FORESHORE AND CHANNEL ASSESSMENT OF WUNDOWIE WETLAND AND MAGNOLIA CREEK

DEPARTMENT OF ENVIRONMENT
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2004
WATER RESOURCE MANAGEMENT SERIES

Department of
Environment

FORESHORE AND CHANNEL ASSESSMENT OF WUNDOWIE WETLAND AND MAGNOLIA CREEK

Jointly funded by

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REPORT No WRM 38

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Wundowie Wetland
Phyllis Graham

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Foreword

The Department of Environment (formerly Water and Rivers Commission) recognises diverse community values associated with the management of waterways and encourages owners of properties next to, or near, wetlands and waterways to adopt a stewardship role to protect our precious water resources.

Properties that have a wetland, river or stream running through them are highly prized in Western Australia. Rivers, streams and wetlands are attractive to people and may interest them for environmental, aesthetic, recreational and cultural reasons. Watercourses may be valuable as a source of water supply for domestic and stock use, irrigation crops or as a vital component of a commercial activity.

The objective of this project was to document the current condition and future needs of Wundowie Wetland and Magnolia Creek. This was achieved through consistent field surveys, which were undertaken in consultation with adjacent landholders and the Local Government Authority. The project emphasises community consultation.

The wetland catchment drains a portion of the Shire of Northam. Foreshore and channel assessments along the waterway were undertaken in January and February 2003.

The purpose of the assessment is to provide information to people within the Wundowie Wetland and Magnolia Creek catchment who manage or have an interest in the waterway. It is hoped that this information will encourage and assist them in the planning of management actions that can be undertaken by landholders, the Shire of Northam and community groups from the areas surrounding the waterway.

As a result of pressures such as inappropriate landuse and excessive water usage, many sections of the study area are under threat from degradation. A wide range of management issues, such as sustainable water use, stock and vehicle access, weed invasion and loss of native vegetation have been identified through field surveys and consultation with landholders along the waterway.

Management recommendations have been included on how the foreshore and channel conditions along the length of the waterway can be improved to provide environmental, economic and social benefit to landholders and community members throughout the area.

Although the section of the waterway assessed was done in isolation to the downstream section the long-term management of the wetland environment is dependent upon an integrated catchment approach, whereby landholders within the whole catchment are responsible for working together to improve the condition of the waterways. It is hoped that the results of this report will help to create a sense of ownership of the wetland for the community as a whole and encourage integrated catchment management (ICM) for the conservation of the waterway environment and sustainable water resource usage.

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Disclaimer:

These maps are the product of Department of Environment, and were produced in March 2004. While the Department of Environment 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.

Photos

Summary of recommendations

Wetlands are complex, diverse ecosystems which are directly linked to the landscape that surrounds them. They are important life support systems that shelter and sustain an enormous diversity of wildlife. Many of these species depend on the resources that wetlands provide for their survival.

This document provides the results of the foreshore assessment undertaken along Wundowie Wetland and Magnolia Creek. The main conclusion to draw from the findings is that in many ways the health of the waterway is suffering, both directly and indirectly, as a result of past and present landuse and water usage activities.

Wundowie Wetland and Magnolia Creek are generally degraded. They have been influenced by the activities occurring within the catchment and historically, land and water has been overused. There is hope that with a greater understanding of the condition of the wetland and waterway, landholders will band together to try and recover some of the natural health and beauty of the wetland and creek, and that activities employed within the catchment will become more compatible and ecologically sustainable.

It is recommended that the protection and enhancement of the Wundowie Wetland and Magnolia Creek consists of the implementation of some or all of the following strategies:

- **Fencing the riparian zone to manage stock and vehicle access;**
- **Installation of stock crossings;**
- **Control of weeds;**
- **Revegetation of the riparian zone with endemic native species;**
- **The proposed commercial user of water extracted from Lot 160 commissions a detailed hydrogeological investigation into available water, including drawdown effect on the environment and water quality/quantity.**
- **The proposed commercial user commissions an environmental impact study on the effects of water extraction from Lot 160.**
- **Imposition of Department of Environment licensing of any water extraction from Wundowie wetland and Magnolia Creek, other than riparian rights (stock and domestic purposes).**
- **All water extraction from the wetland at Lot 160 to cease until investigation results are studied and interpreted by Department of Environment as part of the water licensing process.**

Introduction

Western Australia's wetlands are biologically productive systems that support a diverse and distinctive array of plants and animals. It is estimated that a significant proportion of the State's wetlands have been destroyed since European settlement. On the Swan Coastal Plain it is estimated that between 70 to 80 per cent of all wetlands have been filled, drained or cleared (WRC 2001). The wetlands that remain are highly vulnerable to impacts from urban and rural encroachment. It is therefore very important that they are protected and managed in an ecologically sustainable way.

Wetlands are complex, diverse ecosystems which are directly linked to the landscape that surrounds them. The health of wetlands is not just dependent upon biological, chemical and hydrological processes taking place within them, it is also significantly influenced by the activities occurring within their catchments. They are dynamic ecosystems which change, not only over days, months and years, but also over decades and centuries. These changes can take place in response to climatic cycles, random events such as storms and fires or as a result of human activity within the catchment of the wetland.

Wetlands are important life support systems that shelter and sustain an enormous diversity of wildlife. Many of these species depend on the resources that wetlands provide for their survival. They are places where sediments collect, soils and landforms are created, nutrients are recycled and water is purified. All the plants and animal species in a wetland are part of a complex ecological network where individual organisms interact with each other and the non-living environment around them.

Wetlands contain a rich diversity of fauna and several types of vegetation are found in healthy wetlands. The dependant terrestrial vegetation is situated on the higher ground that slopes down towards the wetland, forming a distinct community around the wetland. On the edge of the wetland, where the drier ground merges with the waterbody and the soil is waterlogged or inundated for a significant portion of the year, fringing vegetation and aquatic plants are usually abundant.

Purpose of the survey

The purpose of this survey was to assess and document the current uses, disturbances and health conditions of the Wundowie Wetland and the foreshore and channel of Magnolia Creek, which flows from the wetland, and to highlight areas of degradation if any. It is anticipated that the results will provide a "snapshot" of the current condition for comparison with future data to monitor changes in the environmental condition of the wetland. It is also projected that the results will promote awareness and the need for management of the wetland and surrounding lands.

Background

The Shire of Northam purchased a portion of land, Lot 160 on diagram 95635, Locality of Bakers Hill, containing part of a wetland and a soak. In 1998, Shire council approved the installation of a pump to draw significant quantities of water from the wetland to fill tanks in Wundowie townsite in order to irrigate community sporting facilities.

The attention of the Department of Environment (formerly Water and Rivers Commission) was initially drawn to this situation in February 1999 when downstream landholders became concerned about the diminished flow for the environment and their riparian rights.

Landholders along the creek, downstream of the Shire's property at Lot 160, are dependent on the water supply from the creek for domestic and stock use.

A meeting was held in February 2002 between affected landholders, Northam Shire employees, Water and Rivers Commission officers and a representative of the Avon Valley Environmental Society. The Shire agreed to cease pumping until a hydrogeological study was carried out to determine the quantity of water within the wetland system. A hydrogeologist from Water and Rivers Commission carried out a desktop analysis of the wetland and reported that limited quantities of surface water may be available for pumping off-site.

Study area

Wundowie Wetland, on Lots 7016 and 160, is located approximately 2.5 km north east of Wundowie townsite, in the Shire of Northam. Magnolia Creek flows in a southerly direction from the wetland.

Wundowie Wetland is a permanent, freshwater system and this type of wetland is rare in this area. Rainfall occurring in the upper parts of the catchment is the main source of groundwater seepage for the formation and recharge of the wetland.

The waterway was surveyed from the wetland in Lot 7016 at co-ordinates MGA Zone 50 Easting 442880, Northing 6588740 for approximately 3 km downstream along Magnolia Creek to the downstream (western) property boundary of Lot 16745, MGA Zone 50 Easting 442844, Northing 6486290, on Coates Road. The wetland and creek are located within an area that is proclaimed under the Rights in Water and Irrigation Act (1914).

Map 1 shows the Wundowie Wetland and Magnolia Creek catchment location and study area while Maps 3 and 4 depict cadastre, land tenure and the assessed condition of the surveyed sections. The creek, which flows in a southerly direction from the wetland, is not gazetted and is known locally, and referred to in this study, as Magnolia Creek. West of the waste water treatment ponds, the waterway assumes the name of Werribee Creek.

The primary focus of this assessment was the foreshore and channel areas of the waterway. The area studied includes the wetland, creek bed, channel and embankments, floodway, verge, foreshore and land use adjacent to this waterway. It should be noted that when planning to manage this wetland and waterway there is a need to adopt a whole of catchment approach.

Historical description of Wundowie

Aboriginal heritage

The name Wundowie comes from the Aboriginal word "ngwundow" meaning 'to lie down' (UBD 1998).

No Aboriginal sites of significance are recorded in this area.

European heritage

Wundowie, in the Shire of Northam, is one of the youngest towns in Western Australia, and is located 68 km north east of Perth.

Before 1943 Wundowie was a railway siding supporting farming and vineyards. The town came into existence in 1947 after the establishment of a wood distillation and charcoal-iron plant for the production of high-grade pig iron. The site for the plant and service town was located on the then Perth-Kalgoorlie railway line, close to the Goldfields Water Supply main pipeline.

Catchment description

Wundowie Wetland and Magnolia Creek are located in the Swan Coastal Basin of the Swan Catchment in the South West Division of Western Australia. Magnolia Creek flows initially in a southerly direction before turning to flow south-west. About 10 km downstream from the wetland Magnolia Creek joins Wooroloo Brook which then flows south-west for 31.5 km until it's confluence with the Avon River where it becomes the Swan River.

The catchment is predominantly cleared for agricultural use. The catchment was initially cleared by 17% prior to 1942. Between 1942 and 1968, the proportion of land cleared was approximately 90% and the figure jumped to approximately 93% between 1972 and 1979 (Jackson 1997). A revegetation scheme was implemented in 1987, reducing the cleared portion of the catchment to 83% (Jackson 1997).

The catchment landscape is undulating with tree-clad hills dotted with bare rock outcrops. Large portions of land to the east and west of the waterway are vested in the Conservation Commission of WA for the protection of flora and fauna.

Population

The population of Wundowie is 897 according to the 2001 census of population (Australian Bureau of Statistics 2003).

Climate

The Shire of Northam experiences a Mediterranean type climate, with hot dry summers and mild wet winters. Data for Bakers Hill, (Climate station 010244, Latitude: -317608 S Longitude: 116.4767 E) is provided as no data was available for Wundowie. Table 1 gives a summary of climatic data at Bakers Hill.

Table 1: Climatic Averages (Source: Bureau of Meteorology, 2003).

Climatic Factor	Bakers Hill
Annual mean rainfall	602.1 mm
Annual mean daily maximum temperature	23.1°C
Annual mean daily minimum temperature	10.9°C
Annual mean evaporation	5.6 mm/day
Annual mean wind speed (at 9 a.m.)	16 km/h

Although the region was experiencing drought conditions at the time of this survey, landholders have stated that the

2002 local annual average rainfall was 540 mm, which is only slightly lower than normal.

Geomorphology and soils

The Magnolia Creek catchment area is approximately 11 km^2. The elevation of the catchment divide varies between 390 and 445 m AHD. The catchment has a gentle to moderate undulating topography with major drainage occurring towards Wundowie Wetland and Magnolia Creek.

The soil and sediment is underlain by weathered bed rock material.

Leached sands, ironstone gravel and sandy clay comprise surficial sediments. This overlies duricrusts of recemented ironstone gravels and/or vesicular laterite, and/or weathered bed rock (Granitoid). These soils also cover catchment ridges and slopes.

Appendix 1 provides a description of the soil units of the catchment.

Hydrology

The wetland and the flow of water in Magnolia Creek is governed by seasonal rainfall patterns. The rainfall recharge that occurs in the elevated parts of catchment (hilly terrain) flows through the sediments and discharges to the surface as springs at break of slope forming swampy areas. The Wundowie Wetland occurs at 300 m AHD at the break of slope (Hundi 2002).

The wetland is recharged from groundwater discharge from a soak/seep. Anecdotal evidence suggests that the groundwater soak first appeared following the Meckering earthquake, possibly from groundwater coming to the surface through a fracture in the rock.

A water balance, prepared by WRC Hydrogeologist Mr N. Hundi in February 2002, estimated that 16 926 kL of water from the wetland system was available per year for use by landholders including the Shire of Northam.

Vegetation

A significant portion of the catchment is vested with the Conservation Commission of WA and contains native vegetation. Map 2 shows the extent of native vegetation in the catchment.

The waterway and wetland are dominated by Melaleuca species, spike rush and bulrush.

Catchment landuse and tenure

Landuse within the Wundowie Wetland and Magnolia Creek catchment is a combination of agricultural land and flora and fauna reserves vested with the Conservation Commission of WA. Maps 3 and 4 show land tenure, freehold land and Crown reserves in the catchment.

The majority of land along the creek in the study area lies within private land ownership, with Lot 160 being owned by the Shire of Northam.

Land ownership along the wetland and creek system in the study area stretches across the waterway and land titles mean that ownership includes the waterway.

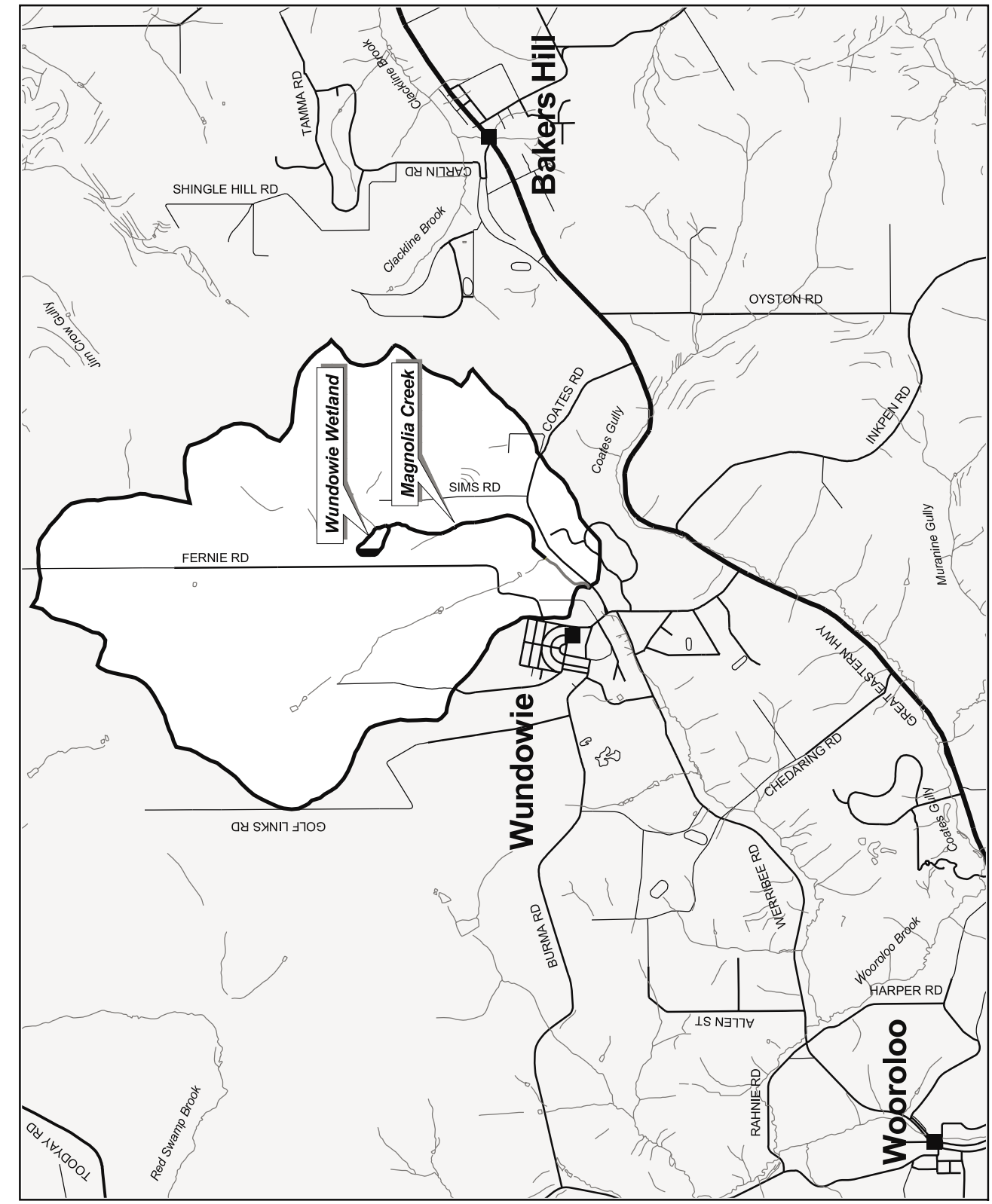
With the exception of Lot 160, private landuse within the study area is agricultural with a focus on the grazing of sheep, cattle and horses. Apart from localised clearing of vegetation by the Shire for installation of the pump, pipework and monitoring bore and access paths, the land in Lot 160 is unused.

