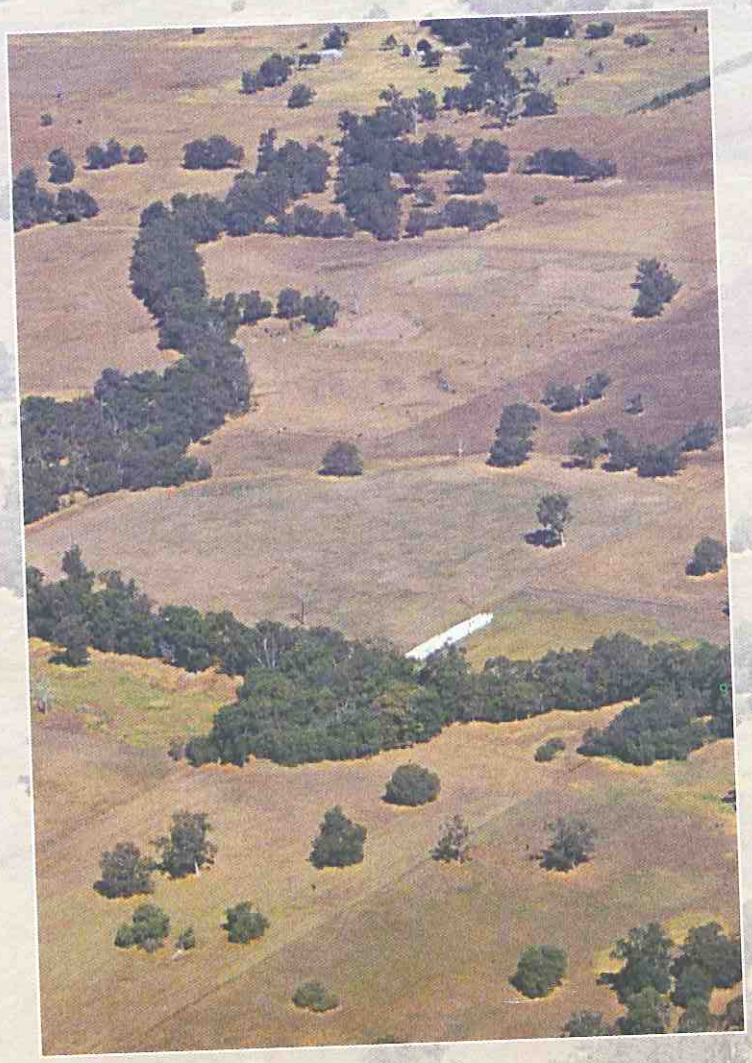
River Action Plan for the Sabina, Abba and Ludlow Rivers

Volume 2. Maps and Recommendations for Abba River



2002

Soil and Land Conservation Council Western Australia

Water and Rivers Commission

GeoCatch

Natural Heritage Trust

River Action Plan for the Sabina, Abba and Ludlow Rivers

Volume 2. Maps and Recommendations for Abba River

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Prepared for the Geographe Catchment Council - GeoCatch
and the Vasse-Wonnerup Land Conservation District Committee

by

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the Water and Rivers Commission

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How to use this river action plan

This report was prepared for GeoCatch, the Vasse-Wonnerup LCDC and landholders in the catchments of the Sabina, Abba and Ludlow Rivers.

Sections 1 and 2 provide background information on the river action plan and the study area. Section 3 details the methodology used in assessing the condition of the rivers. Sections 4 and 5 outline the management issues identified and provide general management advice. Maps showing foreshore condition rating, fencing status, river features, management issues and weeds are included in Section 6 with specific management advice for each section of river.

There are three volumes of this report. One for the Sabina River and Woddidup Creek, one for the Abba River, and one for the Ludlow River and Tiger Gully. Sections 1 to 5 are the same in all the reports. Section 6 differs in each volume and contains maps and specific management advice for each of the river systems.

Figure 11 uses colour codes to show the foreshore conditions of the whole river system. It also provides an index to assist with locating specific sections of river.

Acronyms

NHT	Natural Heritage Trust
LCDC	Land Conservation District Committee
CALM	Department of Conservation and Land Management
GeoCatch	Geographe Catchment Council
WRC	Water and Rivers Commission
DOLA	Department of Land Administration

Cover photo: Sabina River looking towards the Whicher Range. Photo courtesy Bob Humphries.

Acknowledgments

This river action plan was developed in consultation with the Vasse-Wonnerup Land Conservation District Committee (LCDC) and GeoCatch. Thanks are extended to Sheryl Manning, Hal Scott, Cobber Armstrong and David Kemp from the Vasse-Wonnerup LCDC and Robyn Paice, Claire Thorstensen and Shelly Voigt from GeoCatch for their assistance and support. Robyn Paice contributed much to the project, including the excellent background information on water quality of the rivers.

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The Vasse River Action Plan by Margaret Scott, and the Capel River Action Plan by Kirrily White and Sarah Comer were used extensively in the preparation of this report. They provided an excellent basis to work from.

The maps were prepared by Regional Support Branch of the Water and Rivers Commission.

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Reference details

The recommended reference for this publication is: GeoCatch 2002, *River Action Plan for the Sabina, Abba and Ludlow Rivers*, Water and Rivers Commission.

This river action plan is dedicated to Dr Luke Pen in recognition of the enormous contribution he has made towards the understanding and management of our rivers.

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Summary

The Sabina, Abba and Ludlow River systems are found within the Vasse-Wonnerup Land Conservation District in the Geographe catchment. Extensive modification of the river systems has occurred as a result of clearing and drainage of the plains for settlement and agriculture. The desire to protect and improve the condition of the rivers has led to the development of this river action plan.

There are three volumes of this report.

- **Volume 1: Sabina River and Woddidup Creek;**
- **Volume 2: Abba River; and**
- **Volume 3: Ludlow River and Tiger Gully.**

The background information, discussion of management issues and general management advice is the same in each volume. The maps showing foreshore condition and related management advice for each of the rivers is contained within the relevant volume.

The aim of the foreshore condition survey was to provide landholders, the Vasse-Wonnerup LCDC and GeoCatch with information on the condition of the rivers so that the waterways can be better managed. The surveys were conducted in April, May and June 2001 using the Foreshore Condition Assessment method developed by Dr Luke Pen and Margaret Scott, 1995 (Pen & Scott, 1995). Many landholders assisted with the surveys.

A summary of the foreshore condition ratings and length of fencing for the rivers is presented in Tables 1 and 2 below.

The most prominent issues of concern identified during the foreshore surveys and community consultation were:

- Erosion and siltation of the river channels.
- Loss of native fringing vegetation and degradation of remaining vegetation by stock grazing and trampling.
- Weeds - it was noted that serious weed problems are developing in ungrazed and unmanaged sections of river.
- Constraints to landholders fencing the river to control stock access, including the current set out of paddocks, the need for bridges and other crossings, time and cost, and the increased requirements for weed and rabbit control after fencing.
- Water quality and the downstream impacts on the Vasse-Wonnerup wetland system.
- The need for a diverse suite of species to be used in revegetation including trees, shrubs, sedges, rushes and herbs. This is to ensure that revegetation achieves the aims of stabilising the banks and filtering out sediment to protect water quality.

In response to these issues, general recommendations to improve the condition of the rivers are as follows:

- Fence the waterways to exclude stock permanently, or to achieve management that allows for bank stability and native vegetation establishment and protection.
- Protect, as a priority, remaining native fringing vegetation along the rivers by fencing and restricting stock access and controlling weeds.
- Increase the amount and diversity of fringing vegetation along the rivers by revegetation, and restricting stock access to allow natural regeneration.
- Control weeds, rabbits and foxes.
- Seek advice from the Water and Rivers Commission regarding erosion problems and undertake remedial action where possible.
- Minimise nutrient export by establishing buffer strips adjacent to waterways, testing soils to determine fertiliser requirements and maximising vegetation cover on the soil.

Time and funding are the key to restoration works. Some financial assistance to assist with the implementation of these recommendations will be available through the Vasse-Wonnerup LCDC.

Table 1: Summary of foreshore condition rating of the Sabina, Abba and Ludlow Rivers (not including through State Forest in the Whicher Ranges)

Condition rating	Sabina River and Woddidup Creek		Abba River		Ludlow River and Tiger Gully	
	Total Length	Total %	Total Length	Total %	Total Length	Total %
A (pristine)	4.7 km	12%	2.2 km	6%	1.7 km	5%
B (weedy)	4.3 km	11%	18.1 km	51%	15.8 km	45%
C (erosion prone)	9.2 km	24%	7.7 km	22%	12 km	33%
D (ditch)	20.3 km	53%	7.5 km	21%	6 km	17%

Table 2: Length of fenced areas on the Sabina, Abba and Ludlow Rivers

	Sabina River and Woddidup Creek		Abba River		Ludlow River	
	Length Fenced	% of Length	Length Fenced	% of Length	Length Fenced	% of Length
West/south bank only	3.8 km	9.9%	2.6 km	6%	4.9 km	13.8%
East/north bank only	2.9 km	7.6%	1.8 km	4.1%	1.4 km	3.9%
Both sides	3.6 km	9.4%	5.9 km	13.6%	4.8 km	13.6%
Total fenced	10.3 km	26.9%	10.3 km	23.7%	11.1 km	31.3%

1. Introduction

Background

In recognition of a need to address the poor state of the rivers in the Geographe catchment, a Natural Heritage Trust (NHT) application for the development of river action plans was submitted by GeoCatch in 1997, following consultation with the relevant Land Conservation District Committees (LCDC). The project was funded through the National Rivercare component of NHT, which operates under the goal: *To ensure progress towards the sustainable management, rehabilitation and conservation of rivers and to improve the health of these river systems.*

That project led to the successful development and on-going implementation of river action plans for the Capel, Vasse and Carbunup Rivers and Yallingup Brook.

Building on the success of the earlier project, a follow-up application to NHT in 2000 made funding available to develop a combined river action plan for the Sabina, Abba and Ludlow Rivers. The partners in developing and implementing this project are GeoCatch and the Vasse-Wonnerup LCDC, with funding from WRC.

Study Aims

The primary aims of this river action plan are:

- To produce a description of the state of the Sabina, Abba and Ludlow Rivers and a prioritised plan of action to guide works to improve the health of these rivers.
- To provide a benchmark against which the local community's future work to protect and rehabilitate the rivers can be gauged.
- To provide a tool to guide the use of the funding and assistance available for fencing, weed control, erosion control, planting and rehabilitation of native vegetation.
- To provide a sound technical basis for future funding or project submissions.

It was an important aim of the project to involve landholders wherever possible. Much of the river surveying was conducted with landholders and a community meeting was held to report results of field assessments and obtain feedback.

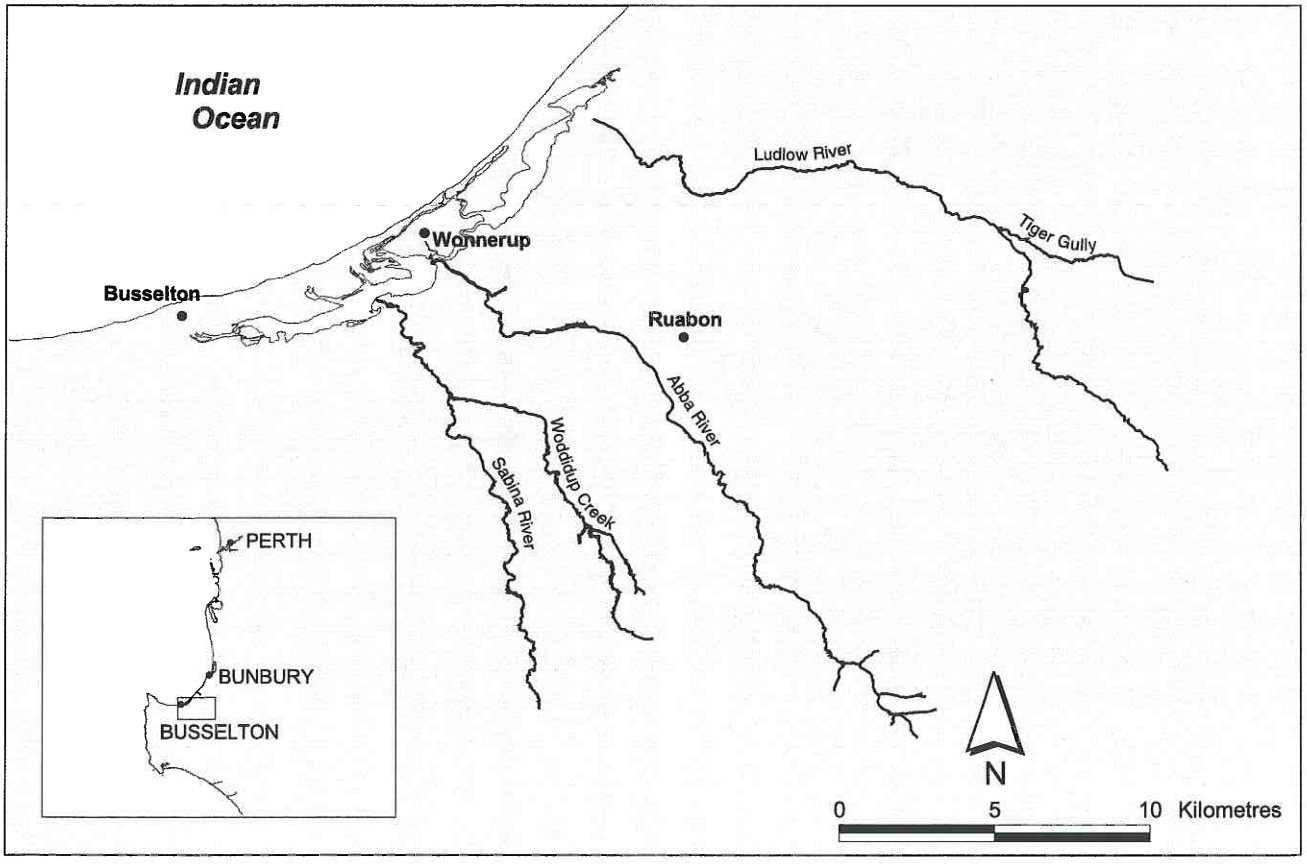


Figure 1: Locality map

2. Study area

The Sabina, Abba and Ludlow Rivers, the major tributary of the Sabina known as Woddidup Creek, and the Ludlow River tributary known as Tiger Gully have been investigated from where they leave State Forest to where they enter the Vasse-Wonnerup wetland system. The location of the study area is shown in Figure 1. Background information about the study area is discussed below.

Landform and soils

The Sabina, Abba and Ludlow River systems occur within two distinct landform units. The rivers begin in the Blackwood Plateau, a gently undulating area of moderately raised land (80-180 m high). They then flow down to the Swan Coastal Plain. The Swan Coastal Plain consists of three distinctive landform types: foothills, alluvial plains and successive coastal dune systems. Within the Blackwood Plateau and the Swan Coastal Plain six land systems[1] have been identified by Tille and Lantzke (1990). These land systems contain a variety of soil types. There is a brief description of the land systems and the soil types below.

Blackwood Plateau

In the Blackwood Plateau the rivers flow through the Treeton Hills, Yelverton Shelf, Whicher Scarp and/or the Goodwood Valleys land systems before reaching the plains.

Treeton Hills land system

The Treeton Hills are undulating rises to rolling low hills on lateritized sedimentary rocks, 80-120m above sea level. The dominant landform pattern is of gently inclined ridges and hill crests with gently to moderately inclined sideslopes down to valley floors. These may be narrow and v-shaped, but are more commonly broad and poorly drained with alluvial soils. On the crests and sideslopes, yellow-brown gravelly duplex soils and pale, grey mottled soils occur. There are some alluvial flats with well-drained red-brown and grey loamy soils.

Yelverton Shelf land system

The Yelverton Shelf adjoins the Treeton Hills. Gently inclined slopes fall to the Swan Coastal Plain. The dominant soil types are yellow-brown gravelly duplex soils and pale grey, mottled soils. Also present are deep bleached sands and shallow gravel over ironstone. There are poorly drained depressions, some of which have ironstone close to the surface. This land system has been dissected by a number of small valleys, some of which have broad swampy floors. Fertile alluvial flats occur along some drainage lines.

Goodwood Valleys land system

The Goodwood Valleys extend into the Blackwood Plateau. Dominant soils are sandy gravel, loamy gravel and deep sands. There are moderately incised river channels, narrow floodplains and well drained alluvial terraces. Poorly drained depressions on valley floors also exist.

Whicher Scarp land system

The Whicher Scarp consists of a low scarp and raised platforms on the northern edge of the Blackwood Plateau. Main soils include sandy gravel, pale deep sands, loamy gravel and non-saline wet soils.

Swan Coastal Plain

On the Swan Coastal Plain the rivers cross the Abba Plain and the Ludlow Plain before reaching the Vasse-Wonnerup wetland system.

Abba Plain land system

The Abba Plain occupies the major portion of the Swan Coastal Plain between Capel and Dunsborough. The dominant landform pattern is an intricate patchwork of slight depressions and slight rises. There is very little height difference between these. The depressions tend to become waterlogged in winter while the rises tend to suffer subsoil waterlogging. The soils on these depressions and rises are generally similar and can be either:

[1] Land systems are defined as an area, or group of areas, throughout which there is a recurring pattern of topography, soil and vegetation (Tille and Lantzke, 1990)

- Sandy topsoil with a bleached A2 horizon and a distinct boundary to a mottled clay subsoil; or
- Sandy grey-brown topsoil with slightly more clay gradating into a mottled clay subsoil.

Superimposed on this general pattern are a variety of areas including the following –

- Depressions and flats which experience even greater winter waterlogging than the remainder of the plain. Some have clayey soils displaying patches of salinity in summer and some have shallow soils overlaying sheet laterite.
- Low rises and dunes of bleached sands, which are especially common on the northern edge of the plain.
- Well drained flats with sandy grey-brown gradational soils and red-brown sandy and loamy soils.

Ludlow Plain land system

The Ludlow Plain occurs as a narrow strip running parallel to and about 2kms inland from the coast of Geographe Bay. It is a level to gently undulating plain formed on aeolianite and calcaranite of the Tamala Limestone.

The northern portion of the plain has deep brownish yellow sands. East of the Sabina River these sands are mainly well drained throughout the year and support Tuart (*Eucalyptus gomphocephala*) forest. West of the river there are areas where some subsoil waterlogging occurs in winter and the natural vegetation is a flooded gum (*E. rudis*) and peppermint (*Agonis flexuosa*) woodland with patches of jarrah-marri (*Eucalyptus marginata-E. calophylla*) forest.

Adjoining the Vasse-Wonnerup wetland system, there is a narrow strip of land which is poorly drained in winter, with shallow brownish yellow sands overlying clay.

The southern portion of the Ludlow Plain consists of a low lying depression with clayey soils. This depression is poorly drained in winter and some areas are saline. It supports paperbark (*Melaleuca* spp.) woodland which has been largely cleared.

Along creeks and rivers there are narrow floodplains in small depressions with sandy alluvial soils or clayey alluvial soils.

Vegetation

The vegetation across the Geographe catchment varies according to landform, geology and soils. Forty six different vegetation communities have been identified in the catchment (Connell, Franke & Jennings, 2000). The area is situated within a region known for its high level of species diversity with many of these species located only in the south-west. A large proportion of the original native vegetation has been cleared, particularly on the Abba Plain where it is estimated that only 10% of the original vegetation remains.

Major vegetation types in the catchment of the rivers include jarrah-marri open forest and woodland, and jarrah-mountain marri (*E. haematoxylon*) woodland in the hills, and marri woodland, paperbark and flooded gum low open forest, banksia low woodland, and tuart forest on the plains. A list of the major vegetation types and species lists for them are contained in the Geographe Bay Catchment Natural Resource Atlas (Weaving, 1998).

During the foreshore surveys species lists were compiled for a number of areas along the rivers that still retain native vegetation. The lists are found in Appendix 1 and can be used to develop species lists for revegetation that take into consideration the landform, soils and geology of the site.

Climate

The area has a Mediterranean climate with hot, dry summers and mild, wet winters. The average annual rainfall varies from about 850mm at Busselton to about 1150mm in the foothills of the Whicher Scarp. The long term rainfall trends are shown in Figure 2.

