

A Rehabilitation Manual for Australian Streams

VOLUME 1

Ian D. Rutherford, Kathryn Jerie and Nicholas Marsh

Cooperative Research Centre for Catchment Hydrology
Land and Water Resources Research and Development Corporation
2000

Published by: Land and Water Resources Research and Development Corporation
GPO Box 2182
Canberra ACT 2601
Telephone: (02) 6257 3379
Facsimile: (02) 6257 3420
Email: <public@lwrrdc.gov.au>
WebSite: <www.lwrrdc.gov.au>

Cooperative Research Centre for Catchment Hydrology
Department of Civil Engineering
Monash University
Clayton VIC 3168
Telephone: (03) 9905 2704
Facsimile: (03) 9905 5033

© LWRRDC and CRCCH

Disclaimer: This manual has been prepared from existing technical material, from research and development studies and from specialist input by researchers, practitioners and stream managers. The material presented cannot fully represent conditions that may be encountered for any particular project. LWRRDC and CRCCH have endeavoured to verify that the methods and recommendations contained are appropriate. No warranty or guarantee, express or implied, except to the extent required by statute, is made as to the accuracy, reliability or suitability of the methods or recommendations, including any financial and legal information.

The information, including guidelines and recommendations, contained in this Manual is made available by the authors to assist public knowledge and discussion and to help rehabilitate Australian streams. The Manual is not intended to be a code or industry standard. Whilst it is provided in good faith, LWRRDC and CRCCH accept no liability in respect of any loss or damage caused by reliance on that information. Users should make their own enquiries, including obtaining professional technical, legal and financial advice, before relying on any information and form their own views as to whether the information is applicable to their circumstances. Where technical information has been prepared by or contributed by authors external to LWRRDC and CRCCH, readers should contact the author/s or undertake other appropriate enquiries before making use of that information.

The adoption of any guidelines or recommendations in the manual will not necessarily ensure compliance with any statutory obligations, the suitability or stability of any stream structure or treatment, enhanced environmental performance or avoidance of environmental harm or nuisance.

Publication data: 'A Rehabilitation Manual for Australian Streams Volume 1'

Authors: Ian D. Rutherford, Kathryn Jerie and Nicholas Marsh
Cooperative Research Centre for Catchment Hydrology
Department of Civil Engineering
Monash University
Clayton VIC 3168
Telephone: (03) 9905 2940
Facsimile: (03) 9905 5503
Email: <rutherford@eng.monash.edu.au>

ISBN 0 642 76028 4 (volume 1/2)
ISBN 0 642 76030 6 (set of 2 volumes)

Design by: Arawang Communication Group, Canberra

June 1999 Web version
March 2000 Printed version

This manual was first published (in colour) on the World Wide Web, where it can be accessed at <www.rivers.gov.au>. For economy and convenience, that pagination of the Web version has been retained here.

Contents

Preamble	4
Acknowledgments	5
Part 1 - Stream Rehabilitation Concepts	8
Introduction	9
An introduction to stream ecosystems	27
Recovery of disturbed stream systems in Australia	43
Conclusions and bibliography	59
Part 2 - A Stream Rehabilitation Procedure	63
An introduction to stream rehabilitation planning	64
A 12-step procedure for stream rehabilitation: a summary	67
The 12 steps in stream rehabilitation	70
Step 1 What are your goals for rehabilitating the stream?	71
Step 2 Who shares your goals for the stream?	76
Step 3 How has your stream changed since European settlement?	84
Step 4 What are the stream's main natural assets and problems?	98
Step 5 Setting priorities: which reaches should you work on first?	107
Step 6 What are your strategies to protect assets and improve your stream?	125
Step 7 What are your specific and measurable objectives?	133
Step 8 Are your objectives feasible?	142
Step 9 How will you design your project to achieve your objectives?	156
Step 10 How will you evaluate your project?	163
Step 11 How will you plan and implement your project?	175
Step 12 Has your project worked?	181
Bibliography	188

A rehabilitation manual for Australian streams

Volume 1: Concepts and planning

Part 1 – Stream rehabilitation concepts

Part 2 – A summary of the stream rehabilitation planning procedure

Volume 2: Rehabilitation tools

Preamble

Over the past two hundred years we have physically and biologically degraded many Australian streams. Catchment managers at the end of the millennium face two daunting tasks: how to minimise further damage to rivers and streams, and how to repair the damage that has already occurred.

We can return natural values to our waterways. This manual is designed to help those professional managers who are accepting the challenge of rehabilitating the physical and biological condition of Australian streams. It has four sections covering the following main topics:

1. rehabilitation concepts;
2. a planning procedure for rehabilitating streams;
3. typical stream problems; and
4. a range of tools that could be useful for rehabilitation.

The concepts provide a firm basis for planning a rehabilitation strategy, while the typical problems and tools provide resources that could be useful to the manager.

It is important to emphasise that this is not a catchment or stream management manual. There are many reasons to intervene in streams and catchments that are not related to rehabilitation of the natural stream values. Thus, the manual will only touch on issues such as erosion control, water supply, flooding, and the sociology of management, in so far as they affect rehabilitation.

This manual was only made possible by the contributions of many managers and researchers across Australia. These contributions are acknowledged in the following pages. We also acknowledge the generous support and vision of the Land and Water Resources Research and Development Corporation, and the Cooperative Research Centre for Catchment Hydrology that has brought this manual to fruition.

We need your feedback!

There has been a long tradition of trying to preserve natural values in Australian streams. But it is only in the last two decades that people have begun to reverse the degradation of the past, and it is only now that rehabilitation is becoming one of the core goals of stream and catchment managers. As a result, there are few projects aimed specifically at rehabilitation of natural values in Australian streams. There are even fewer projects that have been adequately evaluated. Thus, this manual is based more on an evolving set of ideas than on well-established approaches known to be effective in Australian conditions. You will also find many gaps in the manual that need to be filled.

Our hope is that this manual will grow and mature along with the infant stream rehabilitation industry. It is only as we evaluate and record the successes and failures of our stream rehabilitation efforts that we will gain the confidence needed to roll-back the many decades of degradation that our streams have suffered. To this end a ‘feedback form’ (see final two pages) accompanies the manual, so that you can bring your thoughts and experiences to the next edition.

Acknowledgments

This manual was initiated and supported by Dr Phil Price, Executive Director of LWRRDC. Dr Siwan Lovett, as program leader of the LWRRDC Riparian Zone Program, has shepherded the manual through to production. We thank them both for their inspiration and patience, and the people listed below for their valuable contributions. We also thank Ed Highley and his team at Arawang for their tireless assistance, and their creativity in assisting with the editing, design and layout of the manual.

Abbreviations used are spelt out at the end of the table.

We thank the following publishers for permission to reproduce copyright material:

Allen & Unwin — Figure 39, Part 1; Figure 10 in Barnard and Melhorn (1981)

Elsevier Science — Figure 35, Part 1; Figure 2 in Hupp and Simon (1991)

John Wiley & Sons — Figure 40, Part 1; Figure 6 in Brookes (1987)

National Research Council of Canada — Figure 9, Part 1; Figure 1 in Bradshaw (1996)

Person	Affiliation	Contribution
Bruce	Abernethy	CRCCH, Monash University, Vic.
John	Amprimo	DNR, Qld
Mike	Askey-Doran	Parks & Wildlife, Tas.
Rebecca	Bartley	CRCCH, Monash Uni, Vic.
Karla	Billington	DEHAA, SA.
Dominic	Blackham	University of Birmingham, UK
Sally	Boon	Department of Land and Water Conservation, Qld.
Fleur	Bound	CRCCH, Monash University
Jason	Bradbury	Parks & Wildlife, Tas.
Peter	Breen	CRCFE, Monash Uni, Vic.
Gary	Brierley	Macquarie University, NSW
Andrew	Brooks	Macquarie University, NSW
Paul	Brown	MAFRI, Snobs Ck, Vic.
Wayne	Brown	Mount Lofty Ranges Catchment Management Program, SA
Stuart	Bunn	Griffith University, Qld
Jim	Burston	DEHAA, SA
Bryan	Bycroft	Formerly of Brisbane City Council, Qld.
Jason	Carter	ID&A Pty Ltd, SA
Bob	Crouch	DLWC, NSW
Tim	Doeg	Consulting ecologist, Vic.

Person	Affiliation	Contribution
John Douglas	MAFRI, Vic.	Hosted us on a tour of the Broken River rehabilitation site
Judy Frankenberg	Murray Darling Freshwater Research Centre, NSW	Contributed a section on macrophyte revegetation
John Gardiner	Formerly of DLWC, NSW	Kindly hosted us on a tour of streams of the north coast of NSW. Provided information on instream structures including jacks and bendway weirs
Max Giblin	DPIF, Tas.	Contributed the section on legislation and administrative controls for Tasmania
Chris Gippel	CRCCH, University of Melbourne, Vic.	Contributed major sections on large woody debris, as well as much of the 'channel design' section of the Tools volume
John Gooderham	CRCCH Monash, Vic.	Contributed sections on stream ecology, general assistance with construction and editing, and photographs
Lori Gould	ACT Parks & Conservation	Provided information about the Murrumbidgee River for a case-study
Geoff Guinea	DNR, Qld	Assistance with preparing the legislative and administrative constraints section for Qld
Wal Hader	DLWC, NSW	Provided considerable information on techniques for intervening in the channel
Peter Hairsine	CRCCH CSIRO, Canberra	Provided information on buffer strips
Ross Hardie	ID&A Pty Ltd., Vic.	Contributed information on incised streams, and case studies
John Harris	NSW Fisheries Research Institute	Contributed a section on barriers to fish passage, and how such barriers can be overcome
Mark Heatton	Milanda, Qld.	Provided information for a case study
Paul Humphries	CRCFE, Albury, NSW	Contributed information on costs of monitoring
Ross Kapitzkie	James Cook University, Qld.	Provided many useful discussions and access to his own LWRRDC manual
John Koehn	MAFRI, Vic.	Useful discussions, as well as permission to reproduce the tables of ecological impacts on streams
Tony Ladson	University of Melbourne, Vic.	Provided many references, and good conceptual ideas, particularly for the process section
Romeny Lynch	Griffith University, Qld	Prepared early material on degrading biological processes in Australian streams
Fiona Nagel	NSW DLWC, Coffs Harbour	Provided evaluation case studies on the Nambucca and Hunter Rivers
Bob Newbury	Newbury Consulting, BC, Canada	Reviewed the manual and provided both inspiration and excellent comment on the structure and content
Tim O'Brien	DNRE, Vic.	Contributed to the fish passage section
Bill O'Connor	DNRE, Vic.	Constantly emphasised a fish's perspective in many fruitful discussions
Neville Oddie	Consultant, Vic.	Provided information on involving the community in rehabilitation projects
David Outhet	DLWC, NSW	Provided information on willow management, as well as many useful discussions and ideas
Adolphe Parfait	DLWC, NSW	Provided access to his 'Geomorphic assessor' computer program
Luke Pen	Water & Rivers Commission, WA	Contributed the section on legislation and administrative controls for WA
David Perry	CRCCH, Monash Univ, Vic.	Maintained morale and provided invaluable general advice and review
Allan Raine	DLWC, NSW	Provided information on vertical pin ramps, log sills, direct seeding methods, and injection of long-stem seedlings
Tanya Rankin	University of Sydney, NSW	Provided information on the habits and requirements of platypus. Co-authored the chapter: Rehabilitation for platypus, Volume 2
Mike Read	Read Sturgess and Associates, Vic.	Provided information on benefit-cost analysis
Martin Reed	Tas.	Provided information on the ecological impact of willows

Person	Affiliation	Contribution
Ross	Scott	Lake Wellington CMA, Vic. Contributed to the section on willow removal, and hosted us on a field trip to look at the reinstated meander cut-offs of the lower Latrobe River
Barry	Starr	DLWC, NSW Information on chains-of-ponds, useful advice on presentation, as well as copies of his very useful reports
Michael	Stewardson	CRCCH, Melbourne Uni, Vic. Contributed many useful ideas, as well as contributing to the evaluation section
Neil	Sturgess	Read Sturgess and Associates, Vic. Provided information on benefit–cost analysis
Phil	Taylor	Latrobe Region Water Authority, Vic. Field assistance and useful discussions
Martin	Thoms	CRCFE University of Canberra Provided some case studies of NSW streams
Nick	Thorn	Native Fish Australia, Vic. Reviewed the section on fish passage
John	Tilleard	ID&A Pty Ltd, Vic. Reviewed the tools section, made some fundamental suggestions about how works in streams should be planned, and suggested some case studies.
Dave	Tiller	EPA, Vic. Reviewed the nutrients section in common stream problems
Simon	Treadwell	Monash University, Vic. Contributed to large woody debris section
Peter	Volleberg	DNRE, Vic. Contributed the section on legislation and administrative controls for Victoria
Mark	Walker	CRCCH, Monash University, Vic. Assistance with editing and review, and made major intellectual contributions to many sections.
Chris	Walsh	CRCFE, Monash Uni, Vic. Provided information on urban streams, and contributed to our thinking on the role of remediation
Peter	Wem	DLWC, NSW Prepared the legislative and administrative constraints section for NSW, and provided useful feedback (and vigorous debate!) on many parts of the manual
Karen	White	University of Melbourne, Vic. Helped to prepare the section on the reinstatement of large woody debris..
Lindsay	White	CRCCH, Monash University, Vic. Useful review of several sections and helpful discussions
Scott	Wilkinson	CRCCH, Monash University, Vic. General assistance with construction
Geoff	Williams	Australian Platypus Conservancy, Melbourne Provided information on platypus Provided information on platypus, reviewed ‘Rehabilitation for platypus’, Volume 2

Abbreviations

CRCCH	Cooperative Research Centre for Catchment Hydrology
CRCFE	Cooperative Research Centre for Freshwater Ecology
CMA	Catchment Management Authority, Victoria
DNR	Department of Natural Resources, Qld
DNRE	Department of Natural Resources and Environment, Victoria
DLWC	Department of Land and Water Conservation, NSW
MAFRI	Marine and Freshwater Research Institute, Victoria
EPA	Environment Protection Authority
DEHAA	Department for Environment, Heritage, and Aboriginal Affairs, SA
DPIF	Department of Primary Industry and Fisheries, Tasmania

Part 1

Stream rehabilitation concepts

Introduction

- 1. What is stream rehabilitation?**
- 2. Stream rehabilitation is a subset of catchment management**
- 3. What is covered by this manual?**
- 4. Why would a manual be useful?**
- 5. Who is this manual for?**
- 6. How could you use this manual?**
- 7. Some principles for rehabilitating streams**

In 1996 the Lake Wellington Rivers Authority (Gippsland, Victoria) ran a television advertisement that opened with a man and a boy fishing in a rather tired looking river. The banks are cleared and eroding, and cattle are standing in the turbid water. The man is the boy's grandfather, and he is describing how different the river had been when he was a boy: the deep pools, the clear water, the fish he would catch, and the lush vegetation on the banks. The advertisement ends with the plea for all to "join together to make our rivers the way our grandparents knew them".

This advertisement would likely strike a chord with many people right across Australia. No longer are most Australians seeing rivers and streams just as sources of water, or conduits for floodwaters and waste, or as a nuisance that erodes our valuable land. Instead we are seeing them for what they should be—a diverse and complex ecosystem, and the lifeblood of the land.

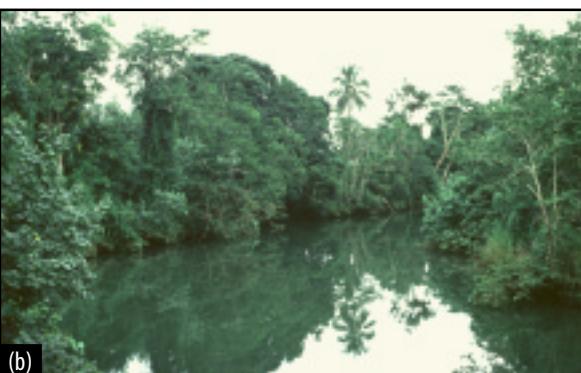


Figure 1. A damaged rural stream (the South Johnstone River, far North Queensland cleared to the banks for sugarcane, compared with the same river further downstream with reasonable riparian vegetation (despite some exotic plants).

However, our streams are in poor condition.

- Over 36% of the length of streams in the Maroochy River catchment in southern Queensland is categorised as being in very poor to highly degraded condition (Anderson 1993).
- Some 8% of Australia's 200 or so native fish species are endangered (Raadick 1985). Contributing to this threat are 28 exotic species. "The alien pest species, carp, are the dominant fish of the Murray and Darling river systems and are threatening a number of coastal systems" (Harris and Gehrke 1997).
- About 27% of all Victorian streams (see eg. Figure 2) are in "poor to very poor" condition, with 65% of streams in cleared areas being in this category (Mitchell 1990). This represents 17,000 km of streams!
- Some 70% of the divertible water resources of the Murray–Darling Basin are now used for irrigation, urban and rural water supply, with most of that water being stored in 84 storages with capacity over 10,000 ML. From 1988 to 1994 water consumption in the basin increased by 7.9%, mostly through growth of the cotton industry (Crabb 1997).
- "...about half of the aquatic habitat of Australia's south-eastern coastal drainages has been obstructed by dams, weirs and other man-made physical barriers" (Harris 1984). See Figure 3.



Figure 2. Typical degraded stream in Victoria (the Hopkins River, SW Vic). Note the monoculture of introduced grasses on the banks.

- Many thousands of kilometres of streams have been entirely isolated from their floodplains by channelisation, by artificial levees, or by flood-control dams. These floodplains often served as spawning areas for fish, and certainly as a basic source of organic matter back into streams. Nobody is sure of the long-term implications of the de-coupling of streams from their floodplains.



Figure 3. Example of a small dam that may form a barrier to fish passage (Albert River, southern Queensland).

Overall, in 200 years we have been remarkably efficient at reducing our coastal streams, and many inland streams, to drains. Having said this, Australia still retains vast stream systems (particularly in the arid zone) that are in reasonable condition. It is not too late to preserve these, and time and again in this manual we will emphasise the folly of expending huge resources rehabilitating some badly degraded streams, while at the same time allowing the remnants that remain in good condition to deteriorate.

We cannot completely rebuild natural streams no matter how hard we try, so it is better not to damage them in the first place.

We are all probably familiar with the damage that we have done to our streams, but it is not enough just to recognise the problem. We must do something to prevent further degradation and set about reversing the damage already done. This is the new vision of an army of people across Australia—farmers, school children, government officers, scientists and many more—who are now dedicated to rehabilitating our ailing streams. This enthusiasm is reflected in a shift in responsibility for stream rehabilitation, away from government, and onto community groups, matched by increases in funding through direct levies on local communities, and some large increases in Federal funding (eg. under the Natural Heritage Trust).

We are not alone in this growing enthusiasm to rehabilitate stream systems. We can learn from an explosion of activity in this arena in North America and Europe.

The goal of this manual is to equip stream managers with some of the skills, ideas and tools required to improve the physical and biological condition of Australian streams. The manual focuses, for the most part, on rural streams, and seeks to encourage the rehabilitation of Australian streams with their full complement of native flora and fauna, preserved in a functioning, sustainable ecosystem. The ultimate target of the work is to encourage the protection of healthy streams, and to return as many of the original (ie. pre-European) values to our damaged streams as possible—within the constraints applied by other uses of the streams.

1. What is stream rehabilitation?

It is important that we are very clear about the goal of stream rehabilitation as espoused in this manual. We can talk in vague terms about ‘environmental values’, but the simplest measure of these values is the original (pre-European) condition of the streams. Thus, the target of this manual is to return, as far as is possible, the vegetation, structure, hydrology, and water quality of the original streams. The assumption is that by providing these physical elements, the original suite of organisms that

occupied the stream will also return. At the end of the day, the success of improvements to vegetation, hydrology, hydraulics and stream morphology, should ultimately be judged in relation to the improvements that they bring to the organisms living in, and relying on, the stream. Importantly, the improvements should be self-sustaining, meaning that the stream should not need continual intervention to retain the improved condition.

It is important to emphasise that rehabilitation does not imply absolute stability. On the contrary, stream systems rely on a certain level of disturbance by flooding, erosion and variable water quality, to maintain their diversity. The natural, pre-European, level of stability would again be the ideal state.

This manual tends to target the visible organisms that make up a stream ecosystem, including native vegetation (overstorey, understorey, grasses, macrophytes and algae), macroinvertebrates, fish, frogs, platypus, water rats, aquatic birds and so on. Although we really focus on only a small fraction of the stream biota, we assume that the less charismatic species will prosper as we improve the environment for the more visible species.

Although this document emphasises stream biology as a goal of stream rehabilitation, there are other environmental values that are not related to the organisms in the stream. For example, the intrinsic beauty of a stream is another environmental value, as is the return of holes to a stream for swimming and fishing. 'Geodiversity' is another reason for rehabilitating streams. This is the notion that the physical structure of a stream itself has intrinsic value, independent of the organisms that live in it (see example box that follows). We agree that it does, but would argue that biological values are equally important and provide a good measure of the general health of a stream system. In any case, restoring streams for ecological reasons usually involves restoring the physical character of the stream as well.

Protecting geodiversity

Organisms living in streams are classified into different groups called genera and species. In the same way there are many different types of stream system with their own unique geomorphology. Australia has its fair share of rare and endangered stream types (in terms of geomorphology and hydrology), and these types also require protection and rehabilitation in their own right, independent of the organisms that live in these streams.

As an example, the Mitchell River in Gippsland has built an impressive silt-jetty into Lake Wellington (Figure 4). The silt-jetties have been classified as sites of 'International geomorphic significance' (Rosengren 1984), representing some of the best examples of this landform in the world. Unfortunately, the jetties are being eroded by wave action, and efforts are now being made to protect and revegetate them, simply because they are a valuable geomorphic feature of the region. There are many other original stream types that are now almost all gone, or fundamentally modified. Other examples are the chains-of-ponds that used to be ubiquitous across South-East Australia (Figure 5), or the original streams of the Monaro Tablelands, the Darling Downs, or the Western Australian wheat belt.

