Department of Water
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AVON
CATCHMENT COUNCIL

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Avon Rivercare Project

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Managing waterways in the Avon wheatbelt

FIELD GUIDE

Looking after all our water needs

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Cover photograph: An aerial view of the Avon River near Northam (Photo courtesy Chantelle Noack)

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Foreword

Who is it for?

This Avon waterways management guide is for all landowners and land managers (including local and state government) to help protect and improve waterways and riparian land.

The guide includes practical information about the importance of rivers, creeks, billabongs, pools and wetlands. It also provides tools for managing waterways in the Avon Wheatbelt region and the issues that affect them, including salinity, sediments, weeds and fire.

Managing waterways can be quite simple if basic steps are followed.

How to use the guide?

Waterways can be complex systems. Understanding them is the first step in better management.

This guide is designed to be practical and concise. However, you may need additional information on particular issues, so a list of sources of information is provided in each section.

The challenge ahead

There is estimated to be more than 50 000 km of waterways in the Avon River Basin. Some are quite large, but most are the smaller creeks or brooks that provide natural drainage for the landscape.

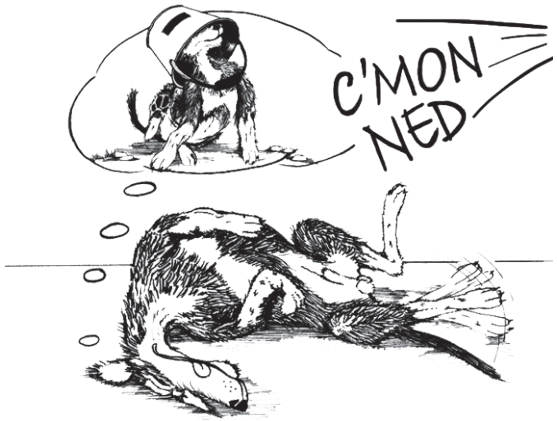
Most farms and recreational lifestyle blocks will have a waterway or drain running through them. Some have wetlands or salt lakes. Almost all waterways and wetlands have been altered in some way since native vegetation was cleared from the landscape. Salinity, flooding, erosion, sedimentation and increased nutrients are all factors of change.

Waterways and wetlands are an essential component of our landscapes. They discharge excess water from the landscape, reduce nutrient loss, lessen the intensity of floods and provide habitat for wildlife.

There are also many places near rivers, creeks or wetlands that revive fond memories or are simply ‘a nice place to be’.

All who own or manage land can respond to the challenge to improve the value of our waterways and wetlands. This field guide provides a best practice approach to do so.

Introduction of Ned



The design of Ned is based on the Australian working dog ‘the kelpie’. The kelpie breed is unique to Australia and was developed especially to adapt to Australian conditions, and Australian methods of handling livestock.

This adaptive characteristic seems to parallel the aims of this field guide which provides techniques so the landowner can best respond to current environmental conditions.

The farm dog is synonymous with farming and there is a special relationship built up between a farmer and his dog as they work together as a team. Ned will appear throughout the field guide to provide a different perspective on waterway management and restoration.

Getting started

Understanding Avon waterways

Waterways include the rivers, creeks, pools, floodways, backwaters, billabongs, wetlands, drains and the adjoining land of the floodplain. They are inter-connected to provide a natural drainage system for both surface and groundwater.

All waterways are characterised by their channel capacity, meander pattern, pool spacing, riffles, sediment load, water quality and fringing vegetation. Prior to the clearing of native vegetation for agriculture, the channel capacity of Avon waterways was adequate for annual stream flow and the floodways and floodplain provided capacity for occasional small and larger flood events. Fringing vegetation was adapted to the seasonally variable conditions in valley floors and formed an ecosystem supporting an array of life. These areas were particularly important as summer refuges or during drought. The riparian zone was quite different to the rest of the landscape and was well adapted to seasonal waterlogging or inundation.

All waterways had a natural meander pattern (as shown in Figure 1). This pattern was ‘subdued’ in valleys of low gradient and low erosion-risk soils and ‘acute’ in valleys with a steeper gradient or where alluvial soils are easily eroded. Most waterways had relatively small single channels although some were braided (having more than one inter-weaving channel). Many waterways also had pools, although in some creeks they were quite small. There were continuous processes of sediment being eroded and deposited as determined by the energy of stream flow.

These dynamic hydrological processes continually re-shaped the waterway characteristics; however, the waterway was in a stable equilibrium.

The fringing vegetation stabilised the banks of the channel and adjacent flood-ways. It also provided the important functions of slowing water flow, reducing sediment transport and filtering nutrients, and providing habitat for flora and fauna.

In the naturally broad and often dry landscapes of the Avon Wheatbelt, the riparian zone provided the important functions of natural drainage and habitat diversity. Such inland Australian waterways were the 'lifeblood' of the landscape.

What has changed?

Agriculture has substantially altered the Avon Wheatbelt. In some catchments, over 90 per cent of natural vegetation has been removed, including the riparian zone of waterways.

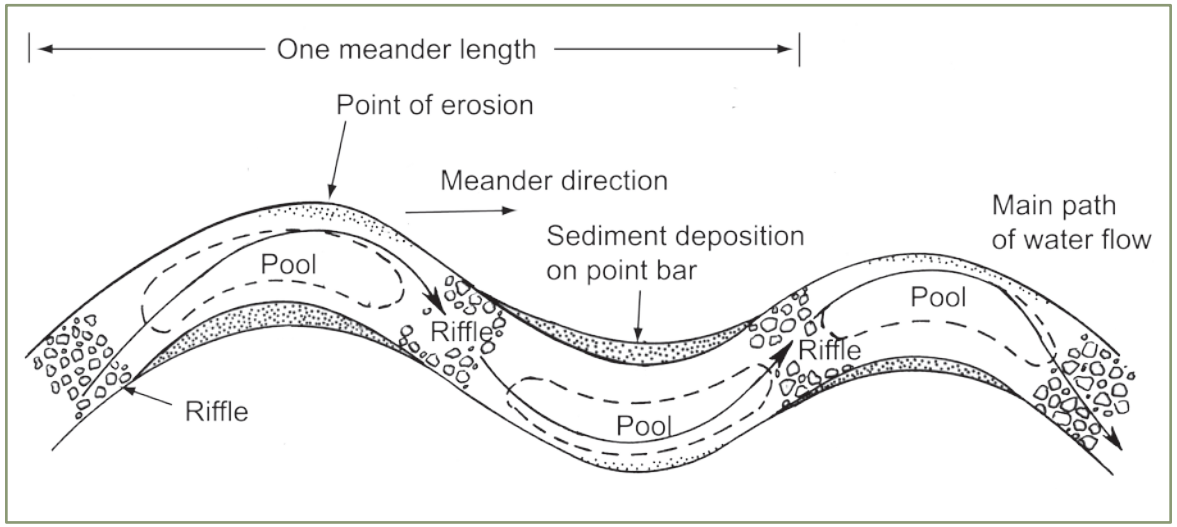


Figure 1 Shows a typical stream meander pattern (modified from Pen, 1999)

This has de-stabilised hydrological processes and altered the natural characteristics of the waterway.

There has been an increase in surface water run-off. The natural drainage system has expanded to accommodate this greater flow, causing channel erosion. This is continuing in many waterways especially where there is little or no fringing vegetation. Sediment from the eroding channel has filled downstream pools and increased the potential for localised flooding. Major flooding due to higher flow causes damage to crops, roads and other assets. It also alters the hydrology of wetlands, which often results in a decline in wetland vegetation and ecology.

There has also been an increase in groundwater flow. While this has resulted in more seepages, some relatively fresh, the major impact is salinisation. The valley floors are most vulnerable to increases in salinity.

These landscape changes have had an impact upon the cultural values of local Indigenous people.

The naturally occurring waterways were important to the lifestyle and beliefs of Aboriginal people, with many burial and ceremonial sites located along waterways. Most early colonial settlement in the Wheatbelt was adjacent to waterways to provide shade and access to water.

Mile Pool (Brookton) is a significant cultural site for the local Aboriginal community and was once widely used for recreation by the local community (Photo courtesy of Judy Williams)

The cultural values of waterways have been neglected in the past but are now of renewed interest to both Aboriginal people and those of non-Aboriginal descent. Rural communities value their rivers, creeks and wetlands for water supplies and as habitat for wildlife, as places for recreation or for fond memories. The strong affinity of those living and working near the Avon River is reflected in a collection of photographs and nostalgic recollections (*Avon Reflections*, Moore, 2000). A number of lakes remain as significant social assets for recreation. These include Lake Baandee, Lake Bryde, Lake Mears, Cowcowing Lakes and Yenyening Lakes.

The challenge for management

The challenge is to stabilise creeks, rivers and wetland systems within a substantially altered landscape. In most catchments, the natural waterway characteristics have been lost and cannot be recovered.

Facing the challenge, stabilising the creek

However, with a stabilised riparian zone, natural reconstruction of the waterway and the associated ecosystem can occur. The focus for management is on assessing the condition of the waterway characteristics and understanding the processes that are threatening further change.

Landscape and waterways of the Avon Wheatbelt

The landscape of the Avon River Basin is of considerable antiquity, originating at least 50 million years ago. The valleys, sometimes occupied by discontinuous chains of salt lakes, are parts of palaeodrainage systems tens of millions of years old. The region is one of the most ancient landscapes in the world. The regional geology of the Avon River Basin has been influenced largely by tectonic uplift about the Meckering fault line (the eastern axis of the Darling fault). West of this line the landscape is 'rejuvenated' (i.e. uplifted and more actively eroding).

The Avon River Basin is vast – the total catchment area is approximately 120 000 km². The Avon River and the Swan River are, in fact, the same river. There is no 'confluence'. The two names simply represent an historical anomaly. The Avon is taken as that section of the river inland of the entry of the Wooroloo Brook in Walyunga National Park.

The basin is the largest catchment area in south–west Western Australia. In contrast to other areas of Australia and the world (where rivers originate in hills or mountains, flow over flat plains and then out to sea), the Avon starts in flat plains, descends through hills in the middle and discharges to the flat plains (the Swan Coastal Plain) and then on to the sea. The Avon is sometimes referred to as a 'back-to-front' river system.

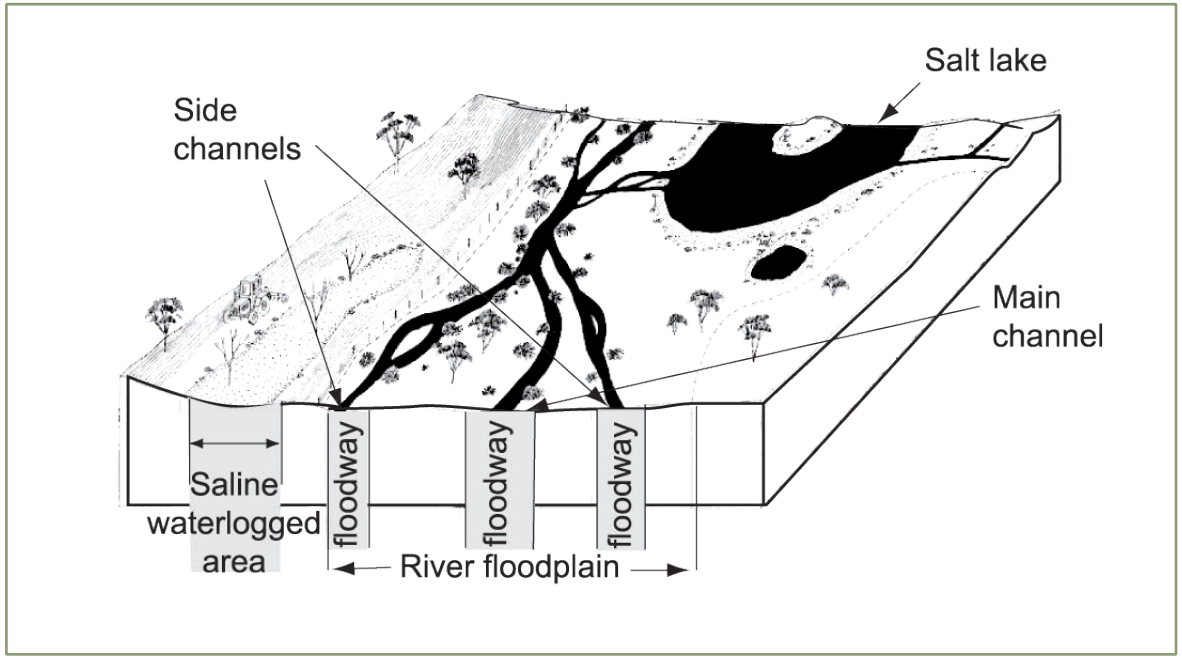


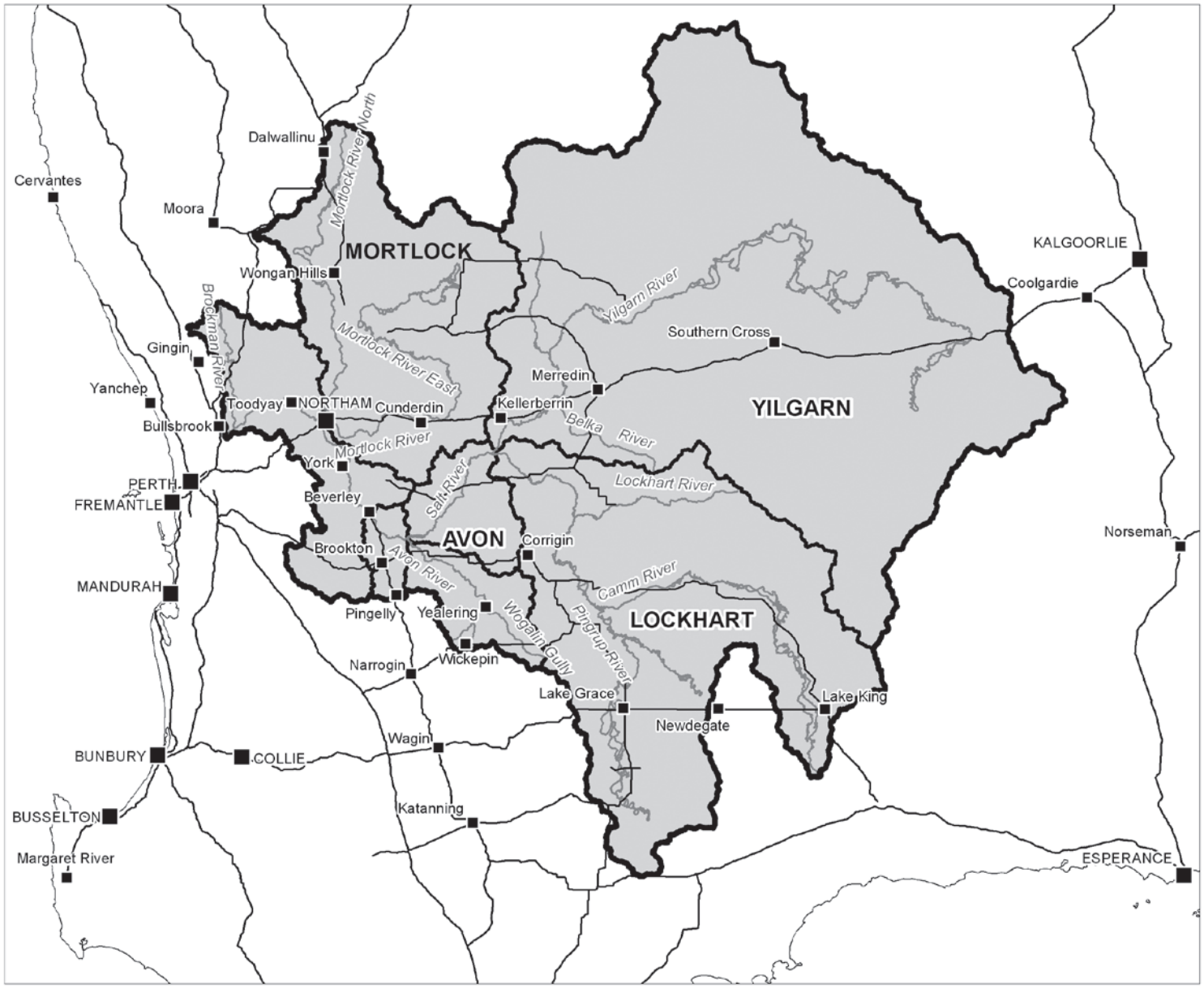
Figure 2 Cross-section of a typical watercourse in the Avon catchment (WRC, 2003)

The Avon River Basin – identifying the location of major tributaries

The Avon River originates at Lake Yealering in the Shire of Wickepin. The catchment area upstream of the confluence with the Salt River at Yenyening Lakes is 91 500 km².

The Mortlock River system has a catchment area of 16 800 km² and joins the Avon River at Northam.

Map 1
Avon River Basin
and subcatchments



The catchment area for the combined Avon River and Mortlock River system is 24 900 km^2 (excluding the Yilgarn and Lockhart river systems).

The Yilgarn River originates north-east of Southern Cross from Lake Seabrook and Lake Deborah, with tributaries to the north and south-east. It flows in a south-westerly direction past Merredin to its confluence with the Lockhart River south of Kellerberrin. The catchment area of the Yilgarn River is 55 900 km^2.

The Lockhart River originates at Lake Magenta and flows north-west through Newdegate, Kondinin, Corrigin and Bruce Rock. There are two significant tributaries:

- The Camm River flows from Lake King through Hyden to Kondinin where it meets the Lockhart River.
- The Pingrup River originates near Lake Cairlocup and flows North to Lake Grace and into the Lockhart River.

The Lockhart River has a total catchment area of 32 400 km^2. The Yilgarn and Lockhart Rivers have annual flow, although this is highly variable. The main river channel of the Avon River was originally braided, with many small channels interweaving between thickly vegetated islands, punctuated by numerous deep, shady pools. The river (like all rivers) did originally contain bed load sediment of sand and silt; however, this material was in equilibrium (i.e. there were gains and losses in balance).

The Avon is now a highly disturbed river system. The riverine ecosystem has been altered due to clearing in the catchment for agriculture and the establishment of towns next to the river. Significantly, the riverbed was deliberately disturbed under the River Training Scheme undertaken from 1958–72. This involved:

- removal of channel vegetation and debris to a width of 60 metres
- removal of dead trees, logs and debris, which impaired the river flow
- ripping of the river bed to induce erosion of a deeper watercourse
- removal of minor kinks and bends in the river.

These works were undertaken for almost the entire length of the river channel (over 190 km) with the objective of reducing flooding in towns and on farms in the floodplain. A major effect of this scheme has been to double the stream flow velocity, which has mobilised sediments and filled river pools.

A survey of the main channel of the Avon has revealed the condition of the river and identified its management needs. For the survey, the river was divided into 18 sections. River recovery plans have been prepared for each of these sections and for major tributaries of the Avon. Over 85 per cent of the river is now fenced to control livestock in the riparian zone.