In 1978, the Western Australian Department of Conservation and Environment granted operating approval for mining operations and a vanadium plant at Wundowie, with production commencing in 1980. The vanadium was to be mined from vanadiferous laterite and magnetite ore reserves located close to Wundowie. However, due to process problems and a severe downturn in the price and demand for vanadium, the mine site and plant were placed on a care and maintenance basis in 1982 (Williams, 1999).

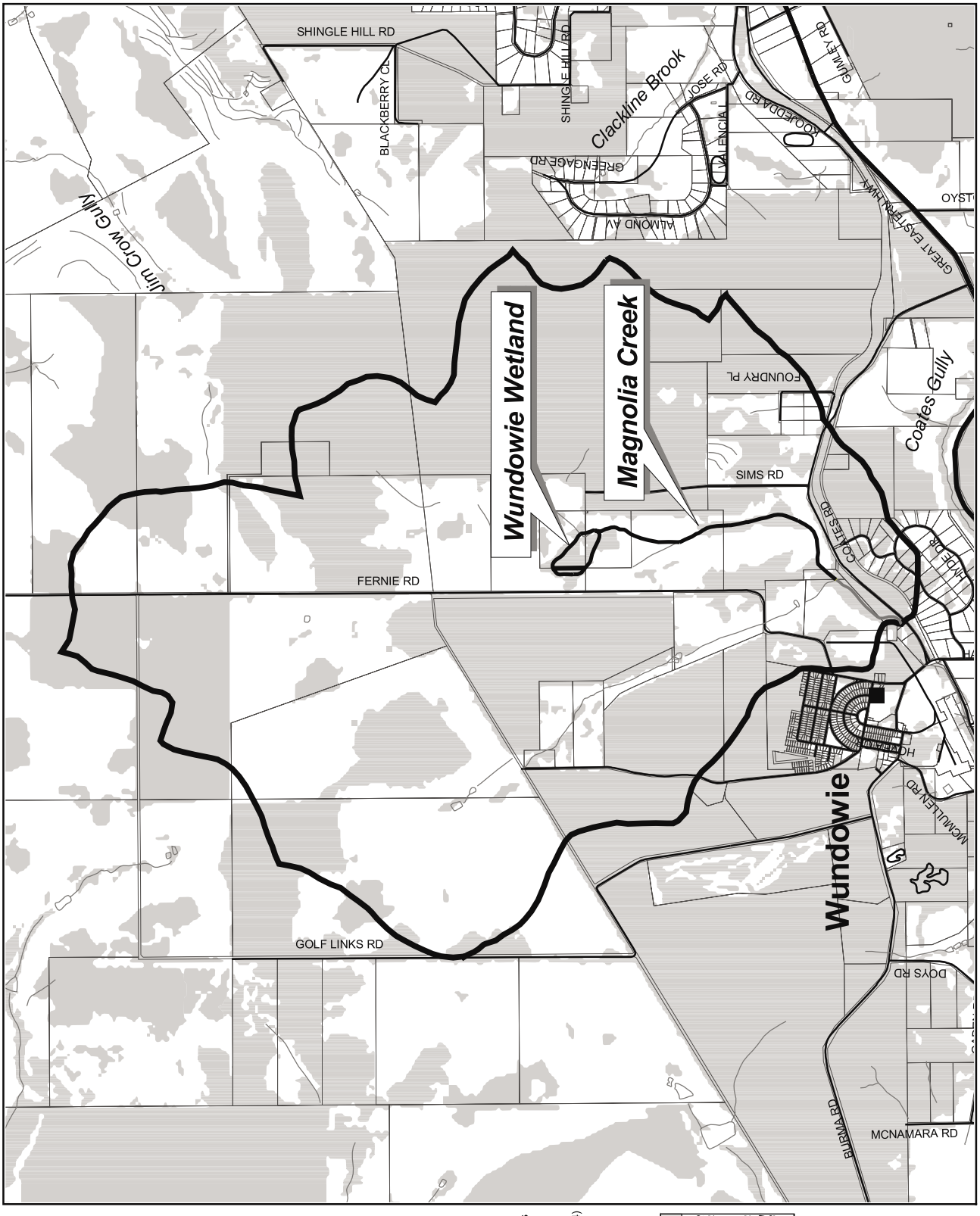
Rights in water and irrigation

The law relating to the rights to surface water is contained in the *Rights in Water and Irrigation Act 1914 (RIWI Act)*. The Department of Environment has licensing and control powers over wetlands and watercourses in proclaimed areas. Taking water in excess of riparian rights may require a licence. Further information regarding the riparian rights and the *RIWI Act* can be obtained in the Water and Rivers Commission's "Rights to take water in licensed areas" and "Taking water from streams and lakes (Water Facts 5)" pamphlets.

Wundowie Wetland is located within an area that is proclaimed under the Act. The Department of Environment encourages owners of properties next to waterways to adopt a stewardship role to protect these precious water resources and recognise the rights of downstream users.



Map 1: Location and catchment study area.



Map 2: Native vegetation.

Survey methods

Community awareness and involvement

A telephone call of introduction was made to landholders along Wundowie Wetland and Magnolia Creek explaining the purpose of this survey. Arrangements were then made by telephone for access onto properties to survey the waterway and wetland.

Assessment technique

A *Foreshore and Channel Condition Assessment Form* was used to standardise the field surveys and keep the collection of data consistent. The assessment template was based on the assessment techniques developed by Pen and Scott in their 1995 publication; *Stream and Foreshore Assessment in Farming Areas*. This template was adapted to meet the requirements to assess the wetland area.

The survey form was divided into the following categories:

- general details;
- bank stability;
- waterways features;
- foreshore condition assessment;
- vegetation health (and coverage);
- fencing status;
- overall stream environmental rating (stream health);
- habitats;
- habitat diversity;
- landform types;
- evidence of management;
- management issues;
- ideas for management;
- vegetation; and
- water quality.

Survey sections were determined by paddock and property boundaries. The length of the surveyed area was divided into 6 sections for the purpose of this survey. Lot 8576 was surveyed as 2 sections, WW4 and WW5, as the condition of the channel changed significantly within the property. Due to the length and similar condition of the creek, property size and ownership, lot 16745 was combined with lot 27729 to form one section, WW6.

Foreshore and channel assessments were conducted along the length of each section by filling out the survey form (see Appendix 3). Factors such as foreshore condition were averaged for the whole of a section with best and poorest conditions also recorded.

In all cases, both sides of the wetland/creek were surveyed on one form and an average was determined for each assessment category.

Foreshore and channel condition was assessed by observation whilst walking along the waterway and recorded on the assessment template. Photographs were taken at points of interest and will be used for future monitoring of the system and its foreshore. Landholders were also asked about changes in waterway condition and health, fauna, past landuse and management of the waterway.

Where vegetation was not identified during field assessments, specimens were taken and forwarded to the WA Herbarium for identification. This will take some time and identification was not complete for inclusion to this report.

The use of a GPS unit (Garmin GPS 12) allowed points of interest to be recorded. Locations such as section start and end points and photograph points were recorded to allow for accurate display of collated data on maps. These data points also allow for accurate location of sections for future monitoring and management.

The assessment format used is comprehensive in recording foreshore and channel condition. A blank assessment form is provided in Appendix 4.

This method was very suitable for the Magnolia Creek section of the study but did have limitations for assessment of the wetland area where banks are not well defined.

Water quality was recorded at six sites using handheld meters. Table 2 shows the meters used for monitoring the waterway in situ. In addition grab samples were taken at four of the sites for analysis at a NATA registered laboratory using standard methods. Results provide a snapshot of the current water quality conditions in the wetland and along the creek.

Table 2: Meters used for water quality monitoring.

Parameter	Meter
pH and temperature	WTW pH 320
Conductivity	WTW LF 320
Dissolved Oxygen	WTW Oxi 320

Method of analysis

Information collected during foreshore and channel assessments was collated and comments made where appropriate. Any anecdotal evidence supplied by landholders and other community sources was also considered.

Five categories have been used throughout the field assessments to determine an overall stream environmental rating. Appendix 5 contains a table explaining the categories used to classify the stream condition and the overall status of the waterway.

The overall stream environmental rating is used to assess the ecological value of the individual sections and allows us to classify the health of the waterway. This rating system determines the current environmental condition of the waterway based on the six individual components listed below:

- floodway and bank vegetation;
- verge vegetation;
- stream cover;
- bank stability and sedimentation;
- habitat diversity; and
- surrounding landuse.

Depending on the rating (very poor up to excellent), points are allocated to each of these components and an overall stream environmental health rating is determined for each survey section. Appendix 5 provides a table that shows the points allocated to each individual component based on the rating the section received.

Survey results

Anecdotal evidence as well as survey results indicate that Wundowie Wetland and its surrounding catchment has been subjected to a wide range of disturbances that have led to a decline in their health. Field observations indicate that the main forms of degradation present are reduced water levels and stream flow and a decline in vegetation cover and health.

Area surveyed

Table 3 shows the lot numbers surveyed with the upstream and downstream MGA Zone 50 co-ordinates. Maps 3 and 4 show the sections surveyed and section boundaries.

Table 3: Cadastre and MGA co-ordinates of surveyed sections.

Survey section no.	Land-holder name	Lot number	Upstream		Downstream	
			Easting	Northing	Easting	Northing
WW1	Parry	7016	442880	6488740	442940	6488686
WW2	Shire of Northam	160	442940	6488686	443232	6488516
WW3	Gilsenan	161	443232	6488516	443242	6488106
WW4	A'Court	8576	443242	6488106	443262	6487516
WW5	A'Court	8576	443262	6487516	443320	6487300
WW6	Crowe	27729 & 16745	443320	6487300	442844	6486290

Bank and channel stability

Erosion, slumping and sedimentation all affect bank and channel stability. Field assessments of each waterway section evaluated the above factors that were used to determine bank stability. Bank stability is an average for the whole section and can be rated as shown in Table 4.

Table 4: Rating system used to determine bank stability.

Bank stability	Percentage of river section affected
Minimal	0-5
Localised	5-50
Significant	20-50
Severe	>50

Bank stability and sedimentation were determined as part of the overall stream environmental rating, which indicated the average stream condition of each surveyed section. It can also be used to give an idea of bed and bank stability within this wetland/creek system. Table 5 provides a collation of results for Wundowie Wetland and Magnolia Creek based on the information provided in Table 4.

Results indicate that three of the sections, WW1, WW2 and WW5 were recorded as having stable banks. Two sections WW3 and WW6 showed minimal erosion and WW4 showed localised erosion and minimal undercutting, subsidence and gully erosion.

Table 5: Bank stability.

Survey section no.	Bank stability	
WW1	Stable	
WW2	Stable	
WW3	Erosion	– Minimal
WW4	Undercutting	– Minimal
	Subsidence	– Localised
	Erosion	– Minimal
	Gully erosion	– Minimal
WW5	Stable	
WW6	Erosion	– Minimal

Waterways features

The features of a waterway are indicative of it's condition. The presence of features such as pools, rapids, anabranches, riffles, bridges, sand slugs and vegetated islands allow us to assess, to some degree, the condition of the waterway and determine options for future management.

The Wundowie Wetland extended over sections WW1, WW2 and WW3, from where Magnolia Creek formed a single channel. The channel broadened out in the downstream end of WW3 to form another wetland area. The creek formed a single channel from WW4 to the end of the surveyed section WW6.

Other features included off stream dams, groundwater soaks, pools, natural rapids and bridges. Table 6 shows the waterways features that were recorded in each section.

Table 6: Waterways features.

Survey section no.	Waterways features
WW1	Wetland, groundwater soak, rocks, off-stream dam
WW2	Wetland, pool, well
WW3	Single channel, wetland, pool, rapids (natural), bridge, off-stream dam
WW4	Single channel, rocks, bridge
WW5	Single channel, wetland
WW6	Single channel, bridge

Foreshore condition

The foreshore condition assessment has been developed from observations of river system degradation throughout south-western Australia and follows the general process of remnant bush degradation, with the added complication of erosion as stream banks become exposed. The foreshore is graded into one of four categories, A, B, C or D beginning at pristine and running through to completely degraded. Each of these four grades has three sub-categories. Appendix 6 provides an overview of all possible grades, from A1 through to D3.

General foreshore condition

The general foreshore condition, averaged for each section, ranged from B-grade, meaning that the foreshore vegetation has been invaded by weeds, in sections WW1, WW2 and WW5 to D-grade, meaning that the creek is little more than an eroding ditch or weed infested drain, in section WW6.

Table 7 shows the general, best and poorest foreshore condition for all of the sections surveyed. Results indicate that there was no distinct pattern and foreshore condition was largely related to past and current landuse. Map 3 depicts the overall general foreshore conditions that were determined for Wundowie Wetland and along the length of Magnolia Creek.

Best foreshore condition

The best foreshore condition recorded along the waterway ranged from A3 (slightly degraded with native vegetation dominating) in section WW2.

Poorest foreshore condition

The poorest foreshore condition ranged from B2 (heavily weed infested) in sections WW2 to D1 (eroding/weed infested drain) in sections WW3, WW4 and WW6.

Table 7: Foreshore condition.

Survey section no.	General foreshore condition	Best foreshore condition	Poorest foreshore condition
WW1	B	B2	B3
WW2	B	A3	B2
WW3	C	B3	D1
WW4	D	D1	D1
WW5	B	B1	B3
WW6	D	B1	D1

Foreshore vegetation

Presence of common species

The most common overstorey species recorded along the Wundowie Wetland and Magnolia Creek were *Melaleuca sp*., *Eucalyptus sp*., *Acacia sp*., *Casuarina obesa* and grass-tree *(Xanthorrhoea preissii)*.

The most common middle story species recorded were weed species including *Juncus acutus* (spike rush), and *Typha orientalis* (bulrush).

The most common understorey species recorded were weed species including *Cynodon dactylon* (couch grass), *Hordeum leporinum* (barley grass), *Avena fatua* (wild oats) and other annual grasses, *Carthamus lanatus* (thistle), *Taraxacum officinale* (dandelion), fern species (not identified) and *Trifolium sp* (clover). Some native understorey species included *Heliotropium curassavicum* (smooth heliotrope). Field observations indicated that weed species were far more common than native species.

Proportion of native species

Table 8 shows the occurrence of native plant species recorded during foreshore assessments of Wundowie Wetland and Magnolia Creek.

The abundance of native vegetation varied along the waterway. The upstream sections had more abundant native species, further downstream the occurrence became less due to landuse and stock access.

Table 8: Native foreshore vegetation.

Plant name		Sites and abundance of native species		
Scientific name	**Common name**	**High**	**Medium**	**Low**
Xanthorrhoea preissii	Grasstree			WW2
Eucalyptus sp	Gum		WW5	WW1 WW2 WW3 WW6
Juncus kraussii	Sea (shore) rush			WW2
Heliotropium curassavicum	Smooth heliotrope			WW1 WW2
Casuarina obesa	Swamp sheoak			WW2
Melaleuca sp	Tea tree	WW1 WW2 WW3 WW5	WW6	WW4
Acacia sp	Wattle			WW1 WW2 WW3 WW4

Regeneration of native species

Natural regeneration of native tree species was observed at 5 of the 6 sites surveyed. Regeneration was mainly confined to *Melaleuca sp.* with some *Acacia sp.* seedlings at 2 sites. Table 9 shows sites where natural regeneration of native tree species was observed.

Table 9: Regeneration of native tree species.

Survey section no.	Regeneration of *Melaleuca sp*	Regeneration of *Acacia sp*
WW1	✓	✓
WW2	✓	✓
WW3	✓	-
WW4	-	-
WW5	✓	-
WW6	✓	-

Death of common native species

Vegetation health along the waterway was generally fairly good, but some dead trees were observed. There was a lack of middlestorey plants in most areas and the understorey was dominated in most sites by weed species.

Some vegetation, especially the crowns of older trees, showed signs of stress. Older established trees are less able to adapt to changes in water regime. Table 10 shows the vegetation health along the waterway in each section.

Table 10: Vegetation condition.

Looks healthy	Some sick trees	Many sick or dying trees	Some dead trees	Many dead trees
WW1			WW1	
WW2	WW2		WW2	
WW3	WW3		WW3	
	WW4		WW4	
WW5		WW5	WW5	
WW6	WW6		WW6	

Vegetation cover

In all of the surveyed sections the majority of native species occurred in the overstorey with all of the sites recorded as being comprised of between 81-100% native vegetation in their overstorey.