As well as arguments of geodiversity, there may well be strong *cultural* reasons to rehabilitate streams. Many families across Australia mourn the loss of swimming holes, and returning these holes is a good example of stream rehabilitation.



Figure 4. The Mitchell Silt Jetties entering Lake King, Gippsland Lakes, Vic. A site of international geomorphic significance.



Figure 5. A remnant of a chain-of-ponds in NE Victoria—an endangered stream type in Australia.

1.1. Restoration

The ideal restoration project will achieve five objectives (often in this order) (modified from National Research Council 1992):

1. restore the natural range of water quality;
2. restore the natural sediment and flow regime (including the seasonal fluctuations, as well as the annual to decadal pattern of floods);
3. restore a natural channel geometry and stability (if this is not achieved under 2.);
4. restore the natural riparian plant community (if this is not achieved under 2. and 3.); and
5. restore native aquatic plants and animals (if they do not colonise on their own).

Once struck by the exciting idea of restoring streams to their pre-European condition, it is important to acknowledge that this will seldom be possible. Firstly, it is often impossible to establish what that condition was. Secondly, such restoration would mean modifying the physical and biological character

of the reach (channel form, biological communities) so that they replicate the original state (see Figure 9). This would involve changing all of the inputs and outputs (water quality and quantity, sediment, and organisms) from upstream, downstream and the riparian zone, to the pre-European state. Because of the connections between the stream and the catchment, in most situations this would only be possible if the entire stream network, and most of the catchment surface, were also restored. Clearly, this will almost never be possible. Even if the attempt was made, the changes that have occurred over the last 200 years may have been great enough to alter many streams irretrievably. More usually the stream manager will aim for ‘rehabilitation’.

1.2. Rehabilitation

Although restoration may be impossible, this does not leave a degraded stream without hope. By improving the most important aspects of the stream environment, you may create a stream that, although only resembling the pre-European condition, is nevertheless an improvement on the degraded stream, and often a valuable environment in its own right (Figure 7). Since restoration is usually impossible, rehabilitation is the more common goal of our work. This is the term used almost exclusively in this manual.

The Thurra River, a candidate for restoration

The Thurra River in East Gippsland, Victoria (catchment area 350 km²), is entirely uncleared except for a small patch of grazing in its upper reaches (extending for about 3 stream kilometres) (Figure 6), and some logging away from stream lines. It is one of the few larger lowland streams in humid Australia remaining in this condition. The small patch of grazed land is cleared on just one side of the stream and the only real disturbance to the channel is cattle access. If this channel were fenced and revegetated, or allowed to naturally regenerate, then this would represent an example of full restoration. There are no threats from up or downstream, and the in-channel condition of the reach is good.



Figure 6. The slightly disturbed reach of the Thurra River, East Gippsland (note the cleared area to the left).

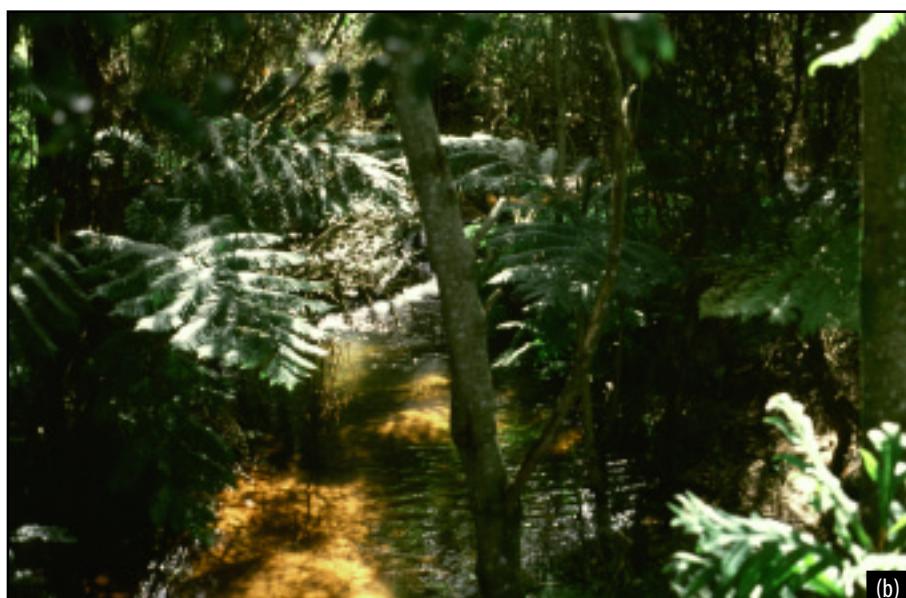


Figure 7. A small tributary to the Johnstone River, far North Queensland (7a) showing the cleared and degraded stream on the right (upstream), completely covered by introduced grasses, with a section that has been revegetated for nearly a decade to the left. 7b is a photograph inside the creek showing how the shaded channel has begun to recover, although sediment from the degraded reach upstream continues to limit recovery of biological communities in the revegetated reaches. 7c shows a nearby stream that has been recently revegetated.

1.3. Remediation (a contribution from Peter Breen and Chris Walsh)

In some cases, even rehabilitation is not possible because of irretrievable changes to the stream. In such a situation, we can say that the original state is no longer an appropriate aim for the stream, because inputs from the

catchment would not support such a condition. In this situation, the suitable treatment is remediation (Bradshaw 1996). The aim of remediation is to improve the ecological condition of the stream, but the endpoint of that improvement will not necessarily resemble the original state of the stream (Figure 9). In fact, we may not be able to predict what that endpoint will be like.

Urban streams: an example of remediation

Urban streams are a good example of the need for remediation, because of the extensive modification of the entire catchment. Many of Melbourne's urban streams would originally have been 'chains of ponds'—low energy streams consisting of pools separated at low flow by grassy chutes. Almost all these streams have been channelised and are now incised. Rehabilitation would seek to return the channel to a chain of ponds. However, even leaving aside the problems of water quality, the large amounts of concrete and other impervious surfaces in urban areas means run-off in a storm event is delivered to the stream very quickly, resulting in higher flood stages, and therefore much greater stream power than under natural conditions.

The original stream channels would not be stable under such a flow regime. Instead of trying to replicate the pre-European conditions, one idea to improve the ecological value of these streams has been to add artificial riffles. Although rocky riffles were not a natural feature in the area, they can improve the stream environment by oxygenating the water, increasing habitat diversity and stabilising the stream (Figure 8).

Once riffles have been added, and water quality improved, it is not clear what biological communities will return to the stream, but it is assumed that they will be more diverse than those surviving in the degraded stream.



Figure 8. Artificial riffles constructed in a small stream in Brisbane by the Brisbane City Council.

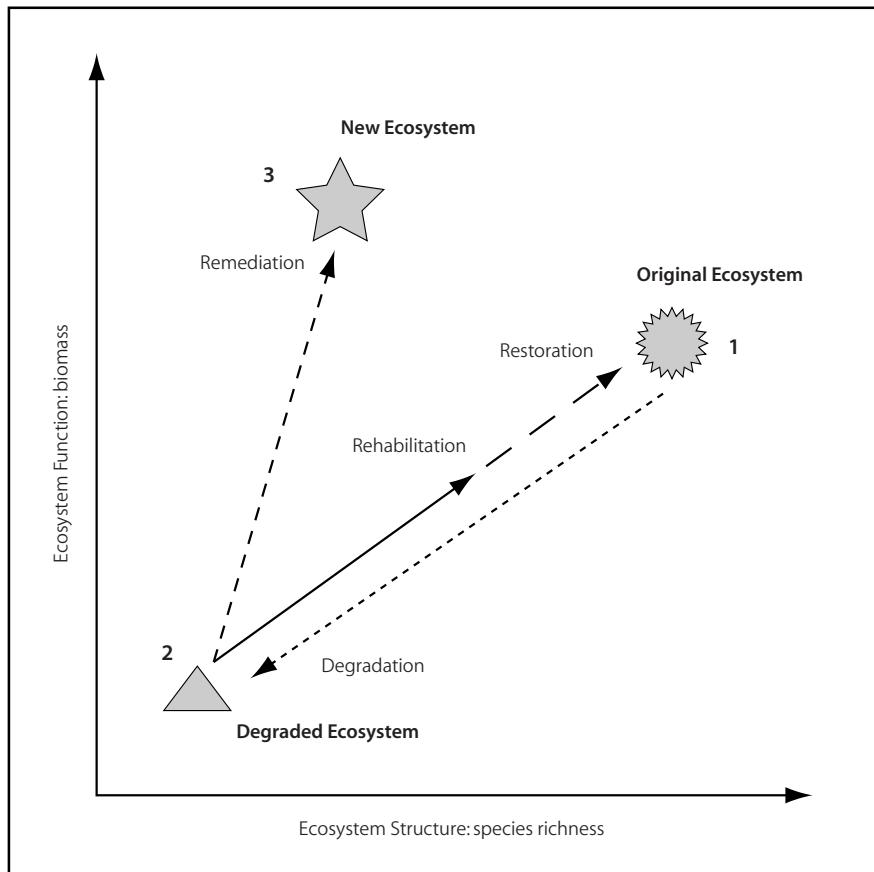


Figure 9. The differences between recovery, rehabilitation and remediation. Restoration involves returning the stream to the original, pre-European condition. Rehabilitation involves fixing only some aspects of the stream, but generally making the degraded stream closer to the original condition. Remediation recognises the stream has changed so much that the original condition is no longer relevant, and aims for some entirely new condition. Figure by Breen and Walsh, from Bradshaw (1996). Reproduced by permission of the National Research Council of Canada.

Summary

The aim of this manual is to preserve and return the natural physical and biological diversity to Australian streams. This can be achieved by assisting stream managers to return the physical character of a stream (including water quantity and quality) to as close to its pre-European condition as possible. The assumption is that this will then encourage, or accelerate the recovery of the native biological communities in the stream. Rehabilitating for organisms will usually also rehabilitate for other values of the stream, such as 'geodiversity'.

It will seldom be possible to successfully restore stream systems to their original state (restoration) so instead the usual goal is to return as much of the original state as possible. This is called rehabilitation, and this will be the term that we will use in this manual.

2. Stream rehabilitation is a subset of catchment management

This is not a stream management manual. Stream management, as a subset of catchment management, involves a mix of goals, and balances the requirements of economic production, asset protection, aesthetics, recreation and the environment (Figure 10). Stream rehabilitation has the goal of maintaining or improving the environmental value of streams, and as such is a subset, although a major part, of stream management.

Figure 10 shows a breakdown of the goals of stream management into some of their component values. Although there is overlap between these goals, single-mindedly pursuing one goal will often be at the expense of the others. For example, a clean straight channel is efficient for flood conveyance, but may have little habitat for plants and animals. Modifying a stream so as to maximise recreational fishing of one species could reduce the habitat available for other species.

Over the last century stream management has emphasised one of the four goals shown in Figure 10: asset protection and economic production. Most of this work has concentrated upon flood protection (channelisation and levees), water supply management (dams and drains), removing riparian vegetation, and erosion control. Over the last two decades there has been a shift in focus in stream management, with a growing emphasis on revegetation of riparian zones, weed control, improving water quality, and further erosion control. While these activities are often justified in terms of ecological or environmental benefits, they are also easy to justify because they often provide benefits to the other goals (they occupy the overlap area between the four goals in Figure 10). For example, controlling erosion protects assets, and revegetation provides aesthetic benefits. We are only now gradually beginning to do things in streams that have only an environmental benefit. Environmental flows, for example,

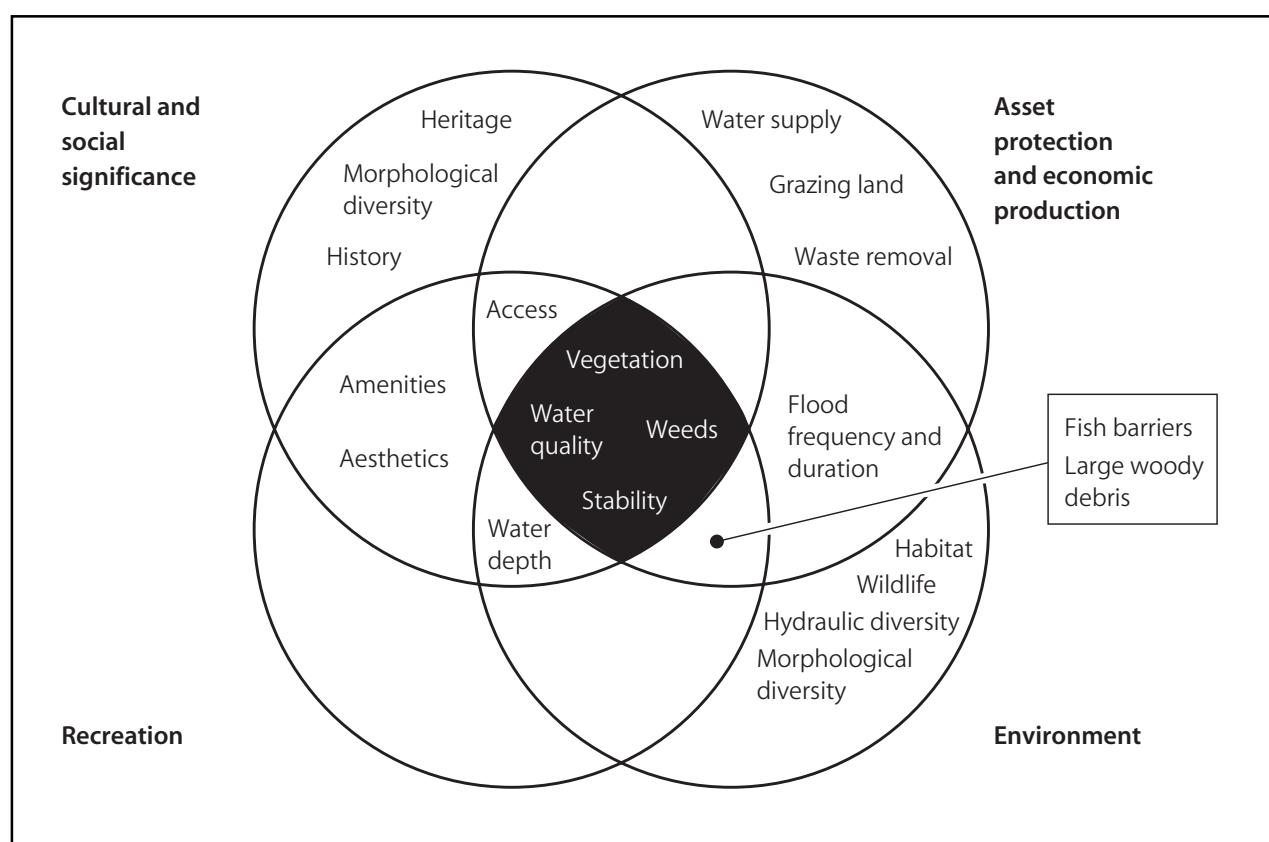


Figure 10. The four basic values for which streams are managed with their shared and unshared components.

are entirely directed at ecological values. As we move away from the centre of Figure 10, toward enhancing environmental values for their own sake, the conflicts with other values are likely to increase. In addition, the traditional approaches and methods used by stream managers who have concentrated upon asset protection and economic production will become less and less appropriate.

Finding the right compromise between stream rehabilitation and the other goals of stream management is not an easy task. In fact, stream and catchment management are examples of what have been called ‘wicked’ public policy problems! They are wicked because they are so tough to resolve—an “ensnared web of tentacles” (Mason and Mitroff 1981). The characteristics of wicked problems are that they are interconnected, complicated, uncertain, ambiguous, and full of conflict (Mason and Mitroff 1981). This perfectly describes catchment management.

We emphasise the complexity of catchment management because the rehabilitation projects planned using this manual have to be implemented within the broader framework of a catchment management program. Thus, this manual is only part of what a stream manager needs to know. We may describe how to carry out a stream rehabilitation project, but you still have to mesh that project with the other competing values within the catchment. Our only advice on the political problem of how to mesh the competing values is given in Step 2 of the planning procedure where we discuss changing peoples values, and in Step 8 where we look at the effect of your plan on other values (eg. flood control). Finally, we would advise that you do not compromise your rehabilitation plan too early. Complete the entire rehabilitation plan, then mesh it with other plans for the catchment. Our experience is that rehabilitation goals often disappear in the face of goals of economic production. To avoid this, complete a full and comprehensive rehabilitation plan so that you will know the environmental cost of any compromise.

2.1. The challenge of stream rehabilitation for stream managers

To be committed to stream rehabilitation does not mean that you cease all other activities in the stream. Assets still need to be protected (Figure 11), water still needs to be managed, but increasingly we are doing these things with the long-term goal of improving the environmental condition of the stream. Incorporating the concepts of stream rehabilitation

into the traditional work practices of stream managers (which included flood and erosion control as their core tasks) often represents a major change of direction. We would argue that there are elements of evolution and revolution in this change. Managers can contribute to stream rehabilitation immediately, by slightly altering some of their present practices: this is evolution. However, if we are to really rehabilitate our streams then other aspects of their work will have to change fundamentally: this is revolution. Here are some examples of the evolution and revolution that is required. We mention them here because they provide themes that run right through the manual.



Figure 11. A railway crossing over Fells Creek, Gippsland, Vic, being threatened by erosion of the channel bed. Note the attempts to protect the structure.

2.1.1. Evolution

- It is easy to damage stream systems, but it is hard and expensive to fix them again. As a result, managers should design and implement works in streams in such a way that they do not damage remaining values of the stream. For example, culverts across streams should be designed to allow fish passage.
- Extending the above point, works in streams can be designed to enhance stream condition. If you are going to protect the stream bank with rock, then do it in a way that leads to an increase in habitat.
- Begin to appreciate that environmental improvement can bring with it many improvements in the other values of streams. Examples would be increased property values, lower maintenance costs, aesthetic values and greater stability.

- Work in multi-disciplinary teams to rehabilitate streams. It takes only one person with a bulldozer to damage a stream, but it can take an engineer, biologist, geomorphologist, botanist and public-relations officer to fix it again.

2.1.2. Revolution

- Adopt ecological values as core goals. This means that it would be acceptable to do works in streams purely for environmental reasons, rather than having to justify work on the basis of the other three management goals described in Figure 10.
- Emphasise preservation of remaining environmental assets as the most important activity for stream

rehabilitators. This is in contrast to the present practice of spending most of the resources on the worst problems (eg. the site with the most erosion).

- Learn to live with uncertainty. We do not know as much about building streams for fish habitat as we do about building erosion control structures. As a result, there is a greater chance of failure. Managers have to learn to live with more uncertainty in their work. As a result, managers will have to evaluate their projects more effectively. This will call for patience because it might take many years for it to become clear that a project has had a biological impact.

3. What is covered in this manual?

There are five interacting elements that define stream condition (Figure 12): the physical character of the stream (ie. the shape and size of the channel, sediments, large woody debris etc.) the water quantity and water quality, the condition of the land adjoining the stream (the riparian zone), and the diversity and population of creatures living in the stream.

This manual does not cover all of these areas in detail. Water quantity and quality—environmental flow allocation, salinity and nutrients, for example—are being covered in separate Land and Water Resources Research and Development Corporation projects, as are the details of riparian zone management. This manual targets local and regional management authorities and groups, which tend to work on reaches of stream, and to concentrate on altering the physical condition of the stream. As a result, the focus is on the physical rehabilitation of stream reaches, with particular emphasis on stream stability and stream habitat.

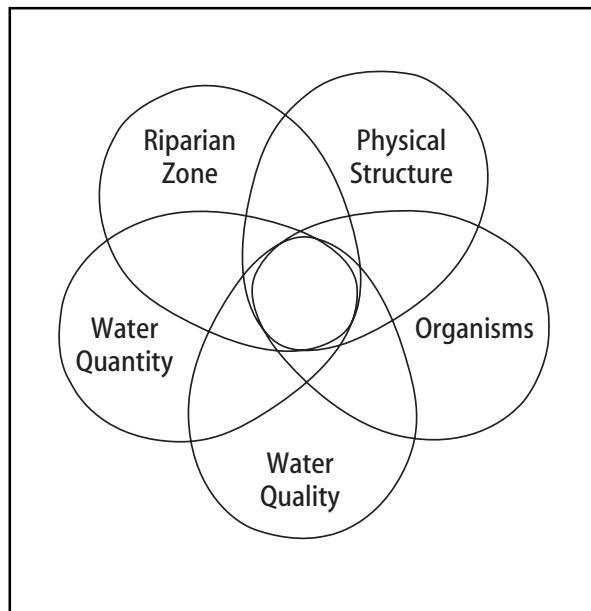


Figure 12. The five key elements of stream health.

4 Why would a manual be useful?

Imagine, for a moment, that you are standing on the bank of Mythic Creek, a typical, small degraded stream somewhere in humid Australia. The stream has been altered by vegetation clearing, removal of snags and of a bend or two, channelisation, access by cattle, a small dam is planned in the headwaters, and so on (Figure 14). A summary of the condition of Mythic Creek is shown in Figure 13.

You are part of a meeting that is in progress. The local Landcare group has gathered on the banks of Reach 4 of Mythic Creek (Figure 13) with its coordinator, to consider what to do with this piece of degraded stream. You have decided to work on this reach because it is generally

considered to be the most degraded on the stream. The group is considering some working-bees, and will be submitting a proposal to the Natural Heritage Trust for some funds to do something about the problems.

The stream-bank discussion goes something like this:

Farmer 1: “The stream obviously needs some more rock on those bends, they’re looking pretty raw”.