The Avon River has significant tributaries including:

- South Branch (which rises above Brookton)
- Dale River (including Talbot Brook)
- Mackie River
- Blands Brook
- Spencers Brook
- Mortlock Rivers (North Branch, South Branch and East Branch)

- Wongamine Brook
- Harper Brook
- Boyagerring Brook
- Toodyay/Yulgan Brook
- Jimperding Brook
- Julimar Brook
- Red Swamp Brook.

The Mortlock River salt flats (east branch) are a Priority One threatened ecological community (TEC) for Western Australia. There are 48 wetlands in the Avon River Basin that are currently monitored for water quality trends by the Department of Environment and Conservation (DEC). The wetlands of national significance in the Avon identified by Environment Australia are:

- Cowcowing Lakes (saline)
- Yealering Lakes
- Yorkrakine Rock Pools
- Lake Cronin.

The state's 'priority freshwater assets' in the region are the Lake Bryde wetlands complex south of Lake Grace. Many of the Wheatbelt wetlands have become degraded from the impacts of clearing, resulting in rising groundwater levels, increasing salinity and loss of fringing vegetation. Other pressures include nutrient enrichment, weed infestation, recreation, deep drainage and mining.

Salt lake systems are a dominant feature in the Yilgarn and Lockhart catchments of the Avon River Basin. They occupy 2.24 per cent of the region (264 825 ha) and vary in size and depth. They are generally internally draining and, in most years, evaporation exceeds input and the lakes do not flow. However, in wet years or above average rainfall periods, the lakes will fill and overflow. Some lakes are altered by road crossings or drains into the lakes, or by re-routing natural drainage channels. Most lakes are highly saline.

Smaller lakes have been formed by freshwater soaks, springs and streams located in extensive sandplain soils (e.g. Maitland's Swamp, west of Beverley). Groundwater salinity ranges from less than 2500 mg/L to the west of the region, to 5 000–10 000 mg/L in the centre of the region, through to 20 000–30 000 mg/L in the east.

The late Jim Masters (Photo courtesy of Bernard Kelly)

The potential for groundwater to be acidic occurs across the region.

Principles for management

The late Jim Masters farmed at Glen Avon near Toodyay. He lived by the Avon River where he developed an understanding of the true nature and complexity of rivers. He recognised the need to regard them as a 'living thing'. Jim dedicated much of his life to protecting and inspiring other people to better understand and protect the Avon River and its tributaries. In 1996, he outlined the following set of principles of river management, which remain relevant to the Avon Wheatbelt.

Table 1 Principles of river management

First principle	Understand the nature of the river being protected	The natural functioning of a river or stream depends on a balance of interrelated factors in nature. All of these factors must be considered before contemplating any works for management of a river. This requires an understanding of the evolution and natural history of a river by observation and research.
Second principle	Maintain the river's energy balance	The energy balance of a river, as determined by nature, should never be tampered with. The energy balance of a river relates to its natural rate of discharge. The energy balance was the dominant factor in forming the river channel and floodplain, and existed long before human interference with the river basin.
Third principle	Base management on long-term observations	Use the river history that is readily available from people who have observed the river carefully for many years.
Fourth principle	Protect natural resources	Landcare must be directed in equal measure throughout the river catchment, including both streams and land, to ensure a functioning natural environment upon which human economic survival depends.
Fifth principle	Respect the forces of nature	Look at the rivers as a universal example, which shows the forces of nature working together. This pre-existing natural balance of time and energy must be retained for effective river management. Time and energy working through the speed of wind and water are the factors in river, land and catchment management. Change this, and everything will be changed.

Seven steps of the best practice approach to management

Actions for waterway management will vary for each situation. The best practice approach to waterway management is based on the principles of management, as outlined by Jim Masters. The most important first principle is to understand the nature of the waterway being protected. There are many actions that will further damage or degrade the waterway if they are incorrectly designed or placed.

The aim of managing all waterways should be to stabilise the system. Many small actions taken to fix the problem are commonly washed out, cause erosion or fail. Examples of these are evident throughout the Wheatbelt and small-scale failures have the potential to lead to large-scale inaction. Actions should be taken with a sound understanding of what is required, and the scale of action that will have the desired effect.

The best practice approach to waterway management in the Avon Wheatbelt has a set of seven simple steps to follow. They are:

Step 1 collate maps, photos and background information

Step 2 arrange field survey and assessment

Step 3 assess the management options

Step 4 prepare site planning and design

Step 5 undertake a feasibility and cost review

Step 6 arrange to implement the actions

Step 7 continue with maintenance and evaluation.

This *Field guide for managing waterways in the Avon wheatbelt* is based on these seven steps.

Sources of information

Brouwer, D 1997, *Managing Waterways on Farms,* NSW Agriculture Tocal Agricultural College, Paterson NSW.

Lovett, S, Price P & Cork, S 2004, *Riparian Ecosystem Services,* Fact Sheet 12, Land & Water Australia, Canberra.

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Pen, LJ 1999, *Managing Our Rivers: a guide to the nature and management of the streams of south-west Western Australia,* Water and Rivers Commission.

Avon Catchment Council 2005, *The Avon Natural Resource Management Strategy. The Regional Natural Resource Management Strategy for the Avon River Basin,* Avon Catchment Council.

Harris, TFW 1996, *The Avon: an introduction. Unpublished Report.*

Water and Rivers Commission 2003, *Establishing Samphires in the Avon Catchment,* WN32, Water and Rivers Commission, Perth, Western Australia.

Step one: Maps, photos and background information

The first step is to collate all available information about the section of river, creek or wetland that is of concern. Local information is valuable. There are almost always old photos, maps and plenty of memories about the waterway. Your shire may have some of the information needed. State government agencies (Department of Water; Department of Environment and Conservation; Department of Agriculture and Food; Department for Planning and Infrastructure) and the Avon Catchment Council (ACC) have excellent facilities to prepare geographic information system (GIS) maps.

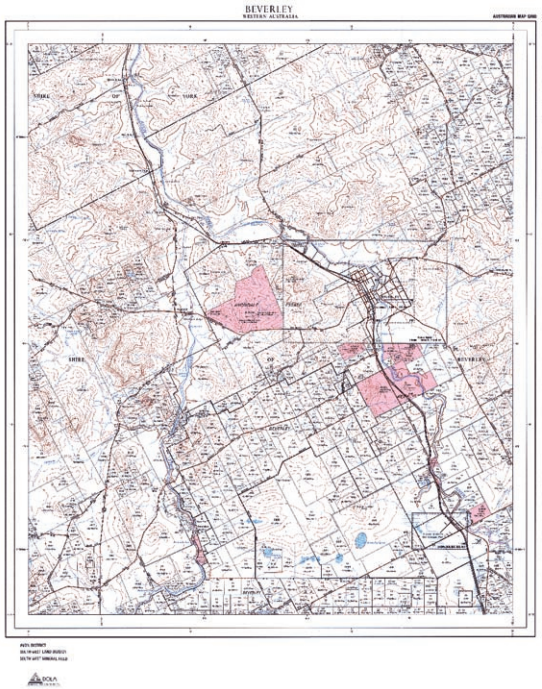
With maps, photos and available information, you should now take three actions:

1 Contact neighbours and interested people to suggest their involvement. A group could be formed (groups usually get more financial support than individuals).

Getting started, information gathering

2 Write a single simple statement about what it is that you are concerned about or want to fix (e.g. *"stop the salt killing the trees by the creek"; "get the creek back as it used to be – fun for families" or "fix Snake Gully once and for all").*

3 Write a statement or sketch what you want it to look like. Be reasonable – it probably can't be restored to natural or pre-settlement condition (e.g. "*healthy trees and shrubs both sides, a good farm crossing that doesn't wash out, the old rubbish tip cleaned up and sharp rush eradicated").*



An example of a topographic map (above) and aerial photograph (below) (Reproduced by permission of the Western Australian Land Information Authority, CL 7/2008)

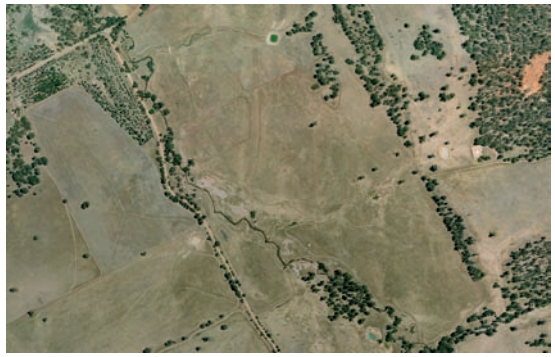


Table 2 Maps, photos and background information

The initial information you should get hold of is:

Information	Sources	Comment
A map of the waterway and catchment	• 100 000 topographic map from Landgate at Department for Planning and Infrastructure in Midland (<www.landgate.wa.gov.au>) • GIS maps from government agencies or ACC • Local shire, Landcare or catchment group office	• Colour ortho-photos (an aerial photo with property boundaries and contour lines) are best, but will cost more • 1:25 000 scale maps are best for local creeks or wetlands • 1:2500 or 1:5000 scale maps may be required for specific site works (e.g. culvert reconstruction)
Photos	• Neighbours, local newspaper, shire and hotel walls	• There are often valuable photos that show the waterway or wetland in previous times. There are often photos of floods available
Name of waterway or wetland	• Maps and local knowledge (these sometimes differ!)	• It is important for a waterway to be named as it will be more valued if it is. If there is no name, identify one that is suitable. Ensure that the name used is locally recognised

Information	Sources	Comment
Local notes and memories	• Older community members • Local histories and memoirs	• A quick review of a local history usually has some reference to the waterway or wetland. Older members of the community often have detailed knowledge of natural history and social events
Regional or state data base information	• Government agencies (start with Department of Water in Northam, phone 9690 2600) • ACC (phone 9690 2250)	• State and regional databases have information about stream flow, floods and salinity for some but not all areas. There will also be information about management responsibilities and land or water controls
Other projects	• Catchment plans • Neighbouring groups doing similar works (ACC or Department of Water can provide contacts)	• Many areas have had some involvement in catchment planning. These usually have useful maps and background information • There will almost always be others in the region doing or planning to do similar works. Get in touch

Sources of information

Moore, S 2000, *Reflections on the Avon,* Environmental science report series No 00-3, Murdoch University and Water and Rivers Commission, Avon Reflections.

Step two: Field survey and assessment

In step one, you will have made a statement about the issue of concern with your waterway or wetland. You may also have prepared a statement or sketch of how you want it to look in the future. The task now is to clearly identify what is causing the problems with your waterway or wetland.

Assessment and field survey

Understanding the issues

The following table will help you to assess the issues and identify the possible causes affecting your waterway or wetland. If you require assistance, you can contact your local Landcare or natural resource management officer or the Department of Water in your area.

Table 3 Understanding the issues

Issue of concern	What to look for	Possible cause
Banks or channel eroding 	• Recent slumping or collapse of bank • Undercut 'B-horizon' soils • Gully head forming in the channel • Tree-fall into waterways • Exposure of tree roots • Vertical banks	• Increased stream flow (channel still increasing in width) • Stock in the river • Soil profile waterlogged • Inadequate fringing vegetation to stabilise the soil

◄ *Active bank erosion (Photo courtesy of Lucy Sands)*

Issue of concern	What to look for	Possible cause
Sediment 	• Heavy bed load of coarse sand that is blocking channel capacity • Pools filling with sediment • A delta of sediment at the confluence of a tributary ◄ *Channel sediments in a degraded river section (Photo courtesy of Lucy Sands)*	• Bank or channel erosion • Sediment from paddock soil erosion entering from a tributary • Drains or road works without sediment control
Local flooding	• Road or culverts washed out • High level of bank erosion	• Excess sediment in channel • Build up of weeds and debris (logs, snags etc.) • Poor management of road run-off or farm surface water

Issue of concern	What to look for	Possible cause
Trees unhealthy or dying 	• Outer branches dead • New regrowth from trunk or branches (a response to stress) • More trees and shrubs dying, none regenerating ◄ *Riparian vegetation in poor condition on Dale River South (Photo courtesy of Lucy Sands)*	• Salinity is a major cause of tree decline in the Wheatbelt • Waterlogging, especially in wetlands where the period of flooding (hydro-period) is altered • Insects or pathogens (e.g. jarrah leaf miner, wandoo dieback) • Cumulative impact of farm stock or chemicals • Frequent fire • Shallow soil profile
Water quality 	• Increasing salinity or acidity of stream flow or pool water • Algal growth • Offensive odours and odd colouration • Less aquatic animals (native fish, insects) than previously ◄ *High levels of algae Northam Town Pool (Photo courtesy of Bernard Kelly)*	• Increasing regional or local salinity • Groundwater discharge (naturally occurring or as a result of drainage) • Excess nutrients (from fertilisers, fine textured sediment or stock manure)

Issue of concern	What to look for	Possible cause
Low flow	• Winter flow is less than normal • Flow starts later or finishes earlier in the season • Water levels are lower	• Drier climate (rainfall has reduced by up to 30% in some areas of the Wheatbelt) • Minimum-tillage practices (there is less run-off from paddocks) • Flow diversion or detention upstream
Weeds 	• High annual weed burden (especially wild oats and ryegrass) • Agricultural weeds 'declared' under the WA *Agriculture and Related Resources Protection Act 1976* (e.g. cape tulip) • Environmental weeds (especially bridal creeper and sharp rush) ◄ ***Sharp rush (Juncus acutus) (Photo courtesy of Lucy Sands)***	• Annual weeds usually associated with high stock access • Riparian canopy too open (or limited understorey) • Neglected management (difficult-to-control weeds)
Fire risk	• High volume of flammable vegetation (fuel load) • Location of valued assets (house, sheds)	• High annual weed burden • Risk increased by stubble burning, farm machinery, recreational activities etc.

Issue of concern	What to look for	Possible cause
Rubbish 	• Fencing wire and other farm rubbish disposal • Chemical drums, batteries • Soil or road repair waste • Domestic or municipal rubbish ◄ *Rubbish dumped along the banks of a waterway (Photo courtesy of Lucy Sands)*	• Inappropriate disposal in waterway or wetland • Washed downstream during flood event
No longer a 'nice place to be' 	• Former sites or facilities for swimming, picnics etc. • Opportunities for access • Places or items of special interest ◄ *Old diving board at Dwarlacking Pool on the Avon River (Photo courtesy of Viv Read)*	• Places become neglected for a range of reasons • Declining water quality and fringing vegetation detract from the social amenity of waterways and wetlands

Field survey

The issues needing management should be assessed in the field. The purpose of a field survey is to:

- identify how extensive the problem is (it may be only a small problem that is easily fixed)
- locate where the problem is occurring (e.g. mapping weeds that need to be controlled)
- understand the cause of the problem (trace back to find out where it is coming from).

Appendix A provides a pro-forma for you to copy and use in the field. This is an assessment with three categories for management:

- **Good condition (green)** – assets that need to be protected.
- **Moderate condition (orange)** – preventative management is required.
- **Poor condition (red)** – urgent action is required for recovery of waterway condition.

An example of a field survey for Snake Gully is provided at the end of this chapter.

For the field survey, you will need to have:

- map, air photo and notebook (notes on maps are best – use a transparent overlay or make sure it is a spare copy)
- your 'Initial Assessment'
- camera (keep a record of where photos were taken)
- GPS (not essential but a good idea for finding the trouble spot or weed outbreak again)
- a salinity meter (not essential)
- permission to enter neighbouring properties.

Walking surveys are generally best for small sites. Four-wheel motorbikes are ideal for most surveys as ute or car access is generally quite limited along most waterways.

For small sites, you should survey the whole section. For larger sites (e.g. more than 1 km of waterway), it is best to mark a few key locations on the map or photo, then access these.

Survey sites should be about 500 metres apart.

Specific site surveys (e.g. for a road culvert) should include reconnaissance walks upstream to determine the cause, and downstream to fully assess the impacts.

While in the field, it is worth making notes about what can be done to fix the problems; but don't make decisions until all options have been considered.

The Department of Water has surveyed a number of the major tributaries in the Avon Wheatbelt and we may be able to provide you with a few tips on what to look for in your area. Give us a call when you have completed the survey to discuss what you have found. We will advise if a more comprehensive technical survey or site assessment is required and we may be able to help.

Now that the field assessment and survey is complete, you are now prepared to consider the management options most suitable for your creek.

Worked example: Snake Gully Creek restoration project field survey

Project title: Snake Gully restoration project
Location: Old House, Paddy's and Back paddocks; one section in Scott's property
Landholders: Bill and Jane Smith
Neighbours: T and E Clarke, B Rose, R and D. Peterson, and J, K, and I Scott
Survey date: 15 September 2007
Survey distance: approx. 2 km
Survey by: Bill and Jane

1 Erosion, sedimentation and flooding

Green (good condition)	Orange (moderate condition)	Red (poor condition)
• Minimal channel erosion (undercutting or slumping) • No gully head erosion (main channel or tributaries) • Minimal sediment deposition • Limited localised flood damage (culverts washed out, sediments in floodways, eroded banks)	• Moderate level of bank or channel erosion • Coarse sediment slugs in sections of the channel • Some localised flood damage	• Extensive and active bank and channel erosion • Bank collapse, tree fall • High level of sediment deposition (filled pools, blocked channel) • High level flood damage (crossings, fences, sediments, other)
Survey Points		
#1 #2 #3 #4 #5 ✔	#1 ✔ #2 #3 #4 ✔ #5	#1 #2 ✔ #3 ✔ #4 #5

2 Vegetation health

Green (good condition)	Orange (moderate condition)	Red (poor condition)
• Dense, healthy fringing native vegetation that extends 25 metres or more into floodplain from the channel • Mixture of trees, shrubs and groundcovers present • Natural regeneration of native vegetation • Sedges and rushes may be present	• Good vegetation cover, but mixture of native vegetation and weeds • Vegetation extends 5–10 metres into floodplain • Little natural regeneration of native species	• Most native vegetation has been cleared or damaged • Mainly weeds or pasture present • No regeneration of native vegetation
#1 #2 #3 #4 #5	#1 ✔ #2 #3 #4 #5 ✔	#1 #2 ✔ #3 ✔ #4 ✔ #5

3 Fencing and stock access

Green (good condition)	Orange (moderate condition)	Red (poor condition)
• Stock-proof fencing both sides of waterway • Stock crossings with restricted access to waterway	• Fencing in need of maintenance • Stock has access to the waterway	• No fencing or existing fencing in need of replacement on both sides • Stock has uncontrolled access to the waterway and is causing damage to the channel and vegetation
#1 #2 #3 #4 #5	#1 #2 #3 #4 #5	#1 ✔ #2 ✔ #3 ✔ #4 ✔ #5 ✔

4 Water quality

Green (good condition)	Orange (moderate condition)	Red (poor condition)
• Water appears clear • Very little obvious algae • Fresh or marginally saline (< 1500 mg/L) • Native fish or other aquatic fauna (e.g. dragonflies) easily observed	• Water slightly coloured but expected to clear • Some algal growth • Water is brackish (1500–5000 mg/L) • Native fish or other aquatic fauna hard to find	• Water is coloured and not expected to clear • Water is saline (> 5000 mg/L) • High level of algal growth • No sign of aquatic fauna
#1 #2 #3 #4 #5	#1 #2 #3 #4 #5	#1 ✔ #2 ✔ #3 ✔ #4 ✔ #5 ✔

5 Weeds and fire risk

Green (good condition)	Orange (moderate condition)	Red (poor condition)
• Low level of annual weeds (e.g. wild oats, veldt grass) • No major perennial weeds (e.g. bridal creeper, sharp rush) • Farm assets (buildings, yards, fences) not at risk to fire	• Annual weeds are common with patchy native vegetation cover • No major perennial weeds • Fire could cause some damage to farm assets	• High level of annual weeds with little or no native vegetation cover • Established perennial weeds • High fuel load and assets at risk
#1 #2 #3 #4 #5	#1 ✔ #2 #3 #4 #5 ✔	#1 #2 ✔ #3 ✔ #4 ✔ #5

6 Road and farm crossings

Green (good condition)	Orange (moderate condition)	Red (poor condition)
• Crossings do not restrict channel or floodplain capacity • Crossing structures are stable	• Crossings partially restrict flood flows but do not affect normal winter flow • Crossing structures are unstable and at risk of damage in floods	• Crossings restrict flood and normal winter flows • Crossing structures damaged • Bank erosion or channel sedimentation caused by the crossing
#1 #2 #3 #4 #5	#1 #2 #3 #4 #5	#1 ✔ #2 #3 #4 #5
Tally from above		
Number of green ticks: 1	**Number of orange ticks: 6**	**Number of red ticks: 19**

Site notes or sketch

The creek is in poor condition, particularly between survey points 2 and 3 (estimated to be about 500 m). There is effectively no vegetation by the creek at all. There is quite a bit of bank erosion that needs to be stopped. None of it is fenced.

