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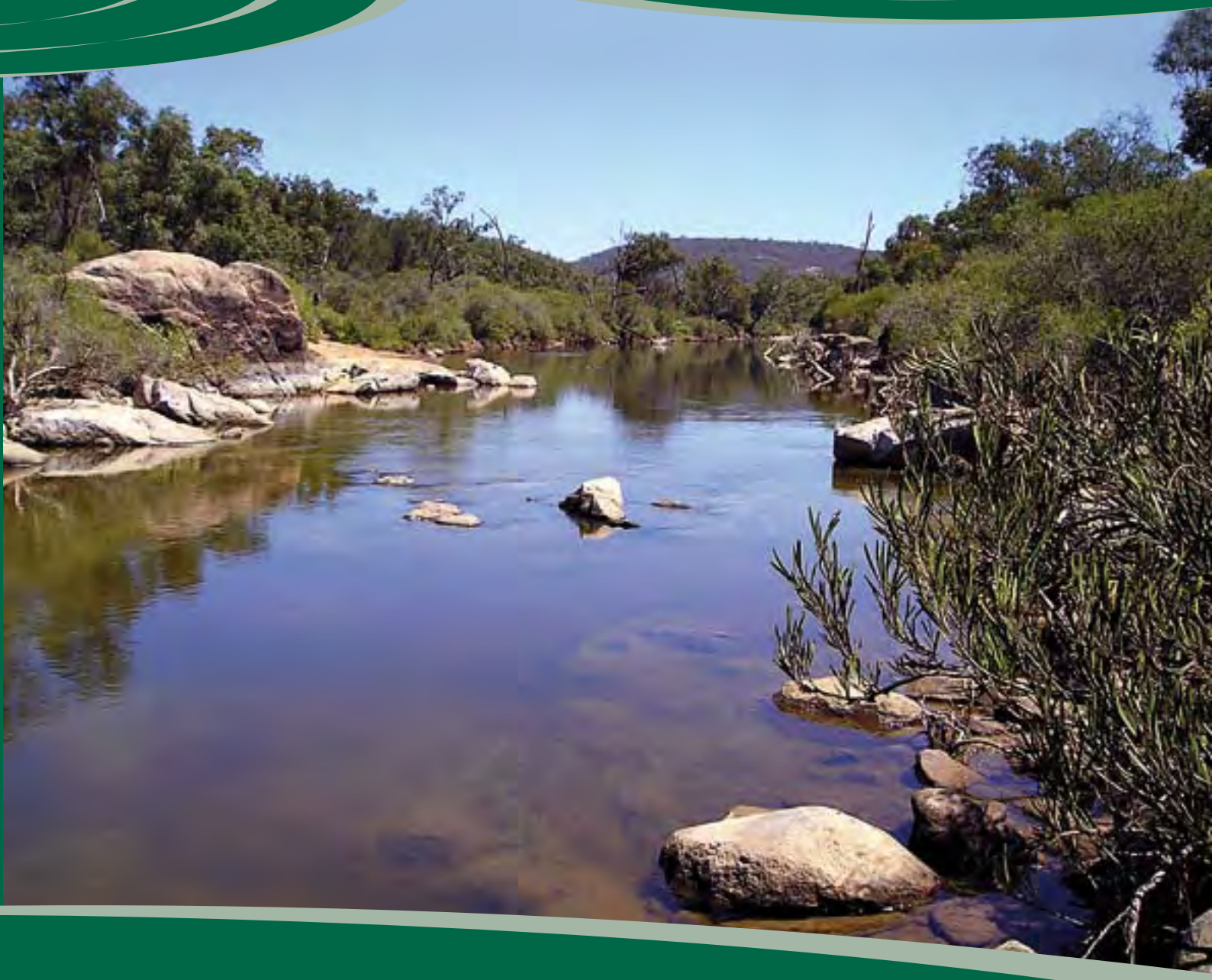

Lower Avon river recovery plan: Incorporating foreshore and channel assessment

River recovery plan series

Report No. RRP 13
June 2008

Department of Water
Government of Western Australia

Lower Avon river recovery plan: Incorporating foreshore and channel assessment

Prepared by Viv Read & Associates for
Department of Water and the Avon Waterways Committee.

This project is funded by the Avon Catchment Council and the
State and Australian Governments through the Natural Heritage Trust
and the National Action Plan for Salinity and Water Quality.

Department of Water

River recovery plan series

Report No. RRP 13

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Cover photograph: One of the scenic river pools of the Lower Avon River
All photographs by Viv Read unless otherwise stated.

Foreword

The foreshore and channel survey combined with the recovery plan for the Lower Avon river section was initiated by the Department of Water for continuity between the recovery planning processes for the Avon River and its major tributaries and management of the Swan River estuary.

The Lower Avon river section is recognised as a high quality river environment. While there are issues identified for management action, particularly for sediment management and further control of wild pigs and environmental weeds, it is equally important to ensure that existing environmental values are maintained.

A key issue of concern has been the transport of sediment from the Avon River to the upper reaches of the Swan River. Significant river pools within the Shire of Toodyay are continuing to fill with sediment. This indicates the potential for significant future sediment deposition, particularly in river pools within Walyunga National Park. Department of Water has commissioned a separate study of river sediment sources and the potential for further river pool infill. This study will be linked with the recovery plan for issues of sediment management.

Management of this section of the Avon River is recognised to be a cooperative effort. This includes the state government agencies with natural resource responsibility associated with the river, Avon Catchment Council, Swan Catchment Council, local government and private landholders (including the Australian Wildlife Conservancy).

Martin Revell
Department of Water
Program Manager, Avon
Swan–Avon Region
Northam District Office

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Abbreviations

ACC	Avon Catchment Council
AHD	Australian height datum
AWC	Australian Wildlife Conservancy
DEC	Department of Environment and Conservation
DPI	Department for Planning and Infrastructure
LHS	Left hand side
PTA	Public Transport Authority
RHS	Right hand side
SCC	Swan Catchment Council
SRT	Swan River Trust
WNR	Westnet Rail

Summary

The *Lower Avon river recovery plan* is based on survey information collected from the eastern boundary of the Avon Valley National Park downstream to the river confluence with Wooroloo Brook.

The field survey, undertaken during September 2006, provides foreshore and channel assessment information for 31 sections of the river, each approximately 1 km in length.

A summary of this information is provided within this plan. The key findings from the survey are:

1 The river channel and meander pattern have not significantly altered in the period since the change in catchment land use. The meander pattern is subdued and controlled primarily by bedrock outcropping, as may be expected in an erosional landscape.

2 There is minimal floodplain development and relatively minor formation of floodways and anabranches indicating that the main channel is efficient in discharging high streamflow events.

3 Although there are many rapids or riffle structures, there is a greater proportion of river pools and reaches. Most river pools are of high value and in stable condition. Moondyne Pool and Boongarup Pool need to be assessed for potential sediment infill.

4 Salinity has minimal impact on the riverine environment.

5 The river banks are generally stable with most survey sections having minimal or localised bank erosion or slumping. There are nine survey sections with significant or severe bank erosion.

6 Wild pigs (*Sus scrofa*) are causing extensive damage by soil disturbance in the floodways, levee and in some locations, the river banks. These medium to fine alluvial soils are vulnerable to erosion during winter flow events and are a potential source of sedimentation downstream.

7 There is only minimal sediment deposition in this section of the Avon River.

8 Riparian vegetation is generally diverse, healthy and regenerating. This provides high quality habitat opportunities for wildlife.

9 Weed infestations are increasing. Watsonia (*Watsonia bulbillifera*), castor oil plant (*Ricinus communis*) and soursob (*Oxalis pes-caprae*) occur frequently and at levels that suppress groundcover vegetation and natural regeneration. There is no evidence of bridal creeper (*Asparagus asparagoides*), blackberry (*Rubus fructicosus*) or sharp rush (*Juncus actus*).

10 River fencing generally does not exist on public land but is not required. River fencing on private land is generally in good condition.

11 Twelve of the 31 survey sections were assessed to have excellent overall environmental health. Only four of the sections were assessed as moderate and none assessed as poor or worse.

12 Foreshore assessment shows all survey sections to be A-grade (pristine or slightly disturbed) or B-grade (degraded by weeds).

13. Many sections had high scenic value. There is very limited public access to these sites.

Consultation with key stakeholder organisations provided a list of additional management issues to be considered in the recovery plan. These, with the survey findings, were used to develop ten management objectives. They are:

1 To enhance the high biological diversity and habitat quality of the natural river environment with linkages to adjacent landscape and catchment values.

2 To increase recognition by government and community of the Lower Avon river section as a significant wild and scenic river.

3 To identify and maintain the significant Aboriginal and European heritage values associated with the Lower Avon river section.

4 To identify and minimise public risk in the river environment.

5 To increase the level of public information and access to the Lower Avon river section, including increased public recreational opportunities.

6 To eradicate, or substantially control, wild pigs within the riverine environment.

7 To eradicate, or substantially control, the two existing dominant weed species in the river environment – watsonia (*Watsonia bulbillifera*) and castor oil plant (*Ricinus communis*) and prevent the introduction of three potentially threatening weed species – bridal creeper (*Asparagus asparagoides*), blackberry (*Rubus fructicosus*) or sharp rush (*Juncus actus*).

8 To monitor change in the level of sediment within significant pools of the Lower Avon river section.

9 To minimise fire risk in the riverine environment.

10 To ensure consistent management is applied for identified river recovery outcomes.

Management actions to achieve the objectives are focused on increasing the capacity of existing planning and management arrangements. This is required particularly for control of wild pigs and priority weed species in the river environment.

1 Introduction

The Avon River basin landscape is of considerable antiquity, originating at least some 50 million years ago, and has been considerably modified over time. The Swan and Avon rivers have a total catchment area of 125 000 km², extending from Dalwallinu in the north, Southern Cross in the north-east and Lake King in the south-east down to the river mouth at Fremantle.

The Avon River and the Swan River are the same river system. The two names simply represent an historical anomaly. The Avon is taken as that section of the river upstream from the confluence with Wooroloo Brook. The Swan River is primarily an estuarine system with other smaller tributaries.

In response to community concern about the declining health of the Avon River during the 1980s, the state government initiated a range of management arrangements in association with local government and the community for river management. In 1996, a foreshore and channel condition survey was undertaken from the eastern boundary of the Avon Valley National Park upstream to Yenyening Lakes – a distance of 190 km (Ecoscape and Jim Davies and Associates, 1996). Based on that survey information, 18 river sections of the main channel of the river were identified for management. Recovery plans for all river sections have since been prepared by the Department of Water, and its predecessors, in consultation with landholders adjacent to the river and local community groups. Map 1 shows the locations of the river recovery plan sections, including the Lower Avon section.

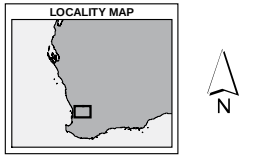
The processes of foreshore and channel assessment with recovery planning have been combined before for the Aldersyde-Kweda section of the Upper Avon River (Viv Read & Associates, 2006) and the Dale River (Department of Water, 2006), a major tributary of the Avon River.

This report documents the survey and recovery plan for the Avon River from the eastern boundary of the Avon Valley National Park downstream to the Wooroloo Brook confluence – a distance of more than 30 km. This is described as the Lower Avon river section.

Survey and planning of this section of the Avon River is significant in that it provides completion of planning processes for the whole Avon River. It is also significant because it is the section of the river that descends the Darling Scarp to the Swan River estuary.

The Lower Avon river section differs to other Avon river sections as most of the adjacent land has public vesting, including two national parks managed by the Department of Environment and Conservation (DEC). Management plans for these two parks are yet to be prepared. Significantly, there is a reserve for rail infrastructure for the full length of the section south of the river. Rail corridor plans exist for the

Map 1
Avon River pools and recovery sections



LEGEND

- Major river
- Minor river
- Main road
- Major Town
- Town
- 3 Section Number
- Avon River Sections
- Pools
- Avon River Basin

0 10 20 30
Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA 94 Zone 50

Project Information
Requested by: Kate Gole
Map Author: Tom Lee
Task ID: 6697
File Location: \\Pentecost\gis_projects\RS\Sn\96209\0005
Filename: map2_AvonPoolsRecoverySections_A4grey
Date: 28th May 2007

SOURCES

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Dataset Name	CUSTODIAN ACRONYM	Metadata Date
Towns	DLI	08/08/2004
Road Centrelines	DLI	01/05/2004
Hydrology, linear (heirachy)	DOW	10/02/2005
Hydrographic Catchments	DOE	23/03/2005

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purposes of infrastructure management and maintenance, however these do not include requirements for river management. One location of public land is currently used for student cadet training.

There are six private landholdings adjacent to the river in this section. There is an environmental management plan for one private landholding, owned by the Australian Wildlife Conservancy (AWC), which extends both sides of the river.

The purpose of the survey and recovery plan for the Lower Avon river section is to provide a strategic approach to management of the river system in a way that is integrated with adjacent public and private land holdings. The plan is based on key management issues identified by adjacent landholders or from river survey information.

1.1 Aim, objectives and scope of the survey and plan

The aim of the foreshore and channel survey combined with a recovery plan for the Lower Avon river section is to provide an informed basis for integrated river management to recover and maintain riparian ecosystem health and high river asset values through cooperative action by adjacent landholders and managers.

The objectives of the survey and plan are to:

1 identify the current environmental condition of the Lower Avon river section

2 provide an information database that enables:
   a comparison of the condition of the Lower Avon river section with other waterways
   b measures of change in the condition of the Lower Avon river section over time

3 identify the effect of the changing condition of the Lower Avon river section on downstream assets (including the Swan River and estuary)

4 engage landholder/manager interest in informed decisions for waterways management

5 provide a recovery plan for management of the Lower Avon river section.

The scope of the survey and recovery plan is limited to the river environment from the eastern boundary of the Avon Valley National Park to the Wooroloo Brook confluence. The plan considers river processes occurring upstream of this section as they may impact upon the Lower Avon although this plan does not recommend on actions to be taken upstream (appropriate actions are recommended in recovery plans for river sections 1–20). Similarly, the *Lower Avon river recovery plan* considers

the potential for downstream impacts but does not recommend off-site actions to ameliorate impacts that may occur.

At a landscape scale, the recovery plan recognises the ecological processes and management implications that occur in adjoining hill slopes and tributary catchments, however detailed management of these areas is considered to be beyond the scope of this plan.

2 Overview of the lower Avon

2.1 Location, land use and tenure

The location of the Lower Avon river section is shown in Map 1. This provides the context for the large scale of the Avon River basin and also the close proximity to the metropolitan area of Perth.

Land tenure of the Lower Avon river section is shown in Map 2. Location of the Avon Valley National Park at the upstream end and Walyunga National Park at the downstream end is significant. The AWC manages 1863 ha of land (Paruna Sanctuary), located mostly south of the river, for conservation purposes in a way that is generally consistent with national park management.

The location and lot numbers for owners and managers of land adjacent to the Lower Avon river section are listed in Appendix 1.

2.2 Riparian environment description

The river environment for the Lower Avon river section is dominated by recent geological dissection of the Darling Scarp. Soils are generally skeletal over granite or metamorphic rock outcropping adjacent to the river. Medium to fine alluvial soils occur on the depositional side of meanders. There is effectively no floodplain development in this section of the river.

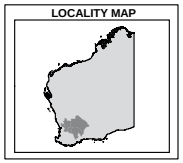
The river valley width is 1.5–3.0 km. The valley ridge is generally 70–80 m above the river bed. The Lower Avon river section descends from 90 m to 20 m at Wooroloo Brook – a total descent of 70 m. Lateritised duricrust remnants of the Yilgarn Plateau occur at approximately 240 m AHD with parent rock extrusions up to 360 m AHD (e.g. Smiths Mill Hill, south of the river).

Natural vegetation is typical of the Darling System, Dale Sub-district, Darling Botanical District (Beard, 1979). Vegetation mapping undertaken by Heddle, Loneragan and Havel (1980) show the river as the *Helena Complex* which has swamp paperbark (*Melaleuca raphiophylla),* wandoo (*Eucalyptus wandoo*) and flooded gum (*Eucalyptus rudis*) as dominant species. Vegetation structure is described as woodland.

A list of Declared Rare and Priority Flora are listed for the sanctuary in the *Paruna Sanctuary management plan* (Australian Wildlife Conservatory, 1998). Fauna species are also listed in the management plan.

The climate for Bakers Hill and for Perth Airport is considered to be representative of the Lower Avon river section. The Bureau of Meteorology records <www.bom.gov.au> show the average annual rainfall to be 552 mm with an average of 64 rain days each

Map 2
Location of the Lower Avon section within the Avon River Basin



LEGEND

- Major Town
- Town
- Major Road
- Major River
- Avon River Basin

N

0 20 40 60 80

Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA 94 Zone 50

Project Information
Requested by: Kate Gole
Map Author: Tom Lee
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Towns - DLI - 08/08/2004
Road Centrelines - DLI - 01/05/2004
Hydrography, linear (heiracthy) - DOE - 13/04/2005
Hydrographic Catchments-Catchments - DOE - 23/3/05
WA Coastline, WRC (poly) - DOE - 01/06/2004

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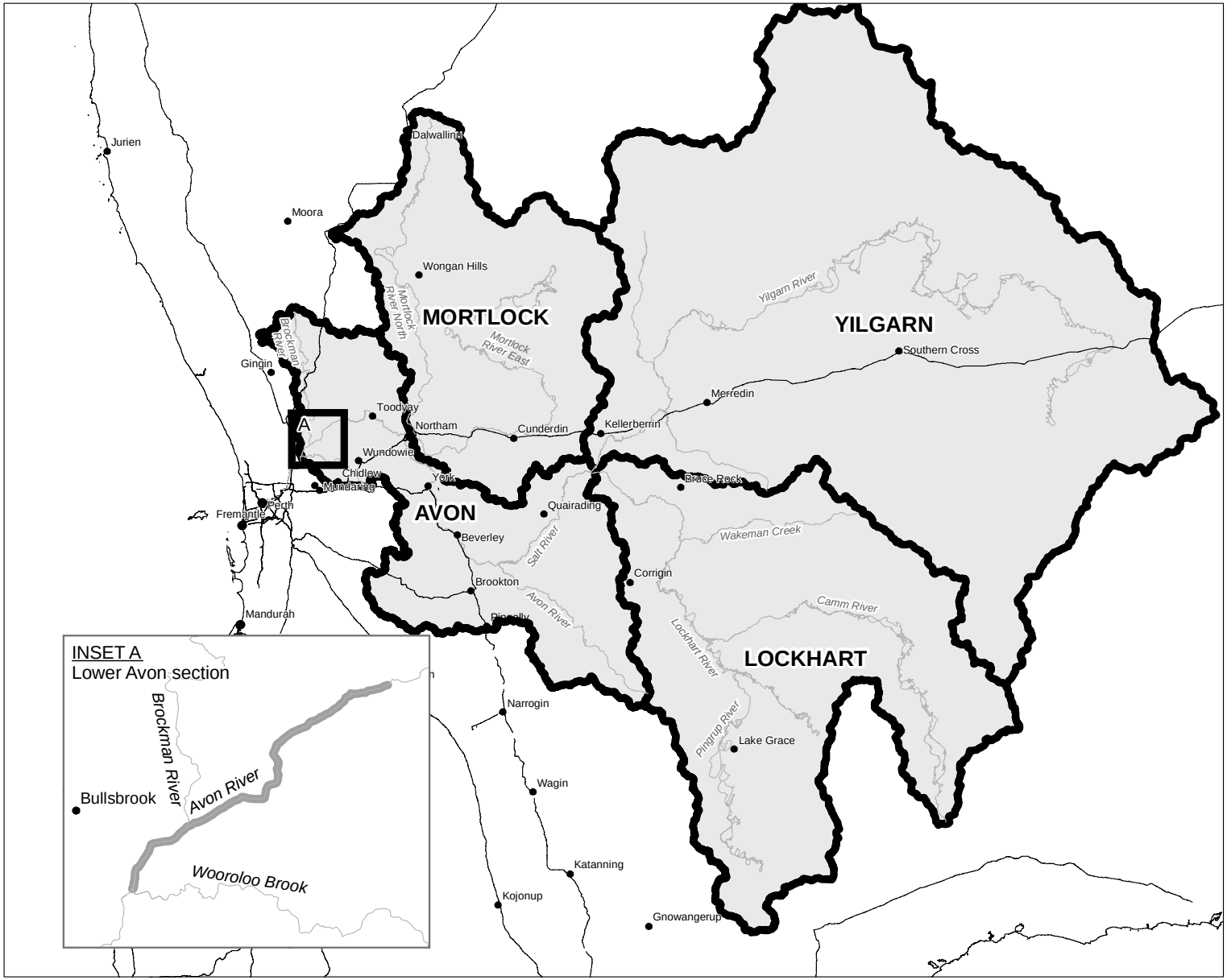

Map 3
Lower Avon section

Legend

- Pool
- Lower Avon section
- Major River
- Minor River
- Main Road
- LGA Boundary
- Freehold Land
- National Park
- Public Land
- Avon River Basin

N

0 1 2 3 4 5

Kilometres

Datum and Projection Information

Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA 94 Zone 50

Project Information

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Map Author: Tom Lee
Task ID: 6697
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SOURCES

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Hydrography, linear - DOE - 01/02/2004
Road centrelines - DLI - 01/05/2004
Local Government Authorities - DLI - 08/07/2004
CALM Lands and Waters - DCLM - 01/06/2005
Hydrographic Catchments - DOE - 23/03/2005
Cadastre, Land Tenure - DLI - 01/05/2005

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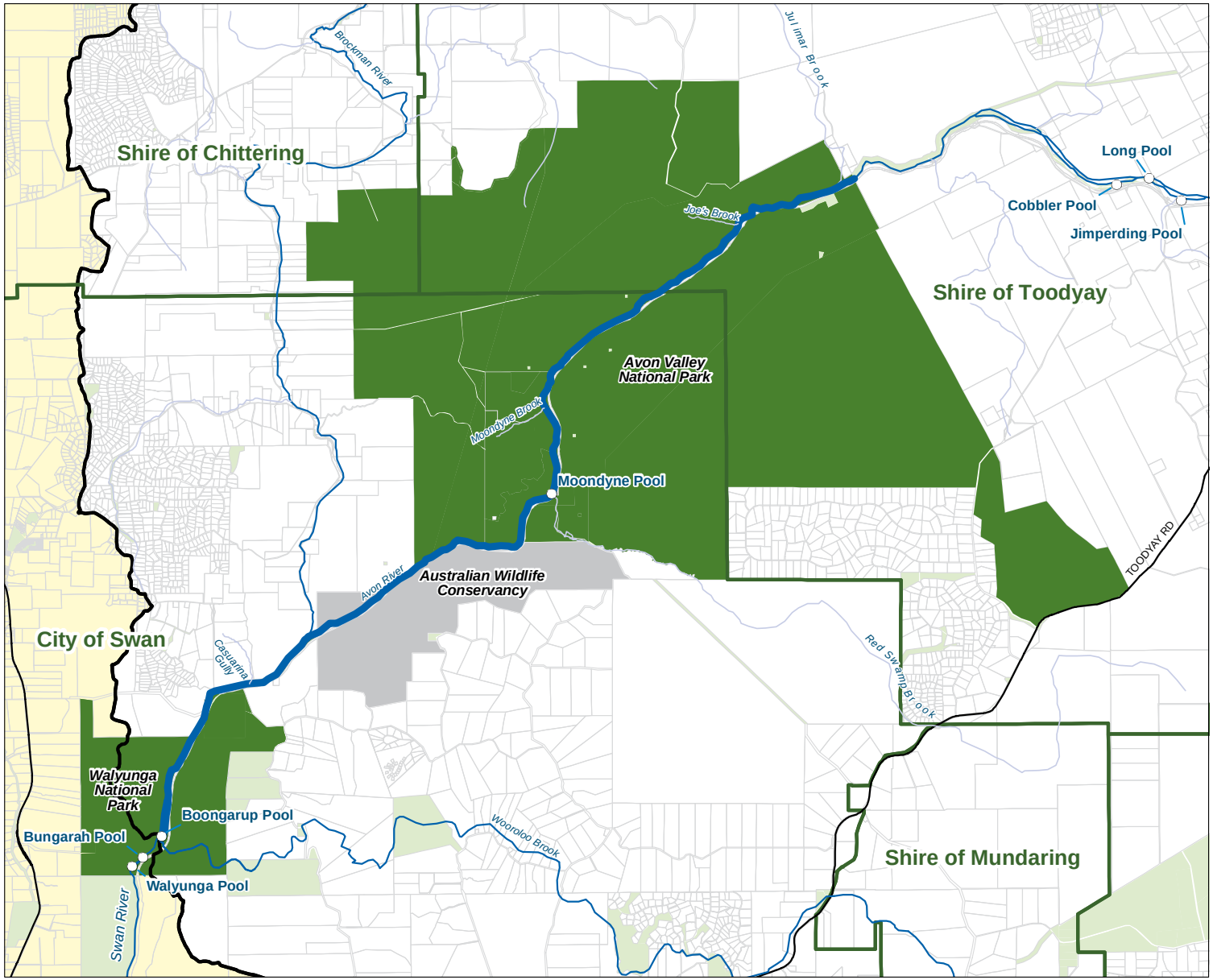


year for Bakers Hill. For Perth Airport, the average annual rainfall is 767 mm with an average of 87 rain days. Most rain occurs in the May–September period and highest monthly rainfall is during June and July.

