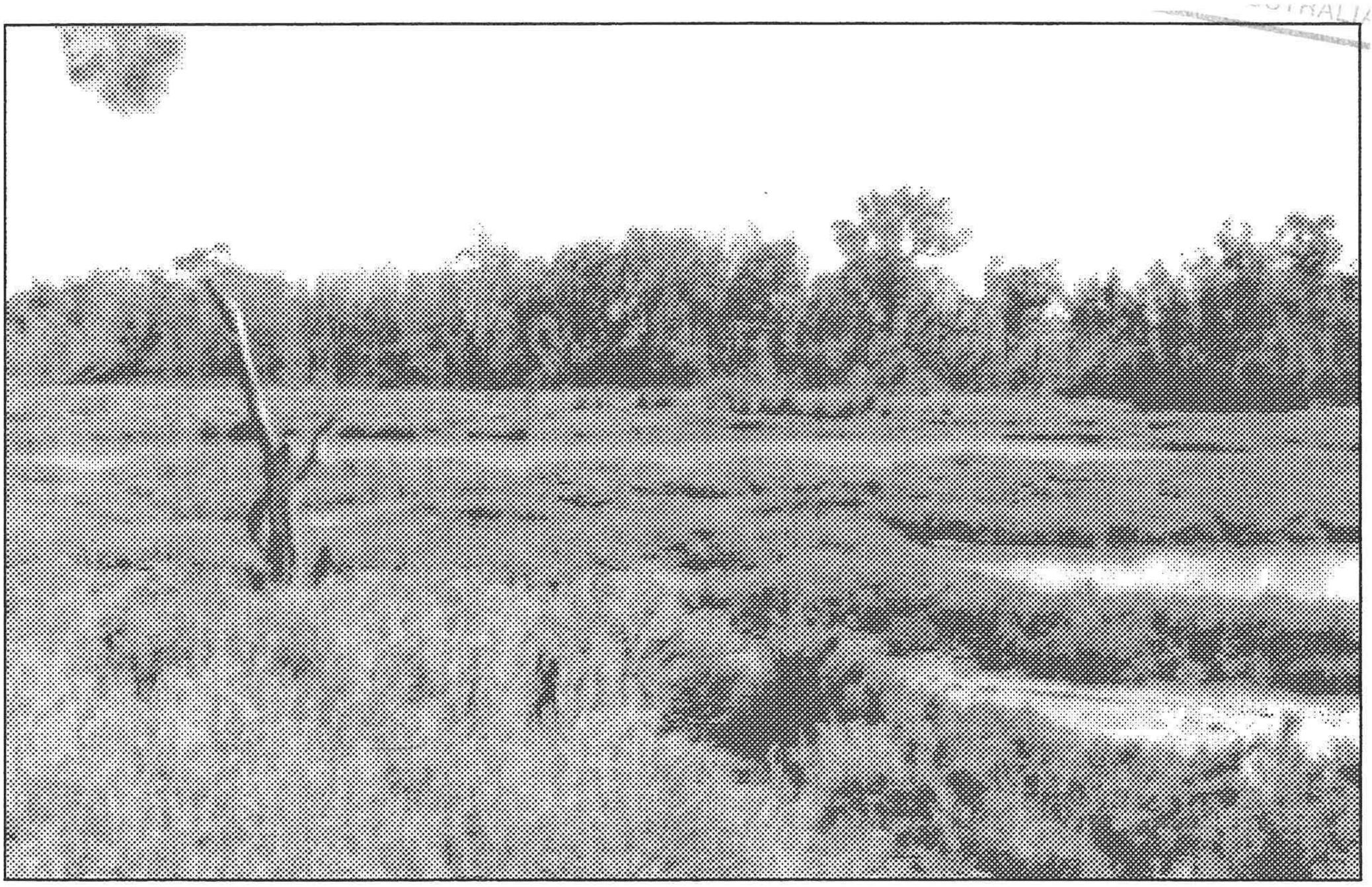
Government of Western Australia

DRAFT SERPENTINE RIVER MANAGEMENT PLAN

Stage 1 - Goegrup Lake to Barragup Bridge



WATER RESOURCE MANAGEMENT SERIES

WATER AND RIVERS COMMISSION REPORT WRM 6

1997

WATER AND RIVERS COMMISSION

DRAFT SERPENTINE RIVER MANAGEMENT PLAN

Stage 1 - Goegrup Lake to Barragup Bridge

A report to the Peel Inlet Management Authority
from the Serpentine River Working Group

Water and Rivers Commission
Policy and Planning Division and South West Region

WATER AND RIVERS COMMISSION
WATER RESOURCES MANAGEMENT SERIES
REPORT NO WRM 6
1997

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Information provided by the City of Mandurah and Shire of Murray greatly appreciated.

Many thanks to all members of the Working Group whose assistance made this report possible.

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Guide for Readers

Abbreviations

Many organisations are mentioned in this draft management plan including State government agencies, local government authorities and community groups. For brevity, initials are used in many references. A list of abbreviations is given below.

AGWA	Agriculture Western Australia
CALM	Department of Conservation and Land Management
COM	City of Mandurah
DEP	Department of Environmental Protection
DOT	Department of Transport
EPA	Environmental Protection Authority
GLASS	Goegrup Lakes Association
LGA	Local Government Authority
MCAC	Mosquito Control Advisory Committee
MFP	Ministry for Planning
MRS	Metropolitan Region Scheme
PIMA	Peel Inlet Management Authority
POS	Public Open Space
REEP	Regional Environment Employment Programme
REMP	Rivers Environment Management Plan
SOM	Shire of Murray
SRT	Swan River Trust
TPS	Town Planning Scheme
WAGG	Western Australian Government Gazette
WAPC	Western Australian Planning Commission
WRC	Water and Rivers Commission
WWC	Waterways Commission

How can I make a submission?

Public submissions on the Draft Serpentine River Management Plan are now invited. All public submissions will be considered before preparation of the final management plan.

If you would like to make a submission towards preparation of the final document please comment on any part of the document that you agree or disagree with. A tear out form is provided on the following page for this purpose. Send this to the Water and Rivers Commission at the address provided on the top of the form before 31 March 1998. Please note that submissions do not have to be confined to the length or layout of the form provided.

If more information is required prior to making your submission, officers of the Water and Rivers Commission will be available to discuss any aspect of the draft plan.

Where can I get other copies of this document?

Further copies of this document will be available for viewing at:

- Local government public libraries
- Shire of Murray offices
- City of Mandurah offices

Copies of the document will also be available free of charge from:

Water and Rivers Commission
The Hyatt Centre
3 Plain Street
EAST PERTH WA 6004

(08) 9278 0300

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MANDURAH WA 6210

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PUBLIC SUBMISSION FORM

DRAFT SERPENTINE RIVER MANAGEMENT PLAN
Stage 1 - Goegrup Lake to Barragup Bridge

Project Officer
Rivers Environment Management Plan
C/- Water and Rivers Commission
PO Box 6740
Hay St East
EAST PERTH WA 6892

Name: .....

Title: .....

Organisation: .....

Address: .....

.....

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.....

I would like to make the following comments on the Serpentine River Management Plan, Draft for Stage 1 - Goegrup Lake to Barragup Bridge and would like them considered in the preparation of the Final Management Plan.

Comments:

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I would also like a copy of the final document sent to the above address on its completion.

Signed

.....

Foreword

Foreshore reserves are provided in accordance with State Government philosophy to allow the community of Western Australia to enjoy the State's waterways. Foreshore areas are highly valued by the community for their aesthetic appeal and high conservation value as well as for their attraction for tourism and leisure activities. Reserves also protect remnant vegetation, act as a buffer against erosion, provide a habitat for fauna, and enhance the health of waterways by attenuating nutrient transport. However, reserves are subject to a wide range of competing pressures.

This draft management plan was prepared by the Serpentine River Working Group which included representatives from the community, local and State government authorities. The draft management plan makes recommendations to conserve, protect and rehabilitate the foreshore area whilst maintaining public access and recreational opportunities for the community in a manner sympathetic with the surrounding environment.

Individuals and groups are encouraged to comment on the draft management plan. The Peel Inlet Management Authority appreciates community input and hopes that the community will continue to work with PIMA in its efforts to manage this area.

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Summary

This plan has been prepared to provide a management framework for the Serpentine River foreshores from Goegrup Lake to Barragup Bridge (Pinjarra Road).

A wide range of management issues have been identified through consultation with State and local authorities, interested groups and the community. Many of these issues have relevance to other foreshore areas while others must be considered within the context of ongoing changes in this locality.

To provide a document that is both spatially and temporally relevant, the plan has provided general management principles as well as specific recommendations.

For each of the issues identified, the management principles provide a framework for the long term management of the foreshores. A summary of issues and principles is provided below.

The management recommendations presented at the end of this plan are generally site specific and suggest actions which are aimed at upholding the principles of this plan.

Issues and management principles:

Native vegetation and fauna habitats

- Any proposed subdivision or development adjacent to the river or existing foreshore reserves should adhere to the principles of this plan, be approved through relevant planning processes, and have special consideration for the following aspects:
  - fencing to prevent unrestricted access to the foreshore and to prevent unauthorised vehicle access;
  - provision for emergency and maintenance vehicle access;
  - provision of formalised or semi-formalised pathways to link with existing pathways and to prevent damage to vegetation and river banks;
  - ensure that existing foreshore vegetation is not degraded;
  - place weed barriers, such as pathways or vegetation buffer zones, along lines of demarcation;
  - undertake weeding and rehabilitation schemes to improve or maintain the integrity of the existing foreshore habitat.
- Protect and enhance native vegetation and habitat areas.
- Restrict human disturbance in conservation areas by blocking informal pathways and/or fencing remnant vegetation to include a buffer zone.
- Encourage school group and community involvement in the management of remnant vegetation and conservation areas.

Weeds

- Where necessary, lines of demarcation between freehold and reserve areas to be defined by weed barriers, such as paths or vegetation buffer zones.

- Reduce weed infestation of native vegetation areas using the following guidelines:
  - Liaise with AGWA and CALM for management considerations.
  - Restrict the use of mowing to well defined, grassed recreational areas.
  - Educate residents on preventing invasion of weeds and exotic plants from gardens and encourage the removal of problem plants.
  - Rehabilitate with locally appropriate native species.
  - Use environmentally friendly methods of weed removal wherever possible (eg manual weed removal, hot water treatment).
  - Keep herbicide usage to a minimum and ensure measures are taken to prevent effects on non-target species.
  - Encourage school group and community involvement and the participation of children in weed control.

Rehabilitation

- Increase existing vegetation and rehabilitate degraded vegetation areas with disease and pest free, locally appropriate native plantings and seedlings, preferably germinated from local stock.

- Encourage school group and community involvement in rehabilitation efforts and the planting of native vegetation on private property.

Foreshore erosion

- Give preference to erosion prevention measures which protect and reinforce emergent and fringing vegetation with locally appropriate native species.

- Direct public access to stable embankment areas and discourage access to erosion prone areas.

- Pathways are to be at a sufficient distance from the river bank to allow for the maintenance of a viable and stabilising plant community.

- Encourage school group and community involvement in bank revegetation and tree planting adjacent to the river.

Water quality

- Protect and reinforce native foreshore vegetation.

- Minimise the use of fertilisers in reserves and encourage landholders and residents to reduce usage.

- Encourage the installation of reticulated sewerage or alternative wastewater treatment units in new developments and subdivisions.

- Drainage systems should be designed to incorporate:
  - slowing drainage water to enhance settling and other nutrient loss mechanisms;
  - use of efficient filtration, compensation or nutrient stripping basins located on land outside foreshore reserves;
  - no direct stormwater discharge into the river or foreshore reserves.

Mosquito control

- Mosquito control programs must maintain the integrity of wetland ecosystems.

- Mosquito control should utilise the latest information available and be in accordance with the Integrated Mosquito Control Strategy for the Peel-Harvey Region and the Mosquito Control Advisory Committee.

- Protect saltmarsh areas from disturbances which increase mosquito breeding areas.

Feral and domestic animals

- Support the trial placement of 'dog latrines' at strategic locations.
- Restrict dog access in high conservation areas and support local government authority by-laws controlling dogs.
- Keep registered dog owners informed of any new initiatives in the local area and encourage requisite behaviour.
- Support the monitoring of feral animal populations and assess control requirements and methods as appropriate.
- Support the trial of a cat control program.

Fencing

- Use fencing materials that will not detrimentally impact on the movement of fauna or on visual amenity.

Fire management

- Reduce weed fuel loads through weeding and rehabilitation of native vegetation.
- Encourage schools to become involved in foreshore management and cadet training schemes.
- Landholders must comply with LGA bush fire break requirements and local residents should be encouraged to take bush fire precaution measures.
- Ensure emergency vehicle access and strategically located fire breaks (ie tracks, drains, lawn, boat ramps etc) are maintained.
- Regularly inspect bushland to assess fire risk and management options.

Public access

- Provide information on sites of interest, tracks and paths and the location and type of facilities available.
- Direct public access mainly to formalised recreational areas and ensure public access to ecologically sensitive areas is controlled.
- Ensure appropriate foreshore reserves are ceded as a condition of any rezoning or subdivision.
- The lines of demarcation between reserves and freehold land should be clearly defined (eg paths, garden beds, posts etc).

Vehicle access

- Restrict the use of fire breaks, bridle paths and walk trails to emergency and maintenance vehicles only.
- Support the establishment of a designated trailbike area in the region.

Bridle trails

- Bridle paths are to be located so as to minimise impact on ecologically sensitive areas and avoid conflict with other recreational use.

Nature trails

- Nature trails are to be designed and located to minimise impact on environmentally sensitive areas, link recreational areas, and take advantage of the visual amenity.
- Nature trail signposting of information such as location, length and time to walk, to be placed at major access points.
- Restrict signage along pathways to flora and fauna information plaques at appropriate locations.

Recreational fishing and crabbing

- Provide access nodes for crabbers and fishers at appropriate locations.
- Encourage local involvement in the Fisheries Department Volunteer Inspector Scheme.

Boating: speed and noise

- Ensure speed signs on river are clearly visible and located near boat launching facilities.
- Encourage Department of Transport policing of the area.

Jetties and boat ramps

- Adhere to PIMA policy that no new private jetties be constructed in areas abutting foreshore reserves.
- Demand levels for boat launch facilities should be monitored and measures to relieve pressure should be investigated and assessed as necessary.
- Licensed jetties must conform to required standards and illegal jetties should be removed.

Boats left on foreshore

- Boats are not permitted to be stored on public land or foreshore reserves and the relevant land manager should ensure that boats are removed by the owner.

Moorings

- Moorings within the study area are not permitted and should be removed by the owner.

Lawn areas

- Lawns are to be maintained only in recreational public open space (areas of high recreational pressure) and the use of fertilisers is to be minimal.
- Enhance recreational public open space areas with native garden beds and increase shade tree numbers.

Parking

- Car parking areas are to be located to provide ready access to formalised recreation areas.

- Parking areas should be clearly defined with barriers that minimise visual impacts while preventing vehicle access to recreation areas.

Ablution blocks

- Ablution facilities should preferably be located in recreational POS, not in foreshore reserves, and be managed by the LGA.

- The design and location of ablution facilities should minimise nutrient input to the ecosystem and minimise disruption to visual amenity.

Playgrounds

- Playground facilities should preferably be located in recreational public open space, not in foreshore reserves, and be managed by the LGA.

- Safe access to playgrounds is essential. Playgrounds should be assessed and traffic calming devices, crosswalks and warning signs installed where necessary.

Picnic facilities

- Restrict picnic facilities such as barbecues, rubbish bins and furniture to readily accessible, formalised public open space recreational areas.

Camping

- Camping is not to be permitted within foreshore reserves.

1. Introduction

1.1 Background

In September 1994, the City of Mandurah, Shire of Murray, Peel Development Commission and staff of the Peel Inlet Management Authority met to express concern over the current lack of management of the foreshore of the rivers discharging into the Peel-Harvey Inlet. The Rivers Environment Management Plan (REMP) aims to provide management plans for the Serpentine, Murray and Harvey Rivers.

A management plan for the lower reaches of the Serpentine River was considered necessary 'to manage growing public access pressure whilst protecting and rehabilitating degraded foreshore areas and conserving areas of natural vegetation'.

Stage 1 of the REMP covers the foreshore areas along the Serpentine River between the southernmost reaches of Goegrup Lake and Barragup Bridge (Pinjarra Rd).

The management agencies recognise that foreshores play an important part in maintaining the health of waterways. Foreshore areas are important because:

- They include plant and animal communities and physical features which form an integral part of the estuarine/riverine system.
- Vegetation within the foreshore reserves provides a buffer between the waterway and possible sources of water pollution and reduces the severity of erosion processes.
- They contain features which are part of the waterway landscape.
- They enable public access in a manner consistent with the multiple use of the waterway.

1.2 Development of the plan

A technical working group was formed in February 1995 to prepare Stage 1 of the Rivers Environment Management Plan. The group consisted of officers listed in Table 1.

The working group had identified various issues to be addressed by the plan when they were approached to take part in a Regional Environment Employment Programme (REEP). Due to this opportunity the focus of the working group shifted from developing a management plan for the whole of the study area to preparing a draft technical plan for the western foreshore.

A community workshop held in July 1995 endorsed the technical plan with minor amendments. Submissions received following advertising, also resulted in minor changes to the plan.

Member	Organisation
Murray Love	CALM
Jason Byrne	Waterways Commission
Caroline Seal	Waterways Commission
Colin Sommerville	City of Mandurah
Kim McCutcheon	City of Mandurah
John Clydesdale	Peel Development Commission
Christine Steer	Youth Options
Brett Flugg	Shire of Murray
Norm Griffiths	Shire of Murray

Table 1. Greenfields Technical Working Group.

As a result of participation in the REEP project several aspects of the technical plan were completed including:

- Completion of a dual use pathway along southern section of Redcliffe Rd.
- Fencing of the conservation area adjacent to Redcliffe Rd.
- Providing two access paths from Redcliffe Rd with raised boardwalks crossing seasonally inundated wetland areas.
- Laying of an informal crushed limestone trail in the conservation area adjacent to Redcliffe Rd.
- Building a boardwalk across the seasonally inundated, southern section of the trail.

Aspects of the technical plan which were not completed were taken into consideration in the future preparation of the draft management plan.

The working group was reconvened in January 1997 and preparation of the draft management plan proceeded. A public meeting was held in February 1997 which identified issues and community concerns in the study area. These issues were addressed by the working group in the preparation of the draft management plan.

Production of the draft plan was primarily carried out by the Water and Rivers Commission in consultation with the members of the working group.

The draft management plan has been prepared to present background information, general management principles and site specific recommendations for public comment. Once the community input has been received, a final management plan will be prepared and implemented.

Member	Organisation
Sue Grayling	Goegrup Lakes and Serpentine Society
Janet Gunn	Riverside Gardens Community Association
Leanne Reid	Goegrup Lakes and Serpentine Society
Lisa Chalmers	Water and Rivers Commission
Jodie Oates	Water and Rivers Commission
Tim Sparks	Water and Rivers Commission (Peel)
Leon Brouwer	Water and Rivers Commission (Peel)
Murray Love	CALM
Daniel Arndt	City of Mandurah
Kylie Carman-Brown	City of Mandurah
Brett Flugg	Shire of Murray
Jan-Paul Van Moort	Agriculture WA / Pinjarra Catchment Centre
Marie Ward	Ministry for Planning
Chris Thompson	Peel Inlet Management Authority

Table 2. Serpentine Working Group

1.3 Aim

It is the aim of the management plan to:

conserve and enhance the waterways, embankments and foreshores of the river environment whilst ensuring provision for public access.

1.4 Objectives

The primary objectives of the management plan were categorised by the working group as either conservation or recreation objectives.

1.4.1 Conservation

- Conserve and enhance native vegetation.
- Conserve and enhance fauna habitats.
- Reduce erosion.
- Protect the river and foreshore areas from pollution.

1.4.2 Recreation

- Provide opportunities for environmentally sensitive recreational use and public enjoyment of the river and foreshore areas.
- Enhance the use of recreation areas.

1.5 Organisational roles

There are a number of different organisations which are responsible for the planning and management of the Serpentine River environment (Figure 1). The responsibilities of some of these agencies are summarised below.

Water and Rivers Commission (WRC)

The role of the WRC is to manage the State's surface and groundwater resources including rivers and estuaries. Its focus is on the protection of environmental values and allocating water for a wide range of uses to support the State's development in a sustainable manner.

Key relevant WRC initiative and program areas include:

- public water supply;
- surface water and drainage control;
- water sensitive urban design;
- groundwater quality protection;
- groundwater allocation;
- estuary, river and wetland management and protection;
- floodplain management.

Peel Inlet Management Authority (PIMA)

PIMA is the community based, practical management arm of the WRC. PIMA has delegated powers, under the *Waterways Conservation Act 1976*, to comment on development within their management area. The Authority receives professional support and advice from the WRC, in particular the Peel office. PIMA in turn provides management advice and comment on development and strategic planning issues in the region. The WRC is then able to provide a consolidated waterways management response to relevant agencies or consultants with community based input from the Management Authority.

Local Government Authorities (LGAs)

There are two local government authorities with boundaries including the Serpentine River environment (Goegrup Lake to Barragup Bridge), the City of Mandurah and the Shire of Murray.

LGAs are responsible for local planning and development control in accordance with the town planning scheme (TPS).

LGAs are also responsible for the provision of recreation facilities and the management and the day to day maintenance of foreshore reserves under their control.

Provisions of the *Town Planning and Development Act 1928-1986* confers several important powers upon LGAs which have direct effect on the management of river environments. They:

- prepare and initiate changes to TPS which control development;
- approve and supervise residential and commercial developments;
- provide advice to MFP concerning the subdivision and amalgamation of land.

Western Australian Planning Commission (WAPC)

The WAPC is the regional planning authority for all areas in the State. It is the agency responsible for the administration of the Metropolitan Region Scheme (MRS) and the Town Planning and Development Act.

It is responsible for land use zoning at a regional scale and approval of town planning schemes. At a local level land use is guided by the town planning schemes.

Ministry for Planning (MFP)

While the WAPC is the statutory authority responsible for planning, the MFP is responsible for developing, reviewing and implementing the land use planning system in Western Australia.

In 1996 the MFP prepared the Inner Peel Region Structure Plan. A structure plan is not a statutory document and as such has no provision for the reservation or acquisition of land, however the plan can be adopted as a guide for new zones and reserves to be

Waterways management responsibilities

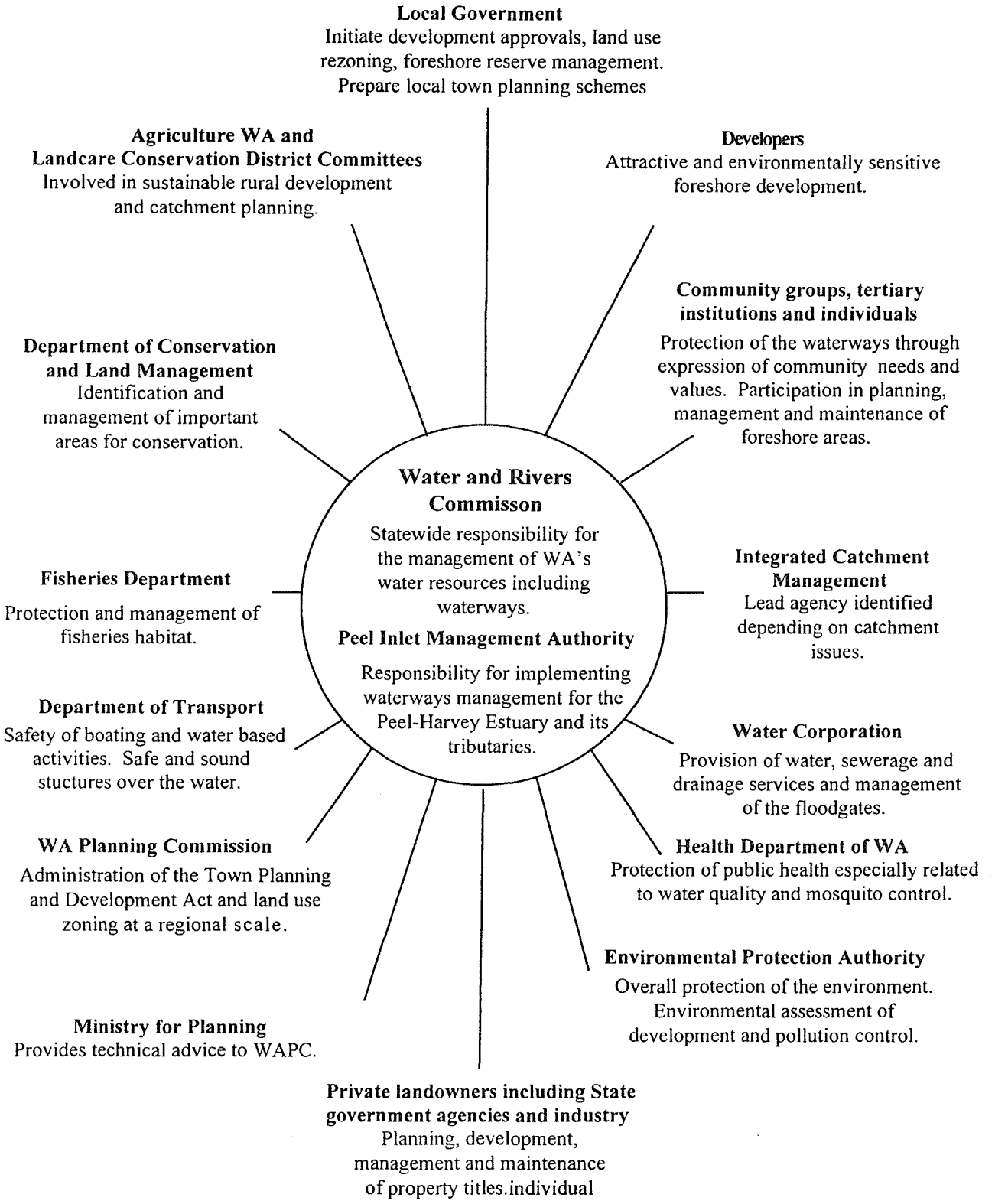


FIGURE 1. ***The role of WRC and PIMA in relation to other organisations and groups in waterways planning and management.***

incorporated in regional and local TPSs. The Structure Plan will be implemented by a Region Scheme to be released early 1998 (Ward, pers. comm. 1997).

