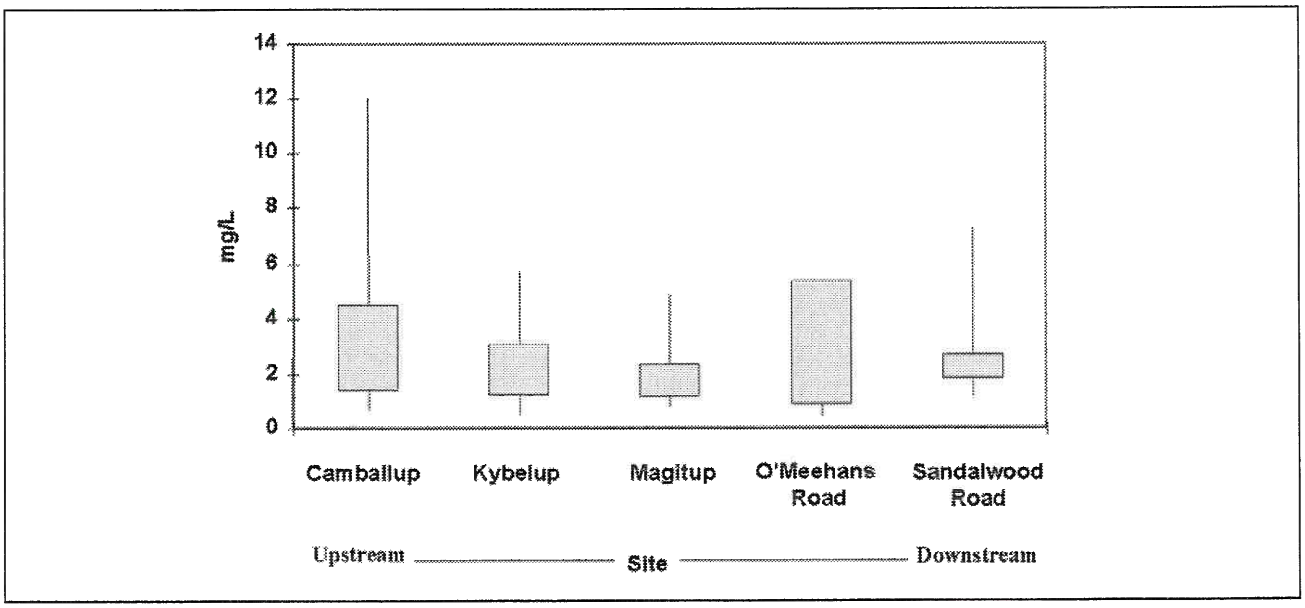


Figure 23. Total Nitrogen (TN) levels along the Pallinup River channel in 1998–2000

Weaver (1999) showed that pool sediments in the Kalgan River contained large amounts of stored nutrients, but there is no data for the Pallinup.

Nitrogen infiltrating through soils will be seen in the Pallinup tributaries during or immediately after storm events. These flows were not often sampled during the Pallinup monitoring program.

The concentration of N in the sampled waters of the Pallinup River, were generally high. Concentrations in natural streams would be expected to be within the range 1.0 to 1.5 mg/L (ANZECC 1992). In the Pallinup approximately 55 % of samples contained more than 1.5 mg/l. N levels in the Oldfield River, over a similar period, had a range similar to the Pallinup. The Oldfield River, however, has a broad and well vegetated, riparian zone with the upper third of the catchment uncleared.

One sample was very high in N (> 10 mg/L). This followed a day, of reasonable rainfall (5 mm) in the area, however there was no observed flow at the time of the visit to the pool and there was evidence of stock having accessed the site. This emphasises the difficulties of interpreting what is happening from limited amounts of water quality data.

The more strategic samples collected the more confident we can be that the true ranges and variation is being observed. Determining cause and effect requires a good deal of thought, program design and adequate data sets.

Although sample numbers are small, the values for sub-catchments do not appear excessively large except for the Peenebup Creek. However much higher values are evident at all main channel sites, although median values are similar.

Phosphorus (P)

Changes in the levels of P, in aquatic environments, have been attributed to fertiliser application, P in sewage, livestock wastes and P in domestic detergents and soaps. While Nitrogen tends to be relatively mobile moving rapidly from catchments in solution, P tends to be present as insoluble fractions and is relatively immobile.

Landowners in the Pallinup catchment are aware that the land is quite heavy (clayey) and clays can lock up phosphorus more strongly than sandy soils. This means that unless phosphorus is washed from catchments during erosion where it is attached to soil particles, it tends to stay where it is applied. Phosphorus as fertiliser, may still be present in soluble organic or inorganic forms, and leached to groundwater. In the alkaline environment of the Pallinup even soluble applied P would tend to quickly form insoluble complexes with calcium. Phosphorus loss then, is usually strongly dependent on sediment transport.

The concentrations of phosphorus in the waters of the Pallinup were low to moderately high (Figure 24). Water in the Pallinup exceeded 0.1 mg/L of P for

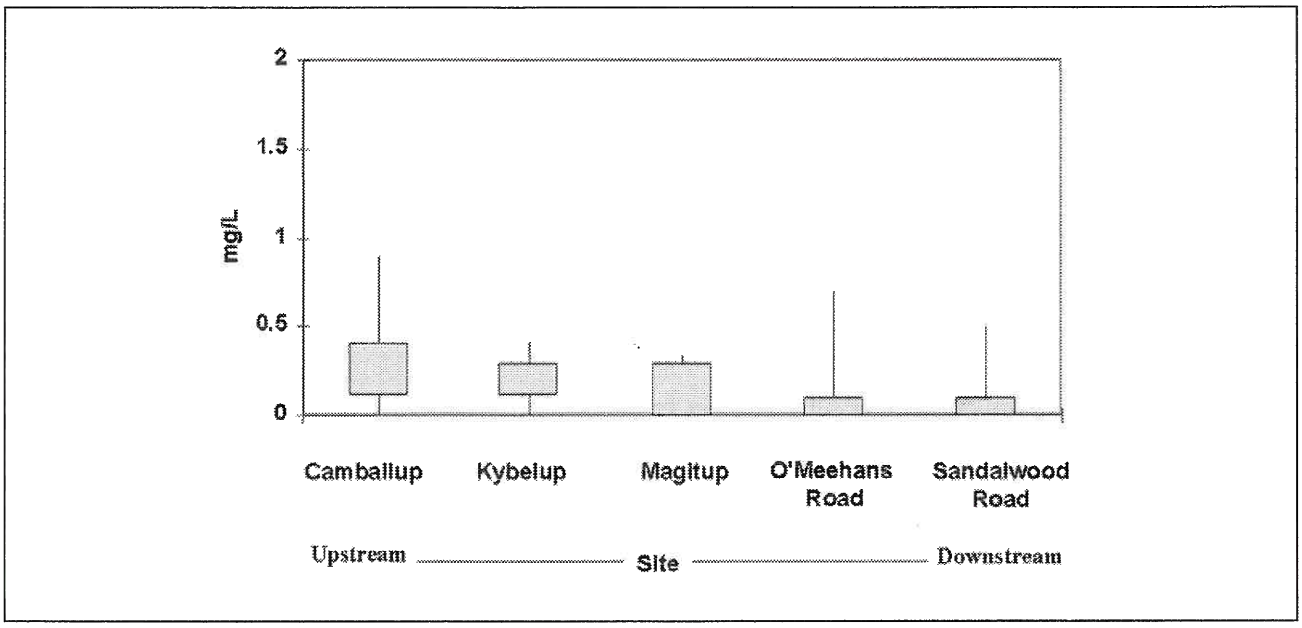


Figure 24. Total phosphorus levels along the Pallinup main channel

approximately 48% of the samples. As was the case for nitrogen, there were some extremely high sample concentrations usually associated with no flow conditions in pools. The highest concentration was 0.9 mg/L and was associated with the high nitrogen sample mentioned above.

The median value for flowing water was 0.07 mg/L and for nil flows from the surface of pools, 0.22 mg/L, three times higher, suggesting, as for nitrogen, local processes increasing nutrient concentrations at specific sites or at particular times.

General comments on site conditions and the monitoring method

A variety of conditions were noted at the monitoring sites. The colour of the water varied considerably and there were even suggestions of blue-green algae blooms. At other times the water was remarkably clear. There was ample evidence of stock moving about in the waterways and this could have a significant impact on water quality.

Small fish were common, particularly the introduced gambusia. Some of the sightings included native species (*Galaxias* sp.), goby's and other larger unidentified species. Schools of juvenile fish, sometimes in large numbers, were seen. Thick streamers of bright green algae filaments were observed attached to rocks and logs, particularly at riffle zones. Free floating algae was found at different times along with ruppia (an aquatic flowing plant), which had times of active growth but also 'died off'. Crustacea such as water snails, shrimp, gilgies and koonacs, were also observed. Although ecological monitoring was not undertaken during the 1998–2000 program, further investigations were proposed by the Water and Rivers Commission in conjunction with the Gnowangerup LCDC. A basic macro-invertebrate sampling, using the AUSRIVAS format, was undertaken on a seasonal basis between November 2001 and September 2002.

The interpretation of the monitoring data is limited by many factors. The seasonal patterns of flow are complicated by unpredictable storm events. Water quality data is seldom comprehensive and the limitations need to be acknowledged. The more samples that are collected, in an unbiased manner, the more confidence we have that they paint the correct picture of overall conditions in the river. It is generally accepted that it takes at least five years of regular monitoring to achieve a satisfactory perspective of water condition.

The first samples of the reconnaissance monitoring program were collected in September 1998. The last sample was collected in May 2000. During this time, flow varied from nil to moderate. Although higher flows occurred during this period, the rapid rise and fall of the river after storms meant that these levels were seldom encountered by the person making the measurements. This is illustrated by the fact that of the 277 site visits that were made, no flow and low flow conditions were encountered for 80% of the time and

moderate flows for the remaining 20%. Some 30% of the site visits were to the main trunk of the Pallinup.

Conclusions

The Pallinup is a naturally saline catchment, hence its earlier name, the 'Salt River'. Increased salinisation of the catchment soils and its waters, and the presence of large amounts of excess sediment in the river, are pressing natural resource problems brought about by human agricultural activity in the area. The discharge and salinity measurements obtained through monitoring programs, suggest an environment subject to dramatic seasonal and annual variations.

Some concern has been expressed by the community with respect to the impacts of pollutants such as pesticides. To date little is known about the impacts of these chemicals on the river system. The elevated levels of basic nutrients such as nitrogen and phosphorus are of concern from an ecological perspective. It is not known if these make their way to the river predominantly in overland flow or through groundwater inputs.

Monitoring results suggested that the levels of nutrients in the aquatic systems, while elevated, especially the concentration of N, are not more so than for other South Coast catchments that were assessed during the same period.

The high nutrient levels put the quality and diversity of the waterways at risk. There are species of phytoplankton that are tolerant of hyper-saline conditions. Lowering species diversity is a key feature associated with degrading natural systems and may even define ecological degradation. There is therefore a need to manage the catchment with the aim of reducing nutrient inputs to the waterways

The pH of the aquatic habitats in the Pallinup is probably naturally alkaline, so any acidification of the soils due to agriculture would put severe stress on organisms adapted to alkaline habitats. There is no evidence in the monitoring data that this is occurring, although acidification of soils is increasing in the catchment (AgWest).

The degradation of pool structures was discussed in the section dealing with channel stability. The infilling of pools with sediment significantly lowers the surface water storage of the river and in turn the water temperature will be influenced by the decreased water depth. The type and diversity of native organisms will be impacted. Erosion and sedimentation impact other values such as social amenity and aesthetics.

3.3 The estuary

3.3.1 Estuary structure

The Beaufort Inlet is on the Register of the National Estate database as it is located in one of the world's most outstanding botanical areas. The estuary has an area of approximately 6.5 km^2, and an average depth of nearly one metre. This equates to an estimated typical volume of 6 500 000 cubic metres below mean sea level. The annual inflow from the river varies from about two to forty times this volume. The surface area and the high evaporation rate, combine to considerably raise the salt concentration while the bar remains closed.

The distance from the ocean outlet to the upper end is 14 km and the estuary is aligned in a north-west to south-east direction, with its upper parts winding and riverine in nature. About one quarter of the inlet area is within the river-like upstream reaches. These reaches lie in a narrow valley where the soft Spongolite rock, is exposed in cliffs and steep slopes on the banks. The river has cut down to the hard basement rock (gneiss). The lower and broader areas of the estuary are shallow and exposed to the frequent strong winds that can raise a 'chop' sufficient to make it hazardous to negotiate in a small dingy. The estuary is the final river pool and these characteristics give it its unique character.

The estuary has considerable habitat value due to the extensive pristine and semi-pristine fringing vegetation. These areas are home for many species of aquatic flora and fauna, including marine fish and invertebrates that enter when the bar is open. The Inlet also supports tourism and recreation, and although these have been mainly low key camping, the area is likely to become of increasing interest to visitors. The estuary also hosts a small commercial fishing operation, with catches between 1992 and 1997 estimated from 1.8 to 2.4 tonnes a year.

Beaufort Inlet has a high sandy bar that is opened periodically to the sea but can remain closed for intervals of several years. The bar is about 500 m in

Figure 25. An aerial view of the Beaufort Inlet with the Stirling Ranges on the horizon

Figure 26. A view from the banks of the inlet at low water level

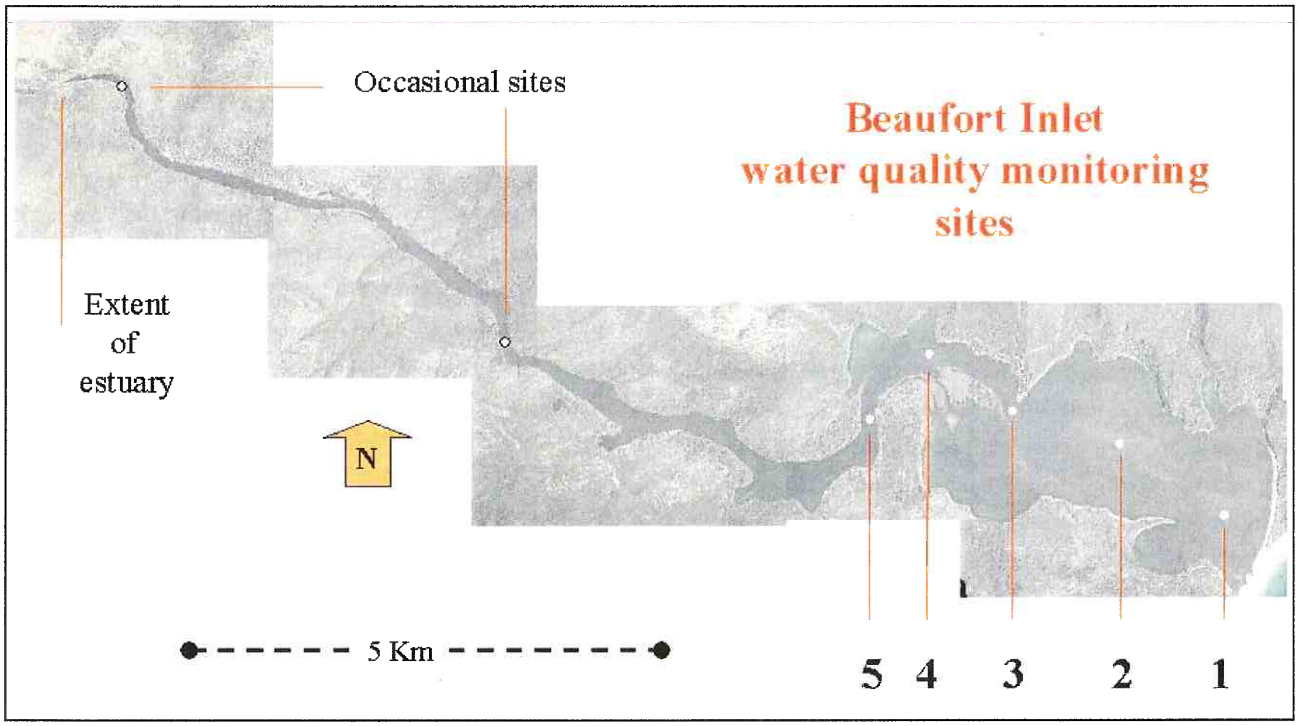


Figure27. Showing water quality monitoring sites in the Beaufort Inlet

length. The opening and closing dates of the bar have been recorded since 1954 (Hodgkin and Clarke, 1988).

The waters in Beaufort Inlet are seldom clear. The turbidity is caused mainly by the abundant phytoplankton and by fine sediment resuspended by wave action. The salinity in Beaufort Inlet varies from one third to about twice that of seawater. The salinity is seldom less than 18 ppt (seawater is 36 ppt) even following river flow. Evaporation may raise the salinity to 50 – 60 ppt before the winter rains. The temperature of the Inlet varies from approximately 12°C in winter to 25°C in summer.

The bottom sediments of the inlet widely consist of bluish black ooze that appears to be quite deep in places and would be risky to stand on. This is not a recent phenomenon as the explorer Eyre, in 1841, commented that they were unable to ford the inlet because of the deep mud and the risk of losing the horses. High river flows have caused scouring and deepening of the bed where the channel narrows or at bends. In the shallow backwaters, tube-worm colonies are prolific and these areas are exposed at low water levels.

High levels of nutrients, typically nitrogen, phosphorus and organic matter, cause water bodies, such as the Beaufort Inlet to become eutrophic, a condition that can be aggravated by the heavy use of agricultural fertilisers in the catchment. High nutrient levels are widespread in the South Coast waterways. In a eutrophic water-body, highly productive plankton and algae growth are a dominant feature of the ecology. Fish kills in estuaries are often natural events arising from the changing seasonal conditions, and have been recorded in past decades, however these appear to be happening more regularly and more extensively in some systems. Toxic phytoplankton has also been identified in the Beaufort Inlet waters during the summer.

The Water and Rivers Commission has carried out water quality monitoring in Beaufort Inlet since 1997. The environmental processes are discussed more fully in the next section. The monitoring results indicate moderate to high nutrient levels. This is indicative of potential degradation of the water quality due to excessive plant growth and a succession of ecologically harmful species. Excessive macroalgae and seagrass growth has been reported in Beaufort Inlet as well as reports of dinoflagellate blooms (WRC, unpublished).