Farmer 2: “Come on, we’ve been putting rock on the banks of this stream for 30 years and it’s not getting any better. Surely it’s time to make this stream more like it was when we were boys. You could at least catch fish in it then”

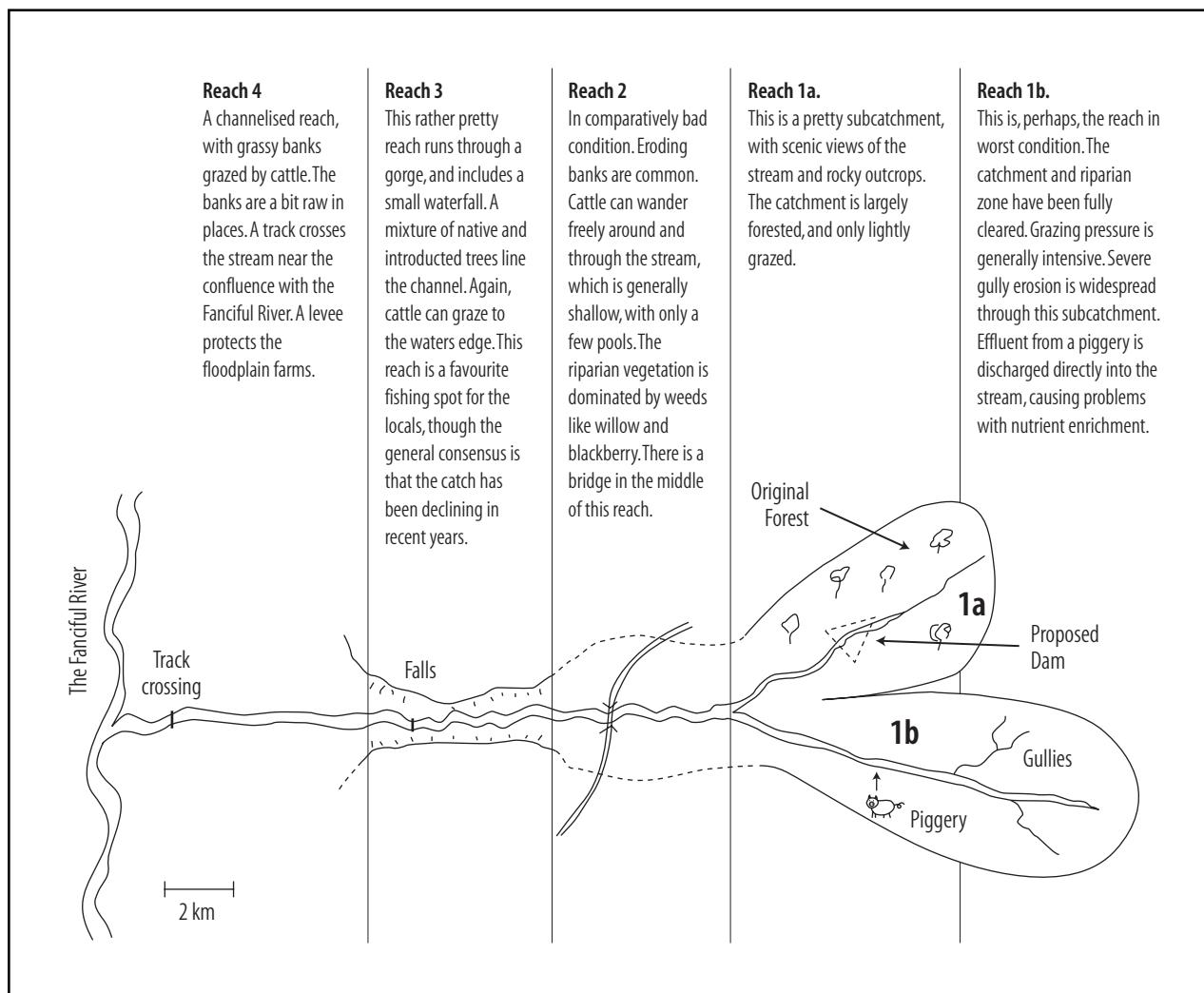


Figure 13. A map of Mythic Creek showing the stream broken into reaches, with the assets, pressures and problems in each reach identified.



(a)



(b)

Figure 14a & b. 14a shows a typical degraded rural stream typical of reach 4 of Mythic Creek. 14b shows the sort of dam that is planned in Reach 1a of Mythic Creek.

Coordinator: “I’ve been thinking about some of the artificial pools and riffles that they talked about in a course I went to in Sydney. They have been very successful in encouraging trout in Canada”.

Farmer 3: “But we don’t want trout, we want native fish back. And I don’t remember that there were ever pools and riffles in this stream anyway”.

Coordinator: “Well, do you remember what the stream was like?”

Farmer 3: “Vaguely. I remember that it was full of timber with deep pools. They’re all filled in now. But we don’t want all those snags back in the river. They cause flooding and erosion”.

Farmer 1: “Perhaps we should do some work up at Don’s place—the banks are worse up there”.

Coordinator: “Perhaps we shouldn’t be working on these bad sections at all, we should be fencing-out that good patch of bush up at Ted’s? Perhaps we need a full GIS of the stream network to help us in planning?”

Farmer 2: “What’s this GIS? Will it help get that sand out of the bed?”

Farmer 1: “Even if we do something here, how will we know that its done any good? Maybe we should get some consultants in—can we afford that?”

Coordinator: “How about if we put in for another riparian fencing and revegetation grant? At least we know that must do some good. Oh, and another thing, we also need to talk to somebody about some better designs for culverts. I am sure that those culverts that the shire put in down at Julie’s will stop any fish getting up the stream. Perhaps I should talk to the shire about that, although I am not sure what to advise them”

The meeting concludes with the coordinator resolved to see if any general information can be found that might help with their decisions next time.

[NOTE: The Mythic Creek example will recur throughout the manual, used as a consistent example of the stream rehabilitation process].

The stream rehabilitation issues raised at our imaginary meeting are typical of those raised at hundreds of real meetings held across the country. They illustrate the sorts of questions that this manual is designed to address:

- How do we design a stream rehabilitation project—where should we start?
- What do we have to do to get fish, platypus and other creatures back into our streams?
- What tools are available for rehabilitating streams, and where should they be used?

- If we do rehabilitate a stream, using a range of methods, can we expect more flooding and erosion, and how much?
- How will we know if the project has been successful?
- If we make mistakes in this project, how can we all learn from them so that we don't make them again?

The knowledge to answer many of these questions already exists, but it is dispersed among technical publications, and among the many experienced stream managers across Australia. This manual attempts to bring together much of the information available on stream rehabilitation, combining the knowledge and experience of people from around the country.

5. Who is this manual for?

Anyone who has anything to do with stream management should find this manual useful. Only a decade ago most stream managers were engineers. Engineers still play a central role in the business, but they are now joined by others trained in environmental management, geography, stream ecology, agriculture, education, and many other disciplines. The breadth of the professional expertise being brought to bear on the problem reflects the real complexity of rehabilitating streams. Participants will often have strong skills in one area of stream management, but will also be keen to learn more about the other disciplines involved in stream rehabilitation. People involved in stream management may work in government agencies, in local government, as Landcare coordinators or as consultants. These are often the people who are actually on the river banks every day, negotiating with landholders, and striving to improve the streams.

We hope that much of what is said in this manual will be pretty obvious to the seasoned stream managers. But there is a high turnover of personnel in the stream management industry, and this manual should be a good multi-disciplinary resource for new recruits.

This manual will not make an engineer into a stream ecologist, or vice versa. But it will provide useful information from across the disciplines. Neither will this manual replace professional advice. In fact, it encourages stream managers to see well-targeted advice as being central to successful stream rehabilitation, and a good investment.

We should make three further points about the manual.

1. Stream rehabilitation is an uncertain business. Any particular aspect of the rehabilitation process is uncertain (eg. "will doing 'x' really produce an increase in fish species 'y'?"). So many cross-disciplinary issues are combined in rehabilitation that the uncertainty is compounded. This manual cannot remove the uncertainty and confusion that plagues many stream managers, because there are still so many things that we are not sure about.
2. One way to reduce uncertainty is to be able to refer to a large range of existing stream rehabilitation projects that we can say have been successful or unsuccessful. Ideally, a manual such as this would be full of such projects that would form the core of our rehabilitation knowledge. Unfortunately, there are almost no rehabilitation projects in Australia that have been evaluated in such a way that we can draw general conclusions from them. As a result, much of this manual consists of suggestions and recommendations rather than iron-clad prescription. We hope that the next version of the manual will include a large range of evaluated projects that will give us all more confidence in rehabilitating streams.
3. Finally, if you live outside of the south-eastern quarter of the continent, you will be intensely annoyed by the constant reference to examples from this region. This bias reflects the density of work done in the area of stream rehabilitation, but also the bias of the authors. We apologise for this failing, but are confident that everybody will find at least some of the concepts in here useful. We are sure that there will soon be a flood of fabulous stream rehabilitation projects from every corner of the continent to improve this document.

6. How could you use this manual?

The manual is split into four parts.

- **Volume 1, Part 1, Stream Rehabilitation Concepts:** Introduction and general information about stream ecology, concepts of disturbance and recovery, and the implications for stream rehabilitation.
- **Volume 1, Part 2, A Stream Rehabilitation Planning Procedure:** A twelve-step procedure for rehabilitating a stream reach. This section summarises the basics of how to plan a stream rehabilitation project, from deciding which reach to work on, through setting priorities, to designing appropriate evaluation and executing the plan.
- **Volume 2, Part 1, Common Stream Problems:** This section contains brief descriptions of the most common problems found in streams, in terms of physical, water quality and biological condition. Each problem is described in terms of how to recognise it, why it is important, how it is likely to develop, and what types of treatment are suitable.
- **Volume 2, Part 2, Planning and Intervention Tools:** This is the ‘tools’ section of the manual. It contains some details on how to complete the twelve steps of the process, along with other useful information such as how to design a natural channel, the uses of benefit–cost analysis and GIS, and the types of instream structures available.

The manual is designed to lead you through the process of stream rehabilitation so that you can quickly find answers to questions. You can use it as a reference source, or you can use it to guide you through a typical rehabilitation project. Here is how the managers of Mythic Creek might use the manual.

6.1. How the Mythic Creek Landcare group might use the manual

First the Landcare coordinator would read the *Introduction* section of the manual to gain a general appreciation of what stream rehabilitation is all about. The coordinator would then, with the Landcare group, run through the 12-step procedure for designing a stream rehabilitation

project. Following this procedure, and referring to Volume 2, the Landcare group decided the following.

- The group resolves that returning as many as possible of the original values of the creek is a worthwhile goal. They have a vision of the creek again having deep pools, vegetated banks, a natural flow regime, and eventually, native fish (*Step 1 of the planning procedure*). While some members are worried about the limits that this vision may put onto some other uses of the stream, in general the group is excited by the prospect, and committed to the years of work ahead! Landholders who are likely to be community leaders, and ‘laggers’, are identified for special attention (*Step 2*).
- The group decides to develop a stream rehabilitation plan independently of other plans for the catchment. They will mesh the rehabilitation plan with the catchment management plan later.
- With the help of an officer from the State Government ‘Department of Environment and Gambling’, the group investigated the creek’s problems and assets, and broke the stream into reaches (Figure 13 is an example of the sort of map they might produce) (*Step 3 and Step 4*).
- There were no good template reaches that could be used for assessing the condition of the stream, so the team had to rely on historical reconstructions of the original state of the stream (which in Reach 1b was a chain-of-ponds) (*Step 3*). This information came mostly from interviews with long-time residents, although some old maps and photographs were also useful. Reach 1b is identified as a typical ‘incised stream’ yielding sediment to Reach 2 (*Volume 2, Common stream problems*), and some evidence of high nutrient levels is found below the piggery (*Volume 2, Common stream problems*).
- Using the priority-setting procedures (*Part 2, Step 5*), protecting Reach 1a and Reach 3 is given highest priority. The piggery in Reach 1b, and sedimentation in pools in Reach 2 are the next priorities, and so on.

- It is decided that all the plans are feasible, but that given the potential resources available, five tasks should be given highest priority:
 1. Stopping the dam in Reach 1a
 2. Removing weeds and cattle from Reach 1a
 3. Investigating piggery effluent in Reach 1b
 4. Fencing parts of the gorge reach (Reach 3)
 5. Fencing and revegetating Reach 2 (this was moved up the priority ranking because the reach is visible from the road, and the farm is owned by a community leader whose support could influence other landholders (*Step 5*).
- What will be the other consequences of the rehabilitation plan? Stopping the dam will have an impact on the horticulture plans of the catchment next door. Money will have to be provided for off-channel stock watering if the group is going to fence-off long reaches of stream, particularly in reach 2. None of the works is expected to cause more flooding or erosion (*Natural channel design, Volume 2*). Also, there is talk about the possibility of the piggery going broke if it has to release effluent of acceptable quality.
- Armed with their plans and priorities, the group then defined ‘measurable objectives’ that they could use as measures of how the rehabilitation was progressing (ie. evaluation) (*Step 7*). For example, stopping the dam being built, fencing 12 km of channel within 3 years, etc. These objectives were developed in concert with detailed designs for the implementation of the plan.
- An evaluation plan was prepared that concentrated on outputs (eg. did they build what they said they would) rather than outcomes (eg. were there really more fish?) (*Step 10*). The only outcome measured would be the change in depth of some pools, and the presence or absence of native fish in reach 2. This would be evaluated by fishing and by annual electro-fishing sweeps by a government department.

The planning took about a month of the coordinator’s time (gathering information and coordinating things) as well as two days for the rest of the Landcare Group (a day in the field, and a day going over the plan). Finally, the plan was prepared as a draft map that could be taken around the catchment to discuss with landholders who were not involved in its preparation. In addition, the plan could be used in discussions with other groups working on the stream eg. the local Shire, water authorities and others. Finally, the coordinator compared their plan with other catchment plans and procedures to see if there was any conflict that could be resolved.

In reality the process seldom goes as smoothly as depicted in this example. It will often be difficult to recognise your stream in the ‘stream problem’ types section (we have covered only the most common types in eastern Australia). More fundamentally you may not have enough information to decide what are the ‘limiting factors’ in achieving your goals (eg. there may be no fish because of some subtle effect of flow regulation that we don’t understand). Nevertheless, following the procedure defined here will certainly lead to a more rigorous rehabilitation project, with realistic goals, and an assessment procedure. The more that we learn from our projects the better each one will be.

7. Some principles for rehabilitating streams

The next two chapters of the manual introduce some concepts of stream ecology, and how streams recover from disturbance. The following six points summarise the main principles for stream rehabilitation that emerge from these two chapters.

7.1. Condition

The health and sustainability of biological communities living in, and relying on, a stream is a good measure of the health of the stream system

You can usually assess the condition of a stream by what lives in it. If the stream contains close to the pre-European population and diversity of organisms, then it is likely to be in fair condition.

7.2. Damage

In the last two centuries humans have damaged a large proportion of Australia's streams

Direct changes to streams, combined with changes to catchments and water quality, have simplified the physical and hydrological character of Australian streams. These impacts have interrupted the life cycles of many species so that they can become locally extinct, or stressed. As a result, the biological communities in streams have also become simpler, such that they are now dominated by relatively few animals and plants. Often the remaining plants are exotic (not native) species.

7.3. Recovery

Some streams may recover naturally from the damage done by humans

Damage to stream systems may be permanent (eg. extinction of species), essentially permanent on human time scales (eg. taking hundreds of years to recover), or resilient systems may recover within years. If you understand the natural process of recovery, then you may be able to work with that recovery to more quickly rehabilitate a stream.

7.4. Rehabilitation

Humans can attempt to return the stream to some approximation of its original condition

Rehabilitation is an effort to artificially return the fundamental elements of the original (pre-European) stream, either by direct intervention, or by hastening the recovery process.

Rehabilitation usually involves managing the physical and chemical conditions in the stream so that you:

- provide for the life-cycle requirements of the community of organisms that you are working with, concentrating on the 'limiting requirements' of the life cycle;
- remove or control damaging processes (eg. altered flow, poor water quality, cattle grazing) that disrupt life cycles; and
- return the natural complexity and variability to stream morphology and hydrology (including a sufficient frequency and magnitude of floods and erosion) that provides the habitat and resources required by organisms.

7.5. Copy

When in doubt, copy

Often, we want to rehabilitate a stream but we do not know enough about the complexities of the natural stream ecosystems to know where to begin. When in doubt about what to do to rehabilitate your stream, either copy the original form and conditions, or find a reach in good condition, that has the physical or biological characteristics you want, and copy that reach.

7.6. Prevention

The first rule of rehabilitation is to avoid the damage in the first place!

It is easy quick and cheap to damage natural streams. It is hard, slow, and expensive to return them to their original state. Usually we are not capable of returning anything approaching the subtlety and complexity of the natural system. For this reason, the highest priority for stream rehabilitators is to *avoid further damage to streams, especially streams that remain in good condition.*

An introduction to stream ecosystems

- 1. How stream ecosystems work**
- 2. Stream ecosystems and rehabilitation:
the importance of limiting requirements**

1. How stream ecosystems work

(By John Gooderham and Kathryn Jerie)

1.1. Introduction

It is possible to rehabilitate a stream without knowing much about the organisms that live in it. This can be achieved by simply copying the physical structure of the original stream and hoping for the best. In fact, we know so little about many ecological communities in Australia, that this ‘suck-it-and-see’ approach is usually what people would do. However, having said this, it can be much more efficient to know something about the group of organisms that you are trying to promote and manage. For example, the concept of ‘limiting requirements’ introduced in this chapter can save you from wasting large amounts of money fixing second-order problems that will not help the organisms. Why, for example, provide expensive habitat if the real problem is water quality? Further, knowing something about organisms can help to avoid costly mistakes. An example would be removing a fish barrier that then allows an exotic fish to invade a pristine reach.

This section outlines the fundamental structures and processes of stream ecology, in the hope that they can then be factored into the design of rehabilitation projects, and their subsequent assessment. What we present here is a simplistic model of stream ecology that may not do justice to the variation and complexity of ecosystems around Australia. However, it does present a good starting point for understanding biological interactions. The next chapter discusses how physical and ecological systems in streams recover after human disturbance.

What is stream ecology?

Stream ecology is the study of communities (stream organisms and the relationships between groups of these organisms), and the way communities and individual species interact with the physical and chemical characteristics of the stream around them. A simple way to look at this complex system is to break it up into three parts: the food web, life cycles and resources. This will provide the framework to consider the characteristics of a good community.

1.2. The Food Web—a framework for stream ecosystems

Figures 15 and 16 show a simplified food web and ecosystem structure from two sections of a typical stream: an upland stream with varied riffle and pool habitats; and the comparatively less complicated channel of a lowland river. In each of these, the basic ecosystem is very similar, the only differences being in the organisms involved (Figure 15), and the proportions of processes occurring (Figure 16). The food web is a structure in which organisms from higher levels consume those on the levels directly below them. Eventually, all organisms die and return to the bottom of the food web to be broken down into detritus and various forms of nutrient. These are then used by the lower levels of the food web, thus introducing life to the food web once again.

A cautionary note

Much more research into stream ecology has been carried out in the northern hemisphere than in Australia, so it is tempting to borrow directly from this work. This is acceptable in some instances but be warned that our ecology can be very different from that of the northern hemisphere. For example: it would be unwise to use information from the northern hemisphere on the effects of leaf litter on streams. Most northern hemisphere trees drop

all of their leaves in autumn, whereas ours only drop slightly increased amounts of leaf litter in summer. This doesn’t mean that all information on stream ecology from Australia is preferable or applicable across the continent either. A stream manager from Tasmania may find more uses for ecological information from northern America/Europe than from the Northern Territory, due to the obvious differences between temperate and tropical systems.

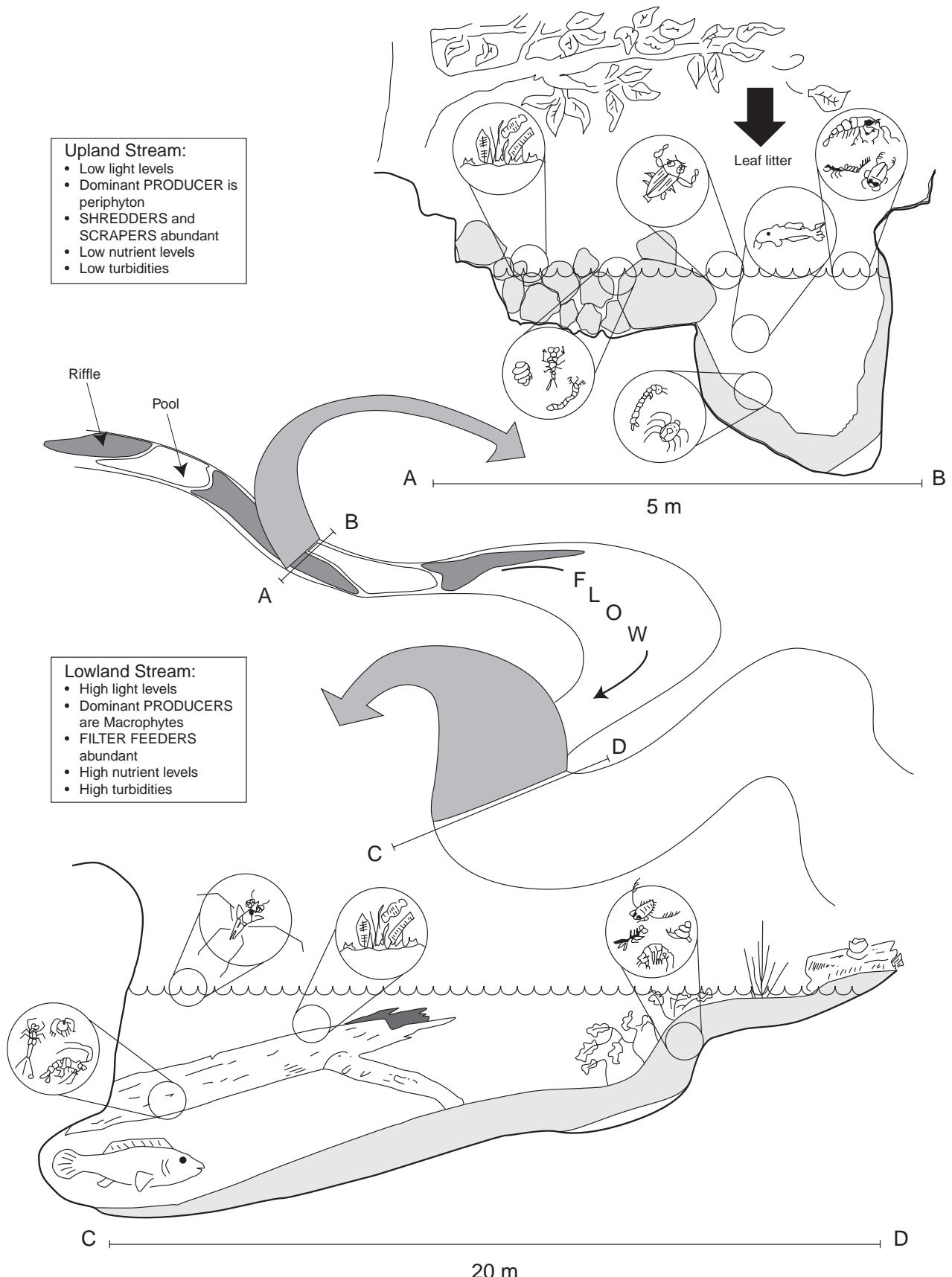


Figure 15. This figure contrasts the types of creatures you might find in upland and lowland streams. Different organisms are associated with the different physical features of these streams.

