FORESHORE AND CHANNEL ASSESSMENT OF THE MACKIE RIVER

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Foreshore and Channel Assessment of the Mackie River

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Helping Communities Helping Australia

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Cover photograph: Channel condition on the Mackie River [*Taken by Patricia Janssen, 2000*]

Preface

This foreshore and channel assessment is a joint project between the Natural Heritage Trust, Water and Rivers Commission and the Avon River Management Authority. A part of the Avon Rivercare Program, this survey is a component of a larger project to undertake management surveys of major tributaries feeding into the Avon River. Foreshore and channel assessments along the Mackie River were conducted between September 2000 and January 2001.

The aim of this project is to document the current condition and management needs of the Mackie River through consistent field surveys, in consultation with adjacent landholders. An emphasis of this project is community consultation, with attempts made to involve landholders along the River in as many aspects as possible.

This report describes the current condition of both the channel and foreshore along the River, focusing on surrounding landuses, current disturbances and management practices that are already in place.

The future is not some place we are going to,
...it is a place we are creating.
The path to the future is not found,
...it is made.

Paul Ellyard
Author/Philosopher

Foreword

Jointly funded by the Natural Heritage Trust and the Water and Rivers Commission, this project aims to document the condition of channel and foreshore areas of major tributaries feeding into the Avon River. As part of the Avon River Management Authority's Avon Rivercare Program, it is hoped that these assessments will encourage community awareness regarding river management.

The Mackie River is a major tributary that drains the eastern parts of Beverley and York into the Avon River. Foreshore and channel assessments along the Mackie River were undertaken between September 2000 and January 2001.

The objective of this project is to document the current condition and future management needs of the Mackie River through consistent field surveys, in consultation with adjacent landholders and surrounding community. The purpose is to provide information to the people within the Mackie River Catchment who manage or have an interest in waterways. It is hoped that this information will encourage the planning of management actions that can be easily undertaken by landholders and community groups from the areas surrounding the waterway.

As a result of development pressures and inappropriate landuse, many sections of the study area under threat of degradation. A wide range of management issues, such as stock and vehicle access, erosion, feral animals and salinisation of the land and water, have been identified through field surveys and consultation with landholders along the waterway.

Management recommendations have been included to suggest ways in which the foreshore and channel conditions along the length of the River can be improved to provide environmental, economic and social benefit to landholders and community members throughout the area.

Although this tributary of the Avon River has been surveyed in isolation to other major waterways, the long-term management of the riverine 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 river. It is hoped that the results of this report will help to create a sense of ownerhsip of the River for the community as a whole and encourage integrated catchment management (ICM), conservation of the riverine environment and sustainable development.

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Disclaimer:

These maps are the product of Water and Rivers Commission, Regional Services Division, and were printed on 28 June 2001. The maps were produced with the intent that they be used for information dissemination at the scale of 1:175 000. While the Water and Rivers Commission has made all reasonable efforts to ensure the accuracy of this data, the Commission accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Introduction

Purpose of the survey

The purpose of this survey is to assess and document the current condition of the Mackie River and provide some guiding management recommendations. It is hoped that the information contained within this document will encourage landholders, Local Government Authorities and community members to use this data to undertake management actions of the Mackie River channel, foreshore and surrounding catchment.

Objectives of this project can be summarised as follows:

- To provide a summary of the condition of the River which can be used to prioritise future management;
- To highlight areas needing future rehabilitation, conservation and/or management;
- To provide a benchmark against which landholders and surrounding communities can monitor future river health and management activities;
- To educate landholders and the community about the causes of waterways degradation; and
- To provide a sound technical basis for future funding or project submissions relating to management, monitoring and/or development.

One of the main goals associated with this assessment is to identify the key issues associated with the future use and management of the Mackie River and its tributaries. Whilst achieving this objective the goal was to involve the adjoining landholders and community members in the foreshore and channel assessment, to strengthen their sense of ownership and encourage awareness of the importance of waterways management and conservation.

This data will eventually lead to a management or action plan for the channel, foreshore and catchment surrounding the Mackie River to provide guidance and direction for future management of the waterway.

Study area

The Mackie River lies within the Avon Catchment, Western Australia, and is one of the larger tributaries feeding into the Avon River. The area assessed was located within the Shires of York and Beverley, and included the entire length of the Mackie River.

The primary focus of this assessment was the foreshore and channel areas of the River. The area studied includes the riverbed, channel embankments, floodway, verge, foreshore and land use adjacent to this waterway. It should be noted that when planning to manage the River, there is a need to adopt a whole catchment approach rather than dealing with the waterway as an entity on its own.

Historical description of the Mackie River

Aboriginal heritage

Data from the Department of Land Administration shows that there are no registered sites of Aboriginal significance along the Mackie River. Anecdotal evidence suggests that there were Aboriginal clans living in the area surrounding the Mackie River, with territories bordering the waterway. Past occupation of the land by Aboriginal people suggests that the land may have important spiritual and cultural meaning to the current generations of these tribes.

European heritage

The Avon region was explored by European settlers in 1830, when an expedition party led by Ensign Dale travelled overland from Guildford. Both Beverley and York were established to service the surrounding agricultural hinterland, York being established in 1831 and Beverley in 1838 (Western Australian Planning Commission, 1999). Land around the York area was subdivided into farming properties around 1842 (Underwood, 1995).

Development of the land centred on the agricultural industry with the introduction of wheat and sheep farming to the catchment. Landuse along the waterway has changed little since European settlement, however in recent years there has been a tendency for land to be subdivided into smaller lots that have a focus on hobby farming and rural lifestyle.

Catchment description

Population

The 1996 census of population determined that there were an estimated 2904 people living within the Shire of York,

and 1453 people residing within the Shire of Beverley (Western Australian Planning Commission, 1999). 11 properties border the length of the Mackie River.

Location

The Mackie River lies within both the Shire of Beverley and the Shire of York. Map 1 shows the location of the River in relation to the townsites of York, Beverley and Quairading.

The Mackie River, approximately 46km in length, is one of the major tributaries feeding into the Avon River. The waterway runs from the east of Beverley in a general north-westerly direction into the Avon River, approximately 6km south east of the York townsite. The catchment draining into the Mackie River covers an estimated area of 326.49km^2.

Climate

Both the Shires of York and Beverley experience a Mediterranean type climate, with hot dry summers and mild wet winters. Climatic data was available for the Shire of York, whereas only data for the Beverley townsite was obtainable.

The Shire of York experiences an annual rainfall ranging from 1100mm in the west, to less than 451mm in the east of the Shire, while Beverley townsite receives an average annual rainfall of 420mm. Average maximum temperatures in York range from 34.3ºC in January down to 15.6ºC in July, while Beverley experiences an average maximum of 34.1ºC to 16.7ºC. Average minimum temperatures in Beverley range from 16.7ºC in February to 4.9ºC in August. York experiences an average minimum temperature of 16.8ºC in January through to 5.3ºC in July. Frosts are common during winter and are most frequent during July and August (Weaving, 1994 and Safstrom, 1997).

Geomorphology and soils

The Mackie River lies within the Zone of Rejuvenated Drainage, characterised by a dissected landscape with steeper, narrow valleys where waterways flow in winter (Lantzke and Fulton, 1992).

Weathering and laterisation of the Yilgarn Block has greatly influenced the soils of the York and Beverley region. Many areas along the river valley are covered by sand overlying clay, whilst surrounding areas are covered by laterite and ironstone gravel. Moving east towards Beverley sand plain formations are dominant (Piggott et al, 1995).

Map 2 shows the soil landscape systems of the Mackie River catchment, and depicts the dominant systems along the Mackie River as the Avon Flats, Greenhills, Goomalling, Jelcobine and Morbinning systems. The valley floors along the waterway are dominated by Goomalling and Avon Flats soil units. Appendix 1 provides definitions and associated characteristics of these soil landscape units.

The Avon Flats system is characterised by brown loamy earths, grey non-cracking clays, and brown deep sands, while the Goomalling system is defined by its deep grey sandy duplexes, alkaline grey sandy duplexes and saline wet soils (Lantzke and Fulton, 1992 and Agriculture Western Australia, 1999).

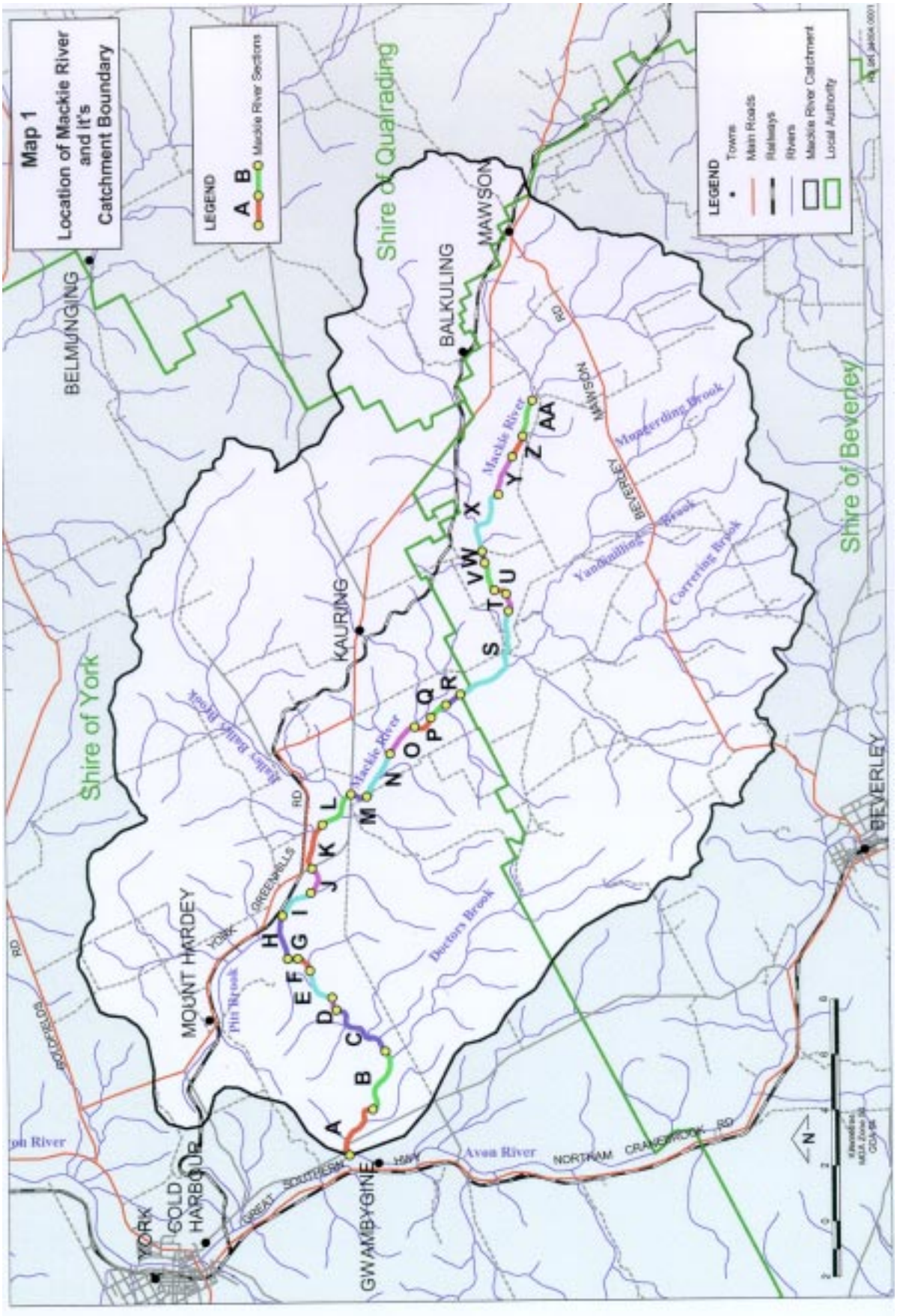
The Greenhills soil system is located along the mid and upper slopes of the surrounding catchment area and is characterised by grey deep sandy duplexes, red deep sandy duplexes and red deep loamy duplexes. The Jelcobine system is also located on the hill slopes but is defined by red deep and shallow sandy and loamy duplexes, grey deep sandy duplexes, bare rock and cracking and non-cracking clays (Lantzke and Fulton, 1992 and Agriculture Western Australia, 1999).
The Morbinning unit is defined by undulating sandplain characterised by grey deep sandy duplexes, pale deep sands and yellow sandy earths (Agriculture Western Australia, 1999)

Hydrology

The Mackie River is one of the tributaries responsible for feeding saline water into the Avon River (Weaving, 1994). It enters the Avon River just north of Gwambygine and drains the north eastern portion of the Shire of Beverley (Reid, undated).

There are several minor tributaries feeding into the Mackie River from around its catchment. The larger of these are Doctors Brook, Balley Balley Brook and Mungerding Brook. There are also many smaller waterways draining the surrounding catchment.

The Mackie River flows actively after rainfall events, which usually means during winter, spring and early summer (Mulcahy and Hingston, 1961). There are now limited numbers of pools along the length of the River,



Map 1. Location of the Mackie River and its catchment boundary

however in the past there were deep pools (such as Wonnobing Pool and Marley Pool), that would hold water throughout the dry summer months and act as a refuge and habitat for terrestrial and aquatic fauna. These pools have now become shallow as a result of sediment deposition and no longer provide these important refuges for organisms during the dry summer months.

The variability of flow and the periodical flooding and drying of the waterway system are important historical features of the waterway which many ecosystems are dependent upon for their long-term survival (Hansen, 1986). However, there has been a change in the frequency of flooding and drying as a result of settlement and development within the catchment, and this has meant that many ecosystems have had to adapt to these variations or perish.

Vegetation

The banks of the River are dominated by York gum (*Eucalyptus loxophleba*), Flooded gum (*Eucalyptus rudis*) and Jam tree (*Acacia acuminata*), vegetation that is typical of saline environments. Agricultural weeds such as Wild oats (*Avena fatua*) and Barley grass (*Hordeum leporinum*) are also common throughout the riverine environment. Native Samphire is endemic to areas highly affected by salt (salt scalds) along the foreshore and sometimes within the dry riverbed. The weed species Spike rush (*Juncus acutus*) is widespread, especially within the channel towards the upstream end of the waterway.