Department of Conservation and Land Management (CALM).

The primary responsibility of CALM is to conserve Western Australia's wildlife and manage public lands and waters entrusted to the Department for the benefit of present and future generations.

It manages State forest, timber reserves, national parks, nature reserves and other land vested in the Lands and Forests Commission and the National Parks and Nature Conservation Authority.

CALM does not currently own or have vesting of any land within the study area.

Fisheries Department

The Fisheries Department is responsible for the conservation and management of professional and recreational fisheries and the state of aquatic and plant life in the estuary and rivers.

The Minister for Fisheries and his Department are responsible for the management of fisheries through the gazettal of Fisheries Regulations and Notices and their enforcement by Fisheries inspectors.

Agriculture Western Australia (AGWA)

AGWA plays an important role in managing the catchment of the Peel-Harvey system. It undertakes research, identifies and monitors sources of nutrient input, provides nutrient reduction advice and assistance to farmers.

AGWA is also responsible for providing support to Land Conservation District Committees (LCDC's). The primary role of the committees is to develop cooperation among land users and agencies to implement sustainable land management systems and to solve local and regional land degradation problems.

Department of Transport (DOT).

The DOT is responsible for safety and navigation in and on the water as well as administering various Acts and Regulations pertaining to:

- control of speed on the river;
- gazettal of swimming, waterski areas etc;
- control of persons in charge of vessels;
- use of public jetties;
- closure of navigable waters for safety or in case of emergency.

1.6 Public consultation

Community involvement in the preparation of the management plan is essential to its success. During the preparation of the draft management plan there were two public meetings. The first, held in July 1995, reviewed and made minor changes to the Greenfield Technical Plan. This meeting also identified general issues relating to the entire study area.

In February 1997 a 'community ideas' session was held at West Murray Hall, Pinjarra Rd. The local community was invited through a letter drop and advertisements in the local papers. Approximately 50 people had the opportunity to comment on the types of issues which they would like to see addressed in the management plan. All attendees were forwarded notes from the meeting and copies were also made available at Water and Rivers Commission, Sholl House, Mandurah.

Now is the time to comment on the draft management plan. Public submissions are invited and information on making a submission is provided at the front of this document. All public submissions received will be considered before preparation of the final management plan.

2. The study area

The Serpentine River is one of four major rivers which contribute to the Peel-Harvey estuarine system. The Rivers Environment Management Plan is a PIMA initiative to provide foreshore management plans for the rivers discharging into the Peel Inlet.

The plans for the Serpentine River are to be completed in four stages. This draft management plan is Stage 1.

The study area covered by this management plan is made up of the foreshore reserves adjacent to the lower reaches of the Serpentine River between the southern end of Goegrup Lake and Barragup Bridge (Map 1).

2.1 The physical environment

2.1.1 Geology, geomorphology and soils

The simplified geology of this area is swamp and estuarine wetland deposits (DCE, 1980). These lake and swamp deposits developed through the Holocene period and rarely exceed 3 m in thickness. The deposits can include various clay, sand, peat gypsiferous and diatomaceous deposits.

The area is characterised by aeolian and marine deposits. There are four main landform and soil units located in the study area: Bassendean, Herdsman, Yoongarillup and Vasse (DCE, 1980).

The Bassendean unit is made up of a series of low dunes with occasional swamps with peaty podzols. The larger swamps of the Bassendean unit have been mapped separately as the Herdsman unit, with soils described as black organic sands, peaty loams, black clays and true peats. The Yoongarillup unit has low ridges and swales with shallow yellow and brown sands deposited over marine limestone. The Vasse unit consists of mixed layers of recent estuarine deposits.

Soil types have an effect on nutrient input to the river and estuary systems as different types of soils vary in their ability to hold phosphorous. The laterite and clay soils of the Darling Scarp and the heavy soils - the loams and clays - of the coastal plain absorb most of the phosphorous applied as fertiliser and it has been estimated that only about 10% of phosphorus entering the estuary comes from east of the Darling Scarp (Bettenay & Schofield, 1984). The Serpentine River catchment is dominated by the Bassendean sands of the Swan Coastal Plain. About 85% of the riverine phosphorus input into the Peel-Harvey Estuary originates from the Swan Coastal Plain.

The high level of phosphorus discharge can be attributed to a number of factors including:

- low phosphorus absorbing and highly permeable soils;
- high rates of application of high solubility phosphorus fertilisers;
- high drainage density;
- high rainfall and runoff; and
- a near flat topography which generates a high proportion of overland flow from a large saturated source area (Schofield & Gerritse, 1988).

2.1.2 Climate

The Mandurah area experiences a Mediterranean climate which is characterised by cool, wet winters and warm dry summers. The study area's average maximum temperature varies from 17°C in July to 29°C in February. The average minimum temperature varies from 8°C in August to 17°C in the summer months (Trudgen, 1991).

The region receives most of its rainfall (approximately 900 mm) during the winter, between May and October. Up to 100 mm of rain may fall through the rest of the year.

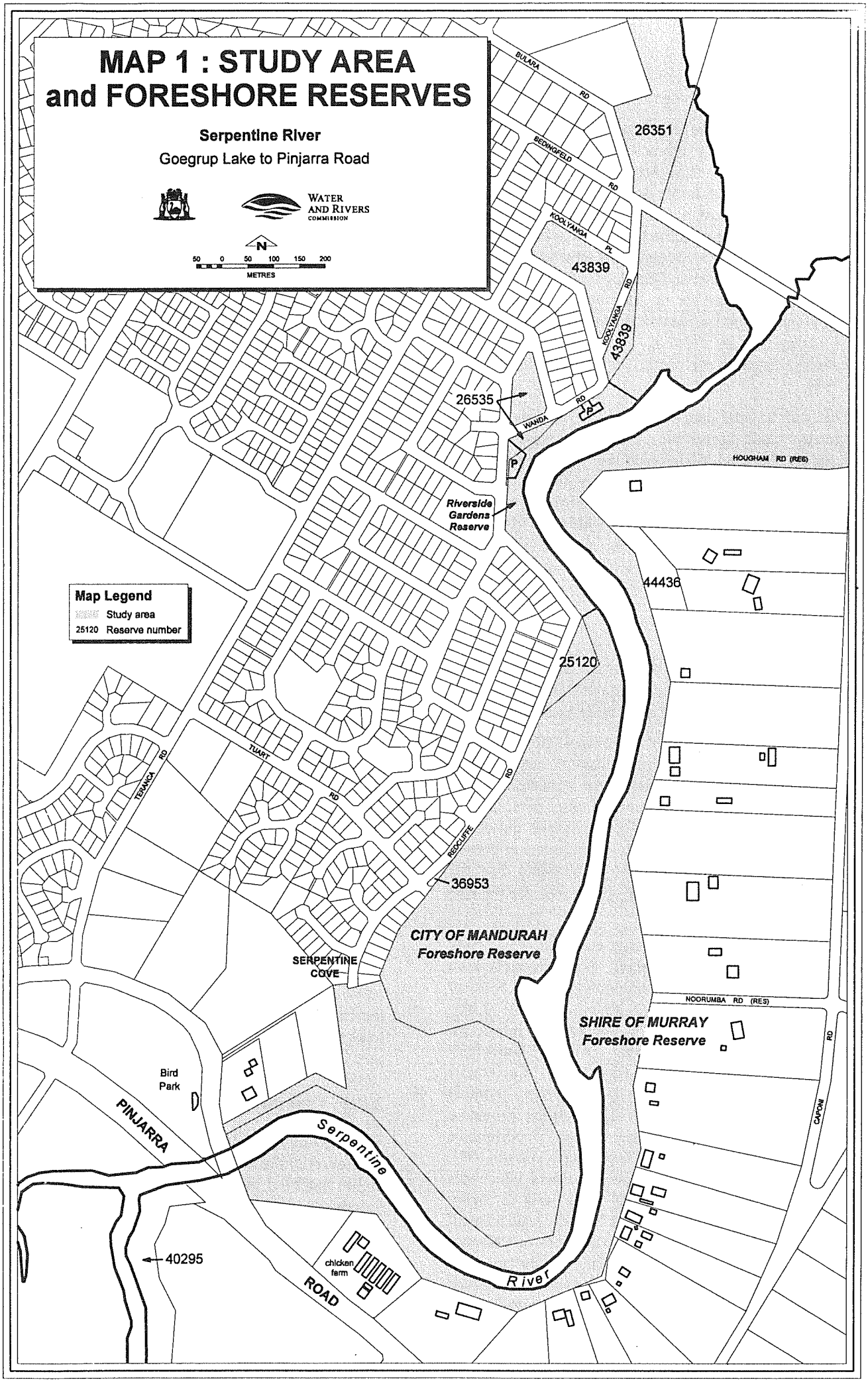
Annual evaporation from wetlands exceeds the annual rainfall for the region. The minimum rates occur in July and maximum in January (Waterways Commission, 1992).

2.1.3 Hydrology and bathymetry

The Serpentine River discharges fresh water originating from agricultural drains, groundwater and rainfall, into the north-eastern side of the Peel Inlet.

During the winter months it is not uncommon for the river to overflow and in summer it can become dry in sections. Lake Goegrup is a sandy, shallow (maximum depth approximately 1.5 m) water body. Algal accumulations are common.

There is tidal exchange up the Serpentine River to approximately two kilometres downstream of Karnup Road Bridge (Tom Rose, pers. comm. 1995). The entire study area is subject to tidal influence. The narrow fringing saltmarshes along


MAP 1 : STUDY AREA
and FORESHORE RESERVES
Serpentine River
Goegrup Lake to Pinjarra Road
WATER AND RIVERS COMMISSION
N
50 0 50 100 150 200
METRES
Map Legend
Study area
25120 Reserve number
BULARA RD
BEDINGFELD RD
KOOLYANGA PL
KOOLYANGA RD
WANDA RD
HOUGHAM RD (RES)
NOORUMBA RD (RES)
CAPOW RD
TEANICA RD
TUART RD
REDCLIFFE RD
26351
43839
43839
26535
44436
25120
36953
40295
Riverside Gardens Reserve
CITY OF MANDURAH
Foreshore Reserve
SHIRE OF MURRAY
Foreshore Reserve
SERPENTINE COVE
Bird Park
PINJARRA ROAD
Serpentine River
chicken farm

the Serpentine River and on either side of Lake Goegrup are flooded during normal winter high tides. The floodplain extends up to 500 m from the river.

The construction of the Dawesville Channel has resulted in tidal fluctuations in the Peel-Harvey system being dominated by flow through the wider and deeper Dawesville Channel rather than through the Mandurah Channel as occurred in the past. With the opening of the Dawesville Channel the tidal range within the Peel-Harvey system has increased from an average of 10cm for both the Peel Inlet and Harvey Estuary, to 32cm for the Peel and 45 cm for the Harvey. Maximum spring tide ranges in the Peel Inlet have increased from 12.3% of ocean tide to 50% of ocean tide, with similar increases noted in the Harvey Estuary (Lord & Assoc, 1997).

This shift in tidal patterns has had effects on both the Murray and Serpentine Rivers, however on a progressively decreasing scale moving upstream from the river entrances. No referenced or known tidal data has been recorded for the rivers, however anecdotal reports suggest tidal movement within the rivers has increased, in varying degrees, in both range and frequency.

2.1.4 Water quality

The lower reaches of the Serpentine River comprise a series of wide, shallow pools and lakes. For most of the year it is poorly circulated and highly stratified.

Fluctuations in salinity (sea water has a salinity level of around 36.5 mg/L) can vary from 0 mg/L during winter periods of heavy river flow and flush, up to around 55 mg/L during summer (Chase, pers. Comm. 1997). Density driven stratification occurs during all seasons and contributes to anoxic conditions in bottom waters. The subsequent release of nutrients from the sediments provides food for algae and encourages phytoplankton blooms.

The Serpentine River is a highly eutrophic water body with blooms of macro-algae and phytoplankton occurring during spring, summer and autumn. Nutrient recycling from sediments provide a high levels of bio-available phosphorous. On average, P levels are around seven times higher than ANZECC Guidelines for the protection of aquatic ecosystems. Favourable conditions (usually during the summer months) combined with high nutrient concentrations, provide a highly productive environment ripe for opportunistic phytoplankton to flourish (Chase, pers. comm.1997). This is a catchment management problem which has been acknowledged for some time and is being addressed as part of the Peel-Harvey Management Strategy (WWC, 1994) and the Statement of Planning Policy No.2 (WAGG, 1992). The Policy specifies nutrient load objectives and outlines methods by which these are to be achieved and maintained including the implementation of the Policy by local authorities through their town planning schemes, and by the State Planning Commission through the Metropolitan Region Scheme.

2.2 The biological environment

2.2.1 Aquatic vegetation and fauna

Extremes in water quality from winter (brackish) to summer (hypersaline), as well as tidal influences, eutrophication and siltation have resulted in the flora and fauna of the lower reaches of the Serpentine River being made up of predominantly highly tolerant species.

Aquatic flora and fauna are sensitive to changes in water quality. The poor water quality in the lower reaches of the Serpentine River is reflected in the lack of diversity found in the biological species composition. The trade-off for this lack of diversity is that the species that do occur are extremely productive, both in terms of biomass and abundance (Day, 1981).

Large numbers of wading birds use the mud flats which is indicative of an abundance of invertebrates as they are the main food source of these birds.

In late spring to early summer the dominate algae is *Nodularia*. During the latter summer months micro algae are replaced with macro species (Crook, pers. comm. 1997).

Invertebrate species vary according to seasons and water quality. In a study of invertebrate distribution of the samphire marshes, Keally *et al.* (1995) found oligochaetes (worms) to be dominant. Other invertebrates commonly recorded were amphipods and isopods. In the Serpentine River there are also chironomids (midge larvae), coleoptera (beetles) and a small variety of other highly tolerant species (Crook, pers. comm. 1997).

Anecdotal evidence suggests that crabs are prevalent in Lake Goegrup and the Serpentine River for the first time in many years. Local residents have reported that since the opening of the Dawesville Channel, in July 1994, they have been able to drop and scoop net from the river banks and catch large numbers of crabs in Lake Goegrup.

2.2.2 Terrestrial vegetation

The vegetation in this area ranges from remnant native vegetation and saltmarshes with few or no weeds to highly modified picnic areas with shade trees with an introduced grass understorey. While much of the remnant vegetation in the study area is disturbed, there are significant stands of vegetation which have maintained their integrity and can be restored with appropriate management (Map 2).

Map 3 shows the generalised vegetation data while the details of the vegetation survey and lists of species identified within the study area are provided in appendices 1 and 2. Species lists will not be exhaustive as the flora survey occurred in the summer months, when many annuals are not present. Six major categories of fringing vegetation have been identified by Pen (1992) for the South West Region:

2.2.2.1 Saltmarsh

Salt-marshes develop in areas which are saline either through direct tidal inundation by saline water or as a result of tidal inundation followed by concentration of salts through evaporation of water trapped on the marsh by a shoreline levee. This community is characterised by samphires (*Sarcocornia quinqueflora* and *S. blackiana*), shrubby glasswort (*Halosarcia indica bidens*), seablite (*Suaeda australis*) and creeping brookweed (*Samolus repens*).

2.2.2.2 Estuarine fringing forest

Estuarine fringing forest is typically dominated by the small saltwater sheoak (*Casuarina obesa*), saltwater paperbark *(Melaleuca cuticularis*), paperbark *(M. viminea*) and swamp paperbark (*M. rhaphiophylla*). Fringing forest occurs as the ground level rises and where salinity levels are not extreme.

2.2.2.3 Fringing vegetation

Fringing vegetation consists of those emergent species which live more or less permanently in shallow water. These shallow water bodies may be seasonal. Species found in the area include marsh clubrush (*Bolboschoenus caldwellii*), samphire (*Sarcocornia quinqueflora)* and a tall weeping sedge (*Schoenoplectus validus).*

2.2.2.4 Sandy rise vegetation

This category is composed of vegetation occurring on remnant coastal dunes and raised beach margins of water bodies. It is made up of mostly banksia woodlands with varied understorey depending on the level of disturbance.

2.2.2.5 Freshwater fringing vegetation

This vegetation occurs in areas receiving substantial freshwater input, either from surface inputs (ie. creeks or drains) or from groundwater seepage which typically occurs at the base of a ridge or sand dune. It is dominated by *Eucalyptus* spp. and *Melaleuca* spp. forest.

2.2.2.6 Disturbance-related plant assemblages

Plant assemblages may develop in areas subject to frequent disturbance which are characterised by either a lack of native plant diversity and regeneration or a high degree of weed infestation. For example, remnant trees in recreational areas are largely prevented from regenerating because of continuous physical disturbance including trampling and fire, therefore the population becomes increasingly aged. Another example of a disturbance-related plant assemblage is in areas which have been subject to changing land use over many years and conditions have not yet established equilibrium. In this case, some native plant species are undergoing decline while others are becoming established or are expanding their extent. At the same time ephemeral weeds exploit communities for invasion, which may in the long term retard the regeneration of native species. Such assemblages appear chaotic and contrast greatly with the homogeneity of native plant communities and the continuums which exist between them.

2.2.3 Terrestrial fauna

The study area provides habitat for a variety of animals including invertebrates, waterbirds, reptiles, forest and scrub birds and mammals.

2.2.3.1 Invertebrates

No formal invertebrate survey has been undertaken in the study area. Dragon flies, three genera of ants, scorpion flies and beetles etc were observed during the vegetation study (Appendix 1).

There are several species of mosquito found in the region. The saltmarsh mosquito *Aedes camptorhynchus* can travel three to five kilometres in a night. *Aedes vigilax* can breed in enormous numbers and has been known to travel 50 kilometres from its breeding site. It is the major coastal vector of Ross River Virus throughout most of Australia. The species is the dominant mosquito during the summer months in the Peel Region. There have been greatly elevated levels of Ross River Virus since the opening of the Dawesville Channel (EPA, 1997).

2.2.3.2 Reptiles

Two species of venomous snake inhabit the study area: the Dugite *(Pseudonaja affinis)* and the Tiger Snake (*Notechis scutatus).* A number of lizards are expected to inhabit the site given the nature of the terrain and vegetation, however no attempt has been made to survey these animals.

2.2.3.3 Birds

Waterbirds use the wetlands in this area for feeding and resting. Compiled by RAOU, Appendix 3 lists bird species observed in the Goegrup Lake area. A list of species observed during the 1995 vegetation survey is also provided in Appendix 1 (Table B).

Herons feed on prey such as crustaceans, small fish and frogs in water, and insects and other small prey on land.

They utilise the tidal flats and shallows of Lake Goegrup and parts of the Serpentine River. They also feed in marsh club-rush stands. The Yellow Billed Spoonbill and Black Duck feed on invertebrates, including mosquito larvae, in the tidal zone.

The *Casuarina obesa* at the entrance to Goegrup Lake is used extensively by roosting herons and spoonbills. A Nankeen Night Heron rookery has been observed on the Barragup foreshore in *Casuarina obesa* opposite the Wanda Rd boat ramp.

A number of terrestrial fringing forest birds have been noted feeding, roosting and nesting within the low dense woodlands and tall open woodlands. These included breeding fantails, Splendid Fairy-wren *(Malurus splendens)*, Common Bronzewing *(Phaps chalcoptera)*, Sacred Kingfisher *(Halycon sancta)*, Red Wattlebird *(Anthochaera carunculata)*, Black-faced Cuckooshrike *(Coracina novaehollandiae)* and a species of pipit.

There are a number of old trees in the study area and some species rely on these for habitat. The range of plant communities provides variety for a diversity of woodland bird species.

2.2.3.4 Mammals

Although there have been no formal mammal surveys it is known that the rare and endangered Southern Brown Bandicoot *(Isoodon obesulus)* lives in the study area. The remains of bandicoots have been found along with numerous distinctive scratchings on the Barragup and Goegrup Lake foreshores and on the Greenfields foreshore in the Serpentine Cove area. The actual size and extent of the population is not known.

Kangaroos and the Common Brush Tail Possum *(Trichosurus vulpecula)* also inhabit the area.

2.2.3.5 Other animals

A number of introduced mammals have been observed in the area. Foxes, rabbits, dogs and cats are present.

2.3 Social environment

2.3.1 Aboriginal significance

O'Conner *et al*, 1989, identified several locations of significance to Nyungah people within the Peel Region. The Nyungah people local to the Peel area are the Binjareb. They had a wealth of land with access to many different environments and natural resources (Bindon & Walley, 1992).

The northern shore of Goegrup Lake was a traditional camping area. The narrow creek which joins Goegrup Lake to Black Lake was originally the site of a wooden fish trap (or *mungur)* and camps spread approximately 200 metres to the south-west and north-east of this trap. It was known as Nambeelup, a name which has been incorrectly applied to a pool over 1km away at the end of Shenton Road (O'Conner *et al*, 1989).

The Serpentine River bifurcates 60 metres south-west of the present Barragup Bridge. Aboriginal people from Pinjarra have identified the site of another *mungur*, approximately 30 m downstream on the eastern arm of the bifurcation. Camps were located nearby and the site was still used in the period 1900-1910 (Bindon & Walley, 1992). Other camping areas in the region include the Coodanup Peninsula.

The area had many other resources, providing food, tools and medicines. For example, blackboy (*Xanthorrea preissii*) were the home of the wichetty grub and the slender flower stems were used to generate fire. The bark of the Christmas tree (*Nutysia floribunda*) was used for making shields and the red gum from the marri tree *(Eucalyptus calophylla)* was used for its antiseptic properties (Bindon & Walley, 1992). The area would have been abundant with tortoise, skinks, freshwater crayfish, crabs, and insects which would also have been important for food.

2.3.2 European significance

The first recorded exploration of the area around the Peel Inlet was in 1829 when Lt R.N. Preston and Dr Alexander Collie anchored the 'Sulfur' in Cockburn Sound and took a whale boat south to a river between the sound and Leschenault Inlet. Thomas Peel obtained the first land grant at *Mandja*, a meeting place for Aboriginals at the mouth of the Peel Inlet. His grant was for 250 000 acres of land which extended to the banks of the Murray River (Lund, 1996).

Among the first settlers to the Peel Inlet were John Tuckey and T. Eacott who were granted 50 acres each from the Peel estate for unpaid wages. The Pinjarra district was first surveyed in 1834 in an expedition led by the Governor, James Stirling, and the Surveyor General, John Septimus Roe. The road to Pinjarra was cleared in the early 1840s (Lund, 1996).

The study area was predominantly rural in the early 1900s. Some rural land has since been subdivided for suburban development, as have some areas which were previously undeveloped.

2.4 Land use and reserves

The Greenfields foreshore (left bank if travelling upstream from Barragup Bridge) of the Serpentine River, delineates the boundary between City of Mandurah and Shire of Murray.

The foreshore areas within the study area which are not covered by the following reserve numbers are owned by the Shire of Murray and the City of Mandurah. From here on, these areas are all referred to as foreshore reserves.

The following reserves are located within the study area (Map 1).

Reserve #	Purpose	Vested Agency
43839	Public Recreation	City of Mandurah
26535	Public Recreation	City of Mandurah
44436	Public Recreation	Shire of Murray
25120	Recreation	No
26351	Public Recreation	No
36953	Public Recreation	No

All of the foreshore reserves are classed as public open space (POS) for either recreation or conservation purposes. The areas currently classed as POS for recreation are:

- Riverside Gardens Reserve, the section of the City of Mandurah foreshore which has been developed into a grassed recreational area with large shade trees;
- Koolyanga Reserve, # 43839, an open, grassed park; and
- Eacott Park, # 26535, an open grassed park and children's playground.