Sally's Creek is carrying a lot of sediment because the channel is eroding.

The bush near the creek on Scott's property is quite good, although stock are doing a fair bit of damage. There is also cape tulip on both sides of the boundary (between survey points 2 and 3).

The farm crossing in Old House paddock washed out two years ago. This needs to be fixed.

The culverts on Town Road are almost fully blocked with sediment. This seems to flood the road about every second year; it is quite dangerous for traffic when it does flood. Need to make sure this is looked at by the shire and sorted out.

GPS references (for location of specific sites – optional)		
Site	**Easting**	**Northing**
1 'Town Road' culvert	123456	7654321
2 Farm crossing	123465	7654312
3 Rubbish to be removed	123470	7654350
4 Sally's Creek confluence	123480	7654365
5 Cape tulip (2 locations)	123490 123520	7654420 7654510
Photo references (suggest at least one for each survey site)		
PR1: At survey site 1 (LHS, upstream view)	123456	7654321
PR2: At survey site 2 (LHS, upstream view)	123475	7654360
PR3: At survey site 3 (LHS, upstream view)	123485	7654485
PR4: At survey site 4 (LHS, upstream view)	123550	7654520
PR5: At survey site 5 (LHS, downstream view)	123580	7654595

Sources of information

Lovett, S & Price, P 2006, *Are my waterways in good condition? A checklist for assessing river, stream or creek health on farms,* Land & Water Australia, Canberra.

Water and Rivers Commission 1999, *Planning and Management: Foreshore Condition Assessment in Farming Areas of South-west Western Australia,* Water and Rivers Commission, River Restoration Report No. RR3.

Water and Rivers Commission and Avon River Management Authority 2001, *River Recovery Plan, Sections 11/12 – Gwambygine to Edwards Crossing,* Water and Rivers Commission, River Recovery Plan Series No RRP6.

Step three: Management options

When the field survey is complete, you should carefully consider the cause of the issue you are dealing with. Where possible, management should be directed to the cause, not just the effects. For example, with issues such as dumping of rubbish, this is quite easy and the management response quite simple. Other issues require cautious consideration.

All situations will differ. It is best to consider a wide range of management options first and narrow the options to those that will serve more than one purpose.

Appendix B provides a form to assist with assessing the management options in response to the field survey information. An example for Snake Gully is provided on page 39 of this chapter.

Considering management options

Table 4 lists the main management options for waterway management in the Avon Wheatbelt and provides guidelines for adoption. More information for some of the options is provided in the sections that follow.

Table 4 Options for waterway management

Management option	Guidelines for adoption	Expected benefits	Further information and comments
Fencing and stock access  *Healthy riparian vegetation at Boyagarra Pool (Photo courtesy of Prue Dufty)*	• Locate new fencing to include existing riparian vegetation and areas identified for revegetation • Avoid fencing across waterways • Use local best practice fence design • Provide alternative shade and water source for stock • Allow limited sheep grazing for annual weed control	• Reduced bank erosion • Regeneration of riparian vegetation • Reduction in annual weeds (with time)	See the 'Fence type and location' section

Management option	Guidelines for adoption	Expected benefits	Further information and comments
Stream channel protection  *Bank protection works at Phillips Brook (Photo courtesy of Prue Dufty)*  *A riffle constructed on Turner Gully (Photo courtesy of Michael Allen)*	• The best bank protection to reduce erosion is healthy natural vegetation • Other options include stone or log walling, brush matting, deflectors and rock riprap. These can be expensive and time-consuming to install, so would mostly be considered for protecting high value assets (e.g. a bridge or farm house) • Artificial riffles can be installed in some specific locations to slow stream flow velocity. The benefit is increased if a series of riffles is installed in a waterway	• Reduced sedimentation • Reduced risk to river pools • Control of erosion • Reduced threat to culverts, crossings, fencing or other assets that may be affected by channel erosion • Increased opportunity for stream bank revegetation	See the ‘Stream channel and bank protection’ section  *Sandbag sedges used to stabilise banks (Photo courtesy of Brendan Oversby)*

Management option	Guidelines for adoption	Expected benefits	Further information and comments
Surface water and sediment control	For most waterways in the Wheatbelt, the best stream bed protection and sediment control method is to reduce stream flow velocity, especially during high run-off events. Options for sediment control include: • Sediment traps on smaller waterways to detain sediment, however these require regular maintenance (i.e. cleaning out and safe disposal of sediments) • Avoid direct discharge to waterway from roads and farm drains	• Reduced erosion and sedimentation of waterways • Opportunity to discharge water from integrated surface water control on farms into vegetated floodplain or floodway	Tille, PJ, Mathwin, TW, George RJ 2001, *The South West Hydrological Information Package – Understanding and managing hydrological issues on agricultural land in the south west of Western Australia.* Agriculture Western Australia, Bulletin 4488 Keen, M., 1998, *Common conservation works used in Western Australia* Agriculture Western Australia, Resource Management Technical Report No 185 Pen, LJ 1999, *Managing our rivers: a guide to the nature and management of the streams of south-west Western Australia,* Water and Rivers Commission Water and Rivers Commission 2000, *Stream stabilisation.* Water and Rivers Commission, River Restoration Report No. RR10

Management option	Guidelines for adoption	Expected benefits	Further information and comments
Natural regeneration and revegetation  *Revegetation along a fenced seasonal stream (Photo courtesy of Prue Dufty)*	• Natural regeneration is more effective and less costly than revegetation. This should take priority wherever there is seed-producing natural vegetation. • Revegetation is useful in areas without vegetation. Care is needed when planting trees and shrubs in waterways to avoid establishing them in the wrong place. Natural establishment via regeneration guarantees correct plant placement.	• Stream bank stabilisation • Filtering sediments and nutrients • Lower groundwater tables • Providing food and shelter as habitat • Increased social amenity	See the 'Natural regeneration and revegetation' section  *Revegetation of 13 Mile Brook (Photo courtesy of Prue Dufty)*
Weed control and fire risk reduction	• Careful use of herbicide will be the most effective method of weed control • Limited grazing • Burning to control weeds or reduce fire risk is not recommended • Use of strategic firebreaks • Identify assets, areas of high value at risk to fire	• Increased opportunity for natural regeneration of riparian vegetation • Reduced fire risk with weed control	See the 'Weed control' section

Management option	Guidelines for adoption	Expected benefits	Further information and comments
Road and farm crossings  *A farm crossing (Photo courtesy of Lucy Sands)*	• Locate crossings in straight section of waterway • Ensure crossings do not decrease channel capacity • Farm crossings should be suitable for vehicles and stock	• Safe vehicle access • Reduced crossing wash-outs during flooding	See the 'Farm and local road crossings' section  *A box culvert road crossing (Photo courtesy of Lucy Sands)*
Rubbish removal	• Ensure chemical drums and other hazardous items are disposed of safely and not near waterways	• Lower risk of environmental contamination • Improved visual amenity	
Improving social values	• Provide easy access to identified favourite places with high visual amenity or sites of active restoration	• Increased interest and appreciation of waterways by providing attractive places to visit	

Information summary 1: Fence type and location

Fencing to control livestock access is the most effective management action that can be taken for waterways and wetlands in the Wheatbelt. The impacts of uncontrolled stock access include:

- bank erosion where unstable banks are trampled
- grazing and trampling of vegetation, preventing regeneration and damaging revegetation
- compaction of soils (especially where there are stock tracks)
- transport of weed seeds
- contamination with nutrients and bacteria directly to the stream through their urine and faeces.

Keeping stock away from waterways and wetlands is also good animal husbandry. Stream flow is often too saline for use as stock water in the Wheatbelt. There is also potential for a high intestinal burden in sheep when they are grazed intensively in moist areas. There is the additional risk of botulism in summer wet areas.

When waterways are fenced, in some situations there is potential for controlled grazing to control weeds without damage to natural vegetation or revegetation. Limited grazing in early spring can be beneficial in some, although not all, situations (e.g. where there are steep or sandy banks).

Fence location

The placement of fencing is important to ensure that riparian vegetation is protected adequately. Incorrect location may result in your fence being lost in a flood, or having a short life in salt-affected areas.

Some practical guidelines:

- Include all existing riparian vegetation and significant patches of remnant bush adjacent to waterways.
- Identify the 'floodway' and 'floodplain'. Ensure all of the floodway is included in the fenced area.
- Minimise fencing that crosses the stream channel, floodway and floodplain.
- Where riparian vegetation does not exist, the fence should be located 20–30 m out from the stream channel to allow for revegetation (this will vary according to stream size).

Fencing for floods and the floodplain

The floodplain is often quite extensive and sometimes poorly defined in the Wheatbelt. Many floodplain areas have been cleared of natural vegetation and used for pasture production or in a crop-pasture rotation. Small areas have been planted to trees to control salinity.

The floodplain has been formed over many years and provides the function of accommodating floodwaters. Restricting floodwater access to the floodplain will cause increased flooding downstream. While the production benefits of floodplain land are recognised, it is important to manage these areas to allow occasional flooding to occur with minimal damage to farm assets. Damage to fencing is one of the highest costs during major floods. However, while it is difficult to

avoid all flood damage, the costs can be minimised by good design. *Water Note No. 19* (WRC, 2000d) provides practical guidelines for fencing to minimise flood damage.

The floodplain should be managed as a separate farm management unit (paddock) to minimise grazing pressure (i.e. to maintain good groundcover and to allow natural re-generation of riparian vegetation).

Figure 3 adjacent provides an example of fence location where the floodplain is broad.

Fencing should be aligned with the direction of flood flows wherever possible.

Fencing in the floodplain that needs to be transverse to flow (e.g. boundary fences) should minimise debris accumulation (e.g. logs, branches, stubble etc.).

Plain wire suspension fencing with collapse mechanisms or sacrificial sections are effective (refer Figure 4, page 36).

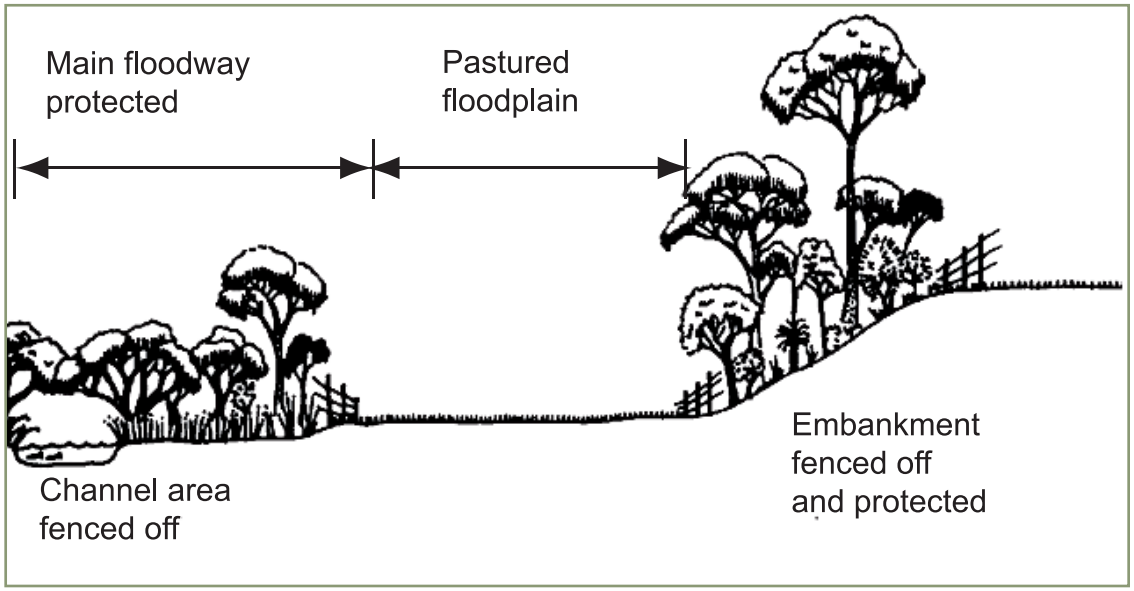


Figure 3 Location of fencing where there is a broad area of floodplain

Fence design

Most people on farms quickly become expert at fencing. There are always many different designs to suit different situations. Local knowledge is usually a good guide to local best practice.

There is a need to ensure that riparian zone fencing is of high quality and is maintained to control stock access. Table 5 provides an assessment of the most commonly used fencing types.

Fencing waterways and wetlands is similar to fencing for soil type or contour fencing. Creeks that meander require more strainer assemblies. Plain wire suspension and electric fencing has the advantage of flexibility in areas requiring irregular alignment.

Table 5 Fence types commonly used for riparian zone fencing

Fencing type	Advantages	Disadvantages
Plain wire suspension fence (line droppers optional)	• Less affected by flooding than fabricated mesh fences • Relatively low cost	• Requires greater maintenance (restraining wires, removing fallen trees or branches)
Prefabricated mesh suspension fence	• Effective in controlling most stock • Quick to erect	• Relatively expensive • Easily damaged during floods
Electric fence (line droppers optional)	• Low cost • Quick to erect • Relatively flood-proof • Effective with cattle	• Three or more wires may be required for sheep • Can be unreliable under wet conditions • Electricity source needed

Stock shelter, access and crossings

Stock needs access to shade during hot, dry summers; riparian vegetation has been commonly used for stock shelter. Fencing for controlled stock access should include providing suitable shelter, preferably as an established tree shelter-belt.

Providing stock access to waterways for water supply is generally not a requirement in the Wheatbelt as the supply is unreliable and usually of poor quality. Almost all properties will have other stock water supplies. For situations where stock access is required, suitable information is available in *Water Note No. 7* (WRC, 2000a)

There is a need for stock crossings on most properties. These are considered in Information summary 5
(see page 81)

Cost of fencing

The cost of fencing will vary from $500 to $6000 per kilometre. The major cost factor is the number of line posts and strainer assemblies that are needed. Fence alignment to minimise bends will keep costs low.

The annual *Farm Budget Guide* produced by the Department of Agriculture and Food in *Farm Weekly* provides good information for estimating costs.

There may be opportunities to share the costs of riparian zone fencing where there is significant public benefit. Contact the Department of Water or the Avon Catchment Council in Northam for information about current funding opportunities for your area.

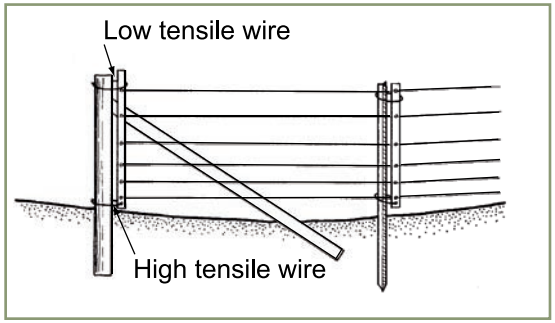


Figure 4 Options for sacrificial or collapsible fencing suitable for flood conditions

The riffles work well to trap the sediment, which has reduced our costs of sediment removal. Prior to constructing the riffles we used to desilt the waterway, now all we have to do is remove the sediment around the riffle. They are a good management system and provided a good learning curve for the volunteers who constructed them."
Colin Stacey

Lessons learned

"If we were to do this again, we would go wider with the revegetation. At the time of planning we were reluctant to 'give the land away'. In fact, it is not giving the land away – we are just using it for different purposes. We can also use the riparian zone for occasional grazing, so long as it is managed appropriately. So in fact, you don't lose any benefits, you just gain them. In 2000, we lost some fencing, which we may have saved if we went wider with the revegetation."
Colin Stacey

Revegetation and fencing on the Stacey's property at Sunnyvale (Photo courtesy of Lucy Sands)

Further information

Contact:
Colin and Trevor Stacey,
phone 9645 1095

An example of an assessmentof the management options for Snake Gully appearson the following pages.