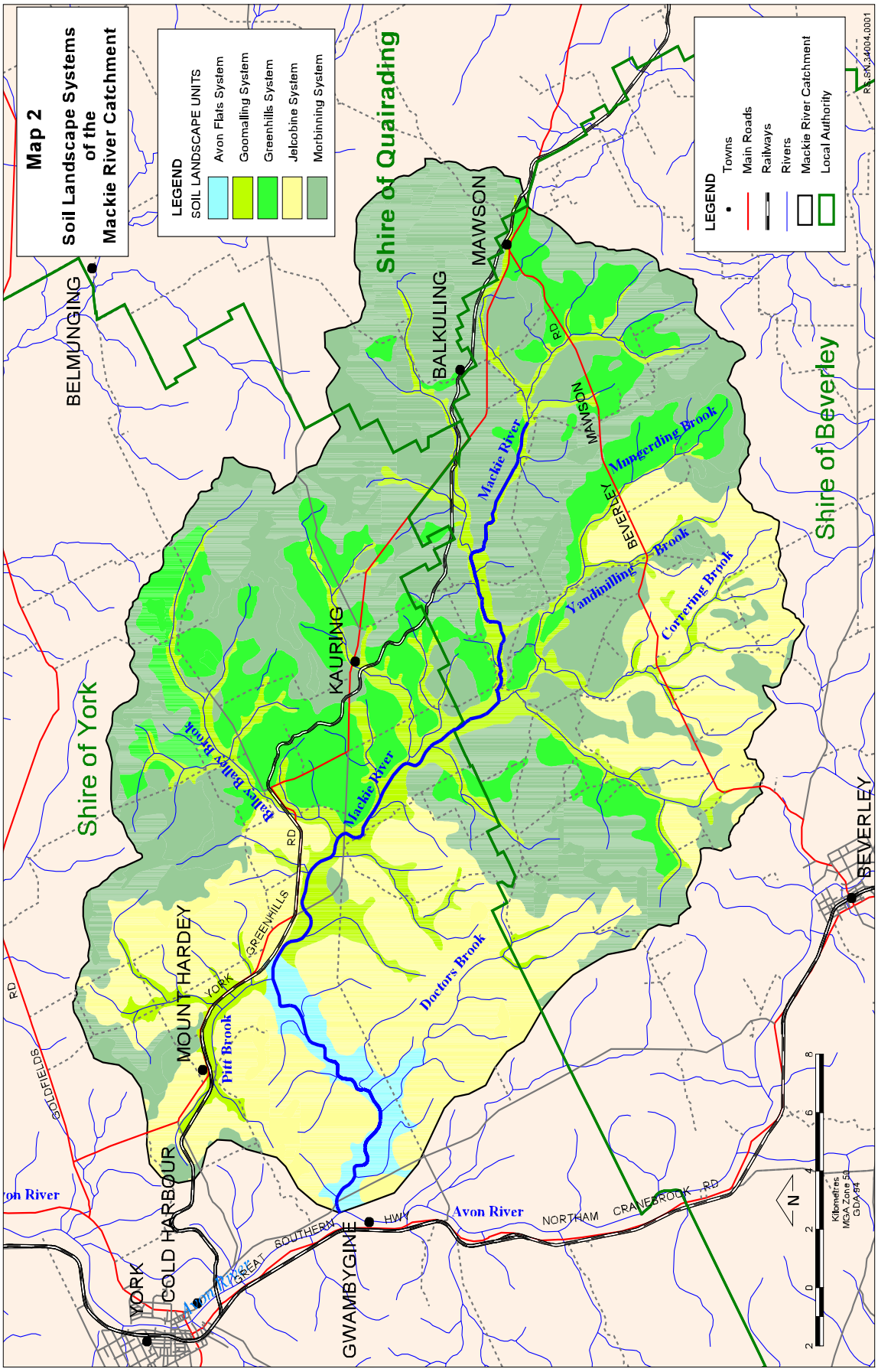
Catchment landuse and tenure

Landuse within the catchment is predominantly agricultural with a focus on sheep and wheat. In recent years there has been an increase in hobby farming with the subdivision of many rural farms into smaller lots.

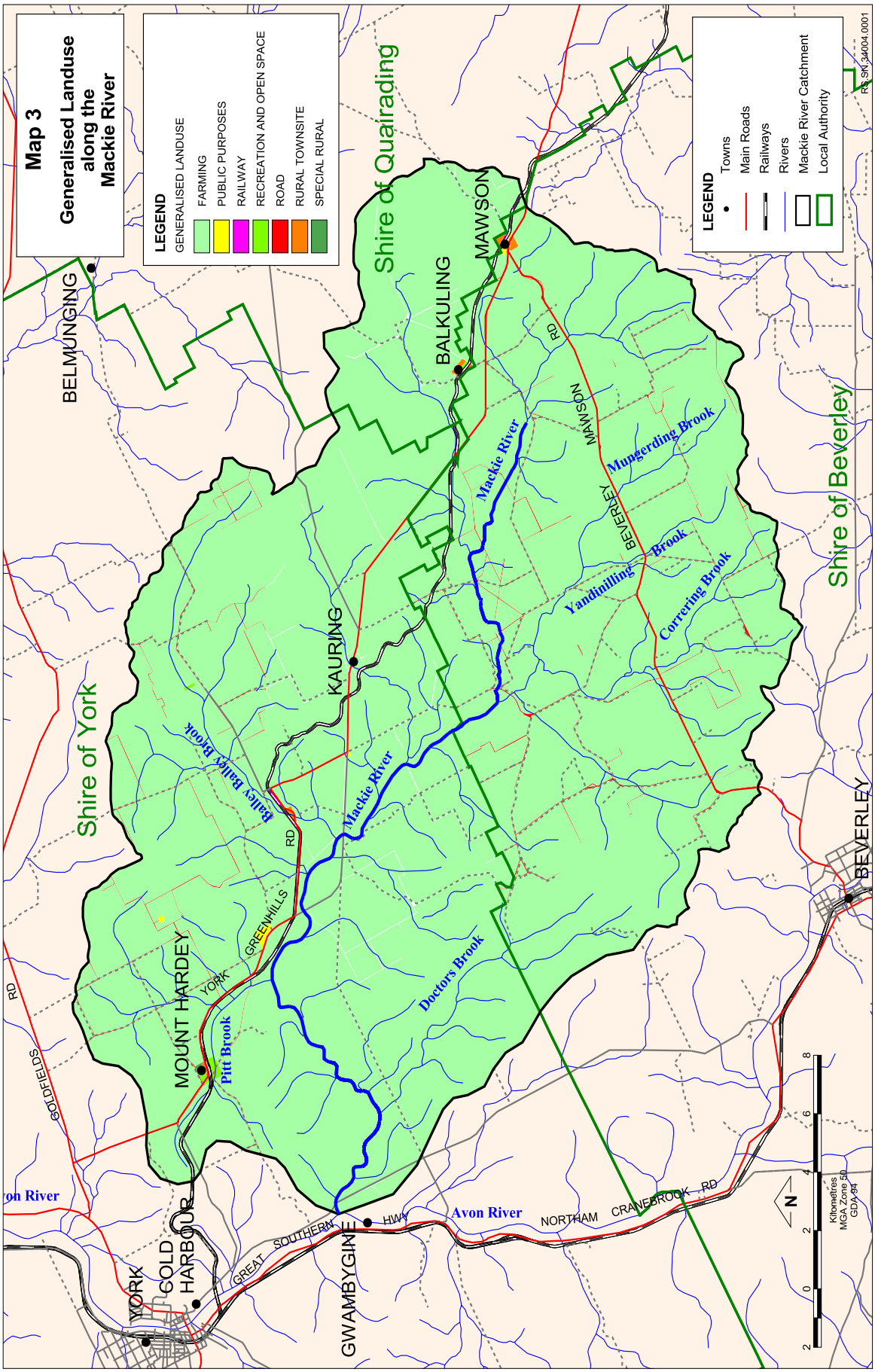
Most of the Mackie River lies within private land ownership. Map 3 provides an overview of land use throughout the catchment of the Mackie River. Although the majority of private holdings within the Mackie River catchment are rural, there is increasing pressure to subdivide land for uses such as rural residential, hobby farming and to cater for activities such as agroforestry and horticulture (Reid, undated).

Many of the historical land titles along the Mackie River award ownership to the centre of the River (Hansen, 1986). In some cases ownership includes the waterway where land ownership stretches past the river boundary.
There are two reserves along the Mackie River within the Shire of Beverley. One Reserve (No 44285 – Avon Location 29139) is vested in the Water and Rivers Commission. It contains isolated stands of York gum, Jam tree and Swamp sheoak (*Casuarina obesa*) and has been vested as a reserve with the designated purpose of public recreation. Another Reserve (No 26897 – Avon Location 16645) is vested in the Department of Conservation and Land Management with the designated purpose of conservation of flora.

The Mackie River in flood during January 2000 at the bridge over the York-Quairading Road in York. [Photo by Daniel Ryan]



Map 2. Soil landscape systems of the Mackie River catchment



Map 3. Generalised landuse along the Mackie River

Survey methods

Community awareness and involvement

A letter of introduction was sent to landholders along the Mackie River explaining the purpose of this survey. This was followed by contact to arrange for access onto properties to survey the River. Letters were also sent out to local landcare, rivercare, catchment and friends groups to allow them the opportunity to become involved in the assessment of the Mackie River. Notices were placed in local newspapers advising of the project and inviting submissions from members of the community.

Articles in local newspapers such as the *York Chronicle*, *York Community Matters*, *The Beverley Blarney* and the *Avon Valley Advocate* provided publicity about this project. Media releases were used to advise community members of the project and gave individuals and group members the opportunity to take part in field assessments.

A draft report was prepared and released for public comment, giving landholders and community members the opportunity to provide comment on report findings and the broad management recommendations that have been made.

Assessment technique

A *Foreshore and Channel Condition Assessment Form* was developed 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*, with some variations included to meet the specific needs of this assessment. The survey form was divided up in to 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;
- vegetation; and
- water quality data (pH and electrical conductivity).

Surveys were conducted along the whole length of the Mackie River with sections being determined by paddock boundaries within each property. The length of the Mackie River was divided into 30 sections.

Foreshore and channel assessments were conducted by walking the length of the River section and filling out the survey form (an example is provided in Appendix 2). In some instances, factors such as foreshore condition were averaged for the whole of a section with best and poorest conditions also recorded.

In most cases both sides of the River were surveyed on one form and an average was determined for each assessment category. However, if each side of the waterway had differed greatly in either condition or surrounding landuse a separate survey sheet was completed for each side. A small percentage of sections had different landholders along each bank, meaning that separate survey forms were used and each side was treated as a separate section. Where assessment referred to each side of the waterway (ie fencing status on left or right side), surveys were conducted facing upstream.

The majority of assessment along the Mackie River was observational. Foreshore and channel condition was assessed whilst walking along the waterway and recording observations on the assessment template. Photos have been taken at points of interest (ie. degraded, pristine or unusual areas) and have been used in later assessment of the river and its foreshore. Photos can also be used for future monitoring of river health. Landholders were also asked about changes in river condition and health, fauna, past landuse and management of the waterway.

Where vegetation was not identified during field assessments, samples were taken for later identification.

Books including *Western Weeds* (Hussey et al, 1997), *Revegetation Guide to the Central Wheatbelt* (Lefroy et al, 1991) and *Trees and Shrubs for the Midlands and Northern Wheatbelt* (Wilcox et al, 1996), were used in conjunction with Commission expertise to identify these specimens. A *Licence for Scientific or other Prescribed Purposes* was obtained from the Department of Conservation and Land Management giving permission to collect flora for scientific and identification purposes subject to certain conditions.

Water samples were taken at random points along sections where water was still flowing, and provided, to some extent, a snap shot of the current pH and salinity levels of the River. Samples were taken randomly during the course of the site assessment and taken back to the office for analysis. A Conductivity-Salinity-pH-Temp Meter (make MC-81) was used to determine electrical conductivity and pH readings for the water samples.

A Global Positioning Satellite unit (Magellan model GPS 315) was used to record the position of points. Locations such as section "start" and "end" points were recorded to allow for the accurate display of collated data on maps. Readings will also allow for accurate location of sections for future monitoring and management. During the period of completing field assessments the Australian system of referencing changed. As a result some data collected during surveys was in Australian Map Grid (AMG) datum while others (after the 4th December 2000) were collected using a new datum called Map Grid Australia (MGA). A program called GDAit was used to convert eastings and northings from the old datum into the new one.

The assessment format used is comprehensive in recording foreshore and channel condition and does not require specialised knowledge or extensive technical assistance to complete. Assessments can therefore be undertaken by community groups, landholders and individuals without the aid of a qualified person. The survey forms are broken into sections so that assessors can use sections that are relevant to their needs, ignoring the other information. A blank assessment form is provided in Appendix 3 that can be copied and used by the community to assess waterways.

Method of analysis

A database has been set up to record information collected during foreshore and channel assessments. The database contains both numerical and written data entered directly on the survey forms. It does not include any anecdotal evidence supplied by landholders and other community sources. Only information that does not breach confidentiality has been included in this database. Data stored within this database is an important source of information that can used to guide future management of the waterway. The collective data on the condition of the foreshore and channel provides baseline information from which future changes can be monitored and compared.

Having information recorded in a database structure (as well as using a standardised assessment form) has allowed comparative analyses to be performed between survey sections as well as along the whole watercourse. Queries within the database structure provided efficient collation of data that was then converted into spreadsheets for inclusion and interpretation in this report.

The overall stream environmental health rating is used to assess the ecological value of individual river 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.

Tables are provided in Appendix 4 to help determine the stream condition and the overall health of the River. Depending on the rating (ranging from very poor to excellent), points were allocated to each of these components and an overall stream environmental rating was determined. Appendix 4 provides a table that shows the points allocated to each individual component based on which rating the section received.

Foreshore condition has been assessed using a grading system (Appendix 5) which allows the assessor to determine the overall (or general), best and poorest foreshore conditions along each survey section. Using a varied level of assessment condition is graded to match the foreshore conditions, based on the general process of

river degradation from pristine (A grade) to ditch (D grade). General foreshore condition was recorded as a basic assessment, where the condition was graded as one of four categories, A, B, C, or D. The best and poorest foreshore conditions were determined using the detailed assessment, whereby each grade has three subcategories and assessment required more detail, for example, A1, A2 and A3.

Results of the foreshore and channel assessment have been stored in a database that has been used to correlate figures for factors such as general foreshore condition and fencing along the River. Data has been collated and is the source information from which maps have been produced. Key findings of the Mackie River assessment have been summarised within this report.

Survey results

Anecdotal evidence as well as survey results indicate that the Mackie River catchment has historically been subjected to a wide range of disturbances that have lead to a decline in the health of this waterway and the many smaller tributaries that feed into it. Field observations indicate that the main forms of river degradation present are salinity, erosion, sedimentation, loss of riparian vegetation, and nutrient enrichment.

Bank and channel stability

Erosion, slumping and sedimentation all affect channel stability. The following factors influencing both bank and channel stability were used in this assessment:

- undercutting;
- firebreak/track washouts;
- subsidence;
- erosion;
- slumping; and
- sedimentation.