The proportion, or abundance, of the overstorey varied within the study area with the wetland section, WW2, having the most abundant vegetation cover, (continuous cover > 80%) in the overstorey and less abundant weeds in the middle and understorey due to the thick native canopy. The disturbed parts of WW2, due to local clearing associated with the pump, trench, pipes and infrastructure is invaded by weeds, in particular *Juncus acutus* (spike rush).

Of middlestorey species present (shrubs and small trees), the 3 upstream sites WW1, WW2 and WW3 were recorded as having between 50-80% native vegetation.

Middlestorey and ground cover was predominantly weed species in the downstream sites, WW4, WW5 and WW6 recording a cover of between 0-10% native species.

Field investigations determined that the downstream sites, WW3, WW4 and WW6 were lacking a dense middlestorey (shrub layer) and were supporting a patchy or sparse upperstorey of tree species. Table 11 shows the surveyed

sections that were classified as either absent, sparse, patchy or continuous (depending on the level of cover) in each vegetation layer.

Table 11: Vegetation cover.

Survey section no.	Overstorey	Middle-storey	Under-storey
WW1	Patchy (20-80%)	Continuous (>80%)	Continuous (>80%)
WW2	Continuous (>80%)	Continuous (>80%)	Continuous (>80%)
WW3	Patchy (20-80%)	Patchy (20-80%)	Continuous (>80%)
WW4	Sparse(0-20%)	Sparse(0-20%)	Continuous (>80%)
WW5	Continuous (>80%)	Continuous (>80%)	Patchy (20-80%)
WW6	Patchy (20-80%)	Patchy (20-80%)	Continuous (>80%)

Weeds

The most common weed species recorded along Wundowie Wetland and Magnolia Creek were *Juncus acutus* (Spike rush), *Typha orientalis* Bulrush, and annual grasses including *Hordeum leporinum* (Barley grass) and *Avena fatua* (Wild oats). Other annual grasses present were not identified as they had been heavily grazed.

Spike rush had a high occurrence in sections WW1, WW2, WW3 and WW4, low occurrence in WW6 and was absent in WW5.

Bulrush was absent in WW1. It had a low occurrence in the wetland section WW2 and high occurrence in the downstream sections WW4, WW5 and WW6.

In the wetland section, WW2, weeds had a higher occurrence around the perimeter and in the area where the thick canopy of native vegetation has been disturbed.

Several species of small flowering plants, which were not identified, occurred in the upstream sections, WW1 and WW2, that are not heavily grazed.

Table 12 shows the occurrence of the more common weeds found along the wetland and creek and the abundance of occurrence.

Habitat diversity

Wetlands provide a variety of habitats in which plants and animals live for all or part of their life cycles. A diversity of fauna utilise wetland habitats for a range of activities, such as foraging for food, breeding and loafing. Wetland and upland vegetation provides feeding and breeding habitat for frogs, waterbirds, insects and mammals. Areas of bare sand, rocks, logs and open water provide a range of habitat requirements for many aquatic and terrestrial animals. They are utilised as substrates for attachment, for breeding, shelter from predators and for obtaining food. Aquatic plants provide microhabitats and food for a variety of invertebrate species.

Field investigations determined the presence of potential habitat for both aquatic and terrestrial fauna. Results indicate that the most common habitat source was instream vegetation types, which was recorded in all six sections. Most sections showed a variety in the instream vegetation although WW4 was predominantly *Juncus acutus* (spike rush) and WW6 was predominantly *Typha orientalis* (bulrush). Other habitat types were also recorded, although not as frequently as the above.

Providing habitat for aquatic organisms such as invertebrates, reptiles and fish:

- protected basking sites (i.e. debris and branches) were recorded at five sections;
- meanders and pools were recorded along two of the upstream sections;
- rushes (a mixture of native and non-native species) were recorded along all of sections;
- instream logs were recorded along five sections;
- a variety of instream and bank vegetation were recorded along five sections;
- instream cobbles and rocks were recorded along three sections;
- emergent plants/soft substrate for eggs were recorded along all sections; and
- cascades, rapids and riffles were recorded along one section.

Providing habitat for terrestrial animals such as invertebrates, birds, frogs, reptiles and mammals:

- trees were recorded along all sections;
- shrubs were recorded along four sections;
- dense streamside vegetation along five sections; and
- dense protective vegetation along four sections.

Instream cover was excellent in two sections and moderate in three sections when determined as part of the overall stream environmental health rating. There was often a mixture of leaf litter, rocks, branches and vegetation. Table 13 shows the sites that had instream cover.

Table 12: Common weed occurrence.

Plant name		Sites and abundance of native species		
Scientific name	**Common name**	**High**	**Medium**	**Low**
	Annual grasses (not identified)	WW3 WW4 WW6		
Hordeum leporinum	Barley grass	WW4	WW2 WW6	WW1 WW3 WW5
Typha orientalis	Bulrush	WW4 WW5 WW6		WW2
Ricinus communis L.	Castor Oil			WW2
Papilionaceae sp	Clover			WW4 WW5 WW6
Cynodon dactylon	Couch grass	WW6	WW1 WW2	WW3 WW4 WW5
Taraxacum officinale	Dandelion			WW2 WW5
Not identified	Fern			WW2
	Flowering plants (not identified)			WW1 WW2 WW3
Macrozamia riedlei	Palm			WW2
Juncus acutus	Spike rush	WW1 WW2 WW3 WW4		WW6
Carthamus lanatus	Thistle			WW1 WW2
Cotula coronopifolia	Waterbuttons			WW1
Avena fatua	Wild oats		WW2 WW5	WW3 WW4

Recommendations:

- **Revegetate the riparian zone with endemic native species.**
- **Control invasive weeds to allow regeneration of native species.**

Table 13: Sites and types of instream cover.

Leaf litter/ detritus	Rocks	Branches	Vegetation
WW1	WW1	WW1	WW1
WW2	-	WW2	WW2
WW3	WW3	WW3	WW3
-	WW4	WW4	WW4
WW5	-	WW5	WW5
-	-	WW6	WW6

Table 13 shows that vegetation and branches were the most common form of instream cover and habitat type, occurring in all six sections, followed by leaf litter/detritus, which was recorded at four sections.

Foreshore habitat differs slightly to that within the wetland/ stream channel. Ratings used during assessment of the overall stream environmental health rating determined that the upstream sections were rated as having excellent habitat diversity. Lower sections were rated as moderate as

they had a range of habitat types, but no permanent water (Water and Rivers Commission, 1999).

A variety of wildlife was observed while conducting field assessments along the waterway. The following is a list of fauna recorded in and around Wundowie Wetland and Magnolia Creek:

- Ants
- Bees
- Bull-ants
- Butterflies
- Cranes
- Crickets
- Crows
- Dragonflies
- Ducks
- Feral goats
- Flies
- Frogs
- Gambusia
- Kangaroos
- Kookaburras
- Ladybirds
- Magpies
- Mosquitoes
- Moths
- Port Lincoln parrots
- Pink and grey galahs
- Scarlet Robin
- Spiders
- Variety of small birds
- Water birds
- Yabbies

Anecdotal evidence suggests that the variety of fauna in the past was more plentiful. Many landholders commented that several varieties of ducks and other water birds that existed prior to the creek drying out are no longer seen.

The current seasonal drying of the creek and variation in water depth in the wetland suggests that habitat now changes significantly from one season to the next (eg. alterations in the level of exposed logs, branches and rocks). During field assessments the depth of water within the wetland and channel of the upstream sections was low and there was no flow downstream of section WW3. There was evidence of a significant fluctuation in water depth, such as debris deposits in vegetation in the WW2 wetland section and dried cracked ground and localised bank erosion. As a result of a lowering of water levels and therefore habitat availability, the diversity and richness of fauna will decrease. This was once a permanent system where the fauna had adapted to permanent fresh water supply and may not be able to adapt to an ephemeral system.

Fencing status

Foreshore assessments determined that one of the six sections, WW2, was completely fenced while one section, WW3, was partially fenced on both sides. A further section, WW5, was fenced on one side only. One section, WW1, was partially fenced on one side while the remaining two were not fenced at all. Results indicated that stock had access to the channel and riparian zone along five of the survey sections, and vehicles had access along four of the sections.

Of those areas that were fenced, four fences were in good condition and two were in poor condition. Of the fencing style used along the fenced sections, two were plain wire, two were a combination of plain and barbed wire, one was a combination of plain and electric wire and one was a combination of barbed, fabricated and electric wire. Appendix 8 provides a definition of each fencing style and examples of fence condition.

The fences in WW1, WW2 and WW5 were in good condition. The property boundary fence between WW1 and WW2 cuts through the wetland and flow channel. Table 14 shows the sites that were fenced and had stock and vehicle access

Recommendation:

- **Complete fencing of the riparian zone to manage stock and vehicle access.**

Vehicle access

Vehicles had access to all sections except WW2 and WW5. There were constructed crossings in WW3, WW4 and WW6.

Table 14: Fencing and access status.

Survey section no.	Fencing left bank (facing upstream)	Fencing right bank (facing upstream)	Proportion fenced	Stock access	Vehicle access	Crossing point
WW1	-	**Good condition** Plain and electric	Partial	Yes	Yes	No
WW2	**Good condition** Plain and electric	**Good condition** Plain and electric	Complete	No	No	No
WW3	**Poor condition** Plain and barbed	**Poor condition** Plain and barbed	Partial	Yes	Yes	Yes
WW4	-	-	-	Yes	Yes	Yes
WW5	-	**Good condition** Fabricated, barbed and electric	Complete	Yes	No	No

Overall stream environmental rating

The overall stream environmental rating is a system used to determine the health of the waterway by rating factors such as habitat diversity and verge vegetation (Appendix 5). Table 15 and Figure 1 show that WW2 had the best overall stream environmental rating of all the sections and WW4 had the poorest. Section WW2 scored the highest in terms of overall environmental health with an excellent rating.

Table 16 shows the rating for the surveyed sections in each environmental health category. Although section WW5 had a range of habitats it only scored 'moderate' which is the highest rating for habitat diversity where there is not permanent water.

Table 15: Overall stream environmental health rating.

Excellent	Good	Moderate	Poor	Very poor
WW2	WW5	WW1	WW3 WW6	WW4

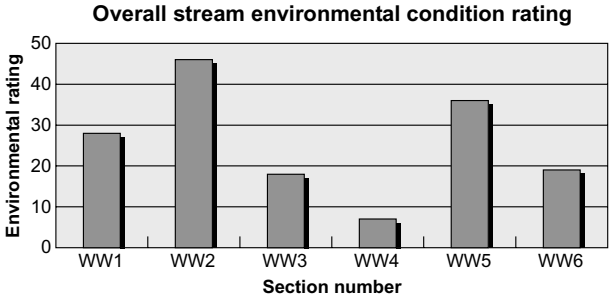


Figure 1: Overall stream environmental health rating.

Table 16: Sites in each environmental condition category.

Rating	Floodway and bank vegetation	Verge vegetation	Stream cover	Bank stability and erosion	Habitat diversity
Excellent	-	-	WW2 WW5	WW2 WW5	WW1 WW2
Good	WW2 WW5	WW2	-	WW1 WW3 WW6	-
Moderate	WW1	WW1 WW5	WW1 WW3 WW6	WW4	WW3 WW5 WW6
Poor	WW3 WW6	WW3 WW6	-	-	WW4
Very poor	WW4	WW4	WW4	-	-

Disturbance

The riparian zone along Wundowie Wetland and Magnolia Creek is subject to many disturbance factors that are contributing to the continual degradation of the channel and foreshore. The following itemises the major disturbances observed during field surveys:

- abstraction of water resulting in the creek drying out and lowering of the watertable;
- all of the sections contained weed species;
- four sections were accessible by vehicles;
- five of the surveyed sections were accessible to stock;
- three of surveyed sections had crossing points allowing stock and vehicle access across the waterway;
- five of surveyed sections were affected by pollution (mainly due to animal manures).

It should be noted that not all sites are grazed by stock all year round. Some sites are used only for a few months of the year while others are continually under pressure from stock grazing and trampling.

Water quality

Water monitoring is an essential element of catchment management since high quality surface and ground water is a key indicator of environment health.

Testing water quality is a complex task made up of different aspects and is determined by a variety of parameters. To correctly characterise the waterway and establish what is the 'normal' range for this particular waterway at least six sets of sample data, taken at regular intervals, should be recorded.

An assessment of the water quality of Wundowie Wetland and Magnolia Creek was carried out on 29 May 2003 to provide a snapshot of the current conditions. Temperature, pH, conductivity and dissolved oxygen were measured in situ at six sites using handheld meters.

In addition grab samples were taken at four of the sites (sample sites 1-4). These were brought to a NATA registered laboratory for the determination of phosphorus and nitrogen concentrations, suspended solids content and determination of turbidity the using standard methods. Table 17 provides the sample site co-ordinates (MGA Zone 50) and a brief site description. Table 18 shows sample results while Figures 2 and 3 graph these results.

Photo 1: Stock accessing the riparian zone eat vegetation, trample regrowth and exacerbate erosion of banks and creekbed.

Table 17: Water Quality Monitoring Sites Description.

Sample site	Survey section	Description	Easting	Northing
1	WW1	Water flowing from soak	442931	6588780
2	WW2	Drain at staff gauge near Shire pump	443211	6488518
3	WW3	Creek near monitoring bore	443260	6488390
4	WW3	Still water in wetland (not flowing)	443224	6488458
5	WW3	Creek at rock riffle	443285	6488305
6	WW3	Creek at downstream property boundary	443252	6488120

Table 18: Water Quality Monitoring Results.

Sample site	Temp °C	pH	Conductivity mS/m	Dissolved Oxygen mg/L	TP mg/L	TN mg/L	Suspended solids mg/L	Turbidity NTU
1	19.4	7.62	182	7.78	0.01	1.7	2	<1
2	13.3	7.07	268	9.97	0.01	0.44	6	2
3	13.9	7.55	294	9.36	0.01	0.34	1	<1
4	13.6	7.62	271	7.05	0.01	0.36	4	<1
5	14.8	7.49	295	11.79				
6	16.4	7.63	296	9.51				

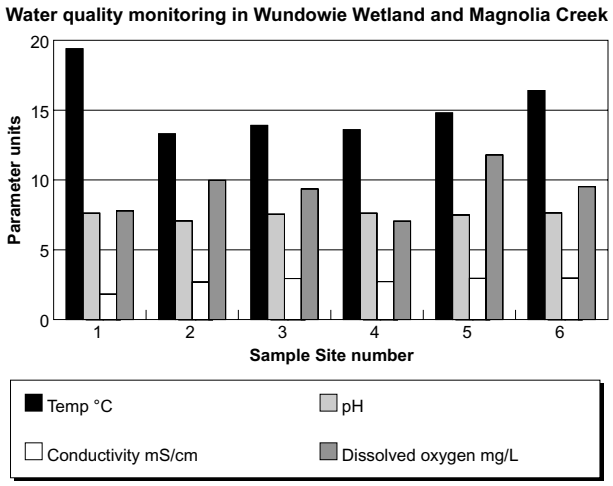


Figure 2: Water quality monitoring results.

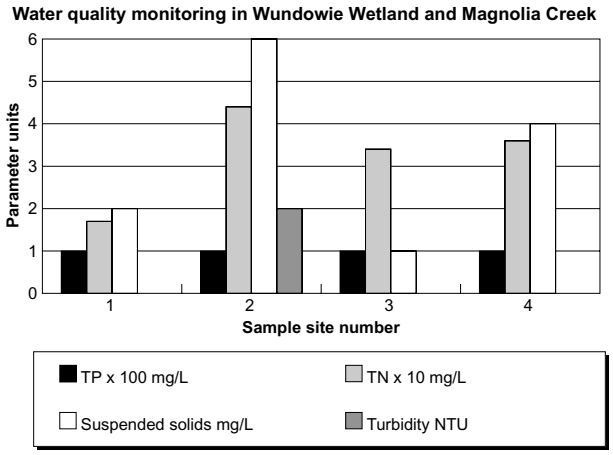


Figure 3: Water quality monitoring results.

Temperature

Water temperature effects the rate of many biological and chemical processes in the waterway, particularly the amount of oxygen gas dissolved in the water. There are natural variations in temperature both seasonally and spatially across a waterway system and is effected by a number of factors including the ambient temperature of the air, the amount of shading or stream cover, groundwater inflows and stormwater runoff.

The ambient temperature at commencement of measurement was 18°C. Water flowing from the ground at the soak (sample site 1) recorded the highest temperature, 19.4°C. The water temperature at sites 2 to 6 ranged from 13.3°C to 16.4°C, increasing as the ambient temperature increased.

pH

pH measures the concentration of hydrogen ions in the water and is expressed on a pH scale ranging from 1 to 14. Low pH values are acidic (a solution high in hydrogen ions), while high pH values are alkaline (a solution low in hydrogen ions).