The river systems and the wetlands

The Sabina, Abba and Ludlow River systems have been modified as a result of the extensive clearing and drainage of the Swan Coastal Plain. Clearing in the catchment and the development of an artificial drainage system has resulted in large increases in river flows. This increased flow, combined with clearing of

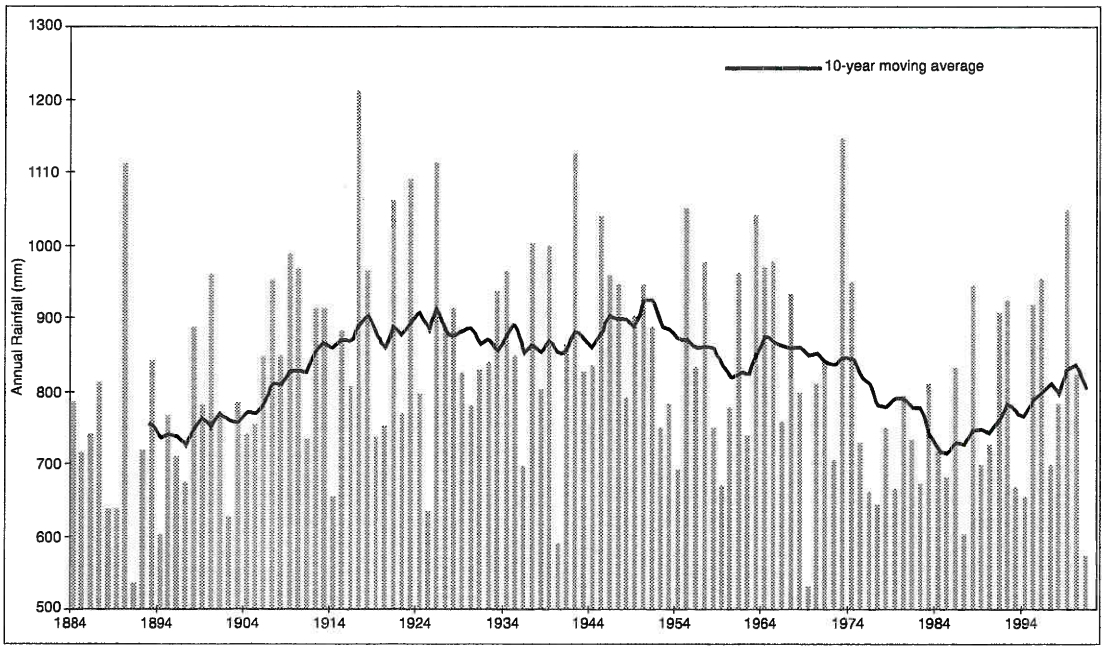


Figure 2: Town of Busselton rainfall data

fringing native vegetation, has lead to erosion problems on all three rivers. Sections of the rivers have also been modified through diversion, channel straightening, desnagging, enlargement of the channel and the creation of levee banks with the excavated spoil.

The Sabina River has been significantly modified with all flow from the upper Sabina diverted to Green Gully drain, then the Vasse Diversion drain and Geographe Bay. The upper section of Woddidup Creek has been diverted into a drain at Sidebottom Rd, with this drain also joining Green Gully. Tiger Gully has been modified close to where it leaves State Forest. It is within an area currently being mined.

The lower Sabina, the Abba and Ludlow Rivers drain into the Vasse-Wonnerup wetland system. The wetland system is listed under the Ramsar Convention as a Wetland of International Importance due to its significance as habitat for waterbirds. It is also an important fish habitat supporting commercial and recreational fisheries. The natural hydrology of the wetland system has been altered by the installation of floodgates in 1908, designed to reduce inundation of agricultural lands and to assist in flood protection for the town of Busselton. While this has enhanced the value for waterbird habitat by retaining fresh water in the estuaries, it has greatly reduced flushing of nutrients from the system out to sea. This change, combined with increased nutrients entering the system from agricultural and urban land uses, has resulted in very poor water quality in the wetlands (WRC, 2001).

Important water quality issues for the Sabina, Abba and Ludlow Rivers, and the receiving Vasse-Wonnerup estuarine system are:

- Enrichment of the waterways and wetlands with nutrients and organic material;
- Deoxygenation causing the death of fish and other aquatic animals;
- Sedimentation of waterways; and
- Salinity.

These have become important issues for management and the community.

Heritage

Prior to European contact the Aborigines of the South West Region formed a distinctive socio-cultural group collectively known as Nyungar (O'Connor, Quartermaine & Yates, 1995). The group of Nyungar people that occupied the coastal area of the Geographe Bay catchment were known as the Wardandi people ' the people that lived by the ocean and followed the forest paths' ('Wardan' meaning ' ocean') (Collard, 1994).

Information compiled from the oral history of the Nyungar people indicated that rivers, estuaries and wetlands generally were very important to these communities, in both a practical and a spiritual sense.

The seasonal movement of Aboriginal groups related to the exploitation of various resources available in the different environmental situations. The early writers noted the Aboriginals tended to congregate around waterways during the summer, and move inland during the winter months. Captain Stirling in 1827 recorded that the Aboriginal groups frequented the coast during the summer to fish, and migrated to higher grounds during the winter to hunt kangaroo and other game and gather roots (O'Conner *et al*, 1995).

Several sites are recorded with the Register of Aboriginal Sites (Department of Indigenous Affairs) within the Sabina, Abba and Ludlow River catchments. These include a fish trap, a camp ground and two historical missions along the Sabina River, a scarred tree on the Abba River and a grindstone artefact site on the Ludlow River. There is also a burial site and an artefact site registered in the area but with uncertain location. Importantly, the Sabina and Abba Rivers are both registered Aboriginal Sites in their entirety. There may be other sites in the area that have not yet been entered on the Register of Aboriginal Sites. All river restoration projects must take into consideration sites of Aboriginal significance, and the local Aboriginal Community will be consulted during implementation of this river action plan.

The first Europeans to explore the area were the French in 1801 in the 'Geographe'. Baudin's expedition went ashore at Minninup and explored the coastline south of the Capel River. Captain Stirling visited Geographe Bay in 1827 and was followed soon after by the Bussell party in 1833 who found the open woodland, freshwater and abundance of cattle feed much to their liking (Horwitz & Wardell-Johnson, 1996).

Settlement of the area has been periodically boosted by various government settlement and development programs. For example, the construction of a road and railway network between 1889 and 1918, the Group Settlement and Returned Soldiers' Settlement Schemes in the 1920's and '30's, and the development of irrigation and drainage facilities under Government Works Programs (O'Connor et al, 1995).

The Busselton drainage system was developed primarily to allow settlement, transport infrastructure and agricultural development of the coastal plain. Because of the topography of the land in the Busselton region, large areas of coastal plain were regularly inundated each winter with water to a depth of around 30cm remaining for several months. The new settlers did not have the resources and expertise to carry out the broad scale drainage that was needed. So in 1894 requests were made to government for drainage improvements. With the passing of the Drainage Act in 1900, extensive drainage works were initiated over the next 30 years, involving the modification of existing natural streams and construction of new drains.

Land tenure

Much of the rivers are privately owned and location and lot numbers are shown on the maps. In the lower reaches, sections of all three rivers are contained within CALM managed land. This includes pine plantation, the Tuart Forest National Park, and the Sabina Nature Reserve. The reserves are listed in Table 3 overleaf.

There are a number of unvested reserves on the rivers. These reserves, with reserve numbers if they have them, are shown on the maps and listed in Table 3.

Table 3: Reserves on the Sabina, Abba and Ludlow Rivers

River	Reserve number or description of location	Map Number	Vesting	Purpose
Ludlow	18047	3	Unvested	Water
Ludlow	Adjacent to locations 1180, 2052, 2015, 4227, 2014, 4227, 2012, 3229.	6 & 7	Unvested	
Ludlow	State Forest No.12	9 &10	CALM	Pine plantation
Ludlow	Adjacent to location 238	11	Unvested	
Ludlow	868	12	CALM	Forest quarters & public recreation
Ludlow	Drain through location 227	12	Unvested	Drainage
Abba	Within locations Pt 650 & 1609	6	Unvested	
Abba	Within location 1830	7	Unvested	
Abba	33734	10	Unvested	Public recreation
Abba	40250	10 &11	Unvested – management responsibility with Conservation Commission of WA.	National Park
Sabina	14567		NPNCA	Conservation of flora and fauna
Sabina	Within locations 1980, 1979, 1978, 1976, 1975 & 1974	3 & 4	Unvested	
Sabina	27534	6	Unvested	Drainage
Sabina	Between Tuart Drive and Bussell Highway	6 & 7	Unvested	Drainage
Sabina	31188	7	NPNCA	Conservation of flora and fauna

3. Study Methodology

Community involvement

This river action plan was developed in consultation with the community. Many of the landholders took part in the assessment of the river at their property. Others provided information and assistance. Following completion of the survey work, a community meeting was held to report results of the field assessments, to discuss recommended management and to obtain feedback.

River foreshore condition assessment

The Pen-Scott method of riparian zone assessment was used. This system provides a graded description of the river foreshore that runs from pristine (A grade) through to degraded (D grade). A summary of the grades of the Pen-Scott system follows (Pen & Scott, 1995). These are also illustrated in Figure 3 and the photos on the following pages.

A grade foreshore

A1: Pristine

The river embankments and/or channel are entirely vegetated with native species and there is no evidence of human presence, or livestock damage. This category, if it exists at all, would be found only in the middle of large conservation reserves where the impact of human activities has been negligible.

A2: Near pristine

Native vegetation dominates but introduced weeds are occasionally present in the understorey, though not to the extent that they displace native species. Otherwise there is no human impact. A river valley in this condition is about as good as can be found today.

A3: Slightly disturbed

Here there are areas of localised human disturbance where the soil may be exposed and weed density is relatively heavy, such as along walking or vehicle tracks. Otherwise, native plants dominate and would quickly regenerate in disturbed areas should human activity decline.

B grade foreshore

B1: Degraded - weed infested

In this stage, weeds have become a significant component of the understorey vegetation. Although native species remain dominant, a few have probably been replaced or are being replaced by weeds.

B2: Degraded - heavily weed infested

In the understorey, weeds are about as abundant as native species. The regeneration of some tree and large shrub species may have declined.

B3: Degraded - weed dominated

Weeds dominate the understorey, but many native species remain. Some tree and large shrub species may have declined or have disappeared.

C grade foreshore

C1: Erosion prone

While trees remain, possibly with some large shrubs or grass trees, the understorey consists entirely of weeds, mainly annual grasses. Most of the trees will be of only a few resilient or long-lived species and their regeneration will be mostly negligible. In this state, where the soil is supported by short-lived weeds, a small increase in physical disturbance will expose the soil and render the river valley vulnerable to serious erosion.

C2: Soil exposed

Here, the annual grasses and weeds have been removed through heavy livestock damage and grazing, or as a result of recreational activities. Low level soil erosion has begun, by the action of either wind or water.

C3: Eroded

Soil is being washed away from between tree roots, trees are being undermined and unsupported embankments are subsiding into the river valley.

D grade foreshore

D1: Ditch - eroding

Fringing vegetation no longer acts to control erosion. Some trees and shrubs remain and act to retard erosion in certain spots, but all are doomed to be undermined eventually.

D2: Ditch - freely eroding

No significant fringing vegetation remains, and erosion is completely out of control. Undermined and subsided embankments are common, as are large sediment plumes along the river channel.

D3: Drain - weed dominated

The highly eroded river valley has been fenced off enabling colonisation by perennial weeds. The river has become a simple drain, similar if not identical to the typical major urban drain.

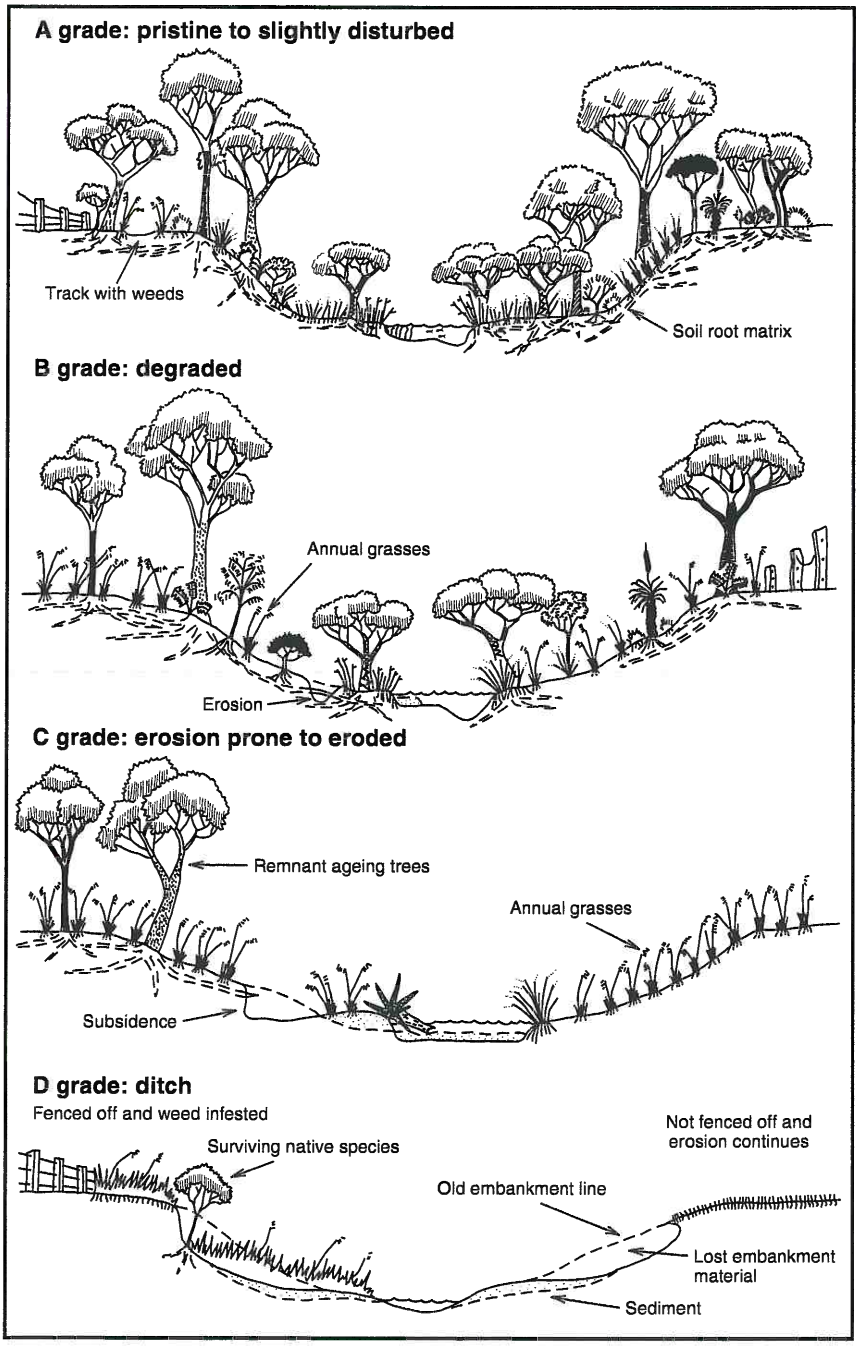
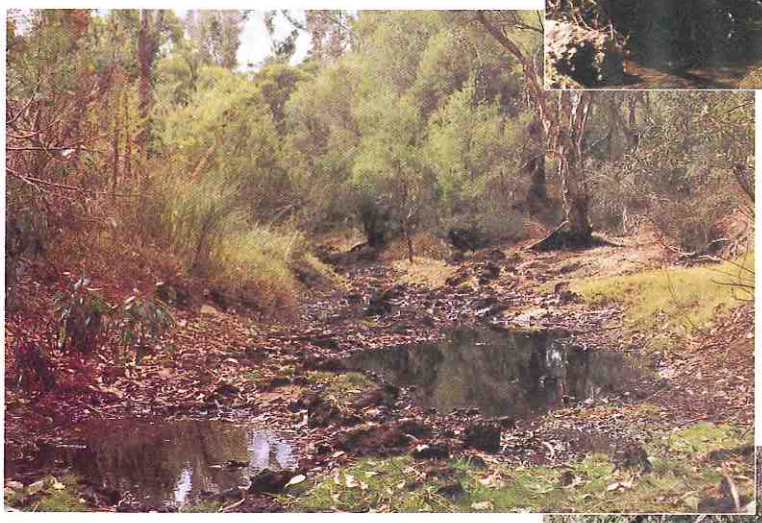


Figure 3: The four grades of river foreshore condition - (A) pristine to ditch (D)

A2 grade foreshore on the upper Sabina River. Native fringing vegetation protects the banks from erosion and traps sediment and organic material before it reaches the river

A2 grade foreshore on the upper Sabina River. Fringing vegetation shades the water, providing a cooler environment for aquatic fauna and limiting algal growth.



B1 grade foreshore on the Ludlow River. Weeds, mainly grasses, have become a significant component of the understorey vegetation.

B3 grade foreshore on the Abba River. Weeds dominate the understorey, restricting the regeneration of native species.

C1-C2 grade foreshore on the Sabina River. Trees remain though there is little evidence of regeneration. The shallow-rooted weedy understorey provides no support to the soil, making the banks vulnerable to erosion.

C3 foreshore on the Sabina River. Soil is being washed away from between tree roots and the undermined trees are at risk of falling into the river. This will cause ongoing erosion problems.

D1-D2 grade foreshore on the Abba River. Large deposits of sediment are accumulating along the river and the channel is widening and eroding back into farmland. The remaining trees retard erosion in places but are doomed to be undermined eventually.

D2 grade foreshore on the Abba River. No vegetation remains to control erosion. The sandy banks are actively eroding and contributing to the accumulation of sediment downstream.

4. Management issues

Management issues vary throughout the catchment depending on landform and soils, past and current land management, level of modification for drainage, and livestock access. The issues identified for the Sabina, Abba and Ludlow Rivers are summarised below.

Erosion and siltation

Banks sometimes naturally erode on bends, however when vegetation is cleared, they can become unstable causing extensive erosion along the floodway and the build up of sediment that is washed downstream (WRC, 1999). While some level of erosion and deposition is natural within any riverine system, the acceleration of these processes can cause management problems.

A combination of disturbance from stock, clearing of fringing vegetation and changes to the water balance from clearing and drainage within the catchment have led to erosion problems on the Sabina, Abba and Ludlow Rivers. Issues associated with erosion problems include:

- loss of valuable soil;
- loss of fences as the river course deviates;
- poor water quality resulting from increased turbidity and nutrients;
- increased flood potential due to the silting up of the channel;
- filling of summer pools;
- increased channel width and loss of agricultural land;
- reduced visual amenity associated with the river; and
- further loss of native riparian vegetation as severe erosion problems cause subsidence.

Loss of native fringing vegetation

Healthy native vegetation remains along parts of the Sabina, Abba and Ludlow Rivers, particularly in the upper reaches. Some of these areas are currently grazed and so are becoming degraded over time. In other areas, there is an overstorey of trees with the native understorey being degraded to highly degraded through clearing, grazing, erosion and competition with weeds. Some areas of the rivers retain little or no native vegetation.

Native riparian vegetation has many values as discussed below.

Erosion control

The roots of trees and large shrubs anchor the river embankments in place and prevent them from slumping and subsiding in to the channel. The finer roots of shrubs, sedges and rushes hold the banks together preventing soil from being washed away, and protecting trees and shrubs from being undermined.

Dissipating flow

Riparian vegetation increases the roughness of the riverbanks, which serves to dissipate the energy of running water thereby reducing the erosive capacity of the flow. The type of vegetation present determines the extent to which water velocity is decreased. Widely spaced trees are not as effective in reducing velocity as rushes and sedges.

Sediment and nutrient retention

Riparian vegetation slows overland movement of water resulting in sediments and nutrients being deposited on land prior to reaching the river channel. This effect is known as buffering. Grasses, rushes, sedges and shrubs are most effective in achieving this buffering effect. The wider the buffer zone, the more effective it is.

Ecological values

Native fringing vegetation provides a range of habitats for many species of flora and fauna, particularly species that are restricted to moist or aquatic environments. Aquatic plants and animals are reliant on the leaf litter, insects and organic debris provided by riparian vegetation. Branches and fallen trees provide habitat for aquatic fauna. The shade provided by fringing vegetation is important in keeping water temperature low. Many native aquatic plants and animals cannot tolerate high water temperature. Lower temperature also reduces the risk of algal growth. Vegetation along stream systems also provides a corridor along which fauna can move and may link areas of remnant vegetation.

Weed invasion

Numerous species of weeds were encountered during the field surveys of the rivers. Many of these are shown on the maps. Disturbance through grazing, clearing, erosion and modification of the channel for drainage purposes has provided ideal environments for the spread of weeds.

Although control of grazing is beneficial to the health and stability of the rivers, exclusion of grazing in disturbed areas often results in weed proliferation. There are areas on all three rivers where grazing has been excluded and very bad weed problems have developed. The worst weeds in these areas include arum lily, bridal creeper, watsonia, pennyroyal, kikuyu and couch. These weeds compete with native vegetation and restrict regeneration. They also provide a seed source for the spread of weeds into other areas. Downstream infestations were noted in all cases.