The deoxygenated waters in the shallow parts of the Inlets in Beaufort Inlet are of concern and are a symptom of eutrophication stress, due to high organic loads. Severely deoxygenated waters can lead to rapid nutrient release from the bottom sediments, increasing the nutrient loads in the water column and leading to further degradation of the waterbody. High levels of picoplankton were also recorded (WRC, unpublished).

In March 1998 there was a significant bloom of phytoplankton especially the dinoflagellates and diatoms. By June a fish kill occurred and there was a bloom of dinoflagellates – especially *Heterocapsa* and a potentially toxic species to fish, *Gyrodinium*. The water was green due to a significant amount of Picoplankton cyanobacteria (cf. *Synnechococcus*). However, no *Prymnesium* species were detected during the fish kill. A steady amount of runoff broke the bar in June 1998 and there was a flushing event that helped to reduce phytoplankton levels. Concerns that pesticides might have been responsible were investigated by having samples analysed, but the conditions were clearly indicative of eutrophic factors being involved. The upper reaches of the inlet have been known to be extremely 'smelly' at times, and dragging up bottom sediments releases pungent hydrogen sulphide gas, with its characteristic 'rotten egg' odour.

Sediment movement into Beaufort Inlet is also a major concern, but there is no reliable data on the rates and quantities of deposition involved and how the various sized floods contribute.

3.3.2 Flora and fauna

A summary of estuarine flora and fauna can be found in the Environmental Protection Authority publication, *Beaufort Inlet and Gordon Inlet*, Estuarine Studies Series No 4, 1988. This is one of a series of booklets prepared by Ernest P Hodgkin and Ruth Clark.

Some additional research has since been carried out on nutrient conditions and biological activity in the bottom sediments of the estuary(1). A detailed study was carried out by Jane Griffith, Phd candidate, Edith Cowan University (1999–2001).

There is a need for further investigations of the ecology of the Beaufort Inlet, which remains poorly understood.

3.3.3 Water quality monitoring

The section details the water quality of the Beaufort Inlet from monitoring data that has been carried out in the Inlet by the Water and Rivers Commission since 1997. The data presented are the first, routine water quality information collected from the Inlet. The Water and Rivers Commission funded a seasonal sampling program, and NHT Coast and Clean Seas funded higher frequency sampling at the time of the December 2001 bar opening.

On each sampling run, in situ measurements were made and water samples collected from fixed sites in the Inlet. Five primary sample sites were chosen and others were added as required. Surface and bottom water samples were collected and sent to the Australian Environmental Laboratories (AEL) for the analysis of nutrient content. A Hydrolab H_20 multiprobe was used at each site to collect temperature, salinity, specific conductivity and dissolved oxygen data at approximately half metre intervals, through the water column. It is known that conditions can often vary dramatically between the top and bottom waters of an inlet. Secchi disk depths (a measure of water clarity) were also collected at each site. Phytoplankton samples were collected and sent to the Phytoplankton[3] Ecology Unit (ECU) of the Water and Rivers Commission to identify the organisms in the water.

The aim of the seasonal monitoring program was to establish some baseline information on the condition of the system, especially in relation to nutrient status. Five sampling sites were selected at about 1 km intervals along the length of the Inlet, starting near the bar (the bar upstream) and finishing at the crook of the first bend past Millers Point (BEA001 to BEA005 in figure 28). While this program was conducted, the impact of bar openings was identified as being poorly understood but critical to the ecology of the estuary. Consequently 31 sampling trips were done during October 1997 to May 2002 at frequencies ranging from up to four monthly to a few days between sampling trips.

Additional sampling took place on the 3 June 1998 following an extensive fish kill. Data following a February 2000 fish kill were available and are included here. Additional sampling sites have been established (occupied) as part of the NHT funded work in response to river flow events, marine intrusions following bar opening and also subsequent to fish kill events (figure 28).

Depending on the site, the measured water quality parameters include:

- water temperature, salinity and dissolved oxygen concentration measured from the surface to the bottom using Hydrolab Datasonde instruments (and more recently pH and fluorescence on the new instrument);
- total nutrients (nitrogen and phosphorus);
- dissolved nutrients (ammonium, nitrate, phosphate, silicate);
- chlorophyll pigments and the composition and concentration of phytoplankton cells; and
- water colour.

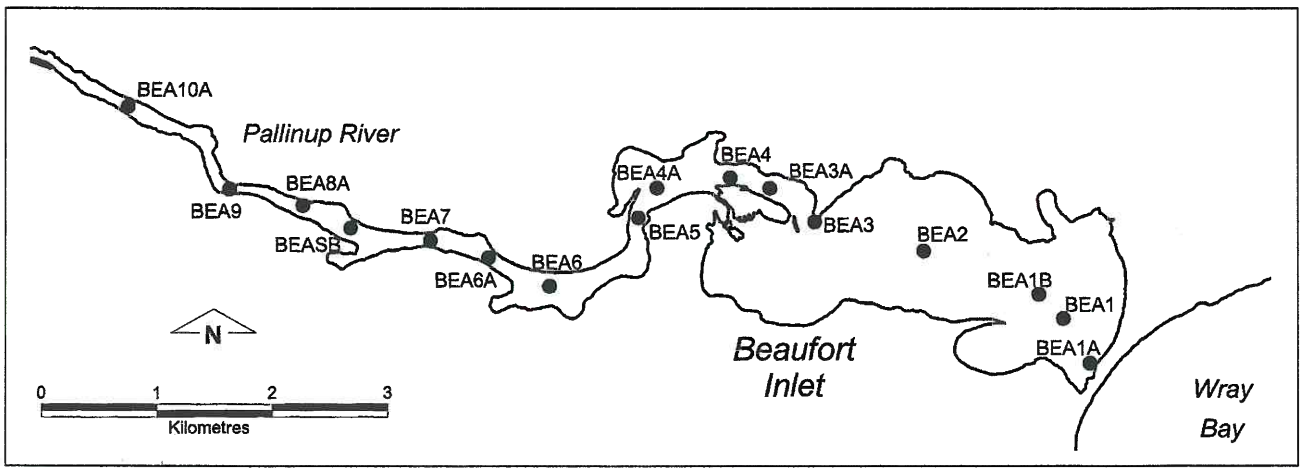


Figure 28. Locations of sampling sites in Beaufort Inlet

Apart from the Water and Rivers Commission data set, the major source of reference information on Beaufort Inlet is the work of Hodgkin & Clark (1988) from which much of the introductory information on Beaufort Inlet is derived.

- Hodgkin, E.P. and Clark, R. 1988, *Beaufort and Gordon Inlets: Estuaries of the Shire of Jerramungup*. Estuarine Studies Series Number 4. Environmental Protection Authority, Perth, WA.

River flow

River flow data is from a gauging station on the Pallinup River at Bull Crossing. Significant flows occurred in April, June and August/September of 1998, February of 2000 and December of 2001. The maximum flow in the period of sampling was nearly 12000 ML/day and occurred on the 5 December 2001.

Bar openings

There have been two bar openings during the period of sampling., one in late June/early July of 1998. Water levels in the estuary had risen in response to rainfall and runoff through April and June of 1998. The bar was artificially breached sometime before the sampling at the end of July (at which time the bar was possibly open) however it was closed by the time of the November sampling. There was a bar opening on 5 December 2001 in response to a significant flow in the Pallinup River in the preceeding 24 hours. River flood flows rose to within 3 – 4 m of the top of the Marra Bridge on the Hassell Highway. On this occasion the bar breached naturally just as efforts were being made to breach it artificially and it remained open for several weeks after. The bar also appears to have come close to breaking in February 2000.

Water Level in the Inlet

Measured water levels ranged from mean sea level during bar open periods to about 1.5 m above mean sea level in mid 2000. However before the bar opening in December 2001 the water level must have been at least 2.5 m above mean sea level and similarly in June of 1998 it was likely to have been about 2 m above mean sea level (note that during the 1998 bar opening the sea level could have risen higher than the 2001 opening – as much as 30 cm above the mean – because of the different time of year; i.e. mid winter versus mid summer). In March 1998 it is possible that the water level (with the bar closed) may have been marginally less than mean sea level because prior to July 1998, water levels are estimates only.

Water levels fell due to evaporation, particularly during summer months, and rose in response to rainfall and runoff and as predicted the water levels fell following bar openings.

Salinity

The median surface and bottom salinities ranged from a low of approximately two parts per thousand (ppt) (brackish water) to a high of about 60 ppt (seawater is 35 ppt). During testing the salinity in the estuary was similar to sea water. Low salinities in the estuary were only recorded after significant river flow, however, high salinities were recorded after prolonged dry periods when salts were concentrated by evaporation.

Significant marine water intrusion was observed following the December 2001 opening (the data following the June 1998 opening was too sparse to draw many conclusions). The intrusion began within a few days of bar opening and continued until bar closure (figure 50). The water balance budgets are estimated at 5 to 10 GL of marine water flowing back into the Inlet during this period.

Vertical salinity stratification was regularly observed in different parts of the Inlet. Stratification means that the salinity varies with depth, generally becoming higher as depth increases. Likewise other parameters such as the amount of dissolved oxygen also change with depth. The presence of vertical salinity stratification has important consequences for nutrient cycling in the estuary as it leads to low dissolved oxygen concentrations which in turn modify nutrient cycling processes.
Both of the holes identified (at 5 and 9 km upstream of the bar respectively) were, at times, subject to extremely strong vertical salinity stratification. The stratification in these holes appears to have largely resulted from evaporation driving the salinity of the entire Inlet upward, with the saltiest water accumulating in the deeper holes, which have continued to retain this after the salinity in the remainder of the Inlet has fallen with rainfall and runoff. While the hole at 5 km upstream of the bar was flushed during strong river flow events, the hole at 9 km was not (figure 52). Strong vertical salinity stratification was also observed following the December 2001 bar opening as marine water intruded back into the Inlet.

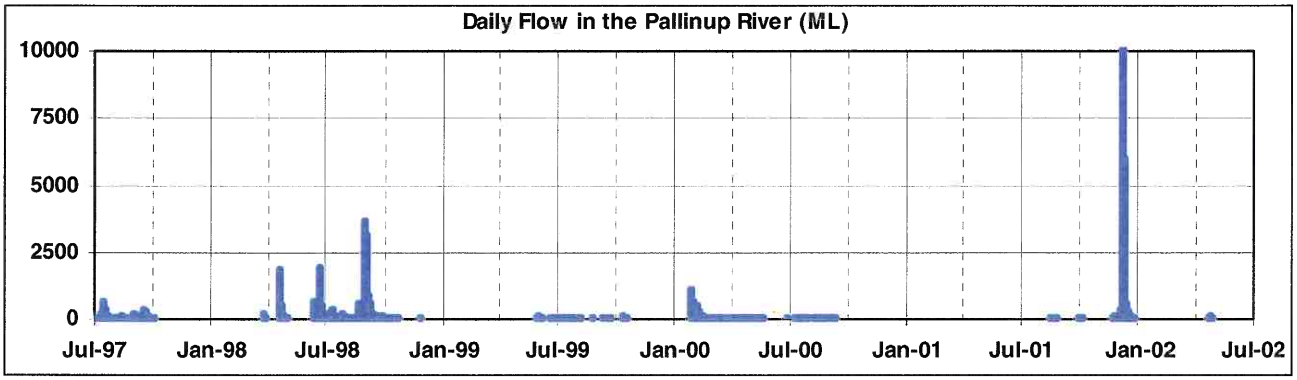


Figure 29. Daily flow in the Pallinup River (ML/day) at Bull Crossing

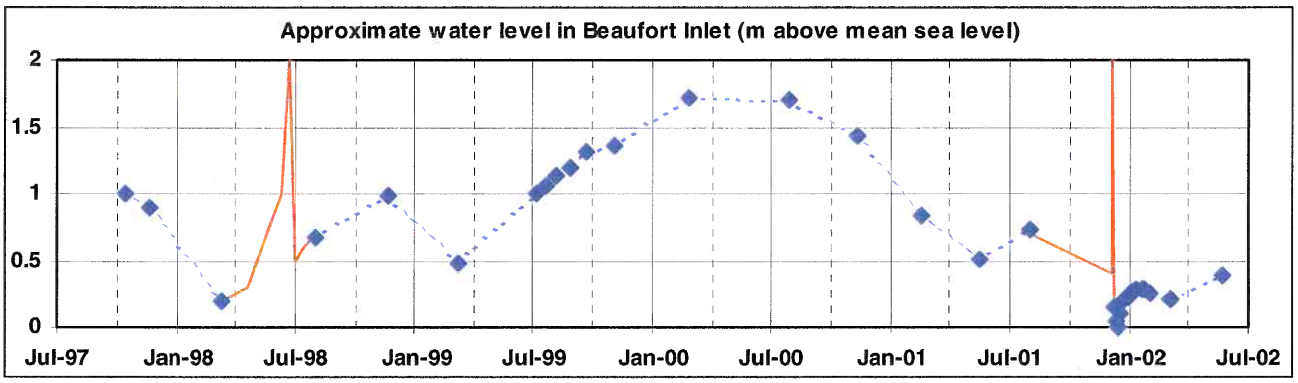


Figure 30. Approximate water level in Beaufort Inlet (estimated metres above mean sea level). Blue squares (joined by dashed line) are the measured water levels, the red line is an estimate of water levels during the bar opening events

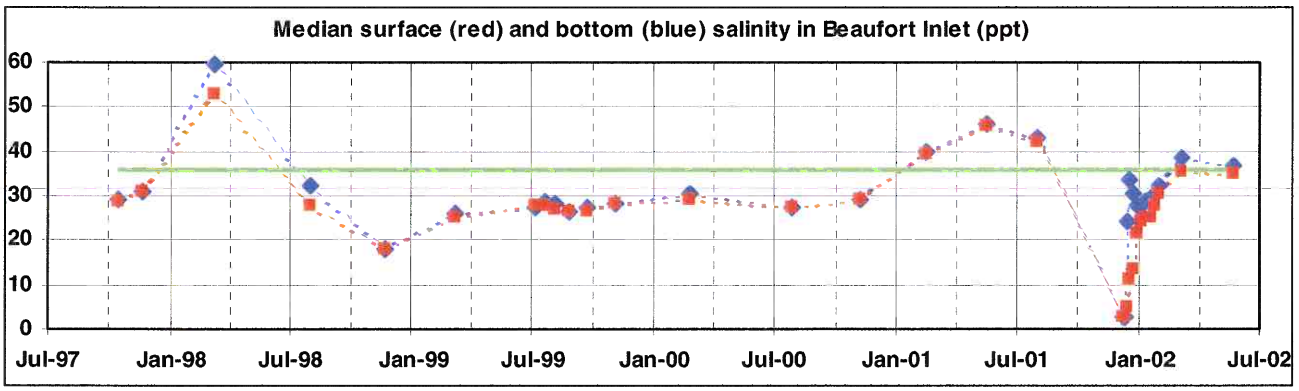


Figure 31. Salinity in Beaufort Inlet (ppt). Medians of surface (red line) and bottom (blue line) data for all sites. The green line is an approximate estimate of seawater salinity for comparison

The major drivers of the salinity and vertical salinity stratification were evaporation, rainfall and runoff, and marine intrusions (in the brief bar open phase). The magnitude of wind-energised mixing was probably also a factor but this has not been investigated here.

There was no clear seasonal pattern in the salinity data recorded (unlike the temperature data recorded in Beaufort Inlet or the salinity data recorded in Wilson Inlet, near Denmark). The main driver of salinity in Beaufort Inlet, and the one with the most seasonal response, is evaporation. Evapo-concentration had occurred over the 1997/1998, 1998/1999 and 2000/2001 summers. It had probably also occurred in the 1999/2000 summer however our late summer sampling on this occasion followed a late summer rain and river flow event. Of the other main drivers the rainfall and runoff is highly variable. While a trend for dilution over the winters, with rainfall and river flow in the winter months (such as occurs in Wilson Inlet) would normally be expected, this effect was only obvious in 1998. This was because the river flow, in the sample period, was not dominated by a clear seasonal pattern.

Temperature

The Inlet water temperature was relatively seasonal. Winter minima down to about 10°C were measured and late summer maxima up to about 22°C were measured. Surface waters were often a degree or two warmer than bottom waters.

Occasionally winter water temperatures at the bottom of deep holes were, counter intuitively, significantly higher than at the surface, although this only occurred under stratified conditions (figure 44). It has been postulated that this is due to some form of bacterial respiration due to the extremely high nutrient concentrations that occur when the deep holes are stratified. It is likely that these higher temperatures are in part due to the trapping and slow cooling (because mixing of any form is prevented by the halocline) of the water warmed in summer.

Dissolved Oxygen

Generally the median dissolved oxygen concentrations (in both surface and bottom waters) were within 20% of the saturation dissolved oxygen concentration; although a number of deoxygenation and supersaturation events were recorded.
Elevated concentrations of dissolved oxygen may have been related to primary productivity. In late December 2001 this primary productivity clearly took the form of phytoplankton blooms, at other times it may have been due to phytoplankton as these appear to be the main, primary producer.

Deoxygenation of bottom waters in March 1998 was related to the active evaporation of water causing evapo-concentration of salts in the lagoon of the Inlet and subsequent vertical salinity stratification occurring in deeper parts of the Inlet (figure 16). Deoxygenation of bottom waters in February 2000 was due to a river flow event causing some vertical salinity stratification and probably washing carbon, in its various forms, from upstream river pools (or possibly the catchment) into the Inlet, consuming all of the dissolved oxygen (figure 19). Deoxygenation of bottom waters in January to March 2002 was due to marine water intrusions following the December 2001 bar opening and minor river flows establishing a vertical salinity stratification (figure 25). Additionally, dissolved oxygen in the deep holes was effectively zero when there was a vertical salinity stratification.

Water temperature, salinity, stratification and phytoplankton blooms are all clear controls of dissolved oxygen concentrations in the Inlet.

Nutrients

Total nitrogen in the Inlet was generally quite high ranging from a low of approximately 0.7mg/L, following episodes of marine exchange, up to 4.5 mg/L following evapo-concentration. Total phosphorus was similarly high ranging from lows of about 0.04 mg/L, in post-bar opening periods, up to a high of 0.4 mg/L following heavy runoff. Total nutrient concentrations rose with evapo-concentration, following runoff from the catchment, and when stratification was occurring. Levels fell primarily with marine exchange.