All other foreshore reserves in the study area are currently classed as POS for conservation. Much of the foreshore bushland and wetland still persist and although the study area is not listed as a System 6 reserve (DCE, 1983), it is classed as a high conservation wetland area in the Inner Peel Region Structure Plan (WAPC, 1996). The study area is considered to be of regional significance because of its high conservation and recreation values and its proximity to the Perth and Bunbury regions.

The predominant land use adjacent to the foreshores surrounding the river is private residential. On the Greenfields foreshore the majority of properties are separated from the foreshore reserves by Redcliffe Road. The Serpentine Cove area has been used for rural purposes in the past but has since been subdivided and rezoned R10 and R30 (Carman-Brown, pers. comm. 1997).

The Barragup foreshore is dominated by small rural properties which are directly adjacent to the foreshore reserve. Some of these properties are fenced while others have adopted de facto ownership of the foreshore reserve.

3. Issues and management principles

3.1 Conservation

3.1.1 Native vegetation and fauna habitats

Foreshore vegetation is important in maintaining a healthy river system, it can trap heavy metals and various hydrocarbons before they reach estuarine and riverine water (Odum, 1990). The vegetation and organic peat which accumulates within these areas can bind pollutants and nutrients, regulating their passage into the river (Thurlow & Pen, 1994). Wetlands fringing the river are a diminishing resource and are under constant development and recreational pressure.

Within the study area most of the remaining areas of fringing vegetation have been disturbed by previous farming activities, nearby housing development and uncontrolled vehicle and pedestrian access. However there are a number of areas which have suffered little disturbance (Map 2). Without careful management, further urban development adjacent to the foreshores may result in increased habitat disturbance.

The Statement of Planning Policy No.2 (WAGG, 1992) general policy provision 5.4 encourages the retention and rehabilitation of remnant vegetation with a catchment target of 50% of land area to be established to deep rooted perennial plants and the retention of remnant vegetation along water courses. The Shire of Murray's policy relating to vegetation management specifies requirements that apply to all new land subdivision and development in Shire areas of the Peel-Harvey Coastal Plain Catchment.

There is considerable diversity of habitat within the study area: ranging from *Banksia* and *Casuarina* woodlands, through *Melaleuca* wetlands to samphire flats (Map 3). A brief description of the vegetation is provided in Section 3.2.2. A detailed vegetation survey is reproduced in Appendix 1.

A continuous foreshore habitat provides shelter for terrestrial fauna and facilitates the movement of species and therefore assists in maintaining genetic diversity. The fauna contribute to the maintenance of the vegetation by undertaking functions including pollination of flowering plants, seed transferral and sometimes consumption of pests. Transitory animals spread seeds over large areas which may increase the distribution and diversity of vegetation.

A reduction in the number and diversity of trees corresponds with a decrease in the fauna dependent on them (Siemon, 1995). It is therefore important to conserve the remaining plant communities to maintain the existing fauna.

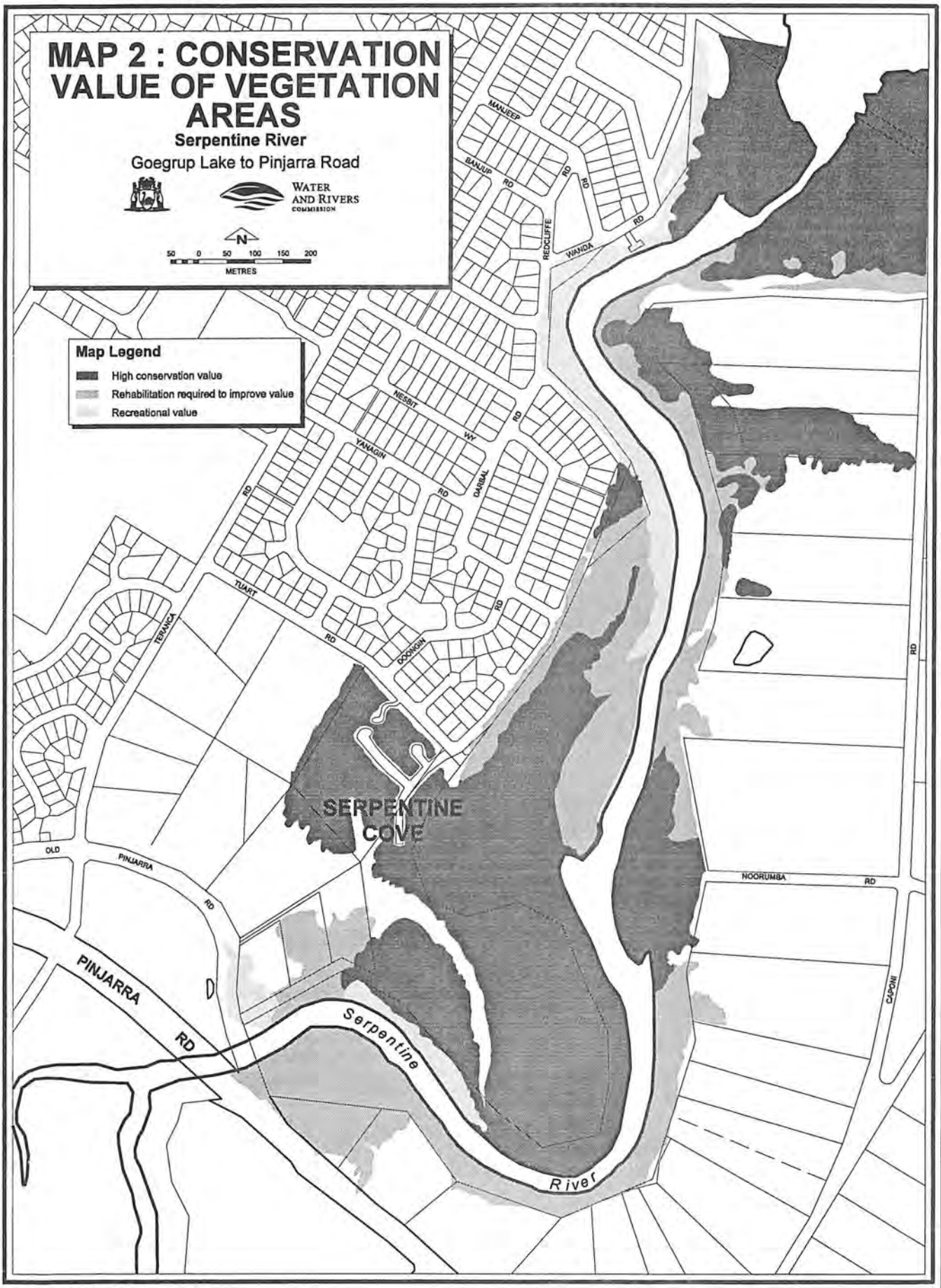
Management Principles

- Any proposed subdivision or development adjacent to the river or existing foreshore reserves should adhere to the principles of this plan, be approved through relevant planning processes, and have special consideration for the following aspects:
  - fencing to prevent unrestricted access to the foreshore and to prevent unauthorised vehicle access;
  - provision for emergency and maintenance vehicle access;
  - provision of formalised or semi-formalised pathways to link with existing pathways and to prevent damage to vegetation and river banks;
  - ensure that existing foreshore vegetation is not degraded;
  - place weed barriers, such as pathways or vegetation buffer zones, along lines of demarcation;
  - undertake weeding and rehabilitation schemes to improve or maintain the integrity of the existing foreshore habitat.
- Protect and enhance native vegetation and habitat areas.
- Restrict human disturbance in conservation areas by blocking informal pathways and/or fencing remnant vegetation to include a buffer zone.
- Encourage school group and community involvement in the management of remnant vegetation and conservation areas.

3.1.2 Weeds

Weeds is the term commonly used to describe plants growing where they are not wanted (Humphries, 1992). In remnant bush, where the aim is to retain a healthy native vegetation community, introduced plants which replace the original native vegetation are environmental weeds.

Environmental weeds are defined as those species that invade native communities or ecosystems and are undesirable from an ecological perspective (Hussey & Wallace, 1993). The typical pattern for weed



Data supplied by: Nicole Siemon, 1995.

invasion involves a period of dormancy followed by invasion and population explosion (Hobbs & Humphries, 1994).

Manual control methods for weeds are preferable, however the use of herbicides is often necessary. There is a discussion of control methods for various weed types in Section 3.2.6 of the Vegetation Survey (Appendix 1).

The foreshore reserves have several weed species and infestation is extensive, although it is greatest in sandy disturbed areas. Human use appears to be the main factor in the spread of introduced plants with highest concentrations of species in areas of disturbance associated with housing, camping, parking and tracks.

The dominant weeds along the Greenfields foreshore are introduced grasses and the tree weeds Japanese pepper *(Schinus terebinthifolius)* and pampas grass *(Cortaderia selloana)*. The grasses are located in most vegetation types in the open sandy areas, whilst Japanese pepper is currently found mostly in the *Casuarina obesa* and *Melaleuca rhaphiophylla* complexes and its removal should be considered a high priority.

Mowing of exotic grasses which have infiltrated the native vegetation is a commonly used management technique in the Greenfields locality. Mowing exacerbates the problem by hastening the spread of weeds (Scheltema & Harris, 1995). At the northern end of the Riverside Gardens Recreational Reserve mowing has resulted in the spread of weeds which has, in turn, resulted in the extension of the area being mowed. This means that mowing now occurs outside the boundary of the area defined as POS for recreation. Barriers, such as paths, fences and bollards, help to define areas which require mowing and prevent the gradual expansion of mowed areas. Advantages of this include reduced mowing, weeding and other maintenance costs in the long term.

There is extensive grass weed invasion along Wanda Rd and Koolyanga Rd which is spreading into the *Casuarina obesa* forest due to disturbance resulting from uncontrolled access and mowing.

The Barragup foreshore also has significant levels of introduced grasses in sandy rise areas. The foreshore area adjacent to the chicken farm off Pinjarra Rd is an extreme example of weed grass invasion to the exclusion of almost all native understorey plants. This area should be considered a high priority to prevent the spread of the infestation.

The spread of exotic plants from gardens is a problem, especially where there is no buffer or physical demarcation between private land and the reserve areas. This occurs on the Barragup foreshore between the chicken farm and Noorumba Rd where many homes directly abut the reserve. Garden areas have often been extended into the reserve toward the river.

Exotic plants such as lawn grasses, Victorian tea trees (*Leptospermum laevigatum*) and rose pelargonium (*Pelargonium capitatum*) have invaded the foreshore adjacent to homes. Rose pelargonium has been observed approximately 100 m south of the Noorumba Rd path, it is particularly tenacious and is difficult to control as the plant will reshoot if the stem is broken at or below ground level. Due to the massive amounts of seed produced, pampas grass can spread rapidly. The removal of these weeds should be considered a priority.

Due to the close proximity of residential areas to the foreshore the natural dispersal of exotic garden plants can be a source of weeds in the native vegetation. Another potential source of weeds is from garden rubbish and fill dumped illegally on the foreshore. This fill often contains cuttings from gardens and contributes to the variety of plants which establish in the reserves. It is important that local residents are encouraged not to discard garden material into the foreshore reserves. This could be included in an information brochure.

Management Principles

- Where necessary, lines of demarcation between freehold and reserve areas to be defined by weed barriers, such as paths or vegetation buffer zones.
- Reduce weed infestation of native vegetation areas using the following guidelines:
  - Liaise with AGWA and CALM for management considerations.
  - Restrict the use of mowing to well defined, grassed recreational areas.
  - Educate residents on preventing invasion of weeds and exotic plants from gardens and encourage the removal of problem plants.
  - Rehabilitate with locally appropriate native species.
  - Use environmentally friendly methods of weed removal wherever possible (eg manual weed removal, hot water treatment).
  - Keep herbicide usage to a minimum and ensure measures are taken to prevent effects on non-target species.
  - Encourage school group and community involvement and the participation of children in weed control.

3.1.3 Rehabilitation

Whilst large sections of the study area are relatively undisturbed, uncontrolled access on highly susceptible sandy soils has led to the removal of vegetation. Many areas have extremely high conservation value, particularly the low dense heaths dominated by Myrtaceae species.

There is evidence of considerable use by trailbikes of the nature trail on the Barragup foreshore as well as 4WD use of tracks to the north and south. Uncontrolled vehicle access damages the vegetation and promotes the spread of weeds. If rehabilitation of degraded areas is to be successful then vehicle access must be restricted. Barrier planting of low prickly species can be an effective deterrent to pedestrians and bike riders. Scattering tree branches and offcuts on sandy or exposed soil areas is also a good deterrent for bike riders and helps in soil stabilisation.

Many weeds require high light availability and hence the extent and density of many weeds could be reduced by increasing shade with native shrub and tree species. Rehabilitation with native vegetation has many long term benefits. Maintenance costs are reduced, as are fire risks which increase with the presence of highly flammable annual weeds. Rehabilitation can result in the creation of a continuous understorey, and improved fauna habitat.

Varied vegetation provides a number of habitats which can correspondingly support a greater diversity of animals. The wide range of habitats in the study area, including the waters, wetlands and tidal marshes, provides for a range of fauna.

The disruption of ecological processes (for example pollination and germination) through modification of vegetation structure and composition threatens the ability of plants and animals to regenerate naturally.

When rehabilitating degraded areas it is important to maintain some level of genetic mixing to avoid in-breeding and the associated deterioration of the plant communities. However it is advantageous to reinforce remnant vegetation with seedlings germinated from local seed which:

- are suited to local conditions,
- maintain genetic stock in the local area, and
- facilitate the maintenance of genetic diversity in a regional context.

The remnant foreshore vegetation in the Greenfields locality is limited to a narrow band. The trees fringing the river are nearing the end of their life span and there is little evidence of natural regeneration. It is important that existing stands of paperbarks, sheoaks etc. are reinforced with seedling plantings to ensure long term persistence of these remnants.

Management Principles

- Increase existing vegetation and rehabilitate degraded vegetation areas with disease and pest free, locally appropriate native plantings and seedlings, preferably germinated from local stock .
- Encourage school group and community involvement in rehabilitation efforts and the planting of native vegetation on private property.

3.1.4 Foreshore erosion

The foreshore is receding and it is important that any development of the reserve should take this into consideration.

Sections of the bank have been stabilised with the use of limestone boulders (rockwalling) and wood logs (logwalling). This type of stabilising structure may be suitable for heavy traffic areas, such as fishing access nodes, where disturbance would not allow stabilising vegetation to establish. A problem with stabilising the banks in such a way is that it does not allow for the return of emergent vegetation and hence further reduces habitat extent. It is preferable to maintain the foreshore in a natural state through the re-establishment of stabilising vegetation.

Vegetation is important in stabilising soils and providing fauna habitat. The foreshore vegetation along the Serpentine River has a limited extent, and in many areas is reduced to a single tree width. The planting of suitable tree species on the river banks will provide long term support and protection against erosion.

Emergent riverine species along the foreshore include samphire *(Sarcocornia quinqueflora)*, grasswort *(Halosarcia* sp.*)*, shorerush *(Juncus kraussii)* and lake club-rush *(Schoenplectus validus)*, which occurs in a homogeneous stand near the boat ramp. Species of fringing and emergent plants could be re-established in areas not currently suffering from moderate to severe erosion. Bank restoration of the river bank (dumping additional sand into the river) and the use of baffle boards may aid in the re-establishment of emergent species.

In many areas the emergent and fringing vegetation is degraded or no longer present. Emergent plants may initially require support, such as baffle boarding, to prevent soil loss while they become established. Bank restoration may also be an appropriate mechanism to slow the rate of erosion and allow for the establishment of emergent vegetation in moderately affected areas.

A preliminary survey of the river bank was conducted in May 1997 to rate the levels of erosion and the state of the riverbank vegetation (Map 4).

Vegetation ratings were based on categories defined for Blackwood catchment farming areas (Pen & Scott, 1995) and are summarised as follows:

A2	**Near pristine** - Healthy bush and emergent vegetation.
A3	**Slightly disturbed** - Healthy bush with some weeds and/or soil disturbance.
B1/2	**Weed infested** - Healthy overstorey. Understorey with weeds and soil disturbance.
B3	**Degraded** - Overstorey degraded. Understorey with weeds and soil disturbance.
C1/2	**Patchy soil exposure** - Overstorey degraded. Understorey with weeds and extensive patches of exposed soil.
C3	**Eroding** - Degraded overstorey, bare soil with no understorey.

The levels of soil loss and erosion were also observed and graded as follows:

S1	No erosion evident
S2	Low level erosion , minor soil loss.
S3	Mid level erosion, tree roots slightly exposed.
S4	Severe erosion, exposed tree roots, undercutting and subsidence

Some degraded sites which present serious threat of erosion have been identified.

- The clearing near the chicken farm at Barragup Bridge has no emergent vegetation and the bank is being undercut.
- The river access point from the Noorumba Road path is degraded, the bank is being undercut and trees on the bank are in danger of falling into the river.
- A section of the Barragup foreshore, upstream from Noorumba Rd path, has been degraded by spot fires resulting in patches of unstable bare sand.
- A lack of stabilising overstorey vegetation is a problem on many sections of the Greenfields foreshore.
- The Greenfields foreshore upstream from the backwater appears to have good vegetation cover but is suffering from erosion.

Management Principles

- Give preference to erosion prevention measures which protect and reinforce emergent and fringing vegetation with locally appropriate native species.
- Direct public access to stable embankment areas and discourage access to erosion prone areas.
- Pathways are to be at a sufficient distance from the river bank to allow for the maintenance of a viable and stabilising plant community.
- Encourage school group and community involvement in bank revegetation and tree planting adjacent to the river.

3.1.5 Water quality

Nutrient enrichment of estuaries in the south-west of Western Australia is an increasing problem. Phytoplankton blooms are commonly associated with the strong stratification of the water column which develops as the river flow decreases and the tidal salt wedge moves upstream. The leading edge of the salt wedge is often oxygen deficient resulting in anaerobic conditions on the river bottom. This causes the release of nutrients from the sediments to the water column which in turn fuels phytoplankton blooms (Woodcock, 1993).

Certain phytoplankton blooms have been associated with a range of health impacts in humans from skin irritations to nervous system dysfunction. The public is at greatest risk when individuals come into direct contact with or consume the algae either directly or indirectly via ingestion of fish, crustaceans and molluscs (Hosja & Deeley, 1994). Swimming or consuming fish or shellfish from infected areas is not recommended. In November 1996 a potentially toxic phytoplankton bloom was detected in the study area. The response strategy was a press release and the erection of warning signs.

The sandy soils of the Serpentine River catchment are typically less able to retain phosphorous than other soil types (see Section 2.1.1). As a result, surface stormwater and runoff transport phosphorous more readily to the river system. The bulk of these nutrients are then either absorbed by algae, or become part of the sediment stores of nutrients, which can be released and become available for algae growth.

Nutrients enter the estuary system from the entire catchment. Poor water quality is often the result of the combined effects of a variety of activities across the catchment. Nutrients entering the system may come from the following sources:

- stormwater drainage;
- fertilisers from parks and gardens;
- septic tanks;
- agricultural runoff containing fertilisers and animal waste;
- phosphate detergents; and
- release from sediment banks in estuary.

The Statement of Planning Policy No.2 (WAGG, 1992) is aimed at addressing nutrient input to the Peel-Harvey estuarine system by incorporating the policies into town planning schemes which operate within the Peel-Harvey Coastal Plain Catchment. The statement covers various issues such as sewerage, recreation areas, industrial development and agriculture, a moratorium on clearing and drainage along with the regulation of new potentially nutrient discharging industries.

The study area is unsewered. Septic tanks are not suitable in areas where the groundwater is close to the surface, the major problem being that septic tanks do not remove nutrients from effluent. These nutrients reach the groundwater and flow into the waterway.

Where septic tanks are present there are several maintenance guidelines which should be followed (WAWA, 1994). These include:

- Solids should be removed by a licensed septic cartage contractor at regular intervals (every 3 to 4 years) to prevent them reaching the leach drain.
- If twin leach drains (or soakwell systems) exist, each should be rested at approximately 6 month intervals.
- If soil in contact with leach drain becomes excessively clogged (generally about the first 150 mm of sand) preventing below ground soakage, then this layer may require replacement with clean sand.
- Septic tanks work best in sandy soils. In clay soils they should be surrounded by several metres of sand.
- Runoff from rainfall should be diverted from the tanks.

There are safe and reliable alternative wastewater treatment processes including aerobic treatment units (ATUs), red mud soil amendment, sealed tank systems and air-vac (dry toilet) systems.

ATUs are small domestic plants. The basic process comprises a settling chamber similar to a septic tank, followed by aeration and clarification through settling. Additional processes such as partial nitrogen removal, disinfection and chemical addition for phosphorus removal may be included.

The red mud soil amendment technique increases the phosphorus retention index of the soil surrounding the septic tank. The system does not bind nitrogen. Estimates are that it will bind phosphorus leaching from the system for 50-100 years.

The importance of foreshore vegetation can not be underestimated. Adequate, well vegetated foreshore reserves filter nutrients before they enter rivers which feed into the estuarine system. Vegetation buffers which draw on the water table also reduce the nitrogen and phosphorus leaching from septic tank systems and animal waste.

Management Principles

- Protect and reinforce native foreshore vegetation.
- Minimise the use of fertilisers in reserves and encourage landholders and residents to reduce usage.
- Encourage the installation of reticulated sewerage or alternative wastewater treatment units in new developments and subdivisions.
- Drainage systems should be designed to incorporate:
  - slowing drainage water to enhance settling and other nutrient loss mechanisms;
  - use of efficient filtration, compensation or nutrient stripping basins located on land outside foreshore reserves;
  - no direct stormwater discharge into the river or foreshore reserves.

3.1.6 Mosquito control

Mosquito control is a major issue within the region, the primary focus of Councils being the prevention of mosquito borne disease. There needs to be a balance between public health concerns regarding the spread of Ross River Virus and the maintenance wetland ecosystems. Mosquitoes make up an important part of the diet of migratory and local waterbirds. Most chemical control of mosquitoes takes place in summer when young birds which feed on mosquito larvae are still present and vulnerable at this time (WWC, 1990).

Health driven mosquito control throughout the Peel Region is carried out by the Health Department of WA and Peel Region local councils (Mandurah, Murray, Waroona and Rockingham) working together as the Peel CLAG (Contiguous Local Authority Group). The main mosquito vectors of Ross River virus in the Peel Region are the saltmarsh mosquitos *Aedes camptorhynchus* and *Aedes vigilax*. Breeding cycles of these mosquitos have changed from seasonal (spring and autumn) to year round due to the impact of the Dawesville Channel on high tides in the estuary (Wright, pers. comm. 1997). The main mosquito control strategy used is aerial application of granular mosquito larvicides on the tidal saltmarsh breeding areas. The frequency of aerial applications has necessarily increased from 2-4 treatments per year before the opening of the Channel to 12-18 treatments per year since it was opened (Wright, pers. comm. 1997). To be most effective, chemicals must be managed to ensure that use is at appropriate stages of the mosquito life cycle and that mosquitoes do not develop resistance.

The current uncontrolled use of the saltmarsh areas has resulted in the formation of tracks, footprints and

wheel ruts which impound water and create mosquito breeding areas. The problem is exacerbated when users attempt to avoid these waterlogged areas and begin the formation of new tracks elsewhere. Controlling access to the saltmarshes and providing raised boardwalks will assist in reducing mosquito breeding areas.

Physical modification may provide an alternative to the recurrent use of chemicals. The possible use of 'runnelling', which modifies drainage patterns so that the mosquito life cycle is not completed, is being investigated (SRT, 1994). It is important to note that 'runnelling' is only possible in certain areas. This is because it is important not to make any physical changes which may degrade important habitat areas and significantly affect the ecosystem. In relation to the Amarillo residential development, the Health Department, on behalf of the Mosquito Control Advisory Committee, has recommended runnelling of the saltmarshes from Lake Goegrup northward (EPA, 1997). Any proposal to undertake runnelling within the study area would be assessed by the EPA.

Management Principles

- Mosquito control programs must maintain the integrity of wetland ecosystems.
- Mosquito control should utilise the latest information available and be in accordance with the Integrated Mosquito Control Strategy for the Peel-Harvey Region and the Mosquito Control Advisory Committee.
- Protect saltmarsh areas from disturbances which increase mosquito breeding areas.

3.1.7 Feral and domestic animals

Introduced species of animals such as foxes, rabbits, cats and dogs, degrade the natural environment through predation, competition for food resources and habitat destruction. Their presence in the isolated habitats characterising this area has led to a drastic reduction of native populations, and may lead to local extinctions.

Feral animals present in the study area include foxes, rabbits, cats, rats and house mice. They are commonly displacing, competing with, or killing native fauna such as the Southern Brown Bandicoot, reptiles and amphibians (Bailey, 1996).

Rabbits are herbivorous and upset the natural ecological balance by destroying native vegetation and competing with native species for food. Juvenile shoots are particularly vulnerable to rabbits as they are tender, and when these leaves are from less common annual plants such as orchids, damage to the populations can be catastrophic.