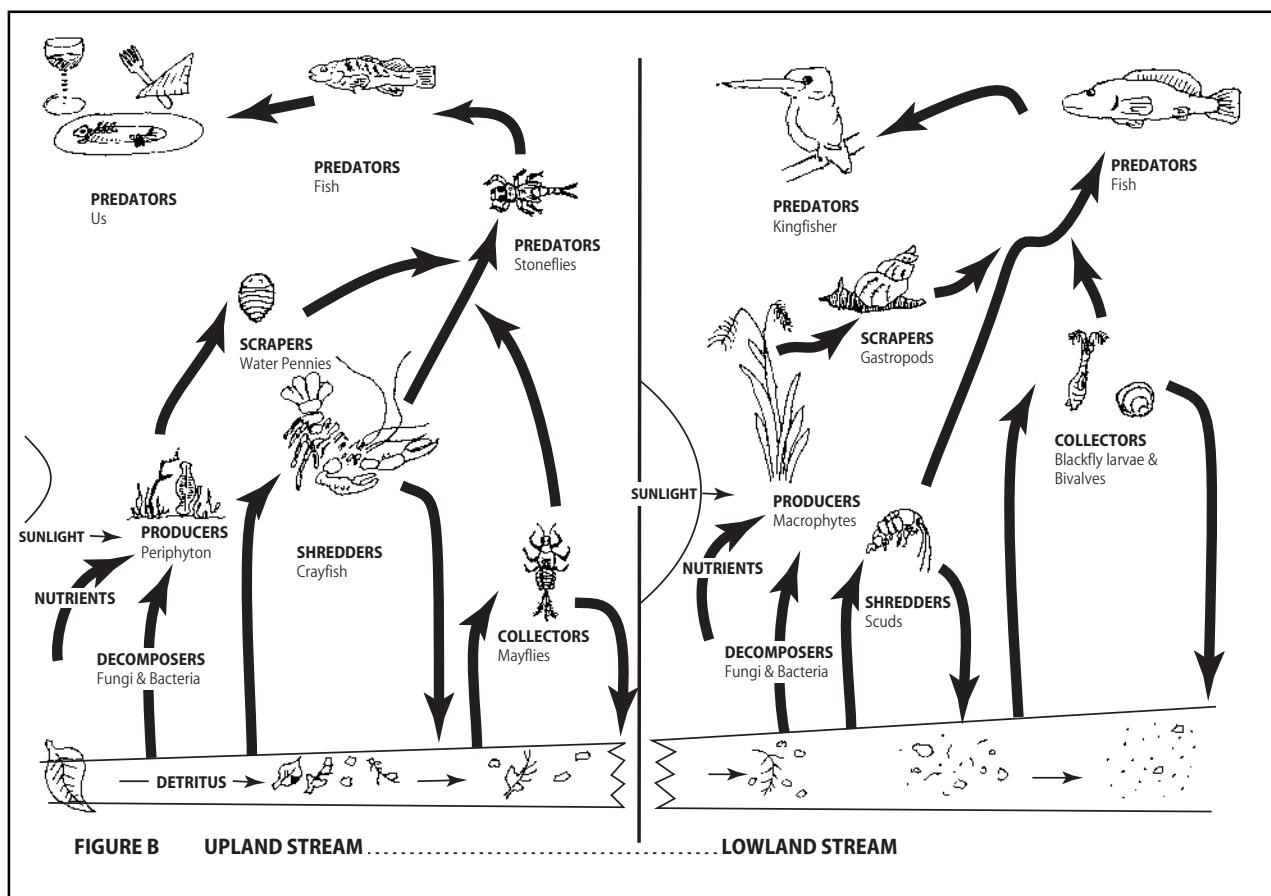


Figure 16. The simplified food web describes the interactions between plants and animals in a community—basically, who gets to eat who. This figure contrasts the food webs from an upland and a lowland stream. Arrows show nutrient flow.

1.2.1. Primary producers

At the bottom of the food web are algae and plants, which create their own energy from sunlight and raw chemicals that are available directly from their surroundings. These are called producers, as they take resources that other organisms cannot readily use, and produce energy in a form that can be readily used by organisms higher up the food web. Unfortunately for them, this usually involves being eaten. In stream environments, the two dominant forms of producers are flowering plants (macrophytes) (Figure 17), and periphyton (from the Greek, *peri* (edge) *phyton* (plants)). The latter refers to the thin layer of algae which coats many of the surfaces in streams. The plants of the riparian zone produce the largest amount of organic matter found in streams and are therefore important producers, despite being out of the watercourse for most of the time.



Figure 17. Sedges and rushes growing in the Campaspe River in Central Victoria. Macrophytes such as these produce food for the herbivores in the stream.

1.2.2. Herbivores

Herbivores occupy the next level up the food web: they consume producers (and decomposers, described below). The two basic types of herbivore present in streams are described by the way they eat. ‘Scrapers’ graze periphyton, scraping the thin layer of algae, bacteria and fungi from rocks and other hard substrates. This group includes many aquatic snails, together with a variety of other invertebrates equipped with brushes or blades on their mouthparts for removing the firmly attached algal layer (see fig 18). ‘Shredders’ can eat macrophytes, by chewing through leaves, or boring into the stems of the plants, but most consume old, dead or rotting plant material or detritus.



Figure 18. The nymph of a leptophlebiid mayfly. This animal lives amongst gravel and cobbles, grazing on the periphyton growing on their surfaces (© Gooderham and Tsyrlin).

1.2.3. Predators

All levels of the food web above herbivores involve predators of one sort or another. These are generally larger invertebrates (like stoneflies (Plecoptera)), and larger animals such as fish, frogs, lizards and birds. Most of the larger stream animals familiar to us are predators, even though they tend to be less numerous than any of the other levels of the food web. The reason there are fewer predators than herbivores is that each predator requires many prey (in a fairly constant supply) to survive (see Figure 19).

1.2.4. Detritivores

Detritivores are more numerous than herbivores in streams. This is because of the huge amount of organic matter that finds its way into streams from the rest of the

catchment. Leaf litter, woody debris, and the bodies of dead organisms provide food for detritivores. When organic matter first enters the stream it tends to be large and chunky. The detritivores that first deal with debris are shredders. They break down the debris into smaller pieces, while extracting what nutrients they can from a combination of the old plant matter itself and the bacteria, and fungi that grow on it. Freshwater crayfish (Parastacidae) are a good example of shredding detritivores. In a lot of cases, shredders are relatively inefficient at extracting nutrients, and their faeces are still rich with nutrients from their food. The abrasive effect of downstream movement of organic matter also contributes to its physical breakdown.



Figure 19. A water skink (*Eulamprus tympanum*). Part of this lizard's diet is aquatic insects emerging from the water.

As organic matter is chewed, digested and broken into smaller and smaller pieces, it moves downstream as a cloud of particles. The detritivores that use this form of organic matter are 'collectors' (or filter feeders). Many of them have specialised hairs upon their legs, or around their mouthparts, which strain the fine organics from the water as it flows past them. Blackfly larvae (Simuliidae) and net spinning caddisflies (Hydropsychidae) (Figure 20) are examples of collectors. Other detritivores collect fine organics in areas of slow flow, where it settles out of suspension and forms an easily harvested film on the substrate.



Figure 20. This tiny structure was built by a caddisfly larva. The carefully constructed net, about a centimetre across, is designed to catch fine particles of organic matter that are washed downstream (© Gooderham and Tsyrlin).

1.2.5. Decomposers

Fungi and bacteria structurally and chemically break down organic matter, releasing the basic components back into the water in the form of nutrients (various states of carbon, nitrogen and phosphorus). These nutrients are then used by producers, completing one of the loops of the food web. Bacteria are found in the water, on most surfaces in the stream, and in the guts of various detritivores.

1.2.6. Implications of ecosystem structure for stream rehabilitation

Animals and plants do not exist in isolation from each other—they require each other for food, shelter, and recycling of waste materials. It is tempting to make some desirable animal (Murray cod or platypus, for example) a basis for stream rehabilitation. However, you must remember to support the rest of the food web, particularly when attempting to encourage predators (which covers most of our charismatic animals). They will not survive without the food provided by the lower levels of the food web.

1.3. Life cycles of organisms in streams

Many stream animals have life cycles that involve exploiting a variety of stream habitats during different life stages. For example, fish commonly spawn in one part of their habitat, use a different part as a nursery area, and then disperse into a third area for adult growth. Habitats used by different life stages of the same species may be as different as upland streams and the ocean (short-finned eels spawn in the ocean and young fish migrate upstream)

Stream rehabilitation and the food web

The entire food web is important. Each part should be considered when rehabilitating a stream.

- To have fish, frogs, and platypus etc., you need to have invertebrates for them to eat.
- To have invertebrates, you need to have plant material for the herbivores and detritivores.
- The riparian zone and floodplain are both important sources of plant material (food for invertebrates).

(Koehn and O'Connor 1990). However, different habitat use may also occur at smaller scales within the same river system, or even within a single reach. Golden perch migrate upstream to spawn. The hatched larval fish drift downstream to floodplain habitat in billabongs and flooded areas where they develop into young fish. Aquatic insects also move around during their life cycles. For example, leptophlebiid mayflies live on the undersides of stones in moving water as nymphs, then leave the stream

as adults and live briefly in the riparian vegetation before returning to the stream to lay their eggs.

Environmental triggers are a very important part of life cycles. Animals may rely on changes such as water temperature, flow or day length, to indicate that the time has come for a particular part of the life cycle. Many aquatic insects, for example, time their emergence from the water by the water temperature. The warmer the water,

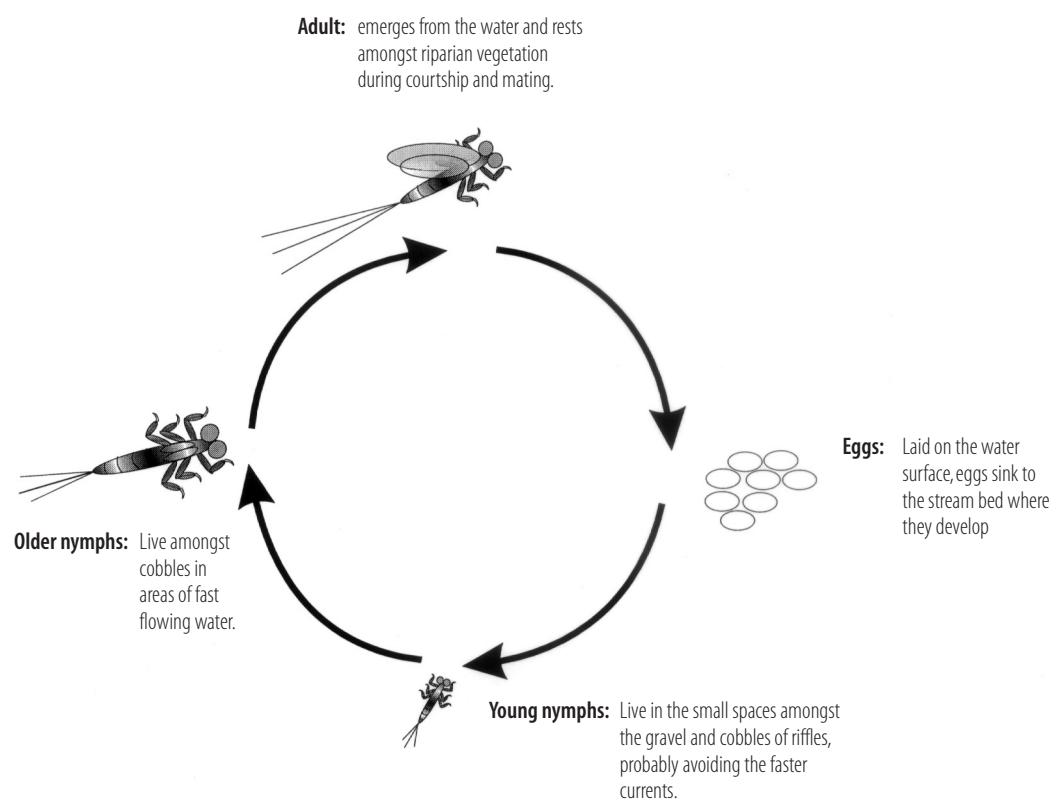


Figure 21. The life cycle of a leptophlebiid mayfly. During the life cycle, the mayfly will use the riparian vegetation and different areas of coarse sediment in fast flowing sections of stream.



Figure 22. A section of the Campaspe River with habitat suitable for mayfly nymphs (moving water over rocky substrate) and adults (emergent macrophytes and other riparian vegetation).

the sooner insects will emerge. If water temperatures are raised artificially insects may emerge early and be unable to cope with cold weather.

Though plants are not mobile, they too will have different requirements of their environment at different stages of life. For example, macrophytes may rely on periods of low flow to establish on the stream bank.

1.3.1. Dispersal and migration

Dispersal is often an important part of the life cycle. It is the means by which organisms colonise new areas.

Mechanisms of dispersal are often built into the life cycle of a species. The three main types of dispersal are drift, aerial dispersal and migration.



Figure 23. An adult leptophlebiid mayfly (© Gooderham and Tsyrlin).



Figure 24. The dragonfly in (a) can fly up and downstream, potentially covering considerable distances, while the amphipod in (b) is limited to drifting downstream, or crawling upstream within the water (© Gooderham and Tsyrlin).

1.3.1.A. Drift

Drift describes the movement of organisms downstream. Most macroinvertebrates drift at some stage in their larval lives, as do larval fish. Drifting generally occurs at night. Individuals will continue to drift until a suitable environment is found. Sampling drift can give an idea of the numbers of organisms drifting that could potentially colonise a stretch of stream.

1.3.1.B. Aerial dispersal

Although this is not an option available to fish, other organisms, such as macrophytes and insects can take to the air to recolonise upstream against the flow, or to disperse between rivers. Many macroinvertebrates, such as flies, mayflies, stoneflies, and caddisflies, are appropriately named and do indeed fly in their adult forms (some are better fliers than others, and stoneflies are a particularly well named group). Most macrophytes disperse as seed, some using the stream to travel to sites downstream, while others rely on wind dispersal to take their progeny (somewhat haphazardly) to sites upstream or in other water bodies.

1.3.1.C. Migration

Many native Australian fish make spawning migrations as part of their life cycle. Migration patterns vary, with adults of some species moving upstream to spawn, and the juveniles then drifting downstream (anadromous), while others reverse the cycle, spawning in the sea or in estuaries, leaving the young fish to swim upstream (catadromous). Others

make migrations within river systems (potamodromous). These distinctions become important when considering the effect of barriers to fish passage. Juvenile fish are not strong swimmers (Beamish 1966), yet catadromous species depend on their upstream migration and are thus more likely to be restricted by barriers to passage.

In many cases, fish migration is seasonal, and fish use the flow and temperature regime of a river as a rough guide to the seasons. In this way, key features of the flow regime act as ‘triggers’ to initiate migration and spawning. Regulating rivers can remove these triggers and reduce the reproductive success of many fish.

1.3.2. Implications of life cycle complexity for stream rehabilitation

For a life cycle to be successfully completed, the stream must meet the requirements of each life stage, in terms of food and habitat, as well as provide free passage between the habitats and the appropriate environmental triggers for movement between stages. Failure to meet these requirements will result in the local extinction of the animal in question. This can happen quite quickly, within one generation, or be a gradual, insidious decline in population. Fish barriers are a classic example of such a breakdown in life cycles. A dam or weir blocking the upstream passage of young fish will eventually result in the extinction of that species above the obstruction. For example, populations of at least six migratory coastal species disappeared from above a small weir at Dight’s Falls in the lower Yarra River before a fishway was installed.

Stream rehabilitation and life cycles

For an organism to be present in the stream, the requirements of **all** life stages must be met. If just one part of the cycle is broken, the population will not be sustainable. To attempt to support the life cycles of as many stream organisms as possible, you should aim for:

- habitat diversity in the channel and riparian zone;
- appropriate water quality;
- an appropriate riparian zone;
- free passage between different habitats;
- connectivity with the floodplain (floodplain habitat such as billabongs and inundated vegetation are important nursery areas for some fish); and
- natural flow (low and high) and temperature regimes.

1.4. Resources required by organisms in streams

The physical character of the stream drives the ecology. In fact, this is the central premise of stream rehabilitation: that the ecology can largely be managed through manipulation of stream resources. These resources can be broken into three groups: the physical habitat available in the stream, the quality and quantity of the water, and the floodplain.

Table 1. Some common organisms and some examples of important resources that they require.

Organism	Examples of important resources
Algae (periphyton)	Light and nutrients
Water millfoil (<i>Myriophyllum</i> sp.)	Light and nutrients, slow moving water
Water skaters (Family: Gerridae)	Pool areas (still water)
Stoneflies (Family: Plecoptera)	High dissolved oxygen, clean coarse substrate, low temperature
Blackfish	Habitat eg. snags, hollow logs for spawning

1.4.1. Habitat

Instream habitat refers to all the physical features of the stream, including the substrate (eg. rock, sand or mud), the depth and velocity of the water (pool versus riffle), the presence of vegetation in the stream (macrophytes) and around it (riparian vegetation), and any instream shelter, such as woody debris, undercutts or large rocks. The floodplain is another important component of habitat (billabongs or inundated vegetation can be important nursery areas for juvenile fish, for example). Streams that offer an array of different habitats are likely to support a greater diversity of organisms. There are several reasons for this.

1. The habitat requirements of one species are seldom exactly the same as those of another species. For example, the emergent macrophyte cumbungi (*Typha* spp.) is found in areas of still or slow-moving water, while ribbonweed (*Vallisneria gigantea*) can thrive in

shallow running water. This is of course rather simplistic—there are obviously many other plants which could thrive in one or both of these environments. However, by having a range of habitats, you create the opportunity for a variety of organisms to utilise those habitats.

2. Most organisms with the ability to move need different types of habitat for day-to-day life. For example, a fish may need foraging areas rich in macroinvertebrates, resting areas sheltered from predators, and areas of refuge from floods or drought. Thus, the maintenance of one species requires a variety of habitats.
3. The habitat requirements of mobile organisms will probably change during their life cycle. A damselfly, for example, needs good pool environments as a nymph, but as an adult it leaves the water and uses the riparian vegetation as perches and shelter. There are also numerous examples of habitat preference changing with life cycle within the water. To support a single species through its life cycle requires a diversity of habitats.

For these reasons, reaches with more habitat complexity will usually support a larger number of taxa (different types of plants and animals). Substrates that contain a range of particle sizes support larger numbers of taxa than homogenous substrates (Williams 1980). Reaches with pool/riffle/bedrock provide more habitat complexity, and therefore biotic diversity, than the same length of reach with a simple pool (Brussock *et al.* 1985; Statzner and Higler 1986).

Unfortunately, a widespread impact of European settlement has been the simplification of stream habitats. Riparian vegetation has often been simplified to pasture or a monoculture of willows, channels have been straightened, incision has caused a loss of bed complexity, desnagging has removed a lot of instream habitat, and sediment deposition has smothered the stream bed (Figures 25 and 26). Reduced flow variability downstream of dams may mean that important triggers for fish spawning migrations are lost, as is access to floodplain habitat.

Human impact not only simplifies the structure of streams, reducing the amount of habitat, but it also reduces the continual *evolution* of habitats within a natural stream. For example, consider a meandering stream that



Figure 25. An extreme example of habitat simplification. On the left is the original urban stream in an Eastern European city. Note the good riparian vegetation, and the varied water velocities in the channel. On the right is the channel after it has been 'channelised' for flood control. Note the simplification of the stream with uniform flow, and a single reed species at the water's edge.



Figure 26. Another example of simplification. A reach of the Glenelg River below an invading slug of sand (a), and in the slug (b). The constant movement of the sand makes it a poor substrate for macroinvertebrates (O'Connor and Lake 1994).

periodically cuts-off its meander bends to create billabongs, or jumps to new courses on the floodplain (avulsions) (Figure 27). Over thousands of years the stream is continually creating billabongs that then progressively fill-in. Different groups of organisms occupy different parts of this succession from open stream to disappearing billabong. In a natural system, at any one time there are always bends in different stages of the succession, providing habitat for all of the communities. By stabilising the stream and limiting the number of cutoffs, humans are terminating the entire process of succession (National Research Council 1992). Thus, by stabilising streams, and by controlling floods, humans reduce the number of habitats, as well as their continual renewal.

1.4.2. Water quality and quantity

The flow regime can have a significant impact on stream ecology. Flow has a direct effect on plants and animals, through its role as a disturbance of the stream in floods and droughts, as a trigger for migrations, and as a means of connecting with floodplain habitats (see next section). Indirectly, flow regime is an important determinant of stream morphology, maintaining instream habitats. Changes in flow are common triggers for spawning migrations in fish. Changes to the flow regime may mean these trigger flows do not occur, or occur at the wrong time. Reducing the number of successful spawning migrations can lead to a decline in the population of the fish species in question.