Dissolved inorganic nutrient concentrations were however low for much of the sample period. Except for periods following river flows and/or stratification, when concentrations of ammonium, nitrate and phosphate increased up to 0.2 mg/L, 1 mg/L and 0.03 mg/L respectively, they were generally below their respective detection limits of 0.005 mg/L, 0.005 mg/L and 0.003 mg/L. Based on the elevated nutrient concentrations observed in the lower water stratum (particularly in deep holes) and considering the findings of work in Wilson Inlet, it is likely that the sediments are a major source of nutrients for the Inlet's primary productivity, and that the availability of oxygen at the sediment water interface is one of the major controls on nutrient recycling.

Although only indicative of potential limitation, a comparison of the dissolved inorganic nutrient molar ratios compared to the idealised Redfield ratio of 16:1, suggests that nitrogen availability may have had a greater capacity to limit phytoplankton growth than phosphorus, except immediately following the December 2001 bar opening when the estuary was awash with dissolved inorganic nitrogen.

The total store of nutrients in the Inlet rose with catchment runoff and stratification, and fell with marine exchange. It would appear that in addition to the small flows from the catchment, sediment nutrient recycling during periods of stratification are major sources of nutrients. While marine exchange may temporarily improve water quality (as in December 2001) it may not necessarily improve the water quality of the Inlet over a longer period where sediment nutrient recycling

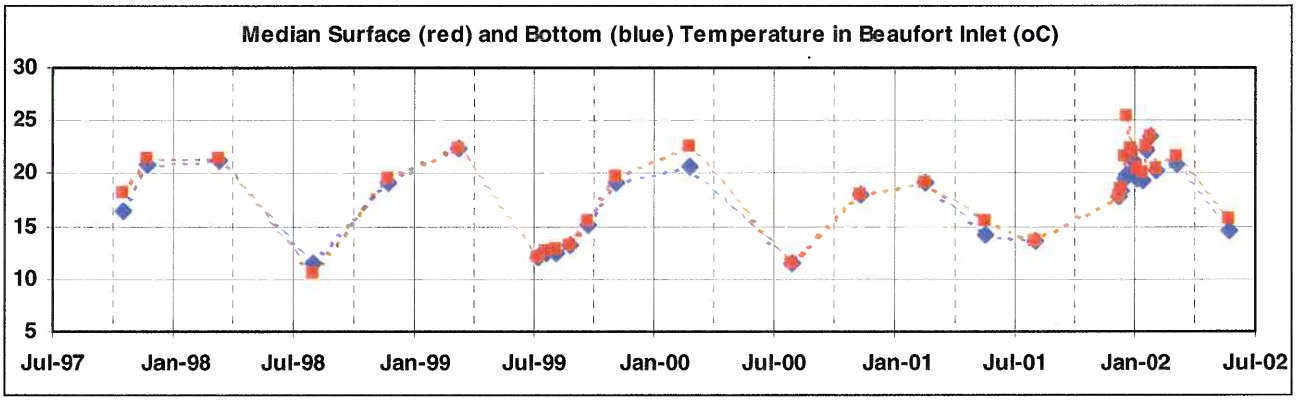


Figure 32. Water temperature in Beaufort Inlet. Strong vertical stratification is present but not obvious at this plot scale

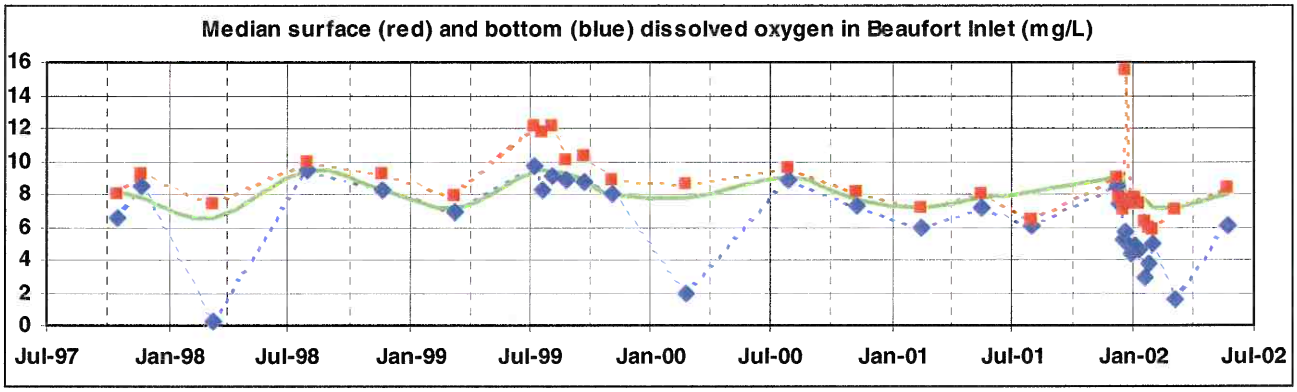


Figure 33. Dissolved oxygen in Beaufort Inlet. The green line is the approximate saturation oxygen concentration. Deviation above the green line indicates supersaturation due to primary production of oxygen and below the line indicates deoxygenation

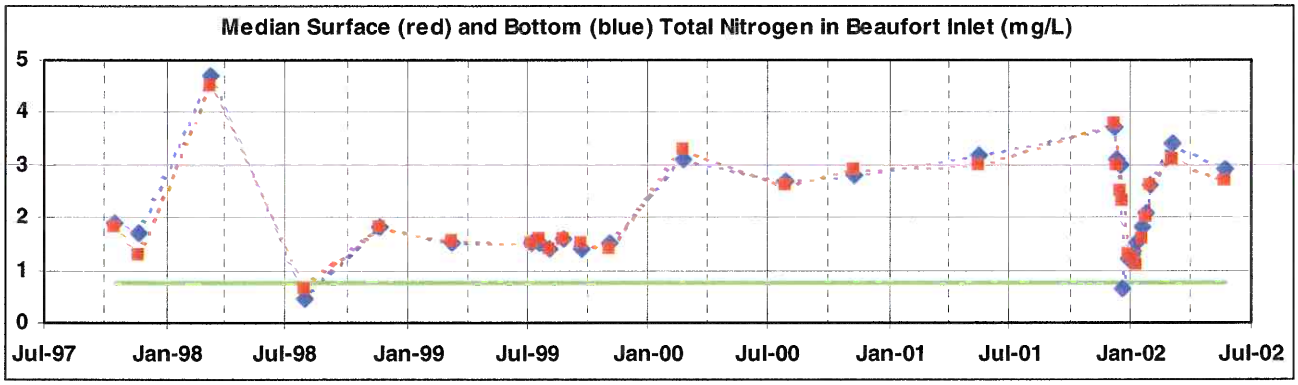


Figure 34. Total nitrogen in Beaufort Inlet. The green line is the ANZECC guideline (developed from a composite of the data from all of the estuaries in the South West of WA)

is dominant, since it leads to stratification and deoxygenation at the sediments.

In Beaufort Inlet, while total nutrients were quite high, dissolved inorganic nutrients were often quite low. Indications are that about 1 – 10% of the total nutrients are accounted for by phytoplankton biomass, and a similar amount by the dissolved inorganic nutrient concentrations (significantly more of the phosphorus is accounted for in this fashion than the nitrogen). Consequently, at times more than 90% of the total nutrients measured in the water column remain unaccounted for. During the flood event of December 2001 this figure fell to 60%. This is a higher proportion of the nutrients than in Wilson Inlet or the Swan River. Comparisons with the Gordon, Wellstead and Hamersley Inlets may help clarify the processes. It is easy to construe a number of possible repositories of these nutrients in the water column, including bacterial and fungal cells, re-suspended sediments and particularly, in the case of nitrogen, dissolved in the organic compounds that give the estuary its darkly-stained colour.

One of the interesting differences between the 1998 and 2001 bar openings was that the elevated total nitrogen and phosphorus concentrations in the post bar opening phase did not occur following the 1998 opening. This is possibly due to the low sampling frequency at the time which may have missed some transient events, or maybe due to less stratification and deoxygenation occurring after the 1998 opening, or perhaps due to differences in biochemical rates and biota between winter and summer. Further work is required to gain a clearer understanding of how bar opening influences the estuary nutrient levels. This work will require more frequent sampling before, during and after an opening event.

Phytoplankton

Unlike nearby Wellstead Inlet, the primary producers in Beaufort Inlet appear, at least on a visual inspection, to be dominated more by phytoplankton than by macrophytes or macroalgae.

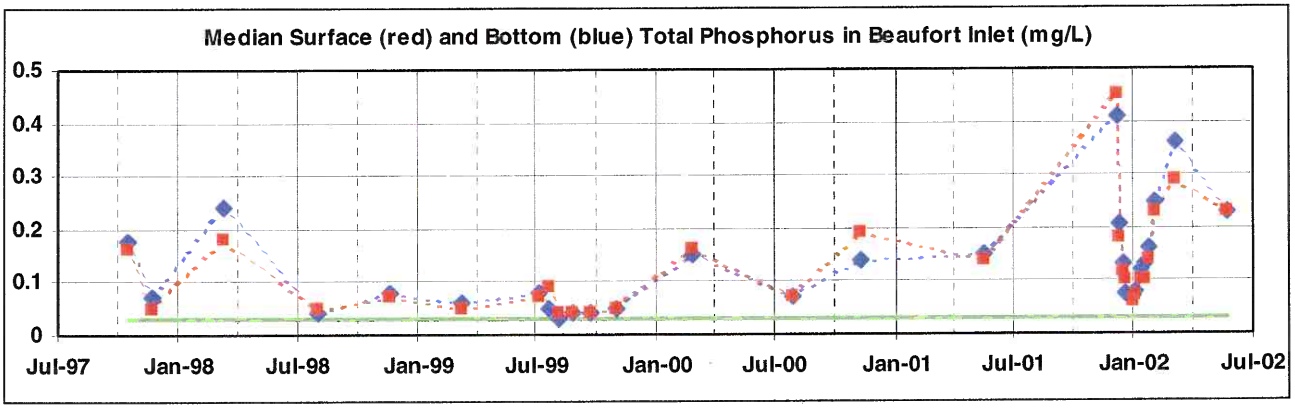


Figure 35. Total phosphorus in Beaufort Inlet. The green line is the ANZECC guideline (developed from a composite of the data from all of the estuaries in the South West of WA)

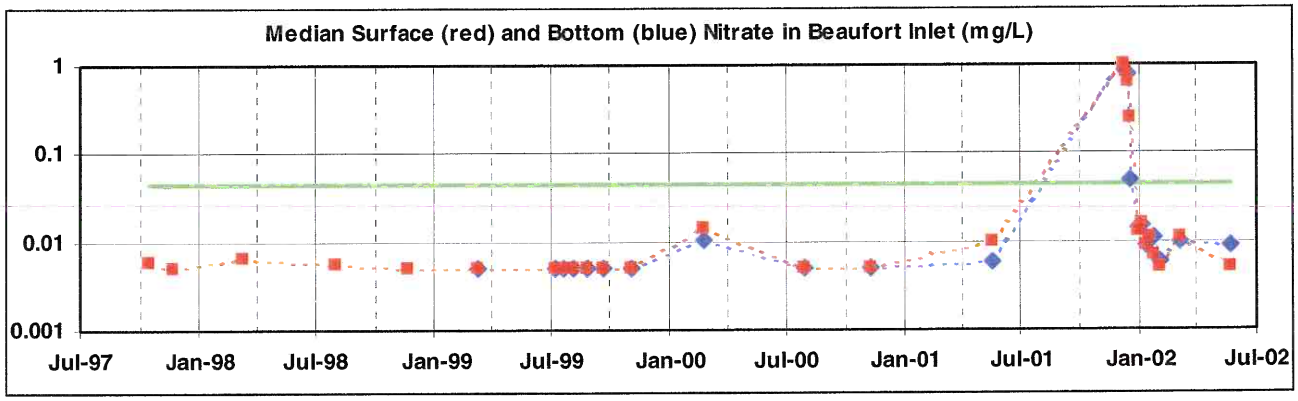


Figure 36. Nitrate in Beaufort Inlet. The green line is the ANZECC guideline (developed from a composite of the data from all of the estuaries in the South West of WA)

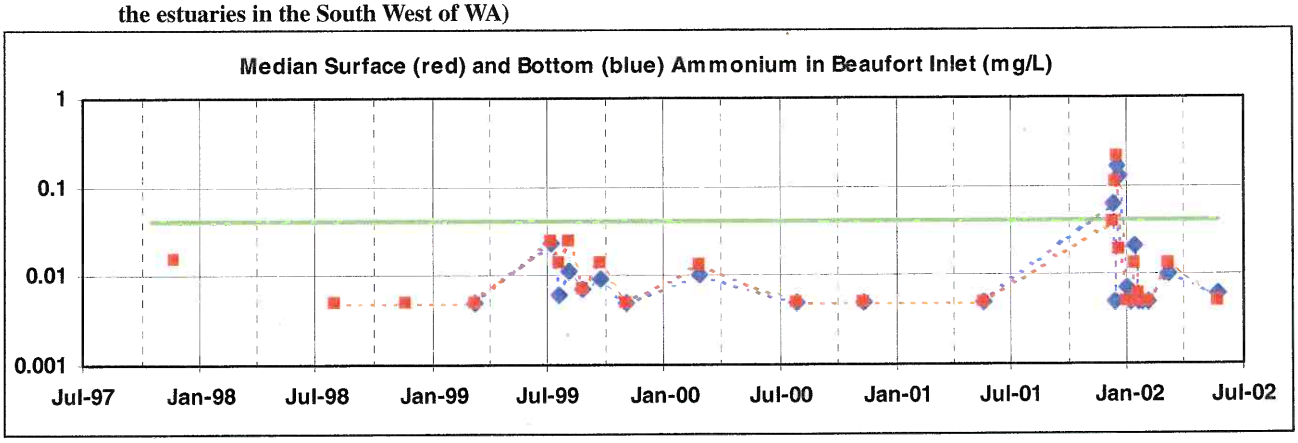


Figure 37. Ammonium in Beaufort Inlet. The green line is the ANZECC guideline (developed from a composite of the data from all of the estuaries in the South West of WA)

The phytoplankton flora is usually dominated by dinoflagellates, diatoms and/or picoplankton. Often cell numbers per unit volume do not appear to be particularly high (e.g. 10 000 cells/mL). The observed picoplankton have not been identified, however in many systems they are found to be small (potentially nitrogen fixing) cyanobacteria such as *Synechococcus* or *Prochlorococcus*. The diatoms recorded in July 1998 and December 2001 were fresh water species, those recorded at other times (including late in December 2001) were marine or estuarine species with greater salinity tolerances than their freshwater cousins. A major part of the dinoflagellate flora observed (including many in the bloom of March 1998) were phagotrophic[9] species without chloroplasts which must feed on true phytoplankton, bacteria, or bacterial predators (such as ciliates and small protists) to survive.

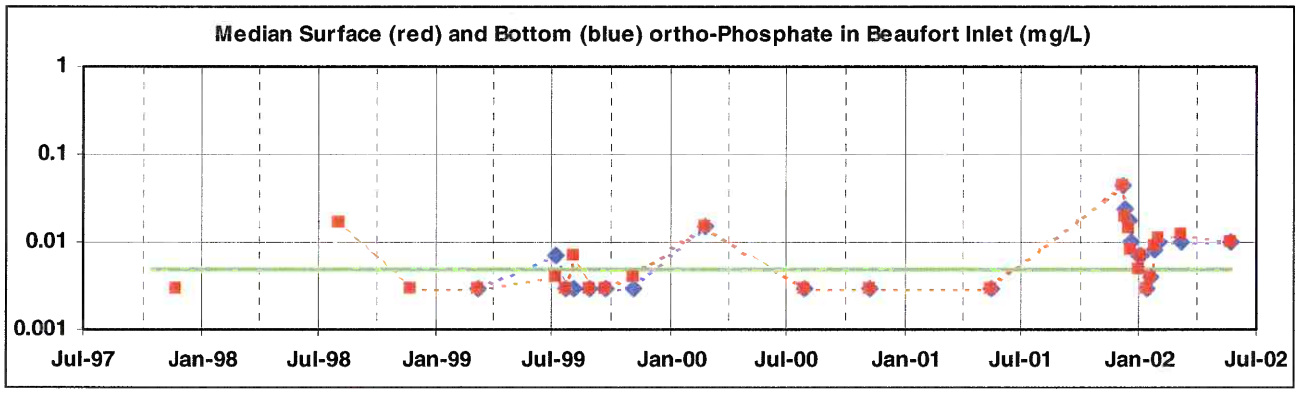


Figure 38. Dissolved inorganic phosphorus in Beaufort Inlet. The green line is the ANZECC guideline (developed from a composite of the data from all of the estuaries in the South West of WA)

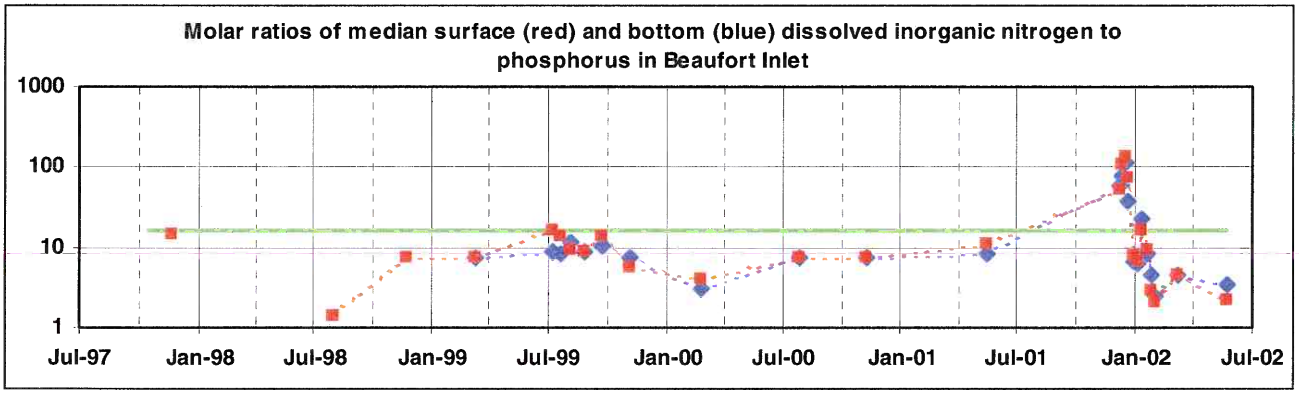


Figure 39. Ratios of dissolved inorganic nitrogen to phosphorus. The green line indicates the supposed ideal ratio for marine phytopalnkton. Deviation below this line indicates that nitrogen is potentially limiting and above indicates that phosphorus is potentially limiting

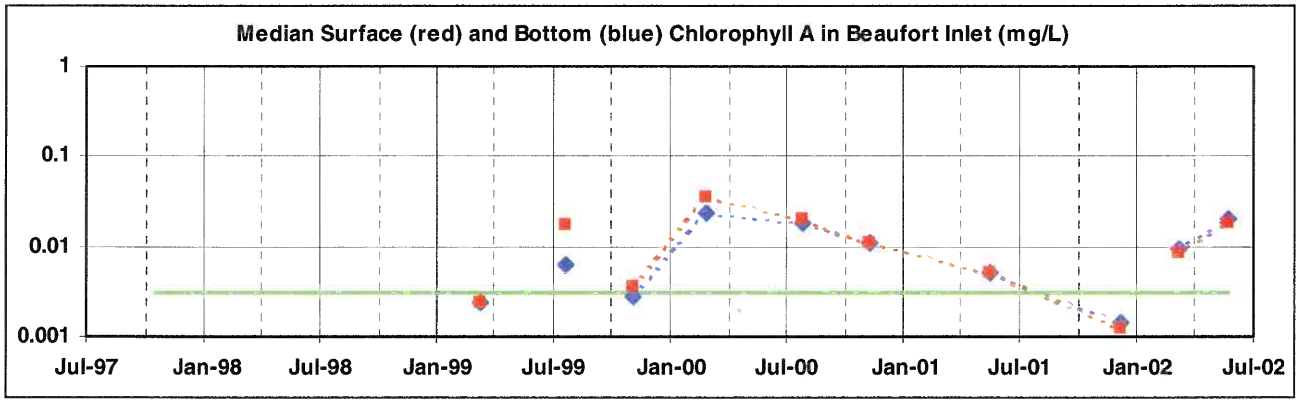


Figure 40. Chlorophyll *a*. The green line is the ANZECC guideline (developed from a composite of the data from all of the estuaries in the South West of WA)

Given the low frequency of sampling it is difficult to link estuarine events, however experience elsewhere, for example in Wilson Inlet, suggests that low dissolved oxygen concentrations translate to phytoplankton blooms. Certainly the blooms of freshwater species that followed the 2001 bar opening appear to have been fueled by recycled nutrients. The March 1998 bloom may have been fueled by recycled nutrients through a bacterial food chain.