Field assessments of each river section evaluated the above factors that were used to determine channel stability. Channel stability is an average for the whole section and can be rated as shown in Table 1:

Table 1. Rating system used to determine channel stability

Channel stability	% of river section affected
Minimal	0-5
Localised	5-20
Significant	20-50
Severe	>50

Bank stability and sedimentation along the Mackie River was determined as part of the Overall Stream Environmental Rating, that indicated the average stream health of a survey section. It can also be used to give an idea of bed and bank stability within this river system. Table 2 shows the rating system used to determine the bank stability and sedimentation rating of each section, and Figure 1 provides a collation of results for the Mackie River which have been based on the information provided in Table 2.

Table 2. Ratings used to determine bank stability and sedimentation (Pen and Scott, 1995)

Condition rating	Bank stability and sedimentation
Excellent	No erosion, subsidence or sediment deposits. Dense vegetation cover of banks and verge. No disturbance.
Good	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.
Moderate	Good vegetation cover. Localised erosion, bank collapse and sediment heaps only. Verges may have sparse vegetation cover.
Poor	Extensive active erosion and sediment heaps. Bare banks and verges common. Banks may be collapsing.
Very Poor	Almost continuous erosion. Over 50% of banks collapsing. Sediment heaps line or fill much of the floodway. Little or no vegetation cover.

Results indicate that the majority of sections were recorded as having poor bank stability and sedimentation when rated in terms of the overall stream environmental health rating.

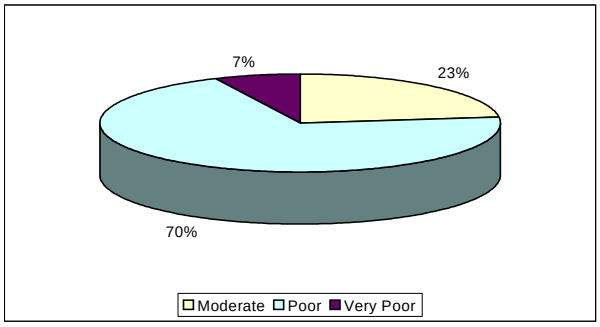


Figure 1. Bank stability and sedimentation ratings for the Mackie River

Figure 1 shows that 23% of surveyed sections were rated as having moderate bank stability and erosion. The majority of sections (70%) were classified as poor and 7% as very poor. None of the surveyed sections used artificial stabilisation techniques along the banks, meaning that no techniques (such as log walling) have been employed along the banks to protect degraded areas from further erosion and undercutting. There were, however, some locations (ie. road bridges) where channel stabilisation had been undertaken to support the construction of such features.

Along the Mackie River undercutting was recorded as being minimal in 50% of sections and localised in 47% of the sections. Of all the surveyed sites, 3% showed no current signs of undercutting.

Firebreak and track washouts were determined to be minimal along 10% of the sites, 7% had no erosion of tracks and firebreaks, while 83% of the sections had no tracks and firebreaks running in close proximity to the channel.

Subsidence (the sinking of ground that is not slope related) was recorded as being minimal in 53% of sites, localised in 31% and significant in 3% of surveyed sites. 13% of the sections showed no signs of subsidence.

Erosion was recorded as being localised in 3% of sections, significant in 60% of sites and severe in 37% of the sections surveyed.

Slumping also affected the banks with ratings recorded as 47% minimal and 23% localised. 30% of the sections were not affected by slumping at the time the assessments were carried out.

Sedimentation was the component most prominent along the River with 77% of the sites recorded as severe and 23% as significant.

The most significant of the above components were erosion and sedimentation. The overall stability of the channel might be defined as moderate (see Table 2) with over half of the sections being highly eroded and unstable with large deposits of sandy sediment. Large sediment deposits were identifiable along the majority of the channel, while there were some areas along the riverbed that have been eroded down to the underlying clays.

Anecdotal evidence suggests that sediment within the Mackie River system is mobile. Field observations determined that the floods of January 2000 caused a lot of damage by eroding the riverbed, banks and foreshore. A lot of fresh sediment was deposited along the banks and foreshore during this period. This was supported by the results of the foreshore and channel assessment.

A 1998 study of the water quality in the Avon and Mackie Rivers determined that a large slug of sediment had been deposited at the confluence of the Mackie River with the Avon River (Taylor, 1998). At the time of the survey there was only a limited amount of sediment lying at the confluence with the Avon River, which may be due in large part to the summer floods of January 1999 and 2000 mobilising sediment and carrying it downstream into the Avon River.

Bank erosion along the Mackie River

Waterways features

The features of a waterway often indicate the level of health associated with the riverine system. The presence of features such as pools, rapids, anabranches, riffles, bridges, sand slugs and vegetated islands allow us to assess, to some degree, the health of the waterway and determine options for future management.

Survey results show that 60% of the sections had a single channel, while 40% were braided and 33% had anabranches running in close proximity to the River.

20% of the sections had natural riffles and 10% had shallow pools at the time of assessment. These pools and riffles are likely to be non-existent during the hotter summer months when the flow of water within the system stops.

20% of sites have bridges crossing the River. 3% of these were located as parts of a driveway, while the other 17% were at junctions with roads.

10% of sites had dams situated in close proximity, 13% had smaller tributaries feeding into the Mackie River from the surrounding catchment, and 7% had drains channelling water in from the surrounding landscape.

100% of the sites had sand slugs within the channel, which coincides with sedimentation being recorded as severe along 77% of surveyed sections.

30% of the sites had man-made crossing points to allow stock, vehicles and machinery to cross the waterway. There had been obvious construction work undertaken to create the crossings.

Foreshore condition

General foreshore condition

97% of sections were rated as having a general foreshore condition of C-grade, meaning that there was minimal vegetation diversity. Essentially, a C-grade foreshore supports a limited diversity of trees over weeds or pasture. There may also be localised areas of bank erosion and subsidence (Pen and Scott, 1995). Appendix 5 provides an overview of all possible grades, from A1 through to D3.

The remaining 3% of surveyed sections were rated as having a general foreshore condition rating of B-grade. This means that they were in slightly better condition than the rest of the River, with a more diverse cover of native vegetation being invaded by grassy weeds (Pen and Scott, 1995).

Best foreshore condition

The best foreshore condition recorded along each section varied greatly with 43% of the sites rated as C1-grade. 30% of sections rated as C2, 17% as B3 and 10% as C3. Appendix 5 provides definitions of foreshore condition ratings that have been used throughout this project.

Map 4 shows the best foreshore condition recorded within each section along the River. Results indicate that there was no distinct pattern, but rather a gradual change in condition from B3 through to C3.

Poorest foreshore condition

Map 5 depicts the poorest foreshore conditions recorded in each section surveyed along the Mackie River. The map indicates that there was less variation recorded in the poorest foreshore conditions with 43% of surveyed sections rating as C3, 30% as D2 and 27% as D1-grade.

Foreshore vegetation

Presence of common species

The most common overstorey species recorded along the Mackie River were York gum (*Eucalyptus loxophleba*), Flooded gum (*Eucalyptus rudis*) and Jam tree (*Acacia acuminata*).

The most common understorey species recorded were weed species including Wild oats (*Avena fatua*), Barley grass (*Hordeum leporinum*) and Spike rush (*Juncus acutus*).

Field observations indicated that weed species were far more common than native species. Results show that 53% of surveyed sections had a frequent occurrence of exotic vegetation (weeds), while 47% were recorded as abundant. Native vegetation, on the other hand, was recorded as frequent in 33% and occasional in 67% of surveyed sections.

Survey results indicated that species diversity of vegetation increases towards the confluence of the Mackie River with the Avon River in York.

Proportion of native species

Table 3 shows the occurrence of native plant species along the Mackie River, while Appendix 6 provides a list of native and weed vegetation species recorded during foreshore assessments.

Table 3. Native species occurrence

Plant name		% of sites species occurred
Common name	**Scientific name**	
Everlasting sp.	*Everlasting sp.*	30
Flooded gum	*Eucalyptus rudis*	73
Jam tree	*Acacia acuminata*	66
Samphire	*Halosarcia spp.*	57
Stipa	*Stipa sp.*	43
Swamp paperbark	*Melaleuca rhaphiophylla*	44
Swamp sheoak	*Casuarina obesa*	53
York gum	*Eucalyptus loxophleba*	85

Field observations determined that the occurrence of York gum, Flooded gum and Jam tree were higher upstream along the Mackie River, while the presence of Swamp sheoak was highest along the downstream sections of the waterway.

As shown in Figure 2, the majority of native species occurred in the upperstorey (top storey). 97% of surveyed sections were comprised of between 80-100% native vegetation within their tree layer.

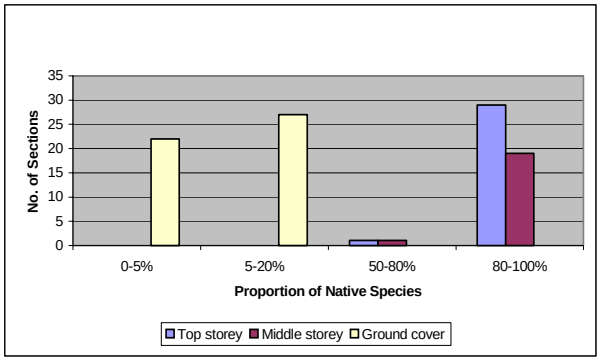


Figure 2. Proportion of native species in each vegetation layer

Of middle storey species present (shrubs and small trees), 64% of sites were recorded as having between 80-100% native vegetation. Ground cover (ie. grasses) was predominantly weed species with 73% of sites recording a cover of between 0-5% native species.

Regeneration of native species

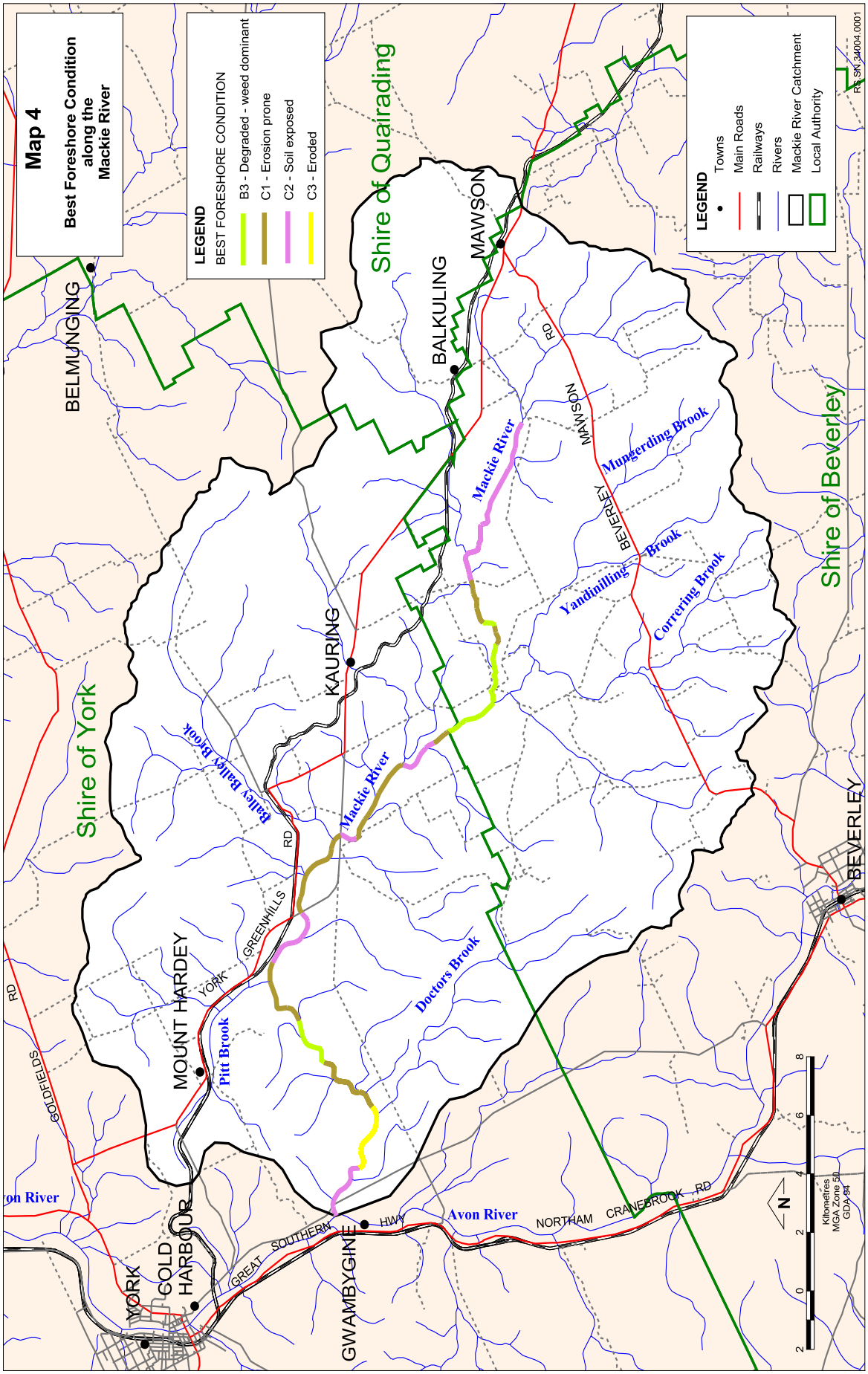
Regeneration of tree species was observed at 73% of the survey sections. A range of different seedling species was recorded along this waterway. The following species were showing signs of regeneration amongst foreshore vegetation along the Mackie River:

- Jam tree seedlings were recorded at 60% of the survey sections;
- Swamp sheoak seedlings were recorded at 10% of the survey sections;
- York gum seedlings were recorded at 10% of the survey sections;
- Flooded gum seedlings were recorded at 10% of the survey sections;
- Golden wreath wattle (*Acacia saligna*) seedlings were recorded at 10% of the survey sections;
- Needlebush (*Hakea preissii*) seedlings were recorded at 7% of the survey sections; and
- Swamp paperbark (*Melaleuca rhaphiophylla*) seedlings were recorded at 3% of the survey sections.