Figure 27. A floodplain with billabongs and avulsed channels in various stages of evolution (the King River, NE Victoria).

Water quality can also be very important. Every organism has a range of water quality that it can tolerate with ease. Outside this range, the ability to compete with other organisms for space and food will decline. In this situation, tolerant species will dominate the stream fauna. Unfortunately, it is often exotic species, such as carp, that show the greatest ability to take advantage of such situations. When water quality falls by too much, sensitive organisms will be completely lost from the stream. Water quality is affected by: land use (farming, urban areas, construction and industry all have accompanying water quality problems); stock access to streams (increases turbidity and nutrient load); cleared riparian zone (decreased buffering effect, and decreased shading of water); and point sources of pollutant such as drains, sewage effluent and industrial wastewater. More information on thresholds of concern for water quality problems can be found in the Common Stream Problems Section of Volume 2.

1.4.3. The floodplain

Floodplains are a surprisingly important part of the stream system, providing habitat important to the life cycles of stream animals, and delivering a large quantity of detritus to the stream (Figure 28). During floods, the inundated area is a vast food source and supplies habitat for fish spawning and nursery areas. The floodplain provides a comparatively slow-flowing refuge from the destructive forces of the main channel during flood. When the floods recede, they take with them a supply of leaf litter and other detritus which provides food for the detritivores and shredders. Floods also play an important role in the floodplain itself, with

some species of plant, such as redgum (*Eucalyptus camaldulensis*), requiring periods of inundation for regeneration.

In most situations, the stream and the floodplain are so intimately associated that it is sensible to consider them as the same system. In fact, in a natural stream, the boundary between the stream and the floodplain tends to be a vague zone rather than an abrupt border. For example, incision of the stream will lead to a dramatic reduction in flooding that will transform the riparian vegetation communities along the stream, and so change the terrestrial animals that rely on that vegetation. Grazing of riparian zones, on the other hand, can lead to channel erosion that in turn alters the biological communities living in the streams.



Figure 28. An incised tributary to the Goulburn River (Vic.) showing a floodplain that is now very rarely flooded. Even when it is flooded, it has been so simplified by agriculture that it provides few resources for the stream.

1.4.4. Implications of resource requirements for stream rehabilitation

The direct relationship between resources and the stream biota is convenient for us as stream managers. We can manage the stream ecology by manipulating the physical habitat and water quality. However, this is a two-edged sword. If the resources are not in good condition, we cannot expect the ecosystem to recover. We emphasise again, for a population of any species to be maintained in a reach, the requirements of all stages of the life cycle must be met. Providing a diversity of habitats will increase the number of species the stream will support, unless some aspect of water quantity or quality is causing a problem. There must be a sufficiently natural flow regime to maintain that habitat complexity, as well as providing appropriate triggers for life cycle changes, and access to flood plain habitat. Managing water quality is another common difficulty. Polluted water can prevent the stream community from improving, even when there is good habitat available.

1.5. Ecological health: what is a good community?

We have so far been discussing the biological and physical influences which shape and support stream communities. In the next sections, we will consider how streams recover from disturbance, and how rehabilitation may be able to speed that recovery. In the course of this discussion, we

will assume general agreement on what constitutes a desirable stream community. But what do we really mean by a ‘good community’?

Which species make up a ‘good community’ is really based on a value judgment that the communities found in pristine streams are ideal. Of course, such communities will vary enormously between different regions (highland versus lowland streams, tropical versus temperate). However, there are two things good communities have in common. They contain a diversity of species, and a significant proportion of these species will be intolerant of ‘bad’ stream health (such as poor water quality, and reduced habitat diversity).

Why is this so? The tolerance of the species present is an indicator of the physical condition of the stream. If there is a variety of sensitive species present, that suggests that the stream is in good physical condition. However, if only species tolerant of polluted or degraded conditions are present, then this is probably because local conditions are degraded. The organisms present indicate the condition of the stream. Admittedly, this is a very circular argument, but in fact it is the association with degraded environments that makes many species appear undesirable.

High diversity is considered valuable because a degraded stream will have only plants and animals that are tolerant of the degraded conditions, whereas a healthy site will still have most of those tolerant species, and a variety of sensitive species as well. However, although this is the general rule, it is important to remember that more is not always better. There are some situations where human interference will artificially increase the number of species present in a reach. For example, slight nutrient enrichment in sandy streams can increase the number of macroinvertebrate species present. However, such a change risks losing sensitive species from the stream. Introducing animals or plants not naturally found in the area is another way of artificially raising diversity. This could eventually lead to the decline of local species, and would also reduce diversity between entire streams. For these reasons, *natural* levels of diversity are best.

Resource needs of stream organisms

To support a diversity of organisms the stream needs to have a complex array of different habitats.

Regulated flows can lead to changes in important habitat features, may remove flow triggers for spawning migrations in some fish, and can restrict access to floodplain habitats.

Water quality must be within the tolerance ranges of the organisms you wish the stream to support.

2. Stream ecosystems and rehabilitation: the importance of limiting requirements

In the first part of this chapter, we described a very basic model of how organisms interact with their environment. Such an understanding is important for seeing the implications of work done in and around streams. There remains an important point to make about achieving biological goals of stream rehabilitation. This is the concept of the limiting resource—that aspect of a degraded environment which has the most influence on the ecosystem.

Since European settlement there have been many far-reaching changes to streams. The resulting shift from good to not-so-good communities in our streams is of course the reason for this manual. But changing everything back to pre-European conditions for the sake of stream ecology is plainly impractical, startlingly expensive, and in most cases impossible. So, when the environment has been so thoroughly altered, and the potential for rehabilitation is limited, how do you know where to start? How do you know which of the changes you can make will have the most effect on improving the stream? This is where the concept of **limiting requirements** is important.

To explain the concept of ‘limiting requirement’, it is easiest to consider the needs of a single species. The freshwater blackfish can be used as an example. The basic needs of this species are good water quality, instream cover in the form of woody debris or rocks, hollow woody debris to spawn in, and a supply of food (benthic macroinvertebrates). Imagine

Look for the limiting requirement

Although there may be many requirements contributing to a degraded stream environment, the **limiting requirement** is that resource which is essential to the stream community, but is most lacking from the environment.

a reach of stream that has fairly good water quality, a moderate food supply, but little woody debris for instream cover and spawning sites. In this case, it is the woody debris that is the limiting requirement (see Figure 29).

Any attempt to increase the blackfish population would first need to increase the habitat available. There would be little point in trying to improve other aspects of the stream, such as the water quality or food supply, when extra fish would not survive in the reach without more habitat (Figure 30). This highlights one of the most important rules for stream rehabilitation: where your objectives involve altering communities, or increasing populations of certain organisms, one of the first steps must be to identify and treat the limiting requirements. If you treat a non-limiting problem, the success of your project will still be restricted by the influence of the limiting requirement (Figure 30).

As always, the real situation is almost never as simple as in the blackfish example, for the reasons outlined below.

1. In many situations, the changes made to the environment since European settlement have had major effects on many aspects of the physical character, water quality and hydrology of our stream systems. The *Common Stream Problems* section in Volume Two discusses most of the more common effects of such changes. Where there are many problems in the stream, all impacting in different ways on stream animals and plants, it can be difficult to judge which is the most important. It is quite possible to have two or more equally limiting aspects of the stream.
2. The requirements of many species are not well understood. In the northern hemisphere, much of the stream rehabilitation is focused on trout and salmon. The requirements of these commercially valuable fish are known in great detail, down to the precise grain sizes of bed material for the most successful spawning, and the preferred radius of curvature for meander bends. This level of information is simply not available for Australian fish, frogs or platypus, let alone the less charismatic creatures such as invertebrates.

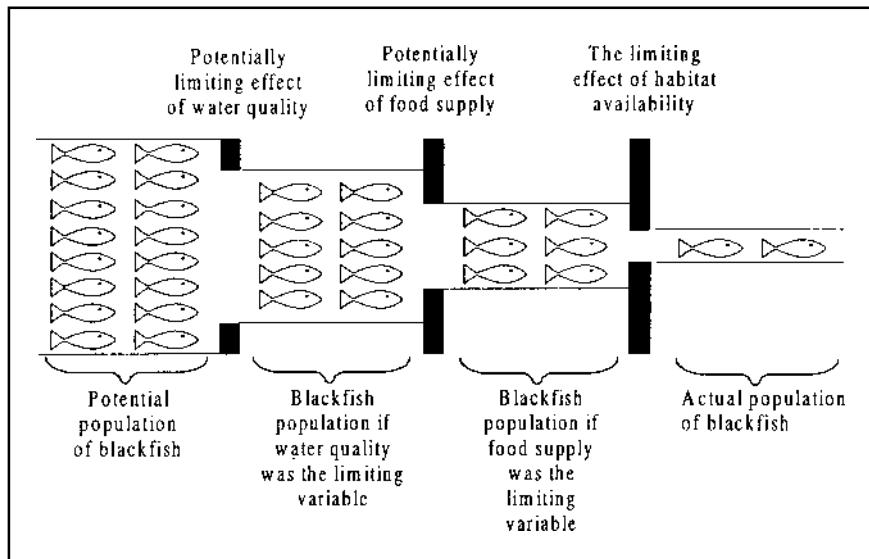


Figure 29. The effect of degraded habitat, water quality and food supply on a hypothetical population of blackfish. Though water quality and food supply could both be limiting requirements, they are overshadowed by the effects of the lack of instream habitat. Modified from Hicks and Reeves (1994).

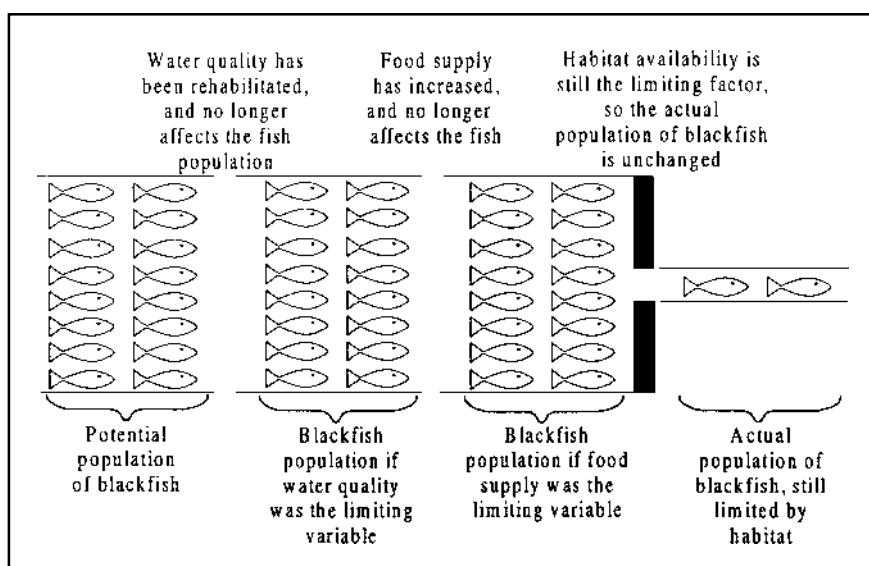


Figure 30. The importance of tackling the 'limiting requirement' first. Here, the water quality and food supply problems have been treated, but the limiting requirement, habitat availability, has been left unchanged. As a result, the population of blackfish has not increased. Modified from Hicks and Reeves (1994).

3. Important limiting requirements need not be continually present. The requirements of most species change through their life cycle. For example, as well as adult habitat requirements, many species of fish require a temperature or flow trigger for spawning, special spawning habitat, and another habitat for rearing larvae and juvenile fish. If one of these is missing at the critical time of year, it could drastically affect the success of reproduction. Requirements also change with the seasons. A lack of shade may not be important in winter, but in summer it can lead to high temperatures and low dissolved oxygen.
4. It is more common, and more environmentally sensible, to rehabilitate a stream for a group of animals, or indeed entire communities, rather than a single species. This means juggling the requirements of all the species involved, where they are known.

Most of the impacts outlined in the Mythic Creek example have the potential to limit the communities of fish and invertebrates. It is possible that several different impacts could have equally important effects. For example, high water temperatures in summer could cause fish kills, but a lack of habitat in the reach may mean almost no fish are present in summer to risk death. Working out which stress is the most limiting can be very difficult indeed. There is always the risk that some requirement you never thought to measure is the real cause of decline in the stream community. Step 5 of the Stream Rehabilitation Procedure (this volume), discusses the different techniques available for working out what your limiting requirements are.

A hypothetical example of human disturbance: Mythic Creek

Reach 4 of Mythic Creek (see Figure 13) is a typical channelised stream of SE Australia. The riparian zone is grazed and almost entirely cleared. Most large logs have been removed from the stream. Locals say there used to be deep pools, but if this is correct most of them have been filled by sediment from erosion in upstream reach 1b. There is also a piggery in reach 1b. What effects could these impacts have on the stream ecology?

Erosion of the tributary upstream (reach 1b) makes the hydrograph flashier, and introduces more sediment to reach 4. Channelisation and desnagging within the reach have altered the hydrology of the stream, so that out-of-bank flows are shorter and less frequent. This, combined with the loss of riparian vegetation, and deposition of fine sediment in the former gravel bed, has reduced the habitat available to

juvenile fish. Another effect is reduced leaf litter input to the stream. The desnagging has contributed to the reduction in habitat available to fish and macroinvertebrates. The loss of the deep pools has also reduced habitat complexity and means there are insufficient drought refuges available to fish during dry summers. The water quality in the reach is also compromised. The water is turbid, a result of upstream bank erosion, as well as cattle grazing in the riparian zone and using the stream as a watering point. There are high nutrient levels, another result of the cattle and of run-off from the piggery. These high nutrient levels have resulted in low levels of dissolved oxygen, which is compounded in summer by high water temperatures in the shallow, unshaded stream. Stress on fish in reach 4 is further exacerbated by the presence of a culvert downstream that makes migration difficult in all but the largest floods.

Recovery of disturbed stream systems in Australia

- 1. Introduction**
- 2. Equilibrium disturbance and complexity**
- 3. Is equilibrium enough?**
- 4. Geomorphic recovery**
- 5. Biological recovery**
- 6. Implications of recovery principles for stream rehabilitation**

1. Introduction

Stream rehabilitation is about the recovery of stream systems following disturbance. That disturbance could come from human impact (such as clearing, flow regulation, dredging, salinity, etc.) or from natural disturbances such as floods or droughts. In many situations, human disturbance has made streams more susceptible to natural disturbances such as floods. A stream manager needs to appreciate the following.

1. Natural disturbance is an important process in streams.
2. Human influence has added new disturbances and has increased the frequency and impact of many natural disturbances.
3. Severe disturbance will reduce complexity (which will in turn reduce ecological diversity).
4. After disturbance, streams will gradually recover complexity. Understanding this recovery path is a powerful tool for stream rehabilitation.
5. Once a disturbance has ceased, streams will gradually recover ‘equilibrium’. This new equilibrium condition may look quite different from the channel before the disturbance.

When you are planning your rehabilitation project, it is important to consider how recovery will proceed. Working with the natural recovery of a stream can lead to much cheaper and more efficient rehabilitation. Understanding recovery will help you to set reasonable objectives for your project—there is

no point aiming at doubling the fish population in two years if the natural rate of population growth means that such an increase would take at least five years.

In this section we describe the basic concepts of equilibrium and disturbance that underpin much of rehabilitation theory. We then discuss the main factors that control the recovery path of stream morphology and biology. Finally, we discuss how a stream manager can use principles of recovery to guide stream rehabilitation.

Natural recovery

A Landcare coordinator has spent long nights in the pub talking to the old-timers about what the local creek used to be like in the 1920s. She discovers that it was choked with snags, and had deep pools, gravel bars, and reed beds. After the floods and erosion of the 1950s much of this complexity disappeared, and you could drive a tractor along the bed of some parts of the stream. Although most of the news was bad, she was very excited to hear that since the 1970s the stream had gradually improved as some vegetation returned to the bed and some bars reformed. One farmer even believed that the pools were gradually getting deeper again. She wondered if they could do something to accelerate this natural recovery of the stream ...

2. Equilibrium, disturbance and complexity

2.1. Equilibrium

In a ‘stable’ stream, both the morphology of a reach (ie. its slope, cross-sectional size and shape, bed and bank material, pool-riffle spacing, and planform), and the organisms living in the reach (ie. populations and diversity) will be in equilibrium with the reach *inputs*. For

stream morphology, the ‘inputs’ are the amount and timing of sediment and water entering the reach (the flow regime). Averaged over time, water and sediment will move through the reach without causing major changes such as aggradation and degradation. For stream ecology, the inputs include water and sediment, but also many other inputs including water quality, energy and food inputs, and

the timing of inputs. This balance can be disturbed by a change in the inputs, or a change in the stream's ability to 'process' those inputs.

It is important to emphasise that a system in equilibrium is not totally inert. Only a fully concrete channel will never undergo any change. Even the most stable stream is constantly responding to small disturbances, although on average it will take on a characteristic form (Figure 31). This is known as *steady-state* equilibrium. For example, a small flood may deepen the channel slightly, and the sediment making up a mid-channel bar will change, although the basic form of the bar remains about the same. The macroinvertebrate community may drift downstream and be largely lost from the reach. However, the normal flows which follow the flood will deposit some sediment in the bed, returning the channel to the average depth. Similarly, the invertebrate community will be quickly replaced from refuges upstream and within the reach, and by breeding.

Steady-state equilibrium covers both seasonal variation (the invertebrates present in winter will naturally be different from summer communities) and year-to-year variation (caused by normal variation in climate). The concept of equilibrium implies a sufficient time to allow the passage of a whole range of flows that form the channel and the stream communities.

Streams are not always the simple equilibrium–disturbance–recovery systems that we present here. In fact, most scientists would instead emphasise the interesting and exciting non-equilibrium, chaotic and complex behaviour of streams. Thus, some streams can have multiple equilibrium states in response to the same inputs (Phillips 1991; Renwick 1992) while others may have no discernible 'stable' state.

Having said this, the notion that stream morphology and biology will return to some form of equilibrium following disturbance underpins most of this manual, and is usually an acceptable starting point for stream management.

2.2. Disturbance

Research over the last few decades has shown that much of the natural morphology and biology of our streams is a product of disturbance as much as equilibrium. It is possible that the frequency of disturbance is critical for the type of biota naturally living in a stream (Lake and Barmuta 1986; Poff and Ward 1990).

In every stream there are occasionally disturbances large enough to disturb the steady-state equilibrium, and change the character of the stream. In biological terms the disturbance is classified according to duration (see Lake and Barmuta 1986), and the same principles apply to geomorphic systems.

Two types of disturbance are:

- **pulse** events, with a short, discrete duration, such as floods; and
- **press** disturbances that may be steadily applied over a long period (eg. climatic change, catchment clearing, removing riparian vegetation).

An example of a pulse-type disturbance is the sudden *avulsion* of the stream channel from one position on the floodplain to another. Such channel changes were common in pre-European Australian streams, and the new channel would gradually develop over time until another avulsion

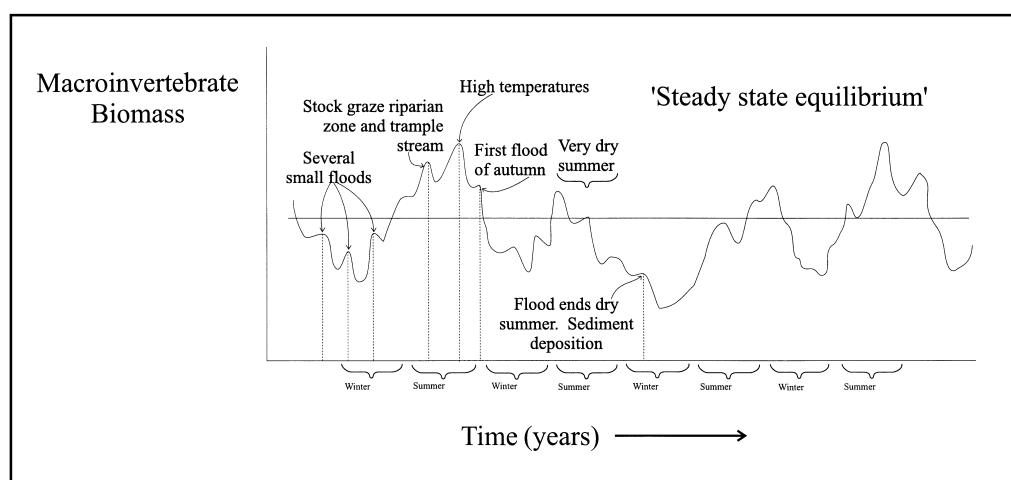


Figure 31. Steady state equilibrium in a stream variable (note that this state is sometimes wrongly called 'dynamic equilibrium', which more correctly refers to oscillations around a gradually changing condition eg. a gradual change in width with a gradual climate change).

occurred. A change in climate would be a natural press-type disturbance. Many pressures on streams can sit between pulse and press types. An example would be a long-term increase in flood magnitude (presses coming from many pulses), or sand and gravel extraction.

Human activity increases the magnitude of natural *pulse*-type disturbances (eg. increased flood frequency, increased impact of drought by pumping from channels) as well as introducing many *press*-type disturbances (eg. increased sediment loads, grazing, salinity, and clearing of catchment vegetation leading to changes in hydrology). This can result in an equilibrium with much greater variability than was naturally present (Figure 32), or a greater frequency of major disturbance events.

How does a stream respond to major disturbance? While a great deal has been written on the theory of this topic, here we will discuss a simple response to press and pulse disturbances.

Response to a pulse disturbance, followed by recovery

When a major pulse disturbance occurs, the stream will have an immediate response, followed by a gradual recovery phase and finally a return to steady-state equilibrium (see Figure 33). For example, a toxic chemical spill will create a pulse of pollution, decimating the fish and invertebrate populations downstream. Once the toxic pulse has passed, animals will recolonise the affected reach, gradually building up populations to something resembling the original levels.