Sediments

Sediment nutrient cycling processes are critical in a system that is shallow, may at times be stratified, is subject to wind-energised mixing and resuspension and is isolated from the ocean for periods of several years with aseasonal flows (potentially many months with no flows) and hence long contact times between the water and the sediments. Based on a first pass over the sediment data collected from Beaufort Inlet and analysed for porosity, particle size, carbon, sulfur, nitrogen, phosphorus, silica, aluminium and iron concentrations the sediments of Beaufort Inlet appear to be in a state of inefficient phosphorus trapping, poor denitrification, low oxygen availability and significant nutrient recycling to the over lying water column (data from GeoScience Australia). Compared to other estuaries, such as Wilson Inlet and the Swan River, the sediments of Beaufort Inlet are recycling much more nutrients back into the water column and therefore considered to be in 'poor health'.

Final comment

It is interesting to compare the scale of seasonal drivers of water quality in estuaries of the South Coast of WA with aseasonal[10] drivers. In particular the implications that this has for cycles of water quality in the Inlet that will reflect both seasonal qualities and (possibly cyclical) adjustments to longer-term aseasonal perturbations. The major sources of these perturbations are rainfall and runoff events. Not only does the rainfall become progressively lower the further east from the rainfall maxima (close to Walpole) that you travel along the south coast, but river flows become less predictable and more aseasonal. Consequently estuaries along this coastline become increasingly dominated by the effects of large aseasonal flow events superimposed over seasonal water quality drivers. An important implication for management is that a sound knowledge of the current state of the Beaufort Inlet and South Coast estuaries generally, are needed to determine in which direction the water quality might proceed if a particular action, such as artificially opening the bar, is undertaken.

Transects

Transects (profiles) along the length of the Inlet, from the bar (at the left hand side of each image) upstream into the Pallinup River channel on the right, are presented below. Matched transects of salinity, dissolved oxygen and temperature have been produced for selected dates amongst the thirty-one sample runs.

The contour intervals in these plots are: for dissolved oxygen the contour interval is 1mg/L, for salinity 2ppt and for temperature 0.5°C.

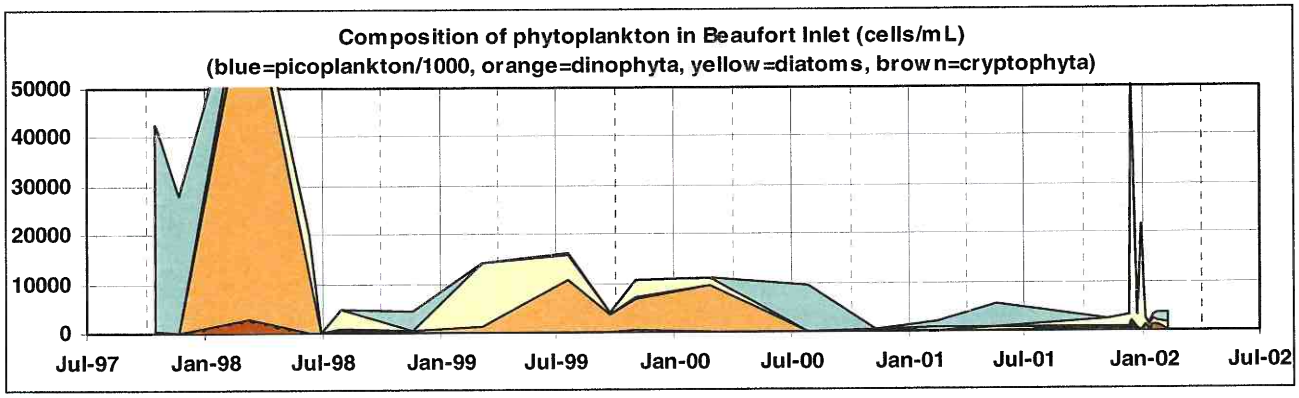


Figure 41. Phytoplankton cells/mL. The picoplankton numbers have been divided by 1000 before plotting them on this graph to account for their cells being so much smaller than the other species. The peak of dinoflagellates in March 1998 (off this chart) was about 80 000 cells/mL. While there appears to be some inconsistency between the chlorophyll *a* concentrations and the cells/mL (e.g. in November 2000) the changes in species over time can account for the discrepancies as the different cells hold different concentrations of chlorophyll. For example in November 2000 the chlorphyll *a* content of cells would have to be in the order of 30 pg/cell, which seems high but is not impossible; given there were 700 cells/mL This would require an average cell volume of 10 000 um^3 – the *Katodinium* cells present may be large enough to explain this

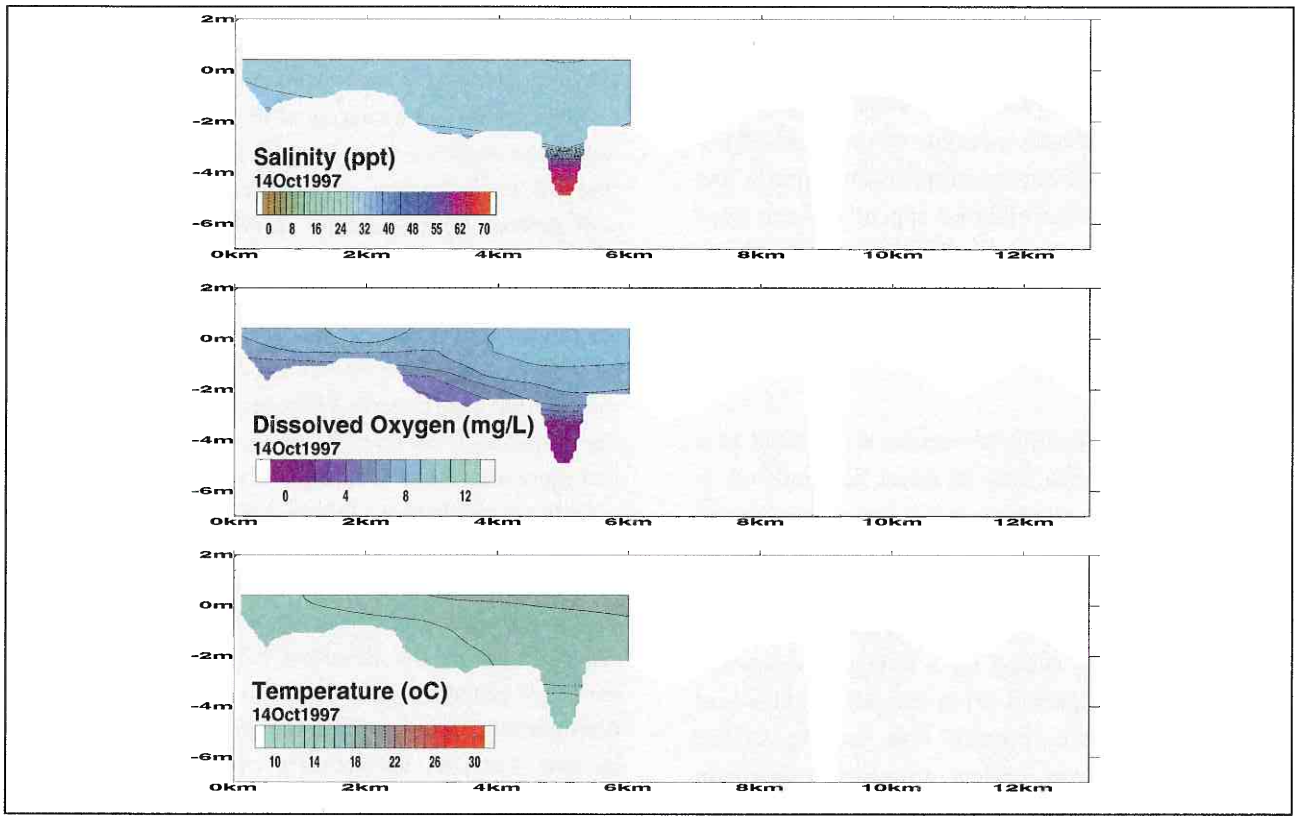


Figure 42. Sample 1. The Inlet was reasonably well mixed and salinity was similar to seawater except for a deep hole located 5 km upstream from the bar (just around the first bend past Miller's Point). The bottom salinity in this hole was more than twice seawater salinity, while below the halocline the dissolved oxygen concentration was zero and nutrient concentrations were extremely high. Bottom water dissolved oxygen concentrations were depressed throughout the Inlet

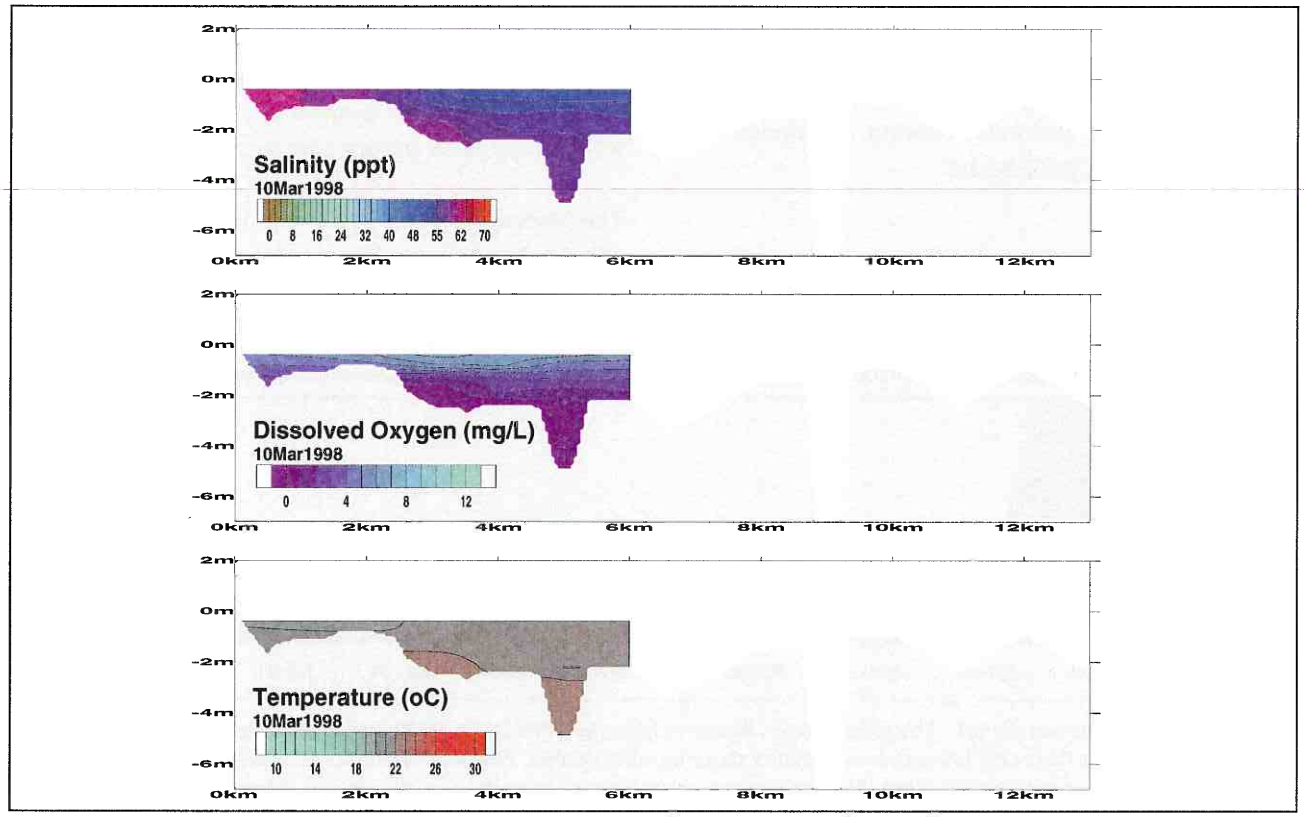


Figure 43. Sample 3. Following the summer period the water level had dropped significantly and the Inlet had become significantly saltier due to evapo-concentration. The waters were generally more deoxygenated (due to the stratification, higher salinities and higher temperatures) than they had been prior to the summer months. The halocline in the deep hole at 5 km was not as strongly defined as it had been previously

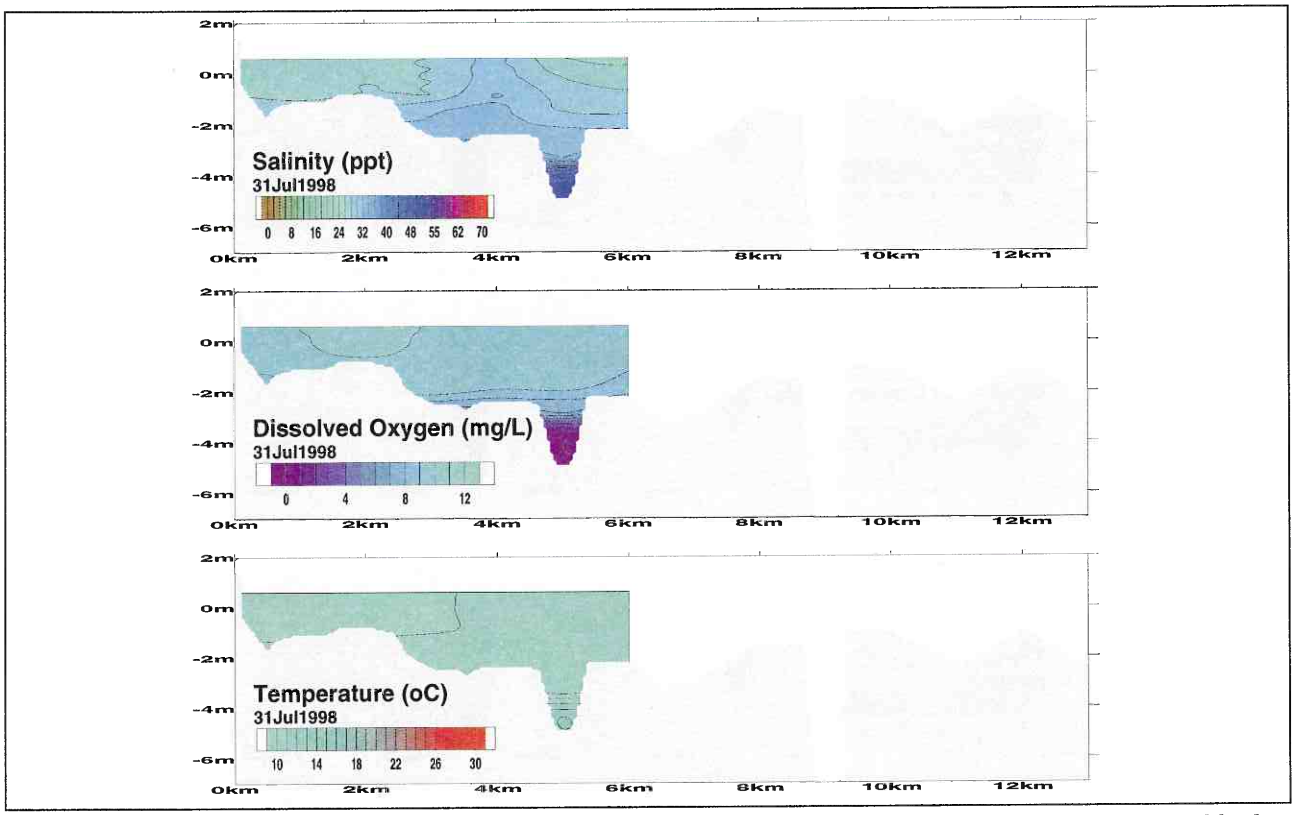


Figure 44. Sample 4. In the months since the last sampling run there had been significant river flow and the bar had broken allowing marine water in. Water in the deep hole was still stratified and extremely deoxygenated – also it was marginally warmer than the remainder of the Inlet, with the temperature and salinity suggesting it was a summer relict and therefore had not been flushed by the river flow in April or June)