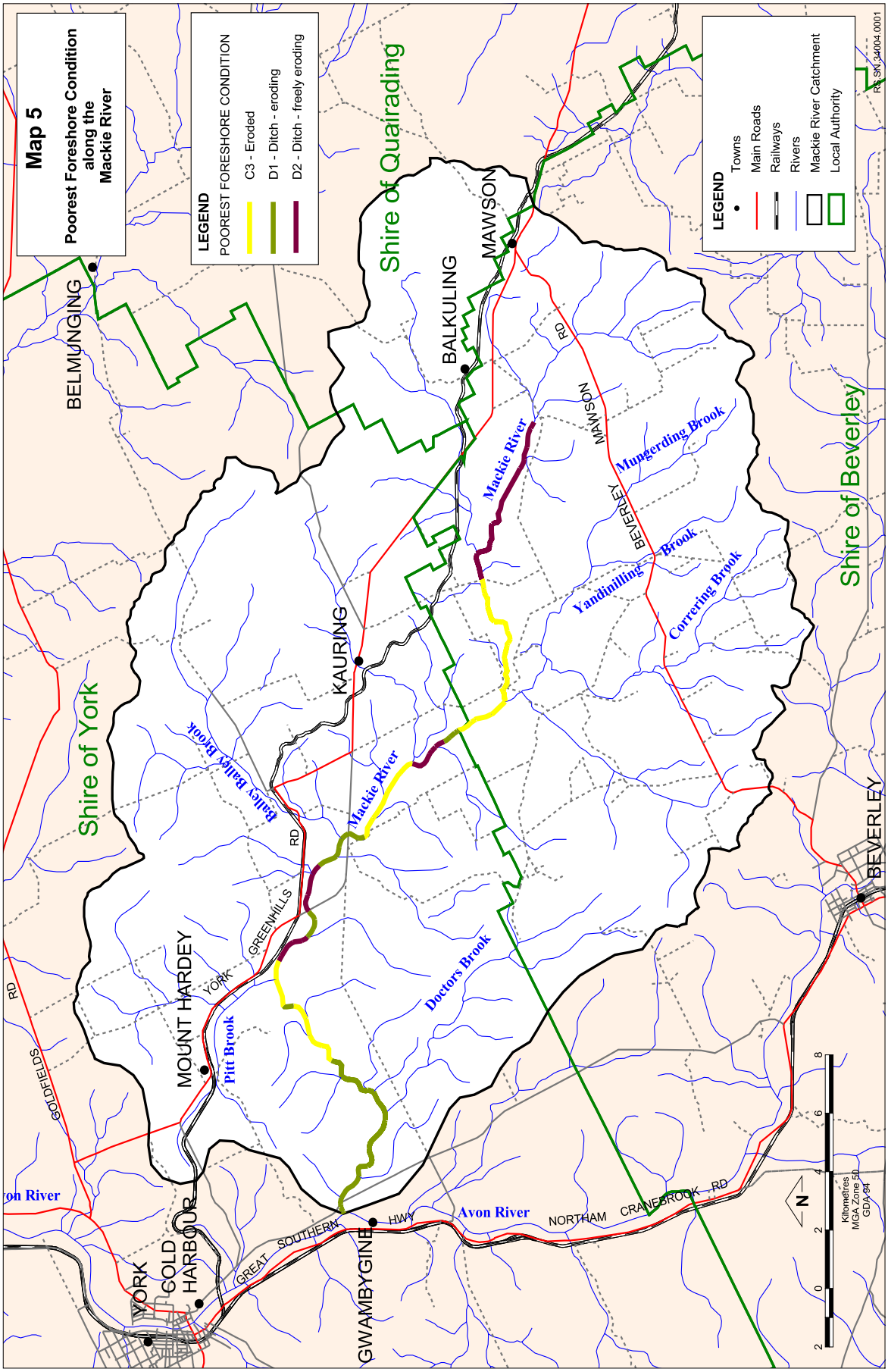
Death of common native species

Vegetation health was moderate along most of the Mackie River and tree death was obvious in many areas. There was a lack of middle storey plants in most areas and the ground cover was dominated in most instances by weed species.

Figure 3 (over) shows that the majority (90%) of surveyed sections recorded some dead trees among the foreshore vegetation. In contrast, 7% of sites had many dead trees and only 3% were recorded as having healthy looking vegetation (ie. lots of leaves, natural regeneration of native species, lack of weeds, diversity of native species and a low level of disease and insects).



Map 4. Best foreshore condition



Map 5. Poorest foreshore condition

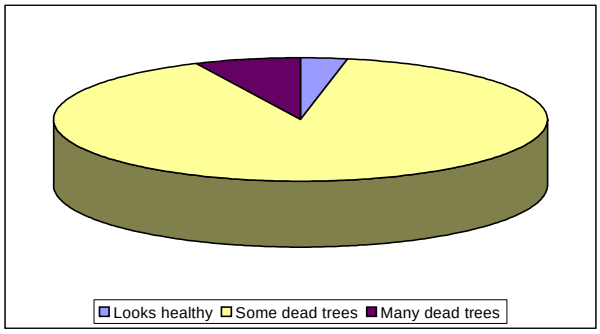


Figure 3. Vegetation health

Vegetation cover

Field investigations determined that the majority of sites were lacking a middlestorey (shrub layer) and were supporting a patchy ground coverage of weed species. Table 4 shows the number of surveyed sections that were classified as either absent, sparse, patchy or continuous (depending on the level of cover) in each vegetation layer.

Table 4. Vegetation cover

	Proportion of vegetation cover			
	Absent (0%)	**Sparse (<20%)**	**Patchy (20-80%)**	**Continuous (>80%)**
Upperstorey (%)	0	7	93	0
Middlestorey (%)	33	67	0	0
Ground cover (%)	0	0	67	33

The data in Table 4 shows that ground cover was the most dominant vegetation layer with 33% of sites recorded as being continuous and 67% as patchy. Middlestorey vegetation was absent in 33% of sites and sparse in 67% of sites. The upperstorey was dominantly recorded as being patchy (between 20 and 80% coverage), with 93% of the sections rated in this category.

All of the surveyed sections had bare ground to some degree. Results indicated that 10% of sections had less than 10% bare ground, 33% of sections had over 20% of bare ground, and the majority of sections (57%) had between 10 and 20% bare ground.

Results collated for stream cover as part of a survey to determine the Overall Stream Environmental Health Rating indicate instream vegetation cover along the River. Stream cover was poor in 73% of the sections, meaning that they had narrow verges of less than 20 metres with vegetation being mainly exotic weed species. 27% of sections were classified as moderate, meaning that there was some permanent shade and overhanging vegetation with some instream cover (Pen and Scott, 1995).

Weeds

The most common weed species recorded along the Mackie River were Barley grass (*Hordeum leporinum*), One-leaf Cape tulip (*Hexaglottis flaccida*), African love

Dead trees along the Mackie River foreshore may be attributed to waterlogging and rising salinity levels

grass (*Eragrostis curvula*), Spike rush (*Juncus acutus*), Soursob (*Oxalis pes-caprae*) and Wild oats (*Avena fatua*). With the exception of Soursob and Wild oats (which were recorded as having a 'high' occurrence in most sections), the other species listed above were all recorded in the majority of instances as having a 'moderate' occurrence at the sites in which they were recorded. Table 5 shows the occurrence of the more common weeds found along the Mackie River as a percentage of sections they occurred in.

Table 5. Common weed occurrence

Weed species	Occurrence (% of sites)		
	High	Medium	Low
African love grass	23	30	3
Barley grass	12	47	0
Cape tulip (one leaf)	23	23	0
Castor oil plant	0	3	20
Corkscrew grass	0	17	0
Rye grass	3	23	10
Salt water couch	3	3	7
Spike rush	23	23	23
Soursob	37	3	0
Wild oats	87	3	0

Wild oats was by far the most dominant weed species, recorded in 90% of survey sections, with a high occurrence in 87% of sites. Barley grass and the Spike rush also have a fairly high occurrence with plants being recorded in 87% and 69% of sites respectively. The occurrence of Spike rush and African love grass was higher towards the upstream end of the River.

Pest plants

Pest plants are weed species that are seen as being a nuisance to the existing landuse. Local Government Authorities have the responsibility of administering the *Agriculture and Related Resources Protection Act 1976* and have the authority to enforce the control of such a species within its boundaries (Hussey et al, 1997). Two pest plant species were recorded amongst the foreshore vegetation along the Mackie River; Dock (*Rumex sp.)*and Pie melon (*Citrullus lanatus*). Dock was recorded in 13% of survey sections and Pie melon in 23%, with both species having a low occurrence in these areas.

Declared plants

Declared plants are those plants that are classified as a high management priority and that have the potential to become a major problem to the environment or to agricultural activities. They are formally declared under the *Agriculture and Related Resources Protection Act 1976* administered by Agriculture Western Australia. Under this Act, landholders are obliged to control any

Spike rush is becoming a problem in upstream areas where it is growing within the channel

declared plants that occur within their properties (Hussey et al, 1997). Two declared plants were sighted along the Mackie River, these being Cape tulip (one leaf) and Soursob. Cape tulip was recorded in 46% of sites with a high and medium occurrence both of 50% in the areas where it occurred. Soursob was recorded in 40% of survey sections and was classified as having a high occurrence in 92% of the sites in which it was recorded.

Habitat diversity

Field investigations determined the presence of potential habitat for both aquatic and terrestrial fauna. Results indicate that the most common habitat sources are trees, protected basking sites (ie. debris and branches) and a variety of vegetation types, with these three habitat types recorded in 100% of surveyed sections. Other habitat types were also recorded, although not as commonly as the above.

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

- instream logs were recorded along 87% of sections;
- rushes (mostly non-native species) were recorded along 80% of sections;
- meanders and pools were recorded along 50% of sections;
- instream cobbles and rocks were recorded along 23% of sections; and
- cascades, rapids and riffles were recorded along 23% of sections.

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

- Shrubs were recorded along 67% of sections.

No stream sections were recorded as having any dense streamside vegetation or emergent plants/substrate for eggs.

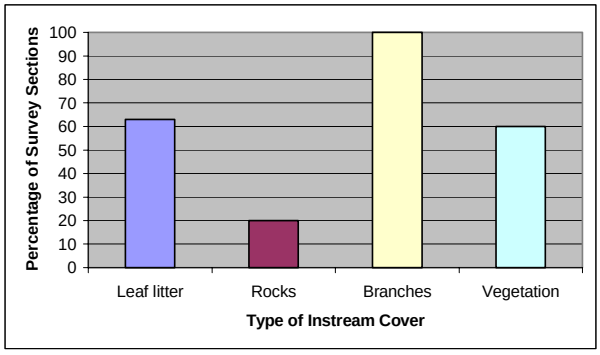


Figure 4. Proportion of instream cover along the Mackie River

Instream cover was minimal along most of the River, but where it did occur there was often a mixture of leaf litter, rocks, branches and vegetation. Figure 4 shows the proportion of sites that had instream cover.

Figure 4 shows that branches were the most common instream cover and habitat type (at 100% of sites), followed by leaf litter that occurred at 63% of sections. Foreshore habitat differs slightly to that within the stream channel. Leaf litter along the foreshore was classified as minimal in 87% of sections and absent in 13%. Ratings used during a survey to determine the overall stream environmental health rating determined that the entire length of the Mackie River was rated as having moderate habitat diversity. This is defined as a stream section with a range of habitat types, but without 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 the Mackie River:

- Ants
- Australian Ringneck Duck
- Bees
- Beetles
- Birds
- Brown Honeyeaters
- Butterflies
- Caterpillars
- Cats
- Crickets
- Crows
- Dragonflies
- Ducks
- Echidna
- Flies
- Foxes
- Frogs
- Gambusia
- Grasshoppers
- Ibis
- Kangaroo
- Lizards
- Locusts
- Mosquitoes
- Owls
- Rabbits
- Racehorse Goannas
- Snakes
- Spiders

Anecdotal evidence suggests that the variety of fauna in the past was more plentiful. Many landholders commented that feral cats, foxes, and rabbits have become more common in recent years, and may account for the declining number of native fauna recorded during field assessments. A seasonal change in water depth in the Mackie River suggests that habitat would change significantly from one season to the next (eg. alterations in the level of exposure of logs, branches, rocks and sand slugs). During field assessments the channel was predominantly dry, but there was evidence of a significant fluctuation in water depth, such as exposed tree roots, dampness along banks, debris in trees, sediment and salt deposits, and bank erosion). As a result of a change in water levels and therefore habitat

availability, the diversity and richness of fauna would also fluctuate. For instance, many birds would visit the waterway seasonally when water is available to fulfil food, shelter and nesting requirements.

Fencing status

Foreshore assessments determined that 85% of river sections were fenced on one or both sides. When facing upstream the majority of sections (67%) were fenced on both sides, a further 11% sites were fenced only along the left bank and 7% along the right bank, while 15% were not fenced at all. Map 6 provides a visual of fencing status along the Mackie River.

Although a large portion of the Mackie River was fenced, in many cases the purpose of the fence was not to exclude stock from the waterway and foreshore area, but to act as a paddock boundary and keep stock in. Only a small portion of the riparian zone had been fenced with the intention of excluding stock access to the waterway. Results indicated that stock had access to the channel and riparian zone along 43% of the survey sections, and vehicles had access along 73%.

Of those areas that were fenced, 70% was in good condition, 25% was in moderate condition and 5% was in poor condition. The fencing style used in the majority of fenced sections (85%) was fabricated, while there was also minimal use of barbed wire fences in 15% of sections. Appendix 7 provides a definition of each fencing style and examples of fence condition.

The position of the fence was also determined, with an approximation given for the distance of the fence line (left and right bank) from the bank of the waterway. Table 6 shows that the majority of fenced sections were fenced within 30 metres of the riverbank.