All animals and plants are adapted to a certain pH range, usually between 6.5 and 8.0. A change in pH of a water body outside this range may cause a loss of species, depending on their sensitivity.

pH is effected by the production of and demand for oxygen and also by catchment geology. Changes in pH may also result from disturbance to acidic soils and agricultural wastes.

The pH of the water in Wundowie Wetland and Magnolia Creek ranged from 7.07 to 7.63 indicating that the water at all sites is in the neutral range.

Salinity

Electrical conductivity is used to measure salinity in a body of water due to the ability of dissolved salts (ions) in the solution to conduct an electric current. Salt water conducts electricity at a faster rate than fresh water, so the higher the conductivity the saltier the water.

Aquatic plants and animals need the natural salts contained in water for growth. If the conductivity increases above the normal range of the particular waterway, the normal community will become stressed and sensitive species will start to die out.

Conductivity is effected primarily by the geology of the area, but flow and caused changes to catchments can significantly alter natural conductivity levels.

Water discharging from the ground at the soak, sample site 1, recorded the lowest electrical conductivity, 180 mS/m. The electrical conductivity at the remaining sites ranged from 260 to 300 mS/m indicating that the system is fresh and becoming moderately brackish. Refer to the classification in Table 19.

Table 19: Classifications for environmental water salinity.

Water quality classification	**Electrical conductivity** (mS/m)
Fresh	< 100
Marginal	100 – 200
Brackish	200 – 900
Low saline	900 – 2000
High saline	2000 – 4500
Hyper-saline	> 4500

Dissolved oxygen

Oxygen is a chemical that is found in air and dissolved in water. It is necessary for all living things and for many of the chemical processes that take place in water.

Oxygen dissolved in the water is important for aquatic organisms. Aquatic micro-organisms use dissolved oxygen to decompose organic and inorganic matter present in the water, such as dead plant material, which then provides a food web for other aquatic organisms. Most aquatic animals breathe dissolved oxygen.

Oxygen enters the water from the surrounding air and is produced by photosynthesis of aquatic plants. Consistently high concentrations of dissolved oxygen in the water are critical for supporting aquatic biota. Studies have shown that fish require at least 5-6 mg/L of dissolved oxygen, while most macro-invertebrates die out at levels below 3 mg/L.

The concentration of dissolved oxygen in water varies with water temperature and depth, flow velocity and the presence of aquatic plants and animals. The concentration of dissolved oxygen in water can be reduced by the addition of oxygen-consuming organic wastes to the water, such as animal and sewerage wastes, nutrients and chemicals, and by altering flow regimes.

The lowest concentration of dissolved oxygen, 7.05 mg/L, was recorded at sample site 4, in a pool in the wetland where the water was not flowing. Water discharging from the soak at sample site 1, recorded 7.78 mg/L dissolved oxygen while the highest concentration of dissolved oxygen, 11.79 mg/L was recorded at the rock riffle, site 5 in section WW3. This demonstrates that rock riffles are effective at aerating flowing water.

Turbidity/suspended solids

Turbidity and suspended solids are a measure of water clarity. Particles suspended in the water, such as clay, silt, sand, algae and plankton, organic and inorganic matter, and living or dead microscopic organisms scatter the passage of light through the water column, are measured as turbidity. Turbidity is reported as nephelometric turbidity units (NTU). Suspended solids are filtered and weighed and reported in milligrams per litre.

These particles enter water through natural or human caused soil erosion, disturbance to the wetland/creek channel and bed, disturbance in the catchment and excessive algal blooms.

High turbidity can cause increased water temperature and reduced light levels for photosynthesis for plant growth. The breathing gills of fish and macro-invertebrates can also be clogged. There is also decreased habitat diversity when suspended solids settle on the bed.

All samples had turbidity and suspended solids within the normal range, with three of the four samples measured having less than the turbidity detection limit of 1 NTU. The sample taken at the drain near the shire pump recorded the highest turbidity and suspended solids, 2 NTU and 6 mg/L respectively.

Table 20: River Water Quality Guide.

Water quality classification	Total Phosphorus mg/L	Total Nitrogen mg/L	Turbidity NTU	Suspended solids mg/L
Near pristine	0 – 0.02	0 – 0.75	0 – 5	0 – 5
Low	0.03 – 0.08	0.76 – 1.2	6 – 10	6 – 10
High	0.09 – 0.20	1.3 – 2.0	11 – 25	11 – 25
Poor	> 0.2	> 2.0	> 25	> 25

Nutrients

Phosphates and nitrates are chemical compounds that are commonly referred to as nutrients. Both phosphorus and nitrogen are essential nutrients for plant and animal growth. There are many natural sources of phosphorus and nitrogen, such as from soil and rocks. Nutrients are also derived from fertilisers, animal wastes and leaking septic systems and enter the waterway from agricultural runoff and uncontrolled stock access to the waterway.

Nutrients, especially phosphorus and nitrogen, encourage the growth of aquatic plants and algal. The algae growing on the bed of streams plays a key role by turning dissolved nutrients into nutritious food (biomass) for invertebrates that are themselves food for fish and birds. Algal growth is controlled by sunlight, streambed stability, water speed, nutrients, and grazing by invertebrates. Healthy streams typically have little obvious algae, because growth is eaten by invertebrates. When excessive amounts of nutrients enter a waterway it may suffer from 'eutrophication' (nutrient enrichment) resulting in nuisance algal blooms. Excessive algae upsets the delicate natural balance of plants and animals and deplete the amount of dissolved oxygen in the water.

Dissolved nutrients are carried downstream and into the receiving waters.

All of the samples had nutrient concentrations in the normal range. All samples had a total phosphorus concentration of

0.01 mg/L. Total nitrogen concentrations were also within the normal range, ranging from 0.34 mg/L, at sample site 3, to 1.7 mg/L at sample site 1 at the soak.

Evidence of management

The most common evidence of management was fencing with four sites having fences along one or both sides of the waterway. Other evidence of management included vehicle and stock crossing points.

Priorities for management

Management along Wundowie Wetland and Magnolia Creek has been prioritised with those issues needing urgent attention classified as having a high priority. Table 21 illustrates the issues that were determined to have a management priority and how each was rated as a matter of urgency.

Results in Table 21 indicate that the main issues for future management of the wetland are the pump for taking water from the wetland at WW2, stock access in five of the six sections, and weeds are high priority for management in three sections. Pollution from animal manure was a medium priority in three sections.

Table 21: Priorities for management.

Management issue	Survey sections requiring management		
	High	Medium	Low
Fire		WW2 WW5	WW1 WW3 WW6
Weeds	WW4 WW5 WW6	WW2 WW3	WW1
Erosion		WW4	WW3
Salinity			
Stock access	WW1 WW3 WW4 WW5 WW6		
Vehicle access		WW3 WW4 WW6	WW1
Rubbish			
Pollution (animal manure)		WW3 WW4 WW6	WW1 WW5
Service corridors			
Crossing point		WW3 WW4 WW6	
Feral animals			WW3
Point source discharge			
Pump or off take pipes	WW2	WW3	WW1
Dam/weir		WW3	WW4
Cultural features			

Interpretation of survey results

Bank and channel stability

Erosion and sedimentation were not determined to be an immediate concern to channel stability along the Wundowie Wetland and Magnolia Creek. The severity of each is directly related to past and present landuse along the waterway. Grazing of the riparian zone and trampling of riverine vegetation by stock is often responsible for causing bank and instream erosion. Cropping activities also lead to sedimentation by increased runoff from cleared paddocks causing soil erosion. The removal of large woody debris from within the channel, or lack of debris due to sparse bank vegetation, results in reduced protection of the banks and foreshore areas, allowing water to erode the banks and transport sediment within the channel.

Cropping of the surrounding catchment means that land is left susceptible to erosion on a regular basis. Any wind or water moving across these paddocks will erode soil particles and deposit them at the lowest point in the landscape – the creek channel.

In all of the surveyed sections the waterway runs through the middle of properties. Most of the sections that provided access to stock had no defined crossing points. This allows stock to have unlimited access to the waterway. These disturbances will continue to contribute to erosion of banks, verges and the creek bed. The three survey sections that were recorded as having man-made crossing points were mainly for vehicle use. Stock access to the riparian zone has led to foreshore areas becoming devoid of vegetation that plays a major role in channel stabilisation. The intricate root network holds soil together to prevent erosion, subsidence and slumping of the banks and verges.

Waterways features and habitat diversity

Permanent systems such as Wundowie Wetland often contain fauna, including macroinvertebrates that have not adapted to an ephemeral system that dries out seasonally.

The waterways features recorded during field observations along Wundowie Wetland and Magnolia Creek are indicative of the health of the waterway, including habitat diversity and aquatic fauna.

Results indicate a variety of waterway features. A groundwater soak was found in section WW1 from where fresh water trickled into the channel. Small pools were found in WW2 and WW3. Rocks, or riffles, which provide habitat and aerate the water, were recorded in three sections.

Instream cover is important for water quality and the dependent aquatic fauna. Results indicate that the level of instream cover from leaf litter, branches, rocks and vegetation is very variable. Sections WW1, WW2 and WW4 had dense vegetation providing abundant instream cover. Section WW6 had one area of dense vegetation providing instream cover. The channel of the remainder of WW6 was invaded by bulrush and, although this is a weed, it serves to provide habitat and instream cover. Section WW4 was recorded as having very sparse overstorey vegetation and only a few branches often not extending far into the waterway, leaving large areas of the channel devoid of any cover and shade. A lack of shade together with shallow water will allow water temperature to increase and may lead to a decline in aquatic fauna and an increase in algal growth.

All survey sections were recorded as having some dead tree species present, four sections had some sick trees and one section had many sick or dying trees. This may be attributed to lowering of the watertable putting stress on the deep rooted upperstorey species. Established trees have adapted to the water regime prior to the extraction of water from the wetland and will not be able to adapt. Some of the crowns of the older trees were showing stress. Younger trees or seedlings and shallow rooted species may be able to adapt. Woody debris found instream and along foreshore areas provides an important habitat for aquatic and terrestrial organisms. An example of habitats along a watercourse and the terrestrial and aquatic fauna that may be found in each is provided in Appendix 9.

Bridges and crossing points allow vehicles and machinery to pass in close proximity to the waterway, increasing the likelihood of pollution by fuel, oil and other contaminants. Structures such as bridges and crossing points using culverts are likely to change the flow of the waterway and

may also lead to problems such as damming upstream of the crossing and increased erosive capacity downstream. Results indicate that crossing points were recorded as having a medium management priority in the three sections where they occurred.

Foreshore condition

Foreshore condition is largely related to the surrounding landuse, disturbances (past and present) and management protocols that are in place. Half of the surveyed sections have been rated as B-grade indicating that the wetland environment is in good condition and is worth preserving. Other sections have been degraded and rated C or D-grades. A number of factors have contributed to the decline in foreshore health and condition. These are:

- surrounding agricultural landuse;
- uncontrolled access of stock to riparian zones (overgrazing and trampling);
- a lack of surface water management systems; and
- a lack of integrated waterway management practices.

The above factors may be attributed to historical landuse practices and a lack of community understanding about waterway management on a long term basis. The volatile nature of farming may also mean that land managers do not have the economic means to change farming practices, improve land and water management practices, provide fencing materials and plants to revegetate the waterway on their property.

Foreshore vegetation

Two sections consisted of a dense overstorey of native vegetation but these need to be protected as they are being invaded by weeds.

A lack of riparian vegetation will adversely affect the health of a waterway. Riparian vegetation assists in providing shade, habitat and the protection of water quality and channel form by decreasing the amount of nutrients and sediments entering the waterway, as well as reducing erosion of banks. Clearing of vegetation, weed invasion, disturbance by stock and salinisation all impact negatively on the health of riparian vegetation (Jackson, 1997).

The composition of native plant communities has been altered significantly as a result of past and present landuse (the introduction of annual crops, annual pasture plants and grazing animals) that have led to changes to the landscape (Walker et al, 1986). A decline in species richness and diversity of native understorey species has encouraged the spread of *Juncus acutus* (spike rush) and *Typha orientalis* (bulrush), grasses and agricultural weeds such as *Avena fatua* (wild oats) and *Hordeum leporinum* (barley grass).

The current lack of native understorey species means that the nutrient stripping ability of the riparian zone is greatly reduced, leading to higher concentrations of nutrients entering the aquatic system and the promotion of weed species. Nutrient enrichment and consequential algal blooms have the ability, directly and indirectly, to kill aquatic fauna.

Understorey vegetation is dominated by weed species, most of which have been introduced and spread by birds, stock, wind, and water erosion of soil particles containing seeds. Species such as *Avena fatua* (wild oats) and *Hordeum leporinum* (barley grass) are agricultural weeds related to the historical use of surrounding land for cropping and grazing and have a medium occurrence along the waterway.

The high number of weed species compared to native species is due to continual grazing and trampling of the riverine environment, hindering the regeneration of the native species. Weeds species are quicker to adapt to fluctuations in the environment and disturbance of the native vegetation gives the opportunity for weed species to invade. Weed species are also able to compete better with the native vegetation in the riparian zone, where moisture and nutrient levels are higher. The increase in shallow rooted exotic species, has left the riparian zone susceptible to bank erosion and nutrient enrichment.

The intensity of grazing in those sections where stock have access to the riparian zone directly relates to the regeneration and survival of native seedlings. Regeneration of native seedlings was observed at five sections. In most cases the number of seedlings was moderate, but declined significantly in number within those sections where stock have access to the foreshore area.

There is a lack of fringing vegetation along some of the banks. Fringing vegetation plays an important role in filtering water entering the channel and keeping the waterway healthy (Water and Rivers Commission, 1997).

Leaf litter and lichens are minimal along the majority of foreshore sections, however they still play an important

role in stabilising the soil surface and assisting in the reduction of soil erosion and compaction. Both are helpful in retaining moisture within the soil and feeding nutrients back into the soils. Leaf litter and debris provide nesting, feeding and shelter sites for many terrestrial invertebrates (Abensperg-Traun, 1995).

It should be noted that the vegetation surveys conducted throughout foreshore and channel assessments are not conclusive. It is likely that there are other species present along the wetland and it is recommended that future assessments include two separate vegetation surveys, at differing times of the year, to determine a more accurate list of species present.

Disturbance

The current condition of the wetland is attributable to a number of past and present disturbances, the key ones being:

- reduced stream flow from pumping;
- current farming practices;
- stock access to the waterway;
- vehicle access to the waterway;
- feral animals; and
- spread of weeds.

Five of the surveyed sections were accessible to stock during the time assessments were conducted, however field observations and landholder comments suggest that two of these sections are not intensively grazed. Over the years however, crop and livestock production has taken its toll on the landscape. Livestock access to the wetland and creek channel and foreshore can lead to problems such as:

- introduction and spread of weeds;
- trampling and eating of native vegetation (particularly regrowth);
- an increase in nutrients (animal faeces) being deposited into the waterway;
- a reduction in fringing vegetation;
- destabilisation and mobilisation of sediment;
- loss of habitat for native fauna (through loss of vegetation as well as competition); and to a lesser extent
- foreshore and channel erosion.