On average, the coldest month is August (8.0°C for Perth Airport and 6.3°C for Bakers Hill). The hottest month for Perth Airport is February (average maximum of 31.8°C) and January for Bakers Hill (average maximum of 31.9°C). The average daily evaporation is 5.6 mm at Bakers Hill.

2.3 River channel and tributaries

The Lower Avon river section is a single channel with only minor areas of braided channel between river pools. Unlike the river channel upstream from Toodyay to Brookton, the channel characteristics have not been altered for flood mitigation purposes. The sediment bed load prior to settlement was in a dynamic equilibrium (i.e. a balance between natural sediment gains through erosion of stream banks and losses through downstream transport).

The major tributaries to the Lower Avon are Julimar Brook, Joe's Brook, Red Swamp Brook, Brockman River, Casuarina Gully and Wooroloo Brook. There are many unnamed smaller tributaries that have limited streamflow contribution to the river.

Photo 1 *The Brockman River confluence*

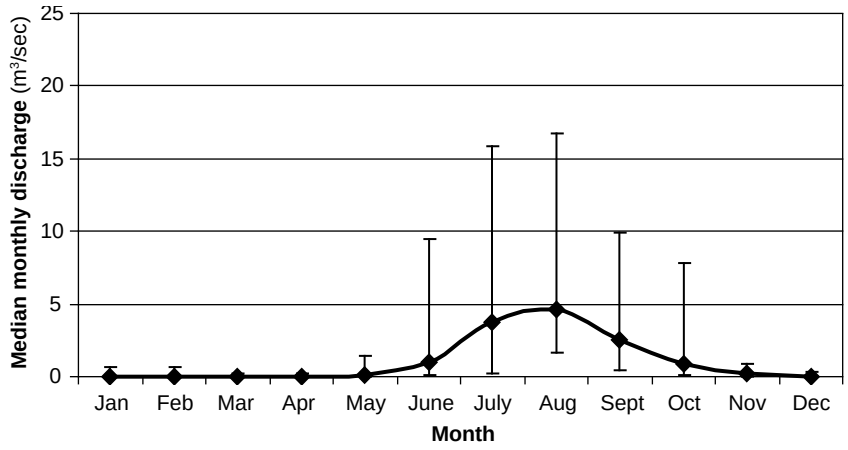
Photo 2 *Wooroloo Brook*

2.4 Streamflow and water quality

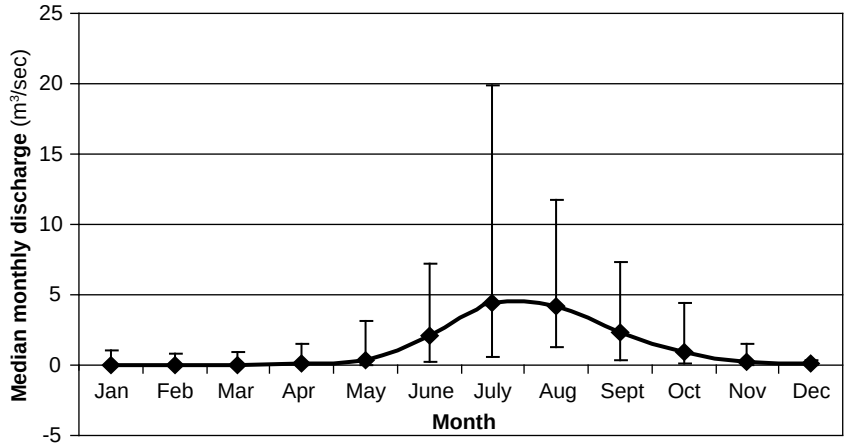
Flow in the Avon River commences in April after the onset of winter rains and with falling temperatures and evaporation. In most years flow diminishes or ceases in upper sections before the end of December. A gauging station at Walyunga (gauging station ref: 616011, downstream of the confluences of the Brockman River and Wooroloo Brook) has records that date back to 1970. The Department of Water maintains the station and records. These show the average flow is for 310 days or 85% of the year.

Monthly streamflow is shown for the Brockman River, Wooroloo Brook and the lower Avon River in Figure 2.1 and detailed in Appendix 2. This shows flow to be least in March and greatest in July and August. It also shows the Brockman River to have similar or greater median flow than the lower Avon River for the January–March period.

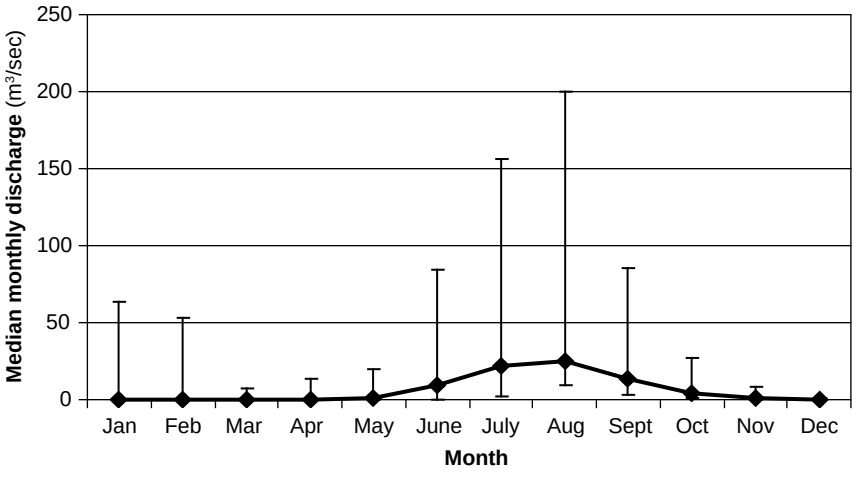
Total annual streamflow at the Walyunga gauging station ranges from 95 GL in 1979 to 1270 GL in 1974. The average annual flow volume is approximately 360 GL. The monthly flow of 171 GL for January 2000 is the highest summer flow and 535 GL for August 1974 is the highest winter flow recorded for this station.



(a) Brockman River



(b) Wooroloo Brook



(c) Avon River

Figure 2.1 *Median monthly streamflow and range for (a) Brockman River at the Yalliawirra gauging station (616019) (b) Wooroloo Brook at the Karl's Ranch gauging station (616001) (c) Avon River at the Walyunga gauging station (616011)*

Conductivity records kept for Walyunga gauging station show that the salinity of streamflow in summer (approximately 6000 mg/L) is about twice that of winter flow. These records include flow from both the Brockman River and Wooroloo Brook which are less saline than the Avon.

About 50 years ago the river downstream from Toodyay was suitable for watering horses and was used for irrigating citrus orchards (Gavin Donegan, pers. comm.). The river is no longer used for stock-water or irrigation due to increasing salinity. The January 2000 flood flow was of high salinity causing shrubs to die and tree trunks to be stained by salt.

The average salt load discharged from the Avon River is approximately 2 160 000 t annually.

Monitoring at this gauging station shows there to be no significant long term trend (Mayer et al., 2005), as shown in Figure 2.2.

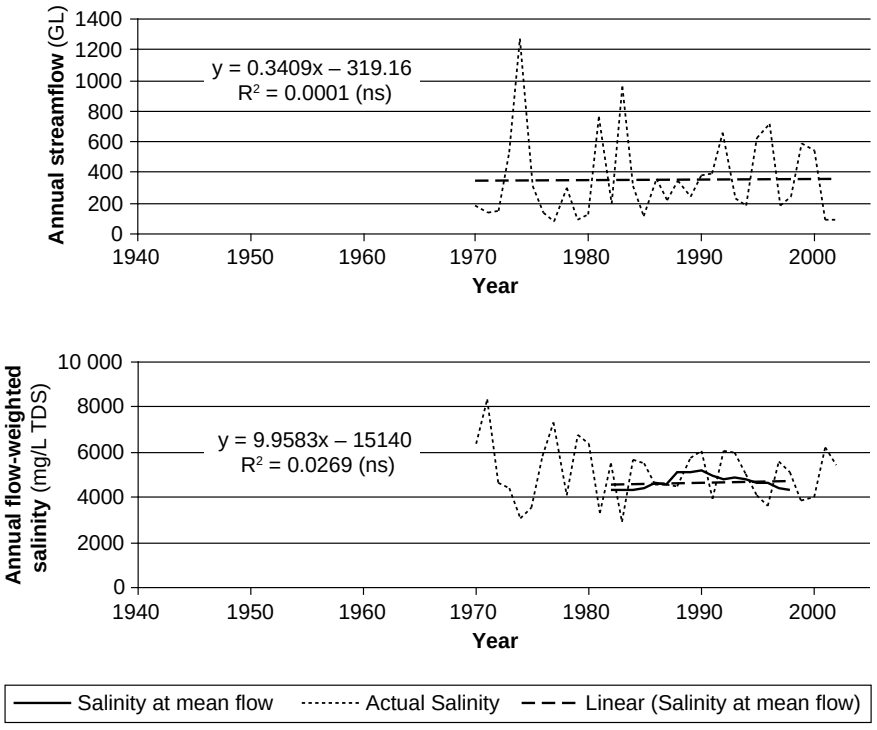


Figure 2.2 *Annual streamflow and salinity in the Avon River at Walyunga (adapted from Mayer et al., 2005)*

The Swan River Trust (SRT) has monitored nutrients in major tributaries to the Swan–Canning Estuary, including the Avon, since 1987. In the period to 1992, the Avon River was a major contributor of nutrients to the estuary. Of the total estimated load of nitrogen, over 50 per cent came from the Avon catchment, primarily due to large annual flow discharge (62 per cent of total flow). About 30 per cent of the phosphorus load to the estuary came from the Avon (Donohue et al., 1994).

Following intense algal blooms in the Swan–Canning Estuary in 1994, a draft environmental protection policy for the Swan and Canning rivers proposed a target phosphorus (P) load of 6.4 t/year from the Avon River. Nutrient loads from the Avon River have been estimated from Department of Water and SRT monitoring between 1994 and 2006. The average annual P load over this period is approximately 340 t/year and the average annual N load is approximately 10.4 t/year.

2.5 Floods

A study of flooding in the Avon River (Binnie and Partners, 1985) shows major floods to have occurred in 1862, 1872, 1910, 1917, 1926, 1930, 1945, 1946, 1955, 1958, 1963, 1964 and 1983.

Significant rainfall in the Avon River catchment during 21–22 January 2000 caused high river levels from Lake King to Perth. The two-day rainfall was in excess of 100 mm over a large area from east of Hyden to Beverley. This event was estimated to have an average recurrence interval of 1 in 8 years (using all records since 1970), and an average recurrence interval of 1 in 20 years for summer events (Water and Rivers Commission, 2000).

Monitoring of this event showed that 58% of the total nitrogen (TN) load (470 t) and 54% of the total phosphorus (TP) load (19 t) came from the large inland Lockhart and Yilgarn salt lake subcatchments. This event caused the Swan River to be closed for public use due to health risks associated with algal blooms.

3 Description of methods

The foreshore and channel survey was undertaken according to standard methods developed for assessment of waterways in the south-west of Western Australia (Pen and Scott, 1995) and adapted for the Avon River catchment.

The recovery plan is based on a set of key issues derived from the survey and from consultation with key stakeholders.

3.1 Contact with landowners and managers

Letters were sent by the Department of Water (Northam office) to all landholders and managers with properties adjacent to the Lower Avon river section prior to the survey. This correspondence was to inform landholders of the purpose of the survey and, where relevant, to request their permission for entry to the properties during the survey.

Meetings were arranged with all public land managers prior to the survey to ensure permission for entry was granted and to obtain information relevant to river management. A permit for entry to the rail reserve during the period of the survey was obtained.

Results of the survey and implications for management were discussed with public land managers at a workshop held on 20 April 2007.

3.2 Field survey

The foreshore and channel assessment was undertaken by walking survey during September 2006. The survey commenced where the river enters the eastern boundary of the Avon Valley National Park and extended downstream to the Wooroloo Brook confluence, an estimated survey distance of 28.7 km.

The field survey was planned using 1:5000-scale colour aerial photo-mosaics (December 2003 photography) showing property boundaries and the approximate location of the railway reserve.

Survey section lengths were measured using a Scalex map wheel along the survey traverse identified on the 1:5000-scale aerial photos. The length of waterway is estimated to be 10% greater than the survey distance due to meanders.

The method of survey was to walk both sides of the waterway making observations of foreshore and channel condition for each of the 31 survey sections. The length of each survey section was estimated during survey planning to be 1 km although the actual distance measured from global positioning system (GPS) waypoints for each

section varied from this (Appendix 3). At the end of each section, records were made of observations for:

- waterway features
- river landform
- stream bank stability
- water quality
- riparian vegetation species and health
- habitat quality and diversity
- birds and other native animals
- weeds and feral animals
- riparian zone fencing and management
- opportunities and needs for further river management
- foreshore condition grade (based on criteria developed by Pen and Scott, 1995)
- stream environmental rating.

The location for start and finish of each section was recorded using a global positioning system (Magellan GPS 315) for the right hand side of the river. The coordinates for each section are provided in Appendix 3 and maps 4 and 5 show the survey section locations. Additional locations for sites of specific interest were also recorded for each section.

A standardised foreshore and channel assessment form was used to record information survey information (Appendix 4).

Stream salinity was measured at each section end and tributary confluence where there was streamflow, using a Hanna HI 8733 conductivity meter.

Plants and weeds were identified in the field and confirmed with relevant flora.

Birds and other animals were recorded for each section by sightings and call identification.

The survey was conducted downstream. However, all information was recorded in the standard format of left hand side and right hand side being as if facing upstream. Recordings were made at the downstream end of each section.

3.3 Information analysis

All quantified information has been recorded in a formatted Microsoft Access database which is held by Department of Water, Northam. This provides for analysis of sites and the complete set of stream sections. These are discussed in the following sections.

The foreshore condition grade is based on an on-site assessment of the foreshore considering a range of factors, but particularly the impacts of weed invasion and erosion. A description of the foreshore condition grades is included in Appendix 5.

The overall stream environmental health rating (OSEHR) is also assessed on-site. It integrates a set of criteria to provide a holistic index of environmental health. The criteria include:

- floodway and bank vegetation
- verge vegetation
- stream cover
- bank stability and sedimentation
- habitat diversity
- surrounding land use.

Assessment of values for each of these criteria is relatively subjective, however the summation of all values does provide a comparative basis for identifying areas of high value and other areas in need of management effort.

The scoring system used to generate the OSEHR is shown in Appendix 6.

4 Survey results

The survey of Lower Avon river section is based on 31 survey sections that vary in length from 599 m (LA20) to 1179 m (LA26). The average survey length is 927 m. The survey length for each section is shown in Appendix 3. The total survey distance was 28.73 km. Assuming the stream length is 10% greater than the survey distance, the length of the Lower Avon river section is approximately 31.6 km.

A description of each survey section is provided in Appendix 7. This includes photo references.

Detailed river channel information for each survey section is provided in Appendix 8.

4.1 Channel assessment

The Lower Avon river section is a single channel river system that descends the Darling Scarp. The steeper gradient of the Avon River system commences downstream from Toodyay and continues through this section of the river to the confluence with Wooroloo Brook (Section LA31) from which point the gradient decreases onto the Swan Coastal Plain. From this section, the river is known as the Swan River and is predominantly estuarine.

There are two sections (LA13 and LA31) where the Lower Avon river section has a partially braided river channel.

The elevation of the Lower Avon river section descends from 95.0 m to 23.8 m AHD over the survey distance. Figure 4.1 shows the elevation for each survey interval. The 71.2 m fall is a gradient of 0.25% over the length of the river section. This is comparable with the gradient of river recovery plan Section 1 of the Avon River (located immediately upstream from the Avon Valley National Park) although it is greater than the gradient for other recovery plan sections upstream to the Northam Town Pool Weir (Water and Rivers Commission and Avon Waterways Committee, 2002), as shown below:

Recovery plan section	**Gradient** (%)
1	0.25
2	0.08
3	0.08
4	0.10
5	0.05

It is significant to note that tributaries to the Avon River in the dissected landscape in the Shire of Toodyay have higher channel gradients. For example, tributaries

to Jimperding Brook (upstream from the Avon Valley National Park) have channel gradients in the range of 1.2%–6.5% (Viv Read & Associates, 2008).

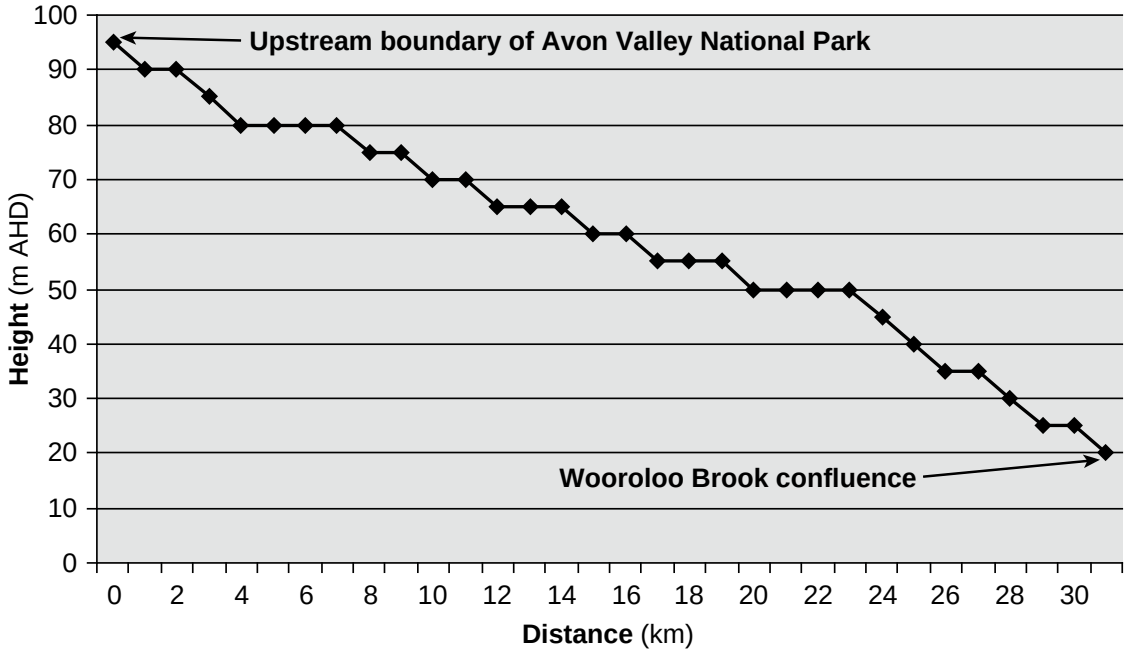


Figure 4.1 *Gradient along the lower Avon River from the upstream boundary of Avon Valley National Park to the Wooroloo Brook confluence*

4.1.1 Floodways and floodplain

Floodways are formed in the lower Avon system by deposition of medium and fine sediments on both sides of the river where there is no rock outcropping. The extent of the floodway varies between sections. The form of floodways is relatively consistent. A small levee is formed adjacent to the river channel 1–2 m high. The floodway is generally 3–5 m wide and elevated such that streamflow is diverted when river levels rise approximately 0.5–1.0 m above normal winter base flow. It is estimated that floodway flow would occur several times each year.

The levees are commonly well vegetated although groundcover is dominated by introduced weeds. The soils of the floodway levees and channels are highly disturbed by pigs and are prone to erosion during floodway flow. This is considered to be a significant source of sediments mobilised in Avon River streamflow.

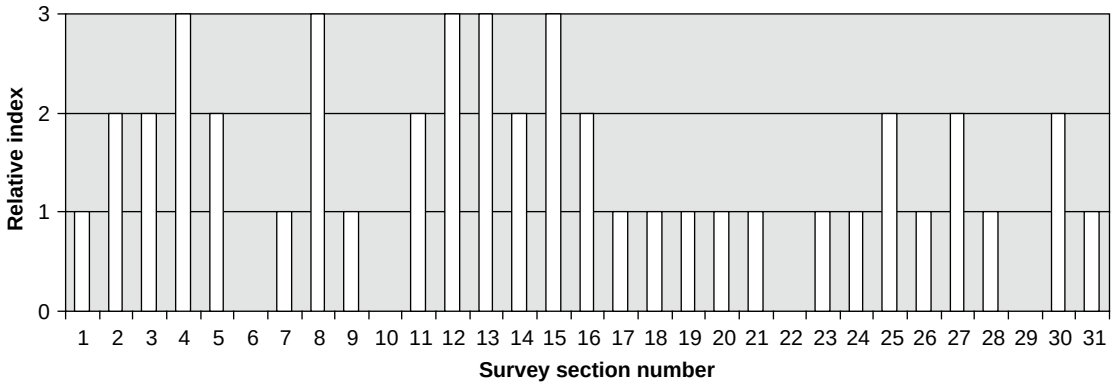
There are two significant anabranches. The one in Section LA29 is geologically controlled and forms a large rock island. The anabranch in Section LA31 is associated with the confluence of Wooroloo Brook. There are several other sections (LA01, LA05 and LA14) where base flow is divided by rock outcropping in the river channel forming rocky islands.