Management options assessment — Snake Gully

Project title: Snake Gully restoration project
Location: Old House, Paddy's and Back paddocks, one section in Scott's property
Landholders: Bill and Jane Smith
Neighbours: T and E Clarke, B Rose, R and D Peterson, J, K and I Scott

Field Survey Assessment (Protection/Prevention/Recovery): Recovery (score: 19 red, 6 orange and 1 green)

Issue	Determining the cause	Considering the options
1 Erosion, sediment and flooding	Stock (cattle and sheep) have uncontrolled access to the full length of the creek – there is no fencing. Between survey points 2 and 3 the channel is actively eroding Sally's Creek has a high sediment load that adds to sediments in Snake Gully creek. There is active gully head erosion extending 50 m up Sally's Creek The culverts on Town Road are blocked with sediment. This causes the road to flood about 2 years in 5. The two culverts (60 cm diameter) are too small and restrict streamflow	• Permanent fencing both sides to control stock access (two crossings required); and revegetate, especially between survey points 2 and 3 • Stabilise gully head erosion on Sally's Creek with paddock rocks (need information on design to avoid washout) • Construct riffles and sand traps on Sally's Creek (about 3 required) and about 100 m upstream from the Town Road culvert • Surface water managements (graded interceptor banks and new dam) for Paddy's and Back paddocks

Issue	Determining the cause	Considering the options
2 Vegetation health	Condition of riparian vegetation on our property is poor. Between survey points 2 and 3 there is no fringing vegetation. The flooded gums between survey points 1 and 2 are regenerating but are damaged by cattle. The bits of bush by Snake Gully creek on Scott's property are quite good but not regenerating. It would be good to have these connected with ours in Back paddock	• Fencing the creek should allow the section of creek in Old House paddock (survey points 1-2) to regenerate naturally. Could revegetate with under-storey shrubs • The complete section of creek in Paddy's paddock needs to be revegetated both sides • Arrange with Scott's to fence their bits of bush and connect with ours in Back paddock. Some in-fill plantings may be needed on our side. Note also to contact the shire to include the road reserve in the creek rehabilitation project
3 Fencing and stock access	There is no effective fencing for this whole section of Snake Gully. There is a good boundary fence on South Road from survey point 1 to 2 (about 500 m), so no new fencing would be needed there. There will be a need to establish other stock shelter when the creek is fenced Fencing in Back paddock needs to be linked with fencing for Scott's areas of bush	• New fencing for both sides of Snake Gully creek (except for section with boundary fence) • Extend fencing 100m up Sally's Creek to include gully head erosion repair work • Arrange bush fencing with Scott's

Issue	Determining the cause	Considering the options
4 Water quality	Water in the creek is salty (7850 mg/L in September during field survey; can go over 12 000 mg/L in summer probably due to groundwater seepage) The growing patch of salt near survey point 4 can't be doing water quality any good There is a lot of green algae in the channel when it is flowing. It smells foul in summer. Nutrients from stock being in the creek is probably making it worse The creek is not suitable for stock water at any time of the year. An alternative supply is needed for Back paddock (existing reticulated troughs in Old House paddock are OK)	• Salinity of stream flow may be difficult to improve without major change in the catchment. Our other catchment group projects should help a bit. We can't expect to get Snake Gully back to stock water quality in our lifetime • Controlling surface water above the salt patch near survey point 4 and revegetating should reduce the salt risk there • Keeping stock away from the creek by fencing should reduce fouling the creek (might also reduce worm burden) • A new dam is needed on Sally's Creek either in Paddy's or Back paddock – link this with interceptor banks for these two paddocks

Issue	Determining the cause	Considering the options
5 Weeds and fire risk	There is a large number of annual weeds in all sections of the creek. The stock keep these at a relatively low level so there is not much fire risk at present. These will increase when the creek is fenced, so weed control will be needed until vegetation cover is well established There are a couple of patches of cape tulip (survey sections 3 to 4). This needs to be eradicated The neighbours upstream of Scott's have found sharp rush which could be coming down the creek to our place. We need to watch out for this We haven't seen bridal creeper here yet, but will keep a close eye on it	• Annual spraying program in restoration area with high priority to eradicate cape tulip • Could consider limited stock access early spring to reduce weeds, but not for first five years after revegetation • Check at least once a year for new weeds, especially sharp rush and bridal creeper

Issue	Determining the cause	Considering the options
6 Road and farm crossings	The creek crossing in Old House paddock is not safe and will probably get washed out in the next flood. This needs to be replaced A new farm crossing is needed near survey point 3 in Paddy's paddock (also to provide good access to the picnic area on the rocks that we want to start using again) Need a better crossing over Sally's Creek. The channel has cut so deep now that it is hard to get machinery across. This could be combined with one of the riffles to be constructed The culverts on Town Road are an ongoing problem. These need to be replaced with something that doesn't cause the road to flood every second year. It is quite dangerous for traffic when it is under water	• Design and construct floodway crossings in Old House (200 m up from survey point 1) and Paddy's paddock (near to survey point 3), and also for the lower end of Sally's Creek • Contact the shire to replace existing culverts with a boxed culvert and floodway structure

Sources of information

Agriculture Western Australia 1999, *Farm Budget Guide 1999, Farm Weekly,* Australia.

McKeon, J, Richardson, K & Dunn, I (ed) 2002, *Managing Wetlands on Your Property, Inland NSW Guidelines.* Prepared for the NSW State Wetland Advisory Committee, Department of Land and Water Conservation, Sydney.

Pen, LJ 1999, *Managing Our Rivers: a guide to the nature and management of the streams of south-west Western Australia,* Water and Rivers Commission.

Water and Rivers Commission 2000a, *Livestock Management: Watering Points and Pumps,* Water Notes WN7, Water and Rivers Commission, Perth.

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Water and Rivers Commission 2000c, *Livestock Management: Fence Location and Grazing Control,* Water Notes WN18, Water and Rivers Commission, Perth.

Water and Rivers Commission 2000d, *Flood-proof fencing for Waterways,* Water Notes WN19, Water and Rivers Commission, Perth.

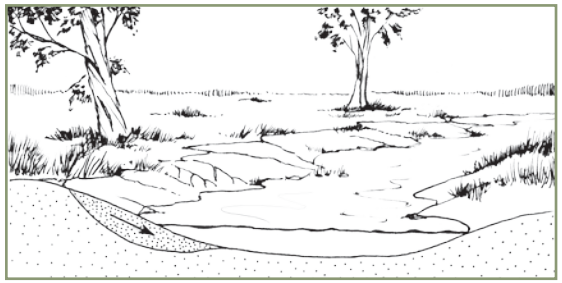
Wright, D & Jacobson, T 2000, *Managing Stream-sides: Stock Control, Fencing and Watering Options,* Tasmania Department of Primary Industries, Water and Environment.

Water and Rivers Commission 2002, *Foreshore and Channel Assessment of Talbot Brook,* Water and Rivers Commission, Water Resource Management Series No. WRM 29.

Information summary 2: Stream channel and bank protection

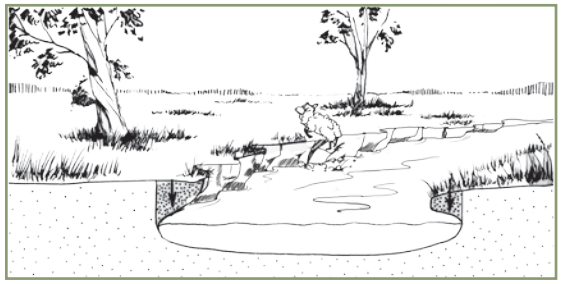
Channel and bank erosion

Erosion of the stream channel bed and banks is common in waterways throughout the Wheatbelt. It is caused by increased stream flow from catchments since clearing for agriculture, and where there is inadequate stream stability from fringing vegetation.

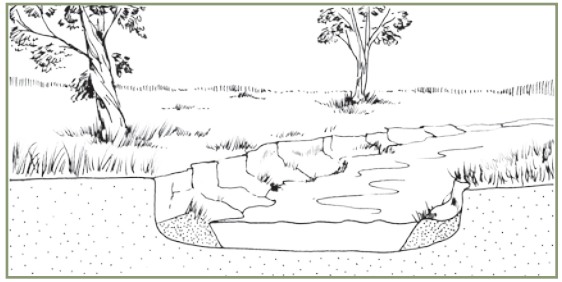


Bank erosion (before)

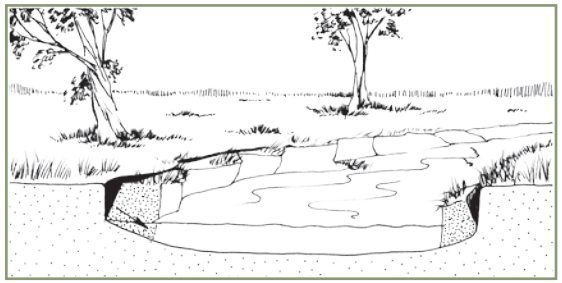
Bank erosion (after)



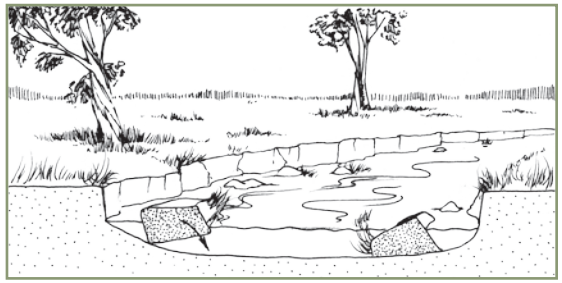
Undercutting (before)



Undercutting (after)



Slumping (before)



Slumping (after)

Figure 5 Erosion processes – bank erosion, undercutting and slumping

Naturally regenerating vegetation is the best protection for stream channels and banks. It is the least expensive, requires little maintenance and provides many other benefits. This requires good riparian zone fencing (see page 33, Information summary 1). Some areas may require revegetation (see page 51, Information summary 3).

Gully head erosion can be very 'active' in waterways. This is controlled best by reducing the cause where possible – redirecting stream flow from small tributaries to an alternative safe disposal area. Where the main channel is eroding, stone structures to stabilise the gully head may be required.

The waterways of the Wheatbelt are too extensive to apply comprehensive systems of constructed erosion control. There are options that can be considered for very active areas of erosion, especially near high value infrastructure assets (e.g. a road or farm crossing).

Options for constructed bank erosion control

Stone walling
(Photo courtesy of Duane Joubert)

Brushing (WRC, 2001)

Log deflectors
(Photo courtesy of Bernard Kelly)

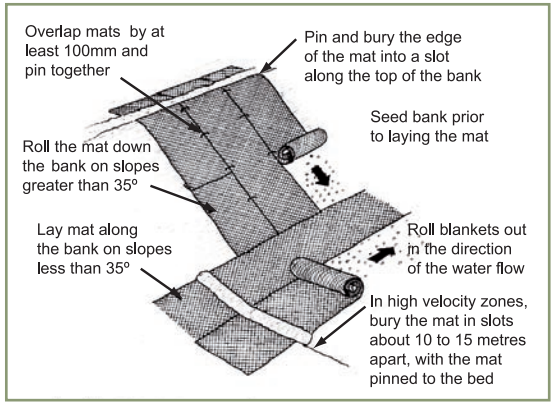


Figure 6 Matting (WRC,2001)

Case study 2: Phillips Brook

Location

Phillips Brook is located north of the town of Toodyay.

Issues

Bank erosion.
Loss of habitat.
Increased salinity and nutrient levels.

What was done?

Site preparation

The floodplain area was prepared for planting with a ripper and mounder, followed by a treatment of Roundup Bioactive, after the first winter rains.

Site works

To prevent further erosion of the banks, logs were laid horizontally along the bank and stabilised using wire and star pickets.

Revegetation

Trees and shrubs were planted along the floodplain (in the rip lines) and along the edge of the brook.

Sedges and rushes were grown in sandbags at a local school and planted at the base of the most-eroded banks during spring. The sandbags were dug in to the bank and pegged to ensure they could withstand high flows.

Expected benefits

Prevent further erosion and stabilise banks.
Provide habitat for local native fauna.

What worked well?

The sandbag sedges have been effective in stabilising the bottom of the bank and have had a high rate of survival. The logs have also been effective in protecting and stabilising the bank.

Lessons learned

Bank stabilisation doesn't need to involve concrete or rocks. Well-placed logs and sedges can be just as effective and also provide aquatic habitat.

Sandbag sedges are very effective in high erosion areas. However, they are expensive and it is not necessary to use them everywhere. Sedges planted into the soil are suitable for areas with low erosion. Sandbag sedges also require damp soil and work best in polypropylene bags.

Weed control is important, as is species selection. When choosing your species to plant, ensure they can cope with the conditions of the site and the drying climate.

Bank stabilisation activities at Phillips Brook (Photo courtesy of Terry Brooks)

Sediment control using constructed riffles

A riffle is a feature of waterways where the channel bed is particularly rough, usually because of cobbles or boulders. Naturally occurring riffles may include rapids, waterfalls or chutes where bedrock occurs in the river channel. These features slow the stream flow velocity and reduce sediment carrying capacity.

Artificial riffles are designed to replicate the effect of natural structures by reducing stream flow velocity.

They are constructed with rocks positioned in a design that deflects flow away from banks. The effectiveness of riffles is increased if built as a series (perhaps three or four in a small creek section) spaced according to criteria, including channel gradient and flow volume.

Constructed riffles can be effective in trapping sediments. Design should include a sediment trap upstream for easy removal of sediment (e.g. by front-end loader) for safe disposal.

Riffle construction at Turner Gully (Photo courtesy of Michael Allen)

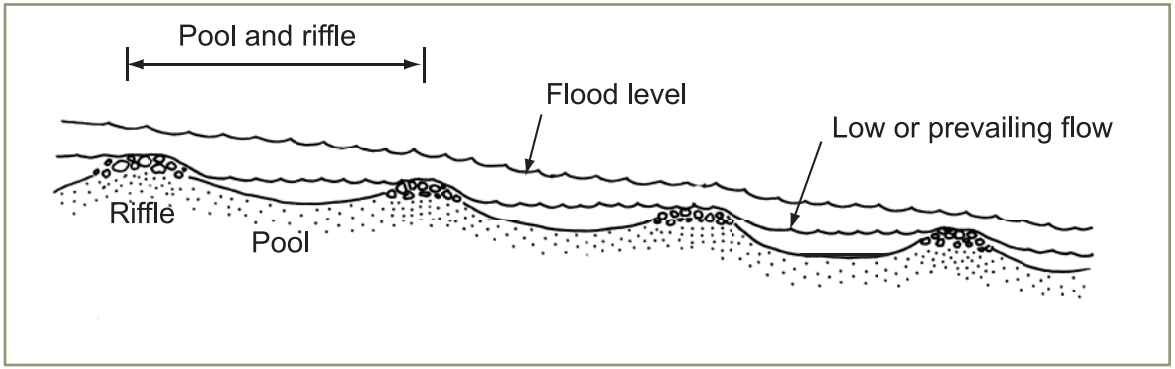


Figure 7 A series of rock riffles in a waterway

Case study 3: O'Brien Creek (Colin Wilkins, Spring Valley)

Location

O'Brien Creek runs through Colin Wilkins property, Spring Valley, in Kellerberrin.

Issues

Sedimentation, causing bank erosion and localised flooding.
Increasing salinity risk.

What was done?

Site preparation

Weeds were treated twice with Roundup bioactive.

Site works

Both sides of the creek were fenced to protect the bed and banks from stock. Two riffles were constructed to slow stream flow and reduce sedimentation. Banks were stabilised using rock.

Revegetation

The Kellerberrin Tree Nursery closed down in November 2000 and much of its stock was being sent to the local rubbish tip. The Wilkins family arranged for the trees to be sent to their property instead, to give them some chance of survival. A mechanical tree planter was used to plant the seedlings. No ripping was done at this site, but is used prior to planting on the property if possible.

Maintenance

November was late for planting; therefore, the seedlings were watered during the first summer. A number of seedlings were lost and replaced the following year.

Expected benefits

Established revegetation could be used to protect shorn sheep from bad weather.
Riffles will trap sediment and slow the flow of water.
The rock used around the riffle will protect the banks from erosion.

What worked well?

"Most things have worked well. Ministry of Justice workers were used to construct the riffle and the rock was obtained from a neighbour, which kept the cost down. We also have an EnviroFund grant to continue our fencing and revegetation. However, I think it will be too dry for lots of planting this year, but we have 18 months or so to get it done."
Colin Wilkins

Lessons learned

"This farm has been like a research station; we give most things a shot. There isn't much that I would change. We were one of the first families to try salt banks, which involved some trial and error. The graded banks seem to work better than the level banks.

If I won Lotto I would try to do more, like excavate the sand out of the creek and tree it up a bit more. However, you have to work with what you have and get it as good as you can get it."
Colin Wilkins

Further information

Contact: Colin Wilkins,
phone 9045 9013

Riffle constructed on O'Brien creek (Photo courtesy of Lucy Sands)

Sources of information

Keen, M 1998, *Common conservation works used in Western Australia,* Agriculture Western Australia, Resource Management Technical Report No. 185.

Water and Rivers Commission 2001, Stream Stabilisation, Water and Rivers Commission, River Restoration Report No. RR10.

Information summary 3: Natural regeneration and revegetation

Riparian zone (fringing) vegetation is important for healthy waterways and wetlands in the Avon Wheatbelt. Table 6 summarises the benefits of fringing vegetation.

Table 6 The benefits of fringing vegetation

Function	Benefits
Decreases waterway erosion and sedimentation	The root systems of fringing vegetation stabilise river banks, floodways and floodplains where they occur. As a result, there is reduced waterway sedimentation.
Filters nutrients	Fringing vegetation can trap soil and nutrients that would otherwise be washed into waterways, resulting in excess algal growth and sedimentation. This is significant in the Wheatbelt during summer flash floods where stubble and sheep manure may be washed into waterways.
Lowers water tables	Deep-rooted fringing vegetation maintains lower water table levels in the valley floor. This reduces the potential for salinity, which is a major threat to Wheatbelt waterways.

Function	Benefits
Provides habitat	Healthy, dense, fringing vegetation provides important habitat for aquatic animals (e.g. fish, frogs and bugs). Shade reduces water temperatures. Water flow over rocks and riffles adds oxygen. In-stream woody debris provides shelter and breeding habitat. Moist sites provide for seedling germination.
Adds scenic landscape value	A waterway with healthy fringing vegetation adds significantly to landscape scenic value. This is important as a 'sense of place' for those who live or work in the catchment and for those who visit.
Increases capital values	Well-managed waterways improve the market value of rural properties and for residential properties in towns along the watercourses.

(Adapted from Lovett et al., 2004)

Plants that grow near streams and wetlands differ to those in mid-slope remnant bush or rocky outcrops. The most common riparian zone plants in the Avon Wheatbelt are the flooded gum *(Eucaluptus rudis),* swamp paperbark *(Melaleuca rhaphiophylla)* and swamp sheoak *(Casuarina obesa).* These all tolerate flooding and waterlogging. The swamp sheoak is more tolerant of salinity than others. These three dominant species readily regenerate with favourable conditions. Other naturally occurring plants of the riparian zone are listed in Table 7.

The highest priority for riparian zone vegetation management should be for protection of those areas in good condition (any green tick sites from your field survey). Second priority should be for areas in moderate condition (orange tick sites) and third priority for those areas in poor condition (red tick sites).

Reconstruction of degraded waterways and wetlands with revegetation and earthworks is ambitious and often quite costly. Success is not guaranteed. It is best to start with the least degraded areas first as these have best chance of success and will cost least.

Natural regeneration

Natural regeneration of existing vegetation is the most cost effective and environmentally efficient method of rehabilitating the riparian zone (i.e. having the right plant in the right place). This is best for areas in good or moderate condition (any green or orange tick sites from field survey).