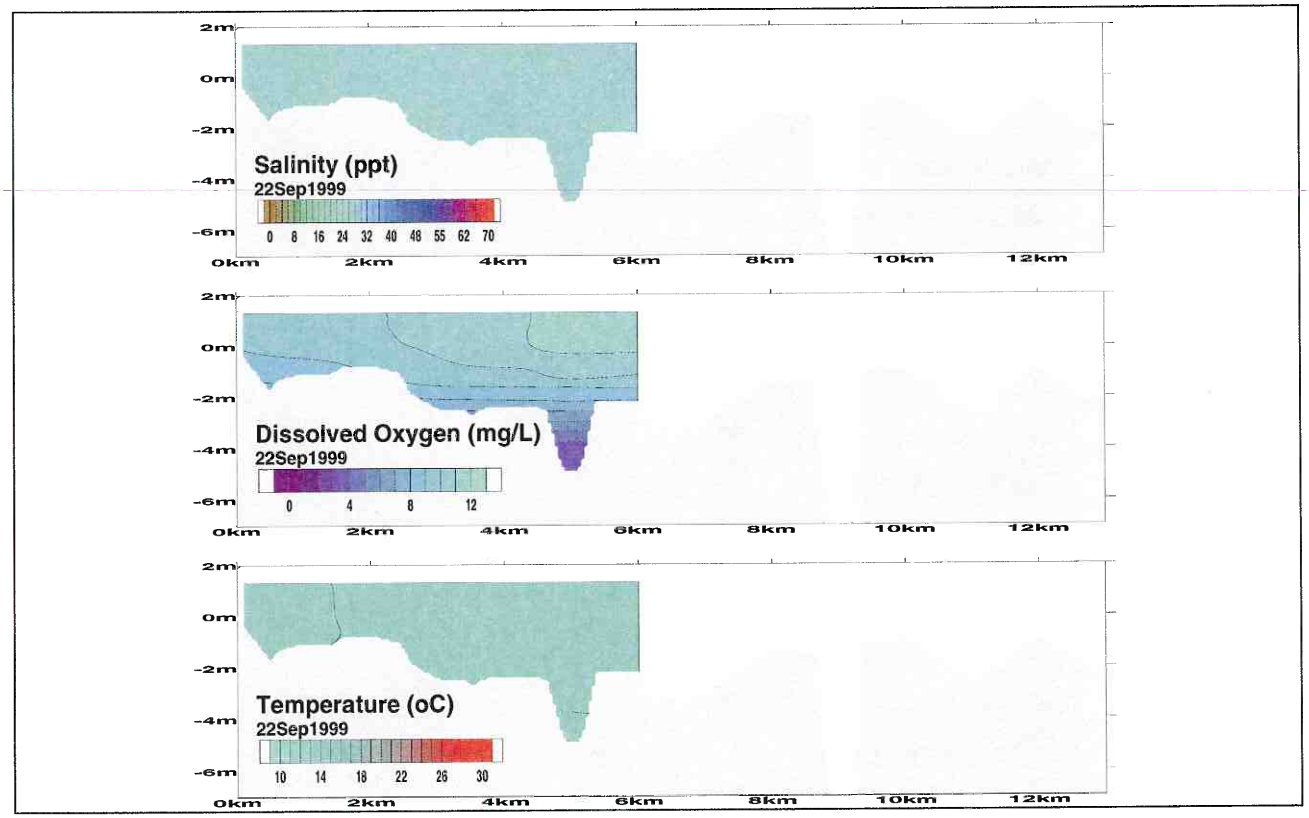


Figure 45. Sample 11. (Intervening sample runs have been omitted since the salinity and dissolved oxygen concentrations had not changed significantly in that period, figure 4). The salinity was marginally less than seawater and the Inlet was well mixed, however deeper bottom waters remained deoxygenated suggesting that oxygen consumption at the sediments may have been high. The deep hole at 5 km upstream had been flushed, possibly by the August/September 1998 river flows

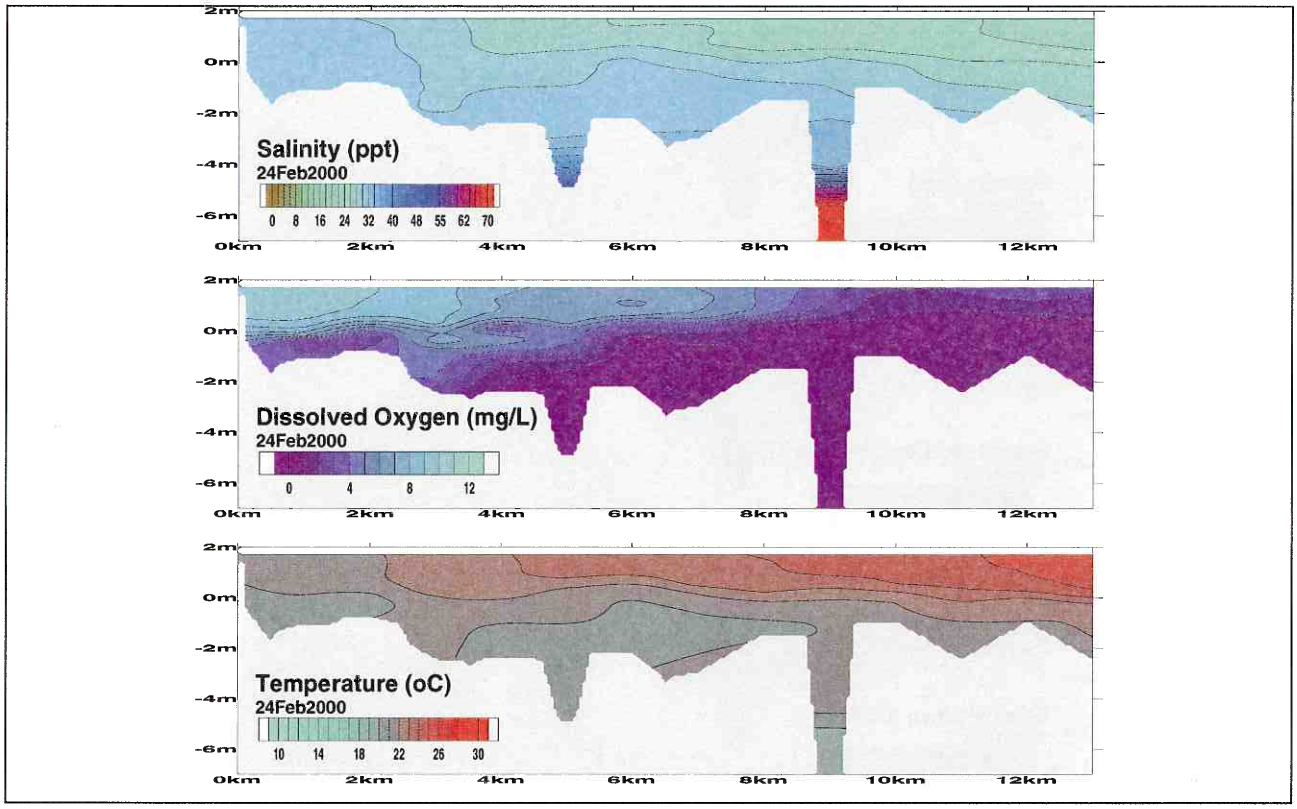


Figure 46. Sample 13. Coincident with a fish kill event, this sample run followed river flow in early February. The Inlet contained a significant amount of deoxygenated water – except for the surface metre or so of the estuary, from the bar upstream for a distance of about 8 km – the Inlet was entirely deoxygenated. The deoxygenated water probably resulted from both the stratification, caused by over flowing freshwater, and labile carbon washed into the estuary by the flow consuming the oxygen. A deep hole at 9 km upstream was also found to be extremely stratified with bottom salinities greater than twice seawater

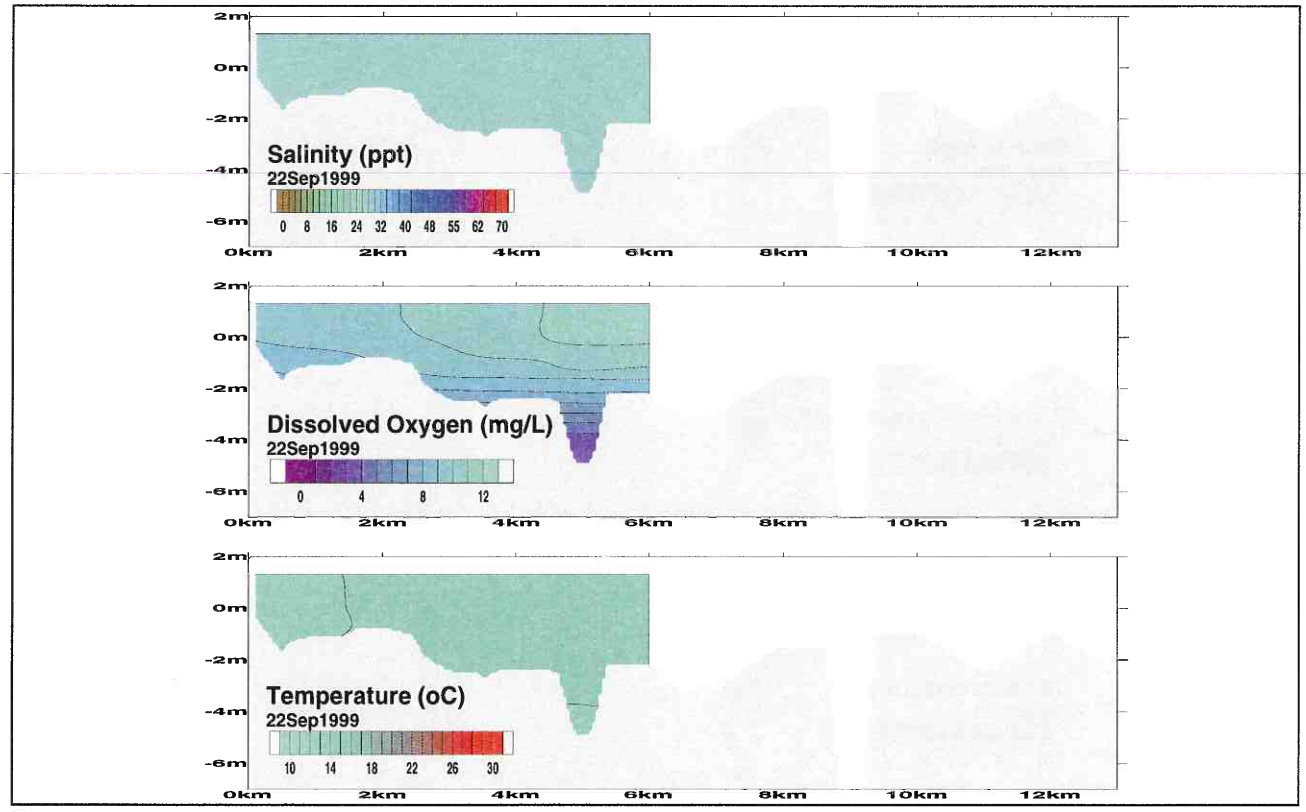


Figure 47. Sample 14. On this occasion the deep portions of the holes at 5 km and 9 km were not sampled. In comparison to the previous sampling run in February the Inlet was largely unstratified and was reasonably well oxygenated, except possibly in the deep holes that were not sampled. Although dissolved oxygen concentrations in the bottom waters upstream were a little depressed, it again suggested a high rate of oxygen consumption at the sediments

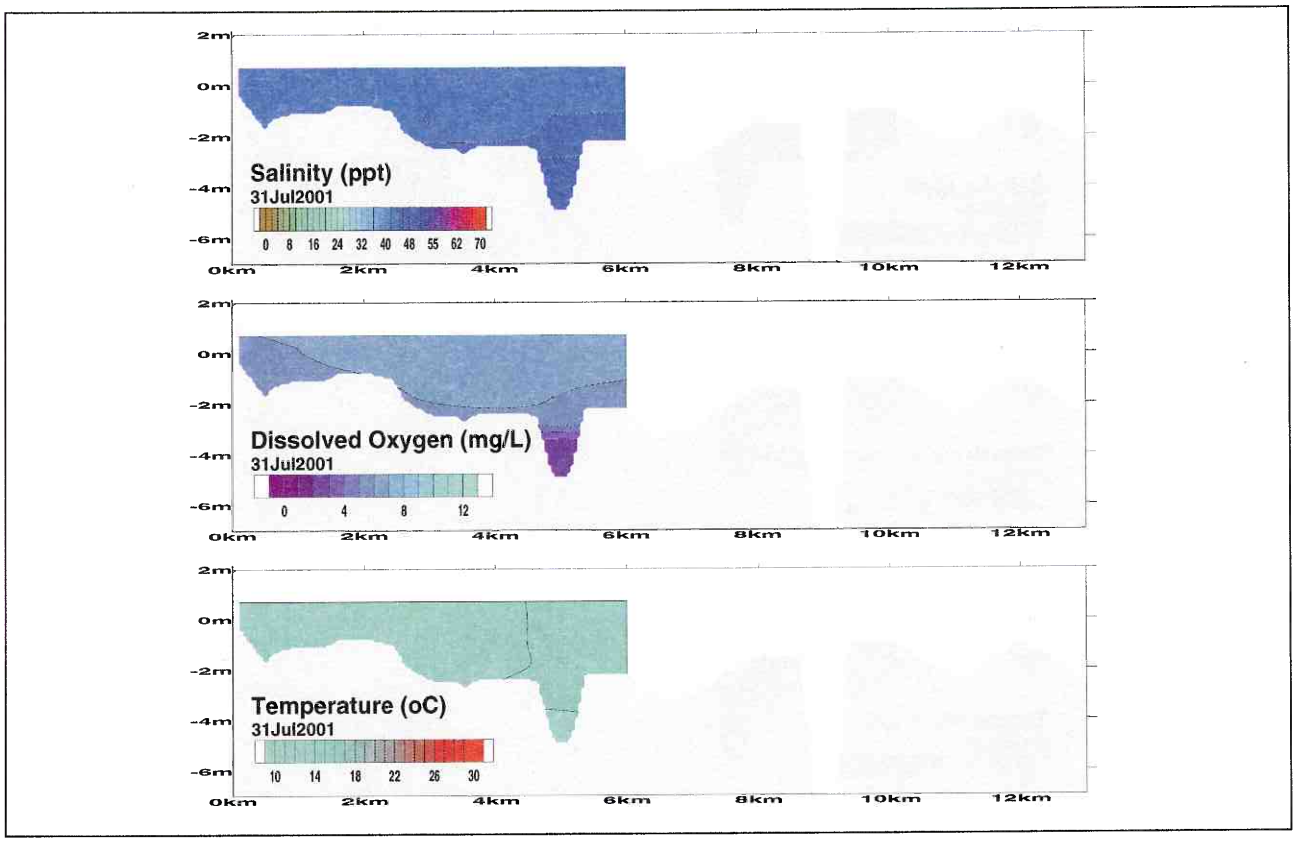


Figure 48. Sample 18. Evapo-concentration of salts in the Inlet has occurred as water levels had fallen and salinities increased. Mild stratification was clearly becoming re-established in the deep hole at 5 km and subsequent deoxygenation below that stratification was occurring

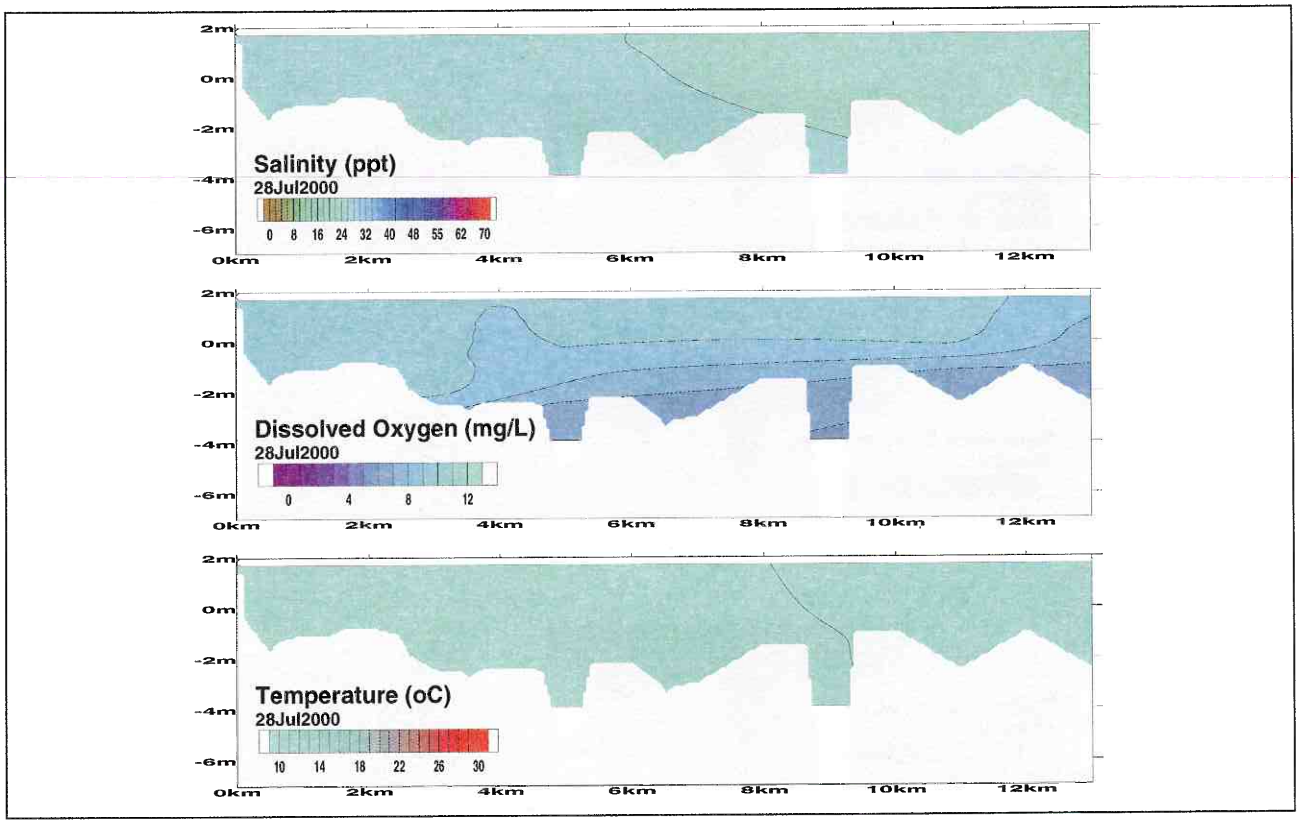


Figure 49. Sample 19. This sample run occurred two days after a significant flow in the Pallinup River had filled Beaufort Inlet, broken the bar (the bar was open at the time of sampling) and completely flushed the Inlet (except for the deep hole 9 km upstream from the bar – as shown in later data)