The Lower Avon river section has a narrow river valley and no floodplain development.

4.1.2 Meander pattern

The meander pattern of the Lower Avon river section is generally subdued with low sinuosity. The river orientation and meander pattern is determined by geologic control particularly where rock outcrops occur within the channel. A relative assessment of the meander pattern for each river section is shown in Figure 4.2.

There are four river sections that are considered to be straight (LA06, LA10, LA22 and LA29). A further 12 sections have only a low meander pattern. Overall, half of the Lower Avon river survey sections have low or no meanders. One continuous set of sections (LA17–24) is a distance of 7.4 km with little or no meandering. The most extensive meandering occurs in section LA02–05 and LA 11–16.



Note: 0 = none, 1 = low, 2 = medium and 3 = high

Figure 4.2 *Relative index of the meander pattern for survey sections of the lower Avon River*

The Lower Avon river section is located in an eroding landscape so the orientation and shape of the river is determined by underlying geology. River sections located in a depositional landscape have a sinuous meander pattern formed by anastomosing streamflow through fluvial sediments (Water and Rivers Commission, 2002).

4.1.3 River pools and riffles

The Lower Avon river section has distinct sequences of river pools and riffles that are a significant characteristic of each river section. There are many river pools ranging in length up to 1000 m (in LA20). The river pools are formed by streamflow scour of river reaches between rock outcropping. The length and spacing of river pools of the Lower Avon river section is not determined by river energy dissipation and sediment deposition processes, as occurs with other river systems through mature landscapes.

Riffles occur where rock is exposed or boulders and cobblestones have accumulated within the river channel. Some riffles are 300 m in length (e.g. in LA09 and LA27). Cobblestone riffles (e.g. the downstream end of LA31) are generally uniformly graded. Rock outcrop riffles vary significantly in shape forming waterfalls of 1–2 m, river chutes and cauldrons. Emu Falls is a complex rock outcrop in section LA04.

Some river sections have as many as five separate pools (LA05, LA22, LA25 and LA29). There are three sections (LA12, LA22 and LA29) that have five separate riffle sequences.

The length of pools and riffles for each river section is provided in Appendix 9. The total length of pools and the total length of riffles are used to provide a pool–riffle ratio (Figure 4.3). This shows Section LA20 to be one continuous pool and Section LA31 to have a substantial pool (Boongarup Pool in Walyunga National Park).

Sections that are most characterised by their riffle sequences are LA03, LA26, LA29 and LA30.

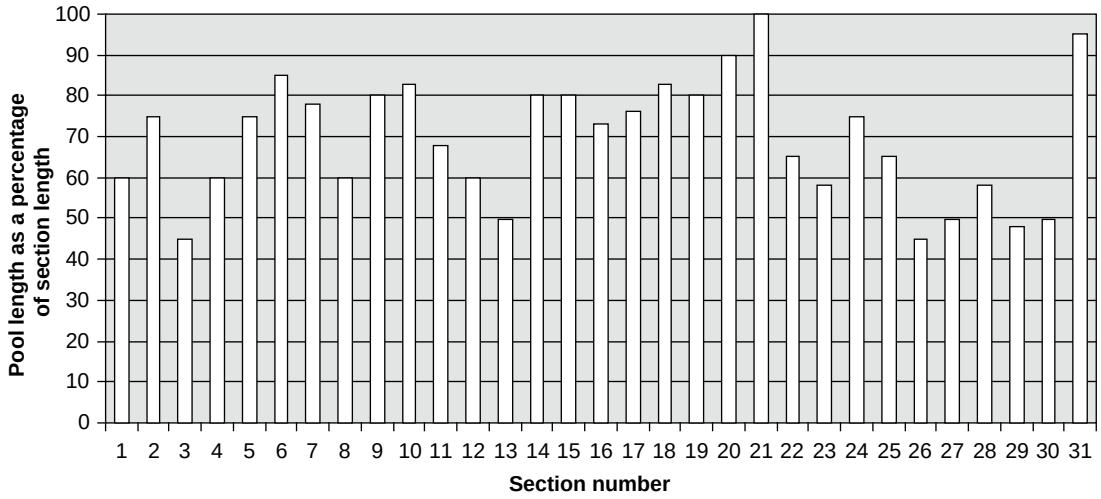


Figure 4.3 *Pool–riffle ratio for survey sections of the lower Avon River*

Photo 3 *A natural rock riffle in section LA09*

4.1.4 Tributaries and groundwater inflow

There are 16 sections of the Lower Avon river section with tributaries. Two are very significant: the Brockman River in Section LA24 and Wooroloo Brook in Section 31. Other smaller but significant tributaries are Julimar Brook (Section LA01 – left hand side [LHS]), Joe's Brook (Section LA05 – LHS), Red Swamp Brook (Section LA15 – right hand side [RHS]) and two other tributaries with low but relatively fresh streamflow (Sections LA20 – LHS and LA25 – RHS). Most tributaries were observed to be small in capacity and dry at the time of survey (September, 2006). It is noted that 2006 was one of the driest years recorded in Western Australia, however, even in a year with an average rainfall pattern, it is expected that the small tributaries would only carry streamflow for a short period.

Groundwater is not considered to be a major contribution to streamflow in the Lower Avon river section. Minor seeps were recorded in only two river sections (LA15 and LA18). There may be some fissured rock with groundwater discharge to the river although this is not considered to be significant in most years.

Photo 4 *A small tributary of section LA04 upstream from Emu Falls*

Photo 5 *A cobbled tributary of section LA19*

4.1.5 Water quality

The salinity of streamflow was measured at the downstream end of each river section (listed in Appendix 6). Figure 4.4 shows the declining salinity trend downstream. Streamflow salinity is relatively consistent (at approximately 9000 mg/L TDS) for the first 14 river sections. It decreases in Section LA15 due to fresh inflow from Red Swamp Brook. Salinity declines significantly in Section LA24 with inflow from the Brockman River (measured at 5775 mg/L TDS at the time of survey) and there is further significant decline in Section LA31 with inflow from Wooroloo Brook.

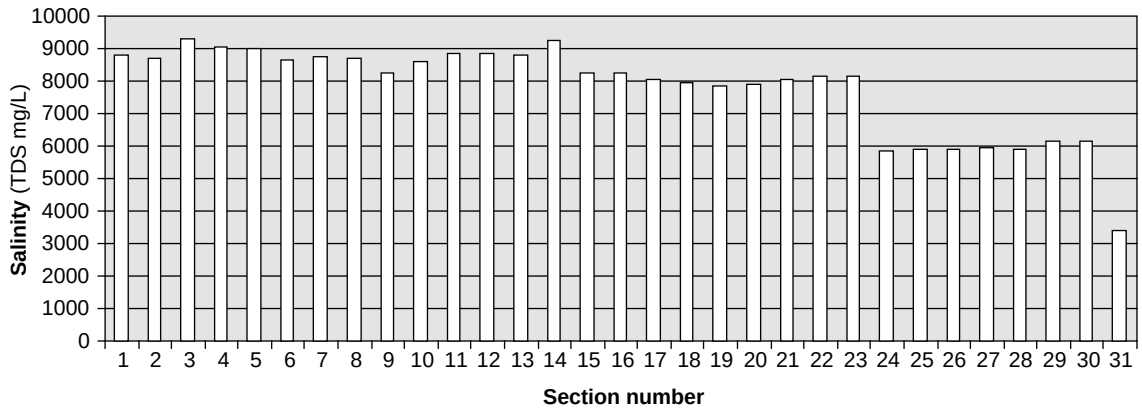


Figure 4.4 *Streamflow salinity (total dissolved salts in mg/L) for survey sections of the lower Avon River*

There are several sections where fringing vegetation appears to be affected by high streamflow salinity, however, there is generally very little evidence of environmental impact from increased streamflow salinity as a result of clearing native vegetation in the Avon River catchment for agriculture. This assessment does not account for ecological change that may have occurred within the pool and riffle aquatic ecosystems.

The streamflow salinity measured at Section LA31 is significantly lower (37%) than the highest recording (at Section LA14).

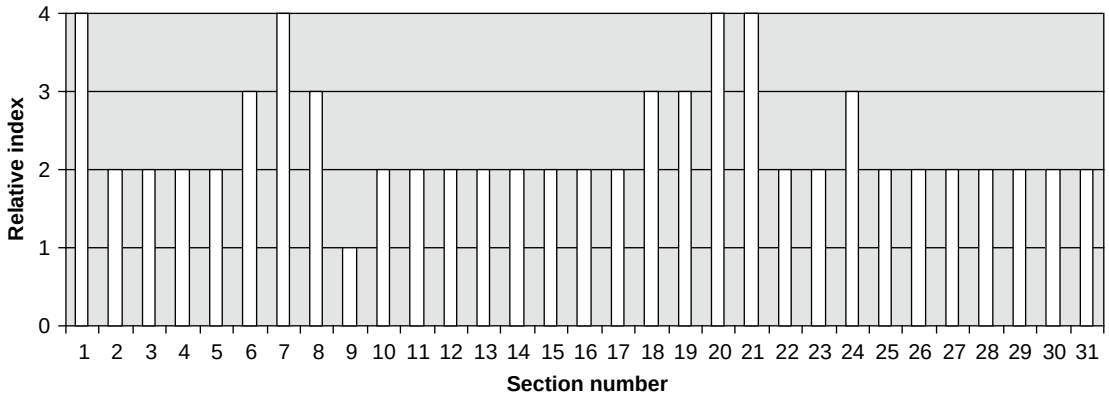
A salinity classification is included in Appendix 8.

4.1.6 River bank and channel stability

The banks and channel of the Lower Avon river section have not been altered by engineering works as has occurred extensively in the Avon River upstream from the Darling Scarp, resulting in higher streamflow velocity for the river. However, increased streamflow in the Lower Avon river section is causing the banks to erode. Figure 4.5 shows that, for most survey sections, erosion is localised. However, for nine sections bank erosion is significant or severe.

The sections that are stable have substantial rock outcropping or fringing vegetation is well established. There are sections where root exposure of the fringing vegetation is substantial however there is only one section (LA31) where tree fall has occurred due to bank erosion.

Photo 6 *Bank erosion in section LA01*

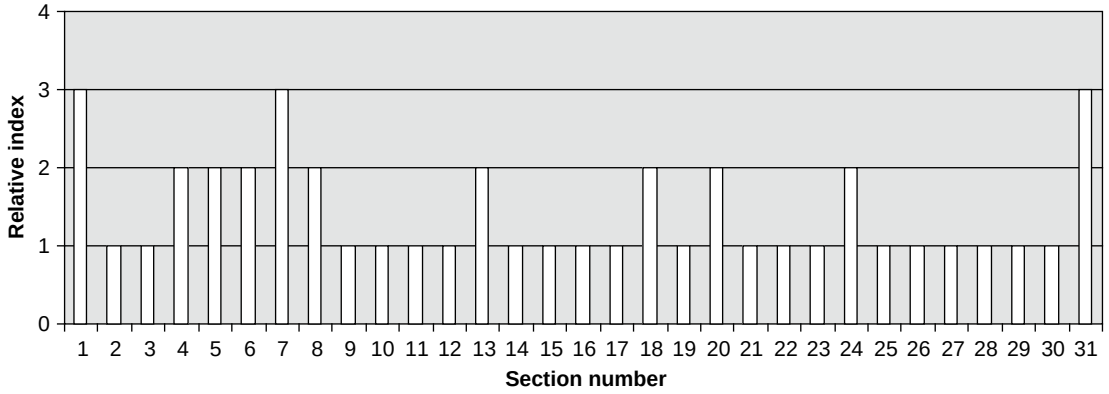


Note: 1 = minimal (0–5% of the survey section affected), 2 = localised (5–20%), 3 = significant (20–50%) and 4 = severe (>50%)

Figure 4.5 *River bank erosion for survey sections of the lower Avon River*

Slumping of river banks is a more substantial form of erosion. Figure 4.6 shows that most sections had minimal slumping (most commonly none occurred) and, in eight sections, localised river bank slumping occurred. This form of erosion is significant at only three sections.

The processes of river bank slumping are due to saturated soil profiles caused either by poor soil drainage characteristics or groundwater seepage. Depositional soils in the banks and adjacent floodways are considered to be well drained and groundwater discharge within the valley is minimal, so increased river bank slumping is not expected to occur.



Note: 1 = minimal (0–5% of the survey section affected), 2 = localised (5–20%), 3 = significant (20–50%) and 4 = severe (>50%)

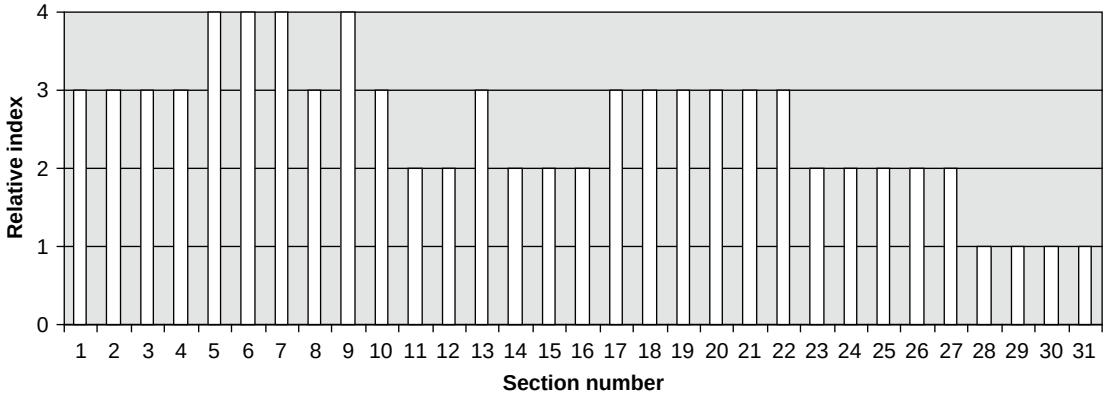
Figure 4.6 *River bank slumping for survey sections of the lower Avon River*

The river bank sediments are medium to fine grained. Where floodways are formed, there is a depositional levee adjacent to the river bank. Where bank erosion continues to occur, these depositional sediments are mobilised downstream.

There was no evidence of the channel depth being increased by streamflow scour.

4.1.7 Erosion and sedimentation

Wild pigs have been introduced to the landscapes of the Lower Avon river section. Small groups of wild pigs forage in the moist floodways and banks of the river, causing very substantial disturbance to the sedimentary soils of the river environment. The pigs range along the length of the river so disturbance is extensive on both sides. From observations made during the river survey, it was clear that soil disturbance occurs frequently, with recent disturbance a common occurrence.



Note: 1 = minimal (0–5% of the survey section affected), 2 = localised (5–20%), 3 = significant (20–50%) and 4 = severe (>50%)

Figure 4.7 *Soil disturbance caused by wild pigs in survey sections of the lower Avon River*

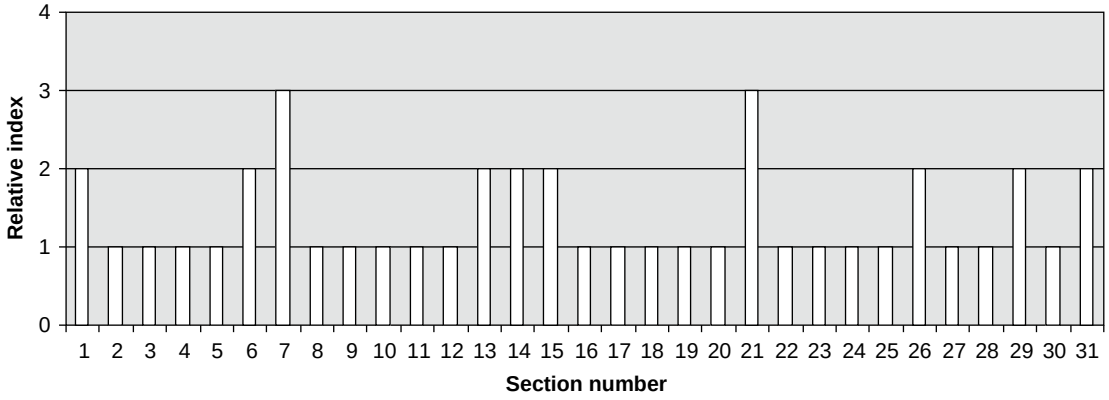
Photo 7 *Disturbance by wild pigs in section LA05*

Figure 4.7 shows that four river sections have severe soil disturbance and a further 13 sections have significant disturbance. Over 50% of the Lower Avon river section has significant or severe soil disturbance caused by pigs. Minimal disturbance occurs only in the four downstream survey sections (LA28–31).

With significant soil disturbance for prolonged periods in floodways, levees and banks of the river, the potential for erosion and sediment transport during high flow events is high. Increasing river levels by just 50 cm from winter base flow would cause erosion. These medium to fine grained sediments are considered to be relatively high in nutrients compared with coarse sand sediments, as coarse sediments have a lower surface area and therefore lower potential for nutrient adsorption. Therefore, these sediments may contribute to nutrient enrichment in upper reaches of the Swan River where streamflow velocity is reduced and sediments are deposited.

Massive mobilisation of coarse sand sediments has occurred in the Avon River channel upstream of the Darling Scarp as a result of the river training scheme. Sediments have filled many river pools and others are continuing to fill. The extent to which these sediments are descending the scarp and being deposited in the river pools within the Walyunga National Park and the upper reaches of the Swan River is not known, although it is expected that these processes of sediment mobilisation are occurring.

Coarse sand sediment was recorded for river sections during the survey. This occurred as small beaches on river banks, sand slugs within the channel or as a trailing deposition downstream from large rocks or small islands. Figure 4.8 provides a relative index of the occurrence of sediment deposition for the Lower Avon river section. Most survey sections had little or no sediment deposition recorded. Compared with sedimentation of the Avon River upstream from the Darling Scarp, the level of sedimentation is generally very low. The coarse sediments that were observed were most commonly as a small unconsolidated sand slug. This suggests temporary deposition.



Note: 1 = minimal (0–5% of the survey section affected), 2 = localised (5–20%), 3 = significant (20–50%) and 4 = severe (>50%)

Figure 4.8 *Occurrence of sediment in survey sections of the lower Avon River*

Section LA07 has two of the larger coarse sand deposits associated with rock outcropping. Sections LA13, 14 and 15 also have localised sand deposits. The higher occurrence recorded for Section LA21 is uncertain. This is the only section that is 100% river pool. The depth of this pool was considered to be shallower than for other pools. There is potential for coarse sediments to be filling this pool.

Moondyne Pool (in Section LA13–14) is considered to be at high risk of sedimentation (Department of Water, 2008). Unconsolidated coarse sand sediments were observed in Section LA13.

Boongarup Pool (Section 31) is a long river pool where the river gradient is decreasing. This pool is considered to be at moderate risk of sedimentation (Department of Water, 2008).

Photo 8 Ruppia species *growing in Boongarup Pool, indicating shallow pool depth*

Other than the three river pools potentially at risk of sedimentation, there is little other evidence to indicate that coarse sand deposition is a major threat to the river environment in the Lower Avon river section.

The Brockman River is a source of medium to fine grained sediment in Section LA24. There is a small delta at the confluence and relatively small sand slugs downstream. While streamflow below the confluence had increased turbidity for 200–300 m, there was little other impact of sedimentation observed from this tributary.

Photo 9 *Sediment deposition in a river pool in section LA06*

Photo 10 *Pig disturbance in a deposit of fine sediments*

Photo 11 *Coarse sand deposition*

4.2 Riparian vegetation

Riparian zone vegetation is relatively consistent in composition and structure but varies in extent, health and regenerative capacity between survey sections.

The frequency of occurrence for the most commonly occurring native riparian zone vegetation species with dominant growth form is shown in Appendix 7. Flooded gum (*Eucalyptus rudis*) and swamp paperbark (*Melaleuca raphiophylla*) occurred in all survey sections and are the two species that characterise the riparian zone vegetation. Swamp sheoak (*Casuarina obesa*) is the next most commonly occurring overstorey species, occurring in 26 survey sections, however, it was abundant in only few sections. The lesser bottlebrush (*Callistemom phoeniceus*) occurred in 24 sections, although most commonly as a small area of a few individual plants associated with rock outcropping in or adjacent to the river.

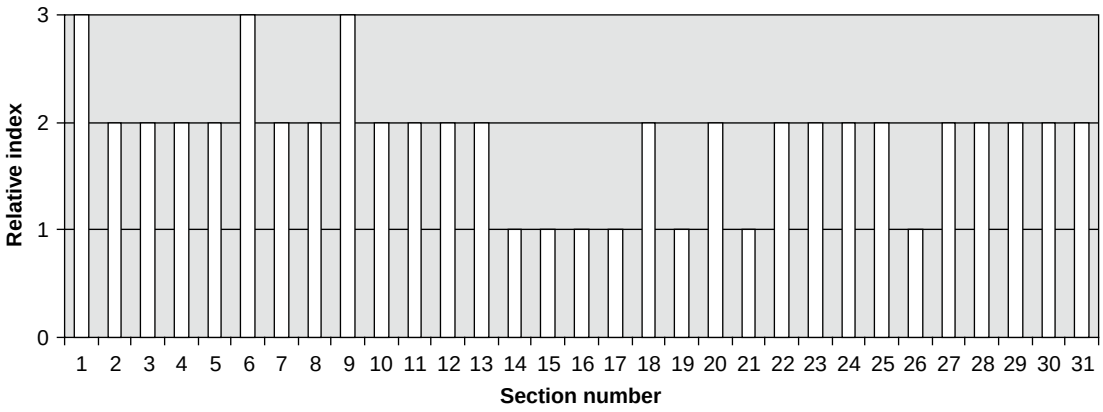
Other commonly occurring species were wandoo (*E. wandoo*), prickly moses (*Acacia pulchella*), zamia (*Macrozamia reidlei*), yellow buttercups (*Hibbertia hypericoides*), *Trymalium floribundum,* mohan (*Melaleuca viminea*) and marri (*Corymbia callophylla)*. A list of native vegetation species identified during the survey is included in Appendix 8.

Photo 12 *Lesser bottlebrush (*Callistemon pheoniceus*)*

Photo 13 *Swamp sheoak (*Casuarina obesa*) growing on a broad rocky island*

A vegetation survey undertaken by the Swan River Trust during the same period of this survey provides more detailed information of vegetation community composition and structure.

There was 20–80% riparian zone overstorey vegetation cover for all survey sections except for LA28 where cover was >80%. Middlestorey cover was also predominantly 20–80% with survey sections LA6, LA10 and LA18 being >80%. Native understorey cover was more variable as shown in Figure 4.9.



Note: 0 = absent, 1 = <20% (sparse), 2 = 20–80% (patchy) and 3 = >80% (continuous).

Figure 4.9 *Understorey vegetation cover for the lower Avon river section*

An assessment of vegetation health showed all survey sections to be classified as very good with only section LA12 having some overstorey degeneration. Riparian vegetation was regenerating at all survey sections.

4.3 Weeds and feral animals

The understorey of the riparian zone is substantially dominated by introduced weeds. Most are annual species. The most commonly occurring species are radish (*Raphanus raphanistrum*) and Patterson's curse (*Echium plantegenium*).