Management to encourage natural regeneration is simple. The key steps are:

1 Select sites where regeneration is already occurring (e.g. flooded gum, swamp paperbark and swamp sheoak often regenerate prolifically after a wet season).

2 Fence to control stock access (some grazing to reduce the weed burden during winter/early spring may not harm regeneration).

3 Control weeds with appropriate low toxicity herbicides (e.g. Roundup Bioactive). Fire may encourage weed growth and is probably not needed for regeneration in the wet areas, so is generally not recommended.

4 Ensure tributaries or surface water control banks discharge to floodways rather than directly to the main channel. This may require minor works to re-direct flow.

Some people have noted that excavated drains in salt affected areas result in regrowth of trees and the return of some native species. Drains and groundwater pumps are being used to protect or recover valued bush in the Avon Wheatbelt, especially in reserves. These potential benefits need to be balanced with the potential risks of sedimentation. Regeneration may be an additional benefit from excavated drainage for salinity control on rural land, however it is unlikely to be the primary purpose for excavated drainage on private land because of the cost and potential off-site impact. Samphires (e.g. *Haloscarcia spp*.) recolonise degraded and salt-affected areas very easily in the Avon Wheatbelt. There is a wide range of samphire species and they occur very commonly in waterways and around wetlands. They are salt and water-logging tolerant and are effective in reducing bank erosion.

Riparian zone revegetation

Revegetation should primarily be undertaken in areas where there is little or no riparian zone vegetation (including red tick sites from the field survey). Revegetation is costly and at risk of low success rates compared with natural regeneration. Direct seeding is an option for some flood-plain situations although sites with clay-dominant soils or with frequent water-logging are probably not suitable.

Management for revegetation with potted seedlings requires:

1 fencing to control stock access
2 weed control before and after planting
3 deep-ripping (if there is a hardpan or compacted layer that will restrict root development)
4 surface water management (to reduce waterlogging and flooding at the site)
5 control of kangaroos, rabbits and sometimes ducks (which may be difficult – replacing damaged seedlings may be best)
6 planting into mounded rows (approximate 3-metre spacing) in spring or early summer
7 controlling wildfires and stubble burns (some sites may need a chemical or graded firebreak).

Table 8 (page 56) provides a comprehensive list of species suitable for revegetation in the riparian zone of the Avon Wheatbelt.

Successful revegetation of waterways and wetlands can be personally very rewarding. It is often well worth the effort.

Successful revegetation at Boyagarra Pool (Photo courtesy of Prue Dufty)

Revegetation with native grasses is worth considering. There are many suitable species (see Table 9 on page 65).

Established native grasses have the advantages of reduced fire hazard and lowering the weed burden. Native marine couch *(Sporobolus virginicus)* colonises and stabilises eroding stream banks. There is little experience in the Avon Wheatbelt with establishing native grasses and the availability and cost of seed is a limitation. However, it is well worth a small trial for those who are keen.

Table 7 Riparian plants occurring naturally in Avon waterways (from Oversby, 2004)

Apiaceae
Apium prostratum (sea celery)

Casuarinaceae
Casuarina obesa (swamp sheoak)

Cheopodiaceae
Atriplex amnicola (swamp/river saltbush)
Atriplex bunburyana (silver saltbush)
Atriplex hymenotheca
Atriplex lindleyi subsp inflata
Atriplex semibaccata (creeping saltbush)
Didymathus raei
Enchylaena tomentoso var tomentosa
(ruby saltbush)
Halosarcia indica subsp bidens (sampire)
Halosarcia lylei (samphire)
Halosarcia pergranulata subsp pergranulata
(black seeded samphire)
Maireana brevifolia (small leaf bluebush)
Rhagodia drummondii
(lake fringe rhagodia)

Cupressaceae
Actinostrobus pyramidalis
(swamp cypress)

Cyperaceae
Baumea articulata (jointed twigrush)
Baumea juncea (bare twigrush)
Baumea preissii subsp laxa
Baumea riparia (river twigrush)
Bolbaschoenus caldwellii (marsh clubrush)
Chorizandra enadis (black bristlerush)
Cyperus gymnocaulas (spiny flat sedge)
Eleocharis acuta (common spikerush)
Ficinia nodosa (knotted clubrush)
Gahnia trifida (coast saw sedge)
Isolepis cernua (nodding clubrush)
Lepidosperma costale
Lepidosperma longitudinale
(pithy saw sedge)
Schoenus subfascicularis

Frankeniaceae
Frankenia glomerata
(cluster head frankenia)
Frankenia pauciflora (sea heath)

Juncaceae
Juncus caespiticius (grassy rush)
Juncus kraussii (shore rush)
Juncus pallidus (pale rush)
Juncus radula

Mimosaceae
Acacia acuminata (jam wattle)
Acacia lineolata subsp lineolata
Acacia meisneri (blue wattle)
Acacia merrallii (Merrall's wattle)
Acacia microbotrya (manna wattle)
Acacia saligna (golden wreath wattle)

Myrtaceae
Callistemon phoeniceus
(lesser bottle brush)
Eucalyptus laxophleba subsp laxophleba
(York gum)
Eucalyptus rudis (flooded gum)
Eucalyptus sargentii subsp sargentii
(salt river gum)
Melaleuca odnata
Melaleuca lateriflora subsp lateriflora
(gorada)
Melaleuca rhaphiophylla
(swamp paperbark)
Melaleuca thyoides (salt-buster myrtle)
Melaleuca viminea subsp viminea (mohan)
Scholtzia invoucrata (spiked schoitzia)

Pittosporaceae
Pittosporum angustifolium (native willow)

cont. Table 7

Poaceae
Aristida holathera (kerosene grass)
Austrostipa elegantissima (feather speargrass)
Chloris truncata (windmill grass)
Erogrostis dielssii (mallee lovegrass)
Sporobolus virginicus (native marine couch)

Proteaceae
Grevillea paniculata
Hakea preissii (needle bush)

Table 8 Species suitable for revegetation in waterways of the Avon Wheatbelt

Tree species (greater than 5 m in height)	Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propa-gation method		Distribution		
	River bank	Creek bank	Swamp land	Lake edge	Flood plain	Sand	Loam	Clay	Permanently wet	Seasonally wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	< 300 mm	Fresh	Brackish	Saline	Unknown	Seed	Cutting	Regionally abundant	Occurs naturally only in certain areas	Outside natural range
Rock sheoak *(Allocasuarina huegliana)*					✔	✔	✔				✔	✔	✔		✔				✔		✔		
Swamp sheoak *(Casuarina obesa)*	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔		✔		✔		
Kondinin blackbutt *(Eucalyptus kondinensis)*				✔	✔	✔	✔	✔			✔	✔			✔	✔			✔			✔	
Flooded gum *(Eucalyptus rudis)*	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔			✔	✔			✔		✔		

cont. Table 8 Tree species (greater than 5 m in height)	Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propa-gation method		Distribution		
	River bank	Creek bank	Swamp land	Lake edge	Flood plain	Sand	Loam	Clay	Permanently wet	Seasonally wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	< 300 mm	Fresh	Brackish	Saline	Unknown	Seed	Cutting	Regionally abundant	Occurs naturally only in certain areas	Outside natural range
York gum *(Eucalyptus loxophleba var loxophleba)*		✔			✔		✔	✔		✔	✔	✔	✔		✔	✔			✔		✔		
York gum *(Eucalyptus loxophleba var lissophloia)*		✔			✔		✔	✔		✔	✔	✔	✔		✔	✔			✔		✔		
Salt gum *(Eucalyptus salicola)*			✔	✔			✔	✔		✔		✔	✔			✔	✔		✔			✔	
Salt river gum *(Eucalyptus sargentii)*	✔	✔		✔		✔	✔			✔	✔	✔	✔			✔	✔		✔				
Swamp mallee *(Eucalyptus sugrandis subsp alipes)*		✔	✔	✔	✔	✔	✔			✔	✔	✔			✔	✔			✔			✔	
Yorrell *(Eucalyptus yilgarnensis)*		✔			✔	✔	✔	✔			✔	✔	✔		✔				✔			✔	
Native apricot *(Pittosporum phylliraeoides)*					✔	✔	✔			✔	✔	✔	✔	✔	✔	✔			✔	✔		✔	

cont. Table 8 Shrub species (greater than 2 m in height)	Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propa-gation method		Distribution		
	River bank	Creek bank	Swamp land	Lake edge	Flood plain	Sand	Loam	Clay	Permanently wet	Seasonally wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	< 300 mm	Fresh	Brackish	Saline	Unknown	Seed	Cutting	Regionally abundant	Occurs naturally only in certain areas	Outside natural range
Jam wattle *(Acacia acuminata)*	✔	✔			✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔			✔		✔		
Wait-a-while wattle *(Acacia colletioides)*		✔			✔	✔	✔				✔	✔	✔					✔	✔				
Acacia meisnerii					✔		✔	✔		✔	✔	✔			✔				✔	✔	✔		
Merrall's wattle *(Acacia merrallii)*		✔			✔	✔	✔	✔			✔	✔	✔		✔	✔			✔	✔			
Manna wattle *(Acacia microbotrya)*	✔	✔			✔		✔	✔		✔	✔	✔	✔		✔	✔			✔		✔		
Golden wreath wattle *(Acacia saligna)*	✔	✔			✔	✔	✔	✔		✔	✔	✔			✔	✔	✔		✔		✔		

cont. Table 8 Shrub species (greater than 2 m in height)	Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propa-gation method		Distribution		
	River bank	Creek bank	Swamp land	Lake edge	Flood plain	Sand	Loam	Clay	Permanently wet	Seasonally wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	<300 mm	Fresh	Brackish	Saline	Unknown	Seed	Cutting	Regionally abundant	Occurs naturally only in certain areas	Outside natural range
Lesser bottlebrush *(Callistemon phoeniceus)*	✔	✔	✔	✔	✔	✔	✔			✔		✔	✔		✔	✔			✔	✔	✔		
Grevillia paniculata					✔	✔	✔				✔	✔						✔	✔				
Rusty grevillia *(Grevillia vestitia)*					✔	✔	✔				✔	✔			✔				✔	✔			
Needle bush *(Hakea preissii)*	✔	✔			✔	✔	✔	✔			✔	✔			✔	✔			✔		✔		
Melaleuca acuminata		✔			✔	✔	✔	✔		✔	✔		✔	✔		✔	✔		✔	✔			
Saltwater paperbark *(Melaleuca cuticularis)*	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔	✔			✔	✔		✔		✔		

cont. Table 8 Shrub species	Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propa-gation method		Distribution		
	River bank	Creek bank	Swamp land	Lake edge	Flood plain	Sand	Loam	Clay	Permanently wet	Seasonally wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	<300 mm	Fresh	Brackish	Saline	Unknown	Seed	Cutting	Regionally abundant	Occurs naturally only in certain areas	Outside natural range
Melaleuca hamulosa	✔	✔				✔	✔	✔		✔		✔	✔		✔	✔	✔		✔	✔			
Melaleuca lateriflora var lateriflora		✔	✔		✔	✔	✔			✔		✔	✔	✔	✔	✔			✔	✔			
Stout paperbark *(Melaleuca preissiana)*	✔	✔	✔	✔		✔	✔		✔	✔		✔	✔		✔	✔			✔	✔	✔		
Swamp paperbark *(Melaleuca rhaphiophylla)*	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔			✔	✔			✔	✔	✔		
Salt lake honey myrtle *(Melaleuca thyoides)*	✔	✔	✔	✔	✔	✔	✔			✔	✔	✔	✔	✔		✔	✔		✔				
Melaleuca uncinata		✔	✔	✔		✔	✔	✔		✔	✔		✔		✔	✔	✔		✔	✔	✔		

cont. Table 8 Shrub species	Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propa-gation method		Distribution		
	River bank	Creek bank	Swamp land	Lake edge	Flood plain	Sand	Loam	Clay	Permanently wet	Seasonally wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	< 300 mm	Fresh	Brackish	Saline	Unknown	Seed	Cutting	Regionally abundant	Occurs naturally only in certain areas	Outside natural range
Mohan *(Melaleuca viminea)*	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔	✔		✔	✔			✔	✔	✔		
Quandong *(Santalum acuminatum)*					✔	✔	✔	✔			✔	✔	✔		✔				✔		✔		
Sandalwood *(Santalum spicatum)*					✔						✔	✔	✔	✔					✔		✔		

cont. Table 8 Shrub species (1 – 2 m in height)	Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propa-gation method		Distribution		
	River bank	Creek bank	Swamp land	Lake edge	Flood plain	Sand	Loam	Clay	Permanently wet	Seasonally wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	< 300 mm	Fresh	Brackish	Saline	Unknown	Seed	Cutting	Regionally abundant	Occurs naturally only in certain areas	Outside natural range
River saltbush *(Atriplex amnicola)*		✔	✔	✔	✔	✔	✔			✔	✔	✔	✔	✔		✔	✔		✔	✔			✔
Silver saltbush *(Atriplex bunburyana)*		✔	✔	✔	✔	✔	✔			✔	✔	✔	✔	✔		✔			✔				
Dwarf saltbush *(Atriplex codonocarpa)*					✔		✔	✔		✔			✔	✔			✔		✔				
Pop saltbush *(Atriplex holocarpa)*		✔		✔			✔	✔		✔	✔	✔	✔	✔		✔	✔		✔	✔			✔
Old man saltbush *(Atriplex nummularia)*		✔	✔	✔		✔	✔	✔		✔	✔	✔	✔	✔		✔	✔		✔	✔			
Marsh saltbush *(Atriplex paludosa)*		✔			✔	✔	✔			✔		✔	✔			✔	✔		✔				

cont. Table 8 Shrub species (1 – 2 m in height)	Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propa-gation method		Distribution		
	River bank	Creek bank	Swamp land	Lake edge	Flood plain	Sand	Loam	Clay	Permanently wet	Seasonally wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	< 300 mm	Fresh	Brackish	Saline	Unknown	Seed	Cutting	Regionally abundant	Occurs naturally only in certain areas	Outside natural range
Kidney saltbush *(Atriplex stipitata)*		✔			✔		✔				✔	✔	✔	✔		✔			✔				
Bladder saltbush *(Atriplex vesicaria)*		✔		✔			✔	✔		✔	✔	✔	✔	✔		✔	✔		✔				
A myrtle *(Melaleuca thymoides)*		✔	✔		✔				✔		✔			✔	✔			✔	✔				

cont. Table 8 Shrub and groundcover species (Under 1 m in height)	Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propa-gation method		Distribution		
	River bank	Creek bank	Swamp land	Lake edge	Flood plain	Sand	Loam	Clay	Permanently wet	Seasonally wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	< 300 mm	Fresh	Brackish	Saline	Unknown	Seed	Cutting	Regionally abundant	Occurs naturally only in certain areas	Outside natural range
Creeping saltbush *(Atriplex semibaccata)*	✔	✔	✔	✔	✔	✔	✔			✔	✔	✔	✔		✔	✔			✔				
Ruby saltbush *(Enchylaena tomentosa)*		✔		✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔			✔	✔			
Bluebush *(Maireana brevifolia)*		✔		✔	✔		✔	✔		✔	✔	✔	✔	✔		✔	✔		✔				
Sea heath *(Frankenia pauciflora)*	✔	✔		✔		✔	✔			✔	✔	✔	✔			✔	✔			✔			
Spring saltbush *(Rhagodia spinescens)*		✔		✔	✔	✔	✔				✔	✔	✔			✔	✔			✔			

Table 9 Native grasses suitable for revegetation in waterways of the Avon Wheatbelt – list of species and their site specific requirements (* see Glossary for explanation)

				Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propagation and sowing		
Native grass species	C3 or C4	Annual	Perennial	Floodway*	River bank*	Swamp land*	Lake edge*	Flood fringe*	Sand	Loam	Clay	Perm wet	Seas wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	< 300 mm	Fresh	Brackish	Saline	Seed	Seed collecting time	Sowing time	Vegetative propagation
Agrostis avenacea (Blown grass)	C3	✔			✔	✔	✔		✔	✔			✔		✔	✔	✔		✔	✔	✔	Jan	Aut	
Amphibromus nervosus (Swamp wallaby grass)	C3		✔	✔	✔	✔	✔			✔	✔	✔	✔		✔	✔	✔	✔			✔	Nov/ Dec	Aut	
Amphipogon turbinatus	C3		✔	✔			✔	✔	✔	✔			✔	✔	✔	✔		✔			✔	Dec/ Jan	Aut	
Aristida holathera (Great kerosene grass)	C4	✔	✔					✔	✔	✔				✔	✔	✔	✔	✔	✔		✔	Dec/ Jan	Spr	

cont. Table 9

Native grass species	C3 or C4	Annual	Perennial	Riparian zone: Floodway*	Riparian zone: River bank*	Riparian zone: Swamp land*	Riparian zone: Lake edge*	Riparian zone: Flood fringe*	Soil type: Sand	Soil type: Loam	Soil type: Clay	Water tolerance: Perm wet	Water tolerance: Seas wet	Water tolerance: Drought tolerant	Rainfall zone: 350 mm – 400 mm	Rainfall zone: 300 mm – 350 mm	Rainfall zone: < 300 mm	Salt tolerance: Fresh	Salt tolerance: Brackish	Salt tolerance: Saline	Salt tolerance: Seed	Propagation and sowing: Seed collecting time	Propagation and sowing: Sowing time	Propagation and sowing: Vegetative propagation
Austrodanthonia setacea (small flower wallaby grass)	C3		✔				✔	✔	✔	✔	✔			✔	✔	✔	✔	✔	✔		✔	Dec/ Jan	Aut	
Austrodanthonia caespitosa (wallaby grass)	C3		✔	✔	✔		✔	✔	✔	✔	✔			✔	✔	✔	✔	✔	✔		✔	Dec/ Jan	Aut	
Austrostipa elegantissima (featherspear grass)	C3		✔				✔	✔	✔	✔	✔			✔	✔	✔	✔	✔	✔		✔	Nov/ Dec	Aut	
Austrostipa macalpinei (golden speargrass)	C3	✔					✔	✔	✔	✔				✔	✔	✔		✔			✔	Nov/ Dec	Aut	
Austrostipa pycnostachya (salt speargrass)	C3		✔	✔		✔	✔		✔	✔	✔		✔		✔	✔		✔	✔	✔	✔	Dec/ Jan	Aut	rhizomes