Stock access

Much of the Sabina, Abba and Ludlow Rivers are unfenced making control of stock access difficult. Problems related to unrestricted stock access include:

- loss of native fringing vegetation;
- weed invasion;
- compacted soils;
- erosion; and
- poor water quality.

During the foreshore surveys and the community consultation it was identified that constraints to landholders fencing the river include the current set out of paddocks, the need for bridges and other crossings, time and cost, and the increased requirements for weed and rabbit control after fencing.

Management of the river after fencing is important. Lack of management can lead to weed problems, an increase in rabbits and possible erosion problems, particularly where woody debris is blocking the channel. It was noted during the foreshore surveys that these problems are occurring in a number of fenced areas of the river.

Water quality

As discussed in Section 2, important water quality issues for the Sabina, Abba and Ludlow Rivers, and the receiving Vasse-Wonnerup estuarine system are:

- Enrichment of the waterways and wetlands with nutrients and organic material;
- Deoxygenation causing the death of fish and other aquatic animals;
- Sedimentation of waterways; and
- Salinity.

To help understand these problems, the Waters and Rivers Commission routinely monitors water quality in the Sabina, Abba and Ludlow Rivers as part of its South West Water Quality Reference Program. Robyn Paice of GeoCatch has supplied the following information on water quality using data collected from 1999 to 2001.

Nutrients

Concentrations of both total phosphorus and total nitrogen are generally high in the Sabina River and low to moderate in the Abba and Ludlow Rivers. Figure 4 shows nutrient data for the three rivers. Nutrient concentrations vary considerably both within and across years, and tend to be highest during autumn and winter in response to increases runoff from the catchment. Concentrations often exceed the guideline for protection of aquatic ecosystems. This is particularly evident in the Sabina River, where nutrient management should be a priority.

Figure 5 shows average nutrient concentrations, and indicates proportions of organic (particulate) and dissolved fractions of nitrogen and phosphorus. Between 44 and 60% of nutrients in the waterways are in organic form, bound to particulate matter, which often comes from soil erosion and animal wastes. Dissolved nutrients also contribute about half the total amount, and fertilisers are often the main source of these.

Nutrient enrichment is a serious management problem in the receiving Vasse-Wonnerup system, contributing to algal blooms during the warmer months. Algal blooms reduce recreation value and often produce foul odours when decaying. Algal bloom decay has been linked to deoxygenation events causing fish deaths in the Vasse Estuary.

Sediments

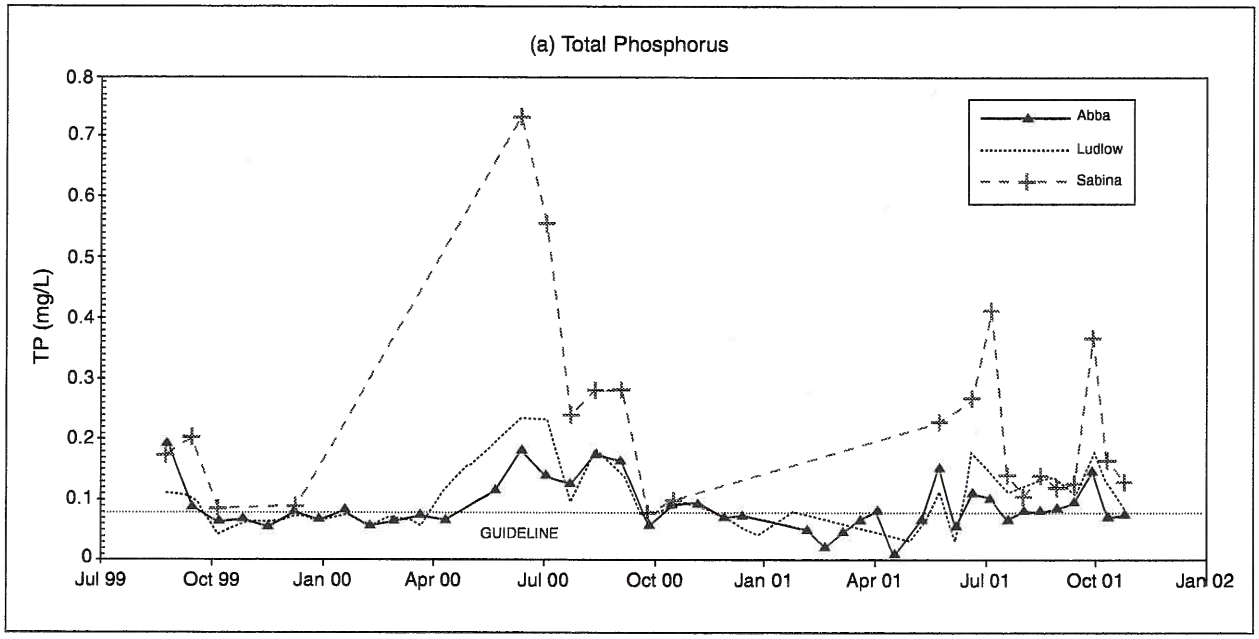
The only indicator of sediment transport in the monitoring program is turbidity. Turbidity may be high in response to runoff during rainfall events, localised erosion problems, disturbance by stock or vehicles, and also as a result of algal blooms. Turbidity levels frequently exceed the level of 20NTU and are sometimes very high in all three rivers. This indicates excess sediment transport in these waterways. Excess sediment is deposited in pools and areas of low flow velocity. This causes infill of deep pools, which are important summer refuge habitat. Sediments also accumulate in the receiving Vasse-Wonnerup system, reducing its depth and contributing to a rich organic layer.

Dissolved oxygen

Dissolved oxygen levels are relatively low in the Sabina, Abba and Ludlow Rivers, with more than 50% of measurements below the recommended guideline of 80% saturation. Very low values have been recorded in all rivers, and oxygen dropped to critical levels in the Abba River in March 2001. This is an indication of excess organic material, which consumes oxygen during the decomposition process. The main sources of organic matter are animal wastes and plant material. Low oxygen levels are potentially a risk to aquatic fauna. Oxygen levels can be increased in rivers by increasing areas of turbulence, such as through creation of riffles.

Salinity

All three rivers generally range in salinity from fresh during winter to moderately brackish during summer. Some highly brackish results have been recorded in all rivers, but particularly in the Abba River. This is quite common in rivers in agricultural catchments, and may be due in part to naturally saline soils in parts of the catchment. Salinity data for these rivers, especially the Abba River, should be watched closely for any increases over time.



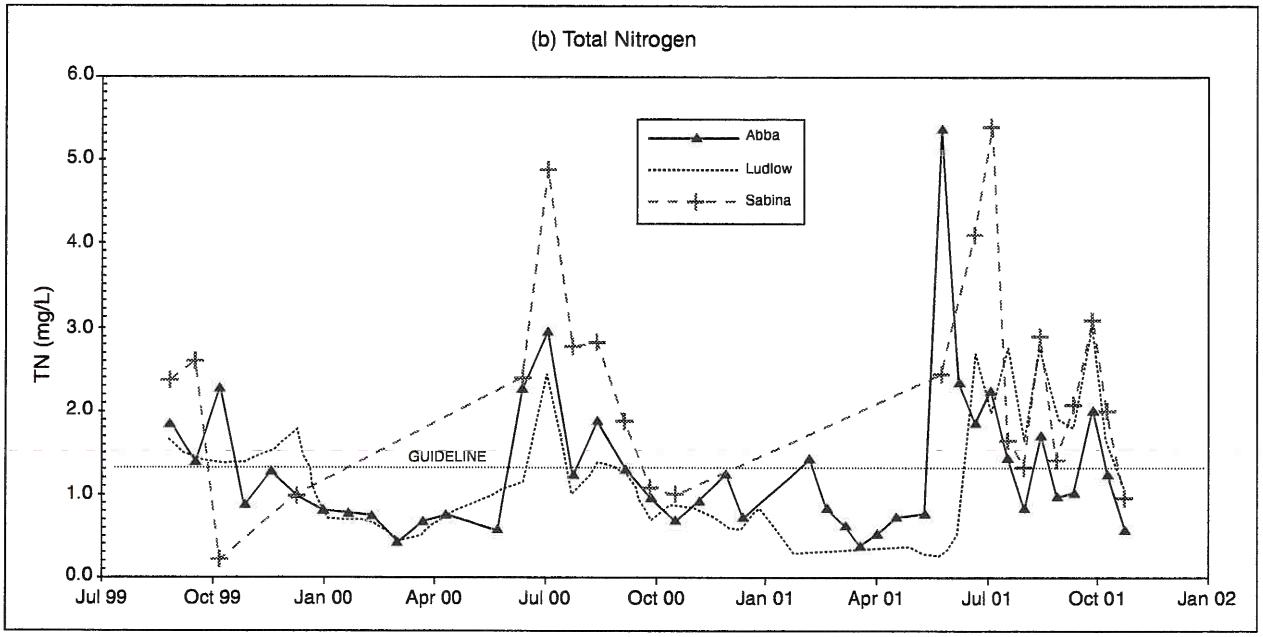


Figure 4: Total nutrient data for the Sabina, Abba and Ludlow Rivers: (a) total phosphorus; (b) total nitrogen

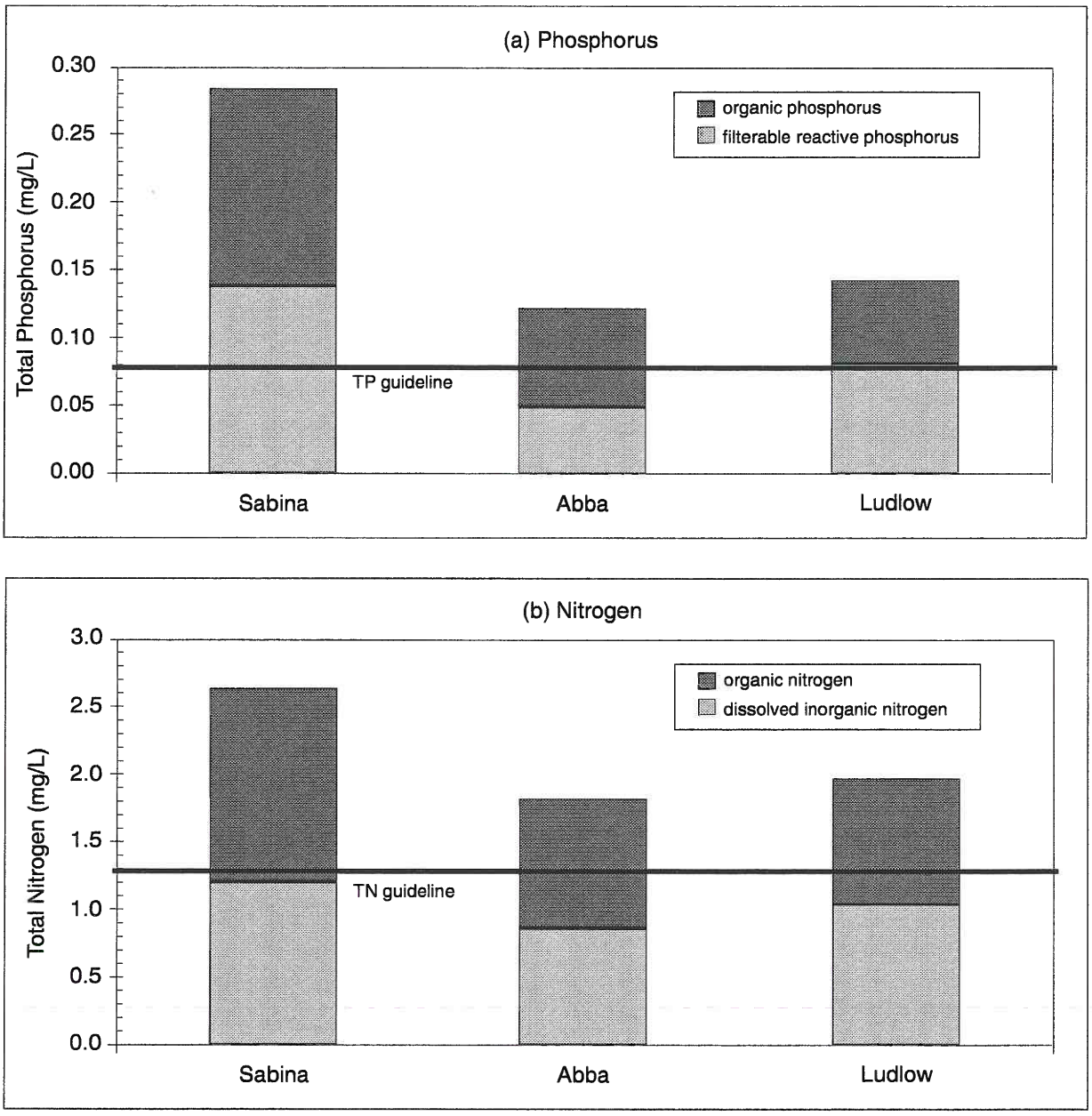


Figure 5: Forms of nutrients in the Sabina, Abba and Ludlow Rivers: (a) total phosphorus; (b) total nitrogen

5. Management advice

Where to start

The main principles for river management are: conserve the best pieces first, move on to those reaches showing signs of recovery, and then treat the more degraded parts of the system. This advice applies to both individual properties and the river system as a whole.

It is cost effective to protect areas still retaining native fringing vegetation. These areas are the most stable and the most likely to regenerate naturally. Assisting natural regeneration is a lot cheaper and easier than undertaking revegetation and erosion control works.

Work on the more degraded parts will be easier if the river upstream is in good condition. Erosion and weed infestations will impact on areas downstream.

The Vasse River Action Plan contains excellent advice on planning a restoration and revegetation project. Parts of this advice are included in Appendix 2 of this river action plan.

Stock control

The control of livestock access is the most important management tool in the protection and restoration of waterways and fencing is the best method to achieve this.

APACE Green Skills & Pen (1995) provide some good advice with regard to the placement of fences alongside waterways. This advice is detailed below.

'Ideally, fences should be placed above the river valley (Figure 4). Depending on the steepness of the embankment, the fence should be placed 5 m to 20 m back from the edge of the river valley (Figure 4 A). Five metres is sufficient for a shallow valley a couple of metres deep but a broader zone, greater than ten metres, is required for valleys deeper than five metres. The purpose of fencing off the shoulders of the river is to enable trees on the upper part of the embankment and those above the river valley to anchor the adjacent land, and thereby prevent subsidence.

In the case of shallow river valleys, there is little chance that embankments will subside. Nevertheless, fence-lines should be located above the river valley (Figure 4 B). This is because fences and firebreaks located within the river valley will be damaged and eroded by floodwaters. When they occur, firebreak washouts can be severe and contribute large quantities of sediment to the river system.

If the river valley is particularly broad and floodplains have been cleared for grazing, fencing them off may mean sacrificing good farmland. In this case it is necessary that only those areas that are prone to water erosion or stock damage, such as embankments and secondary river channels which only flow strongly at times of flood, need to be fenced off (Figure 4 C). Some of these fence-lines will be prone to flood damage, but this can be minimised if fences run, as much as possible, parallel to the direction of floodwaters.

In the flatter and broader valleys it may be acceptable to use fences to control the level of grazing rather than to exclude it altogether. A careful watch would need to be kept to ensure that the grazing is sustainable and is not so heavy as to prevent the regeneration of native trees, shrubs and sedges.'

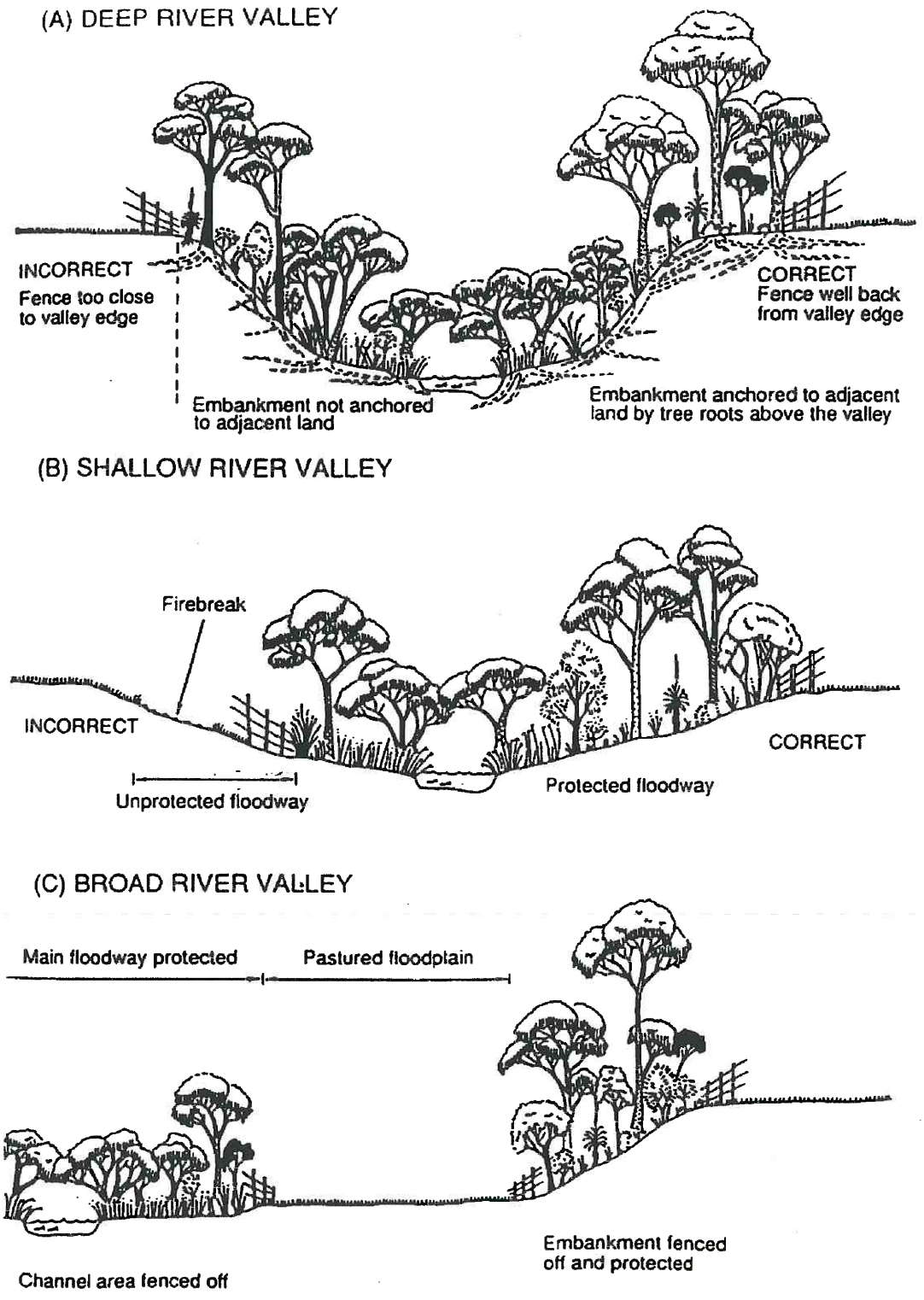


Figure 6: The correct placement of fences in relation to the river valley: (A) the deep river valley, (B) the shallow river valley and (C) the broad river valley with broad flood-plain (APACE Green Skills & Pen, 1995)

Fencing may be used to exclude stock entirely from the river, or to allow restricted grazing. Once native species have regenerated or been re-established it may be appropriate to allow grazing for short periods to control weeds. Grazing may also be used to control weeds prior to planting. Heavy grazing that would degrade the riparian zone and ultimately eliminate native plant species should be avoided. Total exclusion of stock will be necessary where the bank is steep and sandy or prone to collapse or where the objective is to maintain high quality riparian habitat. In these cases, vigilance will be needed to pre-empt any serious weed invasions.

The provision of off-site or restricted access watering points and crossings may be required if the river is to be fenced. Information on design and construction of crossings and watering points can be found in the references listed below.

Useful references on stock control

Water and Rivers Commission Water Note 18, Livestock Management: *Fence location and grazing control.*

Water and Rivers Commission Water Note 6, Livestock Management: *Construction of livestock crossings.*

Water and Rivers Commission Water Note 7, Livestock management: *Watering Points and pumps.*

Water and Rivers Commission Water Note 19, *Flood proofing fencing for waterways.*

Erosion control

Control of erosion is a primary management requirement along the rivers, with many areas showing signs of severe undercutting and bank slumpage. It should be noted that a detailed river geometry survey and a variety of calculations are usually required for the correct design of restoration works. It is also important to remember that rivers are part of a dynamic system, that is, they are in a constant state of change. Care should therefore be taken when attempting to predict the outcome of alterations to channel form and capacity. Site specific technical advice should be obtained prior to commencing any form of physical modification to the river channel. The river action plan coordinator and Water and Rivers Commission engineers can assist with providing technical support.