Table 6. Fence position along the Mackie River

Distance of fence from bank (metres)	Proportion of sections in each category (%)	
	Left bank	Right bank
< 10	4	4
11 – 20	22	22
21 – 30	30	33
>30	22	15
Not fenced	22	26

Water quality

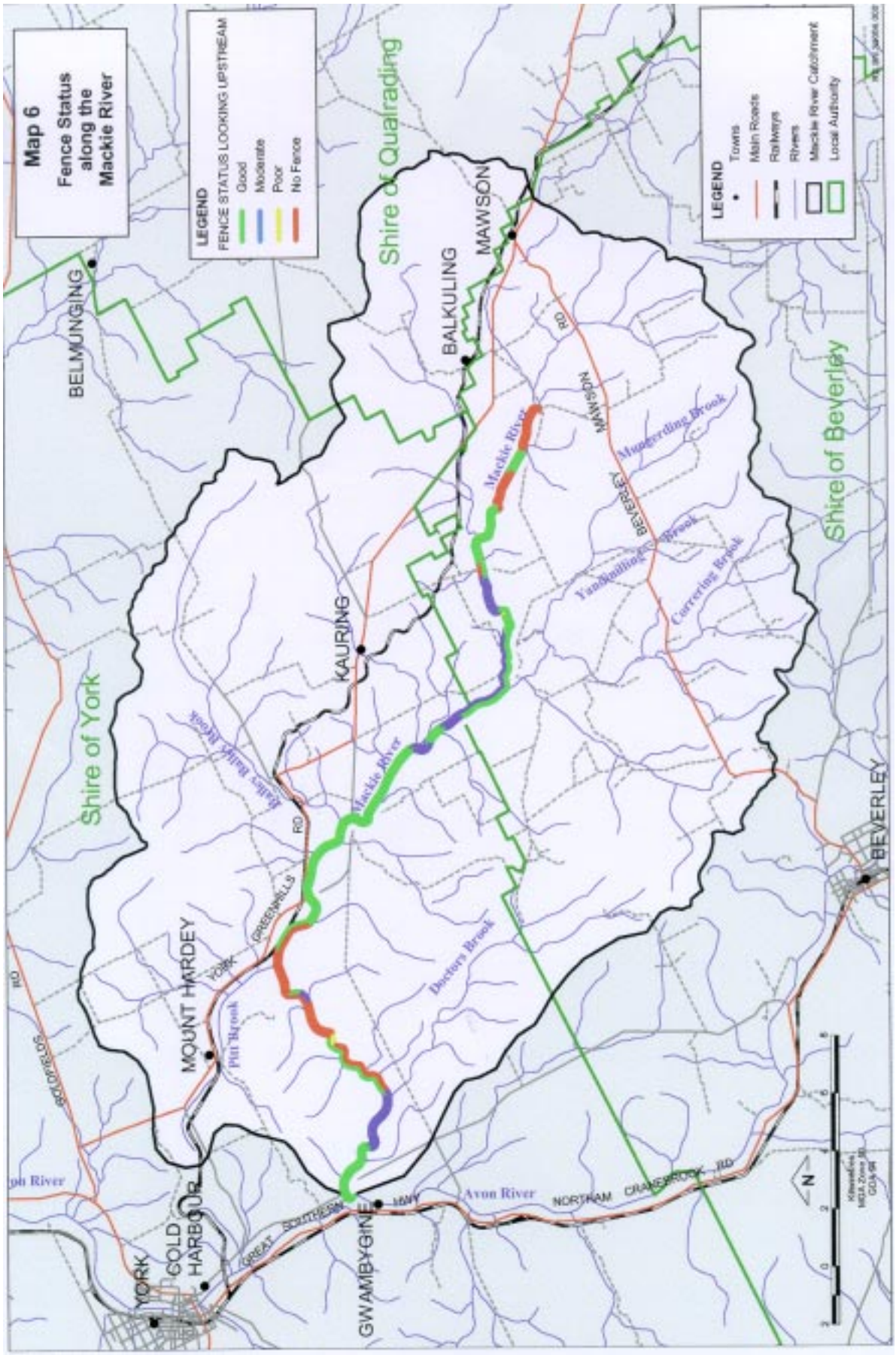
A complete overview of the water quality along the Mackie River was not obtainable during field assessments due to the intermittent nature of the waterway. Water was flowing for a couple of weeks into the surveys and after this time, the riverbed was mainly dry.

A total of 8 samples were taken from 7 different sections along the downstream sections of the Mackie River between late October and late September 2000 before flow ceased completely. Many of the samples were taken from shallow pools that were barely flowing. Results are shown in Table 7, with water sample data entered from the further most downstream sample point to the further most upstream sample point. The results recorded during the surveys provide a 'snap shot' of water quality – that is, values for pH and electrical conductivity at a certain point in time.

The lowest pH recorded was 7.86, whilst the highest was 8.33. The average pH for samples taken from the River was 8.15. The highest electrical conductivity reading was 41.4mS/cm and the lowest reading was 28.0mS/cm. The average electrical conductivity reading for all samples collected during water sampling was 33.25mS/cm.

Table 7. Water quality data collected along the Mackie River

Sample Point	Coordinates		pH	Conductivity mS/cm	Temperature °C	Date
MK008	482960E	6465959N	8.33	41.4	22.1	25/10/00
MK007	486017E	6464722N	8.31	37.4	22.0	25/10/00
MK006	487394E	6466171N	7.98	33.9	22.2	25/10/00
MK006	486411E	6465145N	8.11	34.2	22.0	25/10/00
MK005	-	-	8.25	28.0	25.3	27/09/00
MK003	491523E	6467863N	8.23	31.9	22.1	27/09/00
MK002	490662E	6468433N	8.10	30.7	22.1	27/09/00
MK001	489319E	6468095N	7.86	28.5	21.8	27/09/00



Map 6. Fencing status

Results of samples taken at the Mackie Bridge (along the Top Beverley Road in York, (N 31°56'28.6" and E 116°48'47.0") during 1997 by the York River Conservation Society are shown in Table 8 over.

Table 8. Water quality data - Mackie Bridge 1997

Date	Sample number	pH	Conductivity mS/cm	Temperature °C
16/04/1997	1	8.25	33.10	16.0
19/05/1997	2	8.22	30.90	17.5
23/06/1997	3	8.30	27.30	14.5
28/07/1997	4	7.80	21.20	11.5
21/08/1997	5	7.60	21.80	17.0
29/09/1997	6	8.04	24.40	14.0
23/10/1997	7	8.02	24.90	21.0

Table 8 shows the seasonal changes in water quality along the Mackie River. Dry during the summer months, the influx of water during autumn, from the surrounding catchment sees a higher reading for both pH and electrical conductivity than would otherwise be found later in the season. The highest pH and electrical conductivity readings of 8.30 and 33.10mS/cm respectively, were recorded during April. As rain increases the effect is diluted and the trend during July and August is towards lower pH and conductivity readings that increase again as flow declines in September and October.

A study conducted in 1998 by Taylor looked at the effects of the Mackie River on the water quality in the Avon River. The study determined that the Mackie was more saline than the Avon River, with an average electrical conductivity of 27.27mS/cm and a maximum of 40.91mS/cm.

Overall stream environmental health rating

The overall stream environmental health rating is a system used to determine the health of the waterway by rating health factors such as habitat diversity and verge vegetation.

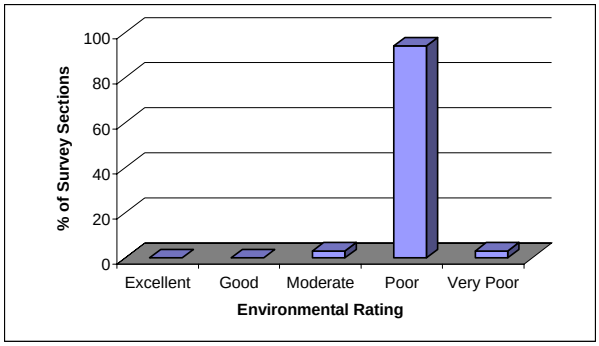


Figure 5.Overall stream environmental health ratings

The results in Figure 5 show that only 3% of the surveyed sections were classified as having a moderate stream health, 94% as poor and 3% as having very poor stream health. The poor health rating of the River was mainly due to low ratings in all of the categories with the exception of habitat diversity as shown in Table 9 below.

As indicated in Table 9, no sections were classified as excellent or good in any of the categories. Habitat diversity rated the best with 100% of sections being classified as having a moderate condition. Floodway and bank vegetation was classified as poor in 83% of sites, while both stream cover, and bank stability and erosion were rated as poor in 70% of sections.

Disturbance

The riparian zone along the Mackie River is subject to many disturbance factors that are contributing to the continual degradation of the channel and foreshore. The following gives a summary of the major disturbance factors observed during field surveys:

- 100% of the surveyed sections were disturbed by feral animals;
- 100% of sections contained weed species;
- 83% of sections were accessible by vehicles;
- 63% of the surveyed sections had stock in the river;

Table 9. Number of sites in each environmental health category

Category	No. of sites rated in each category				
	Excellent	Good	Moderate	Poor	Very Poor
Floodway and bank vegetation	0	0	2	25	3
Verge vegetation	0	0	12	18	0
Stream cover	0	0	8	22	0
Bank stability and erosion	0	0	7	21	2
Habitat diversity	0	0	30	0	0

- 34% of surveyed sections contained dumped rubbish;
- 33% of surveyed sections were affected by pollution (mainly due to animal manures and crop sprays);
- 30% of surveyed sections had crossing points allowing stock and vehicle access across the River; and
- 16% of the surveyed sections were influenced by service corridors (ie. roads).

Map 7 represents all sites along the waterway where stock and vehicles have access to the foreshore and channel of the River. 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.

Evidence of management

All of the 30 sections surveyed showed some evidence of attempts at river management, although not on a large scale. The most common management control was fencing with 67% of sites having fences along both sides of the river. There were also other attempts at river management, with:

- 33% of properties along the River employing surface water management (contour banks) and dams;
- 17% of survey sections showing evidence of tree planting;
- 17% of survey sections using firebreak control;
- 7% of survey sections undertaking feral animal control (baiting);
- 3% of survey sections using man-made riffles to control sediment movement and water flow; and
- 6% of survey sections being zoned with Reserve status.

Although survey data determined that only 7% of sections were employing feral animal control, anecdotal evidence suggested that baiting to control feral animals was much higher.

Priorities for management

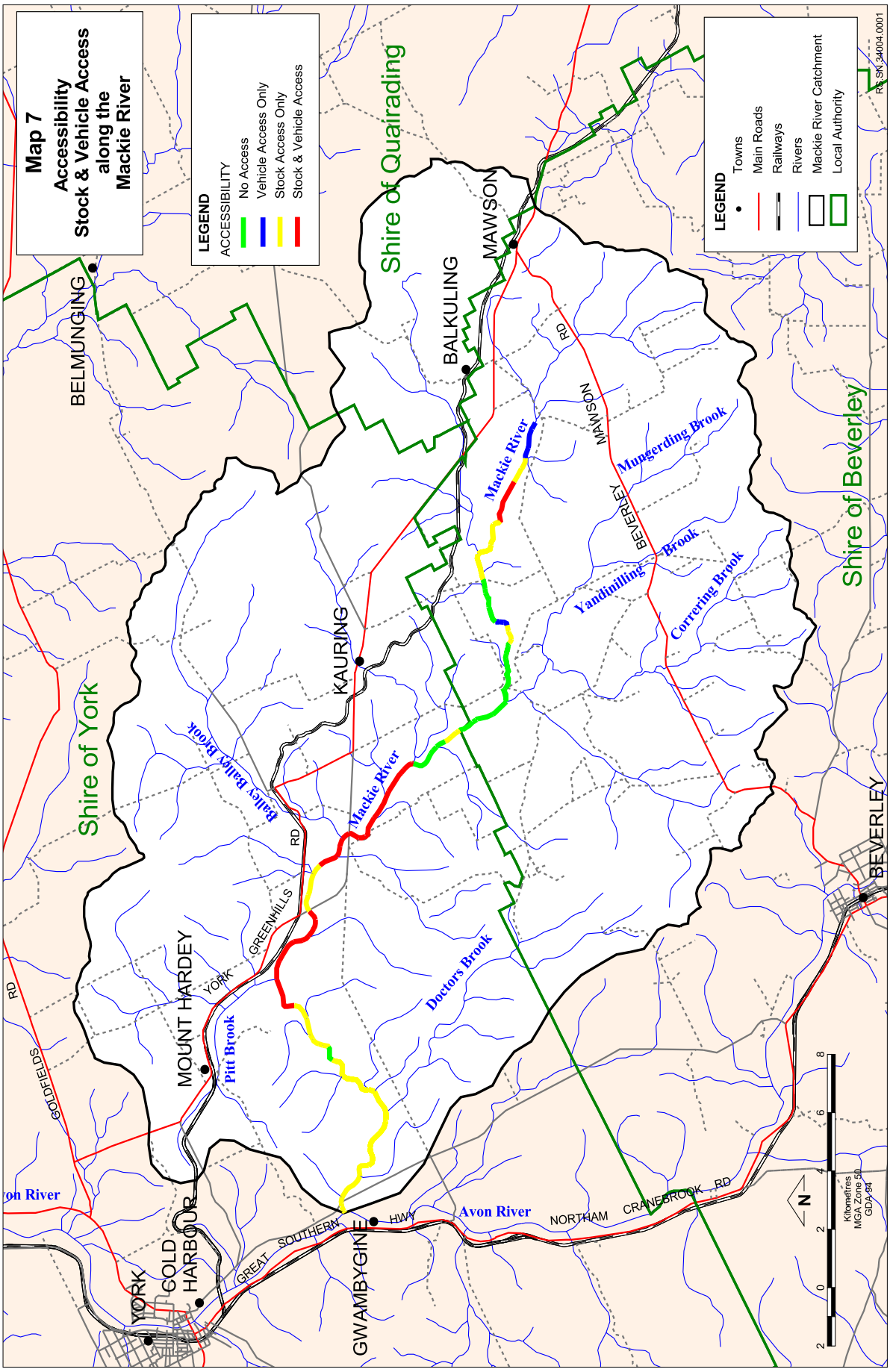
Management along the Mackie River has been prioritised with those issues needing urgent attention classified as having a high priority. Table 10 illustrates the issues that were determined to have a management priority and how each was rated as a matter of urgency.

Table 10. Priorities for management

Management issue	% of survey sections requiring management		
	High	Medium	Low
Fire	17	63	20
Disease	0	3	0
Weeds	93	7	0
Erosion	100	0	0
Salinity	100	0	0
Stock access	30	20	13
Vehicle access	3	27	53
Rubbish	0	7	27
Pollution	0	23	10
Service corridors	0	3	13
Crossing point	0	10	20
Feral animals	20	33	47
Dam	0	7	7

Results in Table 10 indicate that the main issues for future management of the Mackie River are erosion, salinity and weeds with all sections recorded as requiring a high priority for management.

Fire was seen to be of medium management priority in 63% of sections surveyed, while vehicle access was the largest low priority issue with 53% of sections being classified in this category.



Map 7. Accessibility – stock and vehicle

Interpretation of survey results

Bank and channel stability

Erosion and sedimentation have been determined to be the most serious concerns to channel stability along the Mackie River. The severity of each is directly related to past and present landuse along the River. 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 carrying soil particles into the waterway. The removal of large woody debris from within the channel has led to reduced protection of the banks and foreshore areas, allowing water to erode the banks and transport sediment within the channel.

A high level of disturbance will result in erosion and bank scouring which can lead to incision and widening of river channels. The manual straightening of the channel will lead to disturbance and lowering of the channel bed, resulting in an increased flow velocity. This will increase the probability of erosion and incision of the streambed and banks. Increased bank erosion means that there is potentially more sediment available to be moved along the watercourse. Hence, a higher amount of sediment can be deposited in downstream areas amongst woody debris, riffles, on the outside of meander bends, and in areas of slower flow, such as pools, which are important summer refuges providing habitat for aquatic and terrestrial organisms.

Cropping of surrounding land 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 river channel.

In most cases the River runs through the middle of property boundaries, but only 30% of survey sections were recorded as having man-made crossing points. This means that in 70% of sites there was no defined crossing point for vehicles and stock. These disturbances will continue to contribute to erosion of banks, verges and the riverbed. The Mackie River is an unstable system, that has been exacerbated by the mixture of past and present landuse practices. Stock access to the riparian zone has led to foreshore areas becoming devoid of vegetation that plays a role in channel stabilisation. Its intricate root network holds soil together to prevent erosion, subsidence and slumping of the banks and verges.

Erosion has removed mobile sediment from within the channel

Riparian vegetation also performs a necessary function in flood control by reducing flow velocity and dissipating energy (Water and Rivers Commission, 1997). Diminishing species density and diversity has been a great disadvantage in terms of flood mitigation. The floods of January 2000 show the effects of high unseasonal rainfall and the inability of the Mackie River to deal with such a high influx of water. Runoff from the surrounding catchment was excessive due to the large areas of cleared land, and the overland flow carrying sediment that was deposited into the channel.