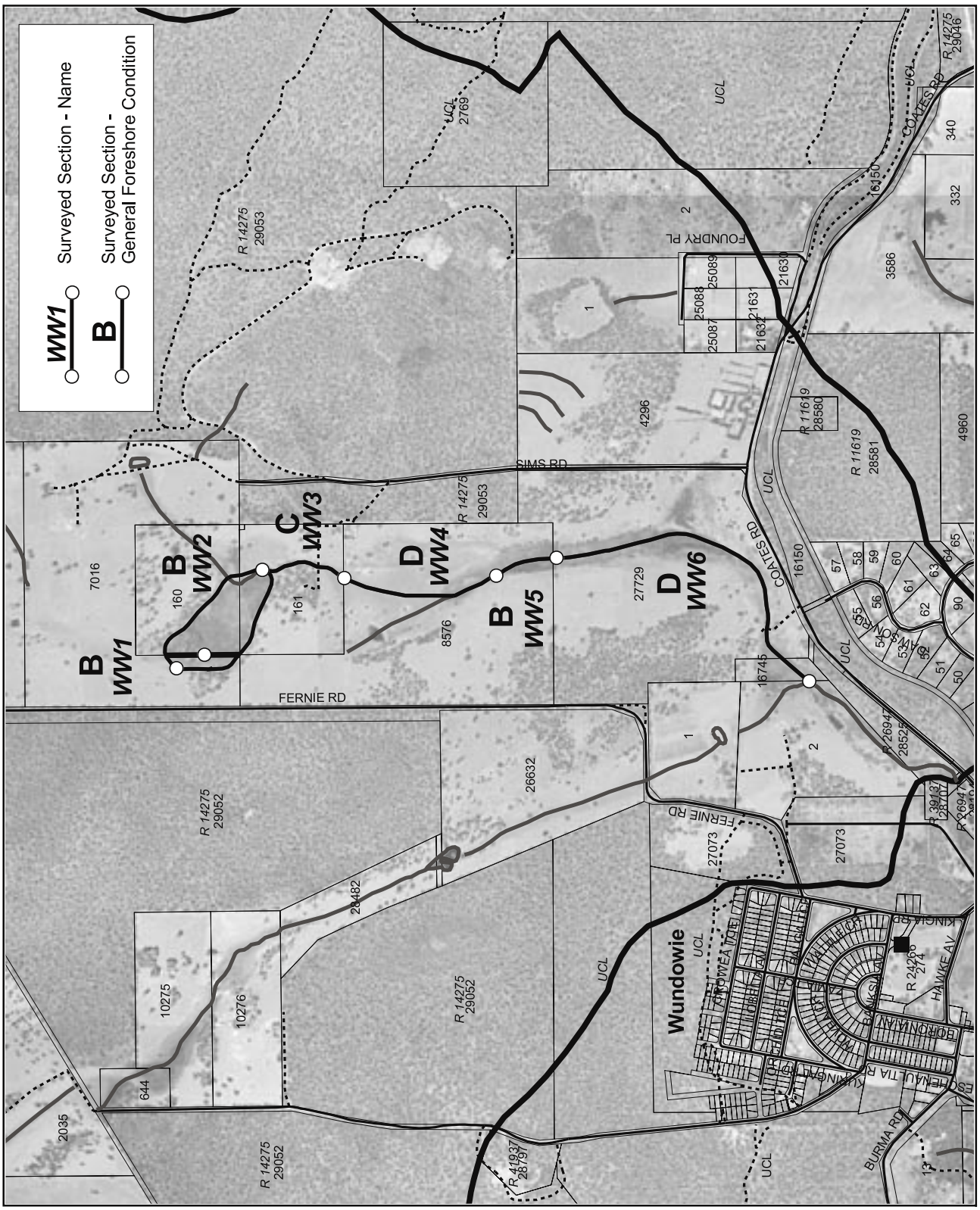
All of these factors combined contribute to the degraded state of the foreshore and channel of Wundowie Wetland and Magnolia Creek. Introducing stock to the landscape should not be seen as the only cause of land degradation within the catchment.

Weed distribution is closely linked to increased levels of disturbance in the wetland from activities that include clearing and grazing. Overgrazing by stock can also degrade the environment through soil compaction, increased nutrient levels, trampling of native wetland plants and the ringbarking of mature trees.

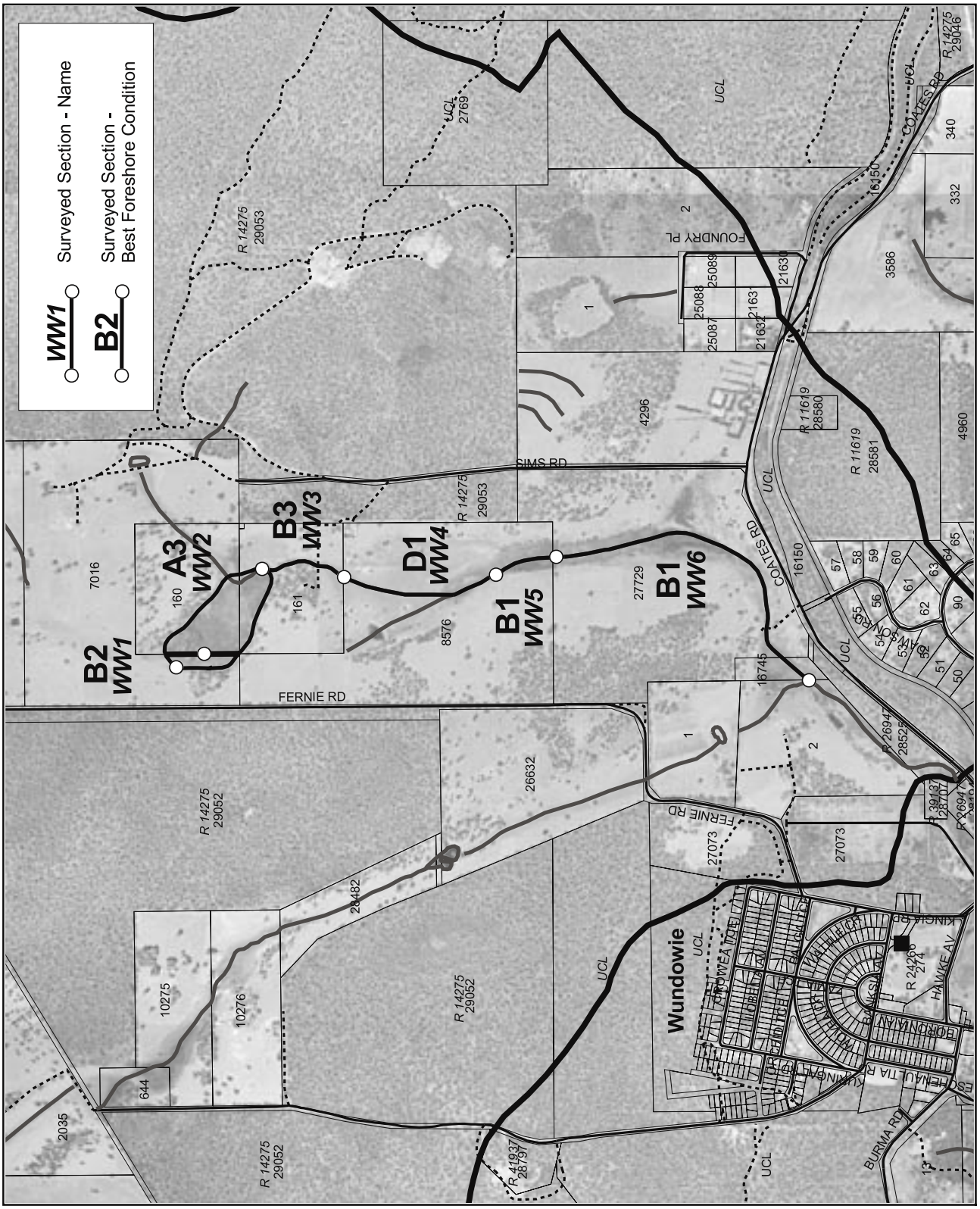
Feral animals may contribute to soil erosion; for example, goats also eat vegetation and increase nutrient levels. Birds nest in vegetation and also forage for food such as seeds and berries. Seeds are spread in bird droppings and are easily carried throughout the riparian zone where the moist conditions are suitable for weed growth.

Evidence of management

Results indicate that the level of management that has been undertaken to protect the waterway was moderate. Four of the sections were fully or partially fenced although only one section provided no access to stock. In most cases landholders indicated a willingness to adopt waterways management and rivercare practices but cost was a major factor hindering further actions.



Map 3: Surveyed sections – General condition.



Map 4: Surveyed sections – Best condition.

Additional comments

Photo 2: WW1 – This area, now dry, was permanently wet prior to unseasonal dry conditions and pumping of water from the wetland.

Section WW1

This section contains a soak where groundwater comes to the surface near some rocks, GPS co-ordinates MGA Zone 50 Easting 442921, Northing 6588773. A steady trickle of water was flowing from the soak at the time of the assessment – see photograph 3. This section contains a windmill to pump groundwater for stock watering.

Anecdotal evidence suggests that parts of this section that are now dry used to be inundated all year round, prior to pumping of water from the wetland by the Shire of Northam. Parts of the channel consisted of dry cracked ground.

Stock have access to the wetland. The property boundary fence runs along the flow channel cutting through the wetland.

This section provided an excellent diversity of habitats as it contained permanent water and rated B for the overall foreshore condition.

Photo 3: WW1 – A steady trickle of water coming from the freshwater soak.

Photo 4: WW2 – Invasion by spike rush along water pipe. Note the waterbird in water trench.

Section WW2

The perimeter of the wetland is rocky with red gravely/ clay.

The Shire of Northam's pump to extract water is located at GPS co-ordinates MGA Zone 50 Easting 443242, Northing 6588527.

The monitoring bore located at GPS co-ordinates MGA Zone 50 Easting 442942, Northing 6588564 is not functioning as no water could be seen in the casing. Another monitoring bore is located in WW3 at GPS co-ordinates MGA Zone 50 Easting 443257, Northing 6588394. The concrete bases of both bores are cracked and neither bore is capped.

The shallow water in the pipe trench near the pump and staff gauge is infested with gambusia.

Section WW2 is enclosed by good fences and is stockproof. The wetland is dominated by dense native vegetation. Pockets have been invaded by weeds particularly by *Juncus acutus* (spike rush), where vegetation was cleared for the water extraction pipes, other disturbed areas, and where a large patch of trees have fallen.

A well or watering hole is located at GPS co-ordinates MGA Zone 50 Easting 442954, Northing 6588656. The

Photo 5: WW2 – Staff gauge for monitoring surface water levels in the wetland.

Photo 6: WW2 – Dead vegetation in the middle of the wetland.

water was approx 20 cm deep and the bore has a soft silt bed greater than 0.5 m deep.

At GPS co-ordinates MGA Zone 50 Easting 442967, Northing 6588631 there was a large patch of weeds, including *Typhus orientalis* (bulrush), in an area containing a lot of dead trees. The ground at this location was wet and very soft to a depth of greater than 0.5 m.

There was a large patch of *Typhus orientalis* (bulrush) where the ground was very soft at GPS co-ordinates MGA Zone 50 Easting 443006, Northing 6588617.

Some debris on the vegetation indicated that the water level had previously been 0.5 m higher than the current level.

This section provided an excellent diversity of habitats as it contained permanent water and rated B for the overall foreshore condition.

Section WW3

The landholder of this section is dependant on flow in the creek for stock-watering purposes. The permanent water hole was almost dry.

A groundwater monitoring bore is located at the upstream boundary of this section at GPS co-ordinates MGA Zone 50 Easting 443257, Northing 6588394. The concrete is cracked and the bore is uncapped. Groundwater level at the time of the survey on 18 February 2003 was 28 cm below ground level.

At the time of survey, adjacent to the upstream boundary of this section, cracks in the soil were observed where the wetland had dried out. Anecdotal evidence suggests that this area was permanently inundated prior to the extraction of water from the wetland.

Only the upstream wetland portion of the surveyed section was fenced and these were in poor condition giving stock and feral goats access to the creek.

The water flowing from the wetland in small tributaries joins to form a single channel near the upstream boundary of the section. The bed material is initially sand becoming

Photo 7: WW3 – Groundwater monitoring bore at the upstream property boundary.

Photo 8: WW3 – Looking downstream along creek channel, monitoring bore to the west (right of photo), dam to the east.

Photo 9: WW3 – Goats have access to the foreshore.

Photo 10: WW3 – Woody debris in creek channel, bed material increasing in roughness.

Photo 11: WW3 – Natural rock riffle.

coarser with the addition of gravel further downstream. This portion of the section contained some woody debris and a natural rock riffle which helps to increase the habitat diversity.

The upstream portion near the wetland has a good cover of native vegetation dominated by weeds. The foreshore was rated as B3 meaning that weeds dominate the understorey but many native species remain and some trees and large shrubs may have disappeared. The foreshore condition and vegetation health deteriorated as the creek flowed downstream. The fence crosses the creek mid distance along the section, at GPS co-ordinates MGA Zone 50 Easting 443288, Northing 6588310. Downstream from this location the creek is not fenced giving access to stock. The foreshore was rated as D1 due to sparse fringing vegetation.

Towards the downstream boundary of this section a small dam has been constructed to pool water for pumping out of the creek for stock watering. The water level in the creek was very low. Some localised erosion was observed towards the downstream boundary of the section.

This section provided a moderate diversity of habitats but did not provide permanent water and rated C for the overall foreshore condition.

Section WW4

There was no flow in the creek in this section. The landholder is dependent on water flow in the creek for stock watering. He has stated that there was a permanent flow of water in the creek prior to the pumping of water from the wetland.

There is a crossing at the upstream boundary of this section and minimal undercutting was observed along the banks immediately downstream from the culvert. Riparian vegetation was sparse and localised erosion of the banks was observed.

The section is not fenced and there were several pads where cattle have crossed the creek.

The channel was not well defined in the downstream portion of this section. From the vegetation and condition of the paddock it appeared that the creek, when flowing, spreads out into the paddock. A minor tributary containing a dam overflows to join the creek channel on the left bank (west).

This section provided limited habitat diversity and no longer provides permanent water and rated D for the overall foreshore condition.

Photo 12: WW4 – Poorly defined channel forming into a dried wetland area.

Photo 13: WW5 – Dying vegetation in the middle of the wetland.

Section WW5

This section was completely dry. The hoof prints from the cattle were very deep indicating the ground in this area can be very wet and soft. This section resembled a wetland rather than a continuation of the creek channel. There were no defined channels or bed, so there was no erosion. The upstream and downstream paddock boundaries were fenced across the waterway and one side of the waterway/ wetland was fenced. Animal tracks and manure were found but the dense vegetation limited stock access.

There was a good diversity of habitats but the rating was reduced to moderate as there was no permanent water. This section rated B for the overall foreshore condition.

Section WW6

Cynodon dactylon (couch grass) and *Typhus orientalis* (bulrush) dominate the vegetation in this section. The bulrush growing in the channel has stabilised the bed and banks of the creek and there is no erosion in those areas. Stock have access to the foreshore. There is one constructed crossing and several non-constructed stock crossings.

The channel is poorly defined in some areas. A soak near the downstream boundary of this property flows into the creek channel keeping the immediate area and the surrounding couch grass moist but the weeds further downstream have dried out.

There is a large stand of *Melaleuca sp* along the left bank (facing upstream), at GPS co-ordinates MGA Zone 50 Easting 443378, Northing 6486677. This area was dry but has been wet in previous years. There are several small dry tributary channels draining the surrounding catchment runoff into the creek. The overstorey is mainly healthy with some dead trees. There is limited localised eroding of the banks as the weeds, which stabilise the banks in other areas, are less dominant at this location.

There was a good diversity of habitats, particularly in the dense protective *Melaleuca sp* segment in the middle of the section, but the rating was reduced to moderate as there was no permanent water. The overall foreshore condition was averaged for the whole section and was rated as D grade.

Photo 14: WW6 – A soak towards the downstream boundary of this property flows into the creek channel keeping the foreground area slightly moist.

Principles for waterways management

The need for management

Wetlands provide a variety of habitats in which plants and animals live for all or part of their life cycles. A diversity of fauna utilise wetland habitats for a range of activities, such as foraging for food, breeding and loafing. Wetland and upland vegetation provides feeding and breeding habitat for frogs, waterbirds, insects and mammals. Areas of bare sand, rocks, logs and open water provide a range of habitat requirements for many aquatic and terrestrial animals. They are utilised as substrates for attachment, for breeding, shelter from predators and for obtaining food. Aquatic plants provide microhabitats and food for a variety of invertebrate species.

Western Australia's wetlands are very diverse in physical and biological composition and in the ecological processes and functions they support. All the plants and animal species in a wetland are part of a complex ecological network where individual organisms interact with each other and the non-living environment around them.

The results of this channel and foreshore assessment indicate that there are many issues that need long term management if the health of the wetland is to be improved. Results indicate a necessity for the implementation of appropriate integrated catchment management practices.

Water supplies in rural Western Australia are limited, and those in abundance are often affected by salinity and have limited use. Wundowie Wetland is a permanent, freshwater system that is not affected by salinity. The catchment has a limited supply of water (surface and groundwater) to satisfy a wide range of competing needs, meaning that water resources need to be used and managed sustainably.

A management or action plan can be used to guide sustainable land and water use, at the same time looking after the riverine environment in conjunction with the economic needs of the landholders. The management or action plan can be devised for individuals or groups of properties and the catchment as a whole. The plan could include such things as:

- identification and prioritisation of potential future threats;
- sustainable water use;
- indications of community and landholder needs and desires;
- actions to address management issues; and
- an implementation plan outlining recommendations for action, timeframes and responsibilities for undertaking actions.

Management of waterways and rural land use are closely related, as the interrelated nature of the two means that they have a wide range of effects on each other (Weaving, 1994). Management of Wundowie Wetland and its surrounding catchment will not lead to the waterway being returned to its pristine, pre-European settlement condition, but will prevent further degradation and encourage the system to become healthier and more resilient in the long-term.

Principles important for inland river management that are relevant to the management of Wundowie Wetland and other tributaries throughout the Avon River Catchment have been identified by Edgar (2001).