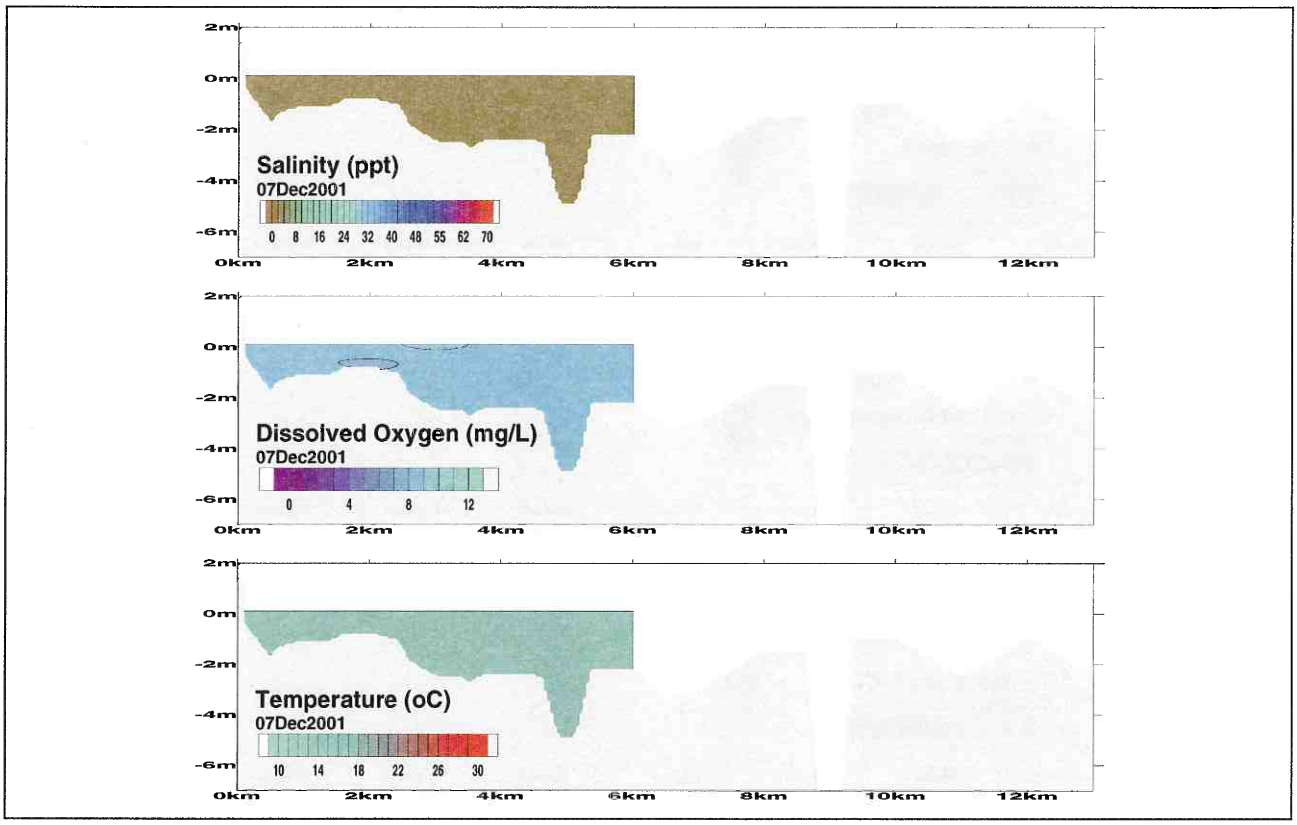


Figure 50. Sample 20. Sampled approximately five days after bar opening and with river flow easing significantly the Inlet remained essentially fresh, however marine water was clearly beginning to intrude into the estuary through the breach in the bar

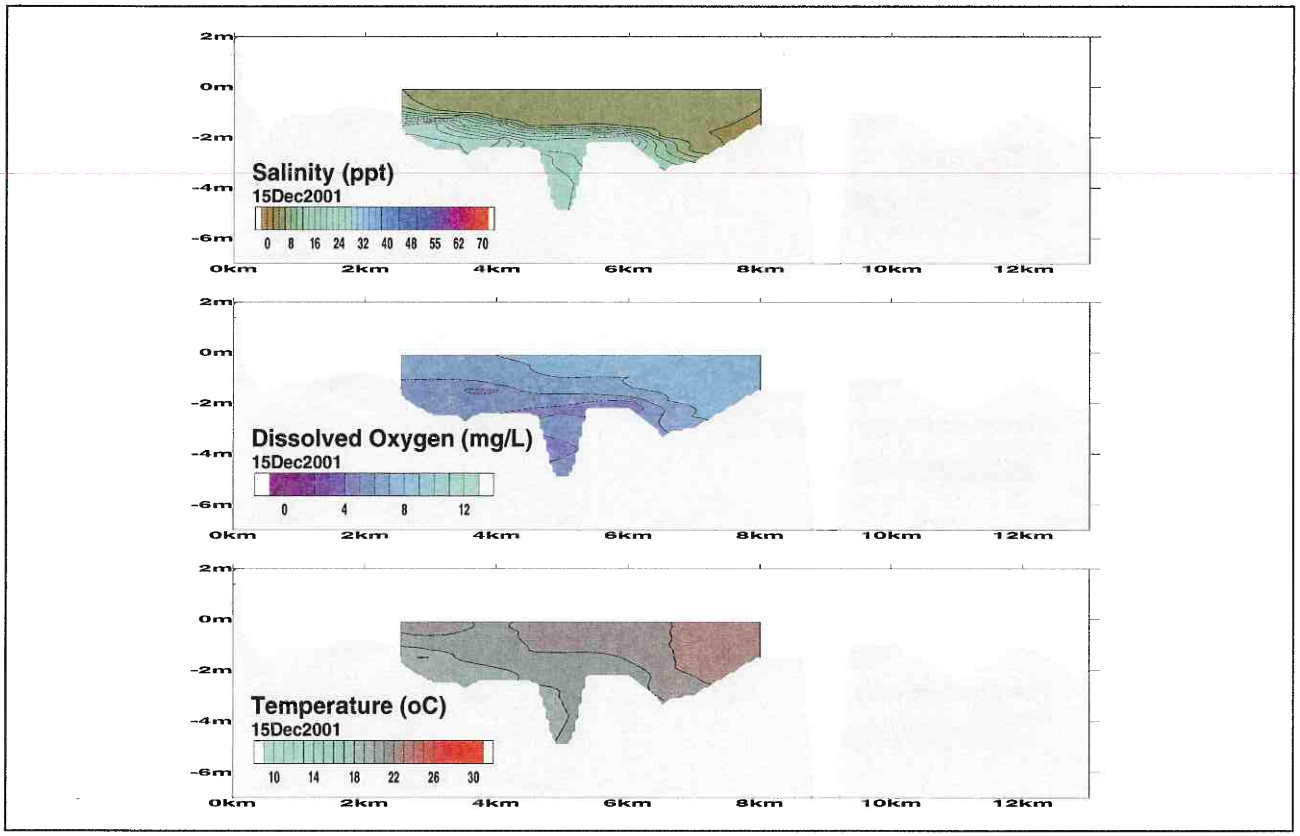


Figure 51. Sample 21. Marine water was seen to have intruded further into the Inlet, stratification was well established and deoxygenation was becoming apparent beneath the stratification

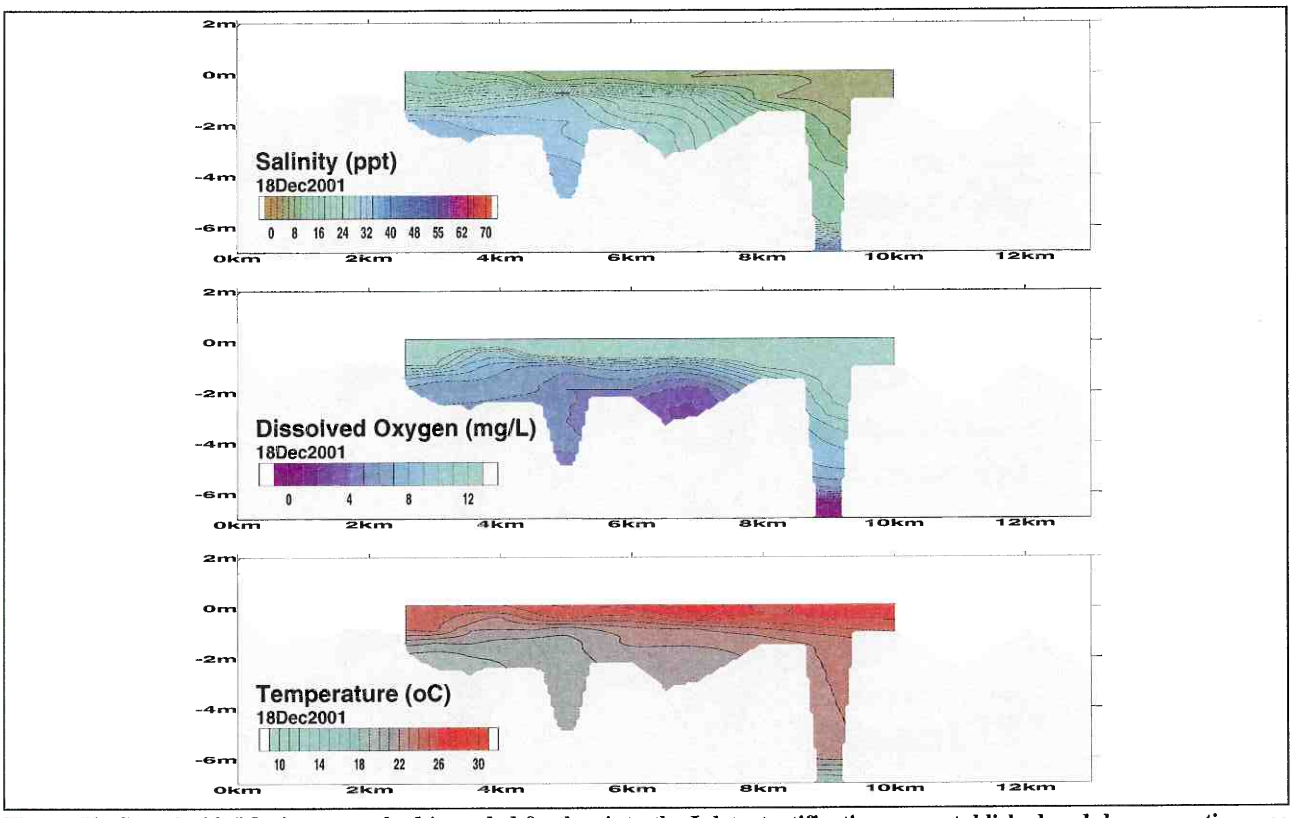


Figure 52. Sample 22. Marine water had intruded further into the Inlet, stratification was established and deoxygenation was becoming apparent beneath the stratification. At this point the deoxygenation was strongest at the nose of the advancing salt wedge as new marine waters continually refreshed the salt water below the halocline close to the bar. It was also apparent that the deep hole at 9 km upstream had not been completely flushed during the flow event. While salinities were somewhat lower than they had been last time this hole was sampled (suggesting some mixing and dilution) they were still much greater than the newly intruding marine water

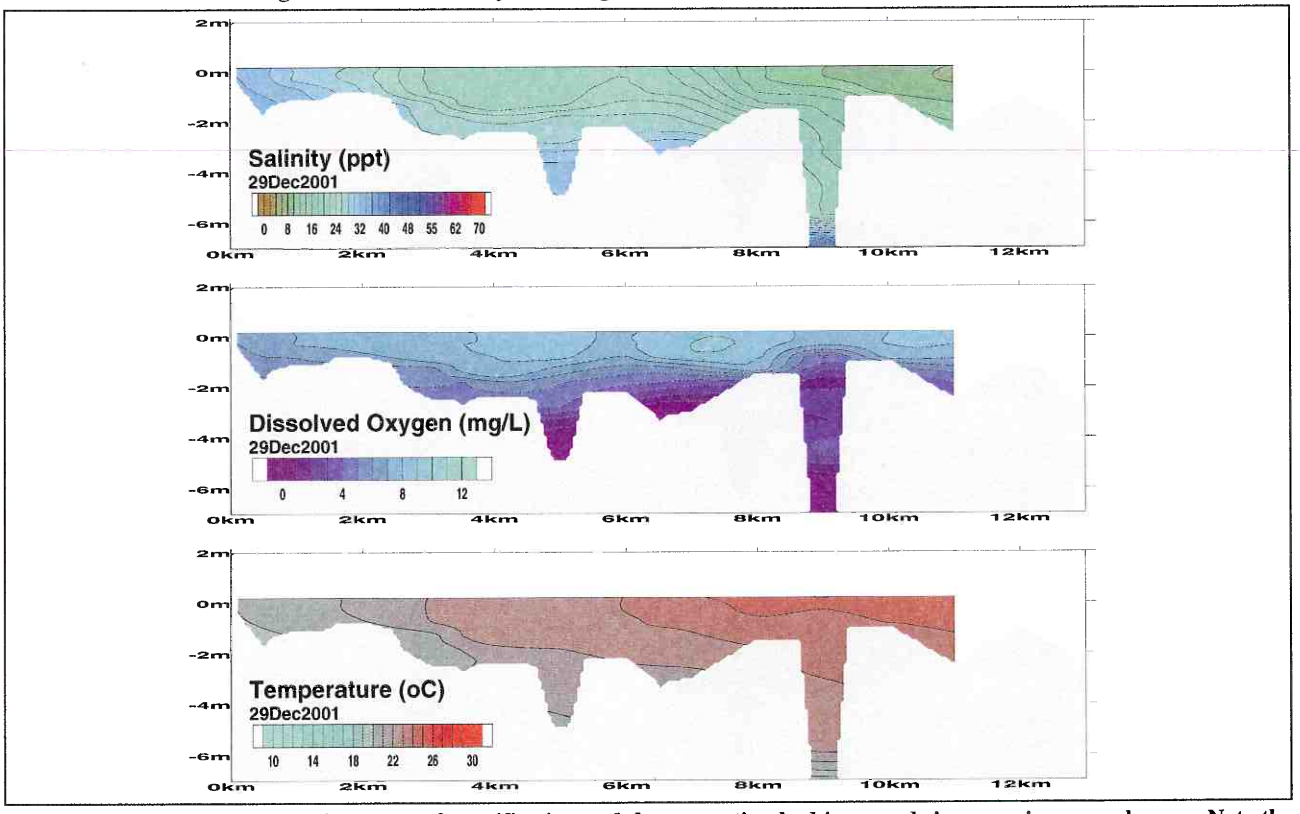


Figure 53. Sample 24. The spatial extent of stratification and deoxygenation had increased since previous sample runs. Note the dissolved oxygen inversion above the halocline (seen throughout the data) in the deep hole at 9 km from the bar. This was possibly related to photosynthetic bacteria above the halocline utilising the high nutrient concentrations trapped below

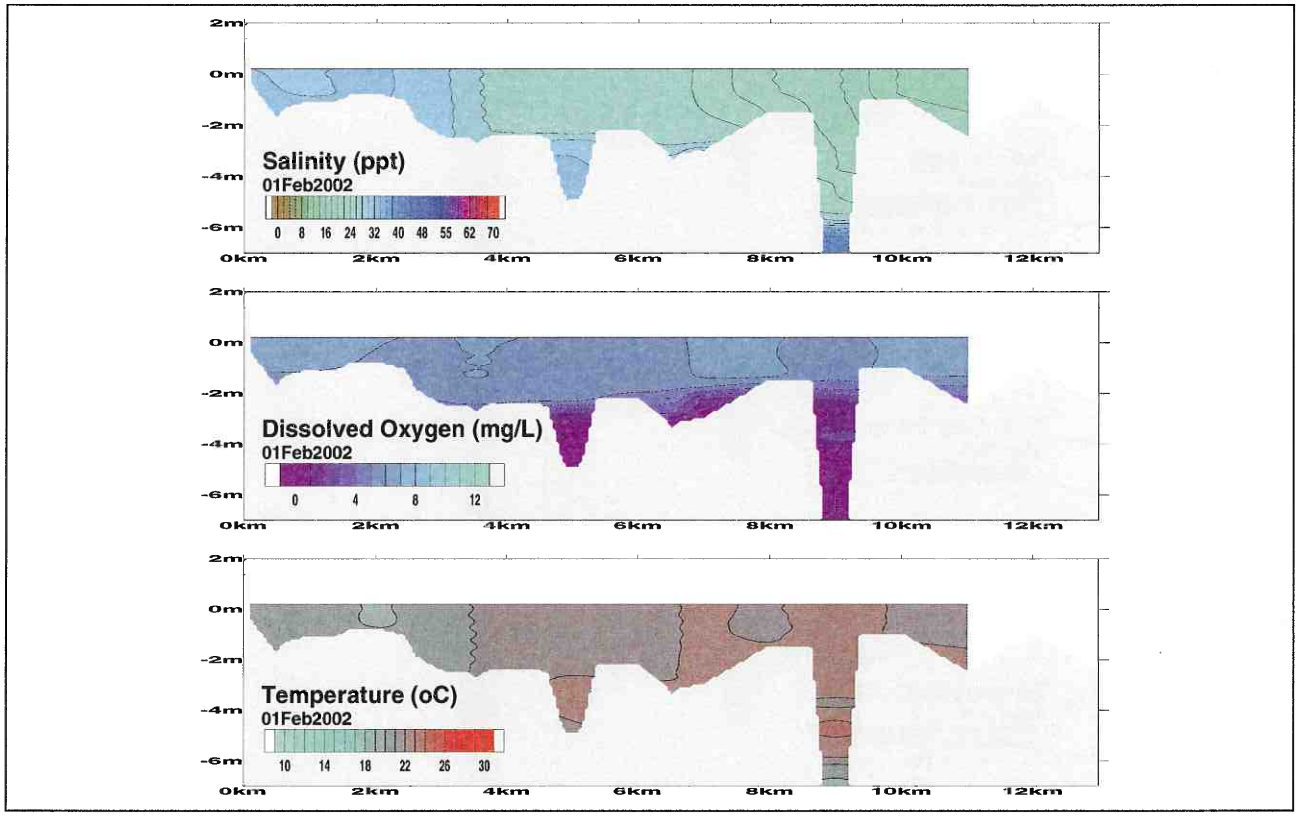


Figure 53. Sample 29. Warmer water in that inversion layer?