The loss of riparian vegetation as a result of bank erosion, stock and clearing may have contributed to the shallowing and widening of the channel. This has lead to deeper pools such as Marley and Wonnobbing Pools filling with sediment and the consequent loss of habitat for fauna.

Waterways features and habitat diversity

The waterways features recorded during field observations along the Mackie River are indicative of the health of the waterway, including habitat diversity and aquatic fauna. Results indicate a variety of waterway features. The lack of small pools along the River during the field assessments can be attributed to the seasonal nature of the waterway, and the variability of flow throughout the year. The unstable nature of the Mackie River has largely contributed to the loss of pools resulting from sedimentation. The high number of sand slugs recorded along the length of the River combined with the shallowing of pools indicates a decline in habitat diversity. In some areas the sandy soils had been eroded within the riverbed, leaving exposed clay bed material which has also led to a loss of habitat.

Sedimentation of the waterway can be degradational as an increase in sediment can alter river habitats and may even remove them altogether. Suspended sediment is deposited in areas of slower flow such as in pools, along rock, cobbles and logs, covering features that provide habitat to aquatic fauna. When deposited on substrate surfaces, sediment will commonly hinder algal growth that is an important food source for many aquatic organisms living in the River (Jackson, 1997).

Removal of large woody debris from within the river channel has allowed flow velocity to increase, resulting in a higher incidence of erosion and sedimentation. This may explain the wide shallow channel that has become the Mackie.

Areas where erosion is localised and a variety of vegetation (such as the Spike rush) is growing along the banks and verges provide important habitat for terrestrial fauna. Species such as birds, frogs and lizards utilise the vegetation for nesting and breeding.

Instream cover is important for water quality and the dependent aquatic fauna. Results indicate that there is a reasonable level of instream cover from leaf litter, branches and vegetation. However, this cover does not extend far into the River as in some places the channel spans a width of approximately 100m. A lack of shade will allow the water temperatures to increase and may lead to a decline in aquatic fauna and an increase in algal growth.

All survey sections were recorded as having tree species present, although 90% of sites were found to have 'some dead trees', which can be attributed to waterlogging and rising salinity levels. The dead trees still provide an important range of habitat for terrestrial fauna. 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 8.

Bridges and crossing points allow vehicles 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 are likely to change the flow of the waterway and may also lead to problems such as increased erosive capacity and a decline in fish migration. Results indicate that service corridors were classified as having a moderate management priority in 10% of survey sections and crossing points a low priority in 20% of sections.

Foreshore condition

The high proportion of the Mackie River foreshore that has been rated as C-grade indicates the degraded state of the riverine environment. 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);
- Removal of large woody debris; and
- Lack of waterways management practices.

Foreshore vegetation

A lack of riparian vegetation will adversely affect the health of a waterway. Riparian vegetation protects water quality and channel form by decreasing the amount of nutrient and sediment entering the River, 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 high salinity level of the water is evident by the moderately high number of Swamp sheoak located along the waterway. In general, the Swamp sheoak is more tolerant of salty conditions than the Flooded gum that can only tolerate moderate salinity (WRC and ARMA, 1999), but survey results show that the Flooded gum is more dominant along the foreshore areas than the Swamp sheoak. Swamp paperbarks can tolerate a mild level of salinity but will tend to die as salt concentration increases. The lower numbers of this species may be attributed to high salinity levels.

Field observations determined that along most sites Flooded gums were located further away from the channel where the effects of salinity were not as great. York gum can withstand moderate salinity levels and Jam tree mild salinity, but both species are susceptible to waterlogging. The wide, shallow nature of the River, coupled with the soil type would mean that the foreshore is likely to be prone to waterlogging during wetter months, and this would kill York gums and Jam trees before salinity. Both species are more dominant farther away from the river channel.

The abundance of Samphire species (at 57% of survey sections) is directly related to the high levels of land and water salinity along the Mackie River. Field observations noted many areas of salt scalds along the foreshore and a large quantity of salt crystals along the banks and within the dry riverbed.

The composition of native plant communities has been altered significantly as a result of past and present landuse (the introduction of crops, annual pasture plants and grazing animals) that have led to changes to the landscape (Walker, 1986). A decline in species richness and diversity of native understorey species has encouraged the spread of grass and pasture weeds such as Wild oats and Barley grass.

Foreshore vegetation is susceptible to waterlogging and salinity

The current lack of native understorey species means that the nutrient stripping ability of the riparian zone is greatly reduced, leading to a higher level of nutrients entering the aquatic system. 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 Wild oats and Barley grass are agricultural weeds (related to the historical use of surrounding land for cropping and grazing) and have a high occurrence along most of the River. Anecdotal evidence suggests that the Spike rush is becoming more dominant along the river banks and bed. This is likely to be due to its tolerance to the seasonal and salty conditions, its unpalatable nature to sheep and cattle, as well as the ease in which seeds are spread by birds and self-cloning. The dominance of weed species compared to native species is due to the continual overgrazing and trampling of the riverine environment, hindering the regeneration of the native species. Weeds species are quicker to adapt to fluctuation in the environment and an increasing level of salinity has lead to the death of many native species, leaving room for weed species to invade. Numerous areas of bare ground, combined with an increase in shallow rooted exotic species has left the riparian zone susceptible to bank erosion and nutrient enrichment.

The change of season during the survey period would account for the differing occurrences of weed species. Weeds such as Barley grass and Wild oats are winter active species and during surveys were recorded in high occurrence even though they had died off. Others such as Soursob, Fumitory and Cape tulip rely on the cooler, wetter weather and hence, became more sparse in occurrence as the surveys continued into the summer months.

A lack of fringing vegetation along most of the banks and verges has contributed to the increase in sediment and nutrients entering the waterway. Fringing vegetation plays an important role in filtering water entering the channel and keeping the River healthy (Water and Rivers Commission, 1997).

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 River 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.

Water quality

Water samples collected and tested during field assessments were limited. The nature of the Mackie River means that flow dissipates seasonally and eventually the water dries up. Hence, only a small number of samples were collected and tested for pH and electrical conductivity.

The acidity, or alkalinity, of waterways is measured by a pH scale ranging from 0 to 14 (Figure 6). As shown, a pH less than 7 indicates the water is acidic; 7 neutral and above 7 is alkaline or basic. The natural pH of a waterway will vary from one location to another because the value depends heavily on the soil and rocks over which the water moves (Swan River Trust, undated).

pH is an important environmental indicator which can be used to monitor water health. A sample showing an extremely high or low pH value means that the water is unsuitable for most organisms, while a change in pH of more than 0.5 units from the natural seasonal minimum and maximums may be detrimental to flora and fauna living within the waterway (ANZECC, 1992).

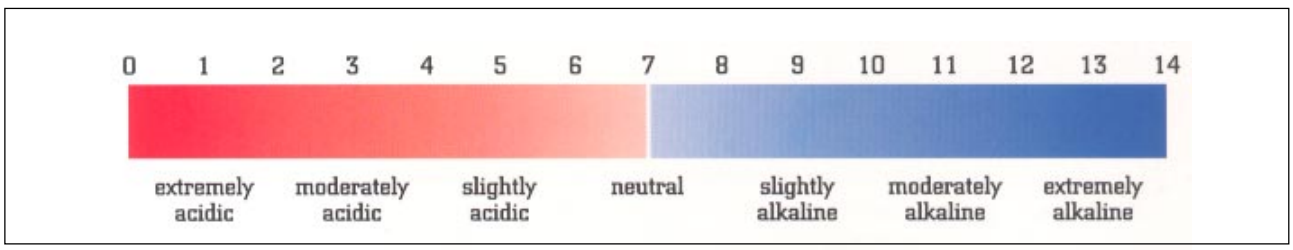


Figure 6. pH Scale

The average pH recorded from samples taken along the Mackie River was 8.15 meaning that the water is moving away from being neutral towards being slightly alkaline. At a pH of 8.15, these samples lie within the *Australian Water Quality Guidelines* recommended for human consumption (between 6.5 and 8.5), and within the acceptable level for freshwater aquatic biota protection, between 6.5 and 9.0 (ANZECC, 1992). The highest and lowest pH values recorded (8.33 and 7.86 respectively) show that the range of values recorded was not high, and that they all lie within the above guidelines.

Electrical conductivity is used to measure dissolved salts within a body of water. Estimates of salinity were made by measuring the electrical charge between dissolved salts (Swan River Trust, undated). Salt water conducts electricity at a faster rate than fresh water, so the higher the reading, the saltier the water. Dilution (due to varying water levels) effects the salt concentrations, making valid comparisons of salinity readings between sites difficult. For the purpose of this report, conductivity readings were measured to provide a 'snap shot' indication of the salinity levels of the Mackie River at a particular point in time, and should be interpreted with respect to this.

Table 11. Classifications for environmental water salinity

Water quality	Classification EC range (mS/cm)
Fresh	< 1
Marginal	1 – 2
Brackish	2 – 9
Low saline	9 – 20
High saline	20 – 45
Hyper-saline	> 45

Table 11 classifies water quality based on ranges of salinity. Electrical conductivity was averaged as 33.25mS/cm, meaning that at the time of water sampling, the water was classified as being high saline. This is likely to be due to seasonal fluctuations as well as past and present landuse activities. Replacement of deep-rooted native vegetation with shallow-rooted crop and pasture species has allowed water tables to rise that, in turn, mobilised salts stores within the soils and have enabled them to leach into the surrounding waterways. Appendix 9 provides some examples of plant and animal tolerances to various levels of salinity.

Historically, the Mackie River has been known to have high salinity levels (Taylor, 1998), and anecdotal evidence suggests that soil and water salinity have increased over time. The Australian Water Resources Council (1992) describes a decline in water quality due to increasing salinity levels as an indicator of long-term unsustainable land management practices. The historical use of the land for cropping and grazing activities has contributed to the salinisation of the surrounding land and water. This can be seen in the death of native vegetation, the introduction of more salt tolerant species (such as Samphire and Spike rush) and the growing number of salt scalds along foreshore areas.

Water quality is determined by measuring a number of inter-related parameters, many of which vary seasonally. Water quality will fluctuate quite significantly over time due to seasonal changes, variations in flow regimes and surrounding landuse practices. Factors such as nutrient enrichment, leaf litter, erosion and water runoff are influenced by seasonal changes in climatic conditions, farming practices and waterway flow.

Agricultural runoff from crop and pasture areas may contribute a large amount of nutrients to the waterway if best management practices are not employed (Australian Water Resources Council, 1992). A lack of fringing vegetation along the River and a high percentage of bare ground throughout the foreshore means that faeces from stock will be washed straight into the River during wetter periods. Animal faeces contribute high levels of nutrients to the waterway and in many instances along the Mackie River, stock had access to the channel.

Instream and bank vegetation provides shade for the waterway, regulating its health and limiting the occurrence and severity of algal blooms. Algae is common in most waterways in limited quantity, but with the right conditions can grow to extreme densities causing an algal bloom. Factors that encourage blooms and that need to be addressed include nutrients in the water, intense sunlight, isolated pools and warm temperatures (Australian Water Resources Council, 1992).

Disturbance

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

- current farming practices;
- stock access to waterways;
- vehicle access to waterways;
- feral animals;
- spread of weeds; and
- frequent fires associated with surrounding farming practices.

43% of survey sections were accessible to stock during the time assessments were conducted, however field observations and landholder comments suggest that the number of sites accessible to stock is actually much higher. Approximately 85% of the Mackie River is fenced on one or both sides. Many farmers graze stock along the waterway when there is a lack of feed and for other reasons such as reducing fire hazards. Over the years however, crop and livestock production has taken its toll on the landscape. Livestock access to the river channel and foreshore can lead to problems such as:

- foreshore and channel erosion;
- 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; and
- loss of habitat for native fauna (through loss of vegetation as well as competition).

All of these factors combined contribute to the degraded state of the foreshore and channel of the Mackie River. However, introducing stock to the landscape should not be seen as the only cause of land degradation within the Mackie River catchment.

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

Feral animals may contribute to soil erosion; for example, rabbits burrow into the ground for nesting purposes and also eat vegetation. Birds nest in vegetation and also forage for food such as seeds and berries. Along the upper Mackie River there is an increasing number of Spike rush (a weed species) taking over the channel. Birds nest within these rushes because they offer protection from predators and the seeds provide a source of food. Seeds are spread in bird droppings and easily carried throughout the riparian zone where the moist conditions are suitable for its growth.

Fencing provides a means of excluding stock from waterways, decreasing erosion associated with grazing and trampling, and allowing native species to regenerate

Evidence of management

Results indicate that the level of management that has been undertaken to protect the River was low. The limited number of landholders employing waterways management practices may be attributable to a lack of community education and awareness about river management. In many cases landholders indicated that cost was a major factor hindering development and adoption of rivercare practices and actions.

Fencing was used along most survey sections and firebreaks were also used, but not strictly to protect the riverine environment. Firebreaks were used to lower the chance of fires spreading across the waterway into cropped areas.

Principles for waterways management

The need for management

The results of this channel and foreshore assessment indicate that there are many issues that need long term management if the health of the River 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. The Mackie River catchment has a low supply of water 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. A management or action plan can be for one property or the whole catchment, and includes such things as:

- identification and prioritisation of potential future threats;
- 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 agricultural land use should be 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 the Mackie River 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.

Management responsibilities

The concept of this foreshore and channel survey is to encourage management activities as well as providing a condition report on the river. The successful management of a waterway entails the successful management of the surrounding landscape. Landscape components within the Mackie River catchment are interrelated and hence need to be managed as a whole.

The River 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 River on its own can be likened to treating a problem but not preventing the cause. A catchment wide approach should be employed with a range of objectives to improve the health of the riverine environment. There are many smaller tributaries feeding into the Mackie River that impact on the quality of water, as well as sediment loads, and channel and foreshore condition.

Establishing a catchment group or Friends group for the length of the River is important to the long-term management of the waterway. Promoting the River as an asset to the community and encouraging community involvement on management may prove difficult as the Mackie runs through private landholdings for the most part. Small groups of landholders along the river and from within the surrounding catchment should be encouraged to band together to plan and implement river management actions.

At present there is one group focused on the Mackie River (the Upper Mackie River Catchment Group) and another committed to the management of Marley Pool (the Marley Pool Land Management Group). There is also the Avon Working Group, which is a community group aiming to promote and coordinate integrated catchment management within the Avon River Catchment for the surrounding community. Members of the River Conservation Society in York have already committed themselves to improving the health of the Mackie River and hold many reference materials 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.

Waterways management should be undertaken with the objective of resolving competition between 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 Mackie River and adjoining tributaries, in order to conserve ecological systems and meet the needs of present and future generations. Flexibility in the management plan is a must if it is to have the long-term ability to combine waterways conservation with agricultural practices which are highly dependent on climate and other environmental factors (Clement and Bennett, 1998).