A number of approaches to erosion control as outlined in the Capel River Action Plan by Kirrily White and Sarah Comer are discussed below (GeoCatch, 1999).

1. Point bars

Once a riverbank becomes disturbed to the point where it is actively eroding, there is large potential for this erosion to create further erosion downstream through the formation of point bars. Currents remove material from the outside banks of meanders and deposit it on the inside banks, where water moves more slowly, forming a point bar (Raine & Gardiner, 1995). Over time these sand bars trap more sediment and continue to accumulate, they may even start to support in-channel vegetation growth. Some point bars are located and shaped in such a way that they actually divert the river flow on to the opposite bank further downstream, thus creating a new erosion point on the next outside bend. This cycle of erosion and deposition often continues downstream, and is the classic symptom of a river in which the hydrological balance has been disturbed (Figure 7).

Removal of point bars may sometimes be needed in order to halt the progression of the erosion downstream. Generally, this should be undertaken in conjunction with other forms of restoration and care must be taken not to exacerbate the disturbance to the river channel. As discussed previously, a detailed river geometry survey of the localised problem areas is required before this type of restoration procedure should be contemplated.

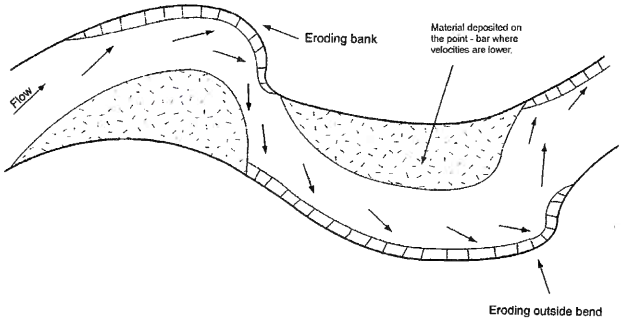


Figure 7: Outside bend bank erosion – Arrows mark the direction of flow showing that outside bends have the greatest erosion potential, so the meanders migrate downstream (Raine & Gardiner, 1995).

2. Undercutting

Undercutting often occurs in conjunction with the formation of point bars. Material is scoured from the toe of the bank, resulting in loss of bank support; this often results in subsidence as illustrated in Figure 8 (Raine & Gardiner, 1995). Previous experience has shown that undercutting can be prevented by supporting and protecting the toe of the bank. Generally undercutting will occur where there is a meander. If this is the case, only the outside bends need to be supported as the flow velocity on the inside bend is much lower. Once an outside bend is stabilised, the corresponding inside bend will usually adjust its width to cater for the change in flow.

3. Bank slumping

Bank slumping can occur when poorly drained material within the bank becomes heavy with saturation and collapses into the river channel (Figure 9). This can occur without prior undercutting. It will often occur in response to the loss of native deep rooted vegetation to improve bank support. The best way to manage this problem is to exclude stock with fencing set well back from the river channel, and revegetate the foreshore with suitable species. Raine & Gardiner (1995) provide the following advice on this process:

- Replant the toe with species that can withstand high flow velocities (e.g. native sedges). This replanting should be dense with spaces between plantings of less than 1 metre.
- Replant the middle to upper bank areas with fast growing, deep rooted trees and large shrubs. These will hold the bank together, enhance drainage and remove excess moisture through transpiration.
- Vary the species that are planted to ensure differing root structures.
- Extend plantings from the toe to the floodplain. If a narrow band of trees is planted, this may serve only to add to the weight of the bank without providing the necessary network of root support.

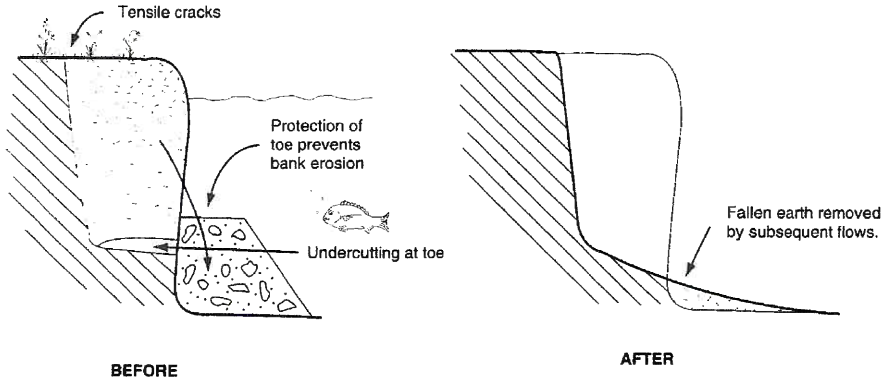


Figure 8: The use of structural works, such as a rock toe, will prevent the process of undercutting (adapted from Raine & Gardiner, 1995).

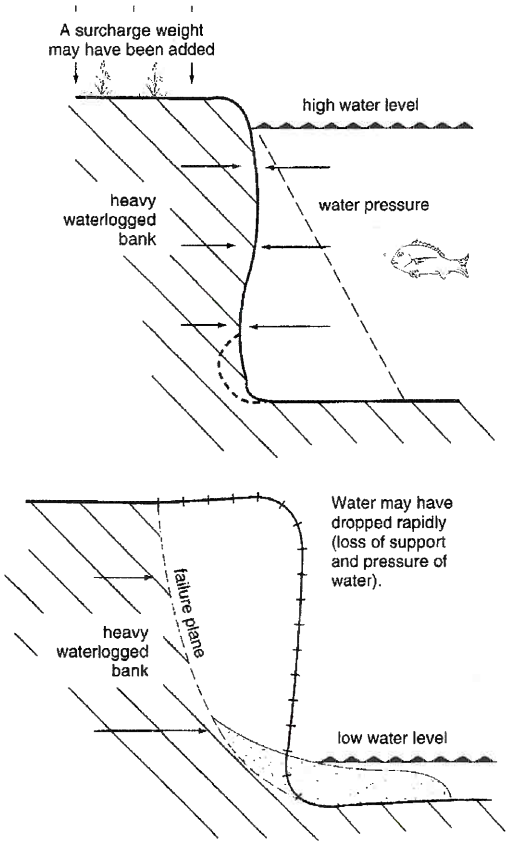


Figure 9: The process of bank slumping caused by excessive weight and lack of support (adapted from Raine & Gardiner, 1995).

4. Large woody debris

Snags, or large woody debris, are a natural component of the river system. They play an important role in the river ecology, by providing a range of flow conditions within the channel and by providing habitat for aquatic life forms.

Occasionally snags can divert the flow onto the bank and subsequently cause erosion in areas lacking support from native vegetation. While de-snagging rivers has been a common practice in the past, the current management emphasis is to leave as much woody debris as possible in order to provide habitat for aquatic plants and animals. Rather than removing large woody debris from the channel, the offending object should be repositioned at an angle 20°-40° to the stream bank (Figure 10). This action will minimise the effect of the snag on the flow levels and direction, while maintaining the habitat available for plants and animals that benefit from low flow conditions. Large woody debris can also be added to deflect flows from unstable areas.

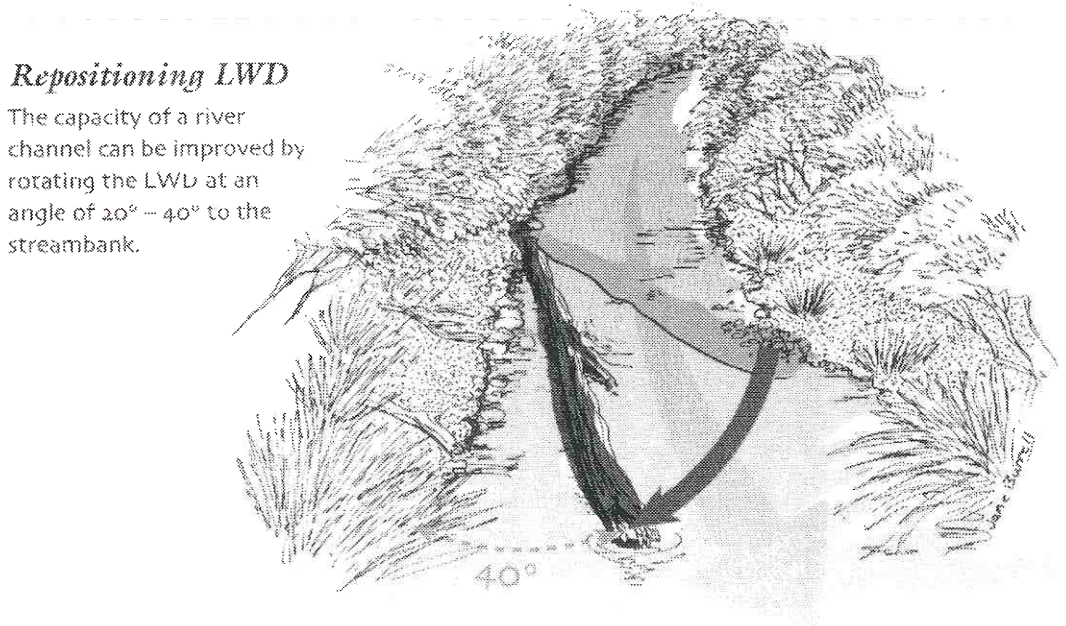


Figure 10: Repositioning large woody debris (Gippel et al, 1998).

Useful references on erosion control

Pen, L.J. (1999) *Managing Our Rivers*, Water and Rivers Commission, Perth.

Water and Rivers Commission (2001) *Stream Stabilisation*. River Restoration Report No. RR 10.

Raine, A.W. & Gardiner, J.N. (1995) *Rivercare — Guidelines for Ecologically Sustainable Management of Rivers and Riparian Vegetation*. Land and Water Research and Development Corporation. Canberra.

Regeneration and revegetation

In areas that still retain native trees and understorey natural regeneration is the cheapest and easiest option. Control of stock access and invasive weeds is essential to this strategy. Natural regeneration can also be assisted by making small piles of branches and burning to promote germination through smoke and heat. Smoke water can also be applied to encourage germination. Another technique to assist regeneration involves laying the seed bearing parts of native plants directly onto the ground, allowing seeds to fall from them. This is called brushing.

Sections of the rivers that have been heavily grazed and cleared generally contain more weeds and have a diminished seedbank. Options for these areas include: direct seeding, brushing with woody natives that contain seed, pre-seeded matting and planting of tube stock. The riparian zone should be planted in a wide band with a mixture of deep rooted trees and shrubs. A diverse suite of species should be planted including trees, shrubs, sedges, rushes, herbs and native grasses. This not only improves the habitat value of the foreshore, but also provides a matrix of different root structures which will improve bank stability and assist in erosion control.

Good site preparation is often crucial to the successful revegetation. Elements that need to be considered are weed removal, soil amelioration and preparation of the soil surface for direct seeding or planting. Pest control and ongoing control of weeds also need to be factored into the project. Planting and sowing at the right time of year, and at the appropriate depth will also influence the success of the revegetation effort.

The different revegetation techniques are outlined below:

Direct seeding

Direct seeding has a few distinct advantages over other methods:

- it is less time consuming and requires less labour than planting tube stock;
- a mixture of trees, shrubs, sedges and ground covers can be planted at the same time, resulting in a plant community with a natural look;
- it is less expensive than providing tube stock, and on the rivers several areas have been identified as having good potential for the collection of local provenance[2] seed; and
- the natural root development of seedlings grown from seed usually results in plants developing deep taproots, requiring less follow-up care.

However, direct seeding can be less reliable than planting, due to predation, specific germination requirements not being met, and poor conditions for direct seeding. Direct seeding may not be possible when high winds or strong water flow is present.

Planting

Planting is the appropriate technique for embankment and in-stream revegetation, and where direct seeding is difficult due to insufficient seed, excessive weed competition etc. In these cases nursery tube stock is ideally supplied from local provenance seed. A rule of thumb guide for planting densities is 500:50:5 herb/sedges to shrubs to trees. Sedges and rushes should be planted in spring, when the water table is beginning to fall and the soil is still moist. Other seedlings should be planted when they are actively growing; the surrounding soil is moist and follow-up rain is likely (usually between May and July). Care should be taken to ensure that specimens are not root

[2] *The term provenance is used to identify the geographic origin of seeds or parent plant. Often, genetically distinct local forms or varieties of a plant have evolved to suit a specific range of conditions, including soil, climate and water regimes. Direct seeding with local provenance seed ensures that the resulting plants will be suited to the localised environmental conditions and maintain the ecological integrity of existing native plant communities (GeoCatch, 1999).*

bound, and that minimal damage to the roots occurs when removing from pots.

Brush

The use of brush is an excellent technique in all zones apart from the channel bed. This technique can be used to spread seed and assist with erosion control simultaneously. Brush should be harvested from plants at seed maturity and laid immediately on to the revegetation site. Brush along the embankment should be secured in place. Species suitable for this technique are those which retain seed on the plant, but shed it when the plant dries out. This includes many of the myrtaceous species (eg. peppermints, tea-tree, paperbarks, marris, jarrah, blackbutts, flooded gums, Astartea, Kunzea).

Pre-seeded matting

Pre-seeded matting involves spreading seeds onto an appropriate fibremulch, and laying the mat on-site in early winter after germination. This technique is excellent for steep embankments, since it provides erosion control and revegetation in a single stage. It is only suitable for seeding with rushes and sedges, since matting usually requires rolling to transport to site.

Useful references on natural regeneration and revegetation

Bradley, J (1988) *Bringing Back the Bush: The Bradley Method of Bush Regeneration*. Lansdowne Press, Sydney.

Buchanan, R.A. (1989) *Bush Regeneration: Recovering Australian Landscapes*. TAFE Open Training and Education Network. Strathfield, NSW.

Scheltema, M (1993) *Direct Seeding of Trees and Shrubs*. Greening Western Australia, Perth.

Water and Rivers Commission (1999) Revegetation: *Revegetating riparian zones in south-west Western Australia*. Water and Rivers Commission River Restoration Report No. RR4.

Water and Rivers Commission (1999) *Revegetation: Case studies from south-west Western Australia*. Water and Rivers Commission River Restoration Report No. RR5.

Water and Rivers Commission (1999) *Using rushes and sedges in revegetation of wetland areas in the south west of WA*. Water and Rivers Commission River Restoration Report No. RR8.

Water and Rivers Commission Water Note 20, *Rushes and Sedges*.

Weed control

Weed invasion is a major threat along the three river systems and within the catchment. Fencing the rivers and restricting stock access will result in the need for extra weed control. There is a need for coordinated weed control across the whole catchment for any eradication and control to be really effective.

In foreshore areas, removal or control of weeds must be completed with great care. In the riparian zone the erosive power of water requires consideration when planning a weed strategy. Clearing weeds in an unplanned manner could result in erosion in the river channel.

Weed control principles to keep in mind include:

- Weeds thrive in disturbed areas and areas of bare ground.
- Fire promotes weeds. Burning a remnant which is weed infested will only make the weeds worse, unless there is follow-up weed control and revegetation. Native plants cannot compete with the rapid growth of weeds, which then become a greater fire hazard.
- Aggressive perennial weeds that spread readily along riparian corridors are the most important to concentrate on eradicating, for example, arum lily, blackberry, bridal creeper, watsonia, and pennyroyal.
- If weed control is carried out, revegetate to prevent further weed invasion in the bare soil.
- Some native plants look and act like weeds. Do not begin weed control until you are sure a plant is a weed.

Chemical control of weeds on waterways requires careful consideration. Issues which must be considered prior to any type of chemical control include the

effects of the herbicides on native flora and fauna and the impact on water quality. The use of Roundup Biactive is recommended.

In some cases it may be appropriate to use restricted grazing to control weeds. Where banks are steep and sandy or prone to collapse or where the objective is to maintain high quality riparian habitat, grazing should be avoided. However, where the riparian zone has a history of grazing and the exclusion of stock would lead to an explosion of weeds, maintenance of the zone by light grazing is an option. The landholder needs to keep a watchful eye on the riparian zone to see that it has an adequate cover of a mixture of native and pasture plant species and erosion is not occurring. Troublesome major weeds should be identified at an early stage and eradicated immediately (Pen, 1999).

Useful references for weed identification and methods of control

Dixon, B. & Keighery, G. (1995) Suggested methods to control weeds. In: *Managing Perth's Bushlands*, Scheltema, M. & Harris, J. (eds). Greening Western Australia. Perth. WA.

Hussey, B.M.J., Keighery, G.J., Cousens, R.D., Dodd, J. & Lloyd, S.G. (1997) *Western Weeds: A Guide to the Weeds of Western Australia.* Plant Protection Society of Western Australia. Victoria Park, Western Australia.

Hussey, B.M.J. & Wallace, K.J. (1993) *Managing Your Bushland.* Department of Conservation and Land Management . Como, Western Australia.

Water and Rivers Commission (1999) *Revegetation: Revegetating riparian zones in south-west Western Australia.* Water and Rivers Commission River Restoration Report No. RR4.

Water and Rivers Commission Water Note 22, *Herbicide use in wetlands.*

Water and Rivers Commission Water Note 15, *Weeds in Waterways.*

Information can also be obtained from the river action plan coordinator and the Department of Agriculture.

Feral animal control

Rabbits are evident along the rivers and in the catchment. Rabbits severely impact on native vegetation and hinder regeneration and revegetation. Landholders and managers are encouraged to control rabbits through baiting, shooting, fumigation and destruction of warrens.

The value to native fauna of vegetated corridors along the rivers is undermined by the presence of foxes. Foxes can be controlled by baiting and shooting. The effectiveness of fox control is greatly improved if undertaken on a large scale, involving as many landholders as possible.

Specific advice on rabbit and fox control can be obtained from the Department of Agriculture.

Water quality

Waterways in agricultural areas receive large quantities of nutrients, either dissolved in water, adhering to small soil particles eroded from the land or contained within dead plant and animal material, including manure washed from paddocks. Outlined below are a number of ways to minimise soil erosion and nutrient loss (Pen, 1999).

Vegetative buffers

Vegetated buffers alongside waterways can intercept and slow runoff and thereby trap suspended sediment, including organic material. Research has shown that vegetative buffers 10-50 m wide can achieve phosphorus and nitrogen filtration rates in the order of 50-100% (Pen, 1999). A vegetative buffer need not be of native vegetation and can be a simple grassy strip which is fenced off to control grazing. The nutrients assimilated by the vegetation can be utilised by crash grazing or preferably in hay production since this latter does not involve livestock returning nutrients to the grassy border as urine and manure.

Vegetation within the waterway itself forms a longitudinal buffer which similarly slows the flow rate, prevents erosion and traps soil, sediment and organic matter.

Farming practices (Kingdon, 2000)

In reducing soil erosion, the key is to keep reasonably high levels of vegetation on the soil for as long as possible, and especially during times of high erosion risk. Achieving these conditions requires:

- use of reduced tillage and direct drilling;
- use of crop and pasture rotations that include well managed perennial grasses and legumes;
- in row cropping, use permanent raised beds and controlled traffic;
- managing organic matter by retaining stubble and including pastures in a crop rotation; and
- keep vigorous plant growth through appropriate soil, crop and water management.

Cultivation along the contours, rather than perpendicular to them, will slow the rate at which water flows across the land, reducing soil erosion by as much as 50% (Pen, 1999).

Soil testing and fertiliser use

Fertiliser is generally applied according to traditional practice, usually some time before the winter/spring growing season. Today, we know that after a number of years of fertiliser application, many soils are rich in nutrients but may be deficient in a few trace elements (Pen, 1999). Soil should be tested to determine fertiliser requirements and avoid excess application of nutrients, a portion of which will find their way into waterways.

Useful references for protecting water quality through farming practices

Kingdon, B.K. (2000) *Fertliser Use Guidelines for the Swan Coastal Plain of WA*. Vasse-Wonnerup LCDC, Busselton WA

Prosser, I. Karssies, L., Ogden, R. & Hairsine, P. (1999) Using buffers to reduce sediment and nutrient delivery to streams. In: *Riparian Land Management Technical Guidelines: Volume Two: On-ground Management Tools and Techniques*, Price, P & Lovett, S (eds), LWRRDC. Canberra.

General recommendations

It is recommended that landholders consider the following:

1. Make the commitment to retain and protect the river, tributaries and drains, and restrict stock access.
2. Fence the river to exclude stock permanently, or to achieve management that allows for bank stability and native vegetation establishment and protection.
3. Create a corridor that promotes the movement of wildlife and recreates their habitat.
4. Eradicate weeds, particularly invasive weeds, dominating the riparian zone.
5. Utilise current sources of funding to fence the river and its tributaries, add stock crossings or bridges, and control pests such as grasshoppers and rabbits that make revegetation difficult.
6. Consider widening the riparian zone in various ways; options aside from indigenous vegetation could include commercial trees, fodder trees, commercial plantings of native shrubs for seed, flower production, dried foliage etc.
7. Use management techniques that will minimise soil erosion and nutrient loss to waterways.