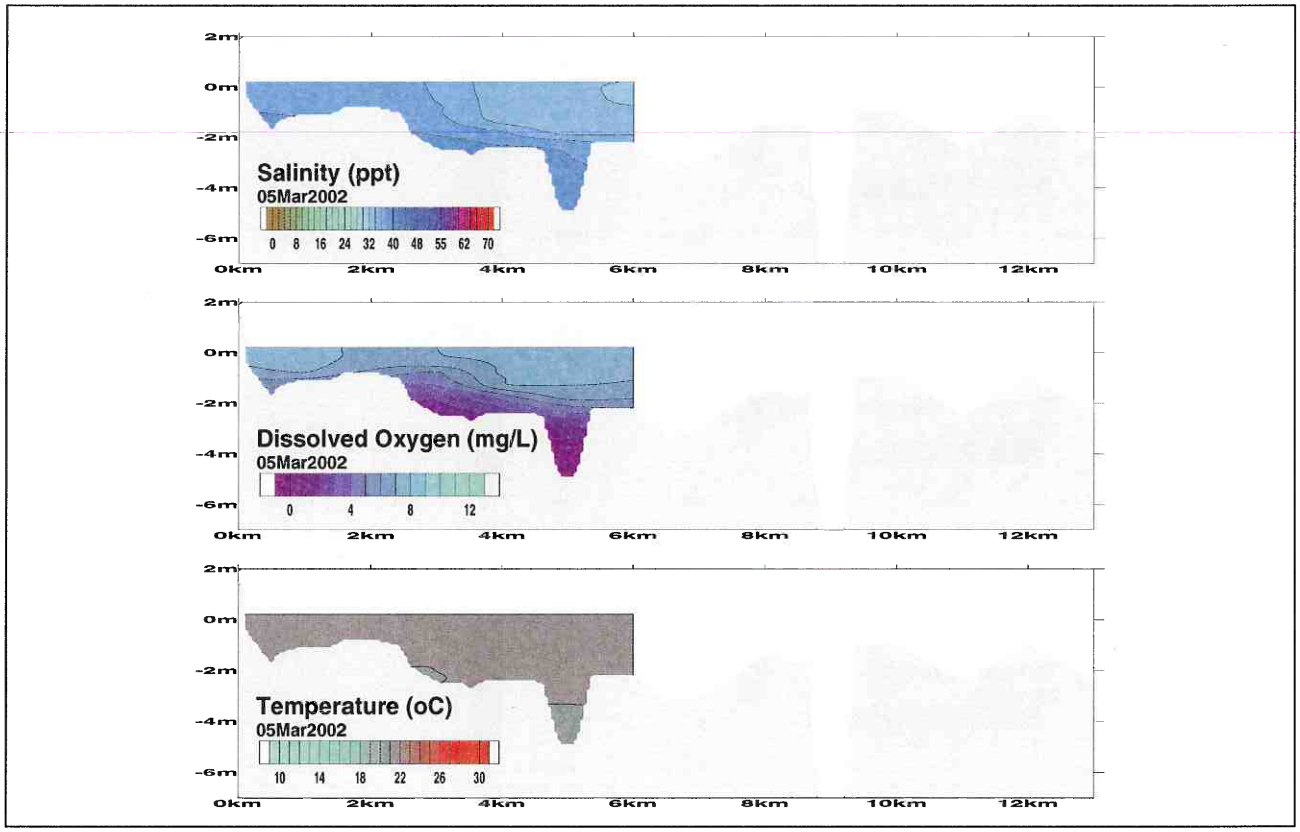


Figure 54. Sample 30

3.3.4 Glossary of terms

Halocline	When fresh water lies on top of more saline water they do not mix easily. This results in a layered effect. The boundary between the two layers is called a *halocline*.
Anoxic	Lacking in oxygen.
Phytoplankton	Microscopic free-floating organisms, mainly algae, living in water.
Picoplankton	Extremely small organisms, a mix of bacteria and algae.
Dinoflagellate	A microscopic organism that is mobile and can move around in water to some extent.
Cyano bacteria	Bacteria (blue green) with some features in common with algae, but a distinct Organism in their own right.
mg/l	Milli-gram per litre. This is a measure of amount, parts per million. It is equivalent to the number of grams of a substance in each cubic metre of water.
FRP	Filterable Reactive Phosphate. The dissolved component of phosphorus.
Phagotrophic	Sources nutrients from surrounding organisms or material.
Aseasonal	Not easily predictable as a seasonal phenomenon.

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4 Management of the Pallinup River

The management issues discussed in this publication deal with the key issues affecting the river's health and are by no means exhaustive. The main recommendation is to create a management plan that incorporates community consultation and involvement. The plan should define environmental standards and be based on best management practices.

4.1 Floodway protection

Riparian zones mark the transition between the valley sides and the stream system. Riparian, comes from the Latin word 'Riparius' meaning "of, or belonging to the bank of a river" (Naiman and Decamps, 1997). The edges of these riparian zones extend outwards to the limit of flooding and upward into the canopy of the streamside vegetation. This fringing vegetation is important for the stability of the Pallinup River ecosystem.

An important role of the fringing plants along the Pallinup River is to act as a water filter system. They filter material that enters the river by runoff and groundwater inflow. The root networks of the riparian plants increase resistance to erosion by binding the soil together. The above ground stems of stream-side vegetation helps retain the floodway soil by increasing the channel roughness which decreased the erosive action of floods.

Stream banks that are largely devoid of riparian vegetation, apart from rock, are often highly unstable and subject to erosion, resulting in the widening of the channel. For example in one study bank erosion has been shown to be thirty times more prevalent on non-vegetated banks exposed to currents as on vegetated banks (Naiman and Decamps, 1997).

Riparian zones are also uniquely situated to intercept nutrients moving into rivers from the adjacent valley sides and from upstream. Dissolved nutrients are transported from the landscape into streams and rivers by surface flow and in groundwater. As soil and water passes through riparian zones, the vegetation intercepts the dissolved nutrients and greatly reduces the nutrient loads reaching the stream. For example, a study in the coastal plains of Georgia USA, riparian forests retained more than 65% of the nitrogen and 30% of the phosphorus contributed in soil solution from surrounding agricultural lands (Gregory et. al., 1991). Similar processes are likely to occur along South Coast rivers, but the relative percentages are unknown.

The foreshore vegetation may filter nutrients entering the river, but the riparian zones can also supply the river system with other forms of nutrients. The food webs of many aquatic ecosystems are supported largely by the input of plant material from the surrounding landscape. The litter from riparian vegetation is consumed or broken down by small water dwelling creatures (aquatic invertebrates) and re-released as dissolved or fine particles of organic matter. The leaf composition determines the time taken for break down and the release of nutrients. Leaves from native vegetation generally take longer to break down than those from imported deciduous trees or weeds. The availability of plant litter influences the quantity and diversity of invertebrates in the river. It is widely accepted that high plant diversity promotes greater diversity of aquatic invertebrates (Palmer et. al., 2000; Gregory et. al., 1991).

The vegetation also supplies the river with woody debris which traps sediment in storm flow, and increases the variety of habitats available for plants and animals. The woody debris that accumulates in piles during floods provides aquatic creatures with another type of habitat.

The debris also helps to dissipate flood energy by creating turbulence in the water. By altering the flow, sedimentation patterns can also change to create patches of fine sediments interspersed with patches of coarse material thereby increasing habitat complexity (Palmer et. al., 2000). The woody debris traps seed and plant material, protecting them from erosion, and in some situations, from drought and grazing. Specialised insects graze on the decaying wood and associated fungi and bacteria.

The overhanging trees on the riverbanks of the Pallinup filter the light energy received by the river. This has a strong influence over the primary biological production of the river. The amount of light entering at stream level will help control the growth of algae and other aquatic

plants. If there is too much shade, whole groups of algal-grazing invertebrates may disappear. The loss of even a few species of plants may have direct effects on biodiversity through the loss of shade-tolerant algal species or the loss of creatures that are sensitive to temperature (Palmer et. al., 2000).

The riparian zones also are commonly recognised as corridors for the dispersal and migration of animals and plants. The river corridors connect the headwaters to the estuary. This is desirable for native species, but undesirable for exotic plants and feral animals. For example, the persistence of bird communities is sensitive to the quality of riparian vegetation. , In many areas the riparian vegetation has been reduced to a bare minimum due to the increased pressure from surrounding landuse. This has led to local extinctions of native plants and animals and reduced the ability of some populations to recolonise.

Figure 55 shows cropping activity well into the floodway. The crop cycle does not provide adequate stabilisation of the banks. Although it represents extra productivity on the farm scale, a substantial increase in buffer width (about 25 metres) amounts to 1 ha every 4 km of river. -This small amount of land sacrificed now, will have significant longer-term benefits including the assurance of the surrounding river and land's health and a reduction in the need to outlay large amounts of money for restoration.

The community needs to acknowledge the importance of the riparian vegetation if a healthy river system is to be achieved. Where riparian vegetation has been removed or damaged, methods must be developed to determine the area needed for its regeneration.

4.2 Stock control, fencing and revegetation

Stock grazing and trampling native vegetation impedes growth and prevents regeneration and reduced the diversity of the riparian zone. Grazing removes the more palatable herbs and understorey first before stock will reach up into shrubs and trees for food that is more edible (Hussey and Wallace, 1993). This is apparent throughout the grazed areas of the Upper Pallinup and the broader floodway reaches towards the lower end of the river. Many reaches of the Upper Pallinup have been reduced to simply an overstorey of mature *Casuarina obesa* (sheoaks) with an understorey of bare soil and a few grassy weeds. These areas are most at risk of bank erosion and add to the sediment being carried downstream.

Weed seeds are carried into the riparian zone on stock and in their dung. Compaction of soils along stock trails is common, resulting in decreased water infiltration and increased runoff. Stock grazing within the river corridor will cross the river where possible, and while moving through the water, will trample riparian and aquatic plants, stirring up silt and causing an overall decrease in the more sensitive species of riparian insects and crustaceans.

Three management scenarios and options should be considered for the Pallinup Floodway. First total exclusion of stock from certain areas. Typically these would be in reaches where all but the largest floods (those which occur on average every 50 to 100 years) are confined within a floodway with high banks and the area currently grazed is relatively small.

Figure 55. Cropping well into the floodway

Figure 56. Stock impact in the channel

Fencing both sides of the river is the most obvious way to protect riparian zones from stock grazing and subsequent damage. Fences are ideally placed not less than 10 metres back from the top of the riverbank or highest recorded flood water mark. This allows adequate room to establish vegetation and protects the fence from flood flow. Where areas of the river have been fenced off and stock removed, the vegetation has improved and regeneration is occurring. Encouraging natural regeneration is a cheaper option while there is still a seed store in the ground.

Secondly, in reaches where the floodway broadens considerably, stock may be afforded access, but in a manner that is controlled, to protect the vegetation cover as much as possible. There is also a case for providing short-term protection to sites that are prone to erosion and where flood flow has, in the past, concentrated.

Landowners have experienced that fencing protection of the broader, low-lying reaches of the river is not as simple. On areas where the flood plain is broad, the landholder would be forced to give up productive land to safely fence and exclude stock to protect the river vegetation.

Despite the objections alternative methods to enhance vegetation in low-lying, flood prone areas should be considered. From the discussion in Section 4.2 the main issue is the prevention of excessive erosion scour and the encouragement of native plants to regenerate. There is scope for some innovative ideas, such as alternative crops and strategic vegetation features. If cropping is to be done at any time, this may provide a window of opportunity to establish native vegetation at high-risk sites. There is scope for innovative control measures for grazing in these sensitive areas and the development of principles and standards that are agreed to by all river managers as part of a river management plan.

For example, Sandalwood (*Santalum spicatum*) establishment is one option that may prove to be financially rewarding and provide essential erosion protection for the floodplain soils. The alluvial soils are suitable and many host plants already grow within the river corridor. Figure 57 shows a remnant sandalwood tree in the floodway. The loss of pasture area could be compensated through establishment of perennial pastures higher in the landscape. This offers summer grazing and reduces groundwater recharge.

Thirdly, the lower river passes through steep-sided and often rocky valleys. These features give a natural protection against stock movement and in fact landowners prefer to exclude stock because of the terrain. Maintaining fences and dealing with livestock 'escapees' is the primary issue in these reaches of the river. For example truant pigs have been noted in the lower river reaches.

4.3 Weed management

Riparian vegetation is commonly recognised as a corridor for the movement of animals, it also plays an important role within the landscape for the dispersal of plants, including weeds!

Of the 10,000 or so, named species of plants growing wild in Western Australia 90% of them are natives. The other 10% have been introduced into this State (Hussey et. al., 1997). Any plant that finds the right environmental conditions for growth will thrive. In this case, we are referring to 'environmental weeds'. Environmental

Figure 57. Remnant sandalwood tree

Figure 58. Sour sob has dominated much of the ground cover along the river banks

weeds are those that invade native ecosystems and are undesirable from an ecological perspective.

For a weed species to become established it must first be transported to the area where it often establishes in disturbed soils and where the original plant cover has been reduced. Around the Pallinup River this happens because of the surrounding agricultural activity, including the grazing of stock, movement of machinery, feral animals (e.g. rabbit diggings) and fallen trees. Once established, seeds can be dispersed via wind, flood waters, animals or humans. Hussey and Wallace (1993) listed the following effects that introduced plants have on natural vegetation communities asthey;

- compete directly with native vegetation, inhibiting growth and displacing species;
- replace diverse native plant communities with more uniform weed communities;
- inhibit native plant regeneration through competition;
- alter the nutrient cycling of natural communities;
- may change the soil acidity;
- may increase the fire hazard; and
- alter the resources available for fauna.

Weed species found along the Pallinup foreshore were:

Oxalis pes-caprae (DP)	Sour sob, South African,; oxalate poisoning in sheep.
Emex australis (DP, PP)	Doublegee, native to South Africa.
Echium plantaginea (DP)	Paterson's Curse, native to Southern Europe.
Lycium Ferocissimum(PP)	African Boxthorn, native to South Africa.

Figure 59. Less common plants such as this cactus were sometimes encountered along the river. They may not pose a threat, but should be dealt with now

Other weeds include; Barley grass (*Hordeum leporinum*), wild oats (*Avena fatua*), puccinellia (*Puccinellia ciliata*), annual veldt grass (*Ehrharta longiflora*), perennial veldt grass (*Ehrharta calycina*), cape weed (*Arctotheca calendula*), bridal creeper (*Asparagus asparagiodes*), brome (*Brome diandrus*) and rye grass (*Lolium rigidum*).

A key weed management issue is the amount of time required to keep infestations under control. The appropriateness of using pesticides in riparian zones and aquatic environments is also an issue.

4.4 Erosion and sedimentation

Movement of soil from non-vegetated gullies and banks, contributes over 60% of the sediment reaching our degraded streams and rivers. It has been estimated that in excess of 127 million tonnes of sediment is delivered to our streams and rivers every year (Bartley, 2001). If this figure is hard to visualise, imagine ten, 10,000-hectare properties, losing the top 10 cm of soil every year. Traditional agriculture practices have hastened this process considerably.

When enough coarse sand gathers in one place, it forms a 'wave-like' feature in the stream called a 'sediment slug'. These coarse, sandy sediment slugs can remain in river systems for hundreds of years. They smother the stream bed and severely reduce the diversity of habitat that is present in the river. In many cases, the loss of pools in rivers is a direct result of increased sediment in the stream bed.

Sedimentation of the Pallinup River is considered one of the most detrimental impacts of clearing.. Field observations indicate that the sediment plumes are not uniformly distributed along the length of the river. Large bank scours from past floods, increase downstream as do large depositional slugs. The increase in sediment delivery to the Pallinup over the last 150 years is a direct result of clearing and grazing in and along the river floodway.

Fine sediment discolours the water and reduces water quality. It smothers the streambed, reduces light penetration and increases the transport of pollutants over long distances. The fine sediment and the nutrients it carries are associated with the seasonal blue-green algal blooms that occur during the warmer months (Bartley, 2001).

4.5 Salinity and waterlogging

A pressing issue in the Pallinup catchment is rising saline ground water. This is of particular concern to landowners in the upper, flatter parts of the drainage system.

This process is now known to be a result of a major shift in the water balance of the catchments. The shift has been produced in many cases by the removal of all or most of the original vegetation cover, but may be moderated by shifts in the climatic pattern.

In many catchments the remaining natural vegetation is found along the watercourses. Although it is often proposed that the waterways should be cleared the outcome of this approach could further destabilise the valleys, choke the rivers and eventually the estuaries with more sediment.

Deep drains also are not considered a 'cure-all' by many qualified people and should be installed only after due consideration has been given to their appropriateness in a specific landscape, their hydrological efficiency and the consequences to the drainage system downstream.

Some reaches of the Pallinup show serious salt scalding that has exposed bare soils, however the loss of vegetation cover could also be attributed to unrestricted stock access in these same reaches.

4.6 Crossing constructions

In section 4.2 the general stability of the Pallinup floodway is discussed in greater detail and this is relevant to the position and durability of road and farm crossings. Repair expenses can be considerable when floods damage a bridge. The main arterial road crossings of the Pallinup River appear to be well positioned with respect to the floodway.

One of the strong design features of these bridges is that they allow the water to flow in a similar pattern to the natural channel. If flows are concentrated, as often occurs with cheaper culvert designs, then stream power is also concentrated at specific points of the crossing and this increases the likelihood of local bank damage.