A blank survey sheet is included in Appendix 3 for use by landholders, catchment groups, and 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 along the Mackie River are aware of the benefits of long term management of the waterway. Economics is one of the main issues hindering 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

Weeds management

Weeds have many negative impacts on the riverine environment. 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 a wildfire along the waterway corridor.

An integrated catchment 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 targeting the best areas and 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 reduced significantly.

Weeds growing along road verges that run in close proximity to the waterway and its tributaries should be controlled, so as to reduce the risk of spreading into surrounding riparian zones.

Riparian revegetation

The health of the bank and foreshore vegetation along a waterway is indicative of the health of the waterway. Riparian vegetation is an important component of the river ecosystem, and when salinity levels increase, for example, many plant species will die off and be replaced by more salt tolerant species.

Vegetation along waterways should be managed with a view to improving catchment health. Riparian vegetation improves waterway 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 vegetation. 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, 1999b).

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 prevents soil erosion by overland flows of water and wind (Coates, 1987).

Fire management

Annual weeds, such as grasses, dry out during the summer months and can pose a serious fire risk if not kept under control. Along the Mackie River the vegetation exists as a corridor, 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 the Mackie River 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

Fringing vegetation stabilises banks and reduces nutrient input

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 river (WRC and ARMA, 1999). This can reduce the threat of fire to those people living and farming along the river. 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 be responsive to the condition of the vegetation, but it is important to remember that leaf litter and debris contribute important habitat for organisms, as well as protecting the soil from erosion. A set time regime should be put into place to monitor burning within the riparian zone. This will deter burning too frequently and minimise the damage caused by doing so (Price and Lovett, 1999a).

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.

Water quality

The data collected during this assessment is useful as a "snapshot" indicator of water quality (salinity and pH) that can be compared to past and future readings taken from the same tributary. Future management of the River requires water quality to be monitored on a regular basis to determine seasonal fluctuations. Comprehensive monitoring should test physical, chemical and biological parameters including salinity, pH, temperature, flow rate, nutrient levels, sediment loads and invertebrates.

Poor water quality can significantly affect the health of the River and its surrounding ecosystems. Clearing of the land, associated with the agricultural development of the catchment, has had a negative impact on the health of this waterway. Combined with current land use practices, the clearing of vegetation has increased the sediment loads and salinity levels within the River and its tributaries, adversely affecting the health of the riverine system (Schofield et al, 1988).

Restricting stock access from the River will help to improve water quality. Stock, (mainly sheep along the Mackie River), 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 a part of integrated catchment management. Managing each 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).

Landuse development

Within the last decade there has been some subdivision of land into smaller lots for hobby farmers. This has occurred mainly towards the middle and upstream sections of the river. Many of the older land titles give ownership to the halfway mark of the River, and in many cases where

land crosses the river, ownership includes the whole river channel. This makes it difficult to encourage management of the waterway.

As landholdings are subdivided for resale, titles are changing and so is the ability of the Water and Rivers Commission to encourage management of waterways. Any future development of land within the region would be through the Shires of York and Beverley (depending on which Shire the landholding is located within).

Applications for subdivision are sent to the Western Australian Planning Commission for assessment and for referral to relevant organisations (including the Water and Rivers Commission and the Avon River Management Authority) to provide advice. It is usual practice for a Foreshore Management Plan/Agreement to be requested where development and/or subdivision is planned for land surrounding a waterway. The agreement aims to protect the environmental, social and economic values associated with the channel and foreshore.

A small number of properties along the Mackie River have houses, sheds and other buildings located close to the waterway, within the immediate floodplain. As small landholdings are becoming increasingly common within the catchment, it is important that landholders and planners are educated about the potential risks of flooding.

The flood regime within the Avon catchment tends to be approximately 10 years apart (Hansen, 1986). When planning development within the Mackie River catchment the flood regime needs to be taken into consideration so that damaged caused by floods is minimised. Development within flood-prone areas should be actively discouraged. Any existing and future landuse should be guided by the Shire of York Town Planning Scheme, the Shire of Beverley Town Planning Scheme, the Ministry of Planning and the Water and Rivers Commission, while providing for the protection and enhancement of the environment and the catchment surrounding the Mackie River.

Areas of cultural significance (both Aboriginal and non-Aboriginal) should be recorded and protected through the Town Planning Schemes to prevent any changes to landuse that may be detrimental to these sites. It should be noted that where Aboriginal sites may be affected by proposals for development and land use change, the requirements of the *Aboriginal Heritage Act, 1972* must be met (Western Australia Planning Commission, 1999).

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. It is common for smaller debris and leaf litter washed downstream to become accumulated at these points, providing an important habitat for many aquatic organisms. Most of the length of the Mackie River has been cleared of this material due to perceived risks of flooding and bank erosion, highlighting the need to educate people to the benefits of keeping the debris within the river system, and the disadvantages of removal.

Contrary to common belief, the removal of large woody debris does not reduce flood risk and will actually lead to bank and channel erosion caused by an increased flow velocity. The increased movement of sediment through the system will be deposited in pools and along floodplains and may lead to a decline in habitat, raised channel beds and increased threat to infrastructure such as low bridges. Reintroducing large woody debris to the system will increase river stability and provide a greater diversity of habitat for native fauna.

In areas where large woody debris has been removed, attempts should be made to add sufficient debris material to the waterway to return it to its natural load. By considering the amount of debris found in healthier parts of the River (or in rivers in close proximity under the same conditions) assumptions can be made as to how much woody debris to return to the system (Price and Lovett, 1999b).

Fencing

When revegetating an area along the riparian zone it is important to exclude stock so that they do not eat and trample revegetated areas. Fencing is the easiest and cheapest means of excluding stock. 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, should be minimised and properly managed.

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.

The type of fence used should be suited to the flood regime. For example, drop fences will drop to the ground during flood events where pressure from water and debris builds up (see Appendix 7 for a description of fencing systems). Using the right type of fence is more economically viable, as it decreases the need for repairs. Fencing along riparian zones should be located parallel to the River to minimise the impact of floodwaters on the fence. Most importantly 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, 1999b).

Feral animals

Field observations and conversations with landholders along the Mackie River determined that there are a high number of feral animals resident within the riparian and channel vegetation. The most common are rabbits and foxes, but feral cats have also been sighted on occasion. Feral animals take over habitats and prey on native fauna, they destroy native vegetation, increase the spread of weeds, contribute to bank destabilisation and erosion through burrowing into the soil, and are often a threat to livestock being grazed along foreshore and surrounding areas.

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 migrate from surrounding properties. There is a need for cross boundary management of feral animals to stop this happening. Surveys show that feral animal control (baiting) is already in practice throughout most of the properties surveyed. Controlling weeds (such as the Spike rush) will also help to deter pest animals due to a lack of food, nesting and breeding sites.

Waste disposal

Field observations determined that along some sections of the River it is commonplace to dispose of unwanted farm machinery, cars and chemical containers along the banks of the waterway. Refuse can cause pollution of the waterway and those into which it feeds (the Avon River) when oils, fuel and chemicals leach into the waterway and are moved downstream during periods of flow. Landholders should be encouraged not to dump unused items near the river by educating them on the risks involved in affecting the surrounding environment.

Education and awareness

For the long-term benefit of the riverine ecosystem, measures should be taken to educate landholders in an effort to promote understanding and awareness of the significance of waterways and their management for future use. Landholders along the Mackie River were given the opportunity to take part in the foreshore and channel assessment, and it is important that involvement is on-going, especially in any future plans to improve the health of this waterway.

Catchment management and community action require 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 waterways management, integrated catchment management and land management to community members.

There is a wealth of information already learnt 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.

Concluding comments

This foreshore and channel assessment has been undertaken to provide landholders, interested community groups, Local Government Authorities and state government and non-government agencies within the surrounding catchment an understanding of the current condition of the Mackie River.

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 people to monitor the health and condition of this 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, or between different sites in the same survey season. 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 assessments undertaken along the Mackie River. The main conclusion to draw from findings is that in many ways the health of the River is suffering, both directly and indirectly, as a result of past and present landuse activities.

The Mackie River is generally fairly degraded. Historically, land has been overused but farming practices employed today are becoming more ecologically sustainable. There is hope that with a greater understanding of the condition of the Mackie River, community members will band together to try and recover some of the natural health and beauty of the waterway.

In general the Mackie River is described as a C-grade system, meaning that the foreshore vegetation supports only trees over weeds or pasture. Bank erosion and subsidence is occurring in localised areas. However, practical management actions being undertaken throughout the catchment (including fencing, revegetation and surface water management) are positive steps in restoring the health of the Mackie River. Implementation of waterways management practices means that, in the long term, the Mackie River will be healthier and will become less of an environmental and economic burden to surrounding landholders.

The high sediment loads within the channel mean that the system is very mobile and unstable and is in need of rehabilitation. The high salinity levels of the water are affected greatly by salinisation of the surrounding land, that is due in large part, to the past and present land use activities within the surrounding catchment.

There is a lack of native plants and an abundance of weeds. The most common native vegetation are trees, with York gum, Flooded gum and Jam tree being the most prevalent. Of the weed species invading, the groundcover wild oats and Barley grass were the most common during this assessment. Spike rush has become more dominant in areas of salinisation, and is growing thickly within some parts of the channel.

The major disturbances along the length of this watercourse are feral animals, as well as vehicle and stock access to the riparian zone. Observations determined that the issues in greatest need of management were weed invasion, erosion of banks and verges and salinisation of the waterway and surrounding land.

Survey results have determined that there is a high number of landholders surrounding the Mackie River who are attempting waterways management, whether it be fencing, revegetation, controlled grazing or surface water management.

The need exists, on a long-term basis, to assess competing landuses and determine a compromise that allows for the rehabilitation and conservation of the Mackie River 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 the Mackie River need to be linked to the development of more sustainable farming systems within its catchment. If management of the riverine system is to be effective, degradation associated with the Mackie River must be treated at the cause and not the symptom.

Educating and empowering the community will lead to a sense of pride and ownership in the River. This will lead to enthusiasm and a greater desire to manage the waterway for the economic, social and environmental benefit of present and future generations.

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Glossary

Anabranch A secondary channel of a river which splits from the main channel and then later rejoins.

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.

Carrying capacity The dry stock equivalent or the maximum pressure than an environment can support on a sustainable basis over a given period of time.

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

Channelisation The straightening of the river channel by erosional processes.

Contour farming Plowing and planting across the changing slope of land, rather than in straight lines, to help retain water and reduce soil erosion.

Debris Loose and unconsolidated material resulting from the disintegration of rocks, soil, vegetation or other material transported and deposited during erosion.

Declared plant Plants that are classified as high priority and which may become a major problem to the environment or to agricultural activities.

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

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 one barbed wire, four plain wires of which two are electric.

Environment All the biological and non-biological factors that affect an organisms life.

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.

Eutrophication An excessive increase in the nutrient status of a waterbody.

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 (ie. not indigenous to the region).

Fabricated fence Fence construction includes rabbit netting, ringlock and hinge joint 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.

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 Technically this is the hydrogen ion (H^+) concentration in the water. It is the simplest measure of acidity.

Pollution Any physical, chemical or biological alteration of air, water or land that is harmful to living organisms.

Regeneration Vegetation that has grown from natural sources of seed, from vegetative growth, or has been artificially planted.

Riffle The high point in the bed of the stream (accumulation of coarse bed materials), where upstream of accumulations a shallow pool is formed. Downstream from the crest of the accumulation the water is often shallow and fast flowing.

Riparian zone Refers to the zone directly adjoining a waterway. Any land that adjoins, directly influences, or is influenced by a body of water.

Salinisation The accumulation of salts in soil and water which causes degradation of vegetation and land.

Sand slug A build up of sediment within the channel and along the outside of meanders.

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 A measure of the suspended solids in the water.

Undercutting The undermining or erosion of soil by water from underneath an existing landform (ie. riverbank), structure (ie, fence post) or vegetation (ie. tree).

Verge The area extending from the top of the bank to the next major vegetation or land use change.

Verge vegetation The strip of land up to 20m from the immediate river or creek valley.

Waterlogging Saturation of soil with irrigation water or excessive rainfall, so that the water table rises close to the surface.

Weed A plant growing where it is not wanted.

Appendix 1
Guide to soil-landscape systems in the Mackie River catchment

MU_Symbol	MU_Name	MU_Landform	MU_Soil
257Af	Avon Flats System	Alluvial terraces and flats.	Browns loamy earths, grey non-cracking clays and brown deep sands.
257Gh	Greenhills System	Undulating terrain.	Grey deep sandy duplexes, red deep sandy duplexes and red deep loamy duplexes.
257Go	Goomalling System	Poorly drained valley flats.	Grey deep sandy duplexes, alkaline grey deep sandy duplexes and saline wet soils.
257Jc	Jelcobine System	Major valleys with isolated lateritic remnants.	Red deepand shallow sandy and loamy duplexes, grey deep sandy duplexes, bare rock and cracking and non-cracking clays.
257Mb	Morbinning System	Undulating sandplain remnants, breakaways and slopes.	Grey deep sandy duplexes (often alkaline), pale deep sands and yellow sandy earths.

Source: Agriculture Western Australia, 1999

Appendix 2

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: P. Janssen — Survey Date: 30 October 2000

Tributary Name: Mackie River — Section Number: MK001

Catchment Name: Avon River Catchment — Length of Section: 1.2Km

Sub-catchment Name: Mackie River Catchment — Shire: York

Nearest Road Intersection: York-Quairading Road and Seabrook Road

GPS (start of survey section) E: 509320 N: 6459158

GPS (end of survey section) E: 508091 N: 6459597

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: 9555 5555

Property address: Lot 89 River Road, Riverville

Bank Stability

Proportion of bank affected (% of survey area)	Undercutting	Firebreak/track washouts	Subsidence	Erosion	Slumping	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	✗ Dam	❒ Riffle
❒ Braided channel	❒ Groundwater	❒ Bridge
❒ Pool	❒ Rapids	✗ Sand slugs
❒ Wetlands	❒ Annabranch	❒ Vegetated islands
❒ Other		

.....