It is recommended that the Vasse-Wonnerup LCDC consider the following:

1. Encourage and support community effort to fence the rivers to enable control of stock access.
2. Encourage, as a priority, the protection of areas of the rivers still retaining native fringing vegetation. It is more cost effective to protect these areas now than to restore them later after further degradation has occurred.
3. Seek advice from the Water and Rivers Commission regarding erosion problems requiring remedial action and facilitate rehabilitation where possible.
4. Provide encouragement and support to landholders to undertake revegetation using a diverse suite of local native species (including trees, shrubs, sedges, rushes, herbs and native grasses).
5. Investigate ways of encouraging, coordinating and supporting the community in weed control efforts on a catchment scale.
6. Work with the Department of Conservation and Land Management to improve weed control and management of the rivers within CALM estate.
7. Investigate possibilities for management and vesting of sections of the rivers contained in unvested Crown land.
8. Encourage and coordinate feral animal control along the rivers and within the catchment.
9. Extend the focus to include the rehabilitation of the smaller drains and tributaries to achieve the greatest impact on stripping sediments and nutrients before they reach the river channel.
10. Promote management techniques that minimise soil erosion and nutrient loss to waterways, such as; buffer strips, soil testing and maximizing vegetation cover on the soil.

6. Abba River Foreshore Condition and Recommendations for Management

Maps 1 to 11 show the Abba River and adjoining land titles from Scott Rd to the Vasse-Wonnerup wetland system.

The maps show the foreshore condition of the river as assessed using the Pen-Scott method (see section 3 of this report for details of the study method).
Also shown on the maps are fencing status, weeds and stock crossings.

A fold-out legend is provided at the back of the report.

The notes accompanying each map contain background information and management advice.

Figure 11 provides an index for the individual maps.

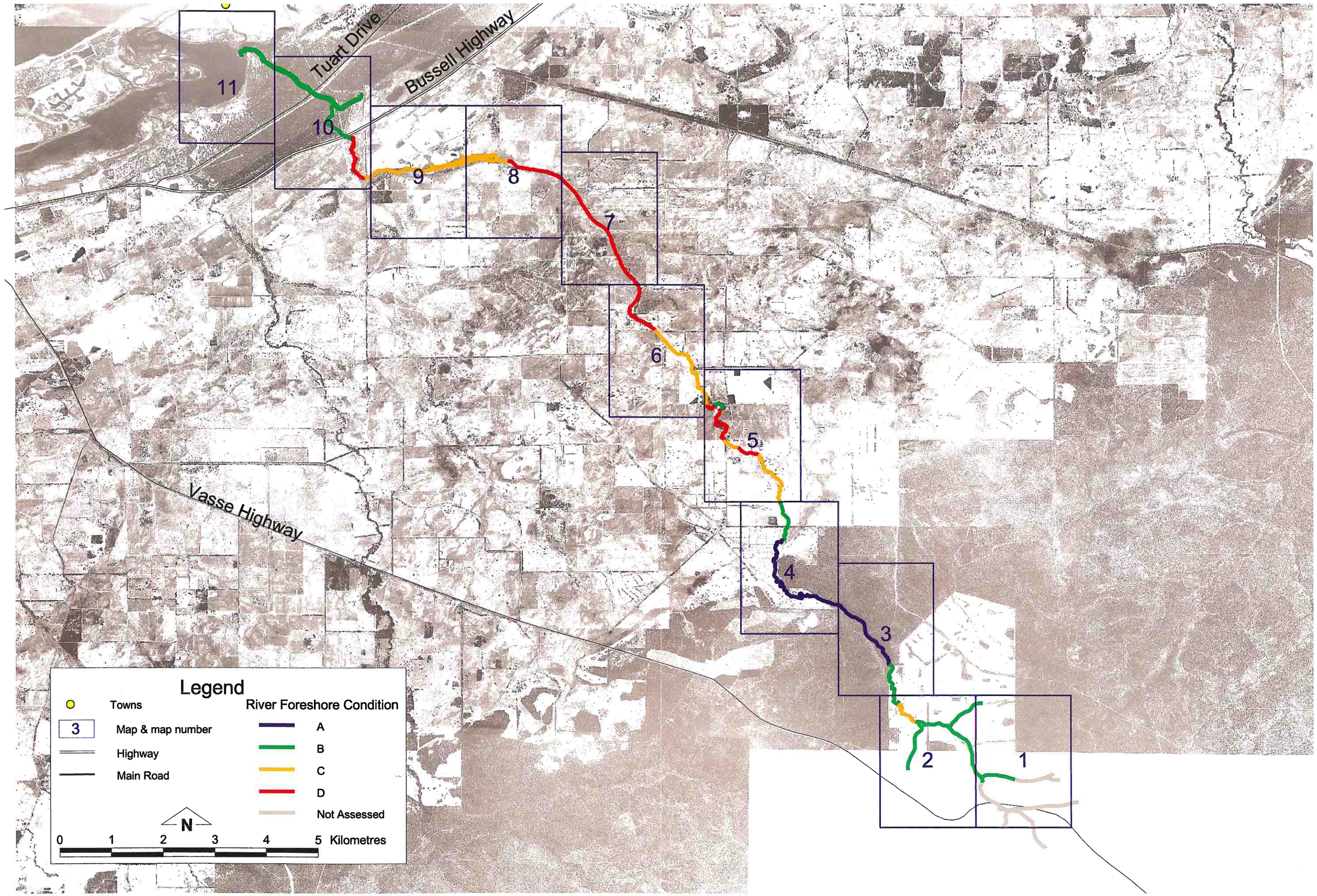
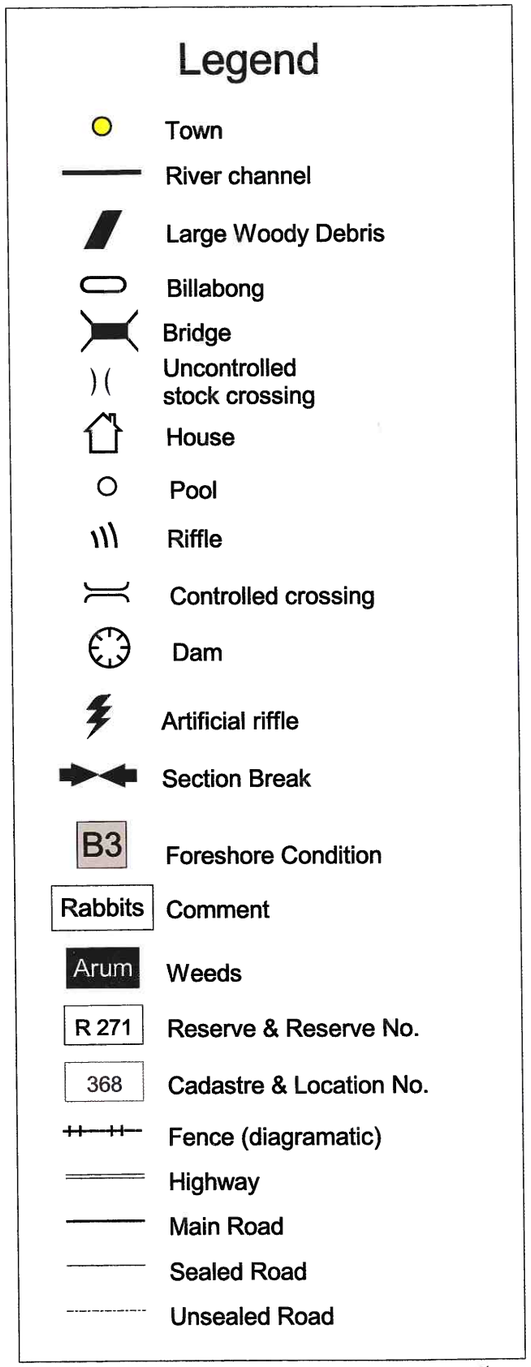


Figure 11: Index map for locating sections of the Abba River. Map also shows foreshore condition.



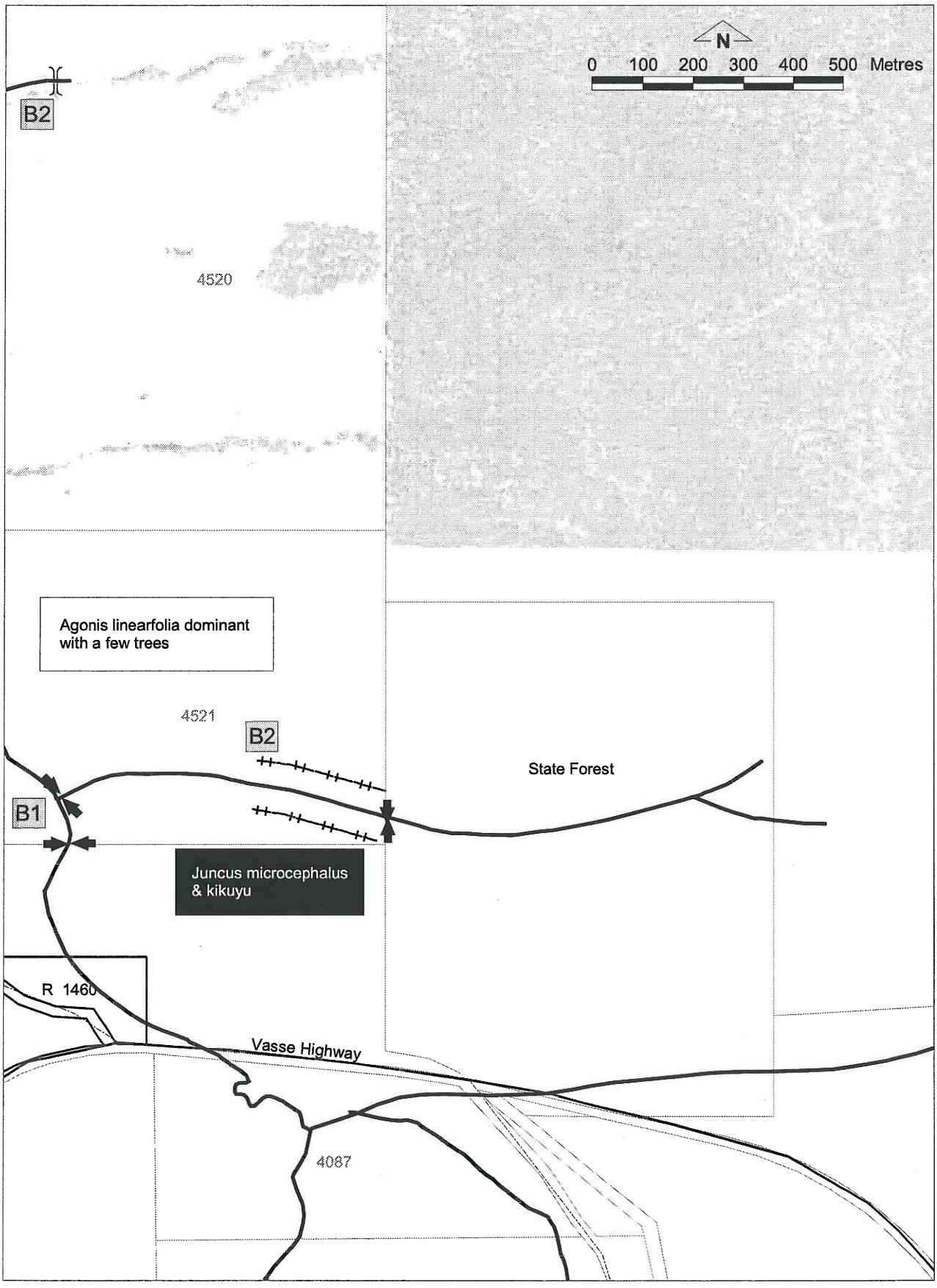
Map 1

The Abba River has a number of headwater streams in farmland in the Treeton Hills land system within the Blackwood Plateau. The dominant landform pattern here is of gently inclined ridges and hill crests with gently to moderately inclined sideslopes down to valley floors. The valley floors may be narrow and v-shaped, but are more commonly broad and poorly drained with alluvial soils.
Outside of State Forest much of this land system has been cleared, but remnants of jarrah-marri forest are still present.

Issues	Comments
Fencing	A small amount of fencing exists on one of the headwater streams on location 4521. The remainder of the streamlines throughout this location are unfenced and ungrazed. A vineyard is the current land use.
Soils and banks	The creeks are contained within the narrow v-shaped drainage depressions of the Treeton Valley land unit. The banks are generally well vegetated and stable.
Vegetation	The creeks are dominated by tea tree (*Agonis linearfolia*) with few trees. A number of trees not native to the area have been planted along the main channel. One of the tributaries was cleared about 13 years ago, then fenced and planted with non-native trees. Mountain marri-jarrah woodland is found in this area.
Weeds	Kikuyu and an exotic rush.
Special features	The landholder considered that *Phytophora cinnamomi* fungus (dieback) was coming from State Forest upstream and affecting trees along the river.

Map 1: Management advice

1. Continue protection of the river from stock grazing and trampling.
2. Monitor weed invasion and control as necessary.
3. Plant with a variety of local native species to increase diversity and width of vegetation in the riparian zone. Plant densely to inhibit weed growth. See Appendix 1, columns 1 and 2 to compile a species list suitable for this area.



Abba River Map 1

Map 2

The river continues through farmland with a number of tributaries joining the main channel. The river has been extensively fenced throughout location 4520 using Streamlining Funds. Native vegetation is regenerating along the river in this location since grazing has been controlled. Further fencing of tributaries is planned. A large dam was constructed on the river during 2000/2001.

Issues	Comments
Fencing	The river has been fenced throughout location 4520 and further fencing of tributaries is planned. There is some fencing along one of the tributaries in location 3810 though the river in the main part is unfenced throughout this location.
Soils and banks	The river is contained within the Treeton Fertile Flats land system. Deep alluvial soils exist, with red-brown sandy and loamy soils.
Vegetation	The native vegetation along the river on location 4520 is regenerating since stock access has been controlled. Exotic vegetation has been planted along a fenced section of the river on location 3810.
Weeds	Kikuyu, thistles, deadly nightshade and an exotic rush.
Special features	A large dam has been constructed on the main channel and one of the tributaries on location 3810 during 2000/2001.

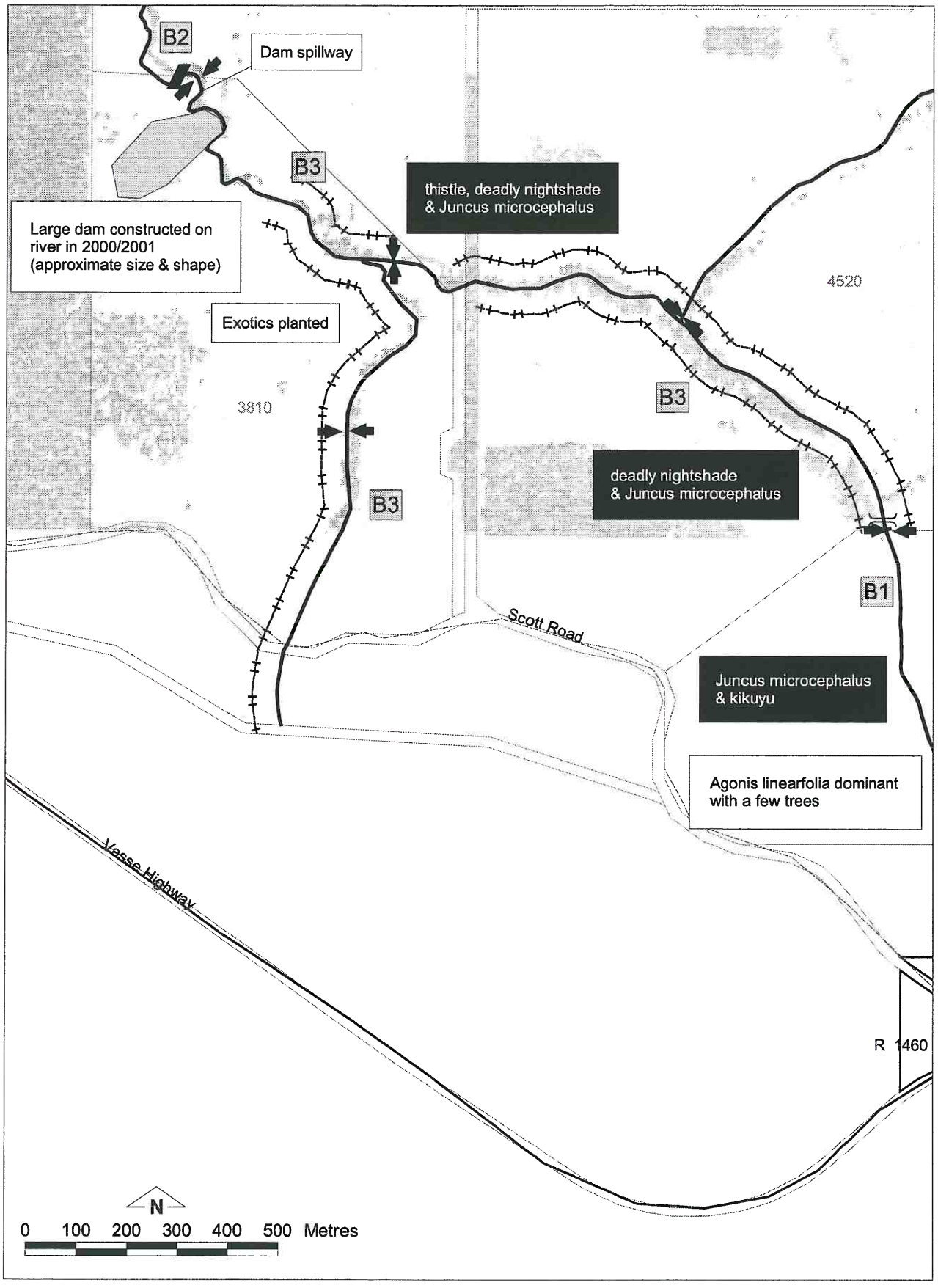
Map 2: Management advice

1. Check the fenced area of river for weed invasions and control as necessary. Kikuyu may begin to dominate now that grazing is being excluded. Dense kikuyu will restrict the regeneration of native species. Control may be required to ensure regeneration of native species can occur.

2. Continue fencing of tributaries on location 4520 to assist with bank stabilisation. Undertake planting with local native species of rushes, sedges, shrubs and trees where natural regeneration is unlikely to occur. Plant densely to inhibit weed growth. See Appendix 1, columns 1 and 2 to compile a species list suitable for this area.

3. Control grazing of the river on location 3810. Establish local native rushes and sedges, shrubs and trees along the river to assist with bank stabilisation and nutrient and sediment stripping. Plant densely to inhibit weed growth. See Appendix 1, columns 1 and 2 to compile a species list suitable for this area.

4. Undertake planting of local native rushes, shrubs and trees around the dam to protect water quality and provide fauna habitat.