The weeds of greater concern in the riparian zone include castor oil plant (*Ricinus communis*), occurring in 19 survey sections, watsonia (*Watsonia bulbillifera*), occurring in 18 survey sections and cape tulip (*Homeria* spp.) and soursob (*Oxalis pes-caprae*) occurring in 17 survey sections. Blackberry nightshade (*Solanum nigrum*) occurs in 11 survey sections. This weed species and castor oil plant occur most commonly in association with soil disturbance caused by pigs. These weeds are currently established in the riverine environment and generally suppress regeneration of native species. Other weeds occur that are unlikely to further devalue the riparian zone. A total of 17 species of weeds were recorded during the survey. Appendix 11 shows the occurrence of these weeds for each survey section.

The distribution of weeds is significant for management. Castor oil plant (*Ricinus communis*) occurs in all sections downstream from LA14 but at only one section

Photo 14 *Patterson's curse (*Echium plantegenium*) in the Avon River floodway*

Photo 15 *Castor oil plant (*Ricinus communis*) regenerating*

Photo 16 *Watsonia (*Watsonia bulbillifera*)*

Photo 17 *Watsonia (*Watsonia bulbillifera*)*

upstream. This weed occurs in isolated patches with vigorous regeneration in response to soil disturbance by pigs.

Watsonia (*Watsonia bulbillifera*) occurs only occasionally upstream from section LA17 but then in all sections downstream from there. This weed is very dominant and sometimes occurs as continuous cover on both sides of the river in the downstream survey sections. African feather grass (*Pennisetum macrourum*) occurs downstream from survey section LA27.

It is significant to note that bridal creeper (*Asparagus asparagoides*), blackberry (*Rubus fruticosis*) and sharp rush (*Juncus acutus*) are not established in the Lower Avon river section.

The sections with most weed species are LA14, LA15, LA18, LA28 and LA29. The sections with least weeds are LA07 and LA08.

The most significant feral animal is wild pig (*Sus scrofa*). While not frequently observed during the survey period, fresh soil disturbance was commonly recorded. Wild pigs are causing very substantial impact on the river environment by soil disturbance. This encourages weed establishment which suppresses opportunities for natural vegetation regeneration. Disturbed soil also increase the risk of erosion during high flow events contributing to sedimentation downstream. The frequency of occurrence for wild pigs is indicated by the measures of soil disturbance shown in Figure 4.7. This is recorded as being significant or severe for 17 of the survey sections.

Feral goats (*Capra hircus*) are commonly found in the national parks and other adjacent land, although none were observed in the river environment during the survey. There were no goat tracks or scats recorded in the river environment and only minor evidence of native vegetation grazing during the period of the survey. Two feral sheep were observed. These are unlikely to significantly damage environmental health.

There are occasional records of rabbits (*Oryctolagus cuniculus*) within the river environment.

4.4 Birds and other native animals

A total of 38 bird species were recorded at survey sections during the survey period. Appendix 12 shows the number of species recorded for each section. This is primarily of general interest and does not provide any significant indication of habitat quality or environmental health for each section. The records are from one sampling period only, rather than from repeat survey methods. There are many variables that influence bird surveys, including time of day and wind conditions, so the lists provided should not be used for assessment of river condition.

Based on the recorded information, no bird species were of disproportionately high population size and most are not considered rare or endangered, with the exception of the white-tailed black-cockatoo (*Calyptorhynchus latirostris*) which is listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999*. Eight species were observed at more than half of the survey sections.

The *Paruna Sanctuary management plan* (Australian Wildlife Conservancy, 1998) provides lists of native animal species that occur in the local area and also those that previously existed but are now locally extinct.

Aquatic fauna were not recorded as a part of the foreshore and channel condition survey. High numbers of small mollusc shells (possibly the small snails *Coxiella glabra* and *Thiara incerta*) were noted in most survey sections.

4.5 Public access, scenic values and river fencing

Public access, river crossings and facilities

Public access is limited on both sides of the Lower Avon river section. Restricted daily public access (9.00 a.m. to 5.00 p.m.) is available to the river within Walyunga National Park and there is seasonally restricted access to the river through the Avon Valley National Park.

There is good access to landscapes associated with south of the river through the Paruna Sanctuary. This includes well developed walk trails with descriptive notes. Access is by arrangement with the owner (AWC). There is further access to the river on the south side from Utah Road through Hart's Farm although permission to enter this property is required. Walyunga Lookout provides picnic facilities and good views of the river from the south. All direct access to the river from the south has the public risk of crossing the rail corridor.

There are public access and picnic facilities at two locations north of the river (Sapper's Road in LA04 and Walyunga National Park in LA31). These sites are not well known and access to them requires greater travel time from Perth compared with potential access south of the river.

There are seven river crossings in the Lower Avon river section. All crossings are accessible only during low flow. All crossings are for four-wheel drive vehicle access with the exception of the one at Sappers Road where there is a concrete floodway. There are no significant road or bridge crossings in this river section.

Appendix 13 shows the public facilities and river crossings for each survey section.

Scenic value

The Lower Avon river section is located through land that is national park or is recovering from previous agricultural use. The elevated and dissected landform of

Photo 18 *River crossing in section LA04*

Photo 19 *Facilities at a public campsite in section LA04*

Photo 20 *Old stock route on the northern side of section LA15*

Photo 21 *Public access trail in Walyunga National Park*

Photo 22 *A reach of the river in section LA03 with high scenic value*

Photo 23 *Long rapid adds to the wild and scenic characteristics of the river in section LA19*

Photo 24 *River chute creating white water challenges for boating events in section LA14*

Photo 25 *River rapid creating white water challenges for boating events in section LA24*

Photo 26 *River fencing in good condition in section LA24*

Photo 27 *Fencing in poor condition adjacent to the rail corridor*

the valley combines attractive river rapids, reaches and pools providing high scenic value. Some river sections are of exceptional scenic quality. Appendix 14 shows there to be 19 locations identified with high scenic value during the river survey. It also shows white water rapid names adopted by canoeists (Bolland, 2001).

River fencing

A fence was constructed on the river-side of the rail infrastructure corridor at the time of rail construction to identify the boundary. This fence is now in very poor condition and serves no function, however there is no requirement for river fencing to exclude domestic animals from the river environment on the southern side of the river.

There is also no requirement for effective fencing adjacent to the river on public land. Private land on the north side of the river currently has effective fencing. There is one section of private land recorded with poor fencing, however this land has native

vegetation and river fencing is probably not required. All other fencing of private land is in good condition. There is no requirement for additional fencing to restrict livestock access to the river.

4.6 Stream environmental health rating

The overall stream environmental health rating (OSEHR) is a multi-factor rating including criteria for floodway and bank vegetation, verge vegetation, stream cover, bank stability and sedimentation, habitat diversity and adjacent land use. While it is not based on measured indices, it does provide a comparative assessment that effectively indicates the relative health of the riparian ecosystem.

The rating classifies the OSEHR as follows:

OSEHR classification	Score range
Excellent	40–55 (maximum value)
Good	30–39
Moderate	20–29
Poor	10–19
Very poor	0–9

The OSEHR score for each section of the Lower Avon river section is shown in Map 4. This shows almost all of the river section to be in good or excellent condition. Twelve sections have a score of 40 or more. There is one sequence of five excellent sections (LA2–6) and other of four sections (LA8–11). There are only three sections classified as moderate. Sections LA13 and LA14 have low ratings for several criteria, including bank stability and sedimentation.

4.7 Foreshore condition assessment

An assessment of the condition of the foreshore was made following survey of each section. It is based on observations made for both sides of the river about environmental condition. While the grading is generalised for each section, it does provide a relative index that shows the higher and lower graded sections of the river. The grading system is shown in Appendix 4.

Map 5 shows that while no sections could be considered pristine, eight sections are assessed as A-grade foreshore (Sections LA3–10). These sections form a 6.5 km continuous length of high-quality river.

All other river sections have B-grade foreshore, due primarily to the high occurrence of weeds. There are no river sections with C- or D-grade foreshore.

4.8 Key findings from the survey

The key findings for the Lower Avon river section from analysis of the survey results are:

1. The river channel and meander pattern have not significantly altered with the change in catchment land use, and remain stable. The meander pattern is subdued and controlled primarily by bedrock outcropping, as may be expected in an erosional landscape.

2. There is minimal floodplain development and relatively minor formation of floodways and anabranches indicating that the main channel is efficient in discharging high streamflow events.

3. Although there are many rapids or riffle structures, there is a greater proportion of river pools and reaches. Most river pools are of high value and in stable condition. Moondyne Pool and Boongarup Pool need to be assessed for potential sediment infill.

4. Salinity has minimal impact on the riverine environment.

5. The river banks are generally stable with most survey sections having minimal or localised bank erosion or slumping. There are nine survey sections with significant or severe bank erosion.

6. Wild pigs (*Sus scrofa*) are causing extensive damage by soil disturbance in the floodways, levee and in some locations, the river banks. These medium to fine alluvial soils are vulnerable to erosion during winter flow events and are a potential source of sedimentation downstream.

7. There is only minimal sedimentation in this section of the Avon River.

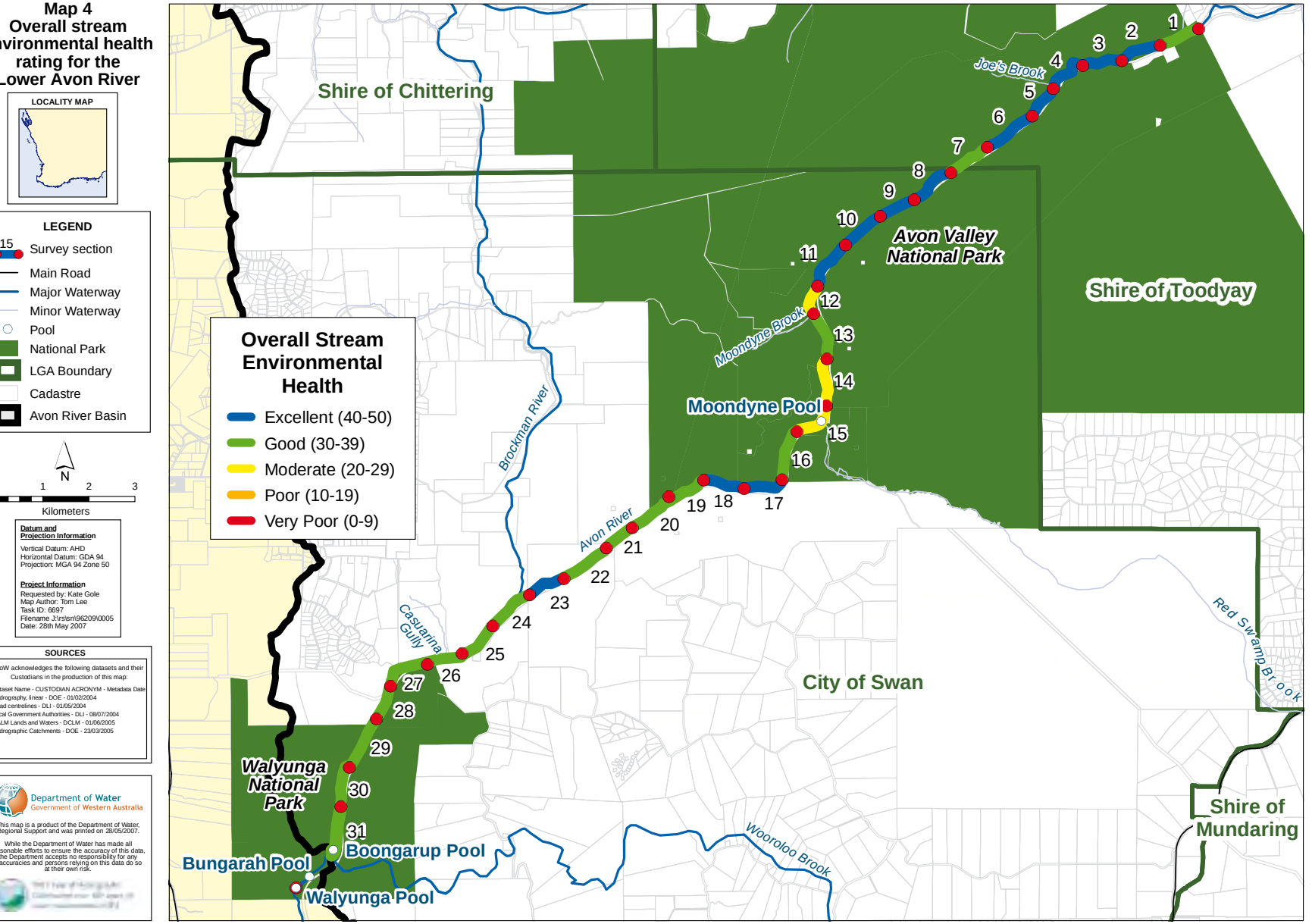
8. Riparian vegetation is generally diverse, healthy and regenerating. This provides high quality habitat opportunities for wildlife.

9. Weed infestations are increasing. Watsonia (*Watsonia* species), castor oil plant (*Ricinus communis*) and soursob (*Oxalis pes-caprae*) occur frequently and at levels that suppress groundcover vegetation and natural regeneration. There is no evidence of bridal creeper (*Asparagus asparagoides*), blackberry (*Rubus fructicosus*) or sharp rush (*Juncus actus*).

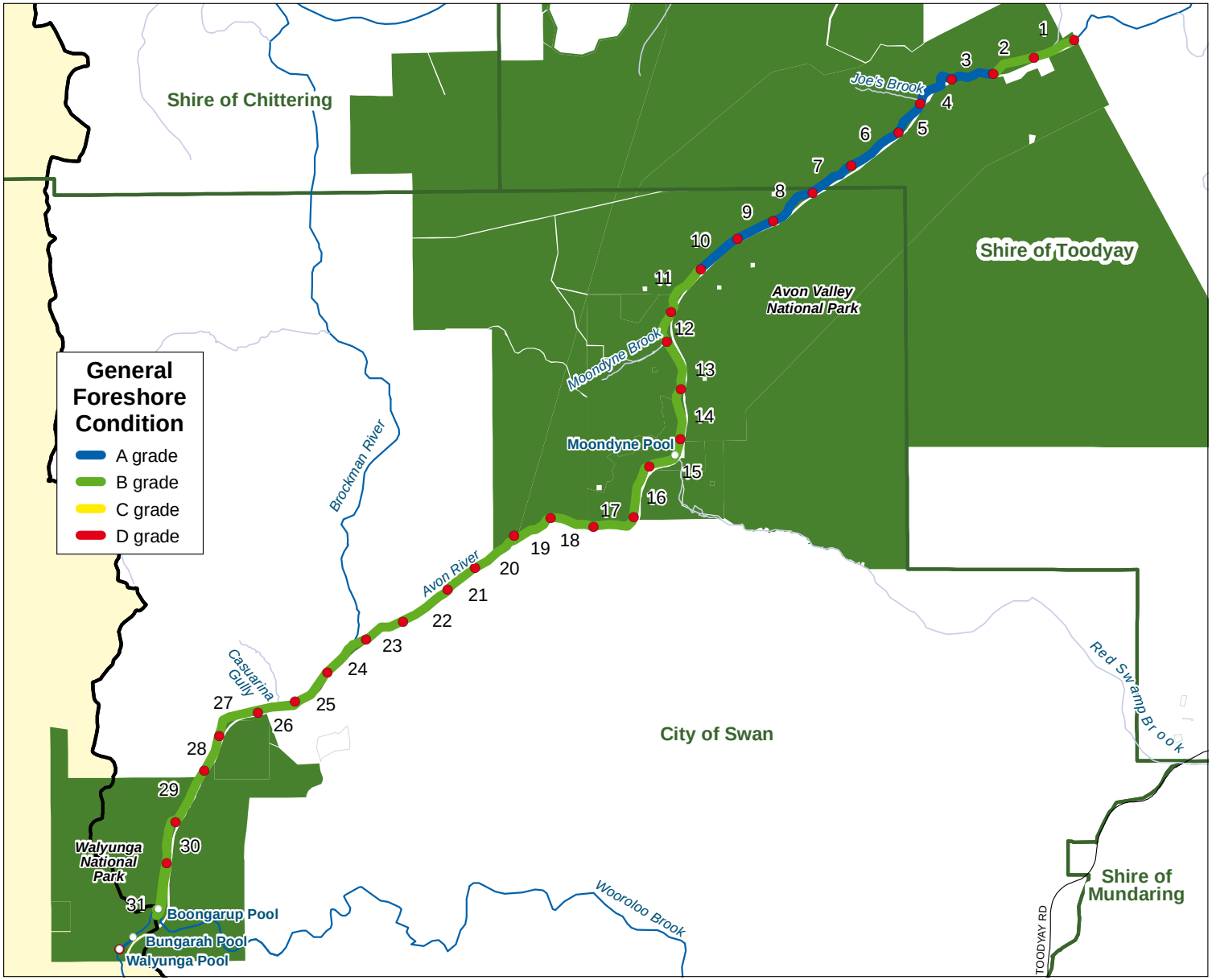
10. River fencing generally does not exist on public land but is not required. River fencing on private land is generally in good condition.

11. Twelve of the 31 survey sections were assessed to have excellent overall environmental health. Only four of the sections were assessed as ‘moderate’ and none were assessed as ‘poor’ or worse.

Map 4
Overall stream environmental health rating for the Lower Avon River



Map 5
General foreshore condition rating for the Lower Avon River



LOCALITY MAP

LEGEND

- 15 Survey section
- Main Road
- Major Waterway
- Minor Waterway
- Pool
- National Park
- LGA Boundary
- Cadastre
- Avon River Basin

N

0 1 2 3
Kilometres

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA 94 Zone 50

Project Information
Requested by: Kate Gole
Map Author: Tom Lee
Task ID: 6697
Filename J:\rs\sn\96209\0005
Date: 28th May 2007

SOURCES

DoW acknowledges the following datasets and their Custodians in the production of this map:

Dataset Name - CUSTODIAN ACRONYM - Metadata Date
Hydrography, linear - DOE - 01/02/2004
Road centrelines - DLI - 01/05/2004
Local Government Authorities - DLI - 08/07/2004
CALM Lands and Waters - DCLM - 01/06/2005
Hydrographic Catchments - DOE - 23/03/2005

Department of Water
Government of Western Australia

This map is a product of the Department of Water, Regional Support and was printed on 28/05/2007.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

12. Foreshore assessment shows all survey sections to be A-grade (pristine or slightly disturbed) or B-grade (degraded by weeds).

13. Many sections had high scenic value. There is very limited public access to these sites.

These key survey findings are significant in determining future management requirements for the Lower Avon river section.

5 A strategic approach to management

The foreshore and channel condition survey provides a systematic assessment of the Lower Avon river section and identifies key issues for management. Other issues have been identified through consultation processes.

Arrangements for management of the river require considerable coordination. The *Lower Avon river recovery plan* provides strategic direction for effective management of identified priority issues.

5.1 Existing management roles and responsibilities

Land title boundaries adjacent to the Lower Avon river section are varied and, in places, unclear. Land title for the Avon Valley National Park overlies the river. Further downstream, title boundaries are unclear for land that is currently vested with the Department for Planning and Infrastructure (DPI). The single line cadastral boundary between the Devereaux property and Paruna Sanctuary (owned by AWC) is also unclear (i.e. this may be interpreted as being the centre of the river or otherwise the top of the bank on one side). One location owned by AWC crosses and includes the river. Downstream from this location, the river is contained within a Crown reserve (no. 2065), which extends down to Walyunga National Park where the land title includes the river.

The rail corridor is formed as an easement for infrastructure with the vesting being with the Commissioner of Railways.

Management roles are identified separately for private and public land.

Private land

The key responsibilities of private land managers are to:

- control livestock access to the riverine environment
- eradicate declared weeds and control feral animals under the *Agricultural and Related Resources Protection Act 1976*
- control other agricultural weeds that affect environmental values
- control soil erosion that may impact upon the river environment
- minimise fire risk, including maintenance of boundary fire breaks according the *Bushfires Act 1954*.

The AWC manages freehold land for nature conservation values. This includes fencing to create enclosures to exclude feral animals, and re-introduction of locally extinct native species. Public access to this land is by arrangement with AWC and people are encouraged to participate in restoration activities. Public access and activities for this land have not previously included the riverine environment.

There is a Land Conservation District Committee (established under the *Soil and Land Conservation Act 1945*) for the Wooroloo Brook catchment, and further community-based natural resource management for the Brockman River. There are no organised catchment groups with direct involvement in the Lower Avon river section.

Public land

Table 5.1 details the existing management responsibilities for public lands.

5.2 Key issues for management

Consultation with key stakeholder organisations, including representatives from DEC, SRT, Department of Water, AWC and WNR and private landholders, prior to the foreshore and channel survey identified the management issues for consideration within the recovery plan.

The issues are listed below without priority and the full details are included in Appendix 15:

- the natural environment
- riparian zone management
- related landscape management
- land ownership and responsibility
- Indigenous interests
- planning
- public interest and access
- invasive weeds
- feral animals
- sedimentation
- fire
- forest disease.

5.3 Goal and objectives for management

Key issues for management are identified from the river survey results and through consultation processes. There are no previous or existing plans for the Lower Avon river section that adequately address the management issues. The river recovery plan provides strategic direction for coordinated management of issues that affect

Table 5.1 Existing management responsibilities on public lands

Vesting	Statutory responsibilities	Roles and functions
Department of Environment and Conservation (DEC)	Managing the reserve estate under the *CALM Act 1985*. Managing the flora and fauna under the *Western Australian Wildlife Conservation Act 1950.*	• Manage the land, vegetation and activities for land defined under the *Act* • Manage the flora and fauna of the state, including rare and endangered species.
Swan River Trust (SRT)	Under the *Swan and Canning Rivers Management Act (2006 – to be proclaimed)* the SRT provides advice and undertakes works and provides facilities required to protect and enhance the ecological and community benefits and amenity of *Riverpark*.	• Establish Swan Canning *Riverpark* and management plan • Undertake foreshore assessment for the Upper Swan (to Avon Valley National Park) a • Implement foreshore restoration priority projects.
Department of Water	Under the *Rights in Water and Irrigation Act 1914*	• Monitoring streamflow and water quality • Managing impact of disturbance to bed and banks.
Public Transport Authority of Western Australia (PTA)	Economic Regulation Authority leases the rail infrastructure to *WestNet Rail* (WNR) under the *Railways (Access) Act 1998* and the *Rail Freight Systems Act 2000*. Corridor plans were prepared by the former WA Government Railways (WAGR) during the 1950s and 60s. These define the boundary of the corridor.	WNR is responsible for: • Fire risk reduction from rail use and maintenance activities (including weed control within 10 m of the track) • Minimise public risk.
Department for Planning and Infrastructure (DPI)	Purchases land for the WA Planning Commission as required under the *Planning and Development Act 2005* for parks and recreation reserves.	DPI: • Invests in public benefit of WAPC freehold land (e.g. Stronghills and Moondyne farms) • Arranges management of land through DEC as part of the regional parks system.
Local government	*Town Planning and Development Act 1928*	• Development approval processes undertaken by Shire of Toodyay and City of Swan. • City of Swan development of the *Gidgegannup/Brigadoon Place Plan* which identifies community values and priorities. It is linked to the rural strategy and planning controls.

the river. The scope of the management plan does not include adjacent landscapes other than to indicate where integrated landscape management is required for river management outcomes.