There are two points to make on this disturbance response.

- Firstly, the stream may not return to the original equilibrium condition, but find a new, steady state (B on Figure 33). For example, the fish population may have been dominated by silver perch before the disturbance, but because, by chance, more yellowbelly colonised the reach, they are now the dominant fish.

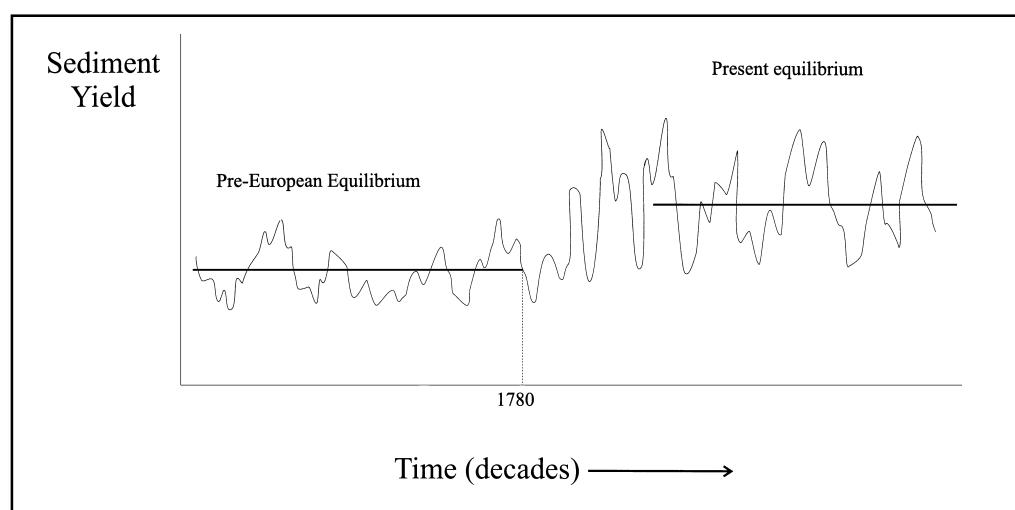


Figure 32. An equilibrium state showing greater variability since European settlement.

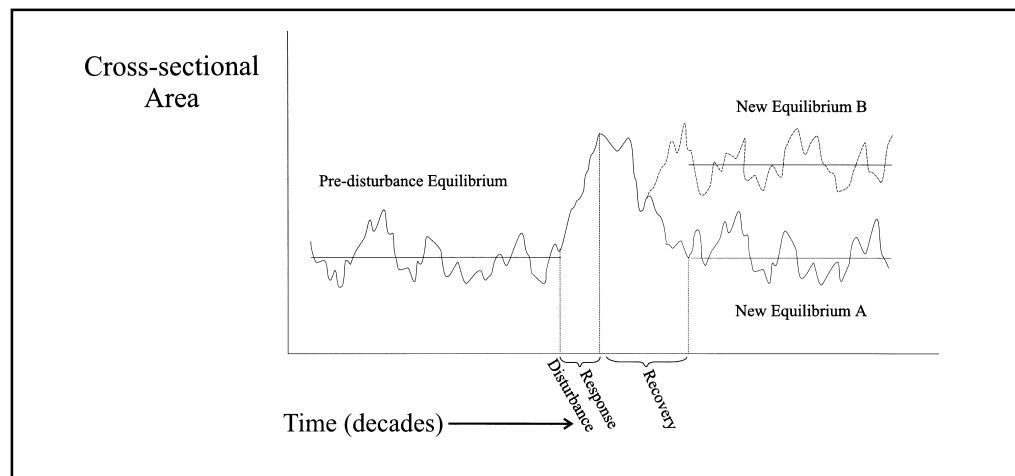


Figure 33. Recovery from a pulse disturbance, to an equilibrium resembling pre-disturbance (A) and a new equilibrium (B).

2. Secondly, quite a small initial disturbance can be sufficient to cause a major response from the stream. This occurs when a disturbance pushes a stream past some intrinsic threshold for major change. A classic example of a threshold response to disturbance is the catastrophic erosion of small vegetated streams in SE Australia following channelisation (see Bird 1985). The construction of small drains led to massive deepening and widening of the channel (up to tens of metres). It is important to realise that threshold exceedance can happen quite naturally, even without external changes.

Response to a press disturbance—achieving a new equilibrium

If the average inputs to the stream are changed for a long period the stream will adjust to be in equilibrium with those inputs. For example, if the annual flood increases in size, this will eventually lead to a commensurately larger channel, with all of the morphological variables adjusting in concert with the size. Thus, a new equilibrium develops. In this case, the ‘recovery’ actually refers to the period of change from the old equilibrium state to the new (Figure 34). If the press disturbance was removed, there would follow another period of recovery, as the stream adapted to the reversion to the old conditions.

2.3. Recovery pathways

‘Recovery path’ refers to the stages that a stream will go through as part of the recovery (Figure 35). The incision of small streams (described earlier) provides a good example of a recovery path. Following incision, the new channel is a bare rectangular trench with very little geomorphic complexity, carrying very flashy flows, and with little biological value.

As the rate of deepening slows, the channel widens and begins to meander. Over time, new bedforms (eg. riffles) are deposited, and a new floodplain is gradually formed within the incised trench (Figures 35–37). This may take decades to develop. At this stage, the channel has reached a steady-state equilibrium, with considerably greater habitat complexity than the original incised trench. Eventually, the stream will fill the trench with sediment and return it to its original form.

Being able to predict the recovery path is a very powerful tool for stream management. It allows you to speed natural recovery, by pre-empting critical stages. In the example in Figure 37, artificially stabilising the bed (say with rock chutes) would mean that the widening phase could begin perhaps decades earlier than otherwise, leading to a faster recovery. This is discussed later, in *Implications of recovery principles for stream rehabilitation* (page 56).

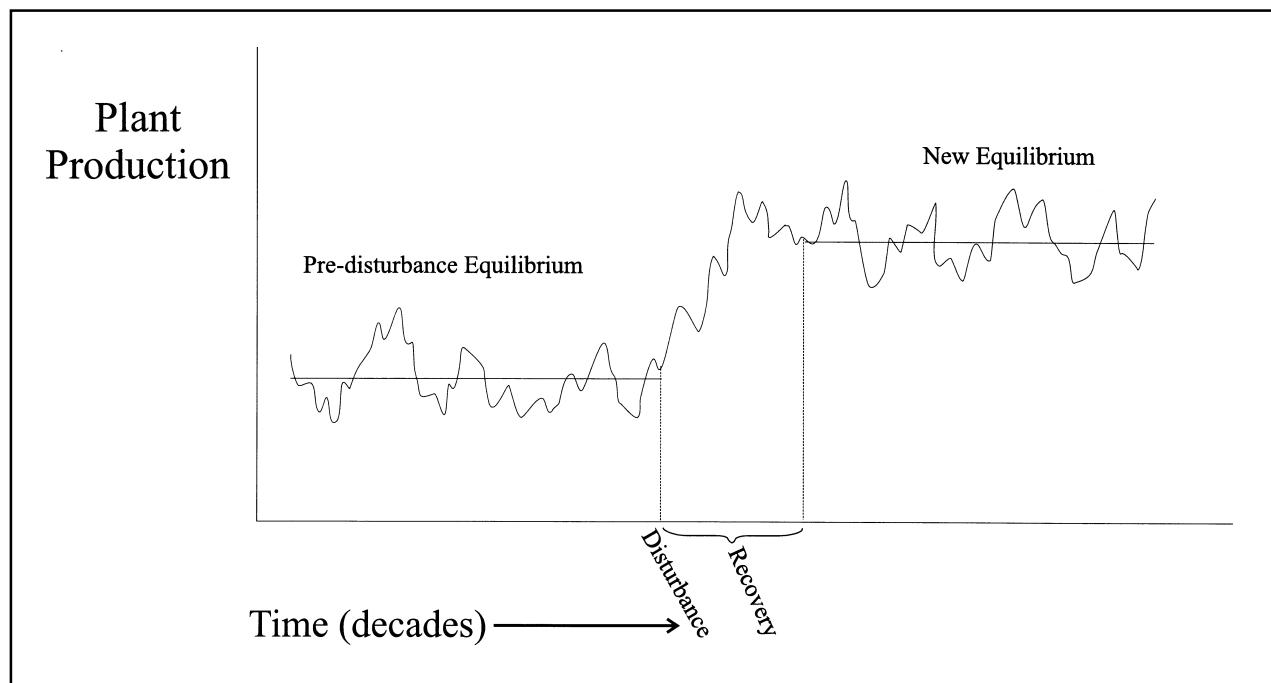


Figure 34. New equilibrium developed in response to a press disturbance.

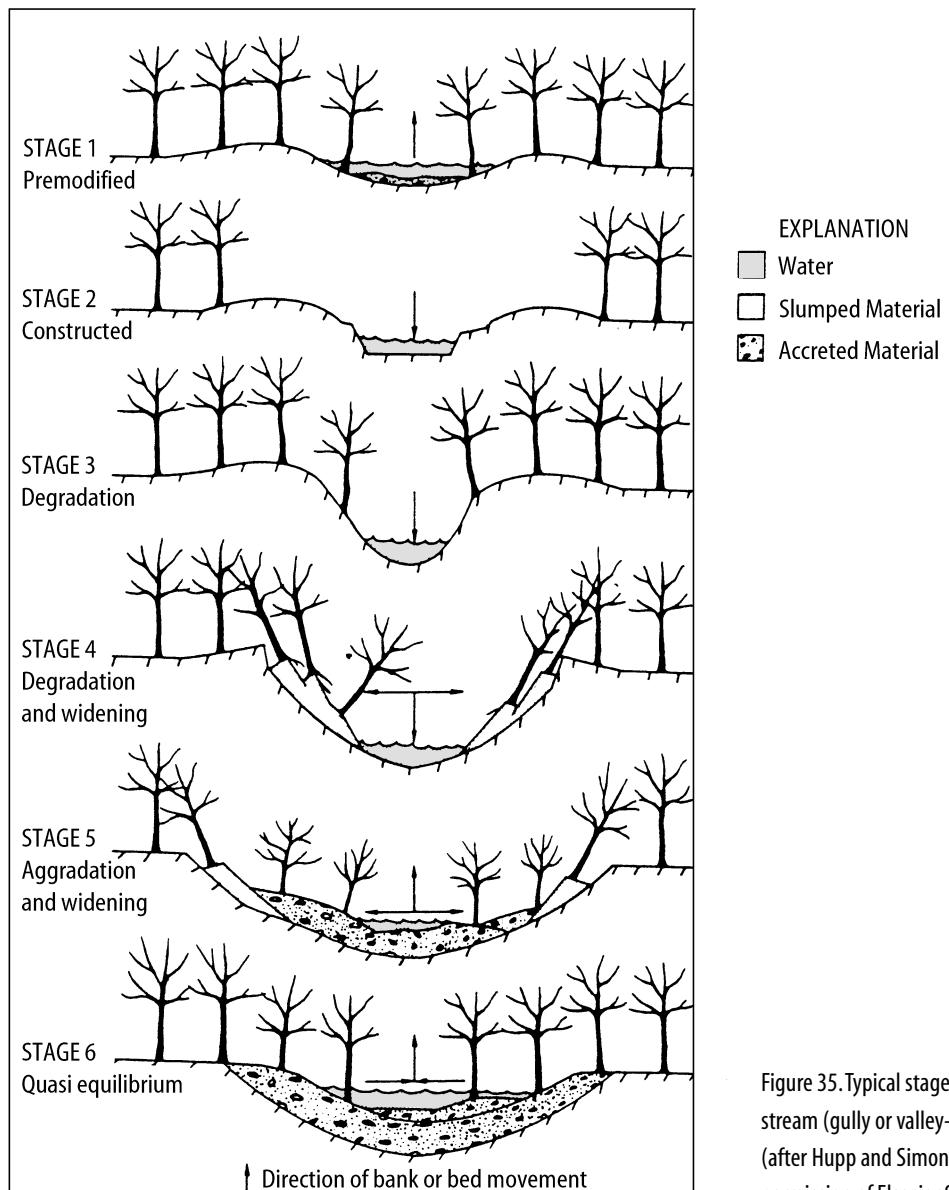


Figure 35. Typical stages of recovery in an incised stream (gully or valley-floor incised stream) (after Hupp and Simon 1991). Reproduced by permission of Elsevier Science.



Figure 36. An incised stream (Flynn's Creek, a tributary to the Latrobe River, Gippsland, Vic.), with a stable bed, that is now developing laterally.



Figure 37. The Soil Conservation Authority in Victoria diverted flow out of this gully about 20 years ago. The bed and banks have stabilised, and vegetation has invaded the channel, producing a much improved habitat.

3. Is equilibrium enough?

So far we have talked about recovery of reach morphology and biology in terms of regaining an equilibrium. But is this the same as a healthy, rehabilitated stream?

Unfortunately, although steady-state equilibrium is a good start, and often a prerequisite for further improvement, it is possible for a degraded stream to have a ‘stable’ channel and biological community. Many rural streams are in this condition (Figure 38). Although such streams are often quite stable, they have been affected by changes to hydrology, clearing and grazing in the riparian zone, often channel incision and bad water quality, and are thus limited in the habitat they offer and the communities they support. Table 22 outlines the characteristics of a stream which has not only recovered from disturbance, but is also in good condition geomorphically and biologically.

Figure 38. A typical degraded but stable rural stream (tributary to the Goulburn River, NE Vic.).



Table 2. The characteristics of streams in good geomorphic and ecological condition. Note that, as well as good geomorphic conditions, appropriate water quality and quantity are important for a diverse biological community.

	Geomorphic condition	Ecological condition
Equilibrium	Rate of channel change is acceptable (ie. the stream is no longer eroding and depositing at an ‘unusual’ rate).	The community structure is fairly stable, taking into account natural seasonal changes. Species diversity is a good measure of this.
Complexity	Presence of appropriate geomorphic complexity, providing sufficient habitat diversity to support the biological community	Species diversity should be similar to natural levels for the stream in question. This should include those species which are sensitive to degradation.
Relationship with floodplain	A natural flooding regime is important for nutrient cycling, and for access to habitats such as billabongs and the inundated floodplain itself.	Presence of riparian vegetation to nutrient inputs to the stream and habitat for aerial stages of stream insects. Access to floodplain habitat (billabongs and inundated vegetation) which can be important for life cycles of fish.

Many of the stream rehabilitation goals that managers have will relate to these three points: stabilising streams, improving geomorphic complexity, and restoring a ‘natural’ flood regime.

In the rest of this chapter we will discuss what determines how long physical and biological systems will take to recover.

4. Geomorphic recovery

The path followed by a stream while recovering from disturbance depends on which elements of the stream have been affected. Disturbances are usually reflected in changes to the following elements of the stream:

- the rate of erosion and sedimentation;
- the particle size of sediment carried on the bed and in suspension;
- the size of the channel (erosion or deposition);
- the shape of the cross-section (eg. may become deeper, or wider and shallower); and
- the planform of the channel (for example, sinuosity).

Different elements of a stream will recover at different rates. This is illustrated by the example above of the recovery path following stream incision (Figure 35). The bed stabilises first, followed by the channel width as the banks stabilise and a meandering channel forms. Eventually the stream will develop a pool–riffle bed morphology, and a new floodplain will form within the trench. This may take decades. Over 100s to 1,000s of years, the stream will gradually fill the trench with

sediment and return it to its original form. Figure 39 shows an example of a channelised stream in the USA that is gradually developing its sinuosity (ie. it is remeandering) as it recovers.

Recovery rates are discussed in more detail in the stream problem type section, but are summarised here (Table 3). It is important to note that it almost always takes much longer for a stream to recover than it does to be disturbed! Gully erosion and major channel changes often occur rapidly in a series of large floods. It will then take decades of lower flows for them to recover their original form, if they ever do. Similarly, it can take only days to artificially remove riparian vegetation or large woody debris. It will take decades or centuries to naturally restore them.

4.1. Variables that limit the rate of geomorphic recovery

The rate at which stream morphology recovers after disturbance often depends on four related factors: the *power* of the stream, *sediment supply*, the frequency of *large floods*, and *riparian vegetation* (assuming that other disturbances have been removed).

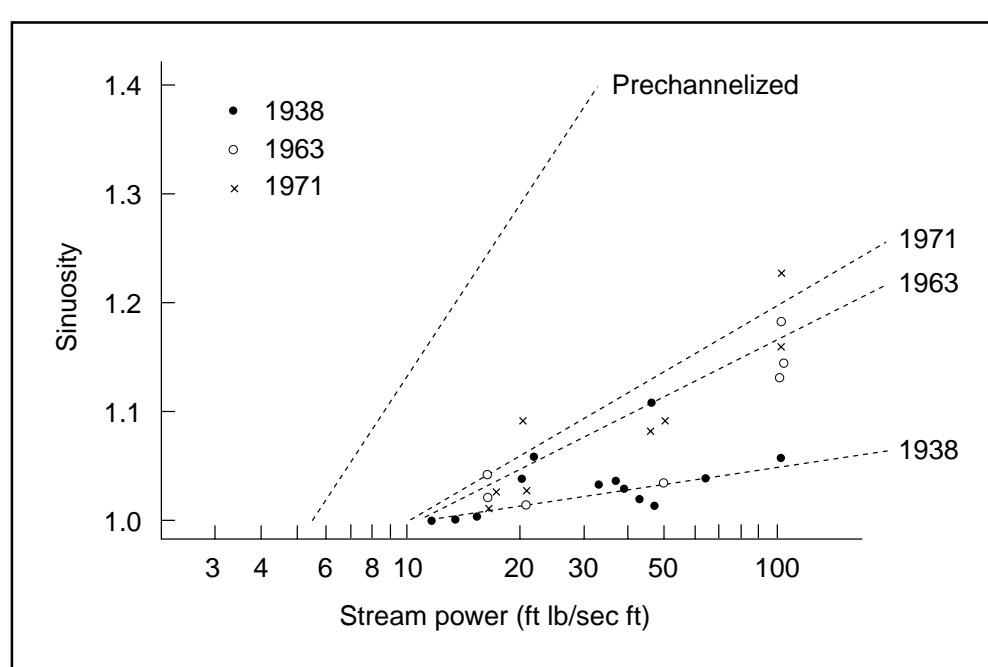


Figure 39. An example of the rate at which an artificially straightened stream recovered some of its sinuosity. Big Pine Creek Ditch was channelised in 1932 and has been gradually resuming a meandering form. Extrapolating the rate of sinuosity increase suggests that it will take 165 years for the stream to 'recover' its original sinuosity (Barnard and Melhorn 1981). Reproduced by permission of Allen & Unwin.

Table 3. Estimated recovery times of various elements of the geomorphology, riparian vegetation, and biology of Australian streams assuming that press and pulse disturbances have declined.

Variable	Recovery time in headwaters	Recovery time in lowland streams
Geomorphology		
Sinuosity in channelised stream	10–50 years	50–100 years
Bars, benches	10–50 years	10–50 years
Sediment slugs (time to move through)	5–10 years	50–100 years
Pool–riffle sequence	5–20 years	–
Riparian zone		
Riparian vegetation	10–50 years	10–50 years
Macrophytes in the channel	–	1–5 years
Large woody debris in the channel	50–100 years	100–200 years

a) The power of the stream—Stream power is a product of channel slope and discharge. It represents the excess energy that is available to do work in the channel (Rhoads 1987). Recovery usually involves a balance of deposition and erosion in the right places. If the stream is too powerful, then the sediment required for recovery is transported right through the reach. If the stream has too little power, then there is insufficient transport of sediment, and erosion of bed and banks to facilitate recovery. This point was made by Brookes (1987) who found that channelised streams with stream powers per unit width greater than 35 W/m^2 developed their own sinuosity over time (Figure 40). Streams with less power did not recover their sinuosity and had to be artificially re-meandered.

a) Sediment availability—Natural recovery often requires the right sort of sediment in the correct amounts. For example, some highly eroded streams require deposition of point bars and benches for the stream to recover. In other streams, natural riffles will form only from coarse sediment. Where will this sediment come from? In yet other streams the deposited substrate is so infertile (eg. sand and gravel) that it cannot be recolonised by vegetation. The fine suspended fraction of sediment has to be trapped somehow to encourage growth. Thus, the rate of recovery often depends upon the rate at which sediment of a particular size is supplied, and the rate at which it is deposited.

b) Frequency of flows of various sizes. The rate of recovery of streams depends upon the range of flows

that they carry. Often the most important flows are the moderate sized floods. For example, many years of low flows will do little to build bars and benches, or remove sediment slugs, while too many large floods will continue to destabilise the channel. Furthermore, many disturbed streams are more susceptible to channel instability than they were before human impact. This is because banks are not protected by vegetation, the bed is not protected by a framework of large woody debris (LWD), and more water is often contained within deepened channels (ie. greater stream power). As a result, floods become more ‘geomorphologically effective’ and do more damage. This means that years of recovery can be reversed by a single large flood and so recovery is delayed.

c) Recovery of riparian and inchannel vegetation.

Although vegetation recovery is a biological variable, the long-term rehabilitation of streams almost always relies on the recovery of associated vegetation in the channel (reeds etc.) and in the riparian zone. Vegetation stabilises sediment in the channel (eg. bars, benches, and banks).

The importance of these factors will vary along a single stream (with rates of recovery usually fastest in the high-energy upper reaches, and decreasing downstream). Climate is also important, because of its influence on stream flow and riparian vegetation. In the wet tropics, riparian vegetation can grow to a closed canopy in less than ten years, whereas the canopy will never close in the semi-arid zone.