Abba River Map 2

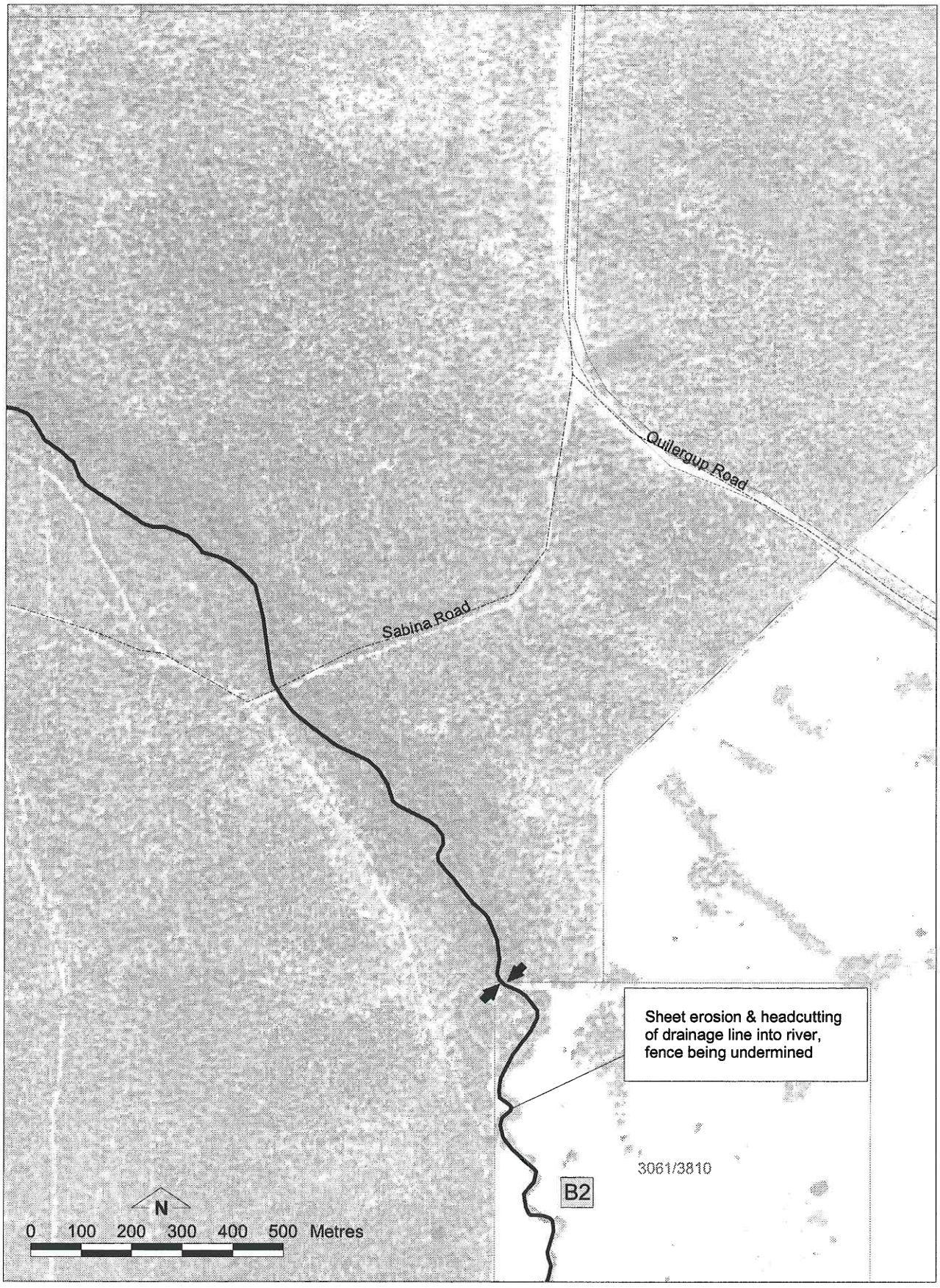
Map 3

The river continues meandering through farmland before entering State Forest.

Issues	Comments
Fencing	The river is not fenced throughout this location.
Soils and banks	The river is contained with the Treeton Fertile Flats land system. Deep alluvial soils exist, with red-brown sandy and loamy soils. Where the river is close to the boundary fence headcutting of drainage lines into the river is occurring. Elsewhere the banks are generally stable.
Vegetation	A thin strip of vegetation exists along the river, mainly tea tree (*Agonis linearfolia*) and marri. In the north-west corner where it enters State Forest the river runs through a small area of remnant vegetation. The river is densely vegetated through State Forest.
Weeds	Pasture grasses.
Special features	The river through State Forest is contained within dense native vegetation.

Map 3: Management advice

1. Fence the river to allow control of stock. This section of the river is a priority for protection as it still retains native vegetation. to maintain bank stability. It is significantly more difficult and expensive to re-establish vegetation than to protect it while it still exists. Natural regeneration will occur in these areas as there is existing native vegetation to provide a seed source.
2. Construct stable stock crossings or bridges and watering points or troughs.
3. Monitor weed invasion and undertake control as required.
4. Seek advice from the Water and Rivers Commission regarding the way to control the erosion where a tributary is headcutting close to the fenceline.



Abba River Map 3

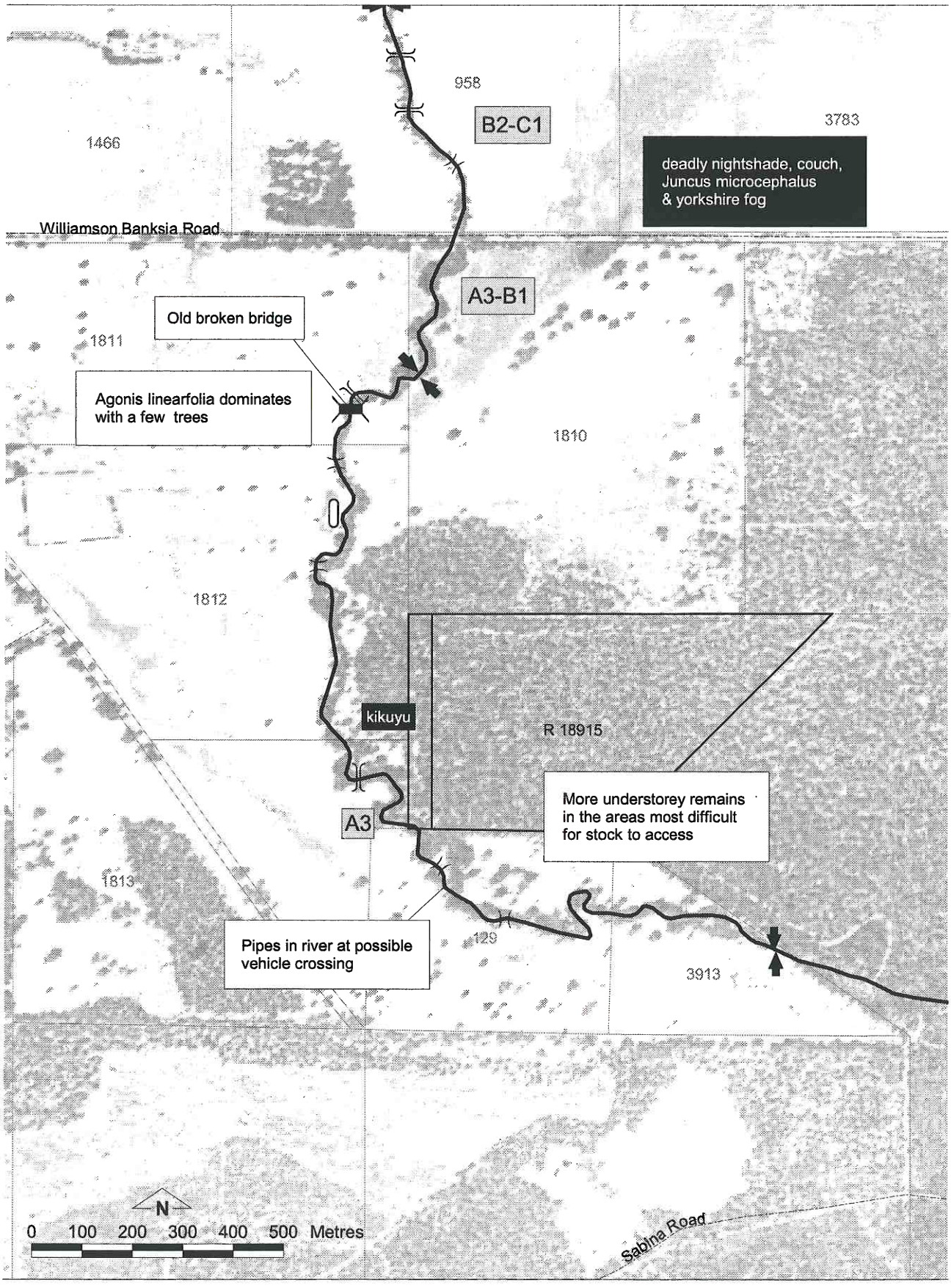
Map 4

After passing through an area of State Forest the river again enters farmland. The first half of the river on this map is contained within the Yelverton Shelf land system on the edge of the Blackwood Plateau. The river then leaves the foothills and moves on to the Abba Plains. Native vegetation remains along the river although it is becoming increasingly degraded as a result of grazing and trampling by stock.

Issues	Comments
Fencing	The river is not fenced and is grazed throughout.
Soils and banks	In locations 3913, 129, 1813 and half of 1812 the river is contained within the Yelverton Fertile Flats land unit. Deep alluvial soils exist, with red-brown sandy and loamy soils. Locations 1810 and 958 are within the Abba Fertile Flats land unit. These are well drained flats with sandy gradational grey-brown soils and some red-brown sands and loams. Bank erosion is occurring at uncontrolled stock crossings.
Vegetation	Through locations 3913, 129, 1813, 1812, 1811 and 1810 native vegetation is still in good condition along the river, particularly in areas where steep banks make access by stock more difficult. A very thin strip of native vegetation still exists along the river in location 958, though it is degraded through trampling and grazing by cattle.
Weeds	Pasture grasses, kikuyu, couch, deadly nightshade and exotic rushes occur in this section.
Special features	Native vegetation in reasonable condition still exists throughout much of this section of river. Natural regeneration will occur if the river is protected from grazing and weeds controlled to minimise competition.

Map 4: Management advice

1. Fence the river to allow control of stock. This section of the river is a priority for protection as it still retains native vegetation to maintain bank stability. It is significantly more difficult and expensive to re-establish vegetation than to protect it while it still exists. Natural regeneration will occur in these areas as there is existing native vegetation to provide a seed source.
2. Construct stable stock crossings or bridges and watering points or troughs.
3. Following fencing, monitor the river for weed infestations. Once grazing is controlled some weeds may flourish, restricting regeneration of native species and posing a fire risk. Undertake weed control as necessary.



Abba River Map 4

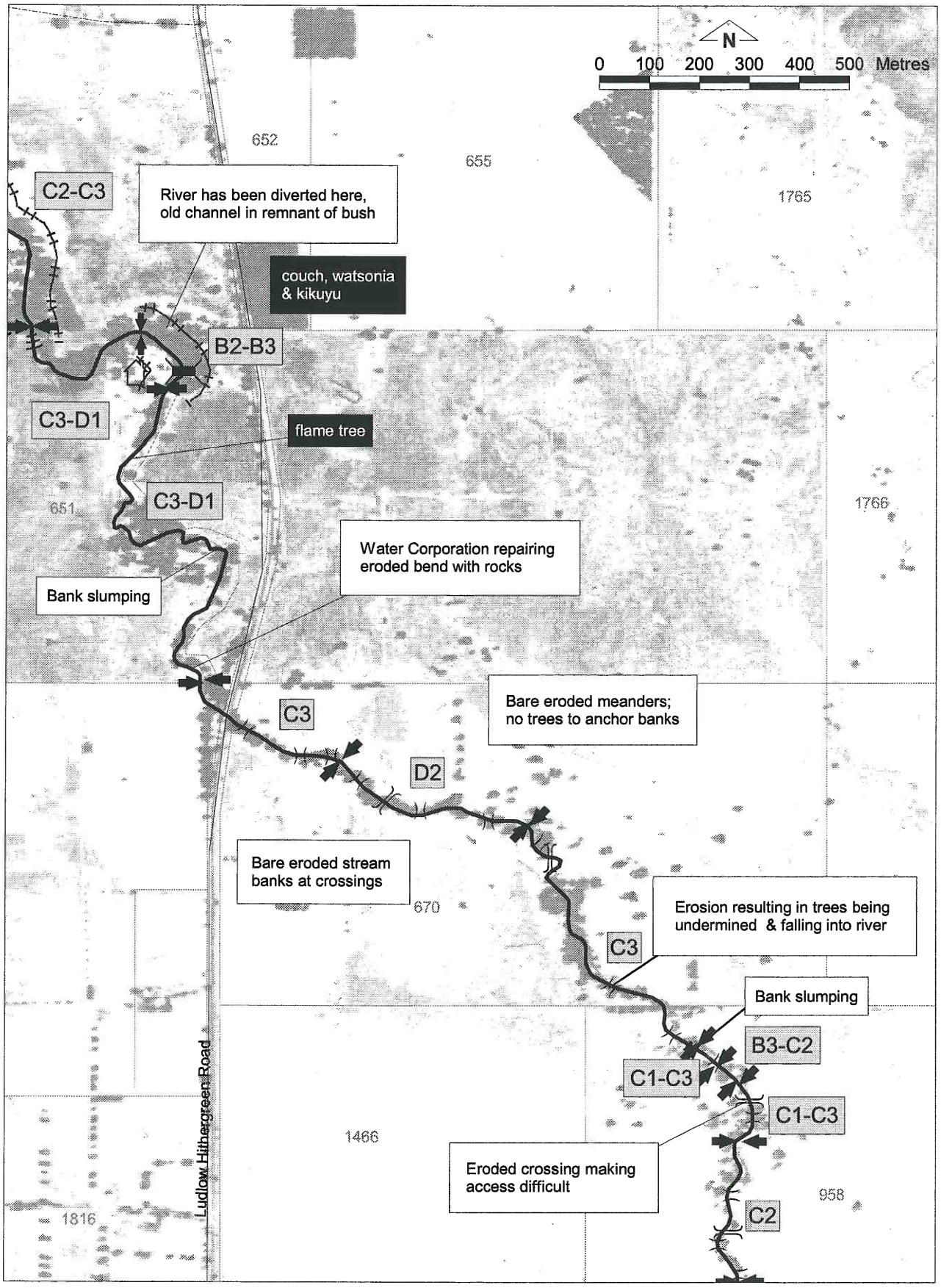
Map 5

The river meanders across the Abba Plain. The Abba Plain occupies the major portion of the Geographe catchment with the dominant landform pattern being an intricate patchwork of slight depressions and slight rises. The depressions tend to become waterlogged in winter while the rises tend to suffer subsoil waterlogging. An extensive drainage network has been constructed on the Abba Plains to allow agricultural development and has resulted in the river being highly modified. Within the Abba Plains are a variety of different landforms and soils.

Issues	Comments
Fencing	Most of the river in this section is not fenced except for a small section on location 651. Location 652 is fenced from the boundary.
Soils and banks	The river is contained within the Abba Fertile Flats land unit. Within this unit are well drained flats with sandy gradational grey-brown soils, some red-brown sands and loams. Bank erosion is occurring throughout particularly at stock crossing points and on meander bends. Erosion is resulting in trees being undermined and falling into the river.
Vegetation	There are some trees along the river, though very little understorey. There is no sign of regeneration.
Weeds	Couch, kikuyu and pasture grasses. Watsonia exists within the fenced area on location 651.
Special features	A badly eroding bend on location 651 is being stabilised with rock by the Water Corporation. A rocky section exists between locations 651 and 652.

Map 5: Management advice

1. Fence the river to allow control of stock.
2. Construct stable stock crossings or bridges and watering points or troughs.
3. Monitor weed invasion and undertake control as required.
4. Control watsonia on location 651.
5. Native vegetation may regenerate on location 958 once stock are excluded. Weed control will be required to ensure natives aren't outcompeted. Monitor natural regeneration for a couple of years and undertake planting if necessary. See Appendix 1, columns 1 and 2 to compile a species list suitable for this area.
6. On locations 670 and 651 establish local native rushes and sedges, shrubs and trees along the river to assist with bank stabilisation and nutrient and sediment stripping. Plant densely to inhibit weed growth. See Appendix 1, columns 1 and 2 to compile a species list suitable for this area.



Abba River Map 5

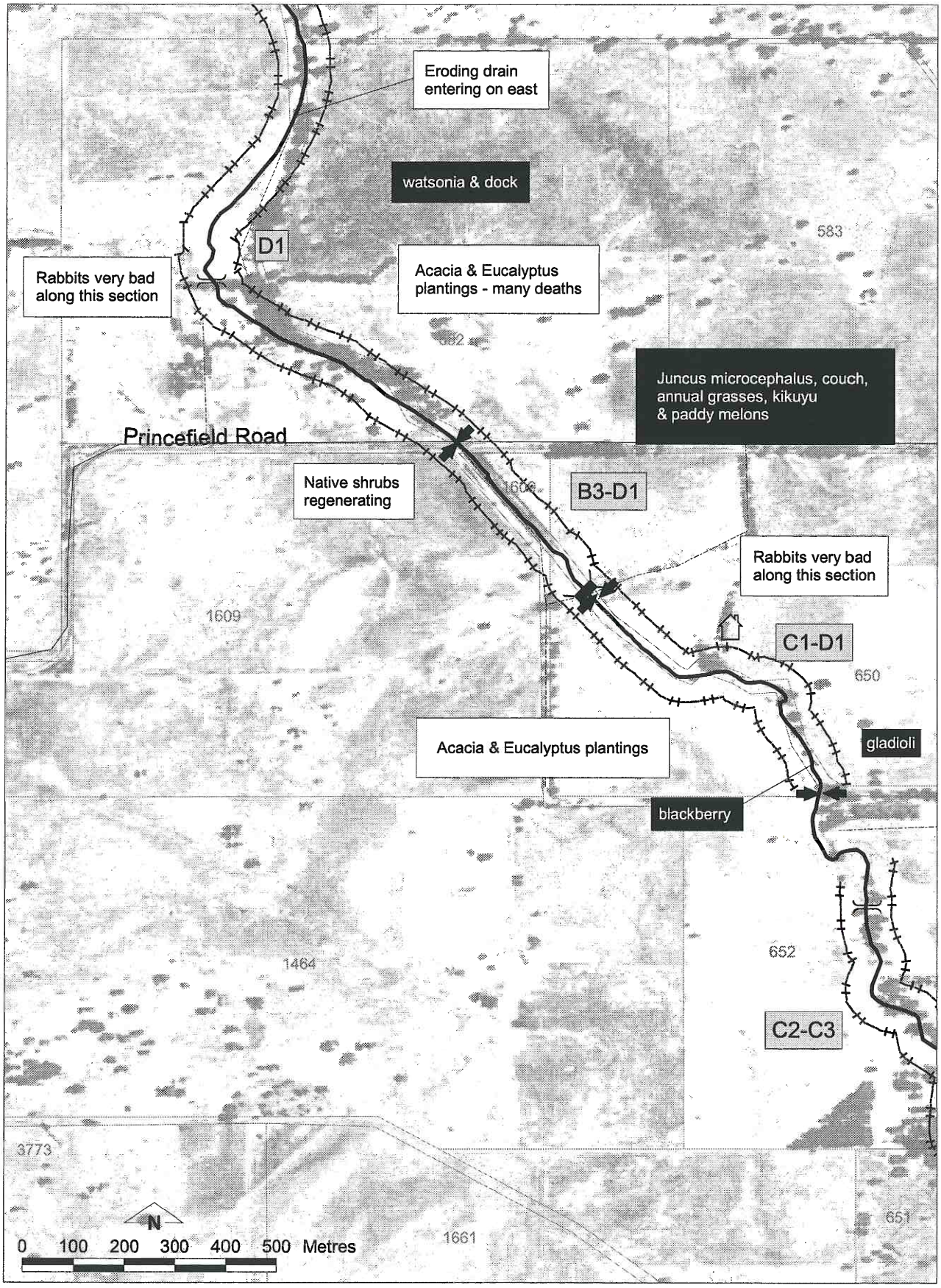
Map 6

The river continues across the Abba Plains. North of Princefield Road, the topography, soils and vegetation change from the Abba Fertile Flats land unit to the less well drained Abba Flats. Soils turn from sandy gradational grey-brown soils, red-brown sands and loams to sandy topsoils over clay. Vegetation communities change as a result with flooded gums and paperbarks becoming dominant. The river has been highly modified through this section as part of the drainage system. Very little native vegetation remains and the channel has been dug out.

Issues	Comments
Fencing	Much of location 652 is fenced on both sides. It is planned to fence the rest of the river on this block. A vehicle and stock crossing has been constructed. The remainder of the river on this map sheet is fenced on both sides.
Soils and banks	Up to location 582 the river is contained within the Abba Fertile Flats land unit. Soils are sandy gradational grey-brown soils, some red-brown sands and loams. From location 582 onwards soils are generally less well drained with sandy topsoil over clay. These soils are less stable and more sediment is mobile in these areas.
Vegetation	There are some trees along the river, though very little understorey. There is no sign of regeneration. Planting of trees has been undertaken in many areas along this section of river with a low success rate due to grasshoppers, rabbits and the need to water during the first summer.
Weeds	Couch, annual grasses, kikuyu, paddy melons, watsonia and dock. Blackberry on location 650.
Special features	Rabbits are very bad along this section of the river.

Map 6: Management advice

1. Finish fencing on location 652 as proposed. Continue with planting using local native rushes and sedges, shrubs and trees for bank stability and nutrient and sediment stripping. See Appendix 1, columns 1 and 2 for species found in Abba Fertile Flats.
2. Control blackberry on location 650.
3. On location 650 establish local native rushes and sedges, shrubs and trees along the river to assist with bank stabilisation and nutrient and sediment stripping. Plant densely to inhibit weed growth. See Appendix 1, columns 1 and 2 for species found in Abba Fertile Flats.
4. On location 582 establish local native rushes and sedges, shrubs and trees along the river to assist with bank stabilisation and nutrient and sediment stripping. Plant densely to inhibit weed growth. See Appendix 1, columns 3, 5 & 8 to compile a species list suitable for this area.
5. Undertake rabbit control, with assistance from Water Corporation where possible
6. Use tree guards to protect seedlings from rabbits.