The strategic direction for management is provided through a management goal to be achieved through a set of management objectives.

The goal of the recovery plan is to:

> *Ensure that the environmental and social values of the Lower Avon river section are well recognised and the river environment and water quality are managed to sustain or enhance these values.*

The management goal provides a specific focus on awareness of river values for the Lower Avon section. This focus is required as very few people are aware of the values in this section of the river due in part to limited public access. The Lower Avon river section is considered to have high river-scape values and is generally in excellent health and condition. Management is required for the threats to these assets to ensure their high-level values are maintained or enhanced.

The management objectives for the recovery plan are stated and described below. An assessment of risk is also provided. This is to indicate the priority required for management response.

5.3.1 Natural riverine environment

> ***Objective 1:*** *To enhance the high biological diversity and habitat quality of the natural river environment with linkage to adjacent landscape and catchment values.*

Description

The natural riverine environment of the Avon and Swan river systems has been substantially altered by clearing for agriculture, salinity, sedimentation, urban development and other factors. This has occurred for their full extent with few exceptions, the most significant exception being the Lower Avon river section.

This section of the Avon River flows west over the Darling Scarp through a recently dissected landscape to the Swan estuary. While some adjacent land was cleared for agricultural use, most of this area has been resumed for public benefit or has relatively low impact land use. The rail infrastructure corridor south of the river is now the most significant development within the river environment.

The bio-geographic significance of the river environment and adjacent landscapes is recognised. The AWC formed Paruna Sanctuary by purchasing private land for the purpose of extending conservation values. This provides almost continuous connection with Avon Valley and Walyunga national parks south of the river.

The river recovery plan for sections 1 and 2 (Avon Gorge and Deepdale Valley) within the Shire of Toodyay (Water and Rivers Commission and Avon Waterways Committee, 2002) identifies the opportunities for bio-geographic linkage east of the Lower Avon river section. The Swan River Trust's proposed *Riverplan* aims to extend bio-geographic linkage to the Swan Coastal Plain.

Risk assessment

Current land tenure and management arrangements ensure that the health of the natural river environment is maintained. While there are threats from weeds, wild pigs, forest disease and fire, these can be managed to retain healthy ecosystem values. The potential to add value to the natural river environment through extension of the reserve system and initiatives of the AWC will further reduce the risk to the natural river environment.

5.3.2 Wild and scenic river values

Objective 2: *To increase recognition by government and community of the Lower Avon river section as a significant wild and scenic river.*

Description

There are very few wild and scenic river sections in the south-west of Western Australia. Most rivers are substantially altered or have subdued characteristics being located on the Yilgarn Plateau or coastal plain landscapes. The Lower Avon river section descends through diverse terrain from the plateau to the coastal plain. It is characterised by steep rocky slopes, rugged rapids and tranquil pools. Although there is frequent use of the rail corridor, there are high-level wilderness values that remain.

The importance of recognising the wild and scenic river values of the Lower Avon river section is in adding to the character of the state's capital city and adjacent landscapes. It adds further opportunity for attachment by urban and rural communities to their landscape.

Risk assessment

The existing rail corridor detracts from the full wilderness value of the Lower Avon river section, although it does provide an opportunity for rail passengers to view the scenery as they travel through the area. Other current threats to the wild and scenic values are moderate and manageable. The more significant issue is the relatively low awareness and appreciation of these values by those who live in or visit Western Australia.

The Avon Descent boating event has drawn public interest to the Avon River although the focus is on the competitive event more than on the wilderness values of the natural environment.

5.3.3 Heritage values

Objective 3: *To identify and maintain the significant Aboriginal and European heritage values associated with the Lower Avon river section.*

Description

There are significant heritage values associated with the Lower Avon river section. The dreaming sites of the Wagyl, the mythical dreaming serpent, are well documented as being significant to south-western Aboriginal cultural values. The river, and its pools, is considered to be the home of the Wagyl.

There are also a range of European heritage values that are not well documented for the Lower Avon river section. These include the stock routes that provided connection from the coastal plain to areas around Toodyay. Western Australia's most famous bushranger from the convict era was Moondyne Joe. While his exploits are well known, his association with the Avon River is generally less recognised.

The City of Swan has prepared a place plan for the Gidgegannup area that has identified community values, including heritage.

Risk assessment

The greatest threat to heritage values associated with the Lower Avon river section is their lack of recognition. There is very limited public information available about these values. Public access to these areas is also limited.

5.3.4 Public risk

Objective 4: *To identify and minimise public risk in the river environment.*

Description

The most significant reason for limited public access to the Lower Avon river section is personal risk. The rail corridor south of the river has high-frequency state and inter-state rail transport use. While caution is taken by train drivers when there is permitted access to the rail corridor, the public risk is high for unregulated access. There are conditions when the sound of locomotives and rolling stock is suppressed and pedestrians and people in vehicles may be at risk.

There is further public risk north of the river in the Avon Valley National Park due to unexploded ordinance remaining from military training camps.

High water levels in the river are a risk to inexperienced canoeists. There are several rapids that are dangerous during high flow events.

Risk assessment

The public risk within the rail corridor is high. The risk can be minimised by risk management policy for caution taken by drivers and by controlled access.

The risk due to unexploded ordinances is not well established. The risk can be reduced in priority areas by detection and clearance procedures.

5.3.5 Public information, access and recreational opportunity

Objective 5: *To increase the level of public information and access to the Lower Avon river section, including increased public recreational opportunities.*

Description

There is only limited public awareness and information available about the Lower Avon river section. Some information is available at the Paruna Sanctuary although visitation rates are relatively low. There is limited information relevant to canoeists and other water craft events available from event organisers and reference material (e.g. Bolland, 2001).

Restricted daily public access (9.00 a.m. to 5.00 p.m.) is available to the river within Walyunga National Park and there is seasonally restricted access to the river through the Avon Valley National Park.

There is good access to landscapes associated with south of the river through the Paruna Sanctuary. This includes well developed walk trails with descriptive notes. Access is by arrangement with the owner (AWC). There is further access to the river on the south side from Utah Road through Hart's Farm although permission to enter this property is required. Walyunga Lookout provides picnic facilities and good vistas of the river from the south. All direct access to the river from the south has the public risk of crossing the rail corridor.

There is seasonally restricted public access and picnic facilities north of the river (Sapper's Road in LA04). This site is not well known and access to them requires greater travel time from Perth compared with potential access south of the river.

The key recreational opportunities associated with the Lower Avon river section include white water adventures (canoeing and rafting), bushwalking, picnicking and contemplative involvement. There are special arrangements made for the annual Avon Descent white water boating event due to its international recognition. There are very few other opportunities for recreation currently available for the Lower Avon river section.

There is public interest in trail-bike riding, off-road driving and pig hunting in this area. These activities are not currently encouraged or permitted on public land. None of

these activities are considered to be complementary to the environmental and social values of the Lower Avon river section.

The most favourable access to the Lower Avon river section is from the north. A former stock route exists for some of the section length. This suggests a significant opportunity to develop a northern public access trail for seasonally restricted use. The trail would be best suited for organised bushwalking. The opportunity is enhanced by the potential for linkage west with the Swan Coastal Plain walk trails and east with stock routes in the Shire of Toodyay.

A developed northern access walk trail would provide for the multiple use benefits of access for control of weeds and wild pigs.

Risk assessment

The risk of increased visitation or recreational opportunity for the Lower Avon river section is primarily associated with vandalism, fire and public liability. The potential for this risk is greatest south of the river. This can be minimised by continuing to control access to the river from the south under current arrangements.

Increased public access north of the river through development of a walk trail on public land adjacent to the river has some risks associated with fire and unexploded ordinances. These risks can be reduced by management.

Development of a public access trail north of the river would require active management to control misuse by trail-bike riders.

5.3.6 Wild pig control

Objective 6: *To eradicate or substantially control wild pigs within the riverine environment.*

Description

Wild pigs are causing significant soil disturbance to the levees and floodways of the Lower Avon river section. This is a potential source of river sedimentation during moderately high streamflow. Soil disturbance also increases weed infestations.

Control of pigs is difficult. This is in part due to indiscriminate pig hunting with dogs which affects pig behaviour such that pigs become trap-shy. There is currently no accurate estimate of pig numbers on private and public land adjacent to the Lower Avon river section. It is understood that pig numbers may be increasing due in part to deliberate re-introductions for pig hunting stock.

A revised trapping program has been initiated for public land. Coordination is required with pig control on private land. Systematic and sanctioned control methods are required.

Risk assessment

Eradication of wild pigs from the river and adjacent land is ambitious although achievable. This would require a coordinated approach for private and public land as well as control over indiscriminate pig hunting and re-introductions.

5.3.7 Weed control

Objective 7: *To eradicate or substantially control the two existing dominant weed species in the river environment – watsonia (*Watsonia bulbillifera*) and castor oil (*Ricinus communis*) – and prevent the introduction of three potentially threatening weed species – blackberry (*Rubus fructicosus*) bridal creeper (*Asparagus asparagoides*) and sharp rush (*Juncus actus*).*

Description

Weeds are a significant threat to riparian zone vegetation. Watsonia (*Watsonia bulbillifera*) is the priority weed for control as it provides complete ground cover in places where it occurs and suppresses natural vegetation regeneration. Castor oil (*Ricinus communis*) is less extensive although significant where it occurs.

There is potential for blackberry (*Rubus fructicosus*) and bridal creeper (*Asparagus asparagoides*) to become established in the river environment. Control of both species would be difficult if they were established. Sharp rush (*Juncus actus*) is also difficult to control although less likely to occur due to shading from relatively high middle and overstorey vegetation.

Risk assessment

Inadequate control of existing dominant weeds will result in their further expansion. While significant control will require intense effort, the risk to natural vegetation health will increase without control.

Introduction of additional invasive weed species will further threaten the environmental and social values of the river environment.

5.3.8 Sediment management

Objective 8: *To monitor change in the level of sediment within significant pools of the Lower Avon river section.*

Description

Prior to the survey, there was community concern about the potential for sedimentation of the Lower Avon river section. This arose from observation of increasing sediment infill to river pools within the Shire of Toodyay and further concern about transport of these sediments to the upper reaches of the Swan River.

The survey shows there to be only minimal sedimentation within the river section. There is an identified need to survey and monitor Moondyne Pool and Boongarup Pool for potential sedimentation.

Risk assessment

The most significant sedimentation risk is to Boongarup Pool. This occurs within Walyunga National Park at a location with high public visitation. Sedimentation of this pool, or others downstream, would have unacceptable impacts on social and environmental values. Many Avon River pools have been completely filled with sediment in upstream sections. The loss of social and environmental amenity is significant to local communities. A similar loss of major river pools within a national park is not acceptable. Prevention of sediment infill is preferred if the risk is confirmed by survey and monitoring. The river pools in Walyunga National Park are considered locally to be the home of the Wagyl. Arrangements for management actions within these pools, including excavation of sediments, would need to be planned in consultation with Aboriginal people.

5.3.9 Fire management

Objective 9: *To minimise fire risk in the riverine environment.*

Description

Fire is a significant threat to the natural environment of the Lower Avon river section. The key potential causes are from within the rail corridor (due to sparks from rail rolling stock or maintenance activities), campfires or farm activities.

There are current arrangements between DEC, local fire brigades and AWC for coordinated fire control. There is an observed requirement for coordinated control to further include the rail corridor.

Risk assessment

The potential impact of fire on the river environment is high. The greatest fire risk is within the rail corridor and near public picnic areas. These risks can be minimised by management.

5.3.10 Coordinated management planning

Objective 10: *To ensure consistent management is applied for identified river recovery outcomes.*

Description

Prior to the river recovery plan, there has been just one plan relevant to management of natural resources for the area associated with the Lower Avon river section;

the *Paruna Sanctuary management plan*. The Swan River Trust is developing the *Riverpark* program with planning to extend upstream to Moondyne Brook. The City of Swan and Shire of Toodyay have statutory and non-statutory planning processes relevant to the area. There are site plans and maintenance schedules for the rail corridor. There are currently no management plans for resource management in the areas of National Park.

The *Lower Avon river recovery plan* provides a resource document for further management planning that is required. Consistent management priorities and actions are required to ensure effective management of the river environment and adjacent landscapes.

Risk assessment

Uncoordinated planning runs the risk of inefficient and ineffective resource management.

6 Management response actions

The actions required to manage the Lower Avon river section are primarily to maintain or enhance current environmental and social values. Recovery actions are required to manage impacts from wild pigs and weeds. Other actions are focused on increasing knowledge and awareness, and prevention of additional threatening processes.

Most of the proposed actions can be achieved through enhancement of existing programs.

Table 6.1 Proposed actions for management objectives

Proposed actions	Management priority (high, medium or low)	Action urgency (high, medium or low)	Comments
Natural riverine environment			
Objective 1: To enhance the high biological diversity and habitat quality of the natural river environment with linkage to adjacent landscape and catchment values			
Action 1.1: Consider opportunities for bio-geographic corridor development for the lower Avon valley with linkage to the Avon and Swan river systems and adjacent landscapes.	H	M	To be considered by SRT (through planning for *Riverpark*), AWC (linkage with Paruna Sanctuary), DEC (through management planning for the two national parks), Department of Water (for the Avon River recovery plans), ACC (through the Avon Natural Diversity Alliance) and SCC.
Wild and scenic river values			
Objective 2: To increase recognition by government and community of the Lower Avon river section as a significant wild and scenic river			
Action 2.1: Recognise and acknowledge the Lower Avon river section as a wild and scenic river of significance near Perth.	M	M	To be considered by DEC through management planning for the two national parks.
Heritage values			
Objective 3: To identify and maintain the significant Aboriginal and European heritage values associated with the Lower Avon river section			
Action 3.1: Recognise Aboriginal and European heritage values associated with the Lower Avon river section in planning and management.	H	M	Heritage values to be considered as a part of the *River protection strategy* (SRT).

Proposed actions	Management priority (high, medium or low)	Action urgency (high, medium or low)	Comments
			Significant heritage values associated with river pools within Walyunga National Park could be threatened by sedimentation.
Public risk			
Objective 4: To identify and minimise public risk in the river environment			
Action 4.1: Current arrangements to limit public access to the rail corridor south of the river.	H	H	An assessment of the risk due to unexploded ordinances has been previously documented (DEC).
Public information, access and recreational opportunity			
Objective 5: To increase the level of public information and access to the Lower Avon river section, including increased public recreational opportunities			
Action 5.1: Ensure that information about the environmental and social values of the Lower Avon river section and the threats to the environment is included in planning and management activities.	M	M	Information about the river environment and opportunities for public access are to be considered in future regional river park and national park planning (SRT, DEC).
Action 5.2: Review options for increased public access to the northern side of the river section.	M	M	
Action 5.3: Consider the opportunity for development of a multi-purpose access river trail in public land on the north side of the river section during future planning processes for public land.	M	M	
Wild pig control			
Objective 6: To eradicate or substantially control wild pigs within the riverine environment			
Action 6.1: Include the potential for impacts on the river environment in plans for wild pig eradication.	H	H	Existing trapping programs on public land (undertaken by DEC) need to be enhanced.
Action 6.2: Undertake an annual survey of wild pig disturbance within the river environment.	H	H	Ongoing surveillance of potential re-introductions is required.

Proposed actions	Management priority (high, medium or low)	Action urgency (high, medium or low)	Comments
Action 6.3: Increase capacity for targeted pig trapping programs within the river environment and adjacent landscapes.	H	H	Opportunities for increased capacity for wild pig control to be considered by DEC, SRT, ACC and SCC
Weed control			
Objective 7: To eradicate or substantially control the two existing dominant weed species in the river environment – watsonia (*Watsonia bulbillifera*) and castor oil (*Ricinus communis*) – and prevent the introduction of three potentially threatening weed species – blackberry (*Rubus fructicosus*), bridal creeper (*Asparagus asparagoides*) and sharp rush (*Juncus actus*)			
Action 7.1: Undertake weed mapping and monitoring for the key threatening species.	H	H	
Action 7.2: Prepare a Lower Avon weed control and prevention plan that is consistent with adjoining land management.	H	H	A targeted response for high priority weeds species in high value river survey sections (SRT, DEC, ACC).
Action 7.3: Undertake weed eradication program for key species.	H	H	
Sediment management			
Objective 8: To monitor change in the level of sediment within significant pools of the Lower Avon river section			
Action 8.1: Undertake sediment surveys of Moondyne Pool and Boongarup Pool.	H	H	Department of Water to arrange pool surveys and ongoing monitoring.
Action 8.2: Arrange periodic monitoring of sediment deposition in river pools identified to be at risk.	H	H	Information from sediment analysis study to be provided to key stakeholder organisations by Department of Water.
Fire management			
Objective 9: To minimise fire risk in the riverine environment			
Action 9.1: Arrange cooperative management and response actions according to the existing fire management plans.	H	M	Liaise with managers of rail corridor infrastructure to ensure that fire risk reduction and fire response capability is coordinated with other public and private organisations (DEC, AWC, WNR).

Proposed actions	Management priority (high, medium or low)	Action urgency (high, medium or low)	Comments
Coordinated management planning			
Objective 10: To ensure consistent management is applied for identified river recovery outcomes			
Action 10.1: Include resource management information from the *Lower Avon river recovery plan* in additional relevant planning processes.	M	M	Opportunities for inclusion of river environment and management information are in *Riverpark* planning, including the *River protection strategy* (SRT), management plans for the national parks and local government statutory and community planning processes.

7 Conclusions

The *Lower Avon river recovery plan* documents the results of the 2006 river foreshore and channel assessment survey and provides key findings from the survey. Further management issues were developed by consultation with key stakeholder organisations during planning processes. The plan provides management responses to enhance river values or prevent further threatening processes.

The recovery plan recognises the Lower Avon river section to be of high environmental quality. It provides significant linkage functions between the Avon and Swan river systems and with adjacent landscapes of high natural diversity value. This section is identified as being a significant wild and scenic river, although the permanent location of the rail corridor detracts from the full social benefit of a wilderness area located near to the metropolitan area of Perth.

The key actions of the recovery plan are to enhance existing management, particularly for control of wild pigs and weeds. The river survey documents the high level of soil disturbance due to pigs. This is damaging to the river environment and is also a sediment and nutrient risk to the Swan River estuary.

Weeds are increasing and there is further potential for establishment of other species. The high weed burden significantly reduces the potential for natural vegetation to regenerate. There is a priority need to reduce the risk of weeds invasion to areas that are identified to be in excellent condition and high environmental health.

There has been community concern about sedimentation of the Lower Avon river section based on the rate at which river pools in the Shire of Toodyay and adjacent areas are being filled with coarse sand. The river survey shows little coarse sand sediment deposition however there are significant river pools, particularly within Walyunga National Park, that are identified to have potential sedimentation risk.

While there are some opportunities to increase public access to the river environment through existing facilities, there are also the further risks of fire, vandalism and liability. New opportunities, including walking trails, are to be considered in preparation of management plans for the two national parks.

The Lower Avon river section is a high value river environment that is relatively inaccessible to the public. Current management arrangements require enhanced capacity to ensure that the key threatening processes, particularly from wild pigs and weeds, are controlled to maintain the environmental and social values of the river.

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Glossary

Algal bloom	The rapid excessive growth of algae, generally caused by high nutrient levels and favourable conditions.
Anabranch	A secondary channel of a river which splits from the main channel and then later rejoins the main channel.
Anastomosing	Braided river channel.
Bank	The steeper part of a waterway channel cross-section, which is usually considered to lie above the normal water level.
Catchment	The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
Debris	Loose and unconsolidated material resulting from the disintegration of rocks, soil, vegetation or other material transported and deposited during erosion.
Discharge	Volumetric outflow of water, typically measured in cubic metres per second.
Ecosystem	A term used to describe a specific environment, e.g. waterway, to include all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Electrical conductivity (EC)	A measure of salinity. The higher the electrical conductivity of a stream the greater the salinity. Measured in millisiemens per centimetre (mS/cm), millisiemens per metre (mS/m) or microsiemens per centimetre (µS/cm).
Electric fence	Any fence design which is electrified, irrespective of whether it consists of electric tape, a single smooth electric wire or four plain wires of which two are electric.
Environment	All the biological and non-biological factors that affect an organism’s life.
Erosion	The subsequent removal of soil or rock particles from one location and their deposition in another location.
Eutrophication	An excessive increase in the nutrient status of a waterbody.
Exotic vegetation	Introduced species of vegetation from other countries or from other regions of Australia (i.e. not endemic to the region).
Fabricated fence	Includes rabbit netting, sheet metal and hinge joint fences.

Floodfringe	The area of the floodplain, outside the floodway, which is affected by flooding. This area is generally covered by still or very slow moving waters during the 100 year flood.
Floodplain	A flat area adjacent to a waterway that is covered by floods every year or two.
Floodway	The river channel and portion of the floodplain which forms the main flow path of flood waters once the main channel has overflowed.
Floodway & bank vegetation	Vegetation which covers the floodway and bank part of the riparian zone. The vegetation which actually grows in the floodway or on the banks above the stream.
Foreshore	Area of land next to a waterway.
Groundwater	Water which occupies the pores and crevices of rock or soil.
Habitat	The specific region in which an organism or population of organisms live.
Hydrology	The study of water, its properties, distribution and utilisation above, on and below the earth's surface.
Large woody debris	A branch, tree or root system that has fallen into or is immersed (totally or partially) in a waterway.
Leaf litter	The uppermost layer of organic material in a soil, consisting of freshly fallen or slightly decomposed organic materials which have accumulated at the ground surface.
Levee	An artificial embankment or wall built to exclude flood waters, or a natural formation next to a waterway built by the deposition of silt from floodwaters.
Monitoring	The regular gathering and analysing of information to observe and document changes through time and space.
Native species	Species that normally live and thrive in a particular ecosystem.
Organism	Any form of life.
pH	Technically, this is the hydrogen ion (H+) concentration in the water. It is the simplest measure of acidity/alkalinity.
Pollution	Any physical, chemical or biological alteration of air, water or land that is harmful to living organisms.
Regeneration	Vegetation that has grown from natural sources of seed, from vegetative growth, or has been artificially planted.

Riffle	The high point in the bed of the stream (accumulation of coarse bed materials) where upstream of accumulations a shallow pool is formed. Downstream from the crest of the accumulation the water is often shallow and fast flowing.
Riparian zone	Refers to the zone directly adjoining a waterway. Any land that adjoins, directly influences, or is influenced by a body of water.
Salinisation	The accumulation of salts in soil and water which causes degradation of vegetation and land.
Sediment	Soil particles, sand and other mineral matter eroded from land and carried in surface waters.
Sedimentation	The accumulation of soil particles within the channel of a waterway.
Slumping	The mass failure of part of a stream bank.
Snags	Large woody debris such as logs and branches that fall into waterways.
Subsidence	The sinking of parts of the ground which are not slope related.
Terrestrial	Relating to land.
Total dissolved salts (TDS)	A measure of salinity. The concentration of dissolved salts measured in milligrams per litre (mg/L).
Turbidity	A measure of the suspended solids in the water.
Undercutting	The undermining or erosion of soil by water from underneath an existing landform (i.e. riverbank), structure (i.e. fence post) or vegetation (i.e. tree).
Verge	The area extending from the top of the bank to the next major vegetation or land use change.
Verge vegetation	The strip of land up to 20m from the immediate river or creek valley.
Waterlogging	Saturation of soil with irrigation water or excessive rainfall, so that the watertable rises close to the surface.
Water quality	The physical, chemical and biological measures of water.
Weed	A plant considered undesirable, unattractive, or troublesome, especially growing where it is not wanted.