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: C Best: C2 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: Needlebush, Jam tree, Swamp sheoak

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

Bare Ground: % cover: 35%

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%

Fencing Status

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

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)
York gum	M		
Soursob	M		
Wild oats	H		
Swamp sheoak	M		
Barley grass	H		
Needlebush	L		
Thistle	L		
Rye grass	L		
Jam tree	L		
Flooded gum	M		
Couch	M		
Samphire	H		

Evidence of Management

Tick the appropriate boxes:

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

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)
York gum	M		
Soursob	M		
Wild oats	H		
Swamp sheoak	M		
Barley grass	H		
Needlebush	L		
Thistle	L		
Rye grass	L		
Jam tree	L		
Flooded gum	M		
Couch	M		
Samphire	H		

Water Quality Data

Sample Number	pH	Conductivity mS/cm	Temperature °C	Location
1	8.33	41.4	22.1	482821 E 6465810 N
2	8.06	39.2	23.8	482834 E 6465873 N

GPS Coordinates

Coordinate	Description
LMK01	Start point of survey section
LMK02	Start of large sand slug
LMK03	End of large sand slug
LMK04	Area of many sick and/or dead trees
LMK05	End of survey section

Photos

1. Channel condition
2. Sand slug
3. Dying foreshore vegetation
4. Infestation of *Juncus acuta*
5. Foreshore condition
6. Fence condition
7. Stock in river
8. Bank erosion

Appendix 3

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

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

Landholder: ..... Contact Number: .....

Property address: .....

Bank Stability

Proportion of bank affected (% of survey area)	Undercutting	Firebreak/track washouts	Subsidence	Erosion	Slumping	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
❒ Annabranch

❒ 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: % cover: .....

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

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

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

Vegetation cover

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

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 = ☐ Environmental rating = ...

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

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)

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)

Water Quality Data

Sample Number	pH	Conductivity mS/cm	Temperature °C	Location

GPS Coordinates

Coordinate	Description

Photos

Appendix 4

Overall stream environmental health rating

Living Streams Survey: Information to determine environmental ratings of streamlines

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 channellised.
Bank stability & 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 20m wide.	Mainly healthy undisturbed native vegetation. Verges less than 20m wide.	Good vegetation cover, but mixture of native & exotic species. Verges 20m or more.	Narrow verges only (<20m wide), mainly exotic vegetation.	Mostly bare ground or exotic ground covers (ie. pasture, gardens or weed infestations, but no trees).
Floodway & 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 & exotic species. Localised clearing. Little recent disturbance.	Mainly exotic ground cover. Obvious site disturbance.	Mostly bare ground or exotic ground covers (ie. pasture, gardens or weed infestations, but no trees).
	Excellent	**Good**	**Moderate**	**Poor**	**Very poor**

Source: (Pen and Scott, 1995)

Overall Stream Environmental Health Rating: Points system

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

Surrounding Landuse

Conservation reserve (8)	**Urban (2)**	**Agricultural (2)**
Rural residential (4)	**Remnant bush (6)**	**Commercial/industrial (1)**

Note: To determine score add the ratings determined in the table above and then add the corresponding score from the determined "surrounding landuse."

Total score = ☐

Overall stream environmental health rating:

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

Appendix 5
Overall stream environmental health rating

A Grade

Foreshore has healthy native bush (ie. similar to that found in nature reserves, state forests and national parks).

A1. Pristine

The 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, but there are some areas of human disturbance where soil may be exposed and weeds are relatively dense (ie. 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 (ie. 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

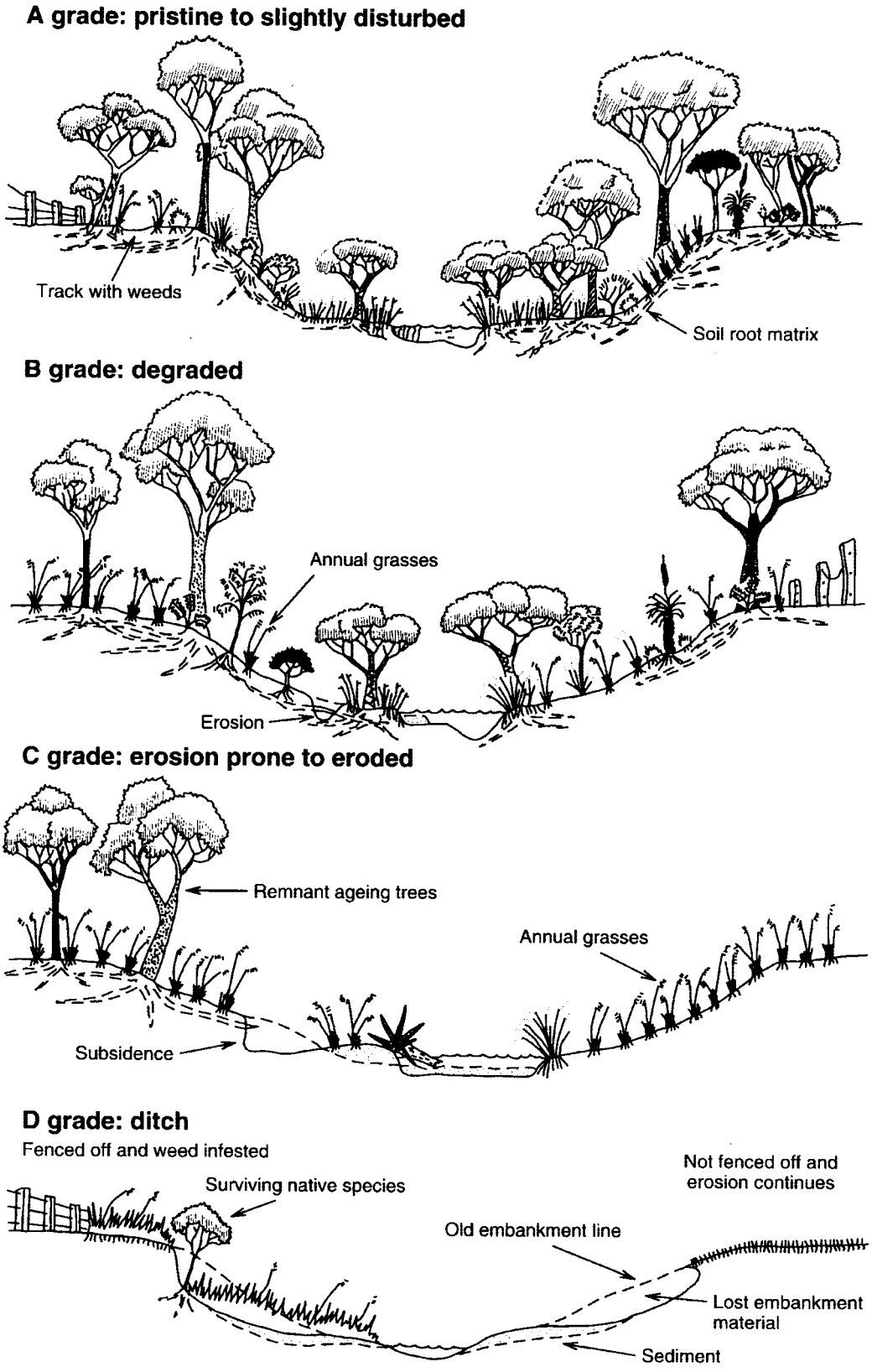
There is not enough fringing vegetation to control erosion. Remaining trees and shrubs act to impede erosion in some areas, but are doomed to be undermined eventually.

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.



Source: Water and Rivers Commission, 1999

Appendix 6
Vegetation recorded along the Mackie River

Native species recorded along the Mackie River

Common Name	Scientific Name
Burr medic	*Medicago polymorpha*
Creeping salt bush	*Atriplex semibaccata*
Everlasting sp.	-
Flooded gum	*Eucalyptus rudis*
Foxtail mulga grass	*Neurrachne alopeciroides*
Golden wreath wattle	*Acacia saligna*
Grass tree	*Xanthorrhoea drummondii*
Green mulla mulla (Bottle washers)	*Ptilotus polystachyus*
Jam tree	*Acacia acuminata*
Needlebush	*Hakea preissii*
Salmon gum	*Eucalyptus salmonophloia*
Samphire sp.	*Halosarcia spp.*
Shore rush	*Juncus kraussii*
Short-leaf bluebush	*Maireana brevifolia*
Smooth heliotrope	*Heliotropium curassavicum*
Stipa sp.	*Stipa sp.*
Swamp paperbark	*Melaleuca rhaphiophylla*
Swamp sheoak	*Casuarina obesa*
Waterbuttons	*Cotula coronopifolia*
York Gum	*Eucalyptus loxophleba. Var. loxophleba*

Weed species recorded along the Mackie River

Common Name	Scientific Name
African love grass	*Eragrostis curvula*
Barley grass	*Hordeum leporinum*
Blowfly grass	*Brizia maxima*
One leaf Cape tulip	*Hexaglottis flaccida*
Castor oil plant	*Ricinus communis*
Corkscrew grass (Crowsfoot)	*Erodium crinitum*
Dock	*Rumex sp.*
Narrow-leaved Fumitory	*Fumaria densiflora*
Pie melon	*Citrullus lanatus*
Puccinellia	*Puccinellia ciliata*
Purple wood sorrel	*Oxalis purpurea*
Ryegrass (annual)	*Lolium rigidum*
Salt water couch	*Paspalum vaginatum*
Soursob	*Oxalis pes-caprae*
Spike rush	*Juncus acutus*
Thread iris	*Gynandriris setifolia*
Veldt grass (perennial)	*Ehrharta calycina*
Wild oats	*Avena fatua*
Wild radish	*Raphanus raphanistrum*

Appendix 7
Types of fencing systems

Barbed Wire Fence: Any fence that is in part barbed wire, usually in conjunction with plain wire and droppers and which is not electrified is classified as 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. It is useful 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: Any fence construction including rabbit netting, ringlock and hinge point fences. These types of fences are useful in areas under high stock pressure, and are also useful in keeping feral animals out.

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.

Drop Fences: Drop fences are designed to be either manually dropped before a flood, or dropped at anchor points under the pressure of floodwater and debris.

Hanging Fence: Hanging fences are suspended fences made out of steel cable or multi-stranded high tensile wire. The purpose of these fences are to keep animals from walking along waterways to bypass fence lines.

Source: BHP Steel International Group, (1999), Waratah Fencing Manual – BHP Wire Products, BHP Steel International Group, Tasmania.

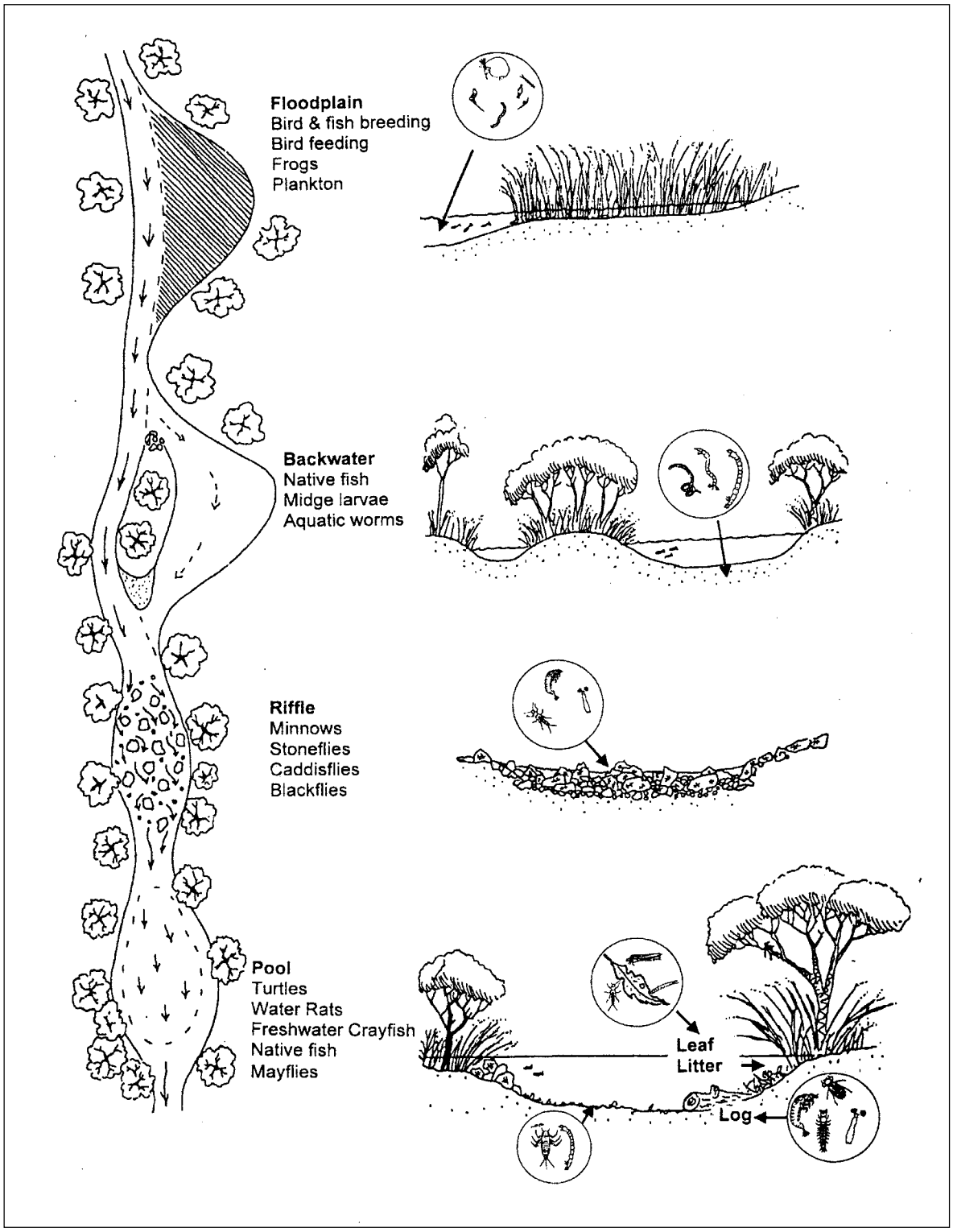
Fencing status – examples of fence condition

Fencing condition – poor

Fencing condition – moderate

Fencing condition – good

Appendix 8
Habitats found along waterways



Source: Water and Rivers Commission, (2000), Water notes: Habitats of rivers and creeks, WN8, Water and Rivers Commission, Perth, Western Australia.

Appendix 9
Salinity data

Salt tolerance ranges

Electrical conductivity		Water status	Use
mS/cm	mS/m		
0 – 1	0 – 100	Fresh	Fresh water suitable for human consumption.
1 – 2	100 – 200	Marginal	Acceptable as drinking water and for most irrigation (ranging with crop type, soil type and level of drainage).
2 – 9	200 – 900	Brackish	Acceptable for most stock and some irrigation.
9 – 20	900 – 2000	Low Saline	Limited farm use. 10 mS/cm Maximum drinking water for horses. 11 mS/cm Maximum drinking water for lambs, weaners and breeder ewes. 16.5 mS/cm Maximum drinking water for beef cattle. 23 mS/cm Unacceptable for most stock use unless during emergency – maximum drinking water for sheep.
20 – 45	2000 - 4500	High Saline	
> 45	> 4500	Hyper Saline	

Compiled by Stephanie Cobb (Avon Coordinator, Ribbons of Blue) July 2000. Based on 'National Water Quality Management Strategy' ANZECC Guidelines for Fresh and Marine Waters (1992).