At low densities rabbits are unlikely to do much damage to the existing vegetation however they are likely to slow rehabilitation efforts by browsing on new shoots and inhibiting plant regrowth and contributing to the spread of weeds.

Foxes occur throughout the Peel-Harvey region and contribute to the reduction of native fauna, including frogs, lizards and mammals.

The existence of foxes and feral cats is acknowledged, however several difficulties arise when attempting to eliminate feral animals from remnant vegetation adjacent to rural and urban areas such as those in the study area.

Baiting with poisons such as 1080 (sodium monofluoroacetate) and Phostoxin in areas of recreational use can result in the poisoning of domestic pets (Bailey, 1996). To be successful baiting needs to be carried out over a wide area so as to prevent feral animals from neighbouring communities moving into the vacated territory (Kinnear, 1991). The same problem is encountered with the trapping and removal of animals as they are quickly replaced by animals from neighbouring communities.

As part of an overall feral animal control program the Kings Park Board operated a cat control program based on trapping cats and transporting them to the Cat Haven where they were either claimed or killed. The Kings Park program was extremely successful in controlling domestic cats, to the point that cats were no longer being captured in the Park. The program has been placed on hold and will be reintroduced as the need arises (Henshaw, 1997). Given the seriousness of cats as a threat to wildlife it may be feasible to implement a similar program within the study area.

It is up to local government authorities to determine areas for dog access. Unrestrained dogs can disturb native fauna particularly frogs, lizards, birds and mammals. Areas with little remnant vegetation are appropriate regions for exercising while dogs should be kept out of conservation areas.

Dog faeces can be a nuisance and a health hazard. The strategic placement of 'dog latrines' with collection bags can effectively reduce the problem.

Management Principles

- Support the trial placement of 'dog latrines' at strategic locations.
- Restrict dog access in high conservation areas and support LGA by-laws controlling dogs.
- Keep registered dog owners informed of any new initiatives in the local area and encourage requisite behaviour.

- Support the monitoring of feral animal populations and assess control requirements and methods as appropriate.
- Support the trial of a cat control program.

3.1.8 Fencing

In order to protect the remaining stands of vegetation it may be appropriate to establish fences. Fencing must facilitate movement of endemic fauna throughout the reserve. The most appropriate form of the fence would be open mesh, as it is important to allow for the free movement of bandicoots and ground dwelling birds.

Vandalism and theft of fences and gates is a common problem. Hanging post and chain gates have been successfully used in the region to prevent vehicle and trailbike access while still allowing for pedestrians.

Aesthetic appeal of fencing materials is also a consideration. Fencing must be harmonious with the natural environment and enhance the sense of place as a natural setting. The impact of fencing on the visual amenity and viewsheds of residents should be minimised where possible.

The post and wire fencing used along Redcliffe Rd allows for the movement of fauna and has been successful in restricting access without detrimental impact to the visual amenity.

Management Principles

- Use fencing materials that will not detrimentally impact on the movement of fauna or on visual amenity.

3.1.9 Fire management

Fire can enhance or reduce the ecological integrity of foreshores. It initiates a multiplicity of complex effects which vary widely with species attributes, fire frequency, intensity and timing. Alteration of the fire regime leads to modification of native vegetation and losses of native species depending on life history attributes (Hopkins & Griffin, 1989).

The distribution and regeneration of some native species are enhanced by occasional fires. However, most common weeds proliferate rapidly after fires. While some native species have a similar response to fire, many have evolved alternative strategies over thousands of years.

There are two basic strategies to cope with fire: seeding and resprouting. Seeders must reach maturity before the next fire in order to survive. The time it takes for individual plants to reach maturity differs, as does the length of time seed will remain viable in the soil. After fire resprouters shoot again from buds protected under the bark or on their rootstock. To do this they use up food reserves stored in roots and stems. If fires are too frequent they do not have enough time to build up these food reserves, so each resprouting becomes weaker and the plant may die (Hussey & Wallace, 1993).

Fire management for vegetation conservation involves ensuring that fires do not occur more frequently than the time needed for all plants to reach adequate reproductive capacity. Too frequent fires have a number of impacts on vegetation including:

- accelerated rate of grass weed invasion from foreshore margins;
- increase in fuel loads (from weed grasses) which can lead to a self-perpetuating increase in fire frequency;
- threat to regeneration and stunting of the growth of trees;
- decrease in the diversity of species (ANPWS, 1991).

Many people perceive the presence of native vegetation as a fire risk, however where exotic grasses such as veldt and African love grass occur, the fire risk is much greater. These weeds germinate, grow and die in one year, rapidly becoming a continuous fuel bed for fire. The presence of weeds alters the fuel load and distribution, creating favourable conditions for more fires (Wycherley, 1984).

The pattern present within the study area is that the introduced species proliferate around disturbed edges of natural systems, and grasses in particular lead to increased fire frequency and an accelerated rate of invasion from the margins (Baird, 1977). Weeding and rehabilitation efforts will reduce the fire risk.

Both City of Mandurah and Shire of Murray reserve the power to burn off where required. Due to the frequency of illegally lit fires, the LGAs rarely exercise controlled burning practices.

It is important to maintain access to foreshore reserves and remnant bushland areas for the purpose of fire management. Fire breaks and access ways should be carefully located so as to cause minimal disturbance while providing the level of access determined necessary by regular assessment of fire risk and management options. Assessment of the fire risks and management options should be a joint project including LGAs, CALM, and the Bush Fires Board.

On the Greenfields foreshore the majority of homes are separated from foreshore reserves by Redcliffe Rd. The greatest hazard to landowners from fire in reserve areas is on the Barragup foreshore where property is directly adjacent to the reserve. The Fire and Rescue Service and the Bush Fires Board of WA produce a checklist aimed at protecting homes and property from bush fire.

At the time of writing most landholders had taken relevant precautions (in accordance with LGA requirements) and fire brigade access to foreshore areas could be gained through private properties. Due to the limited width of the foreshore reserves and the ease of accessibility it is not considered necessary at this time to place a fire break along the landward edge of the foreshore reserve. Should there be future evidence to warrant such a fire break it should be constructed to cause minimal ecological disturbance and be designed in such a way so as to double as a bridle path.

Children are frequently responsible for starting bush fires. Involvement of school children in management of remnant vegetation, through the WRC Ribbons of Blue program and possibly as honorary wardens, would increase their appreciation of these areas. Many Bush Fire Brigade Stations also run Cadet Training Schemes for children aged 11 to 16, encouraging such programs may also be beneficial.

Management Principles

- Reduce weed fuel loads through weeding and rehabilitation of native vegetation.
- Encourage schools to become involved in foreshore management and cadet training schemes.
- Landholders must comply with LGA bush fire break requirements and local residents should be encouraged to take bush fire precaution measures.
- Ensure emergency vehicle access and strategically located fire breaks (ie tracks, drains, lawn, boat ramps etc) are maintained.
- Regularly inspect bushland to assess fire risk and management options.

3.2 Recreation

3.2.1 Public access

It is important to cater for public contact (both physical and visual) with the riverscape without detracting from or endangering its viability as a natural system. With careful management and the cooperation of users the continued provision of facilities such as controlled pedestrian access and bridle trails is considered appropriate at this time.

A high level of indiscriminate and uncontrolled public access now exists within the study area and is leading to a deterioration in the natural environment through trampling of vegetation, weed invasion and damage to banks. Encouraging the use of formalised recreation areas and paths will aid in the rehabilitation of degraded areas and prevent damage to areas of high conservation value.

There is increasing pressure for public access to, and facilities on, the foreshore of the Serpentine River. The local population is increasing with continuing residential developments in the Greenfields locality and there is potential for development including subdivisions in Barragup.

Access for the disabled is restricted on the Barragup foreshore, however there are several pathways in the Greenfields locality which provide for disabled access to the river environment.

Where private land is directly adjacent to the foreshore reserve it is common for residents to adopt de facto ownership of reserve land. This can give the appearance that the foreshore is privately owned and reserve boundaries are often ill defined. Demarcation of the reserve boundary is most effectively achieved through the appropriate positioning of fencing, a minor road or dual use pathway abutting the reserve. Other methods of demarcation may include painted stones, posts, garden beds etc. The Peel Inlet Management Programme (1992) recommended that appropriate foreshore reserves be ceded to the Crown as a condition of future subdivision (area recommendation A181) and therefore should include sufficient room for such a demarcation.

Management Principles

- Provide information on sites of interest, tracks and paths and the location and type of facilities available.
- Direct public access mainly to formalised recreational areas and ensure public access to ecologically sensitive areas is controlled.
- Ensure appropriate foreshore reserves are ceded as a condition of any rezoning or subdivision.
- The lines of demarcation between reserves and freehold land should be clearly defined (eg paths, garden beds, posts etc).

3.2.2 Vehicle access

The unconstrained use of river foreshores by vehicles and trailbikes presents a number of problems, both for the public use of foreshores, and for the management of the riverine environment. These problems include the introduction of weeds, damage to foreshore vegetation, damage to soil through compaction which may initiate wind and water erosion. Vehicle noise can cause disturbance to residents and recreational users. There is also the danger of accident and injury when horses, pedestrians and vehicles are using the same pathways.

The ramifications of damage to vegetation are immediately apparent. In the past the samphire marsh, a valuable nutrient filter and habitat for micro-invertebrates which are a food source for migratory waterbirds, has been reduced to a mosaic of poor quality islands. Nevertheless, with sound management of pedestrian and vehicular access, the samphire rapidly regenerates, restoring health to the river margins.

On the Barragup foreshore there is an informal vehicle track leading from the car park south of Barragup Bridge to the river bank adjacent the chicken farm. This area is extensively used and is now severely degraded. Due to the high level of usage and the degraded state of this area there is potential to develop it into a formalised recreation area. The type of amenity and level of access that can be provided will need to be assessed.

In recent times trailbikes and 4WD vehicles have used the bridle trail to access the Barragup foreshore. This has resulted in widening of the trail and damage to the soil and vegetation.

In view of the preceding, it is considered to be essential that future vehicle access to foreshore reserves is restricted. It is especially difficult to prevent trailbike access to areas while still allowing for pedestrian and equestrian access. Some form of low bollarding which can be stepped over by walkers and horses may be a suitable deterrent to trailbikes.

Preventing trailbikes from gaining access to foreshore reserves via adjoining private property will require the assistance of landowners. Encouraging residents to prevent access via their property will aid authorities in policing 'no vehicle' policies.

There is an obvious demand for a trailbike facility and both Councils should investigate the feasibility of establishing such a facility in their municipalities. The Inner Peel Region Structure Plan (1996) identifies a nearby site which may have potential for such a facility. Located in the Shire of Murray and favoured for regional recreation, the 60 hectare site is just east of the Pinjarra Road/Perth-Bunbury Highway intersection.

Management Principles

- Restrict the use of fire breaks, bridle paths and walk trails to emergency and maintenance vehicles only.
- Support the establishment of a designated trailbike area in the region.

3.2.3 Bridle trails

Horse riding is a very popular pastime around the Serpentine River and there are a series of recognised bridle trails around the Peel-Harvey system.

Horses have the potential to degrade reserves and waterways in a number of ways including:

- spreading weeds and disease (including dieback);
- trampling on native vegetation;
- compacting soils with high clay content; and
- browsing on native vegetation.

Equestrian use of the Greenfields foreshore is not considered appropriate due to the extensive recreational usage of this area. There is a designated bridle trail in Barragup (for ease of reference this will be called the Barragup bridle trail).

The Murray Mandurah Horse Owners Association encourages horse riders to be responsible and minimise disturbance to residents adjacent to the trail, stock and native fauna. They have produced a brochure in support of this.

At present the Barragup bridle trail also provides for pedestrian access. With increased demand for use of the trail the health and safety issues of combining horses and pedestrians must be considered along with habitat protection. In the future it may be necessary to provide for separate pedestrian and equestrian access.

The potential for horses to spread weeds and disease is greater with paths passing through the centre of the reserve. The sandy ground away along the landward edge of the reserve has better drainage and is less easily compacted and is therefore more suitable as a bridle trail than the slippery, clay soils closer to the river. A separate bridal path located on the landward edge of the reserve could also act as a demarcation line. Pedestrian access could remain closer to the river.

Management Principles

- Bridle paths are to be located so as to minimise impact on ecologically sensitive areas and avoid conflict with other recreational use.

3.2.4 Nature trails

The northern area of the Greenfields foreshore and the undeveloped Serpentine Cove area presently have unrestricted access. There are many walking trails in the area between Pinjarra Rd and Serpentine Cove, and there is little or no understorey in many areas. These trails need to be rationalised and rehabilitated because the shoreline is receding in this area. Reducing the degradation of the river bank is best achieved by restricting public access.

In the northern Greenfields locality, weed infestation is spreading from Koolyanga Rd toward Goegrup Lake. There are several tracks leading into the lake and through the high conservation value saltmarsh. These tracks add to vegetation damage and create mosquito breeding areas. As discussed in Section 4.1.1, the high conservation value of this area justifies fencing to

restrict access and the provision of formalised paths and raised walkways.

The foreshore area adjacent to Redcliffe Rd, between Serpentine Cove and Riverside Gardens Reserve, has been fenced and access has been formalised through the provision of crushed limestone paths and raised boardwalks. There is a dual use pathway between the road and the fence. Preventing unrestricted access has had an extremely positive effect on the area. Ongoing rehabilitation efforts will be required to further improve the value of the area (refer Section 4.1.3). There are still a few informal tracks being used in the saltmarsh areas, especially by pushbikes, and these would benefit from blocking with the planting of prickly barrier species.

The nature trail on the Barragup foreshore is currently a combined walk/bridle trail. Although the main trail is well used and quite well defined there are several informal tracks which branch away from the main path.

The walk/bridle trail passes close to a Nankeen Night Heron rookery in the stands of *Casuarina obesa* located on the Barragup foreshore opposite the Wanda Rd boat ramp, however the birds do not appear to be disturbed by the current levels of equestrian and pedestrian traffic.

Nature trails should be designed to maximise significant views, protect vegetation and faunal habitat and to link existing recreational facilities. Community involvement in management and educating users about the conservation value of the area will encourage sympathetic use of the reserve areas. The use of signs can be intrusive and detract from the visual amenity, however strategically located and discrete signage can be appropriate to provide conservation information along pathways and by limiting access to specific points regulatory signage can be reduced.

Management Principles

- Nature trails are to be designed and located to minimise impact on environmentally sensitive areas, link recreational areas, and take advantage of the visual amenity.
- Nature trail signposting of information such as location, length and time to walk, to be placed at major access points.
- Restrict signage along pathways to flora and fauna information plaques at appropriate locations.

3.2.5 Recreational fishing and crabbing

Fishing and crabbing from the shoreline is a popular recreational activity, with summer months the most intensive period. Many species are caught by recreational fishers including black bream, crabs, king and river prawns, mullet etc. Crabbing has become increasingly important in this area following the opening of the Dawesville Channel, due to the increase in crab numbers and the perception by the public that water quality has markedly improved following the opening of the Channel. Scoop-netting or using dropnets from the river banks are popular practices.

There are a number of management issues associated with these activities. The major issues are the potential to increase the rate of erosion of the foreshore by trampling of the remaining vegetation, creating a profusion of tracks and destabilising the river banks.

There is a need to provide direct access for these activities away from remnant vegetation to already degraded areas. These areas may need to be developed as distinct access nodes and could incorporate facilities such as rubbish bins, elevated platforms over the water, and signs advising of legal sizes and catch limits. Signs located at major access points should also clearly state why foreshores need to be protected, and illustrate the location of the nodes for access to the water.

Management Principles

- Provide access nodes for crabbers and fishers at appropriate locations.
- Encourage local involvement in the Fisheries Department Volunteer Inspector Scheme.

3.2.6 Boating: speed and noise

There is concern from local residents that power boats are contributing significantly to erosion as they move along the river. Noise and disturbance to native fauna is also a concern. The speed limit upstream of Barragup Bridge is eight knots. The Department of Transport has received complaints about power boats travelling at excessive speed.

It is important to ensure that Department of Transport speed signs are clearly visible and located near boat launching facilities.

Management Principles

- Ensure speed signs on river are clearly visible and located near boat launching facilities.
- Encourage Department of Transport policing of the area.

3.2.7 Jetties and boat ramps

Jetties and boat ramps are required to be licensed under the *Jetties Act 1926-1976* as either private or public structures. Prior to the gazettal of the *Waterways Conservation Act 1976-82* owners of property abutting

this waterway were allowed to construct jetties adjacent to Crown Reserves. When the Peel Inlet Management Authority's Management Area was defined, the Department of Transport (previously the Department of Marine and Harbours) refused applications for private jetties in accordance with agreed PIMA/DOT policy which states, with regard to jetties abutting foreshore reserves, 'no new structures be allowed'.

There are several private jetties and public jetties in the study area. Any existing jetties which are not licensed are illegal and, if a licence is not granted, should be removed.

Many of the jetties are inadequately maintained and dangerous. It is necessary to ensure that each jetty licensee maintains the jetty to a suitably high standard in accordance with the conditions of the licence.

Anecdotal evidence suggests that many people launch their boats illegally across the foreshore even though a public boat ramp is present near Wanda Road in the City of Mandurah. This formal boat launching facility provides for power boats, and hand launching of kayaks and other vessels.

Management Principles

- Adhere to PIMA policy that no new private jetties be constructed in areas abutting foreshore reserves.
- Demand levels for boat launch facilities should be monitored and measures to relieve pressure should be investigated and assessed as necessary.
- Licensed jetties must conform to required standards and illegal jetties should be removed.

3.2.8 Boats left on foreshore

There is evidence that a number of boats are left on the foreshore periodically, being launched and retrieved at random. Storage, launching and retrieval of boats across foreshores results in foreshore degradation and erosion. Boats are left on the foreshore, as it provides free 'storage' and easy access. These boats restrict access and cause damage to fringing vegetation.

Under WWC legislation, it is illegal to leave boats on foreshore without permission from the foreshore manager. There are many jetties in the area and the public boat ramp off Wanda Road provides for the launch and retrieval of boats.

Management Principles

- Boats are not permitted to be stored on public land or foreshore reserves and the relevant land manager should ensure that boats are removed by the owner.

3.2.9 Moorings

There are no mooring areas recognised by DOT for public use within the study area. Peel Inlet Management Authority policy is that no areas for mooring will be permitted along estuarine tributaries.

There are a number of mooring buoys located immediately upstream of the boat launching facility and boats are frequently moored in these areas.

PIMA and DOT are jointly developing a policy for moorings.

Management Principles

- Moorings within the study area are not permitted and should be removed by the owner.

3.3 Amenities

As the population of Peel-Harvey region increases so does the use of the waterways and their foreshores, and the need to provide public amenities.

Development of facilities on the foreshore requires careful planning to ensure that the facilities are appropriate, correctly located, necessary and compatible with their surrounds. New facilities should not detract from the landscape value of the foreshore.

Provision of facilities may be funded privately or by government. In the public sector, much of the responsibility is held by local government authorities. Additional funding may be provided by State government.

3.3.1 Lawn areas

The POS for recreation, including Riverside Gardens Reserve, is maintained by the City of Mandurah. Traditionally management practices for such areas have typically involved the use of fertilisers with little consideration for the ultimate fate of such nutrients (del Marco, 1990). However, the COM does not fertilise grass so close to the estuary or its tributaries (Carman-Brown, pers. comm. 1997).

Riverside Gardens Reserve is well used, however there may be an opportunity to enhance this recreational space by reducing the total area of grass by planting areas of shrubs around carpark boundaries, and to create more private nodes for groups of picnickers. This would have a number of benefits, including:

- reduced maintenance costs (e.g mowing, water etc);
- improved definition of access points;
- improved aesthetic value; and
- reduction of potential for weed invasion.

Whilst this area of open lawn has several shade trees, additional trees in all recreational POS areas could enhance recreational usage. Preferred shade tree species are local varieties such as flooded gum, tuart and marri, which are suited to the harsh climate of this area and have significantly lower maintenance costs.

Management Principles

- Lawns are to be maintained only in recreational POS (areas of high recreational pressure) and the use of fertilisers is to be minimal.
- Enhance recreational POS areas with native garden beds and increase shade tree numbers.

3.3.2 Parking

Two semi-formal parking areas are provided in the Greenfields area in the northern section of Riverside Gardens Reserve. One is for vehicles with trailers, adjacent to the boat launch ramp, and the other is for picnickers etc.

In the summer vehicles are often driven through the bollard fence onto the lawned area of Riverside Gardens Reserve. Placing native garden beds (as discussed in Section 4.3.1) along the boundary to the parking area would act as a barrier to vehicles and enhance the amenity of the reserve.

Management Principles

- Car parking areas are to be located to provide ready access to formalised recreation areas.
- Parking areas should be clearly defined with barriers that minimise visual impacts while preventing vehicle access to recreation areas.

3.3.3 Ablution blocks

There are no toilet facilities within the study area. The provision of a boat launching facility, children's playground, picnic tables and associated high level of usage of Riverside Gardens Reserve suggests such toilet facilities would be appropriate.

Management Principles

- Ablution facilities should preferably be located in recreational POS, not in foreshore reserves, and be managed by the LGA.
- The design and location of ablution facilities should minimise nutrient input to the ecosystem and minimise disruption to visual amenity.

3.3.4 Playgrounds

The children's playground in Eacott Park is very well developed, catering for a number of different age groups.

One problem is that it is located on the western side of Wanda Road which increases the risk of accidents involving children crossing the road from the car parks and Riverside Gardens Reserve.

It is considered appropriate that traffic calming devices are installed on both sides of a pedestrian crossing sign. This will enhance use of the area and improve safety.

Management Principles

- Playground facilities should preferably be located in recreational, not in foreshore reserves, and be managed by the LGA.
- Safe access to playgrounds is essential. Playgrounds should be assessed and traffic calming devices, crosswalks and warning signs installed where necessary.

3.3.5 Picnic facilities

There several sets of tables and chairs provided in Greenfields Riverside Gardens Reserve near the boat ramp. In the foreshore area south of Riverside Gardens Reserve there are tables located near the river at the end of the two access paths which run from Redcliffe Rd.

There may be an opportunity to capitalise on the Riverside Gardens recreation area by providing additional facilities. Appropriate facilities may include rubbish bins, additional tables and gas or electric barbecues.

The presence of an adjacent bus route could also encourage residents from other parts of Mandurah to visit this location. Provision for a variety of interests, including playgrounds, nature trails, boardwalks, boating and picnic facilities would recognise and enhance the regional significance of the area.

The provision of picnic facilities requires regular access for activities such as general maintenance and rubbish removal. In keeping with recommendations to limit vehicle access and maintain the conservation value of foreshore areas, it is preferable to restrict such facilities to the grassed recreation area of Riverside Gardens Reserve and the proposed access node on the Barragup foreshore.

Management Principles

- Restrict picnic facilities such as barbecues, rubbish bins and furniture to readily accessible, formalised POS recreational areas.

3.3.6 Camping

The foreshore within the study area is not suitable for camping. The damage that can be caused is evident on the Barragup foreshore where evidence of camping is found on the river bank near the chicken farm. Tree branches have been removed to provide wood for campfires, there is no longer any native understorey and the river bank is eroding.

There are many caravan and camp sites in the region which provide camping facilities.

Management Principles

- Camping is not to be permitted within foreshore reserves.

4. Implementation

Once the draft management plan has been made available for public comment and submissions have been taken into consideration, a final plan will be produced and made available to agency stakeholders and the community.

Successful implementation of management plans depends on the willingness of participants to become involved and contribute positively. Various methods of encouraging informed cooperation can be used involving all levels of government and the community.

This management plan has covered management issues and made recommendations on how they could be addressed. This process is part of the public education process which ensures awareness of management problems associated with the protection of the Serpentine system. It is essential to establish community support to address these problems.

This management plan outlines recommendations which are considered necessary for long term management of the Serpentine River study area. Overall responsibility for management of the foreshore rests with the Shire of Murray and the City of Mandurah, however other organisations and agencies have specific expertise or responsibilities which can aid the implementation process. In addition, there are many community groups and individuals who can provide valuable assistance. This is a two way process in that both the government agencies and community groups can seek to liaise with each other on how specific issues can be addressed and actions be taken. A list of contacts is included in this document (Appendix 4).

Overall responsibility to ensure implementation lies with PIMA and WRC who should liaise with other bodies to encourage their participation. This document has identified key players responsible for the implementation of the recommendations (a list of abbreviations is provided in the 'Guide for Readers' at the front of the document). All agencies and community groups involved in the preparation of this plan are committed to the success of the plan and will provide strong backing to the Water and Rivers Commission officers responsible for overseeing implementation.

The recommendations developed in the final management plan will be implemented over a number of years depending on sufficient funding and resources being available. The recommendations in Chapter 5 have been prioritised by the working group.

Monitoring should show which agreed management recommendations are being achieved and which are having difficulty. The plan should be re-evaluated and modified where necessary to allow for the updating of the management principles. The management plan is to be reviewed and revised after a five year period by the Water and Rivers Commission and the Peel Inlet Management Authority. This process includes further public consultation and a review of existing recommendations and implementation progress.