Abba River Map 6

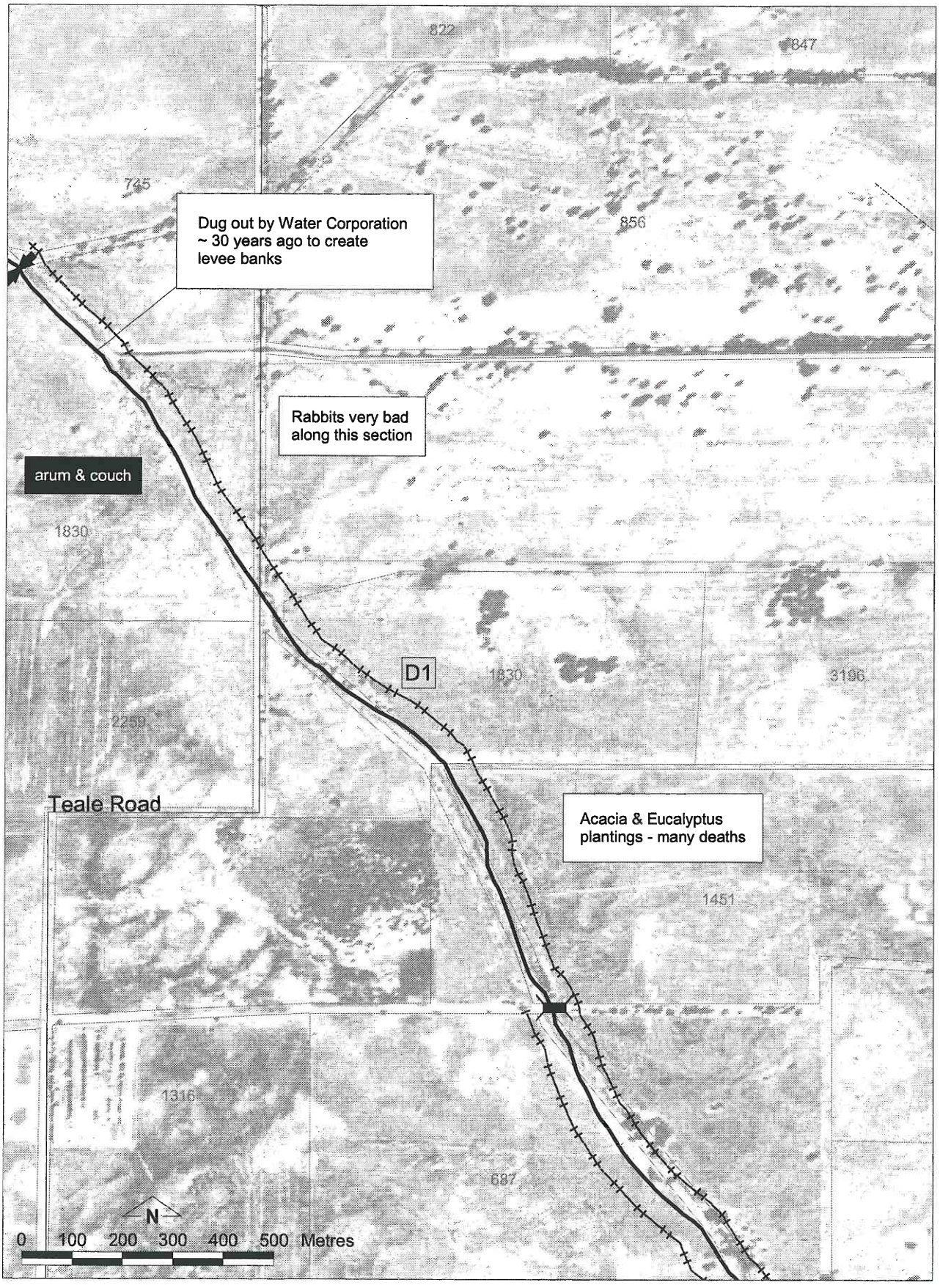
Map 7

The river continues across the plain through a variety of Abba Plain soils, mainly poorly drained sandy topsoil over clay. Very little native vegetation remains to control erosion and the river is actively eroding throughout. The channel has been cleared and modified in the past by the Water Corporation.

Issues	Comments
Fencing	The river is fenced on both sides on location 687. Some fencing exists on one side of the river through other locations.
Soils and banks	Soils are generally poorly drained sandy topsoils over clay. The banks are actively eroding and the sediment is being deposited downstream.
Vegetation	Very little native vegetation remains along this section of river as it has been cleared for drainage works. Some flooded gums, marris, paperbarks and rushes remain and could be a focus for regeneration if protected from stock grazing.
Weeds	Pasture grasses, kikuyu and couch. Arum lily on location 745 sprayed each year.
Special features	Revegetation is very difficult because of grasshoppers, rabbits and the need to water the first summer.

Map 7: Management advice

1. Fence the river to allow control of stock.
2. Construct stable stock crossings or bridges and watering points or troughs.
3. Monitor weed invasion and undertake control as required.
4. Continue arum lily control.
5. Establish local native rushes and sedges, shrubs and trees along the river to assist with bank stabilisation and nutrient and sediment stripping. Plant densely to inhibit weed growth. See Appendix 1, columns 3, 5, and 8 to compile a species list suitable for this area.
6. Undertake rabbit control.
7. Use tree guards to protect seedlings from rabbits.



Abba River Map 7

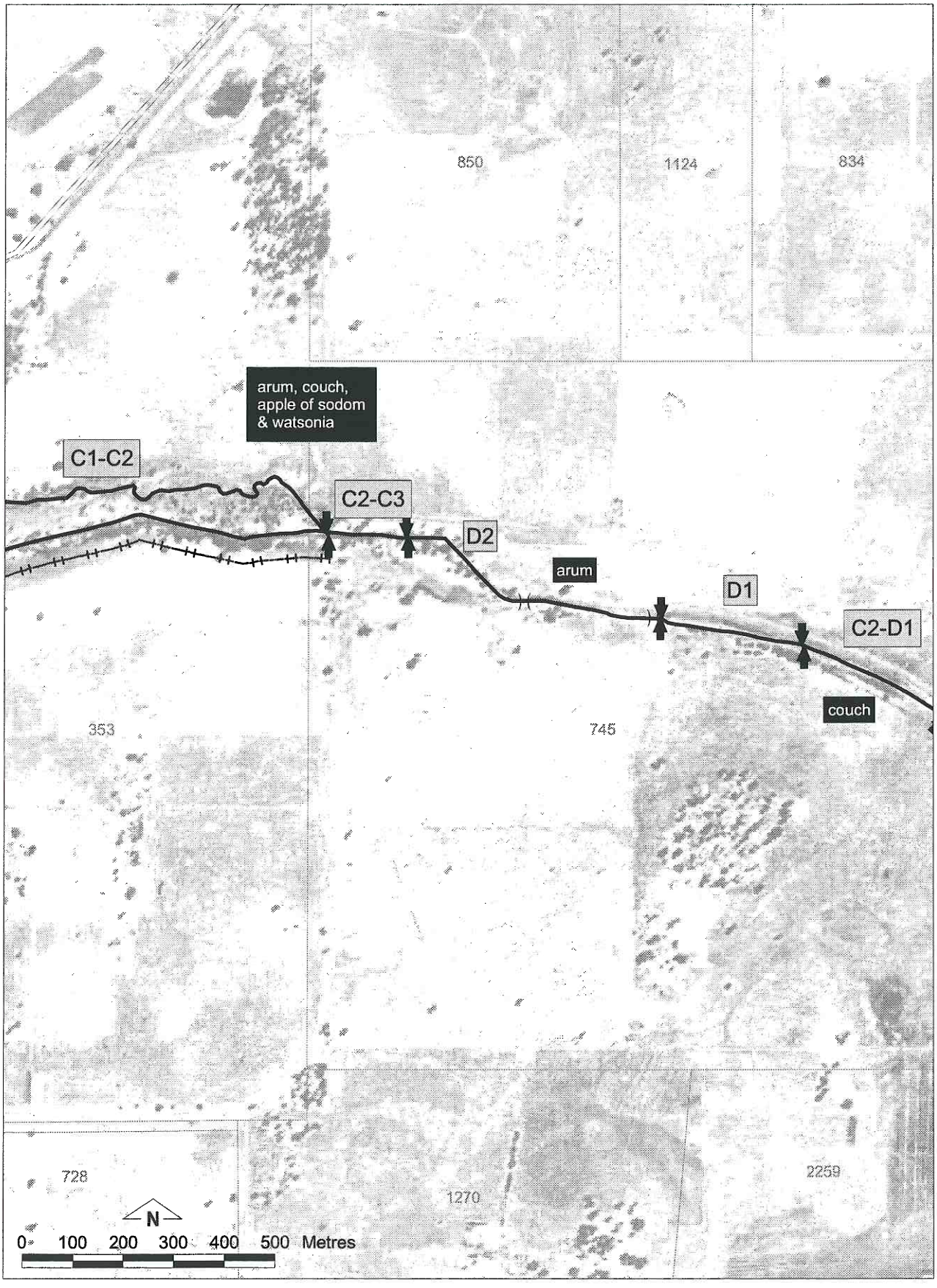
Map 8

The river continues across the plain through a variety of Abba Plain soils, mainly poorly drained sandy topsoil over clay. Very little native vegetation remains to control erosion and the river is actively eroding throughout. The channel has been cleared and modified in the past by the Water Corporation.

Issues	Comments
Fencing	The river is not fenced through location 745. Fencing exists on the south of the river in location 353.
Soils and banks	Soils are generally poorly drained sandy topsoils over clay. The banks are actively eroding and the sediment is being deposited downstream.
Vegetation	Very little native vegetation remains along this section of river as it has been cleared for drainage works. Some flooded gums, marris, paperbarks and rushes remain and could be a focus for regeneration if protected from stock grazing.
Weeds	Couch, arum lily, apple of sodom and watsonia.
Special features	Revegetation is very difficult because of grasshoppers, rabbits and the need to water the first summer.

Map 8: Management advice

1. Fence the river to allow control of stock.
2. Construct stable stock crossings or bridges and watering points or troughs.
3. Monitor weed invasion and undertake control as required.
4. Continue arum lily control.
5. Control watsonia.
6. Establish local native rushes and sedges, shrubs and trees along the river to assist with bank stabilisation and nutrient and sediment stripping. Plant densely to inhibit weed growth. See Appendix 1, columns 3, 5, and 8 to compile a species list suitable for this area.
7. Undertake rabbit control.
8. Use tree guards to protect seedlings from rabbits.



Abba River Map 8

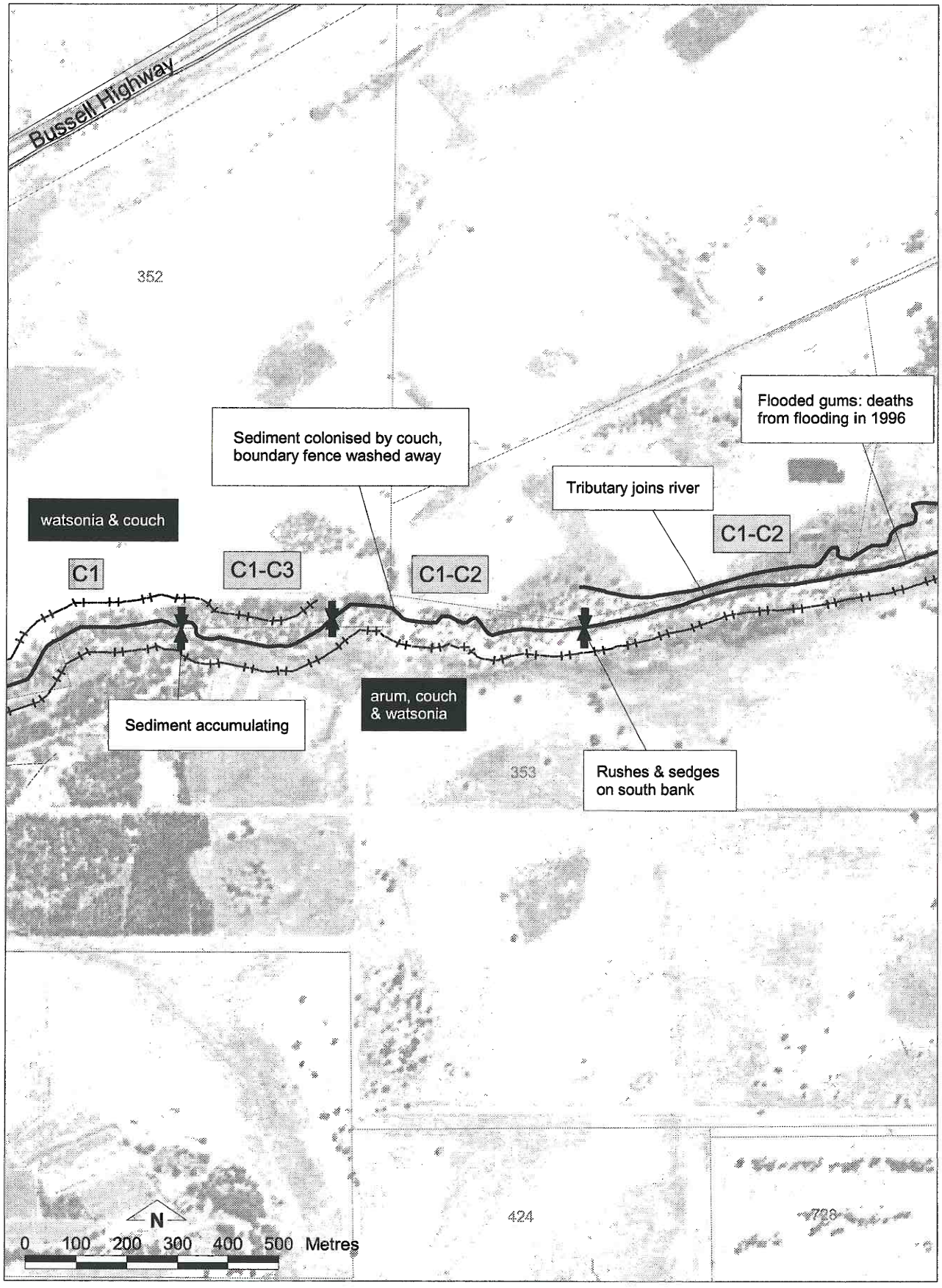
Map 9

The river continues across the plain. The soils surrounding the river change from sandy topsoils over clay to low rises and dunes of deep bleached sands. There is slightly more native vegetation remaining along this section. The banks are eroding and sediment deposits occur in the channel. The sediment in the channel is being colonised by couch.

Issues	Comments
Fencing	The river is fenced on the south in location 353, and on both sides of the river in location 1349. The river is grazed at present.
Soils and banks	Soils are generally poorly drained sandy topsoils over clay. The banks are actively eroding and the sediment deposits occur along this section of river.
Vegetation	Flooded gums, paperbarks and rushes and sedges remain in some areas along the river.
Weeds	Arum lily and couch. Watsonia becomes dense along here.
Special features	The river channel separates into two channels running parallel to each other.

Map 9: Management advice

1. Fence the river to allow control of stock. Limit grazing in fenced areas to allow regeneration of native species.
2. Construct stable stock crossings or bridges and watering points or troughs.
3. Monitor weed invasion and undertake control as required.
4. Continue arum lily control.
5. Control watsonia.
6. Establish local native rushes and sedges, shrubs and trees along the river to assist with bank stabilisation and nutrient and sediment stripping. Plant densely to inhibit weed growth. See Appendix 1, columns 3, 5, and 8 to compile a species list suitable for this area.
7. Undertake rabbit control.
8. Use tree guards to protect seedlings from rabbits.



Abba River Map 9

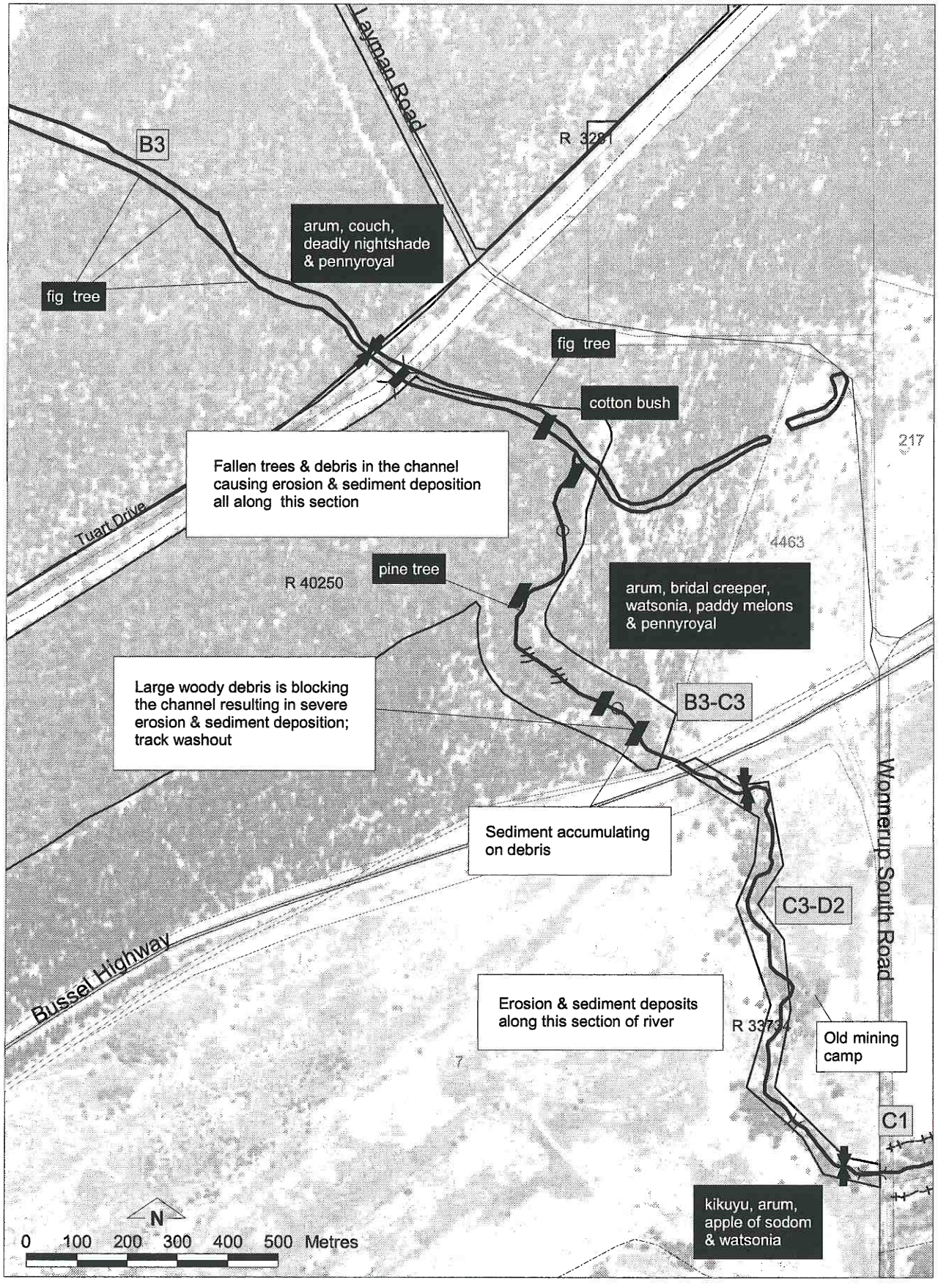
Map 10

The river runs under Wonnerup South Rd and continues through the Abba Plain surrounded by areas of deep sands. Before reaching Bussell Highway the river moves from the Abba Plains to the Ludlow Plain land system. The river is contained within a narrow floodplain and sandy alluvial soils. The surrounding land is either flats and very low dunes with yellow-brown siliceous sands over limestone, or poorly drained flats with heavy clayey soils. The vegetation community changes to Tuart forest. North of Bussell Highway the river is contained within CALM managed land.