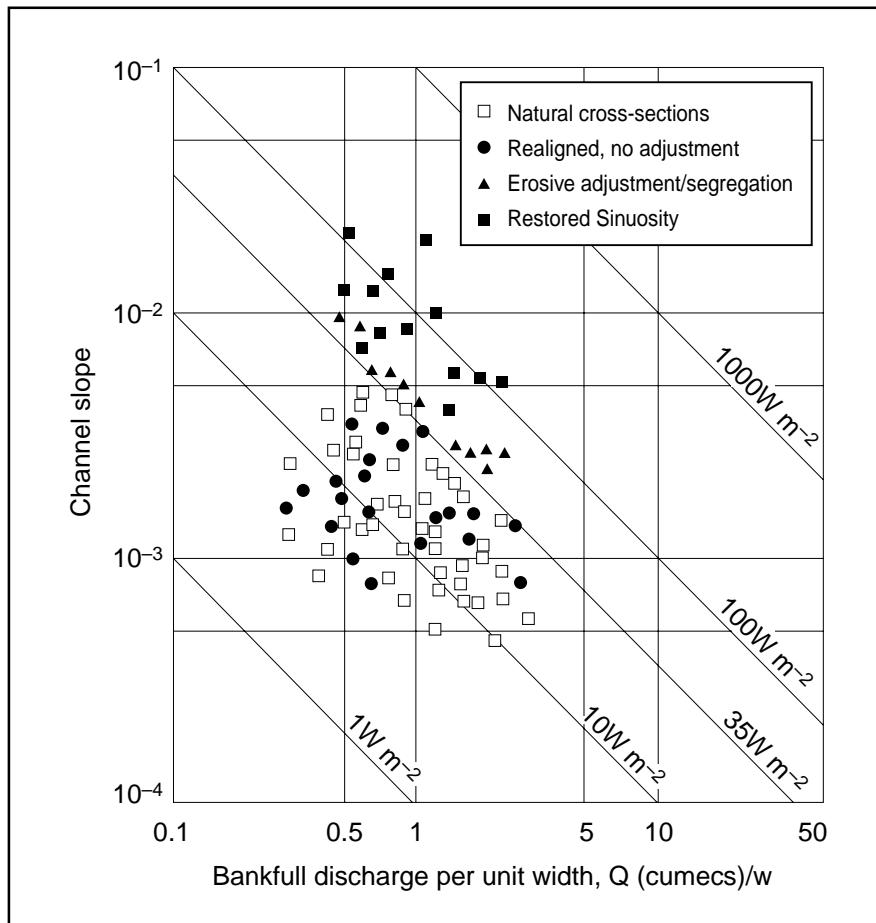


Figure 40. Streams with more power recover faster, while those with less power are unlikely to recover in the medium term. This figure shows that channelised streams with stream power less than 35 watts/m² in Denmark recover their sinuosity while those with less power did not (Brookes 1987). Reproduced by permission of John Wiley & Sons.

Having an understanding of the role these factors play in limiting the rate of recovery can be very useful to a stream manager. In some cases, it may be possible to speed the recovery of a disturbed stream with very little effort, by identifying and treating the limiting factor. For example, consider a stream that has eroded both banks and widened, to become a flat sheet of water with little habitat value. Removing stock access could be sufficient to allow regrowth of reed beds on the stream margins, which may then trap and stabilise sediment, allowing stable benches to form. To create such benches artificially would be a costly process requiring heavy earthmoving machinery and the construction of instream structures.

By treating limiting factors, you can speed the natural recovery of the stream. This is often much cheaper and more efficient than artificially reconstructing the channel.

5. Biological recovery

5.1. What controls the biological recovery of streams?

The rate of recovery of a population or community of stream animals and plants depends on four factors.

- 1. The presence of appropriate environmental conditions in the project area.** This includes the physical habitat that your rehabilitation project has set out to create or improve, as well as water quality and the state of the food web. This will determine the carrying capacity of your reach—the potential population it can sustain.
- 2. A source of animals or plants to recolonise the area.** This source may be small populations within the reach, from up or down stream, or it may be from different catchments, depending on the animal or plant in question. This relies on there being no insurmountable barrier between the source and your reach.
- 3. The rate of population growth.** This will determine how quickly the recolonising individuals will build up the population to the carrying capacity of the reach. This depends on the rate at which colonising individuals arrive, and how quickly they reproduce.
- 4. The nature of the disturbance.** The rate of recovery will also depend on the disturbance that the stream is recovering from, whether it was pulse or press, the intensity of disturbance and the history of disturbance in the area.

5.1.1. The presence of appropriate environmental conditions in the project area

It is easiest to talk about recovery in an ideal sense, where you have removed all influences that are detrimental to stream health, leaving the perfect stream open for plants and animals to recolonise. However, it is very seldom, if ever, that this will be the case, so pragmatically, we must discuss how an incompletely restored stream can affect recovery. Firstly, and rather obviously, while your rehabilitation project may have tackled the worst problem present, there will probably still be others, like water quality, or food sources, which will continue to limit your

target species and prevent the population from reaching its full potential. Secondly, some limiting factors will affect not only the completeness of recovery, but also the rate. Animals and plants under stress tend to develop more slowly. An incomplete recovery can also limit the rate of reproduction, because there will be other limiting variables. For example, adult Murray cod live under and around woody debris and are solitary and territorial. In a desnagged stream where adult habitat is limiting, tripling the amount of LWD could triple the potential cod population. However, it might also be that food supply could limit the population to only twice the original. If there was also limited habitat for the juvenile fish, then any increase in the population would occur slowly.

Before we move on to how long the different groups of organisms take to recover from disturbance, it is worth noting that the ‘appropriate environment’ will usually mean more than the physical arrangement of stream beds and banks. It also includes the stream biology. This point harks back to the food web described in the Aquatic Ecology section. Before any animal can survive in a reach, it needs a food source, whether that be algae, riparian leaf litter, macroinvertebrates or fish.

5.1.2. A source of animals or plants to colonise your reach

Once you have provided suitable conditions for biological recovery, desirable animals and plants have to somehow get to your reach. The three questions to ask yourself about this are:

- is there a source of the animals and plants you want to recolonise this area?
- by what methods can they travel from the source to the rehabilitated area?
- are there any barriers to that dispersal?

Animals and plants can be sourced from anywhere they are found. This can be in refuges in the rehabilitated reach itself, upstream or downstream reaches, or even nearby catchments. The closer this source is to your rehabilitation site the better—individuals are more likely to find the site

quickly. Also, even within one species, there can be a great deal of variation and adaptation to local conditions, so if possible, you should tap into a local source of animals and plants to increase your chance of success.

How will seeds or individual animals actually get from the source to the rehabilitated reach? Dispersal methods will vary between organisms. A fish, obviously, must come from up or down stream, but an adult dragonfly could come from a different catchment altogether. The options available are instream (drifting downstream with the current, swimming or crawling up or downstream), and terrestrial (flying up or downstream, or between catchments, or drifting on wind currents).

There is a variety of possible barriers to dispersal. The most commonly recognised are the instream barriers to upstream movement posed by dams, weirs, road crossings, and in fact anything which creates a waterfall or area of shallow fast flow (*Barriers to fish passage, Volume 2*). Other barriers to both instream and terrestrial movement are less discrete. A reach in very bad condition can form an effective barrier to instream dispersal, either because animals are reluctant to enter, or because water quality is so bad that animals and plants are killed on the way through. Distance in itself can be a barrier. Different species are capable of travelling greater or lesser distances. River blackfish, for example, have a home range of about 30 m (Koehn and O'Connor 1990). If the nearest population was even a few kilometres up or downstream, fish would be unlikely to find a rehabilitated reach. Distance is particularly a problem when there is a lack of suitable habitat between the source and rehabilitation reach. For example, the adults of aquatic insects are terrestrial, and disperse by flight. However, in catchments where the adult habitat (riparian and floodplain vegetation) is fragmented by clearing, dispersal by flight seems to be reduced.

5.1.3. Rate of population growth (immigration and reproduction)

The rate of population growth can be an important factor in the recovery of stream communities. How important it is depends on the number of individual animals or plant seeds that arrive and colonise the new habitat. A disturbed area will 'recover', at least in terms of density, in the time it takes for enough individuals to arrive so that the population is similar to undisturbed areas. For example, some macroinvertebrates are efficient colonisers of small disturbed areas. This is partly due to

their mobility (aerial dispersal and downstream drift), but also to the large numbers of invertebrates in the stream overall. A small disturbed area will be swamped with colonising individuals.

In contrast, where individuals arrive and colonise a rehabilitated area only slowly, then the rate of successful reproduction of those individuals that are present becomes very important to the time taken for recovery. This situation may occur with some fish species. Fish are not found in high densities like macroinvertebrates, so there are fewer available to colonise a new area. In addition, some fish have distinct home ranges, so are unlikely to find new habitat. In this case, the number of successful offspring each new coloniser produces, and how often, can have an effect on the overall rate of population growth in the rehabilitated area.

Overall, the rate of population growth in a newly rehabilitated reach will depend on:

- the number of potential colonisers available (can immigration fully populate the reach?);
- the mobility of those colonisers (how likely are they to find the reach?); and
- where the number of potential colonisers is small, or they are not likely to find the reach, then colonisation will be slow. In this case, the rate of reproduction of those individuals that do find the reach becomes important.

5.1.4. The nature of the disturbance

The nature of the disturbance is an important control on biological recovery, because of its influence on the previous three factors. The timing of the disturbance can affect recovery. For example, recovery may be slower if a disturbance occurs just before winter, when the animals are relatively dormant. Also, the spatial extent and intensity of the disturbance will affect the source of colonists. The intensity will affect how many animals are lost from the reach, and whether there are any refuges present that can act as a germ of recolonisation. The spatial extent will determine the distance to the nearest untouched communities, which will also be a major source of colonists. Table 4 outlines the sort of recovery times you may expect from different types of disturbance.

Table 4. The influence of the type of disturbance on recovery times for stream ecosystems. (Derived from Niemi *et al.* 1990 and Gore 1990.)

Type of disturbance	Examples of disturbance	Typical effects of disturbance	Recovery time
Pulse	<ul style="list-style-type: none"> • Construction in the stream. • Moderate flood. 	Reduces species abundance and diversity, but there is still some community present (ie. the food web is more or less intact).	Less than 1 year
Pulse	<ul style="list-style-type: none"> • Chemical spills affecting a single reach. 	Completely destroys communities, but only one reach affected. Up and downstream sources of colonists.	Less than 2 years
Press	<ul style="list-style-type: none"> • Geomorphic disturbance of one reach, such as limited channelisation. 	Ecologically, similar to above, but habitat is degraded and simplified. Habitat must recover before the stream ecosystem can.	Depends on the rate of geomorphic recovery (decades). Ecological recovery will probably be fast in comparison.
Pulse/press	<ul style="list-style-type: none"> • A very widespread pulse, such as a severe flood through an entire large catchment, poisoning of an entire stream. • Widespread and long-term press, such as occurs in rural areas as a result of changes such as clearing, grazing, decreased water quality, desnagging, etc. 	Stream fauna is depauperate through a very large length of stream. No refuges or other sources of colonists within the stream system. This will be the case for many rehabilitation projects which improve a reach in the middle of a widely degraded stream system.	The more mobile species (insects with aerial stages) will return in around 5 years. Less mobile species will return slowly—may take more than 25 years. Some may never return.

The message from Table 4 is that biological recovery can be relatively fast, unless:

1. It relies on development of physical complexity, which is itself a slow process (see Table 3). Estimated recovery times of various elements of the geomorphology, riparian vegetation, and biology of Australian streams assuming that press and pulse disturbances have declined. Generally, rehabilitation projects are designed to speed the recovery of physical complexity.
2. Colonising organisms must travel great distances to reach the rehabilitated site. Although it is possible to translocate individual animals into a rehabilitated reach, this is fraught with problems (such as accidentally introducing disease or feral species). It is far better to start from a biologically good area, and rehabilitate outwards, than try to create a small island of rehabilitation in the middle of a degraded river.

6. Implications of recovery principles for stream rehabilitation

A major aim of rehabilitation is to establish a stream that is as similar as possible to the original, pre-European stream. Failing this, the aim is to provide appropriate habitat complexity, stability, and resources for the community of organisms that live in the stream. An understanding of disturbance and recovery can aid this quest in several ways. Firstly, it introduces a note of caution. Major disturbance does occur naturally. It is quite possible that some streams were not actually stable at the time of European settlement, but were in the process of recovering from some disturbance, such as a catastrophic flood. Similarly, many disturbances to streams over the last 200 years could have occurred naturally. In this case, the original stream may not be a sensible goal for a rehabilitation project.

Secondly, understanding how your stream is likely to recover from disturbance means you can ‘work with the stream, and not against it’. For disturbances where the recovery is well understood, you should be able to work out:

- what stages your stream will go through (the recovery path);
- roughly how long it will take to get through each stage;
- what may be limiting, or slowing the recovery; and
- what are likely to be the limiting requirements for organisms living in the stream (eg. where will they come from?).

This knowledge provides a basis for deciding whether to intervene in the system or not. Generally, you will be able to choose among the following options.

Option 1. Allow the stream to recover at its natural rate (management then is to control any *new* disturbances that could jeopardise that recovery).

Option 2. Accelerate the natural recovery by controlling factors that would *limit* or *impede* the natural recovery of the channel.

Option 3. Artificially accelerate the recovery of the stream by predicting the recovered condition, and creating this artificially.

Option 4. Decide that there is little hope of the channel ever recovering naturally, so artificially create a better channel.

Option 5. Decide that there is little hope of the channel ever recovering without a huge rehabilitation effort, so decide to spend your rehabilitation effort on a reach that will offer greater rewards.

6.1. An example: the recovery of Black Range Creek

Black Range Creek is a small tributary of the King River in Victoria. In a record flood in 1993 the middle reaches of the stream (where it first entered a broad floodplain) were dramatically eroded. Many hectares of land were eroded as the stream widened from about 30 m to over 100 m in places (Figure 41). The sand and gravel released by the erosion was deposited on the floodplain downstream and in the channel, from where it is passing into the King River as a slug. The event has had a dramatic impact on the instream biology, by replacing a narrow deep, pool-riffle channel in which native fish were common, with a wide, shallow sheet of water over a gravel bed with few organisms (see Figure 42). The major organism was algae because water temperatures were high in the shallow creek.

The erosion in Black Range Creek is an example of a semi-natural pulse disturbance leading to a press disturbance as the slug of sediment moves gradually through the stream system. Given this situation, the stream manager now makes some crude predictions of the response functions of various elements of this system, using these as a guide to managing the rehabilitation of the system. Importantly, there is very good potential for recovery of organisms in the creek because the catchment remains forested, providing an upstream source of macroinvertebrates, vegetation, and fish. The King River, downstream would also provide a source of fish to the creek. For this reason, the manager would probably decide that habitat was the limiting biological variable. The manager would also probably work progressively down from the upstream end of the reach.

The variables controlling recovery of the stream are summarised in Table 5.



Figure 41. Black Range Creek in 1991 before the flood (left), and immediately after the flood (right) in 1994. Note the dramatic widening and deposition of sand downstream (photographs used with permission of Victorian Department of Natural Resources).



Figure 42. A widened section of Black Range Creek.

Table 5. Variables controlling recovery of Black Range Creek.

Limiting biological problem	Recovery type	Natural recovery time	Options to accelerate recovery
The dominance of sand substrate provides poor habitat.	Sediment yields from the catchment will be increased as a result of the flood, but these will gradually decline over time.	1–5 years	Manage road crossings.
	Sand slug will progressively move through the system.	5–10 years	Commercial extraction? Remove slug in 3 years. Stabilise in-channel stores of sediment = reduce sediment yield to slug and halve its life.
The water is too shallow and warm for most organisms.	Vegetation will invade bed and shade the channel. Low flow bed will gradually narrow and form pools and riffles as the slug passes through and bars vegetate.	5–10 years	Fence stream and restrict cattle access to allow regeneration of vegetation. Artificial constriction of channel = new channel formed in 3–5 years.

A key factor here is that the recovery of the system is compromised by the continuing ‘press’ disturbance of grazing which limits riparian vegetation and stabilisation of the bars of sediment in the channel.

The manager decides that the natural rate of recovery (including with grazing) is too slow, and that the system is also vulnerable to more erosion in its damaged state. He decides to accelerate recovery by:

1. fencing the frontage and keeping stock out of the channel (there is a good seed source upstream for natural regeneration of plants);
2. encouraging commercial extraction of the sand slug in the lower channel; and

3. building permeable retard structures on the large bars to encourage deposition and to train the stream into a narrow channel.

6.2. Options for stream managers to design a recovery project

This example demonstrates how decisions about stream rehabilitation must be taken in *relation* to the potential of the system to recover from disturbance. The options and examples of activities are summarised in Table 6.

Table 6. Options in designing a stream recovery project.

Option	Example from Black Range Creek
1. Allow the stream to recover at its natural rate.	The manager would control any road works in the catchment that would increase the sediment load to the stream.
2. Accelerate the natural recovery by controlling limiting factors.	The most important of these would be to reduce grazing in the channel that constrains natural revegetation of the banks and sediment bars.
3. Artificially accelerate the recovery of the stream.	Artificial extraction of sand slugs, or artificially forcing the stream into a narrow channel. Other examples would be to add gravel to already developing natural riffles.
4. Artificially create a better channel, as there is little hope of natural recovery.	Build artificial riffles, or a meandering channel.
5. Decide there is little hope of recovery, and spend rehabilitation effort elsewhere.	Repair bridge and infrastructure, but let the rest of the stream repair itself at its own rate.

Conclusions and bibliography

Conclusions

This brings us to the end of the section dealing with basic principles of stream rehabilitation. At this stage you should be able to answer the questions below before moving to the procedure part of the manual. We assume that you are responsible for a particular stream in answering these questions.

A quiz for stream rehabilitators

1. What is the difference between restoration, rehabilitation, and remediation? What is the best that you could aim for in your stream?
2. What is the main reason for managing the streams that you are associated with (see Figure 10)? What is the scope for introducing ecological goals into your current practice?
3. Do you have a favourite animal in your stream (eg. platypus, perch, Plecoptera (stone flies), pelicans or plankton)? If you do, do you know where it sits in the food web? What are the key resources it needs to survive, such as habitat? Do you know anything about its life-cycle? How does this species disperse through the stream system, and what could be limiting its dispersal?
4. In general, how would you summarise the impact of humans on streams over the last 200 years?
5. Is your stream in physical and biological equilibrium?
6. Can you see any evidence of recovery in your streams over the last few years? What do you think your stream will look like in 10 years if you do nothing? What about in 100 years?
7. Are there any parts of your stream network that are in particularly good condition and worthy of preservation?

Congratulations! You now have your Level 1 Rehabilitator's Certificate. All you need to do before moving on to the Procedure part of the manual is look again at the six basic principles of stream rehabilitation straight after the introduction.

Bibliography

- Anderson, J., 1993. *State of the Rivers: Maroochy River and Tributary Streams*. Maroochy Shire Council & Department of Primary Industries, Maroochy, QLD.
- Barnard, R.S. and W.N. Melhorn, 1981. Morphologic and morphometric response to channelization: The case history of Big Pine Creek Ditch, Benton County, Indiana. In R.G. Craig and J.L. Craft (eds.), *Applied Geomorphology*. Allen & Unwin, London, pp. 224–39.
- Beamish, F.W.H., 1966. Swimming endurance of some Northwest Atlantic Fishes. *Journal of the Fisheries Research Board of Canada*, 23(3): 341–7.
- Bird, J.F., 1985. Review of channel changes along creeks in the northern part of the Latrobe River basin, Gippsland Victoria, Australia. *Zeitschrift für Geomorphologie*, 55: 97–111.
- Bradshaw, A.D., 1996. Underlying principles of restoration. *Canadian Journal of Fisheries and Aquatic Sciences*, 53 (Suppl. 1): 3–9.
- Brookes, A., 1987. The distribution and management of channelized streams in Denmark. *Regulated Rivers*, 1: 3–16.
- Brussock, P.P., A.V. Brown and J.C. Dixon, 1985. Channel form and stream ecosystem models. *Water Resources Bulletin*, 21(5): 859–66.
- Crabb, P., 1997. *Murray–Darling Basin Resources*. Murray Darling Basin Commission, Canberra.
- Gore, J.A., 1990. Island biogeographical theory: can it be used to predict lotic recovery rates? *Environmental Management*, 14(5): 737–53.
- Harris, J.H. and P.C. Gehrke, 1997. *Fish and rivers in stress, The NSW Rivers Survey*. NSW Fisheries Office of Conservation, and Cooperative Research Centre for Freshwater Ecology, Cronulla.
- Harris, J.H., 1984. Impoundment of coastal drainages of south-eastern Australia, and a review of its relevance to fish migration. *Australian Zoologist*, 21: 235–50.
- Hicks, B.J. and G.H. Reeves, 1994. Restoration of stream habitat for fish using in-stream structures. In K. Collier (ed.) *Restoration of Aquatic Habitats—Selected papers from the second day of the New Zealand Limnological Society 1993 Annual Conference*. Department of Conservation, NZ, pp. 67–91.
- Hupp, C.R. and A. Simon, 1991. Bank accretion and the development of vegetated depositional surfaces along modified alluvial channels. *Geomorphology*, 4: 111–24.
- Koehn, J.D. and W.G. O'Connor, 1990. *Biological information for management of native freshwater fish in Victoria*. Dept. of Conservation and Environment, Melbourne, 165 pp.
- Lake, P.S. and L.A. Barmuta, 1986. Stream benthic communities: persistent presumptions and current speculations. In P. De Decker and W.D. Williams (eds.), *Limnology in Australia*. Junk, Dordrecht, pp. 263–76.
- Mason, R. and I. Mitroff, 1981. *Challenging strategic planning assumptions*. John Wiley & Sons.
- Mitchell, P., 1990. *The environmental condition of Victorian streams*. Department of Water Resources Victoria, Melbourne, 102 pp.
- National Research Council, 1992. *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy*. National Academy Press, Washington DC, 552 pp.
- Niemi, G.J., P. DeVore, N. Detenbeck, D. Taylor, A. Lima, J. Pastor, J.D. Yount and R.J. Naiman, 1990. Overview of case studies on recovery of aquatic systems from disturbance. *Environmental Management*, 14(5): 571–87.
- O'Connor, N.A. and P.S. Lake, 1994. Long-term and seasonal large-scale disturbances of a small lowland stream. *Australian Journal of Marine and Freshwater Research*, 45: 243–55.
- Phillips, J.D., 1991. Multiple modes of adjustment in unstable river channel cross-sections. *Journal of Hydrology*, 123: 39–49.