1. Natural flow regimes, (permanent flow in the creek channel), and the maintenance of water quality are fundamental to the health of inland river ecosystems.
2. Flooding is essential to floodplain ecosystem processes and also makes a significant contribution to pastoral activities.
3. Structures such as dams and crossings can have a significant impact on the connectivity along creeks and between the waterway and its floodplain.
4. The integrated management of surface and groundwater supplies is an important concept that needs to be undertaken on a catchment-wide scale.
5. New developments should be undertaken only after appraisal indicates they are economically viable and ecologically sustainable. Promoting greater water efficiency is essential to achieving sustainable industries.
6. High conservation value streams and floodplains need to be identified, and in some cases, protected in an unregulated state.

7. Waterways at risk of further degradation need to be identified, and priorities established for their rehabilitation.
8. Improved institutional and legal frameworks are needed to meet community river management aspirations.
9. With all parties making a commitment to work together, management regimes can be developed that are ecologically, economically, socially and culturally sustainable.

Management responsibilities

The concept of this foreshore and channel survey is to encourage management activities as well as providing a condition report on the wetland and waterway. The successful management of a waterway entails the inclusion of the surrounding landscape. It is important to understand that the landscape components within the Wundowie Wetland and Magnolia Creek catchment are inter-related and hence need to be managed as a whole.

The wetland should not be managed as an entity on its own as there are many issues throughout the catchment that contribute to the current condition. Managing the waterway on its own can be likened to treating a problem but not the cause. A catchment wide approach should be employed with a range of objectives to improve the health of the riverine environment.

Maintaining a catchment group or 'Friends' group for the surrounds of the wetland and length of the creek is important to the long-term management of the waterway to promote the waterway as an asset to the community and encourage community involvement in management.

The Avon and Swan Catchment Councils, Northam LCDC, Avon Waterways Committee, Avon Valley Environmental Society and the Wooroloo Brook LCDC are community groups aiming to promote and coordinate integrated catchment management within the Avon River Catchment for the surrounding community. These groups have committed themselves to improving the health of waterways and their surrounding catchments, and may possess many resources and knowledge that will be useful in the future management of this waterway. These groups will require strong support from Government agencies, Local Government Authorities, other catchment groups, landholders and the surrounding community if they are to contribute to the management of the whole catchment.

Waterway management should be undertaken with the objective of resolving competition between riparian water uses and incompatible land uses to ensure that those values that are high or irreplaceable can be maintained. Efforts should be made to maintain and enhance the quality of the water in the waterway in order to conserve ecological systems and meet the needs of present and future generations. Flexibility in the management plan is essential if it is to have the long-term ability to combine waterways conservation with water demands, agricultural practices and rural lifestyles which are highly dependent on climate and other environmental factors (Clement and Bennett, 1998).

A blank foreshore assessment survey sheet is included in Appendix 4 for use by landholders, catchment groups, or community members who are interested in assessing the condition of their waterway to use for future monitoring and management purposes.

Anecdotal evidence suggests that landholders around Wundowie Wetland and along Magnolia Creek are aware of the benefits of long term management of the waterway. Economics is one of the main issues hindering development of on-ground management actions. The lack of financial resources available for landholders to direct into waterways management and the management of surrounding land may mean that there is a need for government and community groups to provide support and encouragement (Coates, 1987).

Management requirements

Water use

Wetland water levels and stream flow are governed by groundwater levels and seasonal rainfall patterns, runoff generated in the waterway's catchment and groundwater discharge.

Abstraction of groundwater causes a decline or 'draw-down' in groundwater levels in the area surrounding the bore and can reduce water levels in the wetland. The magnitude of the drop in groundwater levels and the size of the area influenced by the drawdown depends on the rate and quantity of abstraction, the rate of recharge and the rate of movement of groundwater through the soil.

It is important to maintain a wetland's seasonal hydrological regime to sustain plant and animal diversity.

Landholders can take water from wetlands wholly on their land, and springs that rise to the surface on their land unless:

- taking the water has a significant impact on the flow or level of water in a watercourse or wetland; or
- the relevant water resources management committee and/or the Department of Environment agree the spring or wetland should be controlled.

Under the *Rights in Water and Irrigation Act (1914)* landholders living next to a watercourse, in proclaimed areas, have the right to take water for stock and domestic purposes. As the Wundowie Wetland is in an area proclaimed under this Act, the Department of Environment has licensing and control powers over water use.

A licence application should be submitted prior to taking water in excess of riparian rights.

Landholders next to fresh-water wetlands or streams need to adopt a stewardship role to protect these precious water resources, limit the amount of water taken and consider the impact that their use will have on neighbours downstream.

Water resource management needs to consider the impact that the use of water has on the environmental integrity of the ecosystem and ensure that water dependant ecosystems are protected. When drawing water from the system, users also need to consider the needs of other downstream users and ensure that the amount of water in the wetland or the flow in the creek is not noticeably diminished.

A desktop analysis of the water balance, prepared by WRC Hydrogeologist Mr N. Hundi, estimated that the available water from the wetland for all users was 16 926 kL per year (Appendix 2). Most of the water withdrawn from the system is taken between October and May when there is minimal recharge. Since the Shire of Northam began to take water from the wetland, flow in the creek has diminished.

Recommendations:

- The proposed commercial user of water extracted from Lot 160 commissions a detailed hydrogeological investigation into available water, including drawdown effect on the environment and water quality/quantity.
- The proposed commercial user commissions an environmental impact study on the effects of water extraction from Lot 160.
- Imposition of Department of Environment licensing of any water extraction from Wundowie wetland and Magnolia Creek, other than riparian rights (stock and domestic purposes).
- All water extraction from the wetland at Lot 160 to cease until investigation results are studied and interpreted by Department of Environment as part of the water licensing process.

Stock access

Unrestricted stock access causes disturbances, which have a number of damaging effects, because livestock:

- graze and trample existing vegetation, preventing revegetation;
- compact the soil and create pathways;
- transport weed seeds in their wool/coats and faeces; and
- contribute nutrients and bacteria to the creek through their urine and faeces.

This disturbance can be eliminated by erecting stockproof fencing with constructed crossing points for access to opposite banks.

Further information may be obtained from the Water and Rivers Commission's Water notes (Advisory Notes for Land Managers on River and Wetland Restoration), WN6 "Livestock management: construction of livestock crossings" and WN18 "Livestock management: Fence location and grazing control".

Feral animals

Field observations along Magnolia Creek determined that there are feral animals resident within the riparian and channel vegetation. The most common were goats. Feral animals such as goats cause the same problems as domestic stock. They take over habitats and disturb native fauna, destroy native vegetation, increase the spread of weeds, contribute to bank destabilisation and erosion and are often a threat to livestock being grazed along foreshore and surrounding areas.

The shallow water in the pipe trench near the Shire of Northam's pump and staff gauge is infested with gambusia (*Gambusia holbrooki*), also known as mosquito fish. Gambusia were introduced into Western Australian

wetlands from North America in 1934 as a biological control agent for mosquitoes. Gambusia feed near the water surface and prey upon a wide range of native invertebrates in addition to mosquito larvae. They are prolific breeders and tolerate a wide range of environmental conditions.

Management of feral animals should be approached as a whole throughout the catchment. There is no use in working to rid one property of pest animals to have them immigrate from surrounding properties. There is a need for cross boundary management of feral animals to stop this happening. Controlling weeds will also help to deter pest animals by reducing food and breeding sites.

Fencing

Fencing is the most effective means of protecting riparian vegetation and is the easiest and cheapest means of excluding stock. Fences can be used to exclude and control livestock movement and grazing and to guide human activities into appropriate areas. Fences serve to delineate land uses and prevent human activities from encroaching upon the riparian zone. There are many different fencing options and it is important to identify the specific management requirements so that the location and design of fencing and gates is effective.

When revegetating an area along the riparian zone it is important to exclude stock so that they do not eat and trample newly planted areas. It is recommended that stock be excluded from the planted area for at least three years to allow plants to grow and recolonise the area (Piggott et al, 1995). After this period the plants should be established and stock access, if allowed for fire reduction grazing, should be minimised and properly managed.

Controlled grazing requires fencing to confine stock to the approved grazing area and to control the intensity of grazing. Fenced areas will regenerate naturally over time, or can be replanted with native trees and shrubs. The vegetation helps to control soil erosion along the river, and provides habitat for wildlife. Riparian vegetation is an effective way of preventing sediment entering the waterway.

Fences should be erected outside the riparian zone, as far away from the bank as possible, to exclude stock from the riparian zone. This will encourage the regeneration of native tree species and the growth of ground covers that will aid in stabilising the waterway banks and verges. Fencing of the zone should follow certain parameters if it is to be of benefit to both the environment and economic pursuits of the landholder. A good management tool is to develop a firebreak inside the riparian zone to allow for easy access and to prevent stock pushing fences down to gain access to vegetation.

Using the right type of fence is more economically viable, as it minimises the need for repairs. Fencing along riparian zones should be located parallel to the waterway to minimise the impact of floodwaters on the fence. The type of fence used should be suited to the surrounding landuse if it is to have the maximum benefit of protecting the water resources for future use (Price and Lovett, 1996b).

Stock watering points

Some sections of the wetland and creek may be suitable for stock watering access for example the inside of a meander bend. Other ways to protect riparian vegetation and the banks while still providing a watering point for stock are by installing a:

- pump
- tank in the paddock; and
- rocky access point down to the bank.

Figure 4: Stock watering point.

Crossing points

Crossing points should be located on a straight stretch of creek that is not eroding and preferably where the channel has a hard bed and the banks are not steep. Due to the concentration of animal or vehicle traffic at the crossing point, the bed and banks will usually need to be stabilised,

commonly with small rocks and stones. Fencing should be located so as to prevent animals from moving along the wetland or creek bed.

Weeds management

Weeds have many negative impacts on the riverine environment. They degrade the bushland along the waterway. Introduced species replace native vegetation, or prevent the regeneration of native vegetation, and are often visually unattractive. They compete with native vegetation for space and water. The resulting loss of native species may lead to a change in the food and habitat source for native fauna, hence altering the food chain.

Weeds are also a fire hazard. Many weeds are winter active, meaning that they die off, or become dormant, during summer. In areas of high weed coverage the dry grasses provide an excellent source of fuel for fire and may increase the possibility of the spread of wildfire along the waterway corridor.

An integrated management approach should be encouraged as the best way to deal with weeds. Weed control needs to focus on the immediate area as well as upstream areas where seeds can be easily transported downstream to susceptible areas. Information should be sought from the Environmental Weeds Action Network to develop a catchment-wide weed control strategy.

Landholders should undertake weed control by initially targeting the best areas and then working towards the worst weed-infested areas. Focusing on invasive species as well as declared and pest plants will give a more productive outcome to weed control. Working from the edge of the weed infestation towards the centre, and removing the seed source followed by new growth is the most effective way to manage weed infestations. Working from upstream areas means that the likelihood of seeds and cuttings being washed downstream and recolonising in weed free areas is significantly reduced.

Some introduced species perform a useful role in rehabilitation and riverbank stabilisation. For example, *Typhus orientalis* (bulrush) colonises bare areas along banks and verges and is often useful in stabilising areas that would otherwise be susceptible to erosion and undercutting. These species should be tolerated in the short term, but in the longer term they will need to be controlled before spreading too far. When undertaking weed management, weeds should only be removed from areas susceptible to erosion when revegetation is about to begin. Areas left bare for long periods will be eroded and may contribute to sedimentation within the waterway.

Planting of native species to replace weed species should be considered as an option when planning for revegetation. For example, native sedges and rushes can be used to replace *Typhus orientalis* (bulrush).

Riparian revegetation

The health of the bank and foreshore vegetation along a waterway is indicative of the health of the waterway. Vegetation along waterways should be managed with a view to improving catchment health. Riparian vegetation is an important component of the waterway ecosystem and improves health by:

- providing habitat for native fauna;
- stabilising the channel bed, banks and verge;
- providing wildlife corridors allowing fauna to move along the river;
- providing shade over the waterway, thus providing a more favourable habitat and decreasing the likelihood of algal blooms;
- providing woody debris for habitat and bank stabilisation;
- filtering runoff from surrounding land to decrease nutrient input into the waterway; and
- protecting soils from wind and water erosion (Olsen and Skitmore, 1991).

Management works should be prioritised to gain the greatest benefit from the available resources. Protecting areas of good (weed free) riparian vegetation and working towards more degraded areas will be more economically viable for landholders (Price and Lovett, 1996b). It is more costly to rehabilitate a degraded area than to protect it before it becomes weed infested.

If revegetation of riparian areas takes place, it is important that stock do not have access to these areas of fringing revegetation. A fence around the revegetated area (or the riparian zone) is the most effective tool to prevent livestock grazing and trampling newly revegetated areas.

Where grazing of the riparian zone is necessary, the following rules should be followed to minimise disturbance and limit the environmental and economic losses associated with an unhealthy riverine system.

- Avoid grazing the riparian zone during the germination, growing and flowering times of the native plants;
- Do not overstock the riparian zone. This will minimise the negative impact that grazing and trampling have on

the productivity of this area, as well as the water quality within the river; and

- Adjust stocking rates and the frequency of grazing within this zone to suit the carrying capacity of the land (Price and Lovett, 1996b).

Riparian vegetation plays an important role in protecting the waterway from degradation. Vegetation along banks, verges and foreshore areas can help to regulate the hydrological processes, filter nutrients from recharge water as well as nutrient cycling, and prevent soil erosion by overland flows of water and wind (Coates, 1987).

Fire management

Australian vegetation is generally well adapted to deal with the effects of fire. However, an increase in the intensity and/or frequency of fire can reduce the successful regeneration of some plant species and encourage introduced grasses (WRC 2000).

Annual weeds, such as introduced grasses, dry out during the summer months and can pose a serious fire risk if not kept under control. Native vegetation is often patchy or sparse along Wundowie Wetland and Magnolia Creek and after frequent or uncontrolled fire, may be vulnerable due to the limited opportunity for recolonisation from surrounding areas (Underwood, 1995).

An abundance of weed species that die off during summer months means that the riparian zone along waterway is susceptible to fire, and hence a management plan to accommodate any risks needs to be decided upon and implemented. There are many disadvantages to fire, including risk to persons and property, livelihood, weed invasion, loss of habitat for fauna, loss of some seed, loss of peat soils and an increase in erosion. Under controlled circumstances, when risks are reduced, there are also benefits of fire to the natural system. For example, fire provides the opportunity for many native plant species to germinate by providing the right conditions.

To reduce any serious threat of fire, it may be necessary to implement controlled grazing along some sections of the waterway (WRC and ARMA, 1999). This can reduce the threat of fire to those people living and farming along the waterway. A controlled fire regime can be a useful tool in the regeneration of native species growing within the riverine environment as many species have adapted to occasional fire and benefit from it. When uncontrolled and on too frequent a basis, fire may lead to a loss of habitat, an increased susceptibility to weed invasion, and can hinder management works if rehabilitation plantings and fences are burnt (Underwood, 1995).

If areas are burnt too frequently, there is a risk of weed invasion. Fire creates bare open ground which is ideal for the germination of weed species, and if fires become too frequent it is easy for weeds to out-compete native plants.

Burning of vegetation and debris along the waterway foreshore and banks should take into account the condition of the existing vegetation. It is important to remember that leaf litter and debris contribute important habitat for organisms, as well as protecting the soil from erosion. The timing of burning should be sensitive to the species present.

Firebreaks along foreshore verges are important to protect the fragile vegetation from unintentional fires that may result from crop and pasture burning in surrounding paddocks. To maintain effective fire control for the riparian zone, firebreaks and fencing should be upgraded and maintained along verge areas of the foreshore. When fencing for protection of riparian vegetation the firebreak should be located on the river side of the fence, as far away from the bank as possible. A firebreak on the river side of the fence will allow easy access to this zone, and prevent stock from pushing the fence over to graze on the other side, as well as giving some protection from falling branches damaging the fence.

The main goals are to manage the fire problem along the waterway, while minimising the threat to the river environment and to neighbours. It is also a priority to educate river neighbours and encourage landholders to take responsibility for protecting their own assets.

Water quality

Poor water quality can significantly affect the health of the waterway and its surrounding ecosystems. It is likely that the clearing of land associated with the agricultural development of the catchment and current land use practices have had a negative impact on the health of this waterway, adversely affecting the health of the riverine system (Schofield et al, 1988).

Restricting stock access from the wetland and creek will help to improve water quality. Stock (sheep, cattle and horses), along with feral goats, are responsible for mobilising plant nutrients, that they distribute via their faeces (Swan River Trust, 1998). Controlled access will minimise the amount of manure within the waterway and limit nutrient enrichment.