Commitments and potential sources for funding will be established following the publication of the final plan by the Water and Rivers Commission. Funding may come from local, State and Federal sources. In addition volunteer support is an essential resource.

5. Management recommendations

The management recommendations below suggest actions which are aimed at upholding the principles of this plan.

General recommendations relate to issues which cover the entire study area. Site specific recommendations suggest actions related to smaller sub-sections of the study area. The respective locations of the site specific recommendations are shown on the Technical Plan, Map 5.

The agencies responsible for implementation are shown in italics. Recommendations which require an action to be performed only once are referred to as 'one off' recommendations, those whose implementation requires further or repeat action are referred to as 'ongoing'. The perceived priority level is denoted as high (✪✪✪), medium (✪✪) or low (✪).

5.1 General recommendations

1. Support GLASS rehabilitation initiatives, assist and advise on:
   - flora and fauna identification,
   - rehabilitation and planting techniques,
   - weed identification, removal and disposal techniques,
   - signposting areas subject to rehabilitation to develop interest in the sites.

   PIMA/WRC, AGWA, CALM *ongoing* ✪✪

2. Provide educational information for residents on:
   - location and general information on nature/bridle trails,
   - the conservation value of riparian vegetation,
   - preventing invasion from garden weeds and exotic plants,
   - encouraging the removal of problem plants from gardens,
   - native alternatives for use in gardens, and
   - minimising fertiliser usage.

   PIMA/WRC *ongoing* ✪✪

3. Undertake regular reconnaissance to identify and treat weeds in areas of native vegetation. A guide for some major weeds identified in the study area is given below.

   LGAs *ongoing* ✪✪✪

April/May	Pampas grass	Remove and destroy flower heads, brush-cut plant to approx 1m, treat with herbicide.
May/August	Rose pelargonium	Hand pull, remove and destroy all plant material.
June/July	Grasses	Spot and blanket spraying is most effective when plants are actively growing. Herbicide selection should be made according to requirements.
Jan/March	Japanese pepper	Fell trees and apply stump-cut herbicide, remove and destroy all cuttings.

4. Conduct workshops for local community groups on weed removal and disposal techniques.

   PIMA/WRC, AGWA, CALM *ongoing* ✪

5. Survey to identify native fauna in the area. Identify habitat extents and corridors. Report on the potential for improving habitat quality through rehabilitation.
   PIMA/WRC, CALM — *one off* — ✪✪

6. Survey native vegetation for dieback and where necessary undertake mitigation measures.
   PIMA/WRC, LGAs — *one off* — *work in progress*

7. Monitor the environmental impacts of equestrian use, and its continued compatibility with pedestrian use, of the current bridle trail. Consider results of the dieback survey and modify or relocate equestrian paths if use is found to be unacceptable.
   Shire of Murray, PIMA/WRC — *ongoing* — ✪✪

8. Undertake regular surveys of embankment profiles and river bank vegetation to monitor erosion processes and identify areas requiring attention. Implement mitigation techniques according to management principles.
   PIMA/WRC — *ongoing* — ✪✪

9. Advise and encourage local residents to establish low water and nutrient requirement gardens.
   PIMA/WRC, LGAs — *ongoing* — ✪✪

10. Develop turf maintenance programs for foreshore reserves which minimise fertiliser usage and restrict mowing to well defined sections in areas of high recreational pressure.
    PIMA/WRC, LGAs — *ongoing* — ✪✪✪

11. Establish a comprehensive inventory of mosquito breeding sites to aid in the development of a mosquito control strategy taking into account management principles identified.
    Health Dept, MCAC, PIMA/WRC, LGAs — *one off* — ✪✪✪

12. Investigate potential sites for, and the feasibility of establishing, a designated trailbike riding area in the region.
    LGAs, MFP. — *one off* — ✪✪

13. Implement a trial placement of 'dog latrines' at strategic locations. Signpost conservation area access points to advise that dogs to be kept on a leash.
    LGAs — *one off* — ✪

14. Undertake annual inspections of bushland areas, fire breaks, access and adjoining properties to assess fire risks and management options taking into account the management principles identified.
    LGAs, Landowners, Bush Fires Board — *ongoing* — ✪✪

15. Support the Fisheries Department Volunteer Inspector Scheme and provide information and contact details.
    Fisheries Dept, PIMA/WRC — *ongoing* — ✪

16. Encourage Department of Transport policing of river traffic. Advise DOT on any perceived replacement/new sign requirements. Remove unlicensed jetties and ensure licensed structures meet required standards.
    PIMA/WRC, DOT — *ongoing* — ✪

17. Continue regular river inspections which include identifying illegal activities such as boats on foreshore reserves, moorings, bait digging, unsound structures etc. Implement control measures or notify relevant agencies to take action.
    PIMA/WRC — *ongoing* — ✪✪

5.2 Greenfields foreshore : Site specific recommendations

5.2.1 Pinjarra Rd to Serpentine Cove

18. Ensure that the high conservation area adjacent to Serpentine Cove is protected by a development foreshore management plan. If development is not proceeding for some time foreshore measures may need to be initiated by City of Mandurah and WRC.
    Some aspects to be considered are:
    - ensure the protection of existing native vegetation and fauna habitats,
    - undertake rehabilitation schemes to improve, or maintain the integrity of, the existing foreshore habitat,
    - pathways to be designed and located to prevent damage to vegetation and river banks
    - fencing to prevent unrestricted access to foreshore
    - no vehicle access to foreshore except emergency or maintenance vehicles.

    MFP, City of Mandurah, WRC, CALM, PIMA *ongoing* ✪✪✪

19. Monitor the ongoing activities of the Western Rosella Bird Park and aquire a wider foreshore reserve from this area as a condition of any further subdivision.
    PIMA/WRC, MFP, City of Mandurah *ongoing* ✪✪

5.2.2 Serpentine Cove to Riverside Gardens Reserve

20. Cease mowing of open areas at base of access paths, initiate a weeding program and replant with native vegetation to exclude weeds and re-establish fringing vegetation.
    City of Mandurah, PIMA/WRC *one off* ✪✪✪

21. Survey for weed invasion, particularly along paths, and initiate a weeding program (see Vegetation Assessment for suggested methods).
    City of Mandurah, PIMA/WRC *ongoing* ✪✪

22. Undertake rehabilitation of informal pathways or block with barrier plantings.
    City of Mandurah, PIMA/WRC *one off* ✪✪✪

23. Define a single informal pathway leading from the dual use pathway(DUP) near Tuart Rd to an access node on the river bank downstream from the backwater. This section of path may later require modification to link with Serpentine Cove development foreshore plan which should include a DUP from Redcliffe Rd to the Bird Park which links existing DUPs.
    City of Mandurah, PIMA/WRC *one off* ✪✪✪

24. Undertake rehabilitation of stabilising and emergent vegetation.
    City of Mandurah, PIMA/WRC, MFP *ongoing* ✪✪

5.2.3 Riverside Gardens Reserve

25. Erect an information board showing path maps, information on flora and fauna, Nyungah and local history.
    City of Mandurah, PIMA/WRC *one off* ✪✪

26. Construct a dual use pathway along the landward edge of the reserve to link the existing Redcliffe Rd dual use pathway with the proposed dual use pathway along Koolyanga Rd.
    City of Mandurah. *one off* ✪✪

27. Clearly define existing parking areas with bollards (or other suitable materials) and native garden beds around outer borders to prevent vehicle incursions into the grassed recreation area.
City of Mandurah. *one off* ✪✪✪

28. Create areas of shrubs between picnic tables and reinforce the number of shade trees by planting seedlings in appropriate locations.
City of Mandurah *one off* ✪✪✪

29. Clearly define the limits of the grassed area to be mowed and implement a turf management program (as per recommendation 10). An informal pathway along the river bank should separate emergent vegetation and prevent lawn grasses from extending to the water's edge.
City of Mandurah *one off* ✪✪✪

30. Investigate the most suitable design options and location for an ablution block in the vicinity of Wanda Rd parking area and boat ramp, possibly Eacott Park.
City of Mandurah *one off* ✪✪

31. Install a crosswalk and traffic calming devices on Wanda Rd connecting Eacott Park and Riverside Gardens Reserve.
City of Mandurah *one off* ✪

5.2.4 Riverside Gardens Reserve to Bulara Road

32. Restrict access to the high conservation area adjacent to Goegrup Lake by erecting fencing from just north of the Wanda Rd boat ramp, along Koolyanga Rd to Bulara Rd.
City of Mandurah, CALM, PIMA/WRC *one off* ✪✪✪

33. Construct DUP between the road and the above fence from Bulara Rd and the existing DUP at Teranca/Bedingfeld Rd to link with the proposed extension of the Redcliffe Rd dual use pathway.
City of Mandurah *one off* ✪✪

34. Provide visual access to saltmarsh via a raised boardwalk, intersections to be off-set. Suggested access points are at Bulara Rd, Bedingfeld Rd and opposite Koolyanga Reserve. *City of Mandurah, PIMA/WRC* *one off* ✪✪✪

35. Erect signs at access points stating the high conservation value and request that people stay on the walkway and keep dogs on a leash. Place flora and fauna information plaques at appropriate points along the walkway.
City of Mandurah, PIMA/WRC *one off* ✪✪

36. Undertake weed eradication and control strategies in the high conservation area near Goegrup Lake.
City of Mandurah, PIMA/WRC *ongoing* ✪✪✪

37. Initiate a rehabilitation scheme along the degraded outer edge of the high conservation area.
City of Mandurah, PIMA/WRC *ongoing* ✪✪✪

38. Survey stands of *Casuarina obesa* for natural regeneration and initiate planting schemes where necessary.
PIMA/WRC *one off* ✪✪

5.3 Barragup foreshore : Site specific recommendations

5.3.1 Barragup Bridge to chicken farm

39. Identify major weed grasses and extent of main infestation. Create a barrier / buffer around the area and initiate a weed control and rehabilitation program.
Shire of Murray, PIMA/WRC *one off* ✪✪✪

40. Initiate manual weed control with spot spraying in less infested areas to prevent greater infestation with grass weeds.
Shire of Murray, PIMA/WRC *ongoing* ✪✪✪

41. Consult with landscape architects in the design of a formalised access node at the severely degraded riverside site near the chicken farm, lot 100 and lot 101. Consultation should include an investigation into the suitability of providing vehicle access, information signs, parking and picnic facilities. The creation of any formalised recreation area must comply with the principles of this plan.
Shire of Murray, PIMA/WRC *one off* ✪✪

5.3.2 Chicken farm to Noorumba Rd

42. Remove rose pelargonium, Victorian tea trees and pine trees from reserve area in front of houses (see Vegetation Assessment for suggested methods).
Shire of Murray, AGWA *ongoing* ✪✪✪

43. Rehabilitate and/or place barriers around grassed clearings in front of houses to prevent the gradual expansion of these areas.
PIMA/WRC, Shire of Murray *ongoing* ✪✪

44. Place low bollards, or other suitable barriers, across the path near lot 2, Pinjarra Rd, to prevent 4WD and trailbike access while still allowing for pedestrian and equestrian access.
Shire of Murray, CALM *one off* ✪✪

5.3.3 Noorumba Rd to Hougham Rd

45. Place low bollards, or other suitable barriers, across the Caponi Rd end of the Naroomba Rd path to prevent trailbike access while still allowing for pedestrian and equestrian access.
Shire of Murray, CALM. *one off* ✪✪

46. Investigate the best method of stabilising the river bank and provide a fishing access node near Noorumba Rd path.
PIMA/WRC, Shire of Murray *one off* ✪

47. Rehabilitate vegetation at the following locations:
    - fire degraded sites near lot 112 Caponi Rd,
    - side path toward house on lot 12 Caponi Rd,
    - right hand (less used) branch of Noorumba Rd path,
    - south branching pathways into small saltmarsh area near Noorumba Rd path.

PIMA/WRC, Shire of Murray *one off* ✪✪

5.3.4 Hougham Rd to Goegrup Lake

48. Block and revegetate informal pathways in reserve 44436 and leading toward and across the small saltmarsh nearby.
    PIMA/WRC, Shire of Murray *one off* ✪✪✪

49. Investigate the suitability of providing a stabilised fishing access node opposite the Wanda Rd boat ramp. The site should be located so as to minimise disturbance of existing Nankeen Night Heron rookery.
    PIMA/WRC, Shire of Murray, CALM *one off* ✪✪

50. Place low bollard, or other suitable barrier, across the bridle path, near the power poles where the fire break thins to a pathway to prevent trailbike and 4WD access while still allowing for pedestrian and equestrian access.
    Shire of Murray *one off* ✪✪

51. Erect an information board showing nature/bridle trail maps, vehicle restrictions, information on flora and fauna, Nyungah and local history at Caponi Rd access points.
    WRC, Shire of Murray *one off* ✪✪

52. Block and revegetate informal pathway from Hougham road reserve fire break to Goegrup Lake.
    PIMA/WRC, Shire of Murray *one off* ✪✪✪

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Map Legend

SALT- MARSH VEGETATION

- *Sarcocornia quinqueflora*
- *Juncus kraussii*

ESTUARINE FRINGING FOREST

- *Casuarina obesa* open-closed forest
- *Casuarina obesa - Melaleuca cuticularis* low open-closed forest
- *Casuarina obesa - Melaleuca rhaphiophylla* low open-closed forest
- *Casuarina obesa - Melaleuca rhaphiophylla Eucalyptus rudis* low open forest

FRESHWATER FRINGING FOREST

- *Eucalyptus* spp. - *Casuarina obesa* open forest
- *Eucalyptus calophylla* woodland
- *Melaleuca rhaphiophylla - Eucalyptus rudis* woodland
- *Melaleuca rhaphiophylla* open-closed swamp
- *Myrtaceae complex* low open shrubland

SANDY RISE VEGETATION

- *Eucalyptus calophylla - Banksia* spp. open woodland
- *Banksia.* spp. woodland

OTHER PLANT COMMUNITIES

- Parkland
- Weed matrix - grasses and weeds

WEEDS

- Saltpan

KOOLYANGA PL
KOOLYANGA RD
WANDA RD
HOUGHAM RD (RES)
TUART RD
REDCLIFFE RD
SERPENTINE COVE
NOORUMBA RD (RES)
CAPONI RD
Bird Park
PINJARRA ROAD
Serpentine River
chicken farm

N

MAP 3 : VEGETATION

Serpentine River

Goegrup Lake to Pinjarra Road

WATER AND RIVERS COMMISSION

0 40 80 120 160 200
METRES

MAP 4 : FORESHORE ASSESSMENT

Serpentine River

Goegrup Lake to Pinjarra Road

WATER AND RIVERS COMMISSION

0 40 80 120 160 200
METRES

N

HOUGHAM RD (RES)

CAPONI RD

NOORUMBA RD (RES)

KOOLYANGA PL

KOOLYANGA RD

WANDA RD

REDCLIFFE RD

TUART RD

TERANGA RD

SERPENTINE COVE

Bird Park

PINJARRA ROAD

chicken farm

Map Legend

R	Grassed recreation area
A2	Near pristine
A3	Slightly disturbed
B1/2	Weed Infested
B3	Degraded
C1/2	Patchy soil exposure
C3	Eroding
S1	No erosion
S2	Low level erosion
S3	Mid level erosion
S4	Severe erosion
	Jetty
	Building

MAP 5 : TECHNICAL PLAN

Serpentine River

Goegrup Lake to Pinjarra Road

WATER AND RIVERS COMMISSION

0 40 80 120 160 200

METRES

N

HOUGHAM RD (RES)

CAPONI RD

NOORUMBA RD (RES)

18 110 111 16 15 112 113 13 11

123

2

Koolyanga Reserve

KOOLYANGA RD

KOOLYANGA PL

BEDINGFELD RD

BULARA RD

Eacott Park

IVANDA RD

Riverside Gardens Reserve

REGCLIFFE RD

TUART RD

SERPENTINE COVE

TERRACA RD

Blind Park

PINJARRA ROAD

Barragup Bridge

Serpentine River

chicken farm

100

101

Map Legend

- Track / Nature trail
- Track requiring closure and rehabilitation
- Combined walk and bridle trail
- Boardwalk
- Proposed boardwalk
- Dual use path
- Proposed dual use path
- Proposed fencing
- Jetty
- Building

APPENDIX 1. : Vegetation Assessment

Vegetation Assessment
Serpentine River Environment Stage 1
1994-1995

Goegrup Lake to Barragup Bridge

Report to the Peel Inlet Management Authority
by
Nicole Siemon

Water and Rivers Commission
South West Region &
Policy and Planning Division

Appendix 1.

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Acknowledgments

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1. Introduction

1.1 Need for study

The Waterways Commission prepared a management programme for the Peel Inlet Management Authority in 1992. The programme identified the need to prepare and implement a riverbank management programme which considered a range of issues including potential for increased boating pressure, the existence of a bird park and possible pollution potential, illegal dumping of rubbish, condition of riverbanks, protection of riparian vegetation and ensuring public access.

In September 1994, the City of Mandurah, Shire of Murray, Peel Development Commission and staff of the Peel Inlet Management Authority met to express concern over the current lack of management of the foreshore of the Serpentine River and suggested a number of facilities to improve public access. The preparation of a management plan for the area is necessary to ensure the facilities and pathways are located appropriately.

Effective planning of the area requires information about the vegetation present in the area, and its value.

This report provides the results of a preliminary investigation into the fringing vegetation of the Serpentine River between Lake Goegrup and Barragup Bridge.

1.2 Terms of reference

The terms of reference for this study are:

- To classify and map the fringing vegetation between the lower reaches of Lake Goegrup and Barragup Bridge (Pinjarra Road),
- To identify the major management issues concerning the conservation of fringing vegetation in the study area, and
- To consider the general quality of the vegetation.

1.3 Study area

The Serpentine River is located between 32.27'11" and 32.23'00" south and 115.47'30" and 115.59'00" and is one of four rivers which contribute to the Peel-Harvey estuarine system. The foreshore reserves adjacent the lower reaches of the Serpentine River between the southern end of Lake Goegrup and Barragup Bridge is the area subject to this study.

2. Methodology

2.1 Vegetation Sampling

Botanical assessments of the study area were conducted on three occasions (December 1994, January 1995 and February 1995) and included description and mapping of the vegetation communities and collection of qualitative (presence/absence) data within each community type. Composition data for a number of sites was established once the species list had been compiled. Communities within the samples were then determined. This data form facilitates rapid and accurate description of vegetation complexes in the field.

Qualitative data is sufficient for descriptive and mapping purposes, however quantitative data collection is essential if baseline information is required to monitor and determine changes over time.

The quality of vegetation was assigned a subjective value according to the level of disturbance, density of foliage and height of dominant tree species.

The vegetation classification system employed was consistent with that established by Pen (1981). This system classifies vegetation as communities on the basis of common species from which community types are derived. The system used in this study varies from that of Pen (1981) in terms of the specific floristic characteristics of some community types.

The quality of the vegetation was assigned a subjective value on the level of disturbance and density of foliage and an estimation of height.

2.2. Vegetation Mapping

Sketch maps were traced from 1992 aerial photographs of the region at a scale of 1 : 20 000. The sketch maps showing the river and peripheral vegetation were digitised using GTCO Digi-pad 3864L. The basic coverages were then transferred to a Microstation 4 environment for the production of the final maps.

Vegetation that fringed the river, any wetland in the immediate vicinity and remnant vegetation associated with the river was recorded. These broad patterns were then ground truthed to ascertain the specific floristics of each dominant vegetation type.

Environmental management issues were identified and documented for inclusion in a management plan for the area. They included fire hazards, weed infestations and mosquito breeding areas. Other impacts noted included vehicle access tracks, associated erosion and areas degraded due to uncontrolled stock access to the river.

The study was limited by the following constraints:

1. Restricted access with fences across foreshore.
2. Difficulties with plant identification to species level.
3. Time frame of the study meaning a number of annuals may have been overlooked.
4. Time constraints limited comprehensive qualitative studies being carried out to establish rigorous community compositions.
5. The scale at which mapping occurred and age of aerial photographs means that recently cleared areas may not be visible on the map series.

3. Vegetation of the Study Area

The native vegetation surrounding the Peel-Harvey estuarine system has been considerably reduced in area and density in the last 30 years. Significant stands of vegetation still remain within the study area, however with further subdivision and increasing pressure to subdivide and develop farmland adjacent to these bush areas is threatening the viability of remaining vegetation communities. Scrubland and woodland understoreys have been thinned by clearing, grazing and annual burns. The rate of degradation of these areas is likely to increase as the neighbouring population increases.

3.1 General vegetation classification

The vegetation fringing the Serpentine River is characterised by areas of fringing saltmarsh, dense sand plain vegetation, and open to closed woodlands. Six major categories of fringing vegetation have been identified for the south west region (Pen 1992).

1. Salt-marsh

These develop in areas which are saline either through direct tidal inundation or as a result of tidal inundation followed by evaporation of water trapped on the marsh by a shoreline levee. It is believed that the latter effect is prevalent where peripheral sediment deposition is greater.

2. Estuarine fringing forest

This vegetation type is typically dominated by the small saltwater sheoak (*Casuarina obesa*), saltwater paperbark *(Melaleuca cuticularis*), paperbark *(M. viminea*) and swamp paperbark (*M. rhaphiophylla*). It occurs as the ground level increases and if salinity levels are not extreme.

3. Fringing vegetation

This consists of those emergent species which live more or less permanently in shallow water. These shallow water bodies may be seasonal.

4. Sandy rise vegetation

This category is composed of vegetation occurring on remnant coastal dunes and raised margins of water bodies.

5. Freshwater fringing vegetation

This vegetation occurs in areas receiving substantial freshwater input, either from surface inputs (ie. creeks or drains) or from groundwater seepage which typically occurs at the base of a ridge or sand dune (Pen 1992).

6. Disturbance-related plant assemblages

Plant assemblages may develop in areas subject to frequent disturbance. Such assemblages are characterised by either a lack of native plant regeneration or a high degree of weed infestation and heterogeneity. Pen (1992) provided examples of these areas. Relic trees in recreational areas are largely prevented from regenerating because of continuous physical disturbance including trampling and therefore the population becomes increasingly aged. Another example of a disturbance-related plant assemblage is in areas which have been subject to changing land use over many years and conditions have not yet established equilibrium. In this case, some native plant species are undergoing decline while others are becoming established or are expanding their extent. At the same time ephemeral weeds exploit communities for invasion, which may in the long term retard the regeneration of native species. Such assemblages appear chaotic and contrast greatly with the homogeneity of native plant communities and the continuums which exist between them.

TABLE A. Flora identified in 1994-95 survey.

cacia pulchella	Prickly moses
Acacia rostellifera	Summer scented wattle
Acacia saligna	Orange wattle
Adenanthos cygnorum	Common woollybush
*Agave americana**	Century plant
Amyema linophyllum	Slender mistletoe
Anigozanthos humilis	Cats paw
Astartea fascicularis	Astartea
Atriplex hypoleuca	Salt bushes
*Avena fatua**	Wild oats
Baeckea sp	Myrtles
Banksia attenuata	Slender banksia
Banksia grandis	Bull banksia
Banksia menziesii	Firewood banksia
Beaufortia sparsa	Swamp bottlebrush
Bolboschoenus caldwellii	Marsh clubsedge
*Briza maxima**	Quaking grass
*Briza minor**	Shivery grass
*Bromus diandrus**	Great brome
Carex fascicularis	Tassel sedge
Cassytha sp.	Dodder laurel
Casuarina obesa	Swamp sheoak
Centella cordifolia	Centella
Chamelaucium uncinatum	Geraldton Wax
*Chenopodium album**	Fat hen
Chenopodium glaucum	Glaucous goosefoot
Conostylis species	Cottonheads
*Conyza bonariensis**	Flaxleaf fleabane
*Cortaderia selloana**	Pampas grass
Corynotheca micrantha	Netbush
*Cotula coronipifolia**	Waterbuttons
Dasypogon bromeliifolius	Pineapple bush
*Ehrharta brevifolia**	Annual veldt grass
*Ehrharta calycina**	Perennial veldt grass
Eriostemon sp	Pepper and salt plants
Eucalyptus calophylla	Marri
Eucalyptus rudis	Flooded gum
Eucalyptus sp	Eucalyptus
Gahnia trifida	Coast saw-sedge
Grevillea vestita	
Hakea amplexicaulis	Prickly hakea
Hakea species	Hakea
Hakea trifurcata	Two-leaf hakea
Hakea varia	Variable-leaved hakea
Halosarcia halocnemoides	Samphire
Hardenbergia comptoniana	Native wisteria
Hemiandra pungens	Snakebush
Hibbertia	Hibbertia
Isolepis nodosa	Knotted clubrush
Jacksonia furcellata	Grey stinkwood
Jacksonia sternbergiana	Stinkwood
Juncus kraussii	Sea rush
Kennedia prostrata	Running postman
Kunzea ericifolia	Spearwood
Lepidosperma drummondii	A sedge
Lepidosperma gladiatum	Coast sword sedge
Lepidosperma gracile	Slender sword sedge
Lepryodia sp	
Leptocarpus sp	A twig-rush
Leptospermum ellipticum	Swamp teatree
Lobelia alata	Angled lobelia
*Lolium perenne**	Perennial ryegrass
Loxocarya flexuosa	
Macrozamia riedlei	Zamia
Melaleuca cuticularis	Saltwater paperbark
Melaleuca lateritia	Robin redbreast bush
Melaleuca preissiana	Moonah
Melaleuca rhaphiophylla	Swamp paperbark
Melaleuca viminea	Mohan
*Naverritia squarrosa**	Californian Stinkweed
Nuytsia floribunda	Christmas tree
*Paspalum vaginatum**	Salt water couch
Patersonia occidentalis	Purple flags
*Pelargonium capitatum**	Rose pelargonium
Polypompholyx species	Pinkfans
Prasophyllum aff gibbosum	Striped leek orchid
Regelia ciliata	A regelia
*Rubus aff. selmeri**	Blackberry
*Rumex crispus**	Curled dock
*Rumex species**	Dock
Sagilla??	
Sarcocornia quinqueflora	Beaded samphire
Scaevola sp	Fan flowers
*Schinus terebinthifolius**	Japanese pepper
Schoenoplectus validus	Lake club-rush
Schoenus curviflorus	
Sporobolus sp	
Stirlingia latifolia	Blueboy
Suaeda australis	Seablite
Synaphea spinulosa	
*Taraxicum officinale**	Dandelions
Thysanotus arenarius	Fringe lily
Thysanotus dichotomus	Fringe lily
Typha domingensis	Bulrush
*Watsonia bulbillifera**	Wild watsonia
Xanthorrhoea preissii	Blackboy
Xylomelum occidentalis	Woody pear

TABLE B. Birds present.