Appendix 1

Landholders adjacent to the Lower Avon river section

Property/owner	Lot numbers	Location	Local Government Authority
Australian Wildlife Conservancy (Paruna)	60, 108, 109, 128, 205, 206, 303	Gidgegannup	City of Swan
Avon Valley National Park	1, 3, 11, 303, 580, 929, 1517, 28390, 28391, 28392, 29050	Bullsbrook	City of Swan, Shire of Toodyay
Devereaux Farm Pty Ltd	1, 44, 566, 863, 866, 874, 882, 1225, 1260, 1330, 1331, 1346, 1418	Bullsbrook	City of Swan
Eagle Nest Properties	122	Bullsbrook	City of Swan
Navarel Pty Ltd	40	Bullsbrook	City of Swan
Taylor, E.J.	51, 52, 53, 54	Bullsbrook	City of Swan
Wallace, I.	1316	Bullsbrook	City of Swan
Walyunga National Park	53, 54, 8439, 8718, 8982, 9733, 9734, 10491		City of Swan
WA Planning Commission	3, 11, 929, 1517	Bullsbrook	City of Swan

Appendix 2

Monthly discharge for the Brockman River, Wooroloo Brook and Avon River (m^3/sec)

Brockman River monthly streamflow (Yalliawirra gauging station – No. 616019)

Variable	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
Mean	0.083	0.053	0.024	0.044	0.215	1.489	4.423	5.536	3.273	1.138	0.250	0.064	1.408
Median	0.013	0.009	0.012	0.029	0.104	0.976	3.748	4.605	2.492	0.885	0.185	0.037	0.191
Max	0.615	0.650	0.170	0.200	1.380	9.426	15.84	16.70	9.894	7.834	0.890	0.384	3.474
Min	0.000	0.000	0.000	0.000	0.046	0.078	0.234	1.619	0.414	0.156	0.043	0.007	0.265

Wooroloo Brook monthly streamflow (Karl's Ranch gauging station – No. 616001)

Variable	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
Mean	0.089	0.043	0.047	0.146	0.600	2.469	5.234	4.848	2.843	1.220	0.334	0.090	1.605
Median	0.008	0.000	0.005	0.083	0.403	2.076	4.421	4.222	2.314	0.953	0.262	0.065	0.384
Max	1.065	0.765	0.944	1.556	3.160	7.230	19.93	11.80	7.341	4.475	1.541	0.378	4.830
Min	0.000	0.000	0.000	0.000	0.042	0.177	0.601	1.280	0.372	0.124	0.031	0.001	0.465

Avon River monthly streamflow (Walyunga gauging station No. – 616011)

Variable	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
Mean	2.673	2.779	0.510	1.024	3.139	15.44	37.57	38.31	19.55	5.962	1.347	0.230	10.54
Median	0.013	0.000	0.001	0.075	1.331	9.794	22.26	25.31	13.49	4.467	0.748	0.087	1.624
Max	63.83	53.38	7.048	13.61	20.05	84.27	156.5	199.5	85.13	27.15	8.462	1.381	39.79
Min	0.000	0.000	0.000	0.000	0.069	0.456	2.425	8.934	3.045	1.216	0.079	0.003	0.000

Appendix 3

Lower Avon survey section length, gradient and coordinates

Section	GPS Coordinates (GDA 94)		Spot height (m AHD)	Distance (m)	Gradient (%)
	E	N			
Start	431222	6506657	95.00		
LA01	430392	6506300	90.00	1091.62	0.46
LA02	429557	6505968	90.00	866.89	0.00
LA03	428703	6505861	85.00	1202.67	0.42
LA04	428062	6505362	80.00	776.56	0.64
LA05	427607	6504762	80.00	927.98	0.00
LA06	426639	6504089	80.00	791.09	0.00
LA07	425848	6503531	80.00	896.41	0.00
LA08	425046	6502944	76.51	1041.73	0.33
LA09	424314	6502588	75.00	819.88	0.18
LA10	423556	6501961	70.86	1145.74	0.36
LA11	422947	6501069	70.53	716.06	0.05
LA12	422861	6500476	65.00	1040.69	0.53
LA13	423153	6499486	65.00	833.69	0.00
LA14	423141	6498476	65.00	900.18	0.00
LA15	422500	6497907	60.00	845.17	0.59
LA16	422182	6496864	60.00	1090.40	0.00
LA17	421358	6496676	55.00	857.11	0.58
LA18	420476	6496856	55.56	1010.07	-0.06
LA19	419725	6496494	NA	1032.16	NA
LA20	418927	6495826	50.00	599.20	NA
LA21	418366	6495381	50.00	1080.07	0.00
LA22	417433	6494716	50.00	983.71	0.00
LA23	416693	6494363	52.47	813.98	-0.30
LA24	415897	6493691	46.71	993.87	0.58
LA25	415231	6493091	47.21	968.01	-0.05
LA26	414475	6492858	40.00	1178.96	0.61
LA27	413679	6492381	35.00	753.01	0.66
LA28	413369	6491669	35.00	812.33	0.00
LA29	412779	6490621	29.87	860.68	0.60
LA30	412599	6489773	25.00	898.58	0.54
LA31	412415	6488697	23.75	903.52	0.14

Appendix 4

Foreshore and channel assessment field survey form

Foreshore and channel condition assessment form

For property and paddock scale surveys

General details

Recorder's name: …… Survey date: ……

Tributary name:…… Section number……..

Catchment name: Avon River Length of section: ……...

Sub-catchment name: …….. Shire: ……..

GPS (start of survey section) E: ……..…… N:……

GPS (end of survey section) E: …….. N: ……

Landholder contacted: Yes ❒ No ❒ Bank(s) surveyed (facing upstream)

Landholder consent obtained: Yes ❒ No ❒ Left ❒ Right ❒ Both ❒

Landholder present during survey: Yes ❒ No ❒

Landholder: …… Contact Number: ……

Property address: ……

Bank stability

Proportion of bank affected (% of survey area)	Undercutting	Firebreak/track washouts	Subsidence (sinking of soil)	Erosion	Gully erosion	Sedimentation	Slumping (mass
0-5% Minimal							
5-20% Localised							
20-50% Significant							
>50% Severe							

Are the banks subject to any artificial stabilisation?: ❒ Yes ❒ No

Give details:

……

……

Waterways features

❒ Single channel
❒ Braided channel
❒ Deep pool
❒ Wetlands
❒ Groundwater seep
❒ Natural riffle
❒ Anabranch
❒ Tributary
❒ Large woody debris
❒ Vegetated island
❒ Constructed riffles
❒ Sediment slug
❒ Crossing
❒ Dam
❒ Bridge
❒ Other
……
……

Vegetation health

❒ Looks healthy ❒ Some sick trees (some foliage loss) ❒ Many sick or dying trees ❒ Some dead trees ❒ Many dead trees

Are there any tree seedlings or saplings present?: ❒ Yes ❒ No Species: …….

Leaf litter: ❒ Absent ❒ Minimal cover ❒ Good cover ❒ Deep cover

Bare ground: % cover: …….

Native vegetation: ❒ Abundant ❒ Frequent ❒ Occasional ❒ Rare ❒ Absent

Exotic vegetation: ❒ Abundant ❒ Frequent ❒ Occasional ❒ Rare ❒ Absent

Instream cover: ❒ Leaf litter/detritus ❒ Rocks ❒ Branches ❒ Vegetation

Vegetation cover (native and weeds)

Proportion cover	Overstorey	Middlestorey	Understorey
> 80% continuous			
20-80% patchy			
< 20% sparse			
0% absent			

Proportion of native species

	Proportion (%) of native species
Overstorey	
Middlestorey	
Understorey	

Habitats

Aquatic organisms

Invertebrates, reptiles and fish

❒ Cascades, rapids, riffles
❒ Meanders, pools
❒ Instream cobbles, rocks
❒ Instream logs
❒ Variety of instream and bank vegetation types

Terrestrial animals

Invertebrates

❒ Variety of vegetation types
❒ Protected basking sites (tree bark, leaf litter)

Birds (roosting/nesting sites)

❒ Trees
❒ Shrubs
❒ Rushes

Frogs

❒ Dense fringing vegetation
❒ Emergent plants/soft substrate for eggs

Reptiles

❒ Variety of vegetation types
❒ Protected basking/nesting sites (leaf litter, logs)

Mammals

❒ Dense protective vegetation

Habitat diversity

Any data or observations on variation in water depth? Evidence – debris, water marks, salt deposits etc

Any data or observations on water quality? (i.e. discoloured water, debris, algal blooms)

Landform types

Description/diagram (ie. major v-shaped river valley with granite outcrops, shallow valley with low relief).

Fencing status

Fence section 1

Start……E Start……..N End……..……E End……..N

Left bank ❒ Right bank ❒ Fence condition: ❒Good ❒Moderate ❒ Poor ❒ No fence

Fence style: ❒ Barbed wire ❒ Electric ❒ Fabricated ❒Ringlock ❒ Plain wire

Approximate distance [m] from main channel: ❒ >10m ❒ 10-20m ❒ 20-30m ❒ >30m

Fence section 2

Start……E Start……..N End……..……E End……..N

Left bank ❒ Right bank ❒ Fence condition: ❒Good ❒Moderate ❒ Poor ❒ No fence

Fence style: ❒ Barbed wire ❒ Electric ❒ Fabricated ❒Ringlock ❒ Plain wire

Approximate distance [m] from main channel: ❒ >10m ❒ 10-20m ❒ 20-30m ❒ >30m

Fence section 3

Start……E Start……..N End……..……E End……..N

Left bank ❒ Right bank ❒ Fence condition: ❒Good ❒Moderate ❒ Poor ❒ No fence

Fence style: ❒ Barbed wire ❒ Electric ❒ Fabricated ❒Ringlock ❒ Plain wire

Fence section 4

Start……E Start……..N End……..……E End……..N

Left bank ❒ Right bank ❒ Fence condition: ❒Good ❒Moderate ❒ Poor ❒ No fence

Fence style: ❒ Barbed wire ❒ Electric ❒ Fabricated ❒Ringlock ❒ Plain wire

Approximate distance [m] from main channel: ❒>10m ❒ 10-20m ❒ 20-30m ❒ >30m

Fence section 5

Start……E Start……..N End……..……E End……..N

Left bank ❒ Right bank ❒ Fence condition: ❒Good ❒Moderate ❒ Poor ❒ No fence

Fence style: ❒ Barbed wire ❒ Electric ❒ Fabricated ❒Ringlock ❒ Plain wire

Approximate distance [m] from main channel: ❒>10m ❒ 10-20m ❒ 20-30m ❒ >30m

Stock access to foreshore: ❒Yes ❒ No Vehicle access to foreshore: ❒Yes ❒ No
Crossing Point: ❒Yes ❒ No

Foreshore condition assessment

A-grade foreshore	**B-grade foreshore**	**C-grade foreshore**	**D-grade foreshore**
A1 Pristine	B1 Degraded – weed infested	C1 Erosion prone	D1 Ditch – eroding
A2 Near pristine	B2 Degraded – heavily weed infested	C2 Soil exposed	D2 Ditch – freely eroding
A3 Slightly disturbed	B3 Degraded – weed dominant	C3 Eroded	D3 Drain – weed dominant

(Choose one of the above. Use Grades A, B, C or D for general condition and use sub-grades for best and poorest ratings ie A1 through to D3)

General: Best: Poorest:

Overall stream environmental health rating

Rating	Floodway & bank vegetation	Verge vegetation	Stream cover	Bank stability & sediment	Habitat diversity
Excellent	15	8	8	8	6
Good	12	6	6	6	4
Moderate	6	4	4	4	2
Poor	3	2	2	2	1
Very poor	0	0	0	0	0

Surrounding landuse:

Conservation reserve (8) Urban (2) Agricultural (2)

Rural residential (4) Remnant bush (6) Commercial/industrial (1)

Total score = ☐

Score	40-55	30-39	20-29	10-19	0-9

Evidence of management

Tick the appropriate boxes:

❒ Prescribed burning
❒ Firebreak control
❒Fencing
❒ Weed control
❒ Revegetation
❒ Erosion control
❒ Sediment management
❒ Other:……

Management issues

Tick the appropriate priority box for each management issue. If the issue does not exist along this section of the waterway it can be crossed out.

Issue	Priority		
	High	Medium	Low
Fire			
Disease			
Weeds			
Erosion			
Salinity			
Sediment			
Stock access			
Vehicle access			
Rubbish			
Pollution			

Issue	Priority		
	High	Medium	Low
Recreation			
Service corridors (roads)			
Crossing point			
Feral animals			
Point source discharge			
Pumps or off-take pipes			
Dam/weir			
Cultural features			
Other			

Ideas for management

Tick the appropriate boxes:

❒ Firebreak control
❒ Fencing
❒ Erosion control
❒ Other:
❒ Stock/vehicle crossing
❒ Revegetation
❒ Weed control
❒Riffles
❒ Sediment management

……

Native plant list

Introduced plant list

Native fauna list

Introduced fauna list

Water quality data

Sample number	pH	Conductivity (mS/cm)	Temperature (ºC)	Location

GPS coordinates

Coordinate	Description

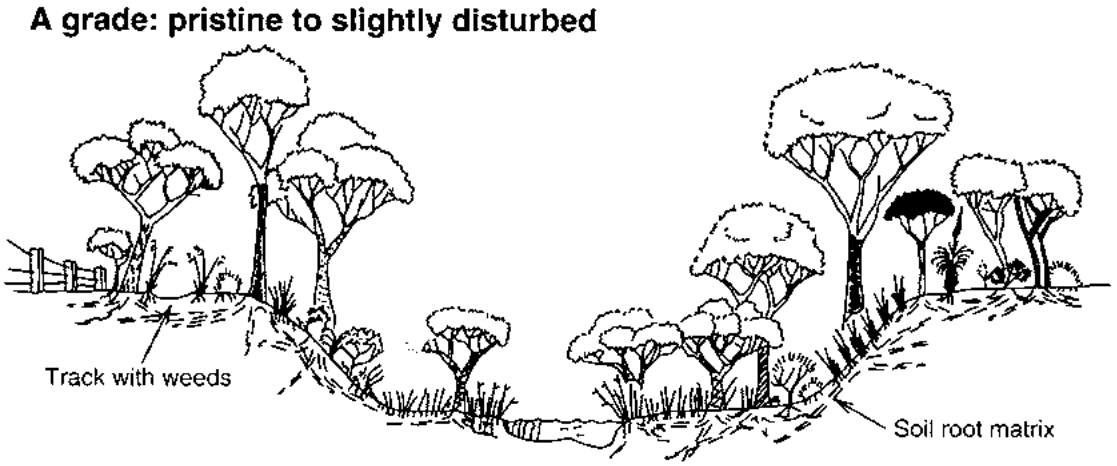
Photos

Photo number	Description

Appendix 5

Foreshore condition for the Lower Avon river section

Section number	General	Best	Poorest
LA01	B2	B2	C3
LA02	B1	A3	B2
LA03	A3	A2	B1
LA04	A3	A2	A3
LA05	A3	A2	A3
LA06	A1	A2	B3
LA07	A3	A3	B1
LA08	A3	A2	B1
LA09	A3	A3	B1
LA10	A3	A3	B1
LA11	B1	B1	B2
LA12	B3	B3	B3
LA13	B2	B2	B3
LA14	B3	B2	B3
LA15	B3	B3	B3
LA16	B2	B1	B2
LA17	B1	A3	B2
LA18	B1	A3	B3
LA19	B2	B2	B3
LA20	B3	B2	B3
LA21	B3	B3	B3
LA22	B2	B3	B1
LA23	B2	A3	B2
LA24	B2	B1	B2
LA25	B2	B2	B2
LA26	B2	B2	B3
LA27	B2	B2	B3
LA28	B3	B2	B3
LA29	B3	B3	B3
LA30	B3	A3	B3
LA31	B2	B1	B3

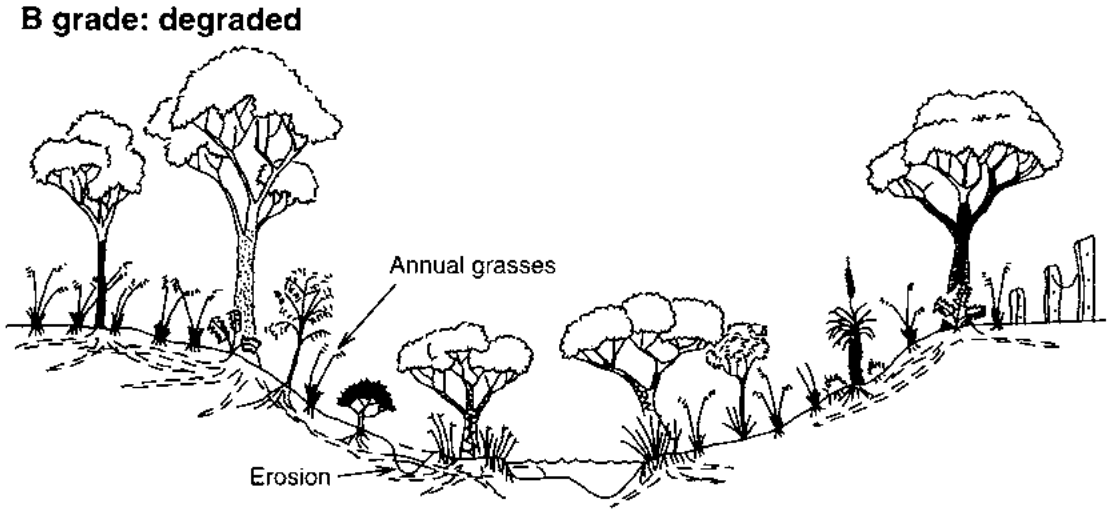


***A-grade** – Foreshore has healthy native bush similar to that found in nature reserves, state forests and national parks:*

A1. Pristine – river embankments and floodway are entirely vegetated with native species and there is no evidence of human presence or livestock damage.

A2. Near Pristine – Native vegetation dominates. Some introduced weeds may be present in the understorey but not as the dominant species. Otherwise, there is no evidence of human impact.

A3. Slightly Degraded – Native vegetation dominates. Some areas of human disturbance where soil may be exposed and weeds are relatively dense (i.e. along tracks). Native vegetation would quickly recolonise if human disturbance declined.

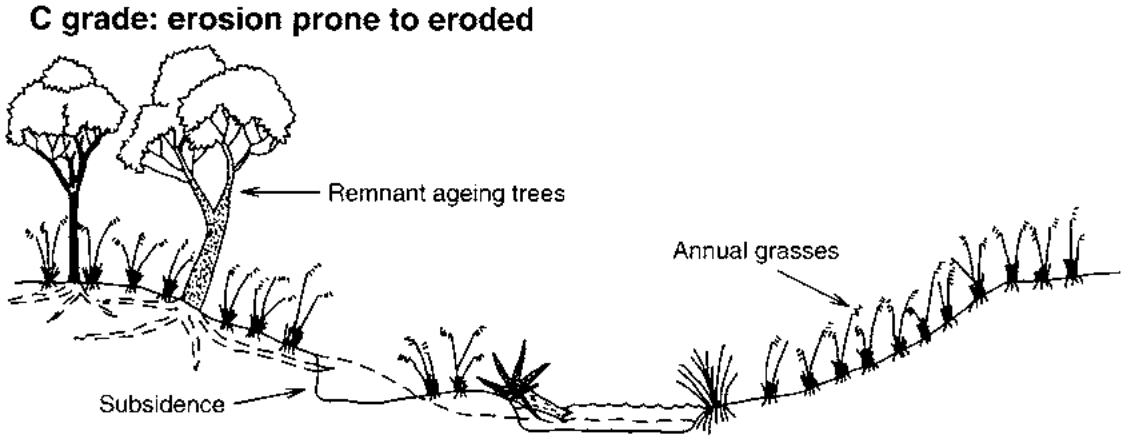


***B-grade** – The foreshore vegetation had been invaded by weeds, mainly grasses, and looks similar to typical roadside vegetation:*

B1. Degraded – weed infested – Weeds have become a significant component of the understorey vegetation. Native species are still dominant but a few have been replace by weeds.

B2. Degraded – heavily weed infested – Understorey weeds are nearly as abundant as native species. The regeneration of trees and large shrubs may have declined.

B3. Degraded – weed dominant – Weeds dominate the understorey, but many native species remain. Some trees and large shrubs may have disappeared.

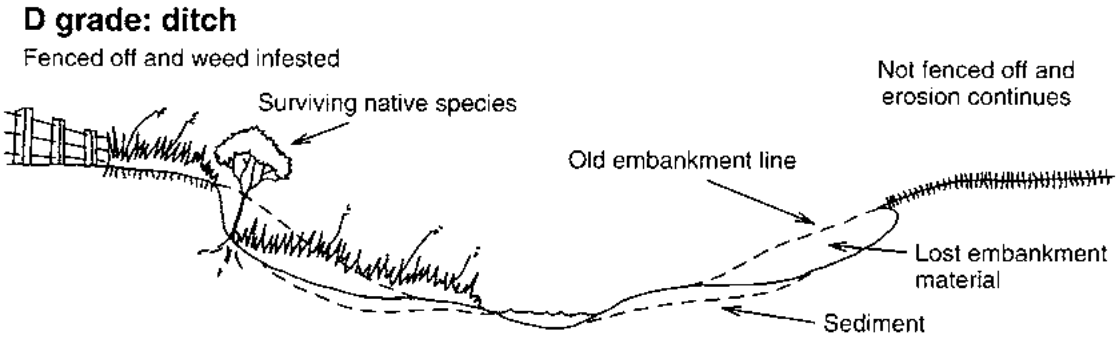


***C-grade** – The foreshore supports only trees over weeds or pasture. Bank erosion and subsidence may occur in localised areas:*

C1. Erosion prone – Trees remain with some large shrubs or tree grasses and the understorey consists entirely of weeds (i.e. annual grasses). There is little or no evidence of regeneration of tree species. River embankment and floodway are vulnerable to erosion due to the shallow-rooted weedy understorey providing minimal soil stabilisation and support.

C2. Soil exposed – Older trees remain but the ground is virtually bare. Annual grasses and other weeds have been removed by livestock grazing and trampling or through human use and activity. Low level soil erosion has begun.

C3. Eroded – Soil is washed away from between tree roots. Trees are being undermined and unsupported embankments are subsiding into the river valley.



***D-grade** – The stream is little more than an eroding ditch or a weed infested drain:*

D1. Ditch – eroding – There is not enough fringing vegetation to control erosion. Remaining trees and shrubs act to impede erosion in some areas, but are doomed to be undermined eventually.