Water resource management is best approached as part of integrated catchment management. Managing the

catchment area as a whole allows the diverse range of social, economic and ecological activities that affect a particular waterbody to be coordinated. Water and biological resources are firmly linked within the natural environment, and disruptions to either one can have significant implications on these resources and the environment as a whole (Australian Water Resources Council, 1992).

Pollution of the waterway

Pollutants and nutrients are washed into the waterway from surrounding land. Stock access can cause direct contamination of stream water as their urine and faeces contribute nitrogen, phosphorus and bacteria directly to the creek. This can result in;

- poor water quality, including oxygen depletion;
- health problems in stock, such as liver fluke and diarrhoea; and
- the excess growth of weeds and algae.

Large woody debris

Large woody debris (also known as snags) are branches, large limbs or whole trees which fall into the watercourse and either remain in place or move downstream where they come to rest. Large woody debris plays an important part in the function of stream systems, providing energy sources, essential to the food web. Large woody debris also traps terrestrial leaf material that falls or is blown into the watercourse and accumulates at these points, providing an important habitat for many aquatic organisms. Some areas along Magnolia Creek reveal a low load or absence of this material due to clearing of the native overstorey. In this type of system the accumulation of woody debris may take many decades to provide adequate stream stabilisation and habitat to restore the ecological balance. Re-introduction of woody debris by landholders will improve creek stability and habitat for native fauna. There is a need to educate people to the benefits of restoring native vegetation that contributes to the debris within the river system, and the disadvantages of removal or absence.

Contrary to common belief, the lack of large woody debris does not reduce flood risk and will actually lead to bank and channel erosion caused by an increased flow velocity. Reintroducing large woody debris to the system will increase river stability and provide a greater diversity of habitat for native fauna.

Sediment deposition

The goal of management is to minimise sediments entering the waterway, to reduce the movement of sediment along the waterway, and to stabilise the riverbanks and channels.

Sediments comprise sand (the heavy, course fraction that is mostly carried in suspension), and silt (the finer fraction that is carried in solution). Both are moved down creek channels to be deposited when either natural pools or natural obstructions slow down the water velocity.

Riparian vegetation creates a buffer zone along the creek and is effective in reducing sediment entering the waterway.

Economic values

A well managed riparian zone is an asset to landholders, rather than a net burden. A healthy riparian ecosystem, including improved water quality with an associated increase in stock health, a decrease in insect and bird pests that damage pastures and crops, provision of windbreaks and shelter which can lead to improved stock growth and productivity through reduced heat and cold stress, decreased bank erosion and topsoil stripping and even an increase in capital value of the land (WRC 2000).

Education and awareness

For the long-term benefit of the riverine ecosystem, measures should be taken to educate landholders and Local Government Authorities in an effort to promote understanding and awareness of the significance of waterways and their management for future use.

Catchment management and community action requires awareness of the issues, education and information, technical advice and practical support. Local Government Authorities, as well as relevant government and non-government agencies, need to provide support to these groups while banding together to promote issues such as sustainable water use, waterways management, integrated catchment management and land management to community members.

There is a wealth of information already learned and gathered from other community, catchment and ‘Friends of’ groups which is valuable and can be passed on through establishing networks between groups in surrounding areas. The Swan and Avon Catchment Councils provide a range of resources helpful to land and waterways managers.

Concluding comments

Wetlands are complex, diverse ecosystems which are directly linked to the landscape that surrounds them. The health of wetlands is not just dependent upon biological, chemical and hydrological processes taking place within them, they are also significantly influenced by the activities occurring within their catchments. Wetlands are dynamic ecosystems which change, not only over days, months and years, but also over decades and centuries. These changes can take place in response to climatic cycles, random events such a storms, fires and earthquakes or as a result of human activity within the catchment of the wetland.

Western Australia's wetlands are biologically productive systems that support a diverse and distinctive array of plants and animals, many of which are unique.

Wundowie Wetland is a permanent, freshwater system and is an important asset because this type of wetland is rare in this area. It is therefore very important that this wetland is protected and managed in an ecologically sustainable way.

This foreshore and channel assessment of Wundowie Wetland and Magnolia Creek has been undertaken to provide landholders, interested community groups, the Local Government Authority and Government and non-Government agencies an understanding of the current condition of Wundowie Wetland and Magnolia Creek channel and foreshore.

The survey process has been developed to suit the needs of this region and can be used by interested individuals, groups and organisations to gain an understanding of the condition of other waterways within their community. It is hoped that this process will be useful for these people to monitor the health and condition of this wetland and waterway into the future.

By using a standard methodology to gather information it is possible to compare and contrast foreshore conditions of the same area over time. Results can then be used to prioritise management needs, determine the impact of new disturbances and assess changes in foreshore and channel condition.

This document provides the results of the foreshore assessment undertaken along Wundowie Wetland and Magnolia Creek. The main conclusion to draw from findings is that in many ways the health of the waterway is suffering, both directly and indirectly, as a result of past and present landuse and water usage activities.

Wundowie Wetland and Magnolia Creek are generally degraded. Historically, land and water have been overused. There is hope that with a greater understanding of the condition of wetland and waterway, landholders will join together to try and recover some of the natural health of the wetland and waterway and that activities employed within the catchment will become more compatible and ecologically sustainable.

It is recommended that a detailed hydrogeological investigation into available water and an environmental impact study on the effects of water extraction from Lot 160 is carried out.

There is a decline of native plants and an abundance of weeds. The most common native vegetation are trees, *Melaleuca sp* being the most prevalent. Of the weed species invading, *Juncus acutus* (spike rush), *Typhus orientalis* (bulrush) and introduced annual grasses were the most commonly observed during this assessment.

The major impacts along the length of this watercourse are decreased stream flow, weeds, as well as vehicle and stock access to the riparian zone. Observations determined that the issues in greatest need of management are water management, stock access, weed invasion and revegetation of the riparian zone with native species.

The need exists to assess competing land and water uses and to determine a compromise that allows for the rehabilitation and conservation of the wetland along with sustainable and economically viable land use practices. This will lead to many economic, environmental and social advantages both now and into the future.

Future strategies to improve the ecological health of Wundowie Wetland and Magnolia Creek need to be linked to the development of more sustainable farming systems within its catchment. If management of the creek system is to be effective, degradation associated with waterway must be treated at the cause and not the symptom.

Management of this waterway requires knowledge and understanding of the factors that are present and how they are affecting, either positively or negatively, the surrounding catchment. This survey provides that information so that the community can work together to initiate an integrated approach to improving the health of Wundowie Wetland and Magnolia Creek. The data collected throughout this foreshore and channel assessment is also an effective tool to monitor future changes in the stability and health of this waterway.

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Glossary

Bank The steeper part of a waterway channel cross-section, which is usually considered to lie above the usual water level.

Barbed wire fence Any fence that is in part barbed wire.

Bed stability When the average elevation of the streambed does not change much through time.

Biodiversity The number, relative abundance and genetic diversity of life forms within an ecosystem.

Catchment The area of land drained by a waterway and its tributaries.

Conductivity Conductivity is a measure of dissolved salts. Common salt, sodium chloride, is the main cause of water salinity problems. Since dissolved salts conduct a charge estimates of salinity can be derived directly form electrical conductivity. The international unit is millisiemens per centimetre (mS/cm).

Degradation Specifically the general excavation of a streambed by erosion processes over a number of years. Has a broader meaning of reduction in quality.

Dissolved oxygen The concentration of oxygen dissolved in water, measured as milligrams per litre (mg/L).

Electrical conductivity A measure of salinity. The higher the electrical conductivity of a stream the greater the salinity.

Electric fence Any fence design which is electrified, irrespective of whether they consist 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 the life of organisms.

Environmental degradation Depletion or destruction of a potentially renewable resource such as soil, grassland, forest, or wildlife by using it at a faster rate than it is naturally replenished.

Erosion The subsequent removal of soil or rock particles from one location and their deposition in another location.

Evaporation A physical change in which liquid changes into a vapour or gas.

Exotic vegetation Introduced species of vegetation from other countries or from other regions of Australia (i.e. not indigenous to the region).

Fabricated fence Includes rabbit netting, ring-lock and hinge point fences.

Floodplain A flat area adjacent to a waterway that is covered by floods every year or two.

Floodway and 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.

Habitat The specific region in which an organism or population of organisms live.

Hydrological regime (In the context of a wetland) The pattern of water availability in a wetland over a yearly cycle.

Large woody debris A branch, tree or root system that has fallen into or is immersed (totally or partially) in a stream.

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.

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.

Overgrazing Destruction of vegetation when too many animals feed too long and exceed the carrying capacity of a rangeland area.

Pest plant Weed species that are seen as being a nuisance to the existing landuse. Local Government Authorities can enforce the control of such a species.

pH The acidity of alkalinity of a waterway is measured by a pH scale from zero to 14. A pH less than seven indicates the water is acidic, seven is neutral, and above seven is alkaline or basic. Technically pH is the concentration of hydrogen ion (H^+) in the solution.

Phosphorus The phosphorus found in both surface and groundwater is in a form called phosphate. It is naturally derived from the weathering of rocks and the decomposition of organic material, but it can also enter waterbodies in runoff or discharges – soil and fertiliser particles can carry phosphorus, and sewage is also rich in phosphorus. Concentrations are generally measured in milligrams per litre (mg/l).

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.

Rights in Water and Irrigation Act The Rights in Water and Irrigation Act (1914) gives the landholder the right to take water for domestic and stock water and other specific non-commercial purposes.

Riparian rights Riparian rights are the rights of landholders whose land has direct contact with a watercourse or wetland to take water for domestic and ordinary use, watering cattle or stock that are not being kept under intensive conditions, and to irrigate a household garden up to 2 hectares.

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 a waterway, which leads to a decline in water quality.

Slumping The mass failure of part of a stream bank.

Snags Large woody debris such as logs and branches that fall into rivers.

Subsidence The sinking of parts of the ground which are not slope related.

Terrestrial Relating to land.

Turbidity Muddiness or opaqueness of water due to suspended particles in the water causing a reduction in the transmission of light. Turbidity is reported as nephelometric turbidity units (NTU). Suspended solids are filtered and weighed and reported in milligrams per litre.

Undercutting The undermining or erosion of soil by water from underneath an existing landform (i.e. riverbank), structure (ie, 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.

Weed A plant growing where it is not wanted.

Wetland A wetland is an area of seasonally, intermittently or permanently waterlogged soil or inundated land, whether it is fresh or saline, flowing or static.

Appendix 1
Soils of the Wundowie Wetland Catchment

Soil Unit Descriptions

Soil code	Description
JZ2	Dissected plateau having a gentle to moderately undulating relief, and with broad swampy drainage-ways and basins. It is characterised by lateritic gravels and block laterite: the chief soils are ironstone gravels with sandy and earthy matrices (KS-Uc4.2), (KS-Uc4.11), (KS-Gn2.24), and (KS-Uc2.12). They overlie duricrusts of recemented ironstone gravels and/or vesicular laterite, and/or mottled-zone and/or pallid-zone material. These soils cover ridges and slopes where some (Dy3.81 and Dy3 .82) soils containing ironstone gravels also occur. Leached sands (Uc2.2 and Uc2.3) are a feature of the drainage-ways and basins. Areas of (Dy5.41) and (Dy5.82) soils occur on pediments in some areas of this unit where it merges with unit Tf3. Occurs on sheet(s): 5
Tf3	Low hilly to hilly terrain that occupies a zone flanking unit JZ2. It comprises valleys that are frequently narrow and have short fairly steep pediments, along with breakaways, mesas, and occasional granite tors. Included also are undulating areas representing elements of unit JZ2: chief soils are hard acidic yellow mottled soils (Dy3.81) along with sandy acidic yellow mottled soils (Dy5.41) and (Dy5.81), all of which contain moderate to large amounts of ironstone gravels in their surface horizons. Ironstone gravels (KS-Uc4.2) occur on the ridge crests and on the fine gravel deposits of the gently undulating parts of the unit, along with leached sands (Uc2.21). Occurs on sheet(s): 5

Source: CSIRO, 1967

Appendix 2
Wundowie Wetland water balance estimate

Wundowie Wetland water balance estimate

The Wundowie wetland (Lot 160 and161) catchment area has been defined on the enclosed map and is about 11 km^2. The elevation of the catchment divide varies between 390 and 445 m AHD. The wetland occurs at 300 m AHD at break of slope.

Laterite and weathered bedrock comprising clay underlie the surficial sediments. The Rainfall occurring in the upper parts of the catchment (Lot 20) is the main source of the groundwater seepage and the formation of wetland on Lot 160 and 161.

The rainfall recharge is expected to be very minimal from the areas covered with native vegetation (< 1%). However in the cleared areas it is estimated to be about 4% of the annual rainfall. The groundwater flow path generally follows the topography.

The Water Balance for the wetland can be estimated as follows:

Cleared Catchment Area		= 601 Ha
4% of Rainfall (Mauger Pers. Comm.)		= 240 kL/Ha
Total Recharge	= 601 x 240	= 144 240 kL/year (a)
Seepage and the wetland surface area		= 6 Ha
Pan-evaporation for the wetland surface area (Bari Pers. Comm.)		= 1970 mm/year x 6 Ha
Evaporation Loss		= 118 200 kL/year (b)
Net Recharge	(r = a-b)	= 26 040 kL/year
Environment Water Provision 35%		= 9114 kL/year
Available water for the Shire of Northam and other local users		= 16 926 kL/year

Comments:

The above estimate is fairly reasonable and I am of the view that there is no need for a more detailed investigation by a consultant. In view of the shallow groundwater conditions, Piezometer construction is not necessary at this stage.

The available water (16 926 kL) may be allocated between the Shire and other local users in the area. The Shire should install a flowmeter and monitor abstraction from the seepage/wetland.

Low rainfall conditions appear to be the main cause for declining water levels observed in dams and wells downstream.

Should the Shire of Northam Shire think otherwise a detailed hydrogeological investigation might be carried out using the services of a Consultant. The study should include brief pumping test, monitoring and water balance assessment.

Natti Hundi
HYDROGEOLOGIST

Appendix 3
Completed tributary assessment form

Please note that the information contained in this completed assessment form is an example only.

Foreshore and Channel Condition Assessment Form

For property and paddock scale surveys

General Details

Recorder's Name: Phyllis Graham — Survey Date: 10 February 2003

Tributary Name: Wundowie Wetland — Section Number: WW001

Catchment Name: Wundowie Catchment — Length of Section: 1.8Km

Sub-catchment Name: Swan Catchment — Shire: Northam

Nearest Road Intersection: Sims Road / Coates Road

GPS (start of survey section) E: 442880 N: 6488740

GPS (end of survey section) E: 442940 N: 6488686

Landholder contacted: Yes ✓ No ❒
Landholder consent obtained: Yes ✓ No ❒
Landholder present during survey: Yes ❒ No ✓

Bank(s) surveyed (facing upstream)
left ❒ right ❒ both ✓

Landholder: Jack and Jill Brown — Contact Number: 9573 6666

Property address: Lot 89 Wetland Road, Wundowie

Bank Stability

Proportion of bank affected (% of survey area)	Undercutting	Firebreak/track washouts	Subsidence	Erosion	Gully erosion	Sedimentation
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
✓ Pool
✓ Wetlands
❒ Other
……..

✓ Dam
❒ Groundwater
❒ Rapids
❒ Anabranch

❒ Riffle
❒ Bridge
❒ Sand slugs
❒ Vegetated islands

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

General: C Best: C1 Poorest: D1

Vegetation Health

❒ Looks healthy ❒ Some sick trees ❒ Many sick or dying trees ✓ Some dead trees ❒ Many dead trees

Are there any tree seedlings or saplings present?: ✓ Yes ❒ No Species: Tea tree, Acacia,

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

Bare Ground: % bare: 5%

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

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

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

Vegetation cover

Proportion cover	Overstorey	Middlestorey	Understorey
> 80% Continuous	✓		✓
20-80% Patchy			
< 20% Sparse		✓	
0% Absent			

Proportion of Native Species

	Proportion (%) of native species
Overstorey	> 80%
Middlestorey	> 80%
Understorey	10-20%

Fencing Status

Left bank

Fence present? ✓ Yes ❒ No Fence condition: ❒ Good ✓ Moderate ❒ Poor

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

Right bank

Fence present? ✓ Yes ❒ No Fence condition: ❒ Good ✓ Moderate ❒ Poor

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

Fence position (approximate distance [m] from river bank): LB: 10 – 15m RB: ~ 30m

Stock access to foreshore: ✓ Yes ❒ No Vehicle access to foreshore: ✓ Yes ❒ No

Crossing Point: ❒ Yes ✓ No

Overall Stream Environmental 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 = 15 Environmental rating = Poor

Score	40-55	30-39	20-29	10-19	0-9
Rating	Excellent	Good	Moderate	Poor	Very poor

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 streamside 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?