- Poff, L.N. and J.V. Ward, 1990. Physical habitat template of lotic systems: recovery in the context of historical pattern of spatiotemporal heterogeneity. *Environmental Management*, 14(5): 629–45.
- Raadik, T.A., 1995. Native Fishes of Victoria—their significance, distribution and general biology. *Proceedings of the River Basin Management Society Meeting, Willows, weeds and fishes*, Berkely Lodge, Geelong.
- Renwick, W.H., 1992. Equilibrium, disequilibrium, and nonequilibrium landforms in the landscape. *Geomorphology*, 5: 265–76.
- Rhoads, B.L., 1987. Stream Power Terminology. *Professional Geographer*, 39(2): 189–95.
- Rosengren, N., 1984. *Sites of geological and geomorphological significance in the Gippsland Lakes catchment*. Environmental Studies Series, 402. Ministry for Conservation, Melbourne.
- Rutherford, I.D., A. Ladson, J.T. Tillear, M. Stewardson, S. Ewing, G. Brierley and K. Fryirs, 1998. *Research and development needs for river restoration in Australia*. Report to the Land and Water Resources Research and Development Corporation, Canberra.
- Statzner, B. and J. Higler, 1986. Stream hydraulics as a major determinant of benthic invertebrate zonation patterns. *Freshwater Biology*, 16: 127–39.
- Williams, W.D., 1980. Some relationships between stream benthos and substrate heterogeneity. *Limnology and Oceanography*, 25(1): 166–72.

Part 2

A stream rehabilitation planning procedure

An introduction to stream rehabilitation planning

- 1. The planning task**
- 2. A 12-step procedure for stream**

1 The planning task

1.1 Why plan?

The angry stream manager stands on the stream bank "Just look at that stream—it's ruined and it's getting worse! There's no time for lots of planning. It's obvious what needs to be done!"

Some problems are simple, and some solutions obvious. But just as often the problem is not obvious and the solutions are far from simple. A good plan is just as crucial to good stream rehabilitation as is skill in building structures, or knowledge of how streams work. Here are five reasons for rigorous planning.



Figure 1: Stream reaches that appear to be sorely in need of rehabilitation: (a) the Inman River, SA; and (b) a tributary of the Campaspe River, Vic. Through the planning procedure that follows, we will consider carefully whether the obvious things are really what needs to be done!

1. A transparent planning procedure ensures some public accountability. You can then justify why you did what you did.
2. Setting clear, measurable objectives allows the manager to evaluate the completed project.

3. Planning makes you distance yourself from the obvious/visible problems and think about the catchment context of problems.
4. Setting priorities avoids working on symptoms rather than causes; ie. you can settle on the most important issues instead of the ones that appear superficially important.
5. Planning avoids inefficiency in the execution of the project (eg. doing things in the wrong order).

Further, stream rehabilitation is an expensive business. Even the smallest projects, on small streams, would seldom cost less than several thousand dollars. Major rehabilitation can easily cost millions of dollars. It is not unreasonable to spend around 5 to 10% of the cost of a job on planning. Thus, for even the smallest job you should not be surprised to be spending a few thousand dollars on planning. A well-known stream restoration project in the Mississippi catchment (Twenty Mile Creek) spent 43% of its budget on planning and management (Danley *et al.* 1995).

Although the planning procedure suggested here looks quite long and time-consuming, most of the document is devoted to explaining concepts. If you accept these concepts, the catchment is small, and you already know your stream well, you may be able to apply the procedure in less than a day. On the other hand, large, complex catchments may well require a large, complex stream rehabilitation strategy. Most of the effort will go into understanding the processes occurring in the catchment. Remember, it will probably take many years to rehabilitate a stream. It's worth trying to get the plan right at the beginning!

Finally, planning is required for any stream management project, but even more so in stream rehabilitation projects. This is because attempting to restore physical and biological values to streams is more uncertain, and often more complicated than, say, flood or erosion control projects.

1.2 A stream rehabilitation planning procedure

Several planning procedures are available for stream management. Good examples are the 10-step procedure for bank stabilisation recently published by LWRRDC (Kapitsky *et al.* 1998), or the well known 10-step procedure of Newbury and Gaboury (1993). Both of these procedures are very good

once you have identified the goal—stream channel stabilisation in the former case, and promoting salmonid fish populations in the latter. Our procedure begins somewhat earlier in the planning sequence, by defining the goal that drives the plan as the rehabilitation of the ecological values of the stream. Thus we take a generally ecological perspective.

We want to expand on four key points about planning stream rehabilitation projects. First, that most projects start at the wrong end of the procedure, second, that projects should follow a hierarchy of spatial scales that matches the steps in the project (both of these points are emphasised by Tony Ladson and John Tilleard in Rutherford *et al.* (1998)), third, that including the catchment context need not be difficult, and fourth, that a stream rehabilitation plan should be developed separately from the catchment management plan, and integrated with the larger plan once complete.

1.2.1 Where should planning start?

Planning always starts with people, and what those people value. Unfortunately, this manual cannot cover the range of sociological and economic issues that underlie stream rehabilitation (although we touch on them in Steps 1 and 2). We concentrate here on planning what is best for the stream, rather than mustering support for that plan.

A healthy diet should be based on a foundation of protein, carbohydrates and other essentials, although many of us would rather jump straight to the desserts! The same is true of stream rehabilitation. The foundation of stream rehabilitation is the rather mundane activities of setting goals, identifying problems, setting objectives and developing strategies; well before you get to the fun bits of selecting tools and building things. Many stream rehabilitation projects are based on an unbalanced diet: they leap straight to the design stage and greedily build in-stream structures with little thought for the long-term health of the watercourse, or much consideration of the catchment context of their efforts. Sometimes this approach works, but more often these projects end up in the graveyard of uncertainty. Did the project really work? If it didn't, was that because of flaws in the design, or because of large floods? What were we really trying to do anyway? The most difficult problem is driving the rehabilitation project forward with a clear vision, targeting the right problems, and understanding the catchment context of the work.

1.2.2 On what scale should you make your plans?

In the following planning procedure we describe seven major steps (altogether there are 12 smaller steps) (Figure 2). While all of the steps are important, we believe that the parts that are currently done least well are in the

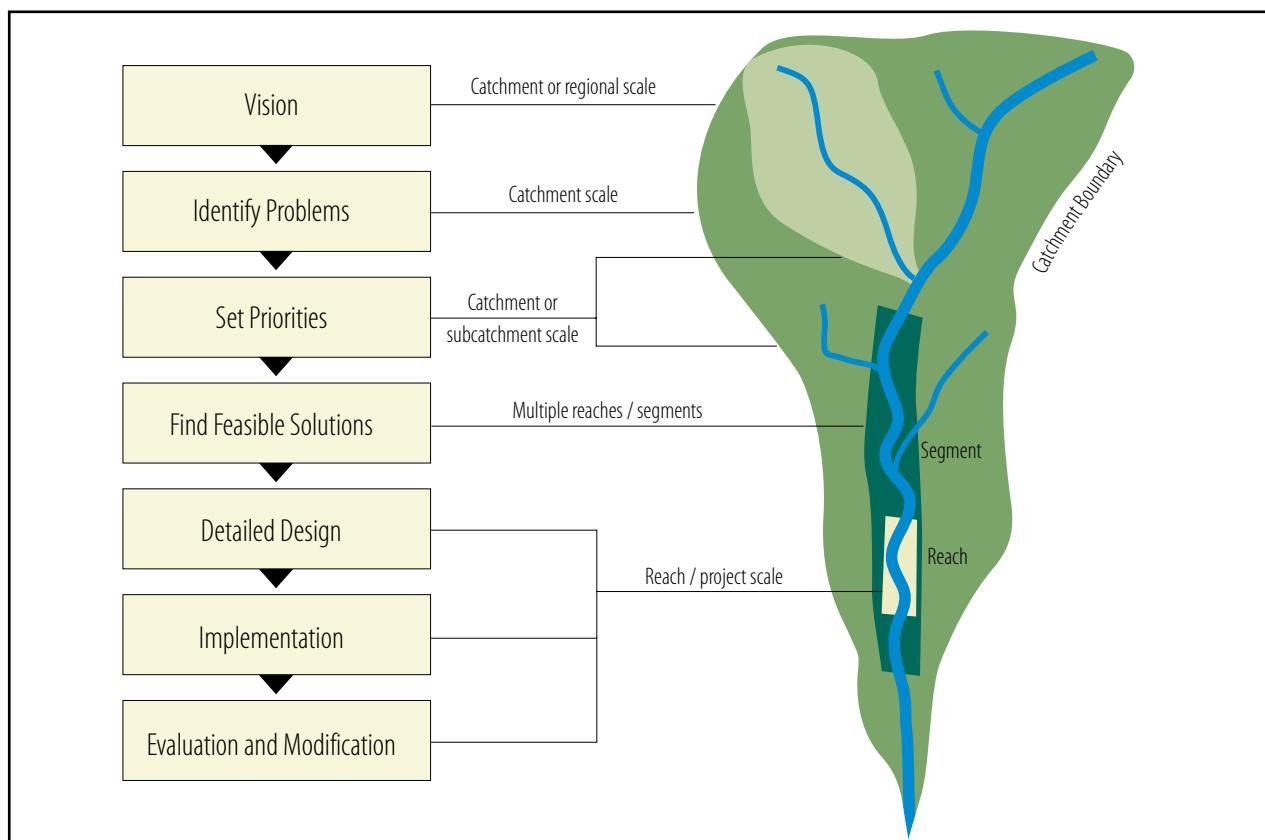


Figure 2. The spatial and chronological steps of the rehabilitation planning procedure.

early planning stages, and in evaluating the project. The chronological hierarchy of steps in a project is matched by a spatial hierarchy (Figure 2). That is, the big end of the planning (vision, setting priorities, and problem definition) should concentrate on the regional or whole-of-catchment scale. As the planning moves to identifying solutions, detailed designs and evaluation, the focus tends to move down in scale to a group of reaches, a single reach, or a single group of stakeholders.

1.2.3 Incorporating a catchment perspective into your stream rehabilitation plan.

Most people accept that effectively managing a stream means, by definition, effectively managing the entire catchment of that stream. This is true, but the cry ‘what about the catchment’ can also be paralysing for the manager. Does it mean that the manager cannot do anything to the stream, until every tiny thing that happens upstream, downstream and on the surrounding slopes has been considered?

In the following stream rehabilitation procedure we take the catchment context into account by using the linked-reach approach (see Figure 3). This simply means you know what is coming into a reach from upstream—water, pollutants, sediment, seeds, animals, nutrients and so on. You also need to be aware of what changes take place within the reach, and so what outputs will be delivered to the reaches up and downstream. To do this, you need to know about storage and transitions in the reach, as well as inputs from the riparian zone and the surrounding slopes. Finally, there are the more restricted inputs to the reach from downstream, such as animals, or erosion headcuts. Once you have identified the interactions shown in Figure 3, you will know the catchment context of the reach. Thus, your catchment plan describes a series of reaches linked through their up and downstream effects .

1.2.4 Integrating the stream rehabilitation plan with other plans in the catchment

An important feature of the planning procedure presented here is its development in isolation from other management plans in the catchment. Catchment management plans must integrate all the competing uses of the stream, relating to their cultural and social significance, recreational value, economic value and ecological values. Unfortunately, many of these uses are contradictory. For example, economic production on floodplains would benefit from the reduction of nuisance flooding, but floods are very important to the ecological health of the river. By developing the stream rehabilitation plan in concert with a general catchment management plan, you risk being left with a plan that includes only the core management activities of revegetation and erosion control. While these are usually important, they might not be the most important tasks. By developing your rehabilitation plan in isolation, you can be sure you have identified the most important ecological problems in your stream, and can later merge these with the general management plan. This is discussed in more detail in *Important concepts for stream rehabilitation*.

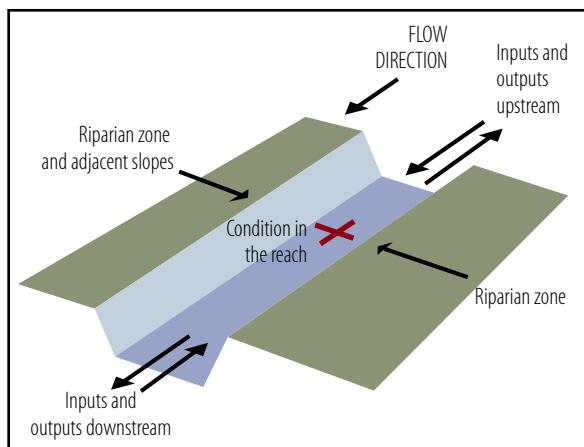


Figure 3: The impacts on a reach from the catchment, upstream and downstream.

2 A 12-step procedure for stream rehabilitation: a summary

The 12 steps of the planning procedure (the Rehabilitators’ Dozen), shown in Figure 4, are summarised below and discussed in detail in the following sections. (Note Figure 4 because it will keep appearing as a road map through the rest of the planning procedure to let you know where you

are in the procedure.) Most of the Steps consist of a set of ‘Tasks’. At the end of each step are examples showing how the rehabilitation plan might develop. This will include the Mythic Creek example that we began in the introduction.

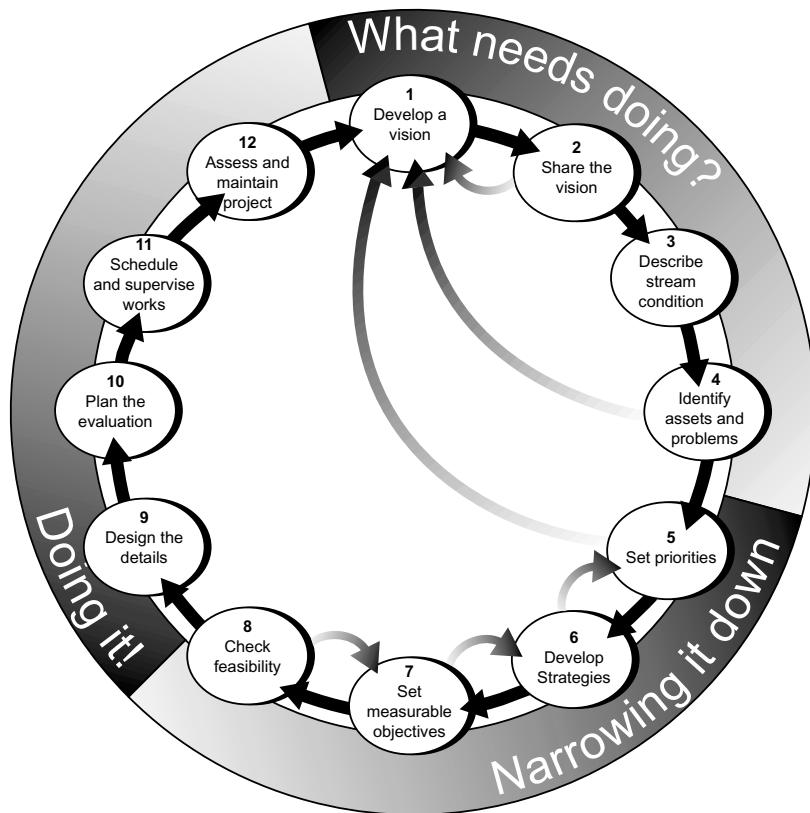


Figure 4. Flow chart summarising the 12-Step stream rehabilitation procedure. The dark lines represent movement between steps, and the faded lines represent the reassessment of past steps as a result of the reality checks.

If you want to actually design a project, then you will require additional information and tools that can be found in Volume 2 of the manual. For example, Step 4 (What Are Your Stream's Main Assets and Problems?) may ask you to test if the water quality is adequate in your reach. Common Stream Problems in Volume 2 contains information on how to test water quality, and some likely 'Thresholds of concern' for water quality problems. Detailed information on designing instream structures, designing a natural channel, riparian zone management and planning tools such as GIS are also in Volume 2, in Stream Rehabilitation Tools.

Although we describe 12 steps, 'step' is probably the wrong word to use, because it implies walking in a straight line. In reality, the planner will constantly return to earlier steps and reassess them in the light of later steps; gradually spiralling-in on a satisfactory plan. For this reason, at the end of each step there is a 'Reality Check' that might return you to earlier steps (as depicted in Figure 4).

Here we summarise 12 steps in the stream rehabilitation planning procedure.

Step 1. What are your goals for rehabilitating your stream?

By the end of this step you should have described a broad goal, or 'vision' of what you want your stream to be like when you have finished the rehabilitation. You will need this vision to keep you on track as you develop your rehabilitation plan.

Step 2. Who shares your goals for the stream?

Stream rehabilitation is a subset of catchment management. Streams have many roles, not all of which relate to their ecological or environmental values. Do other people share your vision of an ecologically rehabilitated stream?

Step 3. How has your stream changed since European settlement?

Describe the pre-disturbance stream, as well as its present condition.

Step 4. What are your stream's main natural assets and problems?

Rehabilitation is about protecting natural stream assets and improving or creating other assets. An asset is any aspect of the stream already in good enough condition to meet your goal. Many stream assets are threatened by stream problems, or have already been degraded. In this step, you identify the main assets, degraded assets, and problems.

Step 5. Setting priorities: which reaches and problems should you work on first?

Which reaches of the stream have the highest priority for attention? Contrary to current practice, you would not usually start with the most damaged reaches, but with preserving the best ones!

Step 6. What are your strategies to protect assets and improve your stream?

Identify and list the things that you can do to protect and improve the important assets in the reaches that you identified as a high priority in the last step.

Step 7. What are your specific and measurable objectives?

From the options defined at Step 6, create detailed objectives that will be the core of your stream rehabilitation plan.

Step 8. Are your objectives feasible?

Are the objectives described in Step 7 feasible? Many factors, such as cost, politics, and undesirable consequences for other users of the stream, will force you to alter the priorities that you have identified. At the end of this step you will have settled on a final list of problems to treat.

Step 9. What is the detailed design of your project?

In Step 6 you identified the general methods that you would use to treat problems. You now need to develop a detailed design. What specific things do you need to do to achieve your objectives? These can range from doing nothing at all, to planning controls, or flow manipulation, to complete channel reconstruction.

Step 10. How will you evaluate your project?

Measurable objectives were defined in Step 7: these now become the basis for evaluating the project. Importantly, our practical evaluation procedure emphasises that not all evaluation needs to be detailed and expensive.

Step 11. How will you plan and implement your project?

The plan needs to be implemented by developing a time line, allocating responsibilities, finalising funding, doing the works, and organising the evaluation schedule.

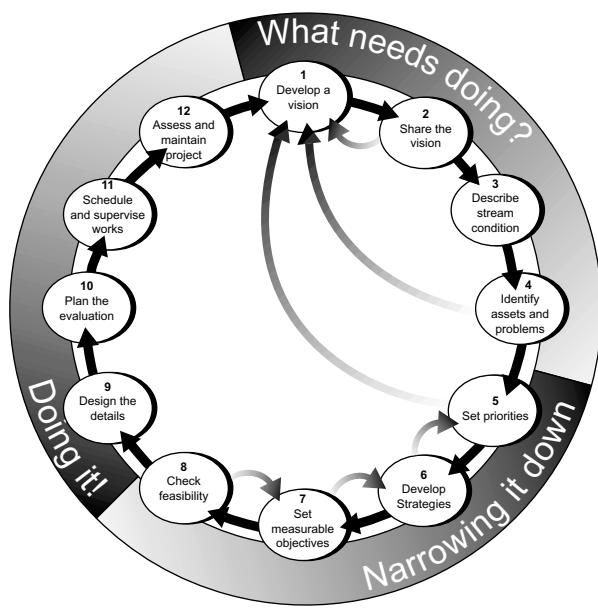
Step 12. Has your project worked?

The final step of the procedure is to maintain the work that has been done, and to set a point in the future at which the project will be formally assessed using the information gathered by the evaluation plan.

Stop press!

Please note. From this point on we are assuming that you already know the stream that you have decided to rehabilitate. In reality this may not always be the case. In fact, it is much better that you select the stream that you want to rehabilitate on a rational basis. Step 5 of the procedure describes a method for setting priorities for action in a selected stream. However, the procedure of setting priorities is hierarchical and should first be applied at a regional level to decide which catchments should be treated first. If you do not know which catchment to begin with in your region, you might like to begin by reading Step 5.

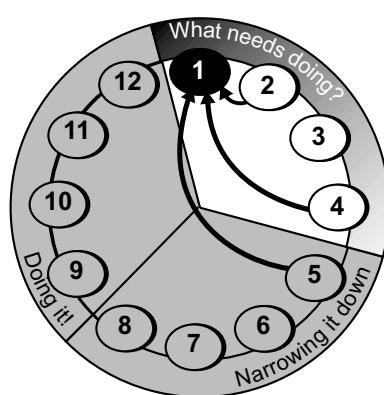
12 steps to a stream rehabilitation plan



Step 1:

What are your goals for rehabilitating the stream?

AIM: by the end of this step you should have described a broad goal, or 'vision' of what you want your stream to be like when you have finished the rehabilitation.



"The human species faces a grave obligation: conserve this fragile planet Earth and its human cultural legacy for future generations. We now recognise that humans have the power to alter the planet irreversibly, on a global scale. Humans must be concerned with the condition of the planet that is passed to future generations"

E. Brown-Weis
Environment (April 1990)
Cited in National Research Council (1992)

A community group defined the goals for its stream management program as follows:

"The stream would be stable, nuisance flooding would be reduced, and the stream would be environmentally improved and attractive".

Over the next ten years the group seemed to put most of their effort into erosion control, because it was easy to see