D2. Ditch – freely eroding – No significant fringing vegetation remains and erosion is out of control. Undermined and subsided embankments are common. Large sediment plumes are visible along the river channel.

D3. Drain – weed dominant – The highly eroded river valley has been fenced off, preventing control of weeds by stock. Perennial weeds have become established and the river has become a simple drain.

Adapted from Water and Rivers Commission, 1999

Appendix 6

Overall environmental stream health rating

	Floodway and bank vegetation	Verge vegetation	Stream cover	Bank stability and sedimentation	Habitat diversity
Excellent	Healthy undisturbed native vegetation. Virtually no weeds. No disturbance. **(15 points)**	Healthy undisturbed vegetation. Verges more than 20 m wide. **(8 points)**	Abundant cover: shade, overhanging vegetation, snags, leaf litter, rocks and/or aquatic vegetation. **(8 points)**	No erosion, subsidence or sediment deposits. Dense vegetation cover of banks and verge. No disturbance. **(8 points)**	3 or more habitat zones. Some permanent water . **(6 points)**
Good	Mainly healthy undisturbed native vegetation. Some weeds. No recent disturbance. **(12 points)**	Mainly healthy undisturbed native vegetation. Verges less than 20 m wide. **(6 points)**	Abundant shade and overhanging vegetation. Some instream cover. **(6 points)**	No significant erosion, subsidence or sediment deposits in floodway or on lower banks. May be some soil exposure and vegetation thinning on upper bank and verge. **(6 points)**	2 habitat zones. Some permanent water. **(4 points)**
Moderate	Good vegetation cover, but mixture of native and exotic species. Localised clearing. Little recent disturbance. **(6 points)**	Good vegetation cover, but mixture of native and exotic species. Verges 20 m or more. **(4 points)**	Some permanent shade and overhanging vegetation. Some instream cover. **(4 points)**	Good vegetation cover. Localised erosion, bank collapse and sediment heaps only. Verges may have sparse vegetation cover. **(4 points)**	Mainly 1 habitat type with permanent water, OR range of habitats with no permanent water. **(2 points)**
Poor	Mainly exotic groundcover. Obvious site disturbance. **(3 points)**	Narrow verges only (< 20 m wide). Mainly exotic vegetation. **(2 points)**	Channel mainly clear. Little permanent shade or instream cover. **(2 points)**	Extensive active erosion and sediment heaps. Bare banks and verges common. Banks may be collapsing. **(2 points)**	Mainly 1 habitat type with no permanent water. **(1 point)**
Very poor	Mostly bare ground or exotic groundcovers (i.e. pasture, gardens or weed infestations, but no trees). **(0 points)**	Mostly bare ground or exotic groundcovers (i.e. pasture, gardens or weed infestations, but no trees). **(0 points)**	Virtually no shade or instream cover. **(0 points)**	Almost continuous erosion. Over 50% of banks collapsing. Sediment heaps line or fill much of the floodway. Little or no vegetation cover. **(0 points)**	Stream channellised. **(0 points)**

Appendix 7

Lower Avon survey section descriptions

Note: (1) LHS and RHS references relate to facing upstream.
(2) All GPS coordinates are given in GDA 94 and are taken from the RHS river bank

Section	Description
LA01 Section length – 1092 m	Section starts at the north-east boundary of the Avon Valley National Park. It has a subdued meander pattern with a 60:40 pool–riffle ratio. There are two island formations. One is located 400 m downstream with a high debris load (E 430954 N 6506515). Julimar Brook is a tributary midway on the LHS (Ph 06 E 430797 N 6506457). There is a high level of bank erosion of the erosional face of meanders. There is subsidence in floodplain soils. Depositional levees (3–4 m height) are established but eroding. Coarse sediments are in the channel with one conspicuous sand slug (E 430526 N 6506341). Riparian vegetation is healthy, diverse and multi-strata. Weeds are extensive. Pig damage is high (LHS, E 430914 N 6506498).
LA02 Section length – 867 m	Section starts downstream from a small island. A minor tributary without flow occurs in the LHS. It has a subdued meander pattern with a significant meander with rapids of high scenic value at the downstream end (E 429699 N 6506568). The section has a 75:25 pool–riffle ratio. A distinct floodway is formed both sides. The pools have high scenic value (e.g. 400 m downstream at E 430082 N 6506222). There is no sediment deposition within the channel or pools. Riparian vegetation is healthy, diverse and multi-strata. Weeds are extensive. There is a high level of disturbance by pigs (e.g. 200 m downstream at E 430 254 N 650 6252) although there are parts where this damage is low.
LA03 Section length – 1203 m	Section is orientated with westerly flow. It has a moderate meander pattern with a 45:55 pool–riffle ratio. There is a high level of rock outcrop, scenic rapids and relatively low sediment deposition. Floodways are continuous on both sides. There is evidence of a former dwelling on the LHS (yucca plant – E 429 151, N 650 5940). Riparian vegetation is healthy, diverse and multi-strata. Weeds are extensive. There is a high level of disturbance by pigs.
LA04 Section length – 777 m	Flow in this section is orientated south-west. There is a significant meander with extensive rock outcrop at Emu Falls. The section has a 60:40 pool–riffle ratio. There are two LHS tributaries, one upstream and the other just downstream from Emu Falls, both are without streamflow. Sappers Road campsite with a toilet and BBQ facilities is on the LHS. There is a significant road crossing. Erosion and sediment deposition is minimal although there are three small sand slugs at the upstream end of this section and some sediments above the falls. Riparian vegetation is healthy, diverse and multi-strata. The first observation of *Ruppia sp.* is in the pool upstream from Emu Falls. Weeds are extensive. Castor oil plants are recorded on the RHS (E 4282663 N 6505618) and further downstream. Watsonia occurs on the LHS near Emu Falls. There is a high level of disturbance by pigs.

Section	Description
LA05 Section length – 928 m	The channel is orientated south-west and has a very subdued meander pattern. There is a minor bend associated with rock outcrop midway in the section (this location is of high scenic value). The pool–riffle ratio is 75:25. The floodway is well defined on both sides. There is one major tributary (Joe's Brook) of the LHS. Erosion is minimal and there was no sediment observed in pools. There is a very high level of soil disturbance by pigs on both sides. Weeds are colonising the disturbed areas. Watsonia is a significant weed on the LHS in this section. Riparian vegetation is healthy, diverse and multi-strata. There is a sedge bed on the LHS (E 427710 N 6504932) adjacent to the rock outcrop midway in the section. *Ruppia* occurs commonly in pools.
LA06 Section length – 791 m	This section has a high quality pool at the upstream end. The channel is orientated south-west with very subdued meander pattern. The pool–riffle ration is 88:15 with a series of minor rapids in the upstream end. The rapid at LA06 is of high scenic value. There is coarse sand sediment in the pool downstream of the series of rapids (E 427316 N 6504566). There is woody debris in the channel and a moderate level of bank erosion. Riparian vegetation is in good condition being diverse and multi-strata. There is a high occurrence of watsonia and radish on the RHS (E 427431 N 6504630) and in other locations. There are isolated areas of castor oil on the LHS (E 426831 N 6504259). There is a very high level of disturbance by pigs.
LA07 Section length – 896 m	This section is orientated south-west and has a subdued meander pattern. Downstream from LA06 is a rapid with high scenic value with a billabong on the RHS and wandoo on the LHS. Further downstream the river bifurcates around a rocky outcrop. The pool–riffle ration is 78:22. Floodway formation is extensive on both sides. There is significant bank erosion with some slumping. There is coarse sediment deposition upstream and downstream from the river island (E 426380, N 6503863). There is sediment deposited on the island although this is vegetated and stable. There is a high level of pig disturbance that destabilises the banks and floodways. Riparian vegetation is healthy and in good condition. There is watsonia on the RHS and blackberry nightshade on the LHS.
LA08 Section length – 1042 m	The channel is orientated south-west in this section. There is one broad meander associated with extensive rock outcrop. The extensive river pools are narrow with rock outcrop on banks in some places. The pools are potentially quite deep. The pool–riffle ratio is 60:40. There is one tributary on the LHS. Floodways exist where there is not rock outcropping. The river is of high scenic value in this section, particularly where there is extensive rock outcrop in the channel (E 425682 N 6503470). Bank erosion is localised however there is significant disturbance due to pigs in this section. Riparian vegetation is healthy, diverse and is in excellent condition. There is a high occurrence of weeds on the RHS for the first 100–200 m downstream from LA07. Castor oil is located at E 425394 N 6503243.

Section	Description
LA09 Section length – 820 m	This section is without meanders. It is dominated by a long pool between rock outcrops. The pool–riffle ratio is 80:20. There is a small rock tributary without streamflow (at the time of survey) on the LHS up stream from LA09. There is bare rock exposure on the RHS. This rocky landform has caused the access road on the RHS to be located relatively close to the river channel (less than 10 m). There is no bank erosion due to rock outcropping. There is severe pig disturbance. Riparian vegetation is healthy and in excellent condition. Castor oil is located at E 424598 N 6502724.
LA10 Section length – 1146 m	This section is orientated south-west and there is no meander pattern. The pool–riffle ratio is 83:17. There is one long pool followed by a regularly spaced pool and rapid sequence. There are floodways both sides. There is minimal bank erosion and no observed sediment deposition. Pig disturbance is significant. Riparian vegetation is healthy, diverse and in excellent condition. Castor oil is very common, particularly at E424150 N 6502483. It is continuous in some areas of the LHS.
LA11 Section length – 716 m	The river channel in this section is orientated south-west then bends significantly to the south 200 m upstream from LA11. There is a large rock island midway in the section with an extensive rapid in the LHS and with relatively shallow rocky pools upstream and downstream. The pool–riffle ratio is 68:32. There are two small tributaries on the LHS. There is minimal bank erosion and only localised pig disturbance in this section. There is a slug of coarse sand sediment downstream from the rock island (E 423819 N 6501654). *Ruppia* spp. is in the shallower pools. Riparian vegetation is healthy and is in excellent condition. Blackberry nightshade occurs in the LHS. There is a potential campsite on the LHS with adjacent road access. A boundary fence to the river is on the LHS (E 423061 N 6501434). The adjacent LHS land has been previously cleared for grazing.
LA12 Section length – 1041 m	Section 12 has a continuing significant bend that orientates towards the south-east. There is a subtle meander pattern determined by rock outcrops. The pool–riffle ratio is 60:40 indicating the extensive rock outcropping that occurs. There is a small tributary on the LHS 300 m downstream from LA11 and near an area of rock outcrop that has high scenic value. There is minimal bank erosion and localised pig disturbance. There is one small slug of coarse sand sediment on the LHS. Moondyne Road has caused gully erosion on the LHS. This has been repaired. The riparian vegetation has been diminished by a high level of agricultural weeds on the LHS. The fringing vegetation near LA11 shows stress from high salt levels, possibly from a flood event. It is one of the few locations where swamp paperbark appears to be affected by salinity.

Section	Description
LA13 Section length – 834 m	The river channel is orientated south with a subtle meandering pattern determined by extensive rock outcropping. The pool–riffle ratio is 50:50. There are extensive rocky sections in the main channel with flow chutes. There is a small tributary in the LHS. A major feature is extensive rock outcrop in the LHS for 400 m upstream from LA13. There is unconsolidated coarse sand on this rocky area with potential to be mobilised downstream in high streamflow. There is a levee of coarse sand on the LHS midway in this section. Floodways are formed on both sides of the river. Bank erosion is minimal but there is significant disturbance by pigs where castor oil is colonising (e.g. at E 423089 N 6500123). Riparian vegetation is healthy and there is good upper- and mid-strata cover. There is a high occurrence of weeds in this section.
LA14 Section length – 900 m	The channel is orientated south with a very subdued meander pattern. The section commences upstream with the substantial area of cobblestone outcrop on the LHS which has unconsolidated coarse sediment. The anabranch flow channel on the LHS is a potential source of sediment in higher flow events (E 423089 N 6499268). There is one small tributary on the LHS. The pool–riffle ratio is 80:20. Several locations have high scenic value. An old trail suitable for walking or small vehicle access commences on the LHS. Downstream is a set of rapids and a significant river flow chute which form the upstream end of Moondyne Pool. This pool could be threatened by the sediment source on the cobblestone outcrop upstream. This section has minimal bank erosion and localised disturbance by pigs. Riparian vegetation is generally healthy although there are some *E. rudis* stags on the banks. The understorey is dominated by weeds.
LA15 Section length – 845 m	This section has a significant bend to a western orientation with no meander pattern. The pool–riffle ration is 80:20 due mainly to the section being dominated by Moondyne Pool. This pool appears to be relatively shallow. Red Swamp Brook is a major tributary on the RHS with relatively high, fresh streamflow. There is a groundwater seep on the LHS. Floodways are almost continuous both sides. There is minimal bank erosion and localised disturbance by pigs. Riparian vegetation is generally healthy although the understorey is dominated by weeds. Castor oil is commonly occurring (e.g. E 423138 N 6498324 and at LA15). There is a road crossing at the lower end of Moondyne Pool. An old trail is continuous on the LHS.

Section	Description
LA16 Section length – 1090 m	The river is without significant meanders with a west to south orientation. The section commences with a stable vegetated island. A small peninsular protrudes on the LHS. The pool–riffle ratio is 73:27. There are two tributaries on the LHS that probably have high flow for a short period with runoff from steep rocky slopes. One had low flow at the time of survey. The floodway is relatively stable on the LHS. Bank erosion is minimal and there is localised disturbance by pigs. Minimal coarse sand sediment is deposited on the banks. Riparian vegetation is healthy although the understorey is dominated by weeds. Dense growth of *Ruppia* spp. occurs in some pool sections. An active cormorant rookery exists on swamp paperbark on the small peninsular. Little pied and little black cormorants were nesting at this site. An old trail is continuous on the LHS. A four-wheel drive access crossing is located at LA16.
LA17 Section length – 857 m	This section of the river has a major bend to the west from where it is straight without significant meanders. The pool–riffle ratio is 78:22 with long pool sections. There is high scenic value for this section of the river, particularly the river pools, and there is good viewing access from the LHS track. There is a floodway on the LHS that is in places unstable and may discharge fine sediments to a river pool. There is minimal bank erosion although there is significant disturbance by pigs. Riparian vegetation is healthy, diverse and in excellent condition. There is natural regeneration at E 421804 N 6496697 although watsonia and castor oil are very common at this location. Castor oil is also substantial at E 422018 N 6496481.
LA18 Section length – 1010 m	This section of the river is orientated west with only subdued meandering. The pool–riffle ratio is 83:17 . There is localised bank erosion and significant disturbance by pigs in this section. There is significant gully erosion on the LHS at E 420708 N 6496810. This requires control and restoration. Coarse sand is deposited on the RHS 100m down from LA17 and on the LHS 450 m down from LA17. Riparian vegetation is in excellent condition although there are significant numbers of castor oil at several locations. There is good access for pig control on the LHS track although gully erosion has cut the track.
LA19 Section length – 1032 m	The river is orientated south-west with a subdued meander pattern. The adjacent vegetated hills on both sides provide very high scenic value. The mid-section rapids also have high scenic value. There is a significant stable tributary on the LHS. The floodway on the LHS is well defined although disturbed by pigs. There is localised bank erosion and significant disturbance by pigs. Riparian vegetation is healthy and in good condition although has high weed infestation of the understorey. Watsonia is extensive on both sides but particularly on the LHS down from E 419588 N 6496559. There is four-wheel drive access across the river at E 420377 N 6496777. The old track on the LHS provides good access.

Section	Description
LA20 Section length – 599 m	This section of the river is orientated south-west and has a gentle meander pattern. The pool–riffle ratio is 90:10 indicating only limited areas of rock outcropping and extensive pool lengths. There is a significant rocky tributary on the LHS (E 419572 N 6496261) with low flow at the time of the survey. The river bank has significant bank erosion with some bank slumping down from LA19 which may be the cause of sediment deposition downstream. There is significant disturbance by pigs. Riparian vegetation is healthy although the understorey is dominated by weeds, particularly watsonia on the LHS down from the property boundary (E 419177 N 6495962). There are significant numbers of watsonia and castor oil on the RHS 100 m down from LA19. There is an isolated patch of bamboo on the RHS (E 419517 N 6496203). There is good access on the LHS old track.
LA21 Section length – 1080 m	The river channel is orientated south-west in this section and there are no bends or meanders. The dominant feature is a long river pool commencing upstream from LA20 and with a rock constriction 200 m upstream from LA21. The pool–riffle ratio is 100:0. There are two small tributaries on the LHS and one that is eroding near the confluence on the RHS. There is significant bank erosion and significant disturbance caused by pigs. It appears that fine sediments from the eroding depositional banks and disturbed floodway are entering the pool. The margins of the pool appear to be shallowing as a result. Riparian vegetation is healthy although the understorey is dominated by weeds, particularly watsonia and radish. *Ruppia* spp. grows densely in the major river pool suggesting that it may be shallow on the margins. The old track continues on the LHS.
LA22 Section length – 984 m	The orientation of the river in this section is south-west. There is a subtle meander pattern at the downstream end of the section associated with extensive rock outcropping in the channel and adjacent LHS bank. The pool–riffle ratio is 65:35. There is a well defined pool–riffle sequence. The pools seem well scoured and relatively deep (estimated to be 2–4 m). There is minimal erosion although significant disturbance by pigs, particularly on a LHS river terrace. Riparian vegetation is healthy and in good condition although the understorey is dominated by weeds. There are significant numbers of watsonia.

Section	Description
LA23 Section length – 814 m	This section has a south-west orientation with one significant meander midway followed by a subtle meander pattern determined by rock outcropping. The pool–riffle ration is 58:42 indicating that there is quite extensive rock outcropping in the channel, some forming extensive rapids. The floodway is well defined for 25% of the section on the RHS and 50% of the section on the LHS. There is a small dry tributary on the RHS 350 m from LA23 (E 417109 N 6494577) and another small dry tributary on the LHS 100 m further downstream. There is minimal bank erosion and localised disturbance by pigs although this is significant where it occurs, particularly in the upstream banks of this section. The riparian vegetation is healthy, diverse and in excellent condition although the understorey is dominated by weeds. The RHS bank has extensive depositional soils on which swamp sheoak has established. This is the commencement of further areas of swamp sheoak further downstream. The extensive rock outcropping and excellent riparian vegetation condition adds to the high scenic value of this section.
LA24 Section length – 994 m	This section is orientated south-west and has a broad, subtle meander pattern. The pool–riffle ratio is 75:25. Floodways are well formed on the LHS but are limited in extent on the RHS. There is one small dry tributary on the RHS 400 m upstream from LA24. The confluence of the Brockman River is on the LHS 250 m downstream from LA23 (E 416429 N 6494251). There is fine sediment deposited downstream from the Brockman Riverand coarse sediment on the RHS. The downstream pools have higher turbidity due to the fine sediments from the Brockman River. The salinity of streamflow in the Avon River is lower (10.6 mS/m) downstream from the confluence due to the fresh inflow from the Brockman. There is minimal erosion, and disturbance by pigs is relatively low. Slumping occurs on the LHS bank 450 m upstream from LA24 (E 416343 N 6494014) although this is now relatively stable and has flooded gum regeneration. Riparian vegetation is healthy and in good condition although with the understorey dominated with weeds. Castor oil is commonly occurring, particularly on the RHS. There is a distinct increase in agricultural weeds downstream from the confluence of the Brockman River. Puccinellia and salt water couch are in the channel of the Brockman and have established to a limited extent in the Avon downstream from the confluence. LHS river fencing on private property is in very good condition. This section has high scenic value
LA25 Section length – 968 m	The orientation alters from south-west towards the west in this section. The meander pattern is subtle, determined by rock outcropping. The pool–riffle ratio is 65:35. Floodway development is extensive on the RHS. One tributary occurs on the RHS (E 416632 N 6493274). Streamflow was relatively fresh (3.8 mS/m). There is minimal bank erosion and disturbance by pigs is localised. Riparian vegetation is healthy although the understorey is dominated by weeds. Watsonia is commonly occurring. Some parts of this section have high scenic value.

Section	Description
LA26 Section length – 1179 m	The river maintains a west-south-west orientation in this section with moderate meanders determined by rock outcrops. There are two long rocky rapids 200–300 m in length. Floodways are formed. There is a dry LHS tributary (‘Casuarina Gully’) that flows adjacent to private campground facilities midway in the section. There is minimal bank erosion and disturbance by pigs is localised although significant where it occurs. There is coarse sediment on the RHS at E 414698 N 6492951. Riparian vegetation is healthy and in good condition although the understorey is dominated by weeds. Watsonia is commonly occurring.
LA27 Section length – 753 m	This section of the river has a significant bend that alters the orientation broadly from west to south. The river valley is narrower than further upstream. The pool–riffle ratio is 50:50 and the pools are shorter and the rapids longer. There is a dry tributary on the LHS 450 m downstream from LA26. There is another dry tributary 450 m upstream from LA27 on the LHS (E 413694 N 6492463). Floodway formation is very limited on both sides. There is minimal bank erosion. Disturbance by pigs is localised although significant where it occurs. There is one area of conspicuous coarse sand sediment deposition (E414298 N 6493845). Riparian vegetation is healthy and in good condition although the understorey is dominated by weeds. Watsonia is commonly occurring. There is also a frequent occurrence of African feather grass in this section. There are locations with high scenic value in this river section. The hill with Walyunga Lookout is on the RHS.
LA28 Section length – 812 m	This section has a gentle re-orientation to south-west. There is a subtle meander pattern determined by rock outcropping. The river pools are longer than section LA27. The pool–riffle ratio is 58:42. There is a dry tributary at E 413409 N 6491739. Floodways on both sides are in short sections and of limited capacity. There is minimal bank erosion and disturbance by pigs limited to one LHS location. Riparian vegetation is healthy although the overstorey is sparse (<20% cover) and the groundcover is dominated by weeds. There is very high watsonia cover and some areas with castor oil.
LA29 Section length – 861 m	The river has south-west orientation in this section. The section is dominated by a major anabranch on the LHS that truncates an island. There are extensive sections of rapids on both the main channel and the anabranch. The pool–riffle ratio is 48:52. There is one dry tributary on the LHS prior to the anabranch. There is minimal bank erosion and minimal disturbance by pigs. There is one small area of coarse sand deposition upstream from the anabranch and another area downstream for the anabranch rapid (‘Syd’s Rapids’, E 413139 N 6491200). There is very little coarse sediment and a limited amount of fine sediment on the rocky island. Riparian vegetation is healthy and in good condition. The rocky island has dominant cover from swamp sheoak with effectively no understorey or groundcover. This section has high scenic value.

Section	Description
LA30 Section length – 899 m	The confluence of the anabranch with the main channel is approximately 200 m downstream from LA29. The river orientation becomes southerly from this point. The pool–riffle ratio is 50/50. There are two dry tributaries on the LHS. Riparian vegetation is healthy and in good condition. Watsonia is dominant on the RHS but has been controlled on the LHS. This section has high scenic value. There is a walking track adjacent to the river on the LHS.
LA31 Section length – 904 m	This section of the river is orientated south. The pool–riffle ratio of this section is 95:5. Boongarup Pool commences approximately 200 m downstream from LA30 and continues to the section end. It is a significant pool within Walyunga National Park. The confluence with Wooroloo Brook is on the RHS at LA31. At this location, the river has a significant meander and a RHS anabranch which forms a vegetated rocky island. There is a dry tributary on the LHS that passes through a picnic area. This has active gully erosion. A walking track on the LHS has runoff contributing to bank erosion. An inflow to the river at LA31 has been stabilised with a concrete flume. There is one small area of coarse sediment at LA31. There is a vehicle track across the river and the anabranch at LA31. Riparian vegetation is healthy. The rocky island has swamp sheoak as the dominant species. There is some tree-fall on the LHS. Wooroloo Brook has a very high watsonia groundcover at the confluence and areas with active bank erosion. Upstream from the railway line, the brook is in excellent condition.