-	Dotterels	*Larus novaehollandiae*	Silver Gull
-	Sandpipers	*Lichenostomus virescens*	Singing Honeyeater
Anas superciliosa	Pacific Black Duck	*Malurus splendens*	Splendid Fairy-wren
Anthochaera carunculata	Red Wattlebird	*Neophema elegans*	Elegant parrot
Anthochaera lanulata	Little Wattlebird	*Phalocrocorax carbo*	Great Cormorant
Ardea alba	Great Egret	*Phalocrocorax melanoleucos*	Little Pied Cormorant
Ardea novaehollandiae	White-faced Heron	*Phalocrocorax sulcirostris*	Little Black Cormorant
Barnardius zonaris	Ringneck parrot / Twenty-eight parrot	*Phaps chalcoptera*	Common Bronzewing
		Platalea flavipes	Yellow-billed Spoonbill
Coracina novaehollandiae	Black-faced cuckoo-shrike	*Platycercus icterotis*	Western Rosella
Grallina cyanoleuca	Australian Magpie-lark	*Rhipidura leucophryus*	Willy Wagtail
Gymnorhina tibicen	Australian Magpie	*Sericornis frontalis*	White-browed Scrubwren
Haematopus ostralegus	Pied Oystercatcher	*Streptopelia senegalensis**	Laughing Turtle-dove
Halcyon sancta	Sacred Kingfisher	*Threskiornis aethiopica*	Sacred Ibis

3.2 Specific vegetation of the study area

The vegetation in this area ranges from salt marsh areas with few or no weeds to totally degraded picnic areas with shade trees with an introduced grass understorey. While much of the study area is disturbed, there are significant stands of vegetation which have maintained their integrity and can be restored with appropriate management.
Brief descriptions of the dominant vegetation communities are provided below. A list of species identified within the study area is given in Table A. This list is not exhaustive as the flora survey occurred in the summer months, when many annuals are not present.

Eighteen vegetation types occur in the study area.

3.2.1 Saltmarsh vegetation

- *Sarcocornia quinqueflora* closed herbland

This community is characterised by samphires (*Sarcocornia quinqueflora* and *S. blackiana*) and *Halosarcia indica bidens*, *Suaeda australis* and creeping brookweed (*Samolus repens*). It forms low dense meadows over large areas on the periphery of Lake Goegrup, and by increasing sediment deposition is extending its distribution. Other associated species include fat hen (*Chenopodium album**), glaucous goosefoot (*Chenopodium glaucum*) and patchy marsh clubrush (*Bolboschoenus caldwellii*).

Downstream, there are two extensive stands of this herbland however for the most part this community is restricted to a narrow fringe. Other species present include occasional stands of the native bulrush (*Typha domingensis*). The annual ryegrass (*Lolium multiflorum**) is prevalent adjacent walk trails and areas disturbed by vehicles.

- *Halosarcia indica bidens* low open heath

The shrubby glasswort (*Halosarcia indica bidens*) forms an open heath in relatively high, saline regions of the saltmarsh. This large shrub occurs in association with the closed samphire herbland.

- *Juncus kraussii* closed sedgeland

Landward of the closed samphire (*Sarcocornia quinqueflora*) herbland are occasional dense homogeneous stands of shorerush (*Juncus kraussii*). Closed shorerush sedgeland occurs more commonly as the understorey of fringing estuarine forest vegetation.

3.2.2 Fringing vegetation

- *Bolboschoenus caldwellii* closed sedgeland

The marsh clubrush (*Bolboschoenus caldwellii*) forms stands in the Greenfields locality. It occurs within a mosaic of homogeneous stands including communities of samphire (*Sarcocornia quinqueflora), Halosarcia indica bidens* and the introduced rye grass (*Lolium multiflorum**).

- *Schoenoplectus validus* closed sedgeland

Immediately downstream of the small boat launching facility in Greenfields Park Reserve, is a limited monospecific stand of the tall weeping sedge *Schoenoplectus validus*. *Schoenoplectus validus* is an emergent lake club-rush found growing in shallow waters (Siemon et al. 1993). This is the only occurrence of this vegetation type in the study area. This sedge contributes to maintaining the stability of the foreshore and can also provide an important habitat for a variety of birds (Table B).

3.2.3 Estuarine fringing forest vegetation

- *Casuarina obesa* low open-closed forest

A few limited stands of saltwater sheoak *(Casuarina obesa)* with an understorey dominated by the shorerush (*Juncus kraussii*) and samphires including *Sarcocornia quinqueflora* and the shrubby glasswort *(Halosarcia indica bidens)*. In some areas the litter is very deep and there are no understorey species. This community is typical of delta regions of rivers (Pen 1993). Large numbers of nankeen night herons were observed in *C. obesa* stands with no understorey species.

- *Casuarina obesa - Melaleuca cuticularis* low open - closed forest

There is one area dominated by these species upstream of Pinjarra Road Bridge in the Greenfields locality. Access could not be gained into this area because of fencing and vegetation was mapped from the river. The area appears to be extremely dense.

Other areas immediately north of the study area with the same overstorey composition were investigated. The shrub layer comprised *Kunzea ericifolia, Beaufortia sparsa, B. squarrosa, Melaleuca vinimea* and *Acacia saligna.*

Understorey species present include the striped leek orchid (*Prasophyllum aff gibbosum*), *Gahnia trifida, Leptocarpus spp., Watsonia bulbillifera*, Lepidosperma drummondii, Lepryodia spp., Centella cordifolia*, dodder (*Cassytha sp), Scaevola spp.*, fringe lilies *Thysanotus* and *Eriostemon sp.* Blackberry is present in patches.

This area should be investigated further once the foreshore reserve becomes accessible. Indications are that this area is in very good condition and any development should not disrupt the amenity.

- *Casuarina obesa - Melaleuca rhaphiophylla* open-closed forest

Casuarina obesa and the swamp paperbark *(Melaleuca rhaphiophylla)* form a low closed forest occur opposite Riverside Gardens on the eastern foreshore and adjacent to Redcliffe Road. Occasional flooded gum (*Eucalyptus rudis*) are present. The stinkwoods *Jacksonia furcellata* and *Jacksonia sternbergiana*, and the coojong (*Acacia saligna*) are present in the middlestorey.

The level of disturbance and weed invasion in the understorey of this community is highly variable with some areas retaining a native grass and sedge understorey and others dominated by introduced grasses. The most frequently occurring combination of understorey species within this community includes plants such as blueboy (*Stirlingia latifolia*), *Corynotheca micrantha, Conostylis spp*, native sedges and *Macrozamia reidlei.* Occasional stands of the jointed twigrush (*Baumea articulata*) are present. The common introduced grasses include bearded oats, blowfly grass and shivery grass, veldt grass and wild oats.

Pampas grass and Japanese pepper are present in this community and there are a large number of juvenile plants which indicates this plant is spreading.

- *Casuarina obesa - Melaleuca rhaphiophylla - Eucalyptus rudis* low open - closed forest

The fringing vegetation immediately adjacent the river comprises saltwater sheoak (*Casuarina obesa*), swamp paperbark (*Melaleuca rhaphiophylla*) and the medium to tall flooded gum (*Eucalyptus rudis*). This community is prevalent both in the Greenfields and Barragup localities ranging from thin fringes to areas of several hectares. Occasional *Banksia littoralis* are present. Tall shrubs present included *Acacia saligna, Acacia. rostellifera* and *Acacia sp*, the stinkwoods *Jacksonia furcellata* and *Jacksonia sternbergiana, Leptospermum* species and woollybushes (*Adenanthos cygnorum*).

Gahnia trifida and *Gahnia sp.* are conspicuous elements of this community, in some areas forming dense meadows. *Scholtzia involucrata* is also present.

The composition of the understorey is generally highly variable, with the specific composition reflecting variation in sediment type. The dominant members were from families including Juncaceae, Restionaceae, Proteaceae, Liliaceae, Epacridaceae and Myrtaceae. Drier areas retain zamias (*Macrozamia reidlei*), and many of the shrub species listed above.

In some areas this community is highly degraded and the understorey is dominated by introduced grasses including *Lolium,* Ehrharta* spp., Briza maxima** and *B. minor**. Other herbaceous weeds including docks *Rumex* spp.* It is important to note however if the frequency of fire is reduced in the study area, the remaining species would readily regenerate.

3.2.4 Fringing freshwater (riverine) forest vegetation

- *Eucalyptus spp. - Casuarina obesa* open forest

The most dominant plant species in the study area are *Eucalyptus rudis, E. calophylla* and *Casuarina obesa.* These species occur in a range of locations including the floodplain, adjacent the river and in swampy depressions. The sandy areas are dominated by *Eucalyptus calophylla* while the areas with clay support predominantly *Eucalyptus rudis* and *Casuarina obesa.* Small trees within this community includes the swamp banksia (*Banksia attentuata*) and candle banksia.

The understorey reflects the variation in sediments with the swampy areas dominated by members of the Restionaceae and sedges. The drier areas dominated by marri have fringe lilies, *Corynotheca mincrantha, Lyginia barbata, Stipa stipoides* and *Mesomeleana stygia.* Introduced grasses are common components of the understorey in the drier areas as a result of frequent fires.

- *Myrtaceae complex* low closed scrubland

This community is prevalent within Barragup on low, flat clay dominated areas, with occasional stands with this structure within Greenfields. This community is characterised by dense stands of members of the family Myrtaceae Species present include *Beaufortia sparsa, B. squarrosa, Regelia ciliata, Leptospermum ellipticum, Melaleuca lateritia, Kunzea micrantha, Hakea trifurcata, Astartea fascicularis, Scholtzia involucrata* and *Verticordia densiflora. Calothamnus rupestris, Hypocalymma robustum, H. angustifolium* and the one-sided swamp bottlebrush are also present. Many other shrub and understorey species were present however verification of their identifications has not yet been received.

Investigations into this community revealed no introduced plants. The density of the vegetation prevents people and horses from trampling the vegetation. These communities are of extremely high conservation value. Complexes with such compositions are known for their importance to invertebrates (Barbara Main pers comm.).

- *Melaleuca rhaphiophylla - Eucalyptus rudis* forest complex

Fringing woodland of swamp paperbark (*Melaleuca rhaphiophylla*) and the flooded gum (*Eucalyptus rudis*) is restricted to a narrow fringe however there are two large stands, one on the floodplain immediately upstream of Pinjarra Road Bridge the other immediately downstream of the northern saltpan.

Where this vegetation type fringes the river it commonly occurs over patchy shorerush (*Juncus kraussii*), samphire (*Sarcocornia quinqueflora*), creeping brookweed *Samolus repens* and *Halosarcia indica bidens.*

The floodplain is highly disturbed retaining an open overstorey of swamp paperbark and occasional flooded gum over an introduced understorey. Occasional shrubs include astartea (*Astartea fascicularis*), zamia, stinkwoods and herbs including knotted clubrush.

- *Melaleuca rhaphiophylla* low closed swamp

There are two wetlands dominated by this vegetation type. It comprises a dense homogeneous overstorey of swamp paperbark where groundwater is demonstrated, with an understorey dominated by either *Gahnia trifida* or *Lepidosperma drummondii. Centella cordifolia, Scaevola sp.*, and a number of sedges are also present in both areas. There is currently low levels of weed invasion.

- *Eucalyptus calophylla* woodland

Tall marri *Eucalyptus calophylla* occurs on the steep sandy rises adjacent the floodfringe. These sandy areas support fairly open forest or woodland of marri with occasional shrubs and large degraded areas with occasional herbs. Dominant shrubs are an unidentified member of the Myrtaceae, woollybushes, hakeas and stinkwoods.

Frequent fires has resulted in the gradual replacement of native understorey species with introduced annual grasses. The common feature of the understorey is veldt grass. Persistant indigenous species are *Conostylis spp., Dryandra sessilis* with slightly lower areas containing patches of *Melaleuca spp.* over stands of the jointed twigrush (*Baumea articulata*).

3.2.5 Sandy rise vegetation

- *Eucalyptus calophylla - Banksia spp.* open forest

The lower Serpentine River is flanked in some areas by moderately sloped or steep sandy rises. They support an open forest or woodland of tall marri (*Eucalyptus calophylla*), *Allocasuarina fraseriana* and small to medium size banksias including *Banksia grandis*, *B. attentuata*, and *B. menziesii*. The Christmas tree (*Nuytsia floribunda*), woollybush (*Adenanthos cygnorum*), *Adenanthos spp., Hakea prostrata, Hakea spp*, *Acacia saligna* and *Acacia pulchella* are more common elements within this community. While this vegetation type is disturbed in many areas, the communities could be restored with minimal management if the frequency of fires is reduced.

The majority of these stands has been subject to frequent fires and in most areas the diverse native diverse understorey has been replaced by vigorous weeds, particularly grasses. The more common grasses include veldt grass, blowfly grass and wild oats.

Native components of the understorey includes *Conostylis spp., Dryandra sessilis*, members of the Epacridaceae, everlastings, *Corynotheca micrantha* and blackboys *Xanthorrhoea preissii, Kingia australis* is also present.

- *Banksia spp.* open woodland

Five species of Banksia occur as trees on the Coastal Plain. Four of these occur within the study area. Firewood banksia (*Banksia menziesii*) which has toothed leaves 2-3 cm wide and generally has yellow and red flowering spikes. Slender banksia (*B. attenuata*). *B grandis* occurs on grey sand and frequently in association with the common sheoak *Allocasuarina fraseriana.* The fourth species is the holly-leaved banksia *B. ilicifolia.* This tree species prefers less well drained soils.

Banksia menziesii, B. grandis, B. attenuata and *Nuytsia floribunda* form an open woodland with shrubs present including stinkwoods *Jacksonis sternbergiana and J. furcellata*, woollybushes and hakeas. Introduced grasses are prevalent in the understorey. Within this complex are occasional *Acacia saligna, Conostylis spp.*, a variety of Myrtaceae and *Scholtzia involucrata.* In damper areas, the dominant banksias *are Banksia attenuata* and *B. ilicifolia* with a Myrtaceae dominated shrub layer. The understorey in the damp areas is predominantly sedges with occasional introduced grasses.

3.2.6 Other communities

Parkland

Approximately one third of the area within the Greenfields locality is currently open parkland. The Greenfields are was cleared for urban subdivision, although much of the surrounding area has been used for pasture prior to subdivision for housing. Historical records must be investigated to accurately describe the regional changes in vegetation. All that remains of the old native forests and woodlands are the larger trees, with a grass understorey. Immediately fringing the river however is remnant understorey species, including shorerush (*Juncus kraussii*), the native wisteria (*Hardenbergia comptoniana*), knotted clubrush (*Isolepis nodosa*) and other herbaceous species.

Areas such as these provide an important recreational focus however the vegetation lacks the diversity of structure to maximise use by many birds and

mammals. There are opportunities to attract wildlife back to the area, while increasing privacy for picnickers by mulching the area and planting shrubs between picnic tables.

Cleared areas are also present in front of many residences in the Barragup locality. Occasional trees and shrubs remain. This clearing of the foreshore reserve is contrary to the purpose of the reserve. Replanting of the foreshore with indigenous species rather than introduced species including Victorian coastal tea-tree (*Leptospermum laevigatum*) and pines, is appropriate. Some of the species planted within the foreshore reserve in the Barragup locality, particularly the coastal tea-tree, have potential to spread rapidly and degrade the remaining vegetation.

Weeds of concern

The study area has areas which have been degraded by the invasion of noxious weeds. Various species were identified during the vegetation survey (Table C). The species discussed below will need be addressed as a high priority management issue. Methods of control are suggested and further information may be obtained from the Pinjarra Catchment Centre.

Blackberry (*Rubis aff. selmeri**) is a noxious weed and will grow and reproduce rapidly particularly in areas where the vegetation has been disturbed or cleared.There are several methods of removal, the most effective being a combination of manual removal followed by treating regrowth with herbicides from December - April.

Pampas grass (*Cortaderia sellonana**) poses a very serious threat to wetlands, it is strongly invasive, rapidly colonising disturbed lands particularly in damp soils. Flowers appear from March to April and persist through to September. They produce an enormous quantity of seed and it's dry leaves are highly flammable. It is found in the *Casuarina obesa - Melaleuca rhaphiophylla* community.
Small plants can be hand pulled. On larger plants the flower plumes should be removed before reaching maturity and destroyed. Brush-cut the plant to approximately 1m, clear away deris so that cut leaves are exposed, and treat with herbicide. Alternatively, brush-cut plants as as low to the ground as possible and treat new growth (about 20cm high) with herbicide in late spring-summer.

Japanese pepper (*Schinus terebinthifolius**) is a large spreading tree which produces a large number of runners and seeds. It will rapidly colonise fluviatile soils. It has invaded the *Casuarina obesa - Melaleuca rhaphiophylla* community in this study area. Small plants can be hand pulled. Trees can be killed using a cut-stump herbicide application which involves cutting down the tree then painting the cut surface with a herbicide. Treatment should be in late summer/autumn when ground is not waterlogged and follow up treatment is essential. Cuttings can regrow and so must be removed.

Grevillea vestita is a Western Australian native, however, it is highly invasive and will dominate disturbed areas. *Grevillea vestita* is present although it is not endemic to the study area

TABLE C. Weeds found in study area in 1994-95 survey

*Agave americana**	Century plant	*Grevillea vestita*	Grevillea (non endemic)
*Avena fatua**	Wild oats	*Lolium perenne**	Perennial ryegrass
*Briza maxima**	Quaking grass	*Naverritia squarrosa**	Californian Stinkweed
*Briza minor**	Shivery grass	*Paspalum vaginatum**	Salt water couch
*Bromus diandrus**	Great brome	*Pelargonium capitatum**	Rose pelargonium
*Chenopodium album**	Fat hen	*Rubus aff. selmeri**	Blackberry
*Conyza bonariensis**	Flaxleaf fleabane	*Rumex crispus**	Curled dock
*Cortaderia selloana**	Pampas grass	*Rumex species**	Dock
*Cotula coronipifolia**	Waterbuttons	*Schinus terebinthifolius**	Japanese pepper
*Ehrharta brevifolia**	Annual veldt grass	*Taraxicum officinale**	Dandelions
*Ehrharta calycina**	Perennial veldt grass	*Watsonia bulbillifera**	Wild watsonia

Rose pelargonium (*Pelargonium capitatum**) smothers native plants and destroys habitat for burrowing animals. It forms rhizomes which are very difficult to remove with out leaving some part of the plant in the ground. Plants will reshoot if the stem is broken at or below the ground. Manual methods are typically the best and pulling should be done in autumn/winter when the soil is damp. Follow up weeding is essential.
Several species of grasses have invaded the sandy patches of the woodlands and other disturbed communities. These include wild oats (*Avena fatua*), perennial rye grass (*Lolium perenne**) and blowfly grass (*Briza maxima*). Small infestations can be controlled with manual removal and spot spraying, dense infestations may require blanket spraying.

Manual control methods for weeds are preferable however the use of herbicides is often neccessary. Special care should be taken to prevent herbicide drift and avoid chemicals which are known to persist in the soil and hence leach into waterways. Herbicides are best used only for severe infestations and native plants should be shielded when blanket spraying heavily infested areas. Shields can be easily made from plastic bottles or ice cream containers, remove weeds under the shield by hand either before spraying or a few days after (Scheltema, 1995).

3.3 Conservation value of the remaining vegetation

This area of vegetation is of regional importance in terms of its extent, diversity of vegetation communities in two adjacent reserves and diversity of flora in their own right. Further it is important to protect native biota from further fragmentation of the natural landscape to provide for residential and recreational developments.

Map ? shows the conservation values for the study area. There areas of high consevation value have been identied as being those areas with good overstorey and understorey with only a few weeds present. Areas which have some remnant vegetation which has been degraded by weed invasion have been classified as being suitable for rehabilitation. With weed removal and regeneration of understorey species, these sites can be upgraded to high conservation value. Areas which have been converted to parkland and have only a few trees have been classified as being important for recreational value.

According to available information the presence of the species of *Scholtzia* found within the study area is unusual as data about the distribution of this species suggests these stands occur in the most southern extent of the species distribution.

The loss of vegetation and habitat has had a major impact on natural ecosystems and fragmenting vegetation can result in a possible decline in the abundance and range of some fauna species, habitat destruction from local overstocking, fragmentation of the landscape, local extinction of fauna and flora and improved access for introduced pest fauna and finally, the effect of land management practices on soil fauna, soil structure and nutrient regimes.

All of the impacts of settlement combined, particularly feral animals, are responsible for the decline of native mammals. Habitat fragmentation has exacerbated these effects by restricting native animals to small, isolated areas, thus keeping their populations small. Vegetation remnants are vulnerable to the consequences of faunal species loss, such as an increase in seed predators, non dispersal of seeds and impacts on soil fauna. Longer term effects of fragmentation such as population decline and loss of habitat diversity also degrade remnants. Disturbance to successional stages, genetic deterioration, loss of evolutionary potential and non viable populations sizes are among the factors involved (Siemon 1994).

Information provided by local naturalists suggests the area contains populations of a high diversity of orchid species (Table D). It is important to maintain these populations because of the increasing urban development in the vicinity of the study area. The information provided about the vegetation communities above does not include the orchid distribution information. This information should be incorporated at a later stage.

Residents contacted during the vegetation survey indicated their support for maintenance and enhancement of the vegetation in this locality.

There are closed wetland communities dominated by a suite of species representing at least some of the following families; Myrtaceae, Proteaceae, Casuarinaceae, Epacridaceae, Goodeniaceae, Rutaceae, Stylideaceae, Juncaceae and Restionaceae. These communities are of particular importance to many invertebrates (Main, 1995) so are of particular

importance in conservation. Another area containing complexes characterised by similar vegetation composition is on the eastern foreshore of the Serpentine River. Field investigations between the Perth metropolitan region and the southern reaches of the Harvey Estuary have not revealed any areas with similar vegetation structure and composition.

These wetter areas are particularly vulnerable to *Phytophthora*, drainage, clearing and frequent burning. It has also been noted that the dense canopies of trees support an enormous abundance and variety of invertebrate fauna (Catterall, 1993).

3.4 Species recorded by a local naturalist

A local member of the Orchid Club has undertaken extensive surveys in the area. The following information was provided.

Five species of Banksia occur as trees on the Coastal Plain. One is firewood banksia, (*Banksia menziesii*) which has toothed leaves 2-3 cm wide and generally has yellow and red flowering spikes. Slender banksia (*B. attenuata*) is found in the study area. *B. prionotes* occurs on yellow soil pockets, *B grandis* occurs on grey sand and frequently in association with the common sheoak *Casuarina fraseriana.* The fifth species is the holly-leaved banksia *B. ilicifolia.* This tree species prefers less well drained soils.

A shrubby member of the banksia family, Proteaceae, is the common woollybush, (*Adenanthos cygnorum*) found in conjunction with ephemeral swamps.

Salt water lakes and estuaries are surrounded by the salt water paperbark, (*Melaleuca cuticularis*) the only others are *Nuytsia floribunda*, the Christmas tree, this semi-parasite is a member of the mistletoe family.
Marsh-dwelling plants, bulrush *Typha domingensis*, jointed rush *Baumea articulata* another paperbark is *Melaleuca rhaphiophylla* also their are the ground dwelling members of the bladderwort family red coats, *Utricularia menziesii* and the related genus *Polypompholyx.*

Bulbous and rhizomatous plants Hoary twine rush *Leptocarpus canus* and Restionaceae family. The most common shrub of the lower swampy areas is the swamp teatree (*Leptospermum ellipticum*). White myrtle (*Hypocalymma angustifolium*) is quite common in the study area. Slightly drier ground is the home of some members of the kangaroo family Haemodoraceae including the green kangaroo paw (*Anigozanthos virids*). Also found in the area are the red swamp cranberry (*Astroloma stomorrhera*) and the sand bottlebrush (*Beaufortia squarrosa*).