cont. Table 9

Native grass species	C3 or C4	Annual	Perennial	Riparian zone: Floodway*	Riparian zone: River bank*	Riparian zone: Swamp land*	Riparian zone: Lake edge*	Riparian zone: Flood fringe*	Soil type: Sand	Soil type: Loam	Soil type: Clay	Water tolerance: Perm wet	Water tolerance: Seas wet	Water tolerance: Drought tolerant	Rainfall zone: 350 mm – 400 mm	Rainfall zone: 300 mm – 350 mm	Rainfall zone: < 300 mm	Salt tolerance: Fresh	Salt tolerance: Brackish	Salt tolerance: Saline	Salt tolerance: Seed	Propagation and sowing: Seed collecting time	Propagation and sowing: Sowing time	Propagation and sowing: Vegetative propagation
Austrostipa tenuifolia	C3		✔					✔	✔	✔	✔			✔	✔	✔	✔	✔	✔	✔	✔	Nov/ Dec	Aut	
Austrostipa trichophylla	C3		✔			✔	✔	✔	✔	✔	✔		✔		✔	✔	✔	✔			✔	Nov/ Dec	Aut	
Chloris truncata (windmill grass)	C4		✔	✔	✔	✔		✔		✔	✔			✔	✔	✔		✔			✔	Dec/ Jan	Aut	
Cymbopogon ambiguus (scentgrass)	C4		✔		✔			✔	✔	✔					✔	✔		✔			✔	Oct/ Dec	Spr	rhizomes
Enteropogon acicularis (curly windmill grass)	C4		✔	✔	✔			✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔	Oct/ Dec	Spr	
Eragrostis australasica (canegrass)	C4		✔	✔	✔	✔	✔	✔			✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	Oct/ Dec	Aut	

cont. Table 9				Riparian zone					Soil type			Water tolerance			Rainfall zone			Salt tolerance				Propagation and sowing		
Native grass species	C3 or C4	Annual	Perennial	Floodway*	River bank*	Swamp land*	Lake edge*	Flood fringe*	Sand	Loam	Clay	Perm wet	Seas wet	Drought tolerant	350 mm – 400 mm	300 mm – 350 mm	< 300 mm	Fresh	Brackish	Saline	Seed	Seed collecting time	Sowing time	Vegetative propagation
Eragrostis dielsii (mallee lovegrass)	C4	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	Nov/ Dec	Aut	
Eragrostis elongata (clustered lovegrass)	C4		✔	✔	✔	✔	✔		✔	✔	✔		✔		✔			✔			✔	Nov/ Jan	Aut	
Leptochloa fusca (brown beetle grass)	C4		✔	✔	✔	✔	✔		✔	✔	✔		✔		✔	✔	✔	✔	✔		✔	Nov/ Jan	Aut	
Microlaena stipoides (weeping grass)	C3		✔	✔	✔	✔	✔			✔	✔		✔		✔			✔			✔	Jan/ Feb	Spr	rhizomes
Neurachne alopecuroidea (foxtail mulga grass)	C3		✔	✔				✔	✔	✔	✔			✔	✔	✔	✔	✔	✔		✔	Dec/ Jan	Aut	
Polypogon tenellus	C3	✔		✔	✔	✔	✔		✔	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔	Dec/ Jan	Aut	

cont. Table 9

Native grass species	C3 or C4	Annual	Perennial	Riparian zone: Floodway*	Riparian zone: River bank*	Riparian zone: Swamp land*	Riparian zone: Lake edge*	Riparian zone: Flood fringe*	Soil type: Sand	Soil type: Loam	Soil type: Clay	Water tolerance: Perm wet	Water tolerance: Seas wet	Water tolerance: Drought tolerant	Rainfall zone: 350 mm – 400 mm	Rainfall zone: 300 mm – 350 mm	Rainfall zone: <300 mm	Salt tolerance: Fresh	Salt tolerance: Brackish	Salt tolerance: Saline	Salt tolerance: Seed	Propagation and sowing: Seed collecting time	Propagation and sowing: Sowing time	Propagation and sowing: Vegetative propagation
Puccinellia stricta (marsh grass)	C3		✔	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔	✔			✔	✔	✔	Dec/ Jan	Aut	
Sporobolus viriginicus (native marine couch)	C4		✔	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	Jan/ Feb	Spr	rhizomes
Themeda triandra (kangaroo grass)	C4		✔	✔				✔	✔	✔				✔	✔			✔			✔	Dec/ Jan	Spr	
Triraphis mollis (needle grass)	C4		✔	✔				✔	✔	✔	✔			✔	✔	✔	✔	✔		✔	✔	Oct/ Dec	Aut	

Case Study 4: Wallatin Creek (Mike and Sue McFarlane, 'Dangemanning', Doodlakine)

Location

Wallatin Creek flows through Mike and Sue McFarlane's property, east of the town of Doodlakine.

Issues

Rising salinity levels.
Bank erosion.
Flooding.
Silting of creek and farm land.
Construction of deep drains upstream.
Unknown effect of deep drains on sand seams (alluvial channels).

What was done?

The McFarlane family has invested considerable effort over the past 10 years to restoring Wallatin Creek, where it passes through their property. This has included fencing, revegetation of the riparian zone, planting of windbreaks and entering into a foreshore management agreement. More recently, they have become involved in a groundwater monitoring project to monitor any changes to water tables from the construction of deep drains upstream.

Site preparation and works

Prior to planting, the site was sprayed to control weeds and ripped.

Fences were constructed approximately 30 metres from the channel to exclude stock. Fences did not follow the creek exactly so as to reduce the number of bends and strainers used.

In 2007, three groups of three monitoring bores (nine in total) were installed, approximately 500 metres apart.

Revegetation

The riparian zone was revegetated in 1998 using local species, including eucalyptus, acacia, melaleuca and senna.

Expected benefits

Fencing and revegetation

Reduced salinity risk and lowered the water table.
Stabilised banks and reduced erosion.
Improved crop productivity.
Provided a buffer between neighbours' stock and spraying.

Monitoring bores

Improved understanding of the downstream impacts of deep drainage, including changes to the water table and leakage into sand seams.

What worked well?

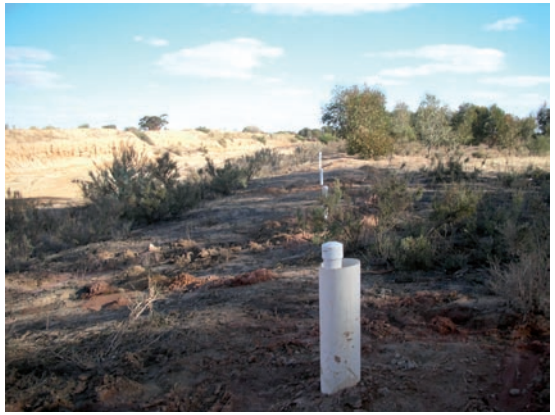
"The creek has been stable for many years due to the revegetation. Creek vegetation was planted in conjunction with other lines of vegetation along contours and has reduced wind damage and supplied shelter to stock. We also value the aesthetics of the revegetated landscape and its importance to local wildlife."
Sue McFarlane

Lessons learned

"Working with neighbouring landowners is so important to ensuring your success. We have also acknowledged the importance of monitoring – knowing what the potential problems are instead of assuming. That is vital."
Sue McFarlane

Further information

Contact: Mike and Sue McFarlane, phone 9045 8244



Revegetation and monitoring bores located along Wallatin Creek (Photo courtesy of Lucy Sands)

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Information summary 4: Weed control

Controlling weeds is the biggest challenge for management of waterways in the Avon Wheatbelt. Most waterways have heavy infestations of annual weeds, especially wild oats and agricultural weeds. Many areas are being invaded by perennial weeds that are difficult to eradicate; sharp rush and bridal creeper are the two most significant.

Weeds suppress natural vegetation regeneration. They also reduce survival rates for revegetation and create a fire hazard.

The weeds most commonly occurring in Avon Wheatbelt waterways are listed in Table 10.

Table 10 Common weeds of Avon Wheatbelt waterways

Weed	Comments
Annual weeds Annual veldt grass *(Ehrharta longiflora)* Cape tulip[1] *(Homeria spp.)* Paterson's curse[1] *(Echium plantagineum)* Wild radish *(Raphanus raphanistrum)* Wild oats *(Avena barbata, Avena fatua)* Soursob[1] *(Oxalis pes-caprae)* Rye grass *(Lolium spp.)*	Cape tulip is toxic to livestock and Soursob is too bitter for grazing. Considering this, uncontrolled grazing in the river will not be an effective form of weed control.
Perennial weeds Sharp rush *(Juncus acutus)* Veldt grass *(Ehrharta calycina)* African love grass *(Eragrostic curvula)*	Sharp rush (*Juncus acutus*) currently chokes smaller tributaries and is a contaminant to wool. Control methods include use of Glyphosate herbicide. Healthy riparian vegetation will reduce available light which inhibits rush growth. There are also some reports of areas planted to trees not being invaded by the rush, probably due to competition for water as well as light.
Vines, creepers, grasses and herbs Bridal creeper[1] *(Asparagus asparagoides)* African feather grass *(Pennisetum macrourum)* Watsonia *(Watsonis bulbillifera)* Arum lily[1] *(Zantedeschia aethiopica)*	

Weed	Comments
Weeds in saline areas	
Rye grass *(Lolium spp.)*	
Barley grass *(Hordeum leporinum)*	
Bearded grass *(Polypogon monspeliensis)*	
Atriplex *(Atriplex prostrata)*	
Wild aster *(Aster subulatus)*	
Saltwater couch *(Paspalum vaginatum)*	
Coast barb grass *(Parapholis incurva)*	
Tamarisk *(Tamarix pentaphylla)*	
Box thorn *(Lycium ferocissimum)*	

Note: [1] = declared weeds under the *Agricultural and Related Resources Protection Act 1976* for which landholders are required to take action for control.

Management

The defining characteristics of weeds are that they establish rapidly even in unfavourable or disturbed environments and are difficult to eradicate or control. The best form of management is prevention – taking action to avoid introduction or expansion of new weeds species to a waterway.

This can be achieved by:

- maintaining a wide riparian zone (30 to 50 m) with healthy natural vegetation
- avoiding disturbance to the riparian zone (e.g. fire, vehicular access and clearing)
- excluding stock from the riparian zone.

Control of existing weeds for extensive areas is achieved best with careful use of herbicides. Hand removal is best for the very early stages of weed establishment but it is not practical for the extensive areas of most Wheatbelt waterways. In some situations, the weed burden can be reduced by controlled grazing.

This will not control or eradicate weeds but can reduce fire risk. However, some weed species are not palatable to stock.

The timing, methods and rates of application should be according to directions for use provided with the chemical product. Most farmers in the Avon Wheatbelt are very experienced with chemical use and are aware of personal and environmental safety issues. Understanding the potential environmental impacts of herbicide use is particularly important when managing waterways.

Table 11 (page 74) provides an assessment of herbicides used for weed control.

Table 11 Herbicide control of weeds in Avon Wheatbelt waterways

Herbicide	Target weeds	Management comments
Glyphosate (Roundup Biactive®, Roundup®, Rodeo®, Davison Glyphosate 450®)	Used for control of a large variety of weeds generally where there are no native plant species present	Glyphosate is a broad spectrum, non-selective systemic herbicide that will kill most plants, including native species Some of the surfactants used in agricultural formulations have been found to be toxic to fish, amphibians and aquatic invertebrates. Roundup Biactive®, which contains a substantially less toxic surfactant and was designed for use in aquatic habitats, is the recommended option Glyphosate is strongly adsorbed and inactivated by soil and by organic and mineral-suspended particles in water bodies, so leaching and contamination of run-off is negligible

Herbicide	Target weeds	Management comments
Fluazifop-p-butyl (Fusilade®)	Commonly used for control of veldt grass, kikuyu, couch and water couch where native plant species are present	Fluazifop-p-butyl is a selective herbicide, which is designed to kill grasses It has a low toxicity to bees and rats and is practically non-toxic to ducks and mammals and with no detectable impact on aquatic invertebrates Fusilade is only slightly soluble in water, and is rapidly degraded. Spraying should occur before the flowering stage
Metsulfuron-methyl (Brushoff, Ally, Groper and Escort)	Used for control of cape tulip, Paterson's curse and blackberry	A systemic herbicide used on broad leaf weeds and some grasses, and can kill native species It has low toxicity to fish, mammals and birds and a very low toxicity to aquatic micro-organisms and terrestrial invertebrates *Application by professional users recommended*

Herbicide	Target weeds	Management comments
Chlorsulfuron (Glean®, Siege®, Tackle®)	Used to control most broadleaf weeds and some grasses Used for cape tulip, Paterson's curse and arum lily	Glean is a selective herbicide which is absorbed by the foliage and roots of plants It has low toxicity to birds, mammals, fish and aquatic invertebrates The chemical may persist in the soil for some time, having a half-life of 4–20 weeks in soil and 1–2 weeks in water *Application by professional users recommended*
Diquat (Aquacide®/Reglone®)	Useful for control of grasses and for floating, submerged and emergent aquatic weeds	Diquat is a contact herbicide used for weed and grass control It has low toxicity to bees and micro-organisms, a low-to-moderate toxicity to fish and aquatic organisms, and a low-to-high toxicity to birds Although Diquat is persistent in the environment, it is rapidly and strongly inactivated in the soil, and becomes biologically unavailable *Application by professional users recommended*

Control of sharp rush

Juncus acutus (sharp rush) belongs to the Juncaceae family and is closely related to a number of native rush species that occur naturally throughout the south-west of the state. Sharp rush originates from South Africa and is considered an invasive environmental and agricultural weed.

It forms dense clumps to 2.5 m high (usually 1.5 m) with the culms (leaves) ending in a hard point that can penetrate the skin. The seed head is rust/brown and is 3–5cm in diameter. Each seed head can produce in the region of 3000 seeds with a viability of between 75 per cent and 95 per cent.

The actual seeds are extremely small (like dust) and need light to germinate. Sharp rush prefers permanently moist sites but can withstand some drought, especially when mature. It may be partially grazed by stock when other feed is not available, but this rarely kills it. It tolerates fresh to semi-saline water/soil and will re-shoot after fire.

Sharp rush (Juncus acutus) growing on a seep area (Photo courtesy of Lucy Sands)

The current best practice relevant to the Avon Wheatbelt for control of *Juncus acutus* is based on the following field experience: Roundup Biactive® will kill *J. acutus* if used with high application rates (20 ml/L of water). This may take two months to be effective, although smaller plants should die more quickly. The results are variable as some plants don't seem to respond as well to Roundup after they have been slashed and regrown.

- Hard slashing at ground level will kill around 30 per cent of mature plants, but most resprout, to some degree.
- Slashing and solarising (covering with black plastic) for five months kills *J. acutus* and all other plants in the trial area.
- Digging out the plants to a depth of 10 cm also kills them, with no resprouting from root stock.
- The use of a diesel and Roundup mix has been used by some people, who say it is effective, although this is not a recommended method of control near waterways.
- A hot fire will reduce the amount of above-ground live plant material, but this does not kill the plant and it will resprout.
- Germination from seed has been an issue at some sites but these small plants are easily removed either physically or by spraying. It is easier to control these seedlings with a glyphosphate spray before other native vegetation is introduced to the site.

J. acutus killed with Roundup Biactive® maintains its spiked form for many months after death. This makes it difficult to undertake a program of revegetation. The dead plants can be burned effectively (ensure plants are dead before burning or they will re-sprout).

J. acutus seeds also need light to germinate. Prevention is the best form of control, so establishing dense cover at vulnerable sites is required. Species that are suitable for use are:

- *Juncus kraussii* (shore rush)
- *Juncus pallidus* (pale rush)
- *Cyperus gymnocaulos* (spiny flat sedge)
- *Ficinia nodosa* (knotted club rush)
- *Gahnia trifida* (coast saw sedge)
- *Sporobolus virginicus* (native couch).

On dry saline land, saltbush can be used to shade the ground instead. Species to use include:

- *Atriplex semibaccata* (creeping saltbush)
- *Atriplex amnicola* (swamp saltbush)
- *Maireana brevifolia* (small-leafed bluebush)
- *Atriplex bunburyana* (silver saltbush)
- *Atriplex codonocarpa* (bell saltbush)
- *Enchylaena tomentosa* (ruby saltbush)
- *Enchylaena lanata.*

A mixed planting of native trees, shrubs and sedges will offer the best long-term solution to controlling *J.acutus.*

Case Study 5: Weed control on a tributary of the Mortlock River South

Issues

The stream has been degraded through clearing and heavy grazing.
Water quality is brackish to saline, depending on the season.
Saline scalds are present and there is evidence of erosion and movement of sediment downstream.
There is little native vegetation and the area is heavily infested with sharp rush (*Juncus acutus*).

What was done?

Site Preparation

The stream was fenced to stop stock accessing the area and *Juncus acutus* was sprayed with Roundup Bioactive in early summer of the year prior to planting.

The following autumn the remnants of *Juncus acutus* was burnt. Following this, the site was ripped on the contour in areas where there is unlikely to be large volumes of overland flow. Dead branches and logs were secured to the banks to prevent erosion and trap sediment. The area was resprayed to control any *Juncus acutus* re-shoots. Following the first winter rains, the winter active weeds were treated with Roundup Bioactive.

Revegetation

10,000 seedlings were planted on-site including a variety of sedge and rush species. Salt tolerant species were planted on the flood fringe including understorey plantings of saltbush and bluebush.

Expected benefits

Stabilisation of banks and reduction in erosion.
Improvement in water quality due to nutrient stripping by sedges.
Removal of weed species.
Increase in biodiversity.
Increase in habitat for local and migratory fauna.

This will all result in the establishment of a more sustainable and aesthetically pleasing landscape.

What worked well?

Seedlings planted in the flood fringe areas have established well and have stopped the spread of the salt scald. Acacia and Melaleuca seedlings have grown and formed good habitat for birds. *Gahnia trifida* and *Juncus kraussii* have also established in the channel.

Lessons learned

There is a need to continually monitor and spray new outbreaks of *Juncus acutus*. Upstream areas of this watercourse are yet to be cleared of *Juncus acutus* and seed is currently washed downstream in the channel. It would be advisable to start restoration at the headwaters of a stream if it is heavily infested with weeds.

After three years there are some gaps in vegetation and it would be useful to do some infill planting on-site.

Grass Valley revegetation site showing the sedges and rushes in the waterway, with trees and shrubs establishing on the flood fringe (two years after planting). (Photo courtesy of Prue Dufty)

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Water and Rivers Commission 2000, *Weeds in Waterways,* Water Note No 15.

Relevant contacts

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Swan Catchment Centre
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Safe use and disposal of herbicides:
Health Department's
Pest Control Branch
phone 9383 4244.

Dr Ken Aplin
Alcoa Frog Watch Coordinator
Western Australian Museum
phone 9427 2826.

Information summary 5: Farm and local road crossings

There is a need to provide crossings over waterways on farms and for local roads. The requirement for bridge structures or culvert crossings for bituminised or larger gravel roads requires engineering design and is beyond the scope of this field guide.

Farm stream crossings

There are almost as many farm-stream crossing designs as there are farmers in the Wheatbelt. Some are robust and safe, others are temporary and a risk to those using them. The important criteria in location and design of farm creek crossings are:

- providing access for a range of uses (e.g. cars, trucks, cultivator bars, headers, stock)
- ensuring safety
- fitting into a farm plan (paddock layout, surface water control banks etc.)
- minimising damage to the waterway (channel, banks, vegetation)
- providing adequate flow capacity (including flood flows).