Issues	Comments
Fencing	No fencing occurs along the river in this section. South of Bussell Highway the river is within farmland and is grazed. North of Bussell Highway no grazing occurs.
Soils and banks	South of Bussell Highway soils are a sandy topsoil over clay surrounded by areas of deep sands. North of Bussell Highway are sandy alluvial soils over limestone. Erosion and sediment deposition is occurring along the river on location 7 and between Bussell Highway and Tuart Drive. Trees are being undermined and debris in the channel is resulting in severe erosion in some spots.
Vegetation	Some trees remain through location 7. More native vegetation remains between Bussell Highway and Tuart Drive though it is degraded and badly weed infested. North of Tuart Drive there are tuarts, flooded gums and paperbarks over arum lily.
Weeds	Kikuyu, arum lily, apple of sodom and watsonia occur along the river in location 7. Between Bussell Highway and Tuart Drive there are very severe infestations of bridal creeper, arum lily and watsonia. Kikuyu is dense where there is more light. There is a cottonbush infestation south of Tuart Drive. North of Tuart Drive arum lily totally dominates the understorey. There are a number of fig and pine trees along the river.
Special features	Between Bussell Highway and Tuart Drive the river is quite pretty with meanders, riffles and pools. CALM is working with GeoCatch and the Water and Rivers Commission to stabilise a severe erosion problem in this area.

Map 10: Management advice

1. Fence the river to allow control of stock on location 7. Construct stable stock crossings or bridges and watering points or troughs. Monitor weed invasion and undertake control as required. Establish local native rushes and sedges, shrubs and trees along the river to assist with bank stabilisation and nutrient and sediment stripping. Plant densely to inhibit weed growth. See Appendix 1, columns 3, 5, and 8 to compile a species list suitable for this area.
2. Undertake rabbit control and use tree guards to protect seedlings from rabbits.
3. Control arum lily, watsonia, apple of Sodom and kikuyu on location 7.
4. The Abba River between Bussell Highway and Tuart Drive has the potential to be used for public recreation. It is in a good location close to an excellent site for bird watching on the Vasse-Wonnerup wetlands. Weed control and restoration of native vegetation communities, along with construction of a walk trail would be required. It is recommended that GeoCatch, the Vasse-Wonnerup LCDC and the Department of Conservation and Land Management look into the possibilities for restoration of this section of river.



Abba River Map 10

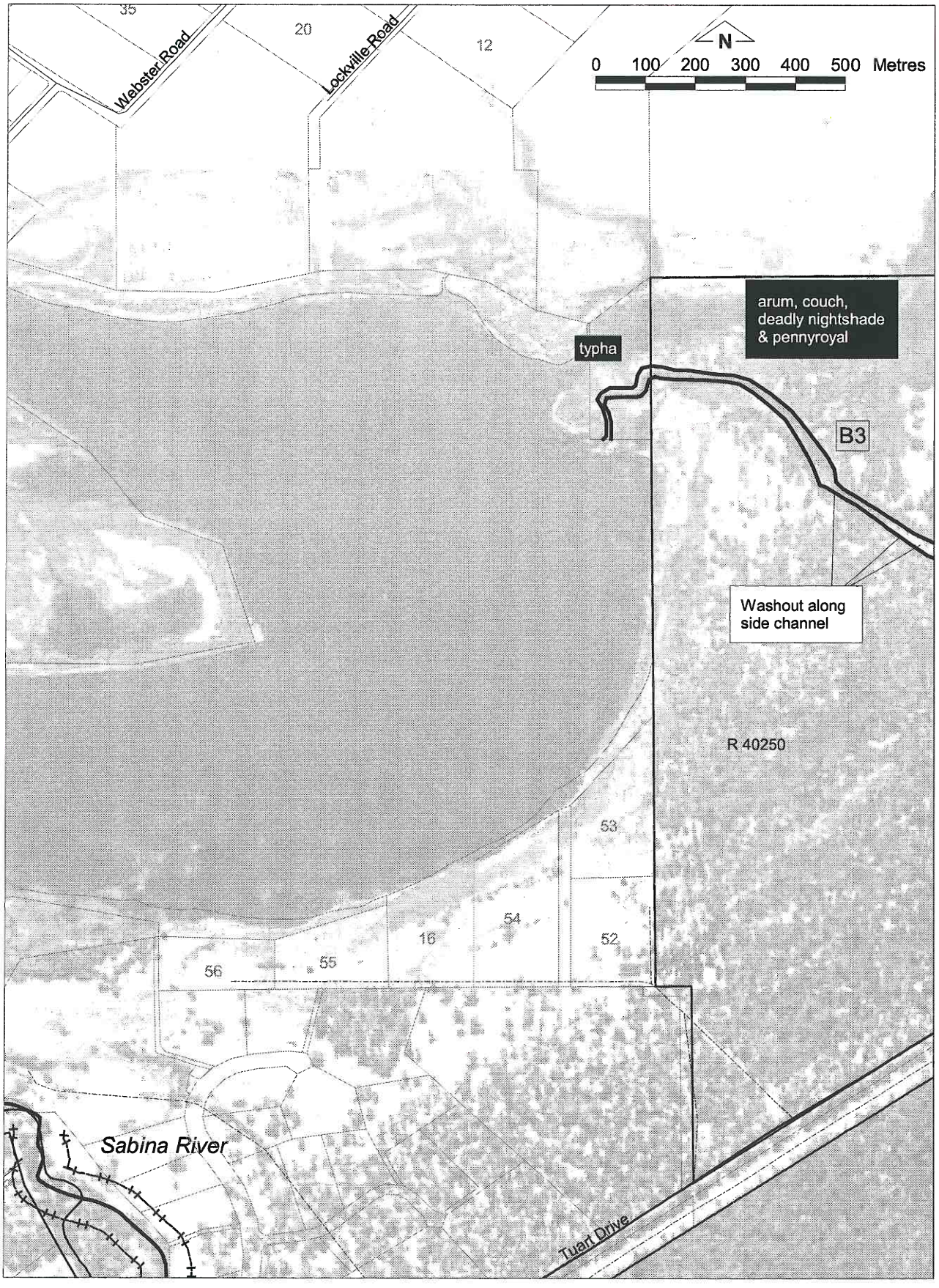
Map 11

The river continues across the Ludlow Plain land system to the Vasse-Wonnerup wetlands. The surrounding soils change from deep brownish yellow sands to a poorly drained area of shallow sands over limestone. The river becomes poorly defined and separates into a number of channels.

Issues	Comments
Fencing	Not fenced or grazed.
Soils and banks	Sandy alluvial soils over limestone.
Vegetation	Tuarts, marris, peppermints, flooded gums over arum lily.
Weeds	Very dense infestation of arum lily. Pennyroyal, couch, fig trees. Typha occurs close to where the river enters the wetland.
Special features	Close to where the Abba River enters the Vasse-Wonnerup wetland system is an excellent site for bird watching particularly during December, January and February.

Map 11: Management advice

1. Seek advice from the Water and Rivers Commission regarding the areas of washout alongside the channel.
2. Control arum lily and other weeds and undertake revegetation of the riparian zone. See Appendix 1, column 4 to compile a species list suitable for this area.



Abba River Map 11

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Appendix 1: Species lists for areas of remnant vegetation on the rivers and Ambergate Reserve

		Location at which species was identified_								Soil-landscape unit				
Habit	Species	1	2	3	4	5	6	7	8	AF	Af	Avw	Aw	Lv
Shrub	*Acacia cyclops*				×									✔
Shrub	*Acacia elata*	×								4				
Shrub	*Acacia extensa*		×			×			×		✔	✔	✔	
Shrub	*Acacia pulchella*	×		×			×	×	×	✔		✔	✔	
Shrub	*Adenanthos meisneri*	×		×				×	×	✔		✔	✔	
Tree	*Agonis flexuosa*				×	×	×	×	×			✔	✔	✔
Tall shrub	*Agonis linearfolia*	×	×	×		×	×			✔	✔	✔		
Tall shrub	*Agonis parviceps*	×	×	×	×			×	×	✔	✔	✔	✔	✔
Shrub	*Allocasuarina humilis*								×				✔	
Herb	*Anigozanthos flavidus*		×				×				✔			
Herb	*Anigozanthos humilis*								×				✔	
Herb	*Anigozanthos viridis*								×				✔	
Shrub	*Astartea fasicularis*	×	×			×		×	×	✔	✔	✔	✔	
Tree	*Banksia attenuata*				✖									✔
Tree	*Banksia grandis*				✖		×							✔
Tree	*Banksia littoralis*					×	×		×			✔	✔	
Rush	*Baumea juncea*								×				✔	
Rush	*Baumea vaginalis*								×				✔	
Herb	*Billardiera variflora*	×							×	✔			✔	
Low shrub	*Boronia crenulata*						×							
Low shrub	*Bossiaea ornata*	×								✔				
Low shrub	*Brachysema praemorsum*			×								✔		
Herb	*Burchardia umbellata*						×		×				✔	
Herb	*Caladenia flava*				×									✔
Herb	*Caladenia latifolia*				×									✔
Tall shrub	*Calostachys lanceolatum*	×								✔				
Shrub	*Calothamnus lateralis*								×				✔	
Shrub	*Calothamnus sanguines*	×							×	✔			✔	
Shrub	*Chamaelaucium roycei*	×								✔				
Shrub	*Chorizema ilicifolium*						×							
Herb	*Compesperma virgatum*							×						
Herb	*Conostylis aculeata*				×			×	×				✔	✔
Herb	*Conostylis* spp.	×	×	×		×			×	✔	✔	✔	✔	
Herb	*Dampiera alata*								×				✔	
Herb	*Dampiera linearis*								×				✔	
Shrub	*Darwinia citriodora*	×								✔				
Shrub	*Darwinia oederoides*								×				✔	

		Location at which species was identified_								Soil-landscape unit				
Habit	**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**AF**	**Af**	**Avw**	**Aw**	**Lv**
Herb	*Dasypogon bromeliifolius*						×		×				✔	
Shrub	*Daviesia decurrens*	×								✔				
Shrub	*Daviesa divaricata*			×								✔		
Herb	*Dichrondra repens*				×									✔
Herb	*Drosera stolonifera*				×									✔
Herb	*Drosera* spp.	×	×						×	✔	✔		✔	
Shrub	*Dryandra* nivea	×							×	✔			✔	
Tree	*Eucalyptus calophylla*	×	×	×	✖	×	×	×	×	✔	✔	✔	✔	✔
Tree	*Eucalyptus gomphocephala*				×			×						✔
Tree	*Eucalyptus marginata*	×	×	×	✖		×	×	×	✔	✔	✔	✔	✔
Tree	*Eucalyptus patens*					✖	×					✔		
Tree	*Eucalyptus rudis*			×	×	×						✔		✔
Shrub	*Geranium retrorsum*				×									✔
Shrub	*Gompholobium venustum*	×								✔				
Herb	*Goodenia micrantha*								×				✔	
Herb	*Goodenia pulchella*								×				✔	
Shrub	*Grevillea quercifolia*	×							×	✔			✔	
Shrub	*Grevillea diversifolia*			×		×	×					✔		
Herb	*Haemodorum simplex*		×								✔			
Shrub	*Hakea amplexicaulis*	×								✔				
Shrub	*Hakea lissocarpha*		×			×	×				✔	✔		
Creeper	*Hardenbergia comptoniana*				×			×						✔
Shrub	*Hibbertia cuneiformis*				×									✔
Low shrub	*Hibbertia hypercoides*	×	×	×			×	×	×	✔	✔	✔	✔	
Low shrub	*Hibbertia racemosa*													
Low shrub	*Hibbertia stellaris*				×				×				✔	✔
Shrub	*Hovea chorizemifolia*	×								✔				
Shrub	*Hovea elliptica*	×	×							✔	✔			
Low shrub	*Hypocalymma angustifolium*	×		×		×		×	×	✔		✔	✔	
Low shrub	*Hypocalymma robustum*	×								✔				
Shrub	*Jacksonia horrida*			×								✔		
Rush	*Juncus holoschoenus*								×				✔	
Rush	*Juncus pallidus*				×				×				✔	✔
Creeper	*Kennedia coccinea*				×				×				✔	✔
Creeper	*Kennedia prostrata*			×	×				×			✔	✔	✔
Shrub	*Kingia australis*	×				×	×		×	✔		✔	✔	
Shrub	*Kunzea micrantha*								×				✔	

		Location at which species was identified_								Soil-landscape unit				
Habit	Species	1	2	3	4	5	6	7	8	AF	Af	Avw	Aw	Lv
Shrub	*Kunzea micromera*			×								✔		
Shrub	*Kunzea recurva*								×				✔	
Shrub	*Kunzea vestita*	×				×				✔		✔		
Low shrub	*Lechenaultia biloba*	×								✔				
Rush	*Lepidosperma angustatum*								×				✔	
Rush	*Lepidosperma carphiodes*													
Rush	*Lepidosperma gladiatum*	×							×	✔			✔	
Rush	*Lepidosperma leptostachyum*								×				✔	
Shrub	*Leucopogon*						×		×				✔	
	conostephiodes													
Shrub	*Leucopogon parviflorus*				×				×				✔	✔
Shrub	*Leucopogon propinquus*				×									✔
Shrub	*Macrozamia riedlei*				×		×							✔
Shrub	*Melaleuca incana*					×		×	×			✔	✔	
Shrub	*Melaleuca lateritia*					×						✔		
Tree	*Melaleuca preissiana*					×		×	×			✔	✔	
Tree	*Melaleuca rhaphiophylla*			×	×	×		×	×			✔	✔	✔
Shrub	*Melaleuca tertifolia*			×								✔		
Shrub	*Mesomelaena tetragona*	×		×					×	✔		✔	✔	
Shrub	*Mirbelia dilatata*	×	×			×				✔	✔	✔		
Tree	*Nuytsia floribunda*	×		×	✖	×			×	✔		✔	✔	✔
Herb	*Operculare hispidula*		×								✔			
Herb	*Patersonia umbrosa var. xanthina*	×								✔				
Herb	*Patersonia* spp.						×		×				✔	
Shrub	*Pericalymma* spp.	×							×	✔			✔	
Tree	*Persoonia elliptica*						×							
Shrub	*Phyllanthus calycinus*	×		×	×				×	✔		✔	✔	✔
Shrub	*Pimelea spectabilis*	×						×		✔				
Shrub	*Podocarpus drouynianus*	×					×		×	✔			✔	
Shrub	*Rhagodia baccata*				×									
Herb	*Scaevola calliptera*								×				✔	
Herb	*Scaevola striata*								×				✔	
Herb	*Senecio quadridentata*				×									✔
Herb	*Sowerbaea laxiflora*				×				×				✔	
Shrub	*Stirlingia latifolia*			×					×			✔	✔	✔
	Stypandra glauca				×				×				✔	
Shrub	*Synaphea petiolaris*	×							×	✔			✔	

		Location at which species was identified_								Soil-landscape unit				
Habit	Species	1	2	3	4	5	6	7	8	AF	Af	Avw	Aw	Lv
Herb	*Thysanotus arenarius*				×									
Herb	*Thysanotus dichotomus*			×								✔		✔
Herb	*Thysanotus multiflorus*						×		×				✔	
Herb	*Thysanotus patersonia*						×		×				✔	
Low shrub	*Tricoryne elatior*				×				×				✔	
Tall shrub	*Viminaria juncea*		×	×		×	×	×	×		✔	✔	✔	✔
Shrub	*Xanthorrhoea preissii*	×	×	×			×			✔	✔	✔		✔
Shrub	*Xanthorrhoea gracilis*	×					×			✔				
Tree	*Xylomelum occidentale*	×	×	×		×	×		×	✔	✔	✔	✔	✔

_ Key to location and soil-landscape unit (Tille & Lantzke, 1990) at which species where identified:

1. Lot 22 on the Sabina River. Abba Very Fertile Flats: Well drained flats with deep red-brown sands, loams and light clays. (AF)

2. Location 670 on the Abba River. Abba Fertile Flats: Well drained flats with sandy gradational grey-brown soils, some red-brown sands and loams. (Af)

3. Location 961 on the Ludlow River. Abba Wet Vales: Small narrow swampy depressions along drainage lines. Sandy alluvial soils over clay. (Avw)

4. Abba River between Bussell Highway and Tuart Drive. Ludlow Vales: Narrow floodplains in small depressions. Sandy alluvial soils. ***Species marked with a dark cross in the table are found where there is limestone outcropping on the surface.*** (Lv)

5. Ludlow River, west of Warns Rd. Abba Wet Vales: Small narrow swampy depressions along drainage lines. Sandy alluvial soils over clay. ***Species marked with a dark cross in the table are found in areas of loam.*** (Avw)

6. Reserve 18047 on the Ludlow River. Goodwood Valleys, Preston subsystem: River channels, narrow floodplains and well drained alluvial terraces. Soils are brown loamy earths and some brown deep sands. (GvPr)

7. Sabina River between Bussell Highway and Tuart Drive.

8. Ambergate reserve (Aw). For a more complete list please see Keighery, Keighery & Gibson, 1996

Note: To compile species lists for revegetation in other soil-landscape units traversed by the rivers please see Appendices 1, 2 and 3 of the Geographe Catchment Natural Resource Atlas.

Appendix 2: Planning advice from the Vasse River Action Plan

The following planning advice is taken from the Vasse River Action Plan and was prepared by Marg Scott and Jenny Dewing.

Planning a project

Write down your objectives:

- What work will be done?
- Who will do the work?
- What will the work achieve?
- Who and what will benefit from the work?

A written list of objectives:

- helps planners to stay within the goals,
- encourages recruitment of volunteers,
- helps volunteers to understand their roles,
- provide benchmarks of progress and success.

Site selection:

- Choose a workable-sized site, small enough to complete the job.
- Select a site within easy travelling distance for volunteers.
- Favour a site which enables the volunteers, and if possible the general public, to view their achievements.

Organising a planning committee:

- Select a diverse group of people with various skills and interests.
- Choose leaders in the community.
- Draw on different groups of people within the community.
- Identify those people with supervising and planning skills.
- Enlist the local media to contribute their support.

Planning creek rehabilitation

Planning a revegetation project should commence in the year preceding the proposed planting or seeding and include researching the best revegetation approach.

Issues to be addressed include:

- the design of remedial work on the banks;
- the selection of suitable plant species;
- how to propagate (by green stock or direct seeding);
- where to obtain seed;
- who to get to propagate the seed;
- the position and design of fencing;
- identifying likely weed problems, developing a weed action plan;
- where to access funds if you intend applying for a grant.

It is essential to study the project site thoroughly. A thorough site survey will provide an inventory of assets such as:

- existing indigenous vegetation;
- plants that are naturally regenerating;
- seed sources;
- potential problems – rabbit activity, weed infestations, eroding banks, areas of sedimentation.

The survey may result in the decision to manage the area to encourage natural regeneration rather than to restore the native vegetation by planting or direct seeding.

A survey can also be used for monitoring the effectiveness of a particular management activity over time.

Bank erosion may require remedial action prior to revegetation. Advice should be sought from the Water and Rivers Commission.

When to survey

Late autumn to early winter is a good time to survey when weed problems are apparent. Impacts of river activity can be easily seen – sections of eroding or slumping banks, and areas where sediment is being deposited. Later in winter, a survey of the river or stream in full flow is more likely to reveal the behaviour of the river rather than its impact.

What's growing on the creek or river bank

A list of existing native vegetation is useful for identifying suitable plant species for revegetation and potential populations of plants for obtaining seed. It is important to establish the position on the stream bank that each plant occupies and the type of soil in which it grows – sand, clay, loam etc.

Native plants are easier to identify when flowering. While different species flower in different seasons throughout the year, the peak season is spring. Fringing species flower later to coincide with falling water levels. They flower and produce seed after winter flooding, to complete their cycle before the next winter rains. It may take several visits from winter onwards to identify all plants.

In summer, flowering suites of plants go mostly unnoticed as they flower when few people are walking and looking. Some of these include *Astartea fasicularis* (a tea tree), *Agonis linearfolia* (swamp peppermint) and *Banksia littoralis* (swamp banksia).

There is a slightly different community of plants growing along the banks of each local creek. These variations reflect the topographical features of the landscape and the soil types unique to that site.

It is not difficult to compile a list of plants specific to a site. The revegetation is then tailored to suit local insects, reptiles, frogs, birds and small mammals, and looks similar to existing remnant vegetation.

Identifying plants

Native rushes and sedges are difficult for untrained people to identify, and are often excluded from revegetation plant lists. The easiest way to identify them is to collect samples, including the base of the plant, and compare them with specimens in the regional or state herbarium. Generally perennial grasses, including spear, wallaby and kangaroo grasses, flower from late spring to summer. Rushes flower at the same time, while sedges flower from late spring through to autumn, depending on the species.

These are important plants that help to hold the bank together, acting as 'foot soldiers' to the trees.

Where most understorey plants have been lost through clearing and grazing, selecting a vegetated site nearby with similar soil type and topography will assist in compiling a species list to use.

CALM's publication *How to Create a Local Herbarium* is recommended for landholders who wish to collect and preserve their own set of field specimens.