Semaphore sedge (*Mesomelaena tetragona*) occurs on the well drained sandy soils. Small herbs include, purple flags (*Patersonia occidentalis*), pink rainbow (*Drosera menziesii*), Red ink sundew (*Drosera erythrorhiza*), also a pink variety of *Drosera erythrorhiza* and purple tassels (*Sowerbaea laxiflora*).

The following list of species of orchids are in the Mandurah area and are soon to be replaced by public open space, houses, roads, shopping centres, and other urban developments. Areas which included the orchids listed in Table D are Coodanup, Terrace Road, south end, Murdoch Drive southern side, Mandurah Hospital north and east side, Halls Head southern aspect, behind greyhound track east side, Gordon Road behind Fredrick Irwin school, Meadow Springs, outskirts of Bunbury Highway to Falcon Country Road Estate.

Orchid Grove estate when surveyed had 67 individual *Corybas sp* and two varieties of leek (*Prasophyllum sp*), three different varieties of *Caladenia sp.* The estate still has Mangles kangaroo paw (*Anigozanthos manglesii*) and green kangaroo paws (*Anigozanthos viridis*), white Hovea two plants only, their are many more to be found still.

TABLE D. Orchids found in the study area.

Burnettia nigricans	Red beaks	*Eriochilus dilalatus subsp. magnus*	Easter bunny orchid
Caladenia discoidea	Dancing orchid		
Caladenia flava	Cowslip orchid	*Eriochilus helonomos*	Swamp bunny orchid
Caladenia huegellii	King spider orchid	*Eriochilus scaber subsp. scaber*	Pink bunny orchid
Caladenia latifolia (white form)	Pink fairy orchid	*Lyperanthus serratus*	Rattle beak orchid
Caladenia varians	a spider orchid	*Prasophyllum calicola*	Limestone leek orchid
Cyrtostylis huegelii	midge orchid	*Prasophyllum elatum*	Leek orchid
Cyrtostylis robusta	Large gnat orchid	*Prasophyllum giganteum*	Bronze leak orchid
Cyrtostylis tennuissima	Gnat orchid	*Prasophyllum parviflorum*	Autumn leak orchid
Diuris corymbosa	Wallflower orchid	*Pterostylis aspera*	Brown viened shell orchid
Diuris laxiflora	Bee orchid	*Pterostylis barbata*	Bird orchid
Diuris longifolia	Common donkey orchid	*Pterostylis nana*	Snail orchid
Diuris magnifica	Pansey orchid	*Pterostylis recurva*	Jug orchid
Diuris micrantha	Dwarf bee orchid	*Pterostylis sanguinea*	Dark banded greenhood
Drakaea livida	Warty hammer orchid	*Pterostylis vittata*	Banded greenhood
Elythranthra emarginata	Pink enamel orchid		

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APPENDIX 2.

GLASS Vegetation List:

Plant species identified by Goegrup Lakes and Serpentine Society.

The following lists have been provided by GLASS and are in addition to the vegetation survey of Appendix 1. Orchid data was supplied to GLASS by Alison Dixon (WANOCSA).

Scientific name	Common Name
Burnetta nigricans	Beak Orchid
Caladenia deformis	Blue Fairy Orchid
Caladenia discoidea	Dancing Orchid
Caladenia flava	Cowslip Orchid
Caladenia hirta	Sugar Candy Orchid
Caladenia latifolia	Pink Fairies
Caladenia longicauda	Coastal White Spider Orchid
Caladenia serotina	Christmas Spider Orchid
Caladenia varians	Common Spider Orchid
Cyrtostylis huegelii	Midge Orchid
Diuris aff. magnifica	Small Pansy Orchid
Diuris corymbosa	Common Donkey Orchid
Diuris laxiflora	Bee Orchid
Diuris mignifica	Pansy Orchid
Drakaea livida	Warty Hammer Orchid

Scientific name	Common Name
Elythranthera brunonis	Purple Enamel Orchid
Elythranthera emarginata	Pink Enamel Orchid
Eriochilus dilatatus	Bunny Orchid
Eriochilus dilatatus (subsp *multiflorus)*	Bunny Orchid
Leporella fimbriata	Hare Orchid
Leptoceras menziesii	Rabbit Orchid
Prasophyllum aff. parvifolium	Scented Autumn Leek Orchid
Prasophyllum parvifolium	Autumn Leek Orchid
Pterostylis aff. sanguinea	Coastal Banded Greenhood
Pterostylis sanguinea	Dark Banded Greenhood
Pterostylis vittata	Banded Greenhood
Thelymitra benthamiana	Leopard Orchid

Gazetted rare flora species identified in the Goegrup Lakes area.

Caladenia huegelii
Diuris micrantha
Diuris (subsp of *laxiflora* and *micrantha)*
Drakaea elastica
Pimelea rara
Thelymitra stellata

APPENDIX 3.

Bird Species List

Supplied by WA Group of the Royal Australasian Ornithologists Union.
Birds observed in the Goegrup Lake area.

Common Name	Scientific Name
Musk Duck	*Biziura lobata*
Black Swan	*Cygnus atratus*
Australian Shelduck	*Tadorna tadornoides*
Australian Wood Duck	*Chenonetta jubata*
Pacific Black Duck	*Anas superciliosa*
Grey Teal	*Anas gracilis*
Australasian Grebe	*Tachybaptus novaehollandiae*
Darter	*Anhinga melanogaster*
Little Pied Cormorant	*Phalocrocorax melanoleucos*
Pied Cormorant	*Phalacrocorax varius*
Great Cormorant	*Phalacrocorax carbo*
Australian Pelican	*Pelecanus conspicillatus*
White-faced Heron	*Ardea novaehollandiae*
Little Egret	*Egretta garzetta*
Great Egret	*Ardea alba*
Australian White Ibis	*Threskiornis molucca*
Yellow-billed Spoonbill	*Platalea flavipes*
Osprey	*Pandion haliaetus*
Whistling Kite	*Haliastur sphenurus*
Brown Goshawk	*Accipiter fasciatus*
Australian Kestrel	*Falco cenchroides*
Eurasian Coot	*Fulica atra*
Common Greenshank	*Tringa guttifer*
Red-necked Stint	*Calidris ruficollis*
Curlew Sandpiper	*Calidris ferruginea*
Broad-billed Sandpiper	*Limicola falcinellus*
Black-winged Stilt	*Himantopus himantopus*
Banded Stilt	*Cladorhynchus leucocephalus*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Grey Plover	*Pluvialis squatarola*
Red-capped Plover	*Charadrius ruficapillus*

Common Name	Scientific Name
Silver Gull	*Larus novaehollandiae*
Caspian Tern	*Sterna caspia*
Common Bronzewing	*Phaps chalcoptera*
Crested Pigeon	*Ocyphaps lophotes*
Galah	*Eolophus roseicapilla*
Regent Parrot	*Polytelis anthopeplus*
Australian Ringneck	*Barnardius zonarius*
Red-capped Parrot	*Purpureicephalus spurius*
Fan-tailed Cuckoo	*Cuculus flabelliformis*
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*
Sacred Kingfisher	*Halcyon sancta*
Rainbow Bee-eater	*Merops ornatus*
Splendid Fairy-wren	*Malurus splendens*
Striated Pardalote	*Pardalotus striatus*
Western Gerygone	*Gerygon fusca*
Inland Thornbill	*Acanthiza apicalis*
Western Thornbill	*Acanthiza inornata*
Red Wattlebird	*Anthochaera carunculata*
Brown Honeyeater	*Lichmera indistincta*
New Holland Honeyeater	*Phylidonyris novaehollandiae*
Scarlet Robin	*Petroica multicolor*
Golden Whister	*Pachycephala pectoralis*
Rufous Whistler	*Pachycephala rufiventris*
Grey Shrike-thrush	*Colluricincla harmonica*
Magpie Lark	*Grallina cyanoleuca*
Black-faced Woodswallow	*Artamus cinerius*
Grey Butcherbird	*Cracticus torquatus*
Australian Magpie	*Gymnorhina tibicen*
Grey Currawong	*Strepera versicolor*
Australian Raven	*Corvus coronoides*
Welcome Swallow	*Hirundo rustica*
Tree Martin	*Hirundo nigricans*

APPENDIX 4.

Useful contacts

A list of community groups and government agencies relevant to the region.

LANDCARE / COMMUNITY GROUPS

Boomerang Creek Landcare Group PO Box 59 BYFORD WA 6201	Jim Elliott 9525 1377
Como Landcare Group PO Box 103 PINJARRA WA 6208	Irene Stokes 9530 1260
Coolup LCDC	Rosemary Pitter 9530 3207
Mardella Landcare Group Lowlands Road MARDELLA WA 6204	Geof Manning 9525 2274
Medulla Creek Dwellers Medulla Valley Jarrahdale Road MUNDIJONG WA 6202	Jan Star 9525 5152
Myara Brook Committee C/- Post Office KEYSBROOK WA 6206	Denyse Needham 9525 2710
Peel Landcare Group Lot 148 Baldivis Rd BALDIVIS WA 6171	Lillian Waugh 9524 1747
Serpentine River Group PO Box 10 SERPENTINE WA 6205	Mark Angeloni 9525 5070
Serpentine-Jarrahdale LCDC PO Box 41 MUNDIJONG WA 6202	Denyse Needham 9525 2710
Yangedi Landcare Group Yangedi Road SERPENTINE WA 6205	Athol Wigg 9525 2293
Comet Bay Coastal Advisory Group	Penny Ford 9537 1998
Falcon to Halls Head Protection Society	Andrea Evans 9534 2217
Goegrup Lakes and Serpentine Society	Marilyn Ralph 9535 1347

Lake Mealup Preservation Society	Mrs P. Lake 9384 9594
Murray Conservation Group	Dorothy Challen 9537 6195
Peel Preservation Group Suite 12 Lotteries House 7 Anzac Place MANDURAH WA 6210	Griselda Hitchcock 9535 4824

EDUCATIONAL

Alcoa of Australia PO Box 252 APPLECROSS WA 6153	John Collett 9316 5295
APACE AID Winter House 1 Joanna Street NORTH FREMANTLE WA 6159	Tony Freeman 9336 1262
Australian Trust for Conservation Volunteers C/- Perth Zoo PO Box 489 SOUTH PERTH WA 6151	James Clayton 9474 3445
Community Catchment Centre (Pinjarra) 6 George Street (PO Box 376) PINJARRA WA 6208	Jan-Paul van Moort 9531 1788
Conservation Council of WA Lotteries House 79 Stirling Street PERTH WA 6000	Joan Payne 9220 0652
Environmental Weeds Action Network WA Herbarium 15 Rabon Way BOYA WA 6056	Patrick Piggot 9334 0495
Greening WA 1118 Hay Street WEST PERTH WA 6005	Janette Huston 9481 2144
Men of Trees	George Richards 9582 2055
Roadside Conservation Comittee C/- 50 Hayman Road COMO WA 6152	David Lamont 9334 0333

MISC COMMUNITY GROUPS

Mandurah Birdwatchers Club	Frank Pridham 9535 4853
Mandurah Historical Society	Beryl Slade 9535 2639
Mandurah Walking Club	Fred Baines 9581 6535
Mandurah Wildflower Group	Ted Rushton 9535 3137

APPENDIX 5.

Dieback Assessment

NOTE: This Dieback Assessment Study was completed prior to printing and so has been included as an appendix, however it must be noted that it was not available for consideration when the draft management plan was being produced. The final management plan will take the Dieback Assessment Study into consideration.

Distribution of *Phytophthora* and *Armillaria* in vegetation adjacent to the Serpentine River from Goegrup Lake to Barragup Bridge and recommendations for management.

Report to the Peel Inlet Management Authority

by

Fieldview Nominees P/L trading as

FUNGUS DOCTORS

DISTRIBUTION OF *PHYTOPHTHORA* AND *ARMILLARIA* IN VEGETATION ADJACENT TO THE SERPENTINE RIVER FROM BARRAGUP BRIDGE TO GOEGRUP LAKE AND RECOMMENDATIONS FOR MANAGEMENT.

PREPARED BY

FIELDVIEW NOMINEES P/L TRADING AS
FUNGUS DOCTORS.

October, 1997

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GLOSSARY

Armillaria luteobubalina
A native wood rotting fungus that attacks the sapwood of living plants.

Autonomous disease spread
The natural movement of infective motile spores in saturated soils and growth of mycelium between connecting root systems.

Cambium
The layer of conductive tissue between the wood and outer bark of vascular plants.

Canker fungi
A group of fungi associated with twig, branch and upper trunk deaths.

Cryptic disease
The situation in which a host plant is infected with a pathogen but there are no visible symptoms.

Dieback
In Western Australia, the term is specifically used to describe the disease in native vegetation caused by the *Phytophthora cinnamomi* fungus. The term is also generally used to describe any progressive deterioration of tree crowns.

Disease
The decline in plant health as a result of the presence of a pathogen and environmental conditions favourable to the pathogen.

Hyphae
Threadlike strands or filaments that constitute the body (mycelium) of a fungus.

Impact
The effect of disease on plant health.

Keystone species
A plant species in an ecosystem that provides conditions pivotal for the survival of other flora and fauna.

Mycelium
A mass of fungal hyphae forming the body of a fungus.

Non-susceptible species
Plant species that do not display secondary symptoms of *Phytophthora cinnamomi* infection when exposed to the pathogen. They may display primary symptoms of infection including the death and discolouration of root tissue and lesion development.

Phytophthora
A genus of microscopic fungi responsible for widespread damage in native vegetation of Western Australia.

Phytophthora susceptible species
Plant species that will develop secondary symptoms of *Phytophthora cinnamomi* infection when exposed to the pathogen. Secondary symptoms include crown decline and death of the host.

Pathogen
A pathogen is any agent causing disease.

Sporangium
An oval or ellipsoid spore sac approximately 0.057 x 0.033 mm that produces zoospores within a cell wall.

Vectored disease spread
The spread of infective propergules through the inadvertent movement of infected soil or vegetative material. Agents include vehicles, machinery, animals and walkers.

Vegetation associations
A group of similar plants that grow in a uniform environment that contains one or more dominant species.

Zoospore
A motile spore approximately 0.01 mm in diameter produced within a sporangium.

1. BACKGROUND

1.1 Dieback

The plant disease known in Western Australia as "dieback" or "Jarrah dieback" is caused by an introduced, microscopic, soil-borne fungus of the genus *Phytophthora*. The most destructive and widespread species is *Phytophthora cinnamomi* Rands, which has caused irreversible decline of susceptible species from Eneabba in the north to Cape Arid on the south coast (Shearer & Tippett, 1989).

The *Phytophthora cinnamomi* fungus is highly invasive and will infect the roots of a large range of plant species. The primary symptom of infection is the death and discolouration of root tissue. The secondary symptoms are crown decline and/or the death of the infected plant. Plant species that are partially resistant and do not develop secondary symptoms are classified as "non-susceptible" hosts, and species that develop secondary symptoms are regarded as "susceptible" hosts. There are few native plant species that have been found to be completely resistant to dieback and able to inhibit fungal growth at the point of entry.

Phytophthora cinnamomi mycelial strands spread through the root system of an infected plant and, under certain environmental conditions, develop sporangia. The sporangia release zoospores into the soil where they spread through water movement and, to a lesser degree, through self-propulsion. People and animals can also spread the spores through the movement of infected soil or plant material.

Dieback has been inadvertently spread throughout the coastal sand plains and infected many areas. The impact that dieback will have in native vegetation communities is determined by a complex interaction between the host species, the *Phytophthora* fungus and environmental factors. The banksia woodlands of the coastal plain are especially at risk as they contain many susceptible species.

Until recently, the only method of dieback control was to implement hygiene measures designed to minimise vectored spread. There was no effective method of controlling autonomous spread within infected areas, or protecting susceptible plant communities in high conservation value areas. Several trials undertaken by the Department of Conservation and Land Management have shown that foliar spraying and stem injection of phosphorous acid gives excellent control of *Phytophthora cinnamomi* in a range of susceptible hosts. In a recently published report to the Western Australian Minister for the Environment, phosphorous acid treatment is identified as an effective measure for the protection of threatened flora (Podger, James & Mulcahy, 1996).

1.2 *Armillaria luteobubalina*

Armillaria luteobubalina is a native fungus belonging to the basidiomycetes group of wood rotting fungi. The fungus is readily recognisable by characteristic white mycelial fans in the cambium of infected plants, and the presence of fruiting bodies (basidiomes) in June and July. Infection occurs through aerial dispersal of basidiospores released from basidiomes, or through root to root transmission of mycelium, which results in discontinuous and discrete distribution of infections (Shearer, 1992).

The fungus is a primary pathogen and has a wide range of host species. There are many hosts that are not susceptible to *Phytophthora cinnamomi* that are susceptible to *Armillaria luteobubalina* infection. The impact that an infection will have in a vegetation community depends on many factors including density of susceptible species, stress levels, site, soil, and climatic conditions.

2. SUMMARY

The majority of the vegetation within the survey area is not susceptible to *Phytophthora*. The predicted impact of infection in this vegetation is very low and will be limited to a slight decline in vigour of affected plants. There are four separate areas of highly susceptible vegetation that constitute approximately ten percent of the total survey area. *Phytophthora cinnamomi* is present in two of these areas, while the other two are free of visible symptoms. It is probable that there is a degree of cryptic infection throughout the survey area.

The areas of susceptible vegetation are at risk of *Phytophthora cinnamomi* infection through both autonomous and vectored spread. Infection will result in the death of many native species, which will have a negative impact on the populations of dependent animal species as well as the aesthetic and intrinsic values of the native plant community. It is recommended that a *Phytophthora* management plan is introduced to reduce the risk of vectored spread of disease, and to control the autonomous spread of disease from existing infections.

3. INTRODUCTION

This survey was requested by the Waters and Rivers Commission to determine the disease status of the native vegetation adjacent to the Serpentine River between Goegrup Lake and the Barragup Bridge. The results and subsequent recommendations will be considered in the formulation of disease management strategies for the area.

Field assessment commenced on 16 June 1997 and was completed by 27 June 1997. The method of disease assessment was the systematic examination of vegetation for symptoms of *Phytophthora* and *Armillaria* infections, supported by soil and root sampling. This report contains the results of the survey including the susceptibility to infection of vegetation associations, disease distribution and disease expression, discussion of the issues relevant to management, and the subsequent management recommendations.

4. METHOD OF DISEASE SURVEY

The survey area was assessed for the presence of *Phytophthora* and *Armillaria* by traversing the vegetated areas and examining the susceptible native plant species for secondary symptoms of fungal infection. Secondary symptoms include dead and dying leaves, crown decline and death. When secondary symptoms were detected, the plant was examined for primary symptoms such as lesion development in the roots and stem, and macroscopic *Armillaria* mycelium growth in the root and stem cambium.

It is not possible to conclusively identify *Phytophthora* in the field as the fungus is microscopic during all stages of its life cycle. Samples of root material and soil from around the roots of susceptible plants displaying secondary symptoms of *Phytophthora* infection were collected for laboratory analysis. The sample sites were demarcated in the field with dayglow orange flagging tape and an aluminium identification tag.

The samples were processed by Dr. Elaine Davison of Curtin Consultancy Services. The soil material was flooded with distilled water containing 10 *Eucalyptus sieberi* cotyledons that had been surface sterilised with 70 % ethanol solution. Cotyledons that changed colour from green to beige were examined for sporangia then plated on agar selective for *Phytophthora*. After seven days, all remaining cotyledons were plated on selective agar. The soil was then drained off and the process repeated. Plant tissue was surface sterilised with 70% ethanol solution and cut into small strips before being plated onto selective agar. Plated material was left for one week then examined for the development of fungi. Identification of *Phytophthora* species was determined by the structure, size and development of sporangia and hyphae.

The distribution of sample sites and the disease status of the vegetation were recorded on a 1:5000 scale map (Appendix 2). To minimise visual pollution, no field demarcation of disease boundaries was made.

5. SUSCEPTIBILITY OF VEGETATION TO *PHYTOPHTHORA*

The flora communities within the survey area were classified into five vegetation associations based on the presence of one or more dominant species. The distribution of the vegetation associations has been determined by soil characteristics and drainage patterns. There were no pristine areas of native vegetation noted, which is consistent with

previous observations of remnant vegetation on the Pinjarra Plain (Beard, 1979). All of the vegetated areas have been subject to varying levels of disturbance through fire, weed infestation and unrestricted access. It is probable that some vegetation segments have been modified by *Phytophthora* infestation. The distribution, composition and susceptibility to *Phytophthora* of the five vegetation associations is described below.

Samphire salt marsh
The salt marshes are adjacent to the Serpentine River and Geogorup Lake in low-lying flats subject to frequent inundation. The vegetation composition of the samphire flats is *Sarcocomia quinqueflora* and *Juncus kraussii*, with a sparse fringing overstorey of *Casuarina obesa* over *Melaleuca cuticularis*. There are no *Phytophthora* susceptible species within the salt marshes.

***Casuarina obesa / Melaleuca rhaphiophylla* estuarine fringing forest**
This vegetation association occurs in patches adjacent to the samphire marshes and along the Serpentine River. The overstorey composition is *Casuarina obesa* and *Melaleuca rhaphiophylla,* with occasional *Eucalyptus rudis* and *Melaleuca cuticularis.* The relative density of overstorey species is dependent on the proximity to the estuarine environment, with the salt tolerant *Melaleuca cuticularis* occurring close to the river and *Eucalyptus rudis* occurring in more elevated areas. The understorey consists of a mosaic of sedges and low heath. There are no *Phytophthora* susceptible species in this vegetation association.

***Eucalyptus rudis / Melaleuca rhaphiophylla* woodland**
This vegetation occurs in seasonally wet, freshwater gaining sites within the survey area. The overstorey composition is *Eucalyptus rudis* and *Melaleuca rhaphiophylla* in the seasonally inundated sites, with occasional fringing *Eucalyptus calophylla* and *Eucalyptus gomphocephala* on drier elevated areas. The understorey consists of sedges, reeds and low heath. In many areas the understorey has been modified by fire, grazing and weed invasion, altering the floral composition and reducing the native species density.

Adjacent to Koolyanga Road and Bulara Road there is a segment of *Eucalyptus rudis / Melaleuca rhaphiophylla* woodland containing *Phytophthora* susceptible species not represented in other segments of this vegetation association. The susceptible species are *Banksia grandis, Banksia menziesii, Banksia illifolia, Banksia littoralis, Jacksonia furcellata, Macrozamia riedlei* and *Sterlingia latifolia* (Helyar, 1994). With the exception of this area, the *Eucalyptus rudis / Melaleuca rhaphiophylla* woodlands are not susceptible to *Phytophthora.*

Banksia woodlands
There are three segments of banksia woodland on elevated sandy areas. One segment is located adjacent to Redcliffe Road, extending southward from Doongin Place to private property location 123 Carnegie Place. One segment is to the north west of private property locations 7,12, 13, 15, 16, 17, and 18, Husband Road and location 9 Caponi Road, between the private property boundaries and the Serpentine River. One segment is

north of locations 2 and100, Pinjarra Road, between the private property boundaries and the Serpentine River.

The vegetation composition is a sparse overstorey of *Eucalyptus calophylla* with occasional *Eucalyptus gomphocephala* and *Eucalyptus marginata* over *Banksia grandis, Banksia illicifolia, Banksia littoralis*, *Banksia menziesii* and occasional *Adenanthos cygnorum.* The native understorey composition is variable, dependent on the level of disturbance and weed infestation. Native understorey species include *Acacia pulchella, Acacia saligna, Dryandra spp., Hibbertia hypericoides, Jacksonia furcellata, Macrozamia riedlei, Patersonia occidentalis, Patersonia rudis, Sterlingia latifolia* and *Xanthorrhoea spp.* This vegetation association is very susceptible to *Phytophthora,* as the majority of the native species are susceptible (Helyar, 1994).

Parkland
The parkland (Riverside Garden Reserve) is located adjacent to Redcliffe Road and Wanda Road. The area has been cleared of most native vegetation and replaced with lawn. There is a sparse overstorey of *Eucalyptus calophylla, Eucalyptus gomphocephala* and *Eucalyptus rudis,* with some *Casuarina obesa* fringing the Serpentine River. These species are not susceptible to *Phytophthora.* There are several large *Banksia grandis* and *Banksia littoralis* scattered throughout the parkland. These banksias are susceptible to *Phytophthora.*

6. SUSCEPTIBILITY OF VEGETATION TO *ARMILLARIA*

In the literature available, there is no evidence of research on the distribution and impact of *Armillaria luteobubalina* in vegetation associations similar to those in the survey area. Research in Western Australia has been centred on the Jarrah (*Eucalyptus marginata*), Karri (*Eucalyptus diversicolour*) and Wandoo (*Eucalyptus wandoo*) forests. There were no *Armillaria luteobubalina* affected sites detected within the survey area and the potential impact on vegetation, should the pathogen be introduced, has been predicted from personal observations of the disease in a range of environments.