There are four basic types of farm crossings:

1 *Culverts.* Boxed or piped conduits to convey stream flow under a road crossing. The capacity of the culvert should not restrict the flow of the waterway. Many farm culvert structures are washed-out in high flow events because they were of inadequate capacity. These structures are suited to narrow, deeply incised streams.

An example of a culvert (Photo courtesy of Lucy Sands)

2 *Causeways*. Structures that raise the base of the stream bed. They are designed to allow low flow through culverts but are inundated during floods. They need to be built using concrete. These structures are suited to the wide shallow streams with intermittent flow in the Wheatbelt. Causeways for most situations should not raise the stream bed more than 30 cm. Culverts may not be required in some situations.

An example of a causeway (Photo courtesy of Kate Gole)

3 *Fords.* Vehicle crossings constructed at the level of the stream bed. Low flow passes over the ford rather than through culverts. A ford will suit the purpose of many farm crossings in the Wheatbelt because flow in most streams is infrequent. A ford is less suitable where there are steep banks or there is a continuous flow of highly saline or acidic water.

An example of a ford (Photocourtesy of Kate Gole)

4 *Stock crossings*. Natural stream crossings with little or no modification to the channel.

An example of a stock crossing (Photo courtesy of Lucy Sands)

Figure 8 outlines design criteria for siting farm stream crossings.

When siting a farm stream crossing, you should:

- avoid a stream bend or where active erosion is occurring
- align crossing structures perpendicular to stream flow
- select a site with less than 1:4 bank gradient
- minimise potential for sediment to be trapped by crossing structures
- ensure suitable fencing for crossings to control stock access to the stream environment.

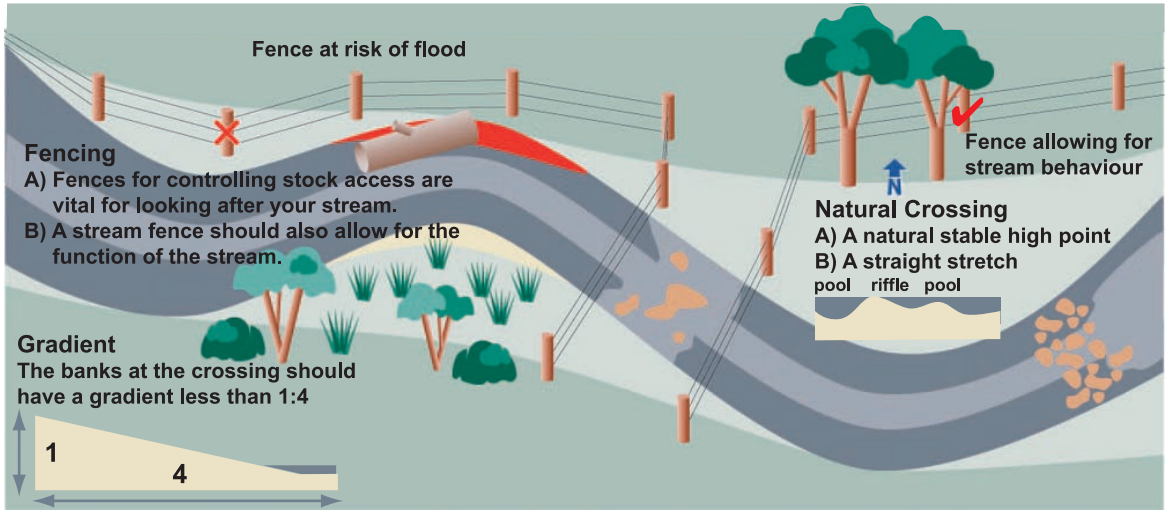


Figure 8 Design criteria for siting farm stream crossings

Bridge structures on farms are generally not recommended. Advice from a suitably qualified engineer should be sought if a bridge is needed as a farm crossing.

Local road crossings

Culvert crossings for local roads in the Wheatbelt are commonly used. Some have adequate capacity for most flow events, others are damaged by floods or 'silt-up' with bedload sediments. Criteria for locating and constructing local road culverts include:

1 The cross-sectional area of the culverts used should simulate stream channel capacity.

2 Numerous low-level culverts are preferred to one or two higher box culverts.

3 Box culverts are preferred because of greater capacity.

4 Culverts are to be aligned with stream flow direction.

5 The length of the culvert should be approximately 57 per cent of the stream channel width.

6 The invert of at least one of the culverts should be set 150 mm below the stream bed to allow sediment to move through the culvert.

7 The road surface needs to be stabilised to prevent failure during over-topping by high flow events. The following protection should be considered:

a) Earth embankment compacted to achieve 95 per cent maximum dry density.

b) 'Riprap' on the downstream batter and bank crest and around the culvert inlet.

c) 'Riprap' on bed and adjacent banks to at least one metre above the track level and extending at least four times the culvert height downstream.

d) The minimum 'Riprap' median rock size (D50) should be 150 mm.

e) Maximum upstream batter gradient of 1(v):2(h) and downstream gradient of 1(v):4(h) as shown in Figure 9.

f) The crest to be covered with 20 mm to 150 mm diameter rock mix, 200 mm thick (compacted thickness), or sealed with bitumen / concrete.

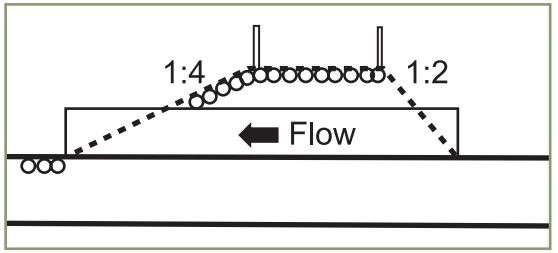


Figure 9 Batter gradient for culvert crossings

Department of Water approval for construction of road crossings may be required under the *Rights in Water and Irrigation Act (1914)*. As part of the planning of a project, seek advice from the department in this regard.

Sources of information

Goulburn Broken Catchment Management Authority (2007)
Work on Waterways Notes No1
Goulburn Broken Catchment Management Authority, Shepparton.

Department of Water (2008)
Crossing creeks - Stream crossings on farms, Department of Water, Perth.

These guidelines should be used in conjunction with appropriate technical advice and literature.

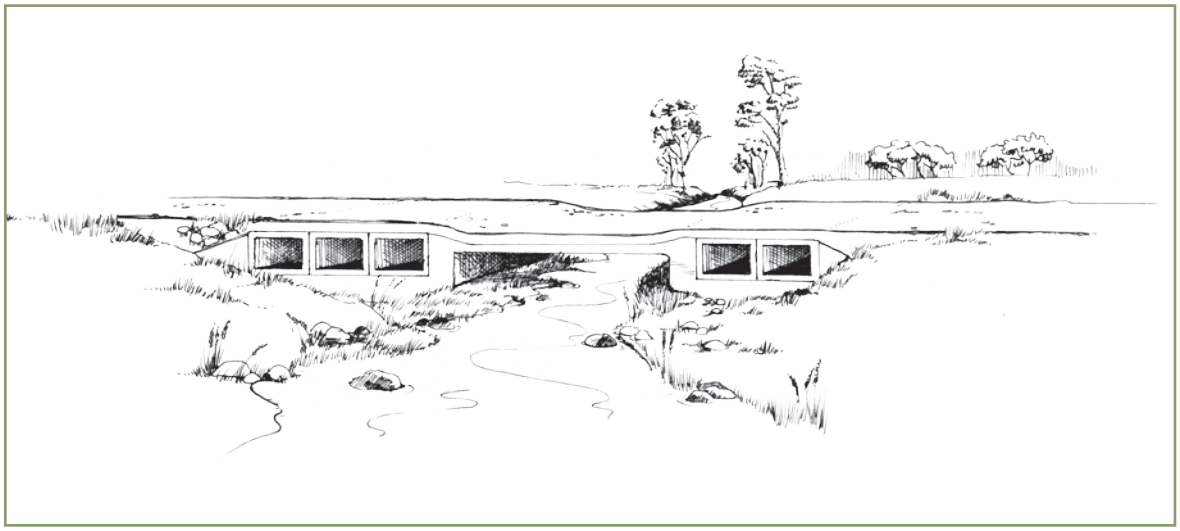


Figure 10 Box culvert design for braided channel road crossings

Case study 6: Avon River (John Barrett-Lennard, Annandale)

Location

The Avon River flows through John Barrett-Lennard's property, Annandale, north of the town of Beverley.

Issues

Requirement for a suitable farm crossing as old one was washed out.
Bank and channel erosion.
Sedimentation of pools.
High velocity flows.

What was done?

Site preparation and works

The crossing was constructed approximately 10 years ago when the river was dry and it was installed at right angles to the flow of water.

A 30 cm high concrete lip was constructed and various-sized rock was placed on either side to provide strength, trap sediment and allow for easier movement of aquatic fauna. Additional rock was also placed on the upstream side for the river crossing to provide a firm base for machinery and stock to cross.

Revegetation

The Avon River at Annandale has been fenced for many years. No dedicated tree planting has been carried out but natural regeneration has occurred and has been very effective in stabilising the banks, with very little erosion evident. Natural braiding of the channel is re-emerging, as existed prior to the River Training Scheme.

Expected benefits

A stable river crossing that doubles as a sediment trap.
Even surface to prevent scouring of the bed by machinery.
Stabilised banks.

What worked well?

"The river crossing has stopped scouring of bed and is silting up. In time, we expect it to silt to the level of wall. It is a stable crossing that has withstood major flows. We have extended the wall and the banks have stabilised and the braiding of the channel is re-emerging."
John Barrett-Lennard

Lessons learned

"Lessons were learned from the old crossing, constructed upstream by my father. Although the intentions were similar, the original crossing was constructed where the river bed was softer. The crossing was too large and acted as a barrier to flows. Consequently, the construction disturbed the flow and scoured the channel. Eventually, most of the rock from the crossing was dislodged and the crossing was washed out. The current crossing was constructed where the river bed is harder and was constructed with a minimalist approach. The aim was not to construct a barrier to the flow of water. The crossing does require some maintenance.

The downstream side of the concrete lip is being undercut and requires additional rock to protect it from being broken and dislodged."
John Barrett-Lennard

Further information

Contact: John Barrett-Lennard
phone: 9646 1278

Sources of information

Goulburn Broken Catchment Management Authority (2007) *Work on Waterways Notes No 1. Goulburn Broken Catchment Management Authority, Shepparton.*

Advice from <www.mainroads.wa.gov.au>

Water and Rivers Commission (2000) *Livestock Management: construction of livestock crossings,* WN6, Water and Rivers Commission, Perth, Western Australia.

Department of Primary Industries and Water (2003) *Waterways and Wetlands Works Manual No 5 Environmental Best Practice Guidelines: Siting and Designing Stream Crossings,* Department of Primary Industries and Water, Tasmania.

Crossing constructed on the Avon River at Annandale (note regeneration of native vegetation)
(Photo courtesy of Lucy Sands)

Step four: Site planning and design

In step three, you will have considered all management options to address the causes of degradation to your waterway or wetland. Using the form provided, you should have the management options assessed and the preferred option listed for each issue. It will become obvious that one option may address more than one issue (e.g. fencing).

Site planning and design

The next step is to plan the options for the site and arrange specific design for some of the works (e.g. revegetation layout, riffle design). The form provided in Appendix C is to assist with planning and design; however, this step is one part of it. The tasks required are:

1 Mark in the location of works required onto the air photo (the photo on page 94 provides an example for Snake Gully). This can be done directly onto the photos if they are laminated, or onto transparent over-lays if they are not.

2 Using the form in Appendix C, prepare notes on the specific actions required and the extent of the works. It is a good idea to also list the benefits that you expect, as this may help you to modify or expand on what you originally had in mind to do.

3 Seek advice for specialist design where required (for example, for construction of riffles or farm crossings). If there is a local catchment group, there is probably good access to local information and experience.

4 Contact your neighbours for works that might involve or impact upon them, and your local shire if there are issues with roads.

Use the planning and design stage for thinking and rethinking the options. Talk to others who have undertaken similar projects. Make sure that the decisions you eventually make (e.g. for plant species selection) are fully informed and best for the site. This will reduce the risk of failure considerably.

The worked example for Snake Gully is outlined on page 88.

Site planning and design: Snake Gully

Project title: Snake Gully restoration project
Location: Old House, Paddy's and Back paddocks, one section in Scott's property
Landholders: Bill and Jane Smith
Neighbours: T and E Clarke, B Rose, R and D Peterson and J, K and I Scott

Recovery action	Planning and design	Extent required
1 Fencing Benefits: • Reduced channel erosion • Flooded gums will regenerate • Reduced nutrients in creek • Reduced stock risks (from poor water quality)	• Locate fencing approximately 30 m out from channel • Use 7-line 'Ringlock', one-barbed wire and treated pine posts and strainer assemblies • Use suspended fence sections for all boundary fence creek crossings • Use existing road fence on RHS (survey point 1 to 2) • Extend fencing 100 m up Sally's Creek • Align creek fence in Back paddock along existing fire break and link with fencing on Scott's (to be arranged)	• Total length of 3.5 km new fencing required (including the bush fencing on Scott's) • Three suspended fence crossings needed (each about 60 m wide using 'Ringlock')

Recovery action	Planning and design	Extent required
2 Natural regeneration and revegetation Benefits: • Stabilise banks • Filter nutrients and sediments • Eventually shade out weeds • Lower groundwater • Add to biodiversity and scenic values	• Rip planting lines 4 m apart parallel to creek. Aim for 5–6 rows either side of the creek) • Spray weeds prior to planting • Revegetate with flooded gum (*Eucalyptus rudis*) and paperbarks (including *Melaleuca raphiophylla*) planted in mixed species with about 3 m spacing (aim for 600–1000 stems/Ha) • Establish sedges and rushes between survey points 2 and 3) – get advice on suitable species • Trial native grasses between survey sections 1 and 2 – get advice on suitable species and establishment methods	• Estimated 6 km of revegetation lines (especially for survey section 2–3) so 2000 seedlings are required – arrange through local nursery

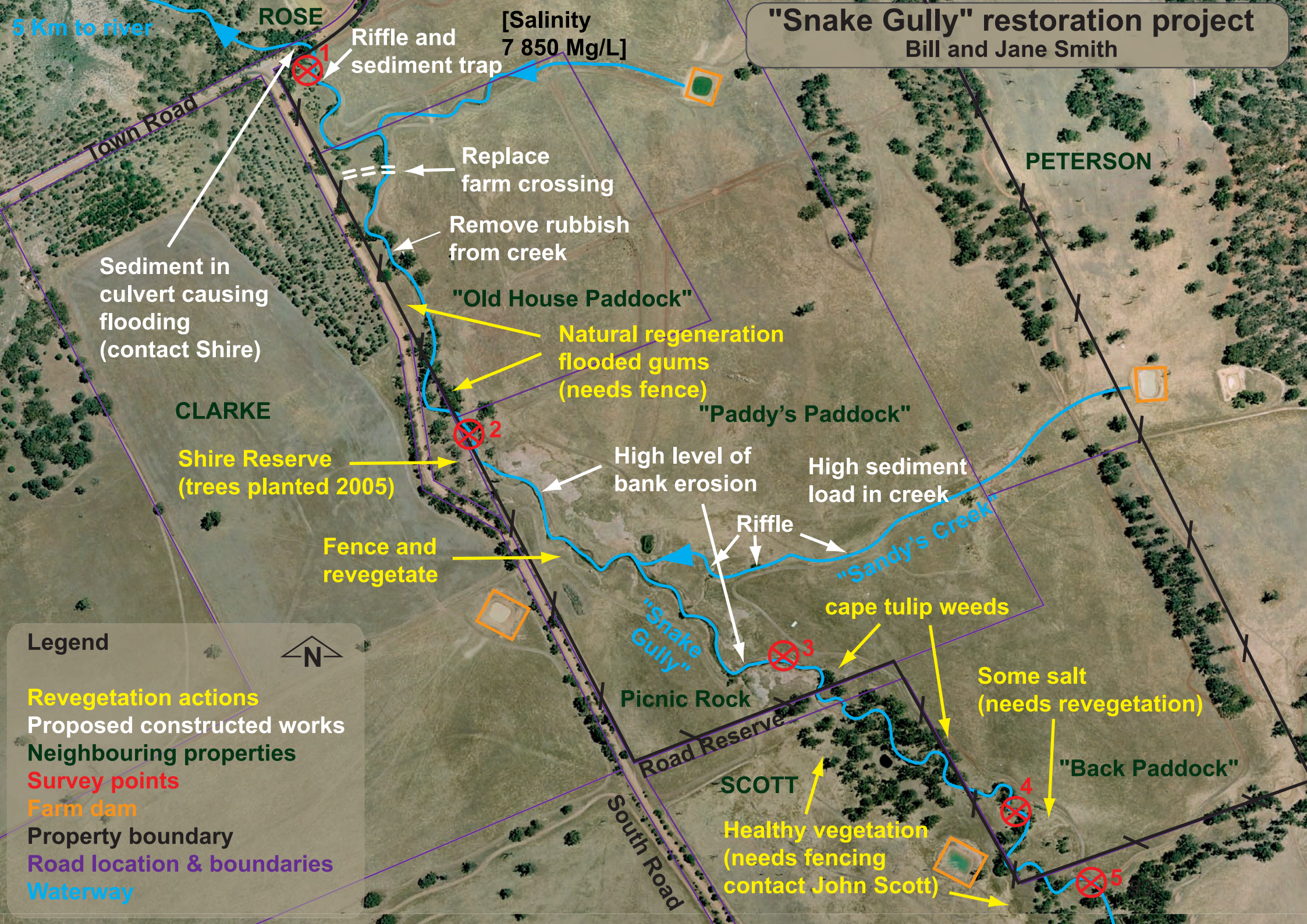
Recovery action	Planning and design	Extent required
3 Sediment control – riffles and sand traps Benefits: • Reduce erosion and sediment in channel • Reduce flooding, especially at Town Road	• Site assessment needed to design 3 riffles on Sally's Creek and one about 50 m upstream from Town Road – contact Department of Water for assistance with site design • Location of riffles for Sally's Creek shown on site plan • Downstream riffle on Sally's Creek to include farm crossing • Riffle and sand trap upstream from Town Road to include new farm crossing (to be relocated from existing crossing)	• Use rocks from Back paddock for riffle construction – all need to be bigger than 10 cm diameter • Sand traps to be the full width of the creek bed and the length is to be just greater that 3 front-end loader widths (about 10 m)
4 Erosion control Benefits: • Stabilise the creek • Reduced sediments • Less risk of farm crossing wash-outs	• Link site planning for control of gully head on Sally's Creek with riffle construction • Use on-farm materials to stabilise gully head • Fence a 100 m section of the creek and revegetate to stabilise eroding banks and site of gully head	• Use rock or logs for erosion control