Salt crystals along the bank.
Bank erosion.
Debris in trees and along fence lines.
Flood channels.

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

Algae.
High sediment load.
Limited overhanging vegetation (minimal shade).
Salt crystals.
Discolouration of water.

Any wildlife (or evidence of presence) observed?

Birds, ducks, flies, goats, 28 parrots, willie wag-tails, dragonflies, ants, spiders, snakes, lizards

Landform Types

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

Shallow valley with low relief. Channel is little more than a wide floodplain.

Evidence of Management

Tick the appropriate boxes:

❒ Prescribed burning
✓ Firebreak control
✓ Fencing
❒ Nest boxes
❒ Recreational facilities (e.g. rubbish bins, BBQ's, benches)
❒ Signs
❒ Planting
❒ Weed control
❒ Erosion control
❒ Earthworks
❒ Dredging

❒ Other: .....

Management Issues

Tick the appropriate priority box for each management issue.

Issue	Priority		
	High	Medium	Low
Fire			✓
Disease			
Weeds	✓		
Erosion			✓
Salinity			
Stock Access	✓		
Vehicle Access		✓	
Rubbish			
Pollution			✓

Issue	Priority		
	High	Medium	Low
Recreation			
Garden Refuse			
Service Corridors			
Crossing point		✓	
Feral Animals			✓
Point source discharge			
Pumps or off-take pipes			
Dam/weir			
Cultural Features			

Vegetation

Plant Name	Abundance (H,M,L)	Plant Name	Abundance (H,M,L)
Teatree	H	Golden wreath wattle	L
Spike rush	H	Couch	M
Wild oats	H	Samphire	L
Swamp sheoak	M	Needlebush	L
Barley grass	H	Ruby saltbush	M
Fat hen	L	Wild geranium	L
Thistle	L		
Bulrush	H		
Swamp paperbark	L		
Flooded gum	L		

Water Quality Data

Sample Number	pH	Conductivity mS/cm	Temperature ºC	Location
1	8.33	18.4	22.1	442889 E 6588620 N
2	8.06	19.3	23.8	442752 E 6588738 N

GPS Coordinates

Coordinate	Description
442880 E 6488740 N	Start point of survey section
442880 E 6588651 N	Natural rock riffle
442871 E 6588634 N	End of large sand slug
442897 E 6588620 N	Area of many sick and/or dead trees
442940 E 6488686 N	End of survey section

Appendix 4
Tributary assessment 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: …….. Length of Section: ……...

Sub-catchment Name: ……... Shire: ……

Nearest Road Intersection: ……..

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	Erosion	Gully erosion	Sedimentation
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
❒ Pool
❒ Wetlands
❒ Other
……...

❒ Dam
❒ Groundwater
❒ Rapids
❒ Anabranch

❒ Riffle
❒ Bridge
❒ Sand slugs
❒ Vegetated islands

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 - rate between A1 and D3)

General: Best: Poorest:

Vegetation Health

❒ Looks healthy ❒ Some sick trees ❒ 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: % bare: …….

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

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

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

Vegetation cover

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	

Fencing Status

Left bank

Fence present? ❒ Yes ❒ No Fence condition: ❒ Good ❒ Moderate ❒ Poor

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

Right bank

Fence present? ❒ Yes ❒ No Fence condition: ❒ Good ❒ Moderate ❒ Poor

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

Fence position (approximate distance [m] from river bank): LB: …….….. RB: ……..

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

Crossing Point: ❒ Yes ❒ No

Overall Stream Environmental 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
Rating	Excellent	Good	Moderate	Poor	Very poor

Environmental rating = …….

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 streamside 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?

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

Any wildlife (or evidence of presence) observed?

Landform Types

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

Evidence of Management

Tick the appropriate boxes:

❒ Prescribed burning
❒ Firebreak control
❒ Fencing
❒ Nest boxes
❒ Recreational facilities (eg. rubbish bins, BBQ's, benches)
❒ Signs
❒ Planting
❒ Weed control
❒ Erosion control
❒ Earthworks
❒ Dredging

❒ Other: ……

Management Issues

Tick the appropriate priority box for each management issue.

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

Issue	Priority		
	High	Medium	Low
Recreation			
Garden Refuse			
Service Corridors			
Crossing point			
Feral Animals			
Point source discharge			
Pumps or off-take pipes			
Dam/weir			
Cultural Features			

Vegetation

Plant Name	Abundance (H,M,L)	Plant Name	Abundance (H,M,L)

Water Quality Data

Sample Number	pH	Conductivity mS/cm	Temperature ºC	Location

GPS Coordinates

Coordinate	Description

Photos

Appendix 5
Overall stream environmental health rating

Living Streams Survey:
Information to determine environmental ratings of streamlines

	Excellent	Good	Moderate	Poor	Very poor
Habitat diversity	3 or more habitat zones. Some permanent water.	2 habitat zones. Some permanent water.	Mainly one habitat type with permanent water, or Range of habitats with no permanent water.	Mainly one habitat type with no permanent water.	Stream channelised.
Bank stability and sedimentation	No erosion, subsidence or sediment deposits. Dense vegetation cover of banks and verge. No disturbance.	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.	Good vegetation cover. Localised erosion, bank collapse and sediment heaps only. Verges may have sparse vegetation cover.	Extensive active erosion and sediment heaps. Bare banks and verges common. Banks may be collapsing.	Almost continuous erosion. Over 50% of banks collapsing. Sediment heaps line or fill much of the floodway. Little or no vegetation cover.
Stream cover	Abundant cover: shade, overhanging vegetation, snags, leaf litter, rocks and/or aquatic vegetation.	Abundant shade and overhanging vegetation. Some instream cover.	Some permanent shade and overhanging vegetation. Some instream cover.	Channel mainly clear. Little permanent shade or instream cover.	Virtually no shade or instream cover.
Verge vegetation	Healthy undisturbed native vegetation. Verges more than 20 m wide.	Mainly healthy undisturbed native vegetation. Verges less than 20 m wide.	Good vegetation cover, but mixture of native & exotic species. Verges 20 m or more.	Narrow verges only (< 20 m wide), mainly exotic vegetation.	Mostly bare ground or exotic ground covers (i.e. pasture, gardens or weed infestations, but no trees).
Floodway and bank vegetation	Healthy undisturbed native vegetation. Virtually no weeds. No disturbance.	Mainly healthy undisturbed native vegetation. Some weeds. No recent disturbance.	Good vegetation cover, but mixture of native and exotic species. Localised clearing. Little recent disturbance.	Mainly exotic ground cover. Obvious site disturbance.	Mostly bare ground or exotic ground covers (i.e. pasture, gardens or weed infestations, but no trees).

Source: Pen and Scott, 1995

Overall Stream Environmental Health Rating: Points system

Rating	Floodway and bank vegetation	Verge vegetation	Stream cover	Bank stability and 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
Rating	Excellent	Good	Moderate	Poor	Very poor

Environmental rating = ……

Appendix 6
Foreshore assessment grading system

A Grade

Foreshore has healthy native bush (i.e. 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 humans 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.

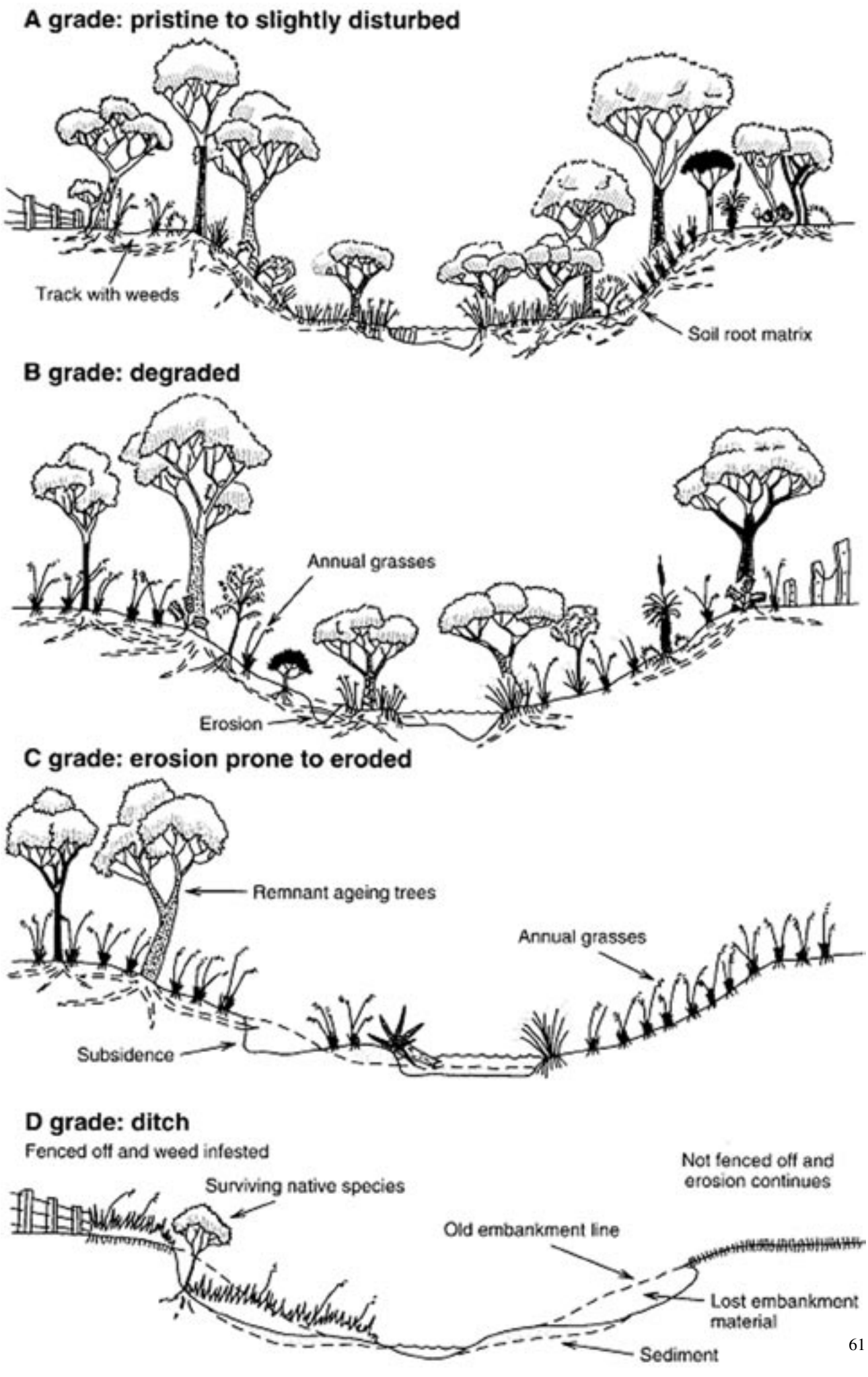
D Grade

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.


A grade: pristine to slightly disturbed
Track with weeds
Soil root matrix
B grade: degraded
Annual grasses
Erosion
C grade: erosion prone to eroded
Remnant ageing trees
Annual grasses
Subsidence
D grade: ditch
Fenced off and weed infested
Surviving native species
Not fenced off and erosion continues
Old embankment line
Lost embankment material
Sediment

Appendix 7
Fencing styles

Barbed Wire Fence: Any fence that is part barbed wire, usually in conjunction with plain wire and droppers and which is not electrified is classified a barbed wire fence. Barbed wire deters stock from rubbing, which is the main cause of fence damage.

Electric Fence: Electric fencing uses a high voltage pulse to deter animals, for both feral animals and stock. Electric fencing has been most commonly used in conjunction with conventional fencing, enhancing its effectiveness and, in case of heavy stock, reducing fence damage.

Fabricated Fence: includes rabbit netting, ring-lock and hinge point fences

Plain Wire Fence: Plain wire fences consist of multiple strands of plain wire, which collect less flood debris and are less prone to flood damage. Provided corner and end strainer assemblies allow wires to be tensioned correctly, post and dropper numbers can be reduced, resulting in considerable savings.

Source: Australian Wire Industries, 1993.

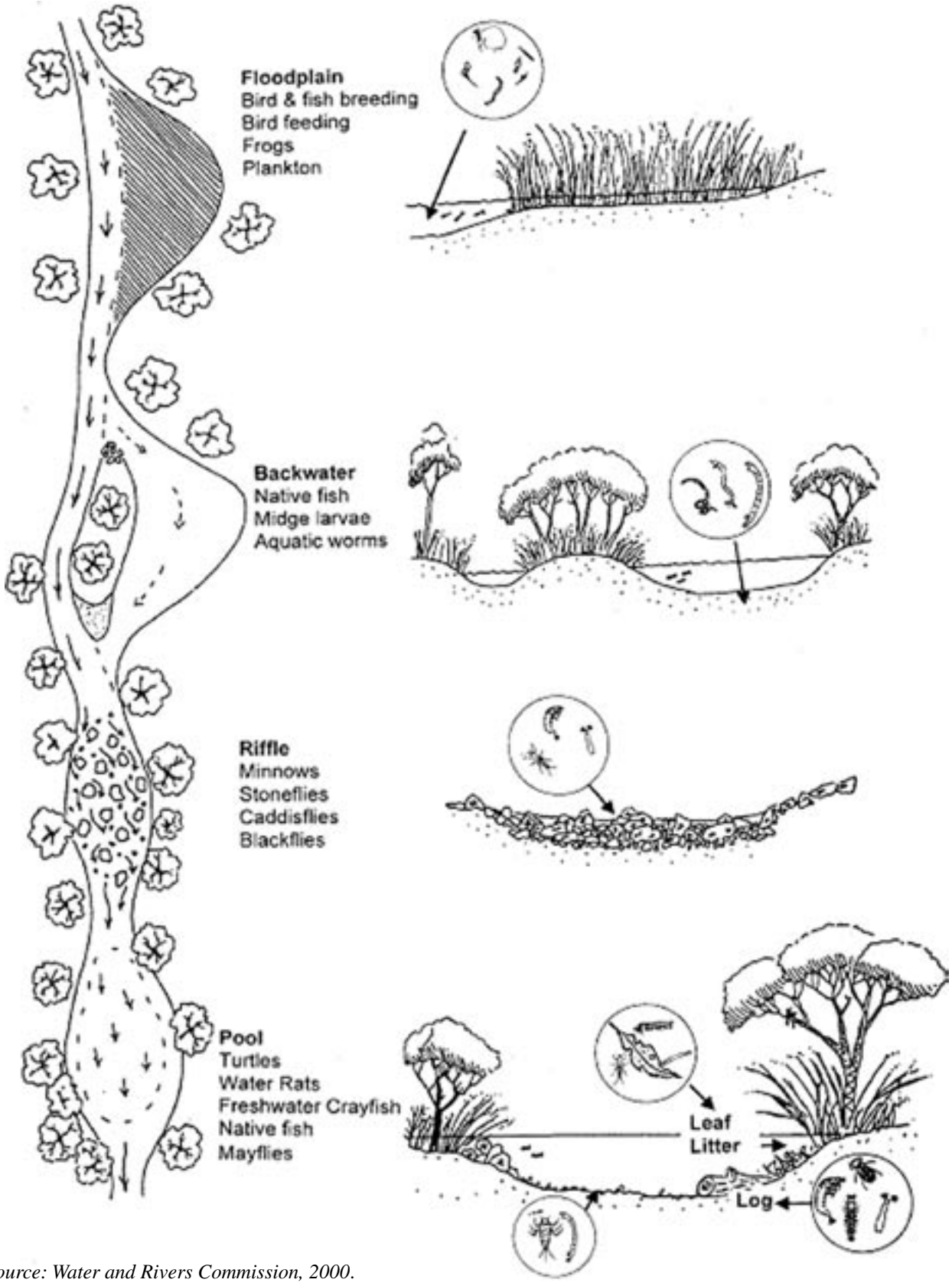
Fencing Status – Examples of Fence Condition

Fence condition:
POOR.

Fence condition:
MODERATE.

Fence condition:
GOOD.

Appendix 8
Habitats found along waterways



Source: Water and Rivers Commission, 2000.

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How did you rate the quality of information?	1	2	3	4	5
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How can it be improved?

.....

.....

.....

.....

How effective did you find the tables and figures in communicating the data?	1	2	3	4	5

How can they be improved?

.....

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FORESHORE AND CHANNEL ASSESSMENT OF WUNDOWIE WETLAND AND MAGNOLIA CREEK

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Department of
Environment

DEPARTMENT OF ENVIRONMENT

254 Fitzgerald Street
Northam
Western Australia 6401

Telephone: (08) 9622 7055
Facsimile: (08) 9622 7155

DEPARTMENT OF ENVIRONMENT

Hyatt Centre
3 Plain Street
East Perth
Western Australia 6004

Telephone: (08) 9278 0300
Facsimile: (08) 9278 0301
Website: www.environment.wa.gov.au