Armillaria luteobubalina is a primary pathogen and has a wide range of host species. It is expected that the impact of infection within the majority of the survey area would be low should infection occur. The impact may be higher in the banksia woodlands due to the high susceptibility of *Eucalyptus callophylla* and moderate susceptibility of *Banksia spp.* and *Eucalyptus marginata.* Impact in individual species will vary in response to infection, with some individuals resisting infection and others dying. The mechanism of variation in response is not well understood (Shearer & Tippett, 1988).

7. DISEASE DISTRIBUTION AND EXPRESSION

7.1 Sample results

Eight soil and root samples were taken from *Phytophthora* susceptible species displaying secondary symptoms of infection. Seven were taken from the survey area, and one was taken from a protea farm on private property location 21 Caponi Road. The samples were processed as described in section four. The laboratory process is selective for the *Phytophthora* fungus and will not detect other species of fungus such as *Armillaria*. Of the eight samples, six returned positive results for *Phytophthora cinnamomi* and two were negative. A summary of sample results forms Appendix 1. Sample sites are annotated on the disease distribution map, Appendix 2.

7.2 *Phytophthora cinnamomi*

Vegetation associations containing no *Phytophthora* susceptible species cover the majority of the survey area. The estuarine environment is hostile to the *Phytophthora* fungus and contains no susceptible species. The low lying, seasonally wet, *Eucalyptus rudis / Melaleuca rhaphiophylla* woodlands provide an ideal, moist environment for *Phytophthora* and it is probable that there is some degree of cryptic infection. The absence of disease expression occurs because there are no susceptible hosts. It is possible that susceptible hosts may have been present in the past, but have been eradicated by *Phytophthora* infection. This is supported by the presence of healthy susceptible species in the *Eucalyptus rudis / Melaleuca rhaphiophylla* woodland adjacent to Koolyanga Road and Bulara Road (Appendix 2).

There are three segments of *Phytophthora* susceptible banksia woodland on elevated sandy areas. Positive results were returned for samples taken from the banksia woodland adjacent to Redcliffe Road and the banksia woodland north west of private property locations 7, 12, 13, 15, 16, 17, and 18, Husband Road and location 9, Caponi Road between the private property boundaries and the Serpentine River (Appendix 2). The disease expression, size of the infection, and the probable pathogen vector is described for each site in sections 7.2.1 - 7.2.5. No secondary symptoms of infection were detected in the banksia woodland north of locations 2 and100, Pinjarra Road, between the private property boundaries and the Serpentine River.

7.2.1 Infection at sample sites two and three

Sample site two is approximately one metre north of the boundary fence of private property location 123 at the southern end of Carnegie Place and is annotated on the disease distribution map (Appendix 2). The sample was taken from a *Banksia littoralis* displaying secondary symptoms of *Phytophthora* infection. The entire crown had died recently, with all leaves turning a golden brown colour. Soil from around the roots and root material was collected to a depth of one metre. There was evidence of fungal infection in the cambium around the root collar with a faint blue/brown lesion and necrotic tissue below the lesion. The sample returned a positive result for *Phytophthora cinnamomi*.

At the time of sampling, it appeared that the disease area extended south from sample site two, through private property location 123. The private property has been cleared of all susceptible understorey species and determination of the disease boundary was achieved through examination of scattered deaths in the sparse *Banksia littoralis* overstorey. Sample three is approximately 80 metres south-east of sample two, and was taken from a *Banksia littoralis* displaying similar symptoms. The sample returned a positive result, confirming the initial field assessment of disease distribution. The area affected by *Phytophthora cinnamomi* is approximately three hectares in size and almost entirely within private property location 123 (Appendix 2).

There is no hygiene restriction on access to the private property, and infected material may have been introduced to the site by vehicles or livestock. There is no pattern development in the age and distribution of *Banksia littoralis* deaths, suggesting multiple points of pathogen introduction.

7.2.2 Infection at sample site four

Sample site four is located in banksia woodland adjacent to private property location 10 Carnegie Place and is annotated on the disease distribution map (Appendix 2). The soil and root sample was taken from a *Banksia menziesii* displaying secondary symptoms of *Phytophthora* infection. There were indications of fungal infection in the roots and stem of the sampled plant and the sample returned a positive result for *Phytophthora cinnamomi*.

The affected site is approximately five metres in diameter and contained two dead *Banksia littoralis* and one dead *Adenanthos cygnorum*. There were no susceptible native species in the understorey, which consists mainly of introduced grasses and weeds. There was a recognisable pattern development and age range of host deaths that indicated the vector for disease was possibly infected material introduced to the site in association with the adjacent residential development.

7.2.3 Infection at sample site six

Sample site six is located in banksia woodland to the south east of the Redcliffe Road / Doongin Road intersection and is annotated on the disease distribution map (Appendix 2). Soil and root material was taken from a *Banksia menziesii* displaying secondary symptoms of *Phytophthora* infection. The plant had died recently with the entire crown dying simultaneously. There was some indication of fungal infection in the roots and root collar. The sample returned a positive result for *Phytophthora cinnamomi*.

There were several deaths in the susceptible overstorey of *Banksia grandis, Banksia menziesii* and *Banksia littoralis*. The affected area is approximately ten metres in diameter and slightly triangular in shape, with the longest side parallel and adjacent to the fence. There are many possible vectors for disease introduction, including infected soil used for the construction of the nearby foot path, contaminated tools or machinery used during construction of the fence, or vehicles depositing infected soil along the road verge.

It appeared that a dead *Banksia grandis* at the centre of the infection had been sampled for disease in the recent past. There was no field identification tag to indicate when the sample had been taken, or who had taken it.

7.2.4 Infection at sample site seven

Sample site seven is located in banksia woodland to the west of private property location 12, Husband Road and is annotated on the disease distribution map (Appendix 2). Soil and root material was taken from a *Banksia littoralis* that had recently died. There was an obvious lesion in the cambium above the root collar and discoloured tissue in the roots. The sample returned a positive result for *Phytophthora cinnamomi*.

The affected site is approximately 15 metres in diameter in a relatively dense stand of susceptible species. There is a recognisable radial pattern of fungal spread through root-to-root transmission, where all susceptible species, including *Banksia littoralis, Adenanthos cygnorum* and *Jacksonia furcellata*, have been killed. The disease vector was not apparent.

7.2.5 Infection at sample site eight

Sample site eight is located in banksia woodland adjacent to the northern boundary of private property location 15, Pinjarra Road, and is annotated on the disease distribution map (Appendix 2). Soil and root material was taken from a large *Banksia grandis* displaying secondary symptoms of *Phytophthora* infection. The leaves were still slightly green, indicating that the banksia had died very recently. There was slight discolouration in conductive tissue around the root collar that may have been caused by fungal infection.

The affected area is approximately ten metres in diameter. It was difficult to determine the disease boundary as the vegetation consists of non-susceptible grasses and weeds. It appears that as the disease has spread through the *Banksia grandis* overstorey, the dead or dying plants have been cut down and removed. This is supported by the presence of *Banksia grandis* stumps with an age range indicating sequential removal.

There are many potential vectors for disease introduction, including vehicle access from the adjoining private property, and the multiple-use track that passes near the infection.

7.3 Other *Phytophthora* species

The laboratory process will detect all species of *Phytophthora* present in a soil and root material sample. There were no *Phytophthora* species other than *Phytophthora cinnamomi* isolated from the samples collected in the survey area. The lack of sample recovery does not exclude the possibility that other *Phytophthora* species are present in hosts not displaying secondary symptoms.

7.4 *Armillaria luteobubalina*

Identification of *Armillaria luteobubalina* infections is made by observing the macroscopic white mycelium sheath or fruiting bodies growing on the infected plant cambium, as sampling is not usually successful. There were deaths not attributable to *Phytophthora* that were examined for *Armillaria* infection during the survey, but no conclusive evidence of the fungus was found.

8 PLANT DEATHS NOT ATTRIBUTABLE TO *PHYTOPHTHORA*

8.1 Negative sample results

Sample site one is located on private property location 21, Caponi Road and is annotated on the disease distribution map (Appendix 2). The property is used for the commercial production of protea flowers, with the majority of the available area under cultivation. The soil and root material was taken from many species of dead and dying proteas displaying a disease pattern development consistent with *Phytophthora* infection. The sample returned a negative result for *Phytophthora*. As the laboratory process is selective for *Phytophthora*, it is possible that the plants sampled were killed by an undetected pathogen. There was no indication of *Armillaria luteobubalina* infection.

Sample site five is located in banksia woodland to the east of private property location 4, Carnegie Road, midway between the concrete footpath and the lower, unsealed walk trail and is annotated on the disease distribution map (Appendix 2). Soil and root material was taken from a *Banksia menziesii* displaying secondary symptoms of *Phytophthora* infection. There was no evidence of lesion development in the roots or root collar. Examination of the stem revealed necrotic tissue in the upper stem and healthy tissue towards the root collar. There was some evidence of lesion development between the healthy and necrotic tissue. The sample returned a negative result for *Phytophthora*. There was no indication of *Armillaria luteobubalina* infection.

It was noted that there were several small dead *Banksia menziesii* and *Banksia littoralis* in close proximity to sample site five. The plants had been dead for one year or more with only single stems and roots remaining. The pattern of tissue death was similar to that in the sampled *Banksia menziesii*. The plant deaths were scattered and did not display a disease pattern development consistent with *Phytophthora*. The symptoms are consistent with drought or the presence of a canker fungus.

8.2 Fire

Field observations of forest fuel loadings and fire damage to plant species indicated that the survey area has had a mosaic of fire events of varying intensities. There have been small fires of sufficient intensity to defoliate or kill some understorey plant communities. These areas are distinguishable from *Phytophthora* affected sites by the non-discriminatory pattern of plant species affected, the lack of pattern development and evidence of fire damage to affected plants.

9. MAP REPRESENTATION

During field assessment, the distribution of vegetation associations and the location of sample sites were recorded on 1:5000 scale map. After the return of sample results, the sample sites with positive results for *Phytophthora* were revisited and the disease boundaries were mapped. From this information, a *Phytophthora* distribution map was produced that indicates the disease status of the forest and the location of sample sites. This map was plotted manually then digitised by the Water and Rivers Commission. The resulting map forms Appendix 2.

Vegetation associations with *Phytophthora* susceptible plant species that are not displaying symptoms of infection are termed "Dieback Free" and are shaded light grey on the *Phytophthora* distribution map. In segments of vegetation displaying secondary symptoms of *Phytophthora* infection where sampling has returned a positive result for *Phytophthora*, the category of "Dieback" has been allocated and the area shaded dark grey on the *Phytophthora* distribution map.

The vegetation associations with no susceptible species and no evidence of the presence of *Phytophthora* have been allocated the category of "Non-susceptible" and shaded mid grey on the *Phytophthora* distribution map. The area of parkland adjacent to Redcliffe Road and Wanda Road has been classified as non-susceptible as the vegetation is predominantly non-susceptible with only the occasional susceptible *Banksia grandis* and *Banksia littoralis* present.

10. RISK ANALYSIS AND DISEASE IMPACT

The principle aims of *Phytophthora* management are to minimise the risk of increasing the occurrence of disease through vectored spread, and to minimise the impact of existing infections (Shearer and Tippett, 1989). The following sections highlight the issues that have been considered in analysing these risks and the potential impact of vectored and autonomous spread of the pathogen within the survey area.

10.1 Non-susceptible vegetation associations

Vegetation associations not susceptible to *Phytophthora* occupy the majority of the survey area (Appendix 2). The predicted impact of *Phytophthora* in these vegetation associations is low and restricted to a possible decline in vigour of some hosts.

It is probable that there is some degree of cryptic infection within the *Eucalyptus rudis / Melaleuca rhaphiophylla* woodlands and parkland vegetation associations, due to multiple vectors, moist soil conditions and the presence of host species. It is difficult to prove the presence or absence of cryptic disease through random sampling as the chance of locating primary infection sites in the root systems of non-susceptible hosts is extremely low. Accordingly, the sampling intensity required to determine the distribution of cryptic disease would be extremely high and impractical.

There were no *Phytophthora* deaths of susceptible species in transitional vegetation zones (between susceptible and non-susceptible vegetation associations) that could be directly attributable to cryptic infection in the non-susceptible vegetation. It can be deduced from this observation that the level of cryptic disease is relatively low.

The non-susceptible *Eucalyptus rudis / Melaleuca rhaphiophylla* woodlands and parkland vegetation associations have been identified as a potential source of infection to *Phytophthora* susceptible vegetation associations through vectoring and autonomous spread. As the level of cryptic disease is considered to be low, the risk is also relatively low. The risk associated with failing to protect the non-susceptible vegetation associations from inward vectoring of *Phytophthora* is an increasing source of infected material for vectored and autonomous spread to *Phytophthora* susceptible vegetation associations (Shearer,1992).

10.2 Susceptible vegetation associations

There are three areas of banksia woodland and one area of *Eucalyptus rudis / Melaleuca rhaphiophylla* woodland that are predominantly free of *Phytophthora* symptoms. There are many susceptible species within these areas that will be killed if *Phytophthora cinnamomi* is introduced through autonomous spread from existing infections, or vectored spread through the movement of infected material.

Many of the banksias are keystone species (Shearer, Wills & Stukely, 1991), providing a food source for insects, birds and mammals. The loss of these keystone species would have a negative impact on the populations of dependent animal species as well as the aesthetic and intrinsic values of the native plant community.

10.3 *Phytophthora* infections and cryptic disease

Positive sample recovery of *Phytophthora cinnamomi* has confirmed that the pathogen is present in two of the three segments of banksia woodland. It is possible that cryptic disease may also be present in hosts adjacent to pathogen vectors throughout the survey area. The rate of spread of mycelium in infected *Banksia grandis* root tissue can be as slow as 20 centimetres per year (Shea & Dillon, 1980) which can result in a significant delay between the initial infection and the development of secondary symptoms.

Apparently healthy susceptible species with roots extending into disease sites are expected to be infected and will display secondary symptoms when the fungus reaches the root collar. Banksias develop extensive root systems that may extend over ten metres from the root collar. When managing *Phytophthora* infections, the zone of cryptic infection surrounding the visible disease symptoms must be taken into account.

10.4 Pathogen vectors

The eastern side of the Serpentine River is subject to use by vehicles, horses and walkers. There is a multiple-use track between the riverbank and adjacent private property that extends from Barragup Bridge in the south, to the northern end of Caponi Road. Extending from the main track are many trails of varying widths and levels of use, including tracks and trails from the adjacent private properties. All tracks and trails are

potential vectors for the introduction of infected material.

The western side of the Serpentine River has four points of vehicle access. Within the Riverside Garden Reserve there are two unsealed car parks with access from Redcliffe road and Wanda Road. There is an unsealed track that extends from the southern end of Carnegie Road to private property location123, and in an easterly direction to the riverbank. There is an unsealed track that extends south from Koolyanga Road along the S.E.C.W.A power line easement. The car parks and unsealed tracks are potential vectors for the introduction of infected material.

The stormwater drainage from Redcliffe Road, Wanda Road, Koolyanga Road and Bulara Road flows freely into the adjacent vegetated areas. Contaminated soil deposited by vehicles onto the road surface may be washed from the road and drained towards susceptible vegetation associations.

There are many walk trails throughout the survey area. The risk of vectoring *Phytophthora* infected material on footwear will vary with the type and moisture of soils traversed. Dry sandy soils present a lower risk than wet clay or loam soils.

10.5 Rehabilitation of degraded sites

There are no pristine vegetation segments within the survey area. Introduced weeds and grasses occupy most of the banksia woodlands and seasonally dry areas of the *Eucalyptus rudis / Melaleuca rhaphiophylla* woodlands, displacing native species. A high level of human activity has further degraded the area through removal of vegetation, livestock grazing, soil compacting, frequent fire events and *Phytophthora cinnamomi* introduction.

It is expected that management planning for the survey area will include the rehabilitation of degraded sites through access control, weed eradication, planting, protection from fire and disease control. Two of the criteria in determining the species of native plants for rehabilitation planting will be the degree of susceptibility to *Phytophthora* and the current disease status of the area to be planted.

10.6 Phosphorous acid treatment

Phosphorous acid is a cheap, biodegradable and non-toxic chemical that has been found to be very effective as both a curative and protectant against *Phytophthora cinnamomi* in a range of susceptible hosts (Kormorek, Shearer, Smith & Fairman, 1997). The impact that *Phytophthora cinnamomi* will have on the susceptible vegetation within the survey area may be reduced with the application of phosphorous acid.

11. RECOMMENDATIONS FOR MANAGEMENT

11.1 Control of autonomous spread of *Phytophthora cinnamomi*

It is recommended that all susceptible species within 20 metres of existing *Phytophthora cinnamomi* infections be treated with phosphorous acid at the rates and frequency recommended by the Department of Conservation and Land Management.

It is recommended that all susceptible species within the survey area be considered for treatment with phosphorous acid to protect against autonomous spread from cryptic disease. The cost of application is the factor that will determine the viability of this protection strategy.

11.2 Control of vectored spread of *Phytophthora* and *Armillaria*

It is recommended that *Phytophthora* susceptible vegetation be protected from the introduction of infected material through vectored spread by controlling access to susceptible vegetation associations. Tracks that should be considered for closure or restricted access in order of priority are:

- the unsealed vehicle track that runs east from the southern end of Carnegie Road to the Serpentine River;
- vehicle access tracks from private property that cross into susceptible vegetation associations on the eastern bank of the Serpentine River;
- the unsealed vehicle access track that extends south from Koolyanga Road along the S.E.C.W.A. power line easement;
- the dual-use walk and bridle trail on the eastern bank of the Serpentine River where the trail crosses susceptible vegetation associations;
- the unsealed walk trail that runs south westerly from the footpath at the intersection of Tuart road and Redcliffe Road, to private property location 123, Carnegie Road.

It is recommended that all susceptible species within 20 metres of existing tracks and trails are treated with phosphorous acid at the rates and frequency recommended by the Department of Conservation and Land Management as a curative measure against any cryptic disease.

It is recommended that no soil or plant material from an external source of unknown or infected disease status (including *Armillaria*) be deposited in the survey area.

11.3 Rehabilitation

Plant species that can be considered for rehabilitation programs in disease free susceptible vegetation associations is dependent on the disease control measures. If the recommendations for disease control listed in 11.1 and 11.2 are incorporated into management planning, and the disease control measures effectively applied, it is probable that rehabilitation with susceptible species will be successful. A list of *Phytophthora* susceptible species endemic to the area that may be considered for rehabilitation programs forms Appendix 3.

If the recommended disease control measure listed in 11.1 and 11.2 are not incorporated into management planning, it is recommended that non-susceptible species be utilised for rehabilitation planting programs in susceptible vegetation associations. As many of the endemic native species are susceptible, non-endemic native species should be considered for rehabilitation programs. A list of non-susceptible native species forms Appendix 4.

It is recommended that *Phytophthora* infected areas are rehabilitated with non-susceptible native species. A list of non-susceptible native species forms Appendix 4.

It is recommended that non-susceptible species be utilised for rehabilitation planting programs in vegetation associations not susceptible to *Phytophthora*. Plants of the same species currently represented in these areas should be utilised.

11.4 Community education

It is recommended that information on disease control measures be provided to members of the community who visit the survey area. The reasons for access restrictions and track closures should be made clear to the public to maximise cooperation and compliance. It is recommended that a network of information signs detailing the disease control measures being undertaken are placed at strategic points within the reserve.

11.5 Evaluation of disease management

It is recommended that the susceptible vegetation associations be surveyed for disease every three years to determine the effectiveness of disease management.

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MAP: DISEASE DISTRIBUTION

Serpentine River

Goegrup Lake to Pinjarra Road

WATER AND RIVERS COMMISSION

N

50 0 50 100 150 200

METRES

BULARA RD

BEDINGFELD RD

KOOLYANGA PL

KOOLYANGA RD

MANJEEP RD

BANJUP RD

REDCLIFFE RD

WANDA RD

HOUGHAN RD (RES)

NESBIT WY

YANAGIN RD

DARBAL RD

TUART RD

DOONGIN RD

TERANCA RD

SERPENTINE COVE

OLD PINJARRA RD

PINJARRA RD

NOORUMBA RD

CAPONI RD

Serpentine River

1 2 3 4 5 6 7 8

MAP LEGEND

DIEBACK FREE
Phytophthora susceptible vegetation complexes free of Phytophthora symptoms.

DIEBACK
Phytophthora susceptible vegetation complexes infected with Phytophthora cinnamomi and showing secondary symptoms.

NON-SUSCEPTIBLE
Phytophthora resistant vegetation complexes with very few or no susceptible species.

1 Sample site and reference number.

Appendix 1

Sample summary

SAMPLE IDENTIFICATION	DATE SAMPLED	PLANT SPECIES SAMPLED	SAMPLE TYPE	RESULT
Serpentine 1	17/6/97	*Banksia spp.*	soil, root, collar	Negative
Serpentine 2	19/6/97	*Banksia littoralis*	soil, root, collar	*P. cinnamomi*
Serpentine 3	19/6/97	*Banksia littoralis*	soil, root, collar	*P. cinnamomi*
Serpentine 4	19/6/97	*Banksia menziesii*	soil, root, collar	*P. cinnamomi*
Serpentine 5	24/6/97	*Banksia menziesii*	soil, root, collar	Negative
Serpentine 6	24/6/97	*Banksia menziesii*	soil, root, collar	*P. cinnamomi*
Serpentine 7	24/6/97	*Banksia littoralis*	soil, root, collar	*P. cinnamomi*
Serpentine 8	24/6/97	*Banksia grandis*	soil, root, collar	*P. cinnamomi*

Appendix 3

Plant species of the coastal plain susceptible to *Phytophthora cinnamomi.*

Family	Species	Common name
Dasypoganaceae	*Lomandra odora*	Tiered mat rush
Dilleniaceae	*Hibbertia hypericoides*	Yellow buttercup
	Hibbertia subvaginata	
Epariedaceae	*Adersonia heterophylla*	
	Adersonia lehmanniana	
	Astroloma xerophyllum	
	Conostephium pendalum	Pearl flower
	Leucopogan conostephioides	
Iridaceae	*Patersonia occidentalis*	Purple flag
	Patersonia rudis	Hairy flag
	Patersonia umbrosa var. xanthina	Yellow flag
Myrtaceae	*Eucalyptus marginata*	Jarrah
	Melaleuca scabra	Rough honey myrtle
	Scholtzia involucrata	Spiked scholitzia
	Verticordia nitens	Feather flower
Papilionaceae	*Bossia ericarpa*	
	Jacksonia floribunda	Holly pea
Proteaceae	*Adenanthos serivea*	
	Adenanthos sygnorum	Woolly bush
	Banksia attenuata	Slender banksia
	Banksia grandis	Bull banksia
	Banksia ilicifolia	Holly leaved banksia
	Banksia litoralis	Swamp banksia
	Banksia menziesii	Menzies banksia
	Banksia prionotes	Acorn banksia
	Banksia sphaerocarpa	Fox banksia
	Conosperma stoechadis	Smoke bush
	Dryandra carduacea	Pingle
	Dryandra nivea	Couch pot dryandra
	Dryandra sessilis	Parrot bush
	Isopogon formosus	Cone flower
	Petrophile linearis	Pixie mop
	Stirlingia latifolia	Blue boy
	Synaphea petiolaris	Synaphea
Xanthorrhoeaceae	*Xanthorrhoea spp.*	Blackboys
Zamiaceae	*Macrozamia riedlei*	Zamia palm

This list of plant species is from the Department of Conservation and Land Management Dieback Interpreters Procedures Manual, Appendix 10. The list is not necessarily complete and is under constant revision.

Appendix 4

Plant species not susceptible to *Phytophthora cinnamomi* suitable for rehabilitation planting in infested areas.

SPECIES	COMMON NAME	DESCRIPTION
	Trees	
Acacia saligna	Orange wattle / Coojong	Dense spreading tree to six metres.
Allocasuarina fraseriana	Sheoak	Erect slow growing tree to 15 metres.
Eucalyptus calophylla	Marri / Red gum	Large erect tree to 20 metres.
	Shrubs	
Acacia pulchella	Prickly moses	Dense shrub to 1.5 metres.
Allocasuarina humilis	Dwarf sheoak	Shrub to two metres.
Anigozanthus manglesii	Kangaroo paw	Small plant with red and green flowers.
Bossiaea ericocarpa		Small shrub to 0.5 metres.
Hakea prostrata	Harsh hakea	Erect shrub or small tree to four metres.
Kunzea ericifolia		Erect shrub to three metres.
	Ground Cover	
Hardenbergia comptoniana	Native wisteria	Climbing shrub that tends to be invasive.
Kennedia prostrata	Red runner	Prostrate shrub with red flowers.