Recovery action	Planning and design	Extent required
5 Surface water control Benefits: • Reduced sheet and rill erosion in paddocks • Less sediments in creeks • Reduced salinity risk (especially near survey point 4) • Link with new dam for stock water in Back paddock	• Survey Paddy's and Back paddocks for surface water control (graded interception banks) • Select site on Sally's Creek for new dam • Re-fence both paddocks aligned with new bank structures	• Estimated 2.5 km of interceptor banks needed • Construction of a 2000 m^3 dam
6 Weeds control Benefits: • Better survival of revegetation • Reduced fire risk • Meeting responsibility for eradication of a 'declared' weed (cape tulip)	• Spray weeds with Roundup Biactive before tree planting and annually (use local group 4WD motorbike and spray unit) • Control cape tulip with Glean	• Annual spraying of 1–2 ha • Eradication of cape tulip from an area of about 0.25 ha

Recovery action	Planning and design	Extent required
7 Construction of farm and road crossings Benefits: • Permanent farm crossings with low maintenance • Crossings suitable for wide machinery and stock • New structure to not reduce channel capacity and impede stream flow causing flooding (especially for Town Road)	• Use 2 x 3 m wide concrete culverts for base stream flow at each farm crossing • Construct 3 m wide concrete and rock low level flood ways • Construct new farm access track to crossing upstream from survey point 1 • Construct new farm access track from South Road to survey point 3 (near rocky picnic site) • Discuss road crossing design with shire	• 6 concrete culverts for the 3 farm crossings • Concrete and rock construction or 3 m wide floodway

► *See page 93*

Location of proposed works shown on the air photo for the worked example (Snake Gully)
(Reproduced by permission of the Western Australian Land Information Authority, CL 7/2008)


"Snake Gully" restoration project
Bill and Jane Smith
5 Km to river
ROSE
Riffle and sediment trap
[Salinity 7 850 Mg/L]
Town Road
Replace farm crossing
Remove rubbish from creek
PETERSON
Sediment in culvert causing flooding (contact Shire)
"Old House Paddock"
Natural regeneration flooded gums (needs fence)
CLARKE
"Paddy's Paddock"
Shire Reserve (trees planted 2005)
High level of bank erosion
High sediment load in creek
Riffle
"Sandy's Creek"
Fence and revegetate
"Snake Gully"
cape tulip weeds
Picnic Rock
Some salt (needs revegetation)
Road Reserve
"Back Paddock"
SCOTT
South Road
Healthy vegetation (needs fencing contact John Scott)
1
2
3
4
5
Legend
N
Revegetation actions
Proposed constructed works
Neighbouring properties
Survey points
Farm dam
Property boundary
Road location & boundaries
Waterway

Information summary 6: Waterways management for rural residential areas and hobby farms

Many hobby farms have a small creek running through the property. Some may be next to the Avon River or one of its larger tributaries. Owners of hobby farms are often interested in the natural environment and may be keen to restore waterways and wetlands on their property. However, there are also small landholders who may be keen but have little experience with land management. Some develop plans that include works to dam or divert watercourses.

The principles and information in this field guide is as relevant to small landholders as it is to commercial-scale farms. Waterways need to be managed as a part of the living landscape, with benefits for those who live or farm nearby the land.

Areas with a number of small-scale landholdings provide good opportunities for group activities for water restoration. It may take a bit of extra planning and coordination with those involved having a diverse range of lifestyles, but it is well worth the effort. This field guide's processes and forms can be used as a local group activity.

The level of management experience of those involved will vary considerably; however, there are a few management guidelines that should be followed by all involved:

- Talk with your neighbours about the plans that you have for your property.
- Try to initiate coordinated group activity for creek restoration.
- Seek advice from your local catchment group (if it exists) and your shire.
- Request information from the Department of Water when you have a clear idea about what you want to do.
- Don't start by burning your area of land. This will only encourage weeds. Riparian vegetation does not need fire to establish.
- Avoid damming or diverting stream flow, which may affect downstream neighbours. It is generally not good waterway management. It may also be illegal without a permit (under the *Rights in Water and Irrigation Act, 1914* where this applies).
- If you are considering building an access crossing, this may not be as easy as you may think at first. Simple structures may wash out in the first flood. If you are building a house or sheds, be ensure to plan for safe and convenient access over waterways with little or no impact on them. You should check with the shire council for planning guidelines for construction of waterway crossings.
- Use locally relevant native plant species wherever possible. Try to restore the character of the Australian landscape. European deciduous trees and palms are better suited to the house yard.

- Think carefully about the potential impacts of the animals you want to have, and make sure the fences are kept in good order. Stock will do a lot of damage to the banks of the waterway, especially horses and cattle. Goats do further damage to natural vegetation and revegetation.
- Don't expect water in the stream to be reliable water for stock. It is probably salty and often unreliable. It is best to ensure there are alternative water sources.

Finally, have fun and celebrate your success!

A rural waterway in the Dale River catchment (Photo courtesy of Lucy Sands)

Step five: Feasibility and costs

With decisions made for site works, step five provides a ‘reality check’ by making an assessment of the feasibility for each of the works and estimating the costs. If the decisions have been considered carefully, the feasibility should be quite high and the works will deliver the expected benefits. There may be some uncertainty about the success or benefits of some actions (e.g. establishing native grasses) so you could consider minimising the risk by having a smaller trial site to start with and building on this if it proves successful.

Feasibility and costs

Itemising the estimated costs is always a good reality check. You should consider the full range of benefits that you can expect from the total investment. Some of these may be considered to be public benefits (e.g. reduced impact on local roads; increase in visual amenity) so there may be opportunities to apply for funding support (contact your local catchment group support person or the Avon Catchment Council in Northam).

Appendix D provides a standard form to assess project feasibility and costs. A worked example for the Snake Gully restoration project appears on page 98.

Feasibility and cost estimate: Snake Gully

Project title: Snake Gully restoration project
Landholders: Bill and Jane Smith
Neighbours: T and E Clarke, B Rose, R and D Peterson and J, K and I Scott.

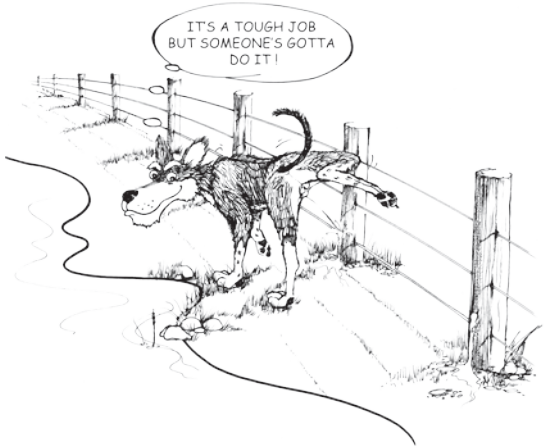
Recovery action	Feasibility	Estimated costs
1 Fencing	The site is relatively easy to fence and the location and alignment should work well with farm management The suspended fence sections on the boundaries will need regular maintenance	3.5 km fence materials at $3000/km = $10 500 50 hrs labour at $30/hr = $1500
2 Natural regeneration and revegetation	Natural regeneration should be successful between survey points 1 and 2 There should be an 80% survival rate for revegetation for the section between survey points 2 and 3 Establishing sedges and rushes may be more difficult, but should work after a few tries The native grasses could be difficult to establish, but consider it a trial	2000 seedlings on site at $1.50 each = $3500 Estimated costs for sedges and native grasses $2000

Recovery action	Feasibility	Estimated costs
3 Sediment control – riffles and sand traps	Assuming they are designed right, the riffles should work well (i.e. slow water velocity, trap sediment and survive a flood) The main issue may be that there are not enough to make a significant difference to either flow velocity or sediment transport. Additional structures can be added at another time Sand needs to be removed from traps every 1–2 years or they will not be effective	4 riffle structures and sand traps at $2000 each (include labour – may be able to reduce some costs) = $8000
4 Erosion control	If well constructed, the stone works and revegetation should fix the problem	Estimated cost, including labour but excluding fencing = $500
5 Surface water control	Graded interceptor banks to control run-off should reduce soil erosion significantly The site seems well suited for dam construction (soil tests needed)	2.5 km banks at $1200/km = $3000 2000 m^3 dam at $3/$m^3$ = $6000

Recovery action	Feasibility	Estimated costs
6 Weed control	Control of weeds should be effective if maintained each year The patch of cape tulip is small so should be easily eradicated on this property	Annual weed control for 3 ha over 5 years, including motor bike/spray unit hire = $500
7 Construction of farm crossings	Culvert structures on-farm. These should also be suitable for stock crossings. The sites selected will be good for moving wide machinery	Low level flood ways are safer than large 3 farm crossings @ $2000 (including labour) = $6000
Total cost estimate = $41 500 (Costs include 2 km creek restoration, three farm crossings, surface water control banks and a new dam. Costs for Town Road culvert reconstruction not included).		

Step six: Implementing the actions

The next step is to work out a schedule for implementing the actions. This should be quite simple, but is important to make sure they are in the right order and undertaken at a time that fits in with other farm or community activities.



Implementing the actions

Appendix E provides a standard form for scheduling the works. A worked example for the Snake Gully restoration project appears below.

Works schedule - Snake Gully

Project title: Snake Gully restoration project
Landholders: Bill and Jane Smith
Neighbours: T and E Clarke, B Rose, R and D Peterson and J, K and I Scott.

Year and season	Recovery action	Schedule comments
Year 1		
Summer	• Stone work for gully erosion	Need to get this completed so that it is stable for other works upstream on Sally's Creek
Autumn	• Contact shire about Town Road culvert	Order fencing materials Contact Scott's re fencing this coming Spring
Winter	• Survey for interceptor banks and siting for new dam	Arrange for drill rig to test dam site with earthmoving contractor
Spring	• All fencing • Spray all areas for weeds (including cape tulip) • Design for first riffle and crossing	Contact Department of Water for assistance with design

Year and season	Recovery action	Schedule comments
Year 2		
Summer	• Build one riffle and one crossing • Order trees from nursery • Arrange tree planter hire	Start with lower riffle and crossing for Sally's Creek
Autumn	• Spray weeds prior to revegetation	Arrange tree planter hire
Winter	• All tree planting	Arrange it for the school holidays
Spring	• Spray weeds	Contact Department of Water for assistance with riffle and crossing design
Year 3		
Summer	• Build two riffles and one crossing	Construct the next two riffles on Sally's Creek and the crossing at survey point 3
Autumn		
Winter		
Spring	• Spray weeds	Contact Department of Water for assistance with riffle and crossing design

Year and season	Recovery action	Schedule comments
Year 4		
Summer	• Build 1 riffle and 1 crossing	Construct the Snake Gully riffle and crossing. This should hopefully tie in with culvert works on Town Road to be arranged with the shire
Autumn		
Winter		
Spring	• Spray weeds	

Step seven: Maintenance and evaluation

The final step is to monitor the results of your restoration efforts. This is an important step as it will indicate maintenance that may be needed. It will also show how effective your works have been.

There are four simple actions that you should do each year:

1 Take repeat photos at each fixed 'photo point' (see step two). It is best to take the photos at the same time each year.

2 Test the water for salinity (there may be regular water quality monitoring by your local catchment group).

3 Check for weeds (those that need to be eradicated and others that may have become established).

4 Check the sediment load in sand traps.

This should not take too much time – about an hour for a 2 km restoration project.

There will be on-going maintenance especially for weeds and the fences. Some areas of revegetation may not have established well. These may need some re-planting. You should review your species selection list for these areas rather than again planting species that have not survived.

Your restoration project should have a lot to show within a couple of years. Let others see your works. It may lead to further extension upstream or downstream by your neighbours.

Above all, have fun while doing the required works, celebrate your successes and spend time enjoying your restored landscape.

Maintenance and evaluation

Appendix A: Field survey form

The easy way to assess your waterway or wetland health is to use a checklist for field survey. The key issues to consider are:

- erosion, sedimentation and flooding
- vegetation health
- water quality
- weeds and fire
- road and farm crossings

There are three assessment categories:

1 **green** (good condition)
2 **orange** (moderate condition)
3 **red** (poor condition).

Description notes are provided as a broad indication of the different categories. Your waterway or wetland may differ to these in some ways.

How to use the checklist

Walk along your creek, river or wetland and assess the condition of the waterway at survey points identified on your map. It is suggested that you have your survey points about 500 metres apart. Fill out a survey form for each set of five survey points. The tally at the end of the survey will show the overall condition of your waterway.

At each survey point, tick the box beneath the description that best matches your site for each of the key issues. Note that some assessments will not meet all criteria listed (e.g. for poor water quality, saline water may not be coloured).

Tally the number of ticks for each key issue. Add notes or a sketch showing other observations for the site.

The field survey information is to be used for planning what needs to be done (step three). While in the field, you could also be thinking about what you want your waterway or wetland to look like and the things you can do to achieve that.

Project title:
Location:
Landholders:
Neighbours:
Survey date:
Survey distance:
Survey by:

1 Erosion, sedimentation and flooding

Green (good condition)	**Orange** (moderate condition)	**Red** (poor condition)
• Minimal channel erosion (undercutting or slumping) • No gully head erosion (main channel or tributaries) • Minimal sediment deposition • Limited localised flood damage (culverts washed out, sediments in floodways, eroded banks)	• Moderate level of bank or channel erosion • Coarse sediment slugs in sections of the channel • Some localised flood damage	• Extensive and active bank and channel erosion • Bank collapse, tree fall • High level of sediment deposition (filled pools, blocked channel) • High level flood damage (crossings, fences, sediments, other)
Survey Points		
#1 #2 #3 #4 #5	#1 #2 #3 #4 #5	#1 #2 #3 #4 #5

2 Vegetation health

Green (good condition)	**Orange** (moderate condition)	**Red** (poor condition)
• Dense, healthy fringing native vegetation that extends 25 metres or more into floodplain from the channel • Mixture of trees, shrubs and ground covers present • Natural regeneration of native vegetation • Sedges and rushes may be present	• Good vegetation cover but mixture of native vegetation and weeds • Vegetation extends 5–10 metres into floodplain • Little natural regeneration of native species	• Most native vegetation has been cleared or damaged • Mainly weeds or pasture present • No regeneration of native vegetation
#1 #2 #3 #4 #5	#1 #2 #3 #4 #5	#1 #2 #3 #4 #5

3 Fencing and stock access

Green (good condition)	**Orange** (moderate condition)	**Red** (poor condition)
• Stock-proof fencing both sides of waterway • Stock crossings with restricted access to waterway	• Fencing in need of maintenance • Stock has access to the waterway	• No fencing or existing fencing in need of replacement on both sides • Stock has uncontrolled access to the waterway and is causing damage to the channel and vegetation
#1 #2 #3 #4 #5	#1 #2 #3 #4 #5	#1 #2 #3 #4 #5

4 Water quality

Green (good condition)	**Orange** (moderate condition)	**Red** (poor condition)
• Water appears clear • Very little obvious algae • Fresh or marginally saline (< 1500 mg/L) • Fish or other aquatic fauna (e.g. dragonflies) easily observed	• Water slightly coloured but expected to clear • Some algal growth • Water is brackish (1500–5000 mg/L) • Native fish or other aquatic fauna hard to find	• Water is coloured and not expected to clear • Water is saline (> 5000 mg/L) • High level of algal growth • No sign of aquatic fauna
#1 #2 #3 #4 #5	#1 #2 #3 #4 #5	#1 #2 #3 #4 #5

5 Weeds and fire risk

Green (good condition)	**Orange** (moderate condition)	**Red** (poor condition)
• Low level of annual weeds (e.g. wild oats, veldt grass) • No major perennial weeds (e.g. bridal creeper, rush) • Farm assets (buildings, yards, fences) not at risk to fire	• Annual weeds are common with patchy native vegetation cover • No major perennial weeds • Fire could cause some damage to farm assets	• High level of annual weeds with little or no native vegetation cover • Established perennial weeds • High fuel load and assets at risk
#1 #2 #3 #4 #5	#1 #2 #3 #4 #5	#1 #2 #3 #4 #5

6 Road and farm crossings

Green (good condition)	**Orange** (moderate condition)	**Red** (poor condition)
• Crossings do not restrict channel or floodplain capacity • Crossing structures are stable	• Crossings partially restrict flood flows but do not affect normal winter flow • Crossing structures are unstable and at risk of damage in floods	• Crossings restrict flood and normal winter flows • Crossing structures damaged • Bank erosion or channel sedimentation caused by the crossing
#1 #2 #3 #4 #5	#1 #2 #3 #4 #5	#1 #2 #3 #4 #5
Tally from above		
Number of green ticks:	**Number of orange ticks:**	**Number of red ticks:**

Site notes or sketch		
GPS references (for location of specific sites – optional)		
Site	**Easting**	**Northing**
1		
2		
3		
4		
5		
Photo references (suggest at least one for each survey site)		
PR1:		
PR2:		
PR3:		
PR4:		
PR5:		

Appendix B:
Management options assessment form

Project title:
Landholders:
Neighbours:
Field Survey Assessment (Protection/Prevention/Recovery):

Issue assessment	Determining the cause	Considering the options
1 Erosion, sediment and flooding		
2 Vegetation health		
3 Fencing and stock access		

Issue assessment	Determining the cause	Considering the options
4 Water quality		
5 Weeds and fire risk		
6 Road and farm crossings		

Appendix C: Site planning and design form

Project title:
Landholders:
Neighbours:

Recovery action	Planning and design	Extent required
1 Fencing **Benefits:** • • • •		
2 Natural regeneration and revegetation **Benefits:** • • • •		
3 Sediment control – riffles and sand traps **Benefits:** • • • •		

Recovery action	Planning and design	Extent required
4 Erosion control **Benefits:** • • • •		
5 Surface water control **Benefits:** • • • •		
6 Weed control **Benefits:** • • • •		
7 Construction of farm and road crossings **Benefits:** • • • •		

Recovery action	Planning and design	Extent required
8 Other management **Benefits:** • • • •		

Appendix D: Feasibility and cost estimate form

Project title:
Landholders:
Neighbours:

Recovery action	Feasibility	Estimated costs
1 Fencing		
2 Natural regeneration and revegetation		

Recovery action	Feasibility	Estimated costs
3 Sediment control – riffles and sand traps		
4 Erosion control		
5 Surface water control		
6 Weed control		

Recovery action	Feasibility	Estimated costs
7 Construction of farm and road crossings		
8 Other management		

Appendix E:
Works schedule form

Project title:
Landholders:
Neighbours:

Year & season	Recovery Action	Schedule comments
Year 1		
Summer		
Autumn		
Winter		
Spring		
Year 2		
Summer		
Autumn		
Winter		
Spring		

Year & season	Recovery Action	Schedule comments
Year 3		
Summer		
Autumn		
Winter		
Spring		
Year 4		
Summer		
Autumn		
Winter		
Spring		