Long-term flow information is essential for good crossing design. The gauging site near Chillinup Road, which has been operating since mid 1973, and the hydrographic record gives a reliable record of the magnitude of floods and their frequency. The Pallinup is well serviced in this respect, however, there are no historical gauging records for many other significant South Coast rivers. The January 1999 and 2000 floods in the Esperance area caused significant damage to many bridges and crossings, particularly where floods were directed through narrow openings or over sharp drops. Most of these crossings have a much shorter history than those on the Pallinup River.

4.7 Refuse

In the past, many landholders along the Pallinup have used the river as a place to dispose of refuse. During the Foreshore Condition Assessment, it was noticed that piles of soil and cleared vegetation, old fencing equipment and machinery had been dumped in the floodway or on the bank. Along parts of the lower sections of the river the peak level of a past flood could be detected from the old bottles lying stranded in the bush well up from the channel bed.

Many landholders now have a sense of responsibility toward the river and have endeavoured to clean up their sections. Rubbish was not an excessive problem along the floodway. People now realise that what enters the river will eventually reach the Beaufort Inlet and perhaps the sea. Anecdotal information suggests that in the past it was not unusual to see chemical drums floating down the river. The Beaufort Inlet is an area where many locals like to visit, camp and fish. This has encouraged a sense of ownership and responsibility among landholders to look after their stretch of river.

Figure 60. Rubbish in the river – a thing of the past

4.8 Feral animal control

Feral animals inhabiting the Pallinup foreshore include rabbits, foxes, feral cats and the Kookaburra. The most troublesome, both from a farming and an environmental point of view, are the rabbit and the fox, with cats posing a substantial threat to native fauna. During the upper foreshore survey in October and November, rabbit warrens did not appear extensive. Over a distance of 50 km only a handful were seen -although populations are known to be quite variable. In addition the observations were made during the day when there is likely to be less activity.

Some comments suggest that past floods destroyed the warrens, taking the unstable riverbanks down the river and reducing rabbit populations. Populations fluctuate for a number of reasons, due to myxomatosis, the recently introduced calicivirus and climatic factors. Rabbits compete for food and habitat with native herbivores, they also graze native plants and prevent regeneration. Heavy grazing pressures can lead to soil erosion and warren construction leaves banks unstable and provides sites for further weed invasion.

Some systematic assessment of rabbit distributions in agricultural areas has been undertaken in the past, including parts of the Pallinup catchment, but not specifically focussed on the river. Some of the evidence suggests that rabbits are more active in light soils such as those found on sandy ridges and not specifically attracted to rivers unless the conditions are suitable. Much of the Pallinup floodway is relatively hard ground. Figure 61 shows one warren encountered in a sandy area in the upper part of the floodway. Systematic assessment of rabbit populations throughout agricultural areas ceased in 2001.

Figure 61. Rabbit warrens in deep sandy area

Several fox holes were seen dug into the loose sand on the riverbanks along the Upper Pallinup (figure 62). No feral cats were seen in the river reserve, but are likely to be using the area as a hunting ground. Both pests can seriously reduce numbers of small and medium-sized mammals, frogs, reptiles, birds and insects, nevertheless bobtail lizards were quite common during the Spring assessment and a number of snakes were also seen. Accurate information on the distribution and intensity of feral animals along the river is not available so landholders are responsibile for individual on-ground control.

4.9 Development and landuse planning

Landuse along the Pallinup River is not currently diverse, however a management plan should establish guidelines for possible future innovations. There are two critical issues with respect to landuse planning that impact the health of the river. The first is the inappropriateness of the Unallocated Crown Land boundary, particularly along the upper river reaches, to define the active part of the channel. At present the Department of Land Administration (DOLA) has no financial capacity to provide resource or management input in this respect. A practical management plan should address this issue and the eventual custodianship of the reserve.

A second important issue is landuse activities that result in effluent (including chemicals, nutrient runoff, saline water, rubbish and sediment) movement, into the river floodway. . While this report has not delineated the state of the tributaries in the catchment, they play an integral role in the health of the main channel.

Figure 62. Fox hole

4.10 Revegetation

For the purpose of revegetation of degraded areas it is important to establish the reason for revegetating the area since different plant communities can be encouraged. To stabilise actively eroding areas the use of native grasses and sedges are an option. These monocots have matted, fiberous root systems that assists soil stabilisation. Figure 63 shows the exposed roots of a *casuarina*. Currently the casuarinas have a major channel stabilisation role along the river, but this can be enhanced with rushes and sedges.

There are other benefits of planting native grasses, rushes and sedges including;

- They are relatively fast growing therefore are able to stabilize areas relatively quickly.
- They have an excellent ability to filter sediment and nutrients, reducing the amount reaching the waterway.
- They provide shelter and food for many native animals and birds.
- In the waterway emergent zone species of rush and sedge use nitrogen out of the water, and release oxygen, providing an ideal environment for small fish and macroinvertebrates.
- The use of rushes and sedges growing in the emergent and damp zones of the waterway reduce the speed of water flow along the edges thus reducing erosion along the banks. During times of peak flow the sedges can also be an asset as they fold down allowing the water to flow over the top but not to erode.
- There are many species of sedges that are not invasive or prone to becoming a problem away from protected areas.

Figure 63. Soil scoured from root system by floods

Restoration of degraded riparian zones should attempt to return as many of the characteristics it had in its previous undegraded condition. Plantings should address sedimentation and nutrient stripping issues, while improving diversity and habitat complexity. Species selection will depend on soil type, salinity tolerance, and position within the riparian zone (on the waters edge, or flood plain). The easiest way to determine suitable species is to look at what is growing in the area and particularly along reaches that are not badly degraded.

Diversity is very important. Trees and shrubs can be planted throughout the riparian zone and rushes and sedges are suitable closer to the water and on more fragile banks. Suitable ground covers will provide habitat for fauna and stabilise the riverbanks. Several areas along the Upper Pallinup would be suitable for direct seeding, other areas not accessible for a tree planter may require hand planting.

To recreate habitat for native animals it is suggested that the use of a range of local native species be planted in revegation areas, as one or more of these species would be flowering at anytime of the year. The reason for this is that some mammals, for example Honey possums (*Tarsipes rostratus*) rely strongly on a continual or specific food source. If this source is not present they will not repopulate the area no matter how suitable it appears.

There may be many emerging opportunities, as far as growing trees, to provide a possible future income. Below are some possibilities, which could be appropriate along the Pallinup. More information is being made available through the departments of Agriculture, and Conservation and Land Management and nurseries. For example

Figure 64. Sediment-filled pool colonised by samphire

information on the establishment and economical value of oil mallees,sandalwood,sheoaks; and cut flowers, (e.g. *Banksia coxcinia).*

Market factors will be critical to the success of projects, however innovative ventures offer scope for better environmental management practices to accompany sustainable agricultural development.

4.11 Linking catchment management and water quality monitoring

One of the aims of the WRAE monitoring program was to complement information from the river gauging station, to describe the current water quality in the Pallinup River catchment. This has helped identify the essential water quality issues. The data were also to help with the development of acceptable water quality objectives, or targets.

Such objectives need to be strongly tied to other riparian condition objectives if a useful monitoring program is to be developed. For example, concern was expressed, about the possible impacts of pesticides on water quality andthis factor was not monitored in the assessment.

Water quality targets can be set at levels that have some environmental significance, however it is suggested that condition targets relating to floodway structural stability should be the main focus for the Pallinup River, with water quality measurements providing the associative data, rather than vice versa.

Structural targets refer to increasing natural regeneration, increasing tree canopy cover, reducing erosion, reducing extreme water velocities and improving habitat opportunities for terrestrial and aquatic species.

Water quality targets for turbidity and basic nutrient levels appear to be of particular relevance for the Pallinup. Attaining such targets would mean that the condition of the system has become more acceptable. The management question that monitoring can answer is, 'how are things progressing'?

For the Pallinup, given that there are differences between sub-catchments as well as changing salinity along the main channels, base flow sampling could be a useful trend indicator for monitoring the effectiveness of water management on a catchment wide basis.

The Foreshore Condition Assessment and the channel stability assessment strongly suggest that setting management objectives would help improve the aquatic environment. Therefore it is recommended that future monitoring programs have a strong ecological focus, particularly oriented to the condition of the river pools.

4.12 Conclusion

Development within the catchment of the Pallinup River has dramatically increased pressure on its structure and ecology. Since settlement , landholders have gradually seen the damage that can be done through inexperience and mismanagement. It has been more than 20 years since the Pallinup had its last big flood, and in that time it is easy to forget the damage that can be caused by such a force.

For the Pallinup River to become a healthier system, an effort to protect and improve the riparian vegetation has to be made. To do this, stock must be largely excluded, weeds controlled and regeneration of trees and understorey species encouraged. Figure 64 shows a river pool long since filled with sediment and with dense samphire happily colonising the floodway with young *casuarinas* along the banks.

The future of the Pallinup River could be bright, with a well thought out river management plan supporting a vegetated corridor, free of weeds and supporting a diverse flora and fauna. Alternatively, the Pallinup may eventually fill with sediment forcing floodwaters to take an even wider path and become little more than a sand choked stream.

To carry out the generic recommendations of the report partnerships need to be encouraged between the community, landholders and government agencies. It is hoped that the damage caused by future floods can be minimised through responsible catchment management and environmental health given a respected place in our plans and purposes.

5 Additional information

Aquatic flora

(Information taken from – Romanowski, N. 1998, *Aquatic and Wetland Plants*. Sydney: UNSW Press)

There has been no long term monitoring programs for macrophytes, phytoplankton or algae in the Pallinup River. Some aquatic plants sampled during the foreshore survey (WRC, unpublished) are described below.

Cotula coronopifolia – which is a plant with small yellow button flowers. This species is found in areas which are frequently inundated, sometimes for long periods. It is an important plant for wading birds, particularly ducks and swans.

It is also common in brackish to very saline waters. It is a valuable habitat plant – provides shelter underwater for a wide variety of animals and prevents erosion in shallow, disturbed areas.

Marsilea sp. (Nardoo) – is another macrophyte found in waterways. It looks like a four leaf clover, but has a long single tap root, and floats on top of the water. It grows in seasonally flooded swamps and along creeks, and is very drought tolerant, dying away in arid conditions but growing back rapidly with rains. Sporocarps of this were used by Aborigines for food (Nardoo).

Juncaginaceae, Triglochin sp. – 'Water Ribbons' were also found in the Pallinup River. These have tuberous roots that were used by Aborigines for food. The seeds germinate readily in the autumn in shallow water and the small plants survive the winter. This plant is very important for habitat for native fish and macroinvertebrates, and as food for wading birds. The plants will survive dry conditions by putting down underground rhizomes and tubers. They will only flower when they are flooded.

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Appendix 1

Aquatic macroinvertebrates sampled in the Pallinup River

The following table summarises data supplied by CALM and collected in September 1997.

The abundance number is a log scale with, 1 = 1-10, 2 = 10-100, 3 = 100-1000.

ABUNDANCE	TRIBUTARY	PALLINUP RIVER			TRIBUTARY	TRIBUTARY
Family name	**Corackerup Creek**	**Kybelup**	**Wellstead Bridge**	**Quorbandam-oongarup Pool**	**Papa Colla Creek**	**Warperup Creek**
Acarina indeterminate	2				2	
Ceinidae	2	3	1	3		3
Ceratopogonidae		1		2	1	1
Chironominae *	3	2	2	3		3
Corixidae					1	1
Culicidae		2		1	1	1
Dolichopodidae	1		1	1	1	
Dytiscidae	2	2	1	2	2	2
Ephydridae	2	1	1	2		1
Haliplidae					1	
Hydrophilidae		1	1			2
Leptoceridae	2	2	3	2		3
Lestidae			1			1
Nematoda indetermin.					1	1
Notonectidae	1				1	1
Oligochaete indeterm.		1	2	1	2	1
Orthocladiinae *	2				2	
Pomatiopsidae						1
Tabanidae					1	
Tanypodinae *	2	3		3		3

Appendix 2
Vegetation list

FAMILY	SCIENTIFIC NAME	COMMON NAME	NOTES
MIMOSACEAE	*Acacia amputata*		
MIMOSACEAE	*Acacia cyclops*	Red eyed wattle	
MIMOSACEAE	*Acacia saligna*		
MIMOSACEAE	*Acacia erinaceae*		
MIMOSACEAE	*Acacia pulchella*		
MIMOSACEAE	*Acacia arcutilis*		Priority listed
MIMOSACEAE	*Acacia subcoerutea*		
MIMOSACEAE	*Acacia glaucoptera*		
MIMOSACEAE	*Acacia declinata*		
MYRTACEAE	*Eucalyptus rudis*	Flooded Gum	
MYRTACEAE	*Eucalyptus loxophleba*	York Gum	
MYRTACEAE	*Eucalyptus occidentalis*	Flat Topped Yate	
MYRTACEAE	*Eucalyptus platypus*	Moort	
MYRTACEAE	*Eucalyptus annulata*	Open Fruited Mallee	
MYRTACEAE	*Eucalyptus mesopoda*		
MYRTACEAE	*Eucalyptus tetragona*	Tallerack	
PROTEACEAE	*Hakea crassifolia*		
PROTEACEAE	*Hakea nitidea*	Frog Hakea	
PROTEACEAE	*Hakea laurina*	Pin Cushion Hakea	
PROTEACEAE	*Hakea lissocarpha*	Honey bush	
PROTEACEAE	*Hakea preissii*	Needle tree	
MYRTACEAE	*Melaleuca uncinata*		
MYRTACEAE	*Melaleuca cuticularis*		
MYRTACEAE	*Melaleuca acuminata*		
MYRTACEAE	*Melaleuca thyoides*		
PROTEACEAE	*Grevillia pectinata*		
PROTEACEAE	*Grevillia maxwellii*		Endangered
SANTALACEAE	*Exocarpus sparteus*		
SPINDACEAE	*Dodonaea* sp.	Hop Bush	
FABACEAE	*Jacksonia furcellata*		
RUTACEAE	*Boronia* sp.		
CASUARINACEAE	*Allocasuarina huegliana*		
FABACEAE	*Gastrolobium parvifloorm*		
FABACEAE	*Templetonia retusa*	Cockies' Tongues	
PROTEACEAE	*Petrophile* sp.		
MYRTACEAE	*Hypocalymma* sp.		
DROSERACEAE	*Drosera menziesii*	Sundew	
MYRTACEAE	*Callistemon phoeniceus*		
MYRTACEAE	*Calothamnus quadrifidus*	Common Net-bush	
THYMELAEACEAE	*Pimelea* sp.		
THYMELAEACEAE	*Pimelea argentea*	Silvery-leaved Pimelea	
CAESALPINIACEAE	*Senna artemesioides*	Silver Cassia	
PROTEACEAE	*Synaphea* sp.		
SANTALACEAE	*Santalum acuminatum*	Quandong	
PROTEACEAE	*Persoonia teretifolia*	Snottygobble	
RUTACEAE	*Microcybe multiflora* var. *multiflora*		
PROTEACEAE	*Dryandra* sp.		
PROTEACEAE	*Banksia media*	Southern Plains Banksia	
ORCHIDACEAE	*Caladenia flava*	Cowslip Orchid	
MAMVACEAE	*Alyogyne huegelii*	Lilac Hibiscus	
FABACEAE	*Bossiaea* sp.		
EPACRIDACEAE	*Astroloma* sp.		
CUPRESSACEAE	*Actinostrobus pyramidalis*	Swamp Cypress	
AIZOACEAE	*Disphyma* sp.	Pigface	
	Cheilanthes austrotenuifolia	Rock fern	
PAPILIONACEAE	*Brachysema lanceolatum*	Swan River Pea	
CASUARINACEAE	*Casuarina obesa*	River Sheoak	

Appendix 3
Fish collected in the Pallinup River

By Dr David Morgan
Murdoch University Fish Research GroupA.
November 1999 – February 2000

LOCATION	SPECIES FOUND
Martinup Creek/Clear Hills Road	0 fish
Pallinup River/Martinup Road	0 fish
Pallinup River/Gnowangerup Tambellup Road	*G. maculatus*, *P. olorum*
Pallinup River/South Formby Road	*G. maculatus*, *L. wallacei*,*G. holbrooki*
Maileeup Creek/Maileeup Road	*G. maculatus*, *L. wallacei*,*G. holbrooki*, *P. olorum*
Pallinup River/Magitup Road	*G. maculatus*, *L. wallacei*, *P. olorum*
Salt Creek/Dejagers Road	0 fish
Martaquin Creek/Salt River Road	*P. olorum*
Ongarup Creek/Smith Road	0 fish
Martaquin Creek/Chester Pass Road	*G. maculatus*, *L. wallacei*,*G.. holbrooki*, *P. olorum*
Pallinup River/O'Meehans Road	*G. maculatus*, *L. wallacei*, *P. olorum*
Peenebup Creek/Borden Bremer Bay Road	*G. maculatus*, *L. wallace*, *P. olorum*
Pallinup River/Sandalwood Road	*G. maculatus*, *L. wallacei*, *G. holbrooki*
Hegarty Creek/Stock Road	*G. maculatus*
Culyerbullup Creek/Stock Road	O fish
Peeniup Creek/Marnigarup West Road	*G. maculatus*, *P. olorum*
Peeniup Creek/Cowalellup Road	*G. maculatus*, *P. olorum*
Corackerup Creek/Cowalellup Road	*G. maculatus*, *P. olorum*
Warperup Creek/Stewarts Road	*G. maculatus*
Warperup Creek/Hart Road	*P. olorum*
Pallinup River/Paperbark Road	*A. Butcheri*, *L. wallacei*
Pallinup River/South Coast Highway	*G. maculatus*, *L. wallacei*,*G. holbrooki*, *P. olorum*
Pendernup Creek/Stockwell Road	0 fish
Pallinup River/Chillinup Road	*G. maculatus*, *L. wallacei*,*G. holbrookiP. olorum*
Monjebup Creek/Monjebup Road	0 fish
Monjebup Creek/Boxwood Hill Ongerup Road	*G. maculatus*
Nalyerlup Creek/Nightwell Road	*G. maculatus*, *P. olorum*
Peenebup Creek/Nightwell Road	*G. maculatus*, *L. wallacei*, *P. olorum*

** this work is unpublished*

Galaxias maculatus = spotted minnow
Leptatherina wallacei = western/Swan River hardyhead
Pseudogobius olorum = Swan River goby (mullet)
Gambusia holbrooki = mosquito fish
Acanthopagrus butcheri = black bream

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