Native plant species	Weed species
Ruppia species	African feather grass (*Pennisetum clandestinum*)
Swamp paperbark (*Melaleuca rhapiophylla)*	Blackberry nightshade (*Solanum nigrum*)
Swamp sheoak (*Casuarina obesa)*	Castor oil (*Ricinus communis*)
Wandoo (*Eucalyptus wandoo)*	Pucinellia (*Pucinellia ciliata*)
	Radish (*Raphanus raphanistrum*)
	Salt water couch (*Paspalum vaginatum*)
	Yucca (*Yucca aloifolia*)

Appendix 8

River channel information for the Lower Avon river section

Section number	Tributary	Large woody debris	Coarse sand	Vegetated island	Salinity (mg/L TDS)	Under-cutting*	Slump-ing*	Gully erosion*	Pig erosion*	Sedimen-tation*
LA001		√	√	√	8800	Se	Si	M	Si	Si
LA002					8690	L	M	M	Si	L
LA003		√	√	√	9295	L	M	M	Si	L
LA004	√		√		9075	L	L	M	Si	L
LA005	√	√			9020	L	L	M	Se	L
LA006	√	√	√		8635	Si	L	M	Se	Si
LA007			√		8745	Se	Si	M	Se	Se
LA008	√				8690	Si	L	M	Si	L
LA009					8250	M	M	M	Se	M
LA010					8580	L	M	M	Si	M
LA011		√	√		8855	L	M	M	L	L
LA012		√	√		8855	L	M	M	L	L
LA013			√	√	8800	L	L	M	Si	Si
LA014	√	√	√	√	9240	L	M	M	L	Si
LA015	√				8250	L	M	M	L	Si
LA016	√	√		√	8250	L	M	M	L	L
LA017					8030	L	M	M	Si	L
LA018		√			7975	Si	L	M	Si	M
LA019		√			7865	Si	M	M	Si	M
LA020		√			7920	Se	L	M	Si	L
LA021	√				8030	Se	M	M	Si	Se
LA022		√	√		8140	L	M	M	Si	L
LA023	√	√	√		8140	L	M	M	L	L
LA024		√			5830	Si	L	M	L	M
LA025	√				5885	L	M	M	L	L
LA026	√		√		5885	L	M	M	L	Si
LA027	√				5940	L	M	M	L	L
LA028	√				5885	L	M	M	M	M
LA029	√		√	√	6160	L	M	M	M	Si
LA030	√			√	6160	L	M	M	M	L
LA031	√	√	√		3410	L	Si	Si	M	Si

Note: (1) √ = occurrence
*(2) * M = minimal, L = localised, Si = significant, Se = severe*

Salinity classification

Classification	**Salinity** (TDS mg/L)
Fresh	< 500
Marginal	500–1 000
Brackish	1 000–2 000
Moderately saline	2 000–5 000
Saline	5 000–10 000
Highly saline	10 000–35 000
Brine	> 35 000

Table adapted from: Mayer, X.M., Ruprecht, J.K. & Bari, M.A. 2005,
Stream salinity status and trends in south-west Western Australia. Department of Environment*, Salinity and land use impacts series, Report No. SLUI 38.*

Appendix 9

Pool and riffle descriptions for the Lower Avon river section

Survey section	**Pools in each section** (length in metres)					Total section pool length (m)	**Riffles in each section** (length in metres)					Total section riffle length (m)	Pool–riffle ratio
	P1	P2	P3	P4	P5		R1	R2	R3	R4	R5		
LA1	100	125	175	200	-	600	100	25	200	75	-	400	60/40
LA2	350	325	75	-	-	750	50	125	75	-	-	250	75/25
LA3	150	150	150	-	-	450	50	125	325	50	-	550	45/55
LA4	150	100	300	50	-	600	200	75	125	-	-	400	60/40
LA5	350	25	300	75	-	750	75	100	75	-	-	250	75/25
LA6	50	100	650	50	-	850	25	25	25	75	-	150	85/15
LA7	175	150	450	-	-	775	150	75	-	-	-	225	78/22
LA8	150	125	25	300	-	600	300	50	50	-	-	400	60/40
LA9	125	675	-	-	-	800	50	150	-	-	-	200	80/20
LA10	550	100	100	75	-	825	50	75	50	-	-	175	83/17
LA11	75	225	375	550	-	675	50	125	150	-	-	325	68/32
LA12	350	150	75	25	-	600	50	25	25	125	175	400	60/40
LA13	50	400	50	-	-	500	50	50	400	-	-	500	50/50
LA14	300	100	50	350	-	800	50	50	100	-	-	200	80/20
LA15	250	100	150	300	-	800	50	100	50	-	-	200	80/20
LA16	100	500	125	-	-	725	100	150	25	-	-	275	73/27
LA17	100	500	175	-	-	775	50	200	75	-	-	225	78/22
LA18	175	100	550	-	-	825	25	50	100	-	-	175	83/17
LA19	150	250	100	300	-	800	75	75	50	-	-	200	80/20
LA20	450	125	325	-	-	900	75	25	-	-	-	100	90/10
LA21	1000	-	-	-	-	1000	-	-	-	-	-	0	100/0
LA22	125	100	225	100	100	650	50	125	25	125	25	350	65/35
LA23	275	150	150	-	-	575	25	175	200	25	-	425	58/42
LA24	150	150	125	325	-	750	50	50	50	100	-	250	75/25
LA25	225	75	125	100	125	650	50	50	50	200		350	65/35
LA26	200	250	-	-	-	450	300	250	-	-	-	550	45/55
LA27	275	100	125	-	-	500	75	100	200	125	-	500	50/50
LA28	375	150	50	-	-	575	125	50	250	-	-	425	58/42
LA29	75	100	100	100	100	475	100	225	100	50	50	525	48/52
LA30	300	150	50	-	-	500	200	50	250	-	-	500	50/50
LA31	950	-	-	-	-	950	50	-	-	-	-	50	95/5

Appendix 10

Native vegetation species occurrence for the Lower Avon river section

(Note: P = present in the survey section)

Section	*E. rudis*	*M. raphiophylla*	*A. saligna*	*E. wandoo*	*C. phoeniceus*	*C. obesa*	*A. pulchella*	*M. reidlei*	*H. hypercoides*	*T. floribundum*	*M. viminea*	*C. calophylla*	Species richness
LA01	P	P		P	P								5
LA02	P	P			P	P		P	P				9
LA03	P	P	P		P	P	P	P	P	P	P		11
LA04	P	P			P	P	P	P		P	P	P	12
LA05	P	P	P			P		P		P	P	P	9
LA06	P	P		P		P		P		P		P	8
LA07	P	P	P		P	P	P			P		P	10
LA08	P	P	P		P	P	P	P		P	P		11
LA09	P	P	P					P					4
LA10	P	P		P	P	P		P		P			7
LA11	P	P			P	P			P				5
LA12	P	P			P	P							5
LA13	P	P	P		P	P		P		P			7
LA14	P	P		P	P	P	P					P	7
LA15	P	P	P		P	P							5
LA16	P	P			P	P		P		P		P	8
LA17	P	P				P	P	P		P		P	8
LA18	P	P	P	P	P	P		P	P	P		P	10
LA19	P	P	P		P					P		P	6
LA20	P	P	P		P	P		P			P	P	9
LA21	P	P						P		P	P	P	6
LA22	P	P			P			P		P	P	P	7
LA23	P	P			P	P	P			P	P		7
LA24	P	P	P			P	P	P		P		P	10
LA25	P	P	P	P	P	P	P				P	P	9
LA26	P	P	P		P	P	P	P				P	9
LA27	P	P	P		P	P	P	P					7
LA28	P	P				P				P		P	5
LA29	P	P			P	P		P		P			7
LA30	P	P			P	P				P	P		6
LA31	P	P			P	P							4
TOTAL	**31**	**31**	**14**	**6**	**24**	**26**	**11**	**19**	**4**	**19**	**10**	**16**	

Scientific name	Common name
Eucalyptus rudis	Flooded gum
Melaleuca rhaphiophylla	Swamp paperbark
Acacia saligna	Golden wreath wattle
Eucalyptus wandoo	Wandoo
Callistemon phoeniceus	Lesser bottlebrush
Casuarina obesa	Swamp sheoak
Acacia pulchella	Prickly Moses
Macrozamia reidlei	Zamia
Hibbertia hypericoides	Yellow buttercups
Trymalium floribundum	
Melaleuca viminea	Mohan
Corymbia calophylla	Marri

Appendix 11

Introduced weed species occurrence the Lower Avon river section

(Note: P = present in the survey section)

River section	W-A	W-B	W-C	W-D	W-E	W-F	W-G	W-H	W-I	W-J	W-K	W-L	W-M	W-N	W-O	W-P	W-Q	Total
LA01	P		P	P	P	P	P		P									**7**
LA02			P	P	P	P												**4**
LA03	P	P		P		P				P					P			**6**
LA04	P			P		P			P						P	P		**6**
LA05	P		P	P	P	P												**5**
LA06	P			P	P	P												**4**
LA07			P		P						P							**3**
LA08	P				P	P												**3**
LA09	P	P			P		P											**4**
LA10	P			P	P		P				P		P					**6**
LA11				P	P											P	P	**4**
LA12	P	P		P	P		P			P						P		**7**
LA13		P		P	P					P	P							**5**
LA14	P	P		P	P		P			P	P	P	P					**9**
LA15	P			P	P		P		P	P	P		P			P		**9**
LA16	P			P	P		P			P	P		P					**7**
LA17				P	P				P				P					**4**
LA18		P		P	P				P	P		P	P			P		**8**
LA19	P				P				P			P	P			P		**5**
LA20	P						P		P		P	P	P					**6**
LA21	P			P	P				P			P	P					**6**
LA22	P	P		P	P				P			P	P					**7**
LA23				P					P			P	P			P		**5**
LA24				P	P				P	P	P		P				P	**7**
LA25					P	P			P	P			P					**5**
LA26				P	P				P	P		P	P		P			**7**
LA27				P	P		P		P	P			P	p				**7**
LA28					P		P		P	P		P	P	P	P			**8**
LA29				P	P		P		P	P		P	P	P		P		**9**
LA30	P								P			P	P					**4**
LA31	P			P					P		P		P	P				**5**
Total	**17**	**7**	**4**	**23**	**25**	**8**	**11**		**18**	**13**	**9**	**11**	**19**	**4**	**4**	**8**	**2**	

Weed species code	Common name	Scientific name
W-A	Soursob	*Oxalis pes-caprae*
W-B	Perennial veldt grass	*Ehrharta calycina*
W-C	Capeweed	*Arctotheca calendula*
W-D	Patterson's curse	*Echium plantegenium*
W-E	Radish	*Raphanus raphanistrum*
W-F	Cape tulip	*Homeria* spp.
W-G	Wild oat	*Avena fatua*
W-H	Ribbon weed	*Ruppia maritima*
W-I	Watsonia	*Watsonia bulbillifera*
W-J	Annual rye grass	*Lolium* spp.
W-K	Mullein	*Verbascum virgatum*
W-L	Blackberry nightshade	*Solanum nigrum*
W-M	Castor oil plant	*Ricinus communis*
W-N	African feather grass	*Pennisetum macrourum*
W-O	Lupin	*Lupinus* spp.
W-P	Medic	*Trifolium* spp.
W-Q	Couch	*Cynodon dactylon*

Appendix 12

Bird species identified in the Lower Avon river section

Scientific name	Common name
Coturnix pectoralis	Brown quail
Acanthiza chrysorrhoa	Yellow-rumped thornbill
Anas gracilis	Grey teal
Anas superciliosa	Pacific black duck
Anthochaera carunculata	Red wattlebird
Aquila audax	Wedge-tailed eagle
Barnardius zonarius	Western ringneck
Cacomantis flabelliformis	Fan-tailed cuckoo
Calyptorhynchus latirostris	White-tailed black-cockatoo
Chenonetta jubata	Australian wood duck
Chrysococcyx basalis	Horsefield's bronze-cuckoo
Chrysococcyx lucidus	Shinning bronze-cuckoo
Coluricincla harmonica	Grey shrike-thrush
Coracina Novaehollandiea	Black-faced cuckoo-shrike
Corvus coronoides	Australian raven
Cracticus torquatus	Grey butcherbird
Cuculus pallidus	Pallid cuckoo
Cygnus atratus	Black swan
Dacelo novaeguineae	Laughing kookaburra
Egretta novaehollandiae	White-faced heron
Eolophus roseicapilla	Galah
Fulica atra	Eurasian coot
Gerygone fusca	Western gerygone
Gymnorhina tibicen	Australian magpie
Hirundo nigricans	Tree martin
Lichenostomus virenscens	Singing honeyeater
Lichmera indistincta	Brown honeyeater
Malurvus splendens	Splendid fairy-wren
Melithreptus brevirostris	Brown-headed honeyeater
Merops ornatus	Rainbow bee-eater
Nycticorax caledonicus	Nankeen night heron
Pachycephala rufiventris	Rufous whistler

Scientific name	Common name
Pardalotus punctatus	Spotted pardalote
Pardalotus striatus	Striated pardalote
Petrocia multicolor	Scarlet robin
Phalacrocorax carbo	Great cormorant
Phalacrocorax melanoleucos	Little pied cormorant
Phalacrocorax sulcirostris	Little black cormorant
Phaps chalcoptera	Common bronzewing
Phylidonyris novaehollandiea	New holland honeyeater
Platycercus icterotis	Western rosella
Porphyrio porphyrio	Purple swamphen
Rhipidura fuliginosa	Grey fantail
Rhipidura leucophrys	Willie wagtail
Sericornis frontalis	White-browed scrubwren
Smicrornis brevirostris	Weebill
Threskiornis molucca	Australian white ibis
Todiramphus sanctus	Sacred kingfisher
Zosterops lateralis	Silvereye

Appendix 13

Tributaries, public facilities and river crossings Lower Avon river section

Survey section number	Number of tributaries	Coordinates	Tributary name	Public facilities	River crossings
LA01	1 (LHS)	E. 430797 N. 6506457	Julimar Brook		
LA02					
LA03					
LA04				Sapper's Road BBQ, toilets, parking on LHS	Sapper's Road crossing
LA05	1 (LHS)		Joe's Brook		
LA06					
LA07					
LA08					
LA09					
LA10					
LA11					
LA12					
LA13					
LA14				Old stock route commences	
LA15	1 (RHS)		Red Swamp Brook	Old stock route continues	4WD crossing downstream from Moondyne Pool
LA16				Old stock route continues	4WD crossing at section end
LA17				Old stock route continues	
LA18				Old stock route continues	
LA19		E. 4203772 N. 6496777		Old stock route continues	4WD crossing
LA20	1 (LHS)	E. 419572 N. 6496261		Old stock route continues	

Survey section number	Number of tributaries	Coordinates	Tributary name	Public facilities	River crossings
LA21				Old stock route continues	
LA22					
LA23	1 (RHS)	E. 417109 N. 6494577			
LA24	1 (LHS)	E. 416429 N. 6494251	Brockman River		4WD crossing upstream of confluence of Brockman River
LA25	1 (RHS)	E. 416632 N. 6493274			
LA26	1 (LHS)		Casuarina Gully	Kamp Krusty (private) on LHS	
LA27	1 (LHS)	E. 413694 N. 6492463		Walyunga Lookout on RHS	4WD crossing
LA28	1 (LHS)	E. 413409 N. 6491739			
LA29					
LA30				Walking trail canoe launching facility, vehicle parking, picnic area, toilets at Walyunga National Park on LHS	
LA31	1 (RHS)		Wooroloo Brook		4WD crossing at section end

Appendix 14

Sites of high scenic value and white water rapids for the Lower Avon river section

Section number	**Number of high scenic value sites**	**White water rapids** (identified from Bolland, 2001)
LA01	0	Rice Pud Stodgy Porridge
LA02	1	Razor Back Emu Falls
LA03	2	Emu Falls Ford Cruncher Dugite
LA04	0	Big Stump Death Adder
LA05	1	Joe's Brook Lizard Island
LA06	1	Bone Breaker
LA07	1	Raging Thunder
LA08	1	Helipad
LA09	0	Hammerhead Haunt
LA10	0	
LA11	0	Accelerator
LA12	1	Moondyne
LA13	0	Debris Rock Easy Street
LA14	2	The Wall
LA15	0	Harts Thicket
LA16	0	Spaghetti Junction
LA17	2	Hypothermic Turn
LA18	0	Crocodile Carcass
LA19	0	Feral Cat
LA20	0	Deadly Mistake
LA21	0	
LA22	0	Tea Strainer
LA23	1	Black Hole Spinning Moon

Section number	**Number of high scenic value sites**	**White water rapids** (identified from Bolland, 2001)
LA24	1	Heart Stopper
LA25	1	Scared Rabbit
LA26	0	The Passage
LA27	2	Championship Rapid
LA28	0	Lonely Bush Redneck Run
LA29	2	Syd's Rapid
LA30	0	Bottom of Syd's Dual Carriageway
LA31	1	Pebble Race

Appendix 15

Key issues for management in the Lower Avon River section

	Issues	Comments
Natural environment	• Vegetation mapping – none available for river, reserves • Faunal survey – Current monitoring in limited areas • Scenic and wilderness values – Wild river landscape values not adequately recognised • Bio-geographic linkage – Paruna Sanctuary – Links to Avon River section 1/2 recovery plan	• Vegetation mapping undertaken by SRT during 2006 (final report not released at the time of publication).
Riparian zone management	• The need to fence out feral animals (e.g. for AWC land)	• Fencing to control livestock required on private land adjacent to the river.
Related landscape management	• Need for integrated management programs (e.g. weeds, fire, feral animals) • Habitat restoration • Rehabilitation of previously cleared land • Native mammal re-introductions • Vermin-proof fencing	
Land ownership and responsibility	• Cadastre and property titles: – Alignment of some property boundaries with the river is unclear – Responsibility for land between the rail and the river is unclear (e.g. ownership/ responsibility for Lot 109 between river and rail corridor) • Public risk due to rail: – Public liability assessment and insurance – Maintaining safety • Public risk due to unexploded ordinances – North-side of Avon Valley National Park • Privacy • River crossings – Opportunity to connect AWC trails • Subdivision adjacent to the river • Management of Wesley and Rechner blocks	• There is considerable uncertainty about land vesting and responsibility for areas other than within the two national parks.

	Issues	Comments
Aboriginal interests	• Native title interests and engagement of Aboriginal people • Cultural values associated with the river • Specific values in Walyunga National Park and Avon Valley National Park – not just in the river pools	
Planning	• Metropolitan Planning Scheme • Darling Range Regional Park • City of Swan (linking with Gidgegannup–Bullsbrook place plans) • Sub-division and development (adjacent to tributaries) – the risk of sedimentation • Linkage between conservation reserves (e.g. Brigadoon, Jumbuck Hill (to be added to Walyunga NP) adjacent to the river • Regional Natural Resource Management Plans and Investment Strategies (Swan Catchment Council and Avon Catchment Council) • Management plans: – *Paruna Sanctuary Management Plan* – There are currently no management plans for the two national parks	
Weeds	• Watsonia, castor oil • African love grass – within rail reserve • Agricultural weeds from tributaries • Weed response to disturbance by pigs • Blackberries, sharp rush and bridal creeper – not occurring now but need to ensure these are not established • Chemical control – effect on riparian environment	
Feral animals	• Damage by pigs – Floodway soil disturbance (sediment source) – Population size estimates – Control by trapping – Nomadic behaviour and re-introductions • Wanton damage by pig-hunters • Goats and deer • Fox and cat control • Rabbit population if predators are removed – What potential for eradication?	

	Issues	Comments
Sedimentation	• Sediments in river pools, reaches and bends (scarp) • Sediments in pools (Boongarra, Walyunga and others) • Aboriginal concern about river values and maintenance • Concern about sediments at Bells Rapids • Increasing sediments downstream to Middle Swan Road • Potential impact on navigable waters (winery tours) – Reference to Public Works Department mapping in 1980s (snags and sand bars)	
Fire	• Cause of fire, including rail, rail maintenance, visitors, arsonists • Coordination between fire suppression units (DEC, West Gidgegannup brigade, East Gidgegannup brigade, Bullsbrook) • Hazard reduction (limited width [10 m] of weed spraying for rail corridor) • High risk areas (e.g. Walyunga Lookout picnic area) • Fire break maintenance – difficult to maintain firebreaks in steep valley country – potential for erosion	• Fire response management is coordinated between DEC, AWC and three local brigades. Identified need for closer cooperation with WNR for railway fire risk management.

	Issues	Comments
Public interest section from PDF	• Walk trails – Links to heritage values (Ingineous culture, stock routes) – Links to coastal plains walks (Yancep National Park) – Links to Avon Arc trails • Mountain bike trails – Increasing demand for places to ride, many illegal trails – Off road vehicles area major problem • Recreational use – Canoeing Midway access for canoeists (Hart's Farm, current north-side access too far) Increase opportunity (more events, training time) Access through ti-trees (relates to Sections 1 and 2 – near West Toodyay) – Avon Descent – Walkers and walk trail facilities – Public facilities (camping areas, rubbish, toilets) – Resources for maintaining public facilities – Risks with fire, rubbish, trains, unexploded ordinances, fence damage • Access for management (eg weed and feral animal control) • Community support and visitor interest – Weed control – Trail maintenance – Bird and botanical surveys • Visitation • Paruna Sanctuary • Walyunga National Park • Avon Valley National Park • Moondyne/Rechners (private property purchased by DPI for public use)	
Forest disease	• *P. cinnamomi* spread by vehicles, walkers, pigs, pig-hunters, others?	

	Issues	Comments
Public interest and access	• Walk trails – Links to heritage values (indigenous culture, stock routes) – Links to Coastal Plain trails (Yanchep National Park) – Links to Avon Arc trails • Mountain Bike Trails – Increasing demand for places to ride – many illegal trails – Off road vehicles are a major problem everywhere • Recreational use – Canoeing Midway access for canoeists (Hart's Farm, current N-side access too far) Increase opportunity (more events, training time) Access through ti-trees (relates more to Sections 1 and 2 – near West Toodyay) – Avon Descent – Walkers and walk trail facilities – Public facilities (camping areas, rubbish, toilets etc.) – Resources for maintenance of public facilities – Risks with fire, rubbish, trains, unexploded ordinances, fence damage • Access for management (e.g. weed and feral animal control) • Community support and visitor interest – Weed control – Trail maintenance – Bird and/or botanical surveys • Visitation – Paruna Sanctuary – Walyunga National park – Avon Valley National Park – Moondyne/ Rechners (private land purchased by DPI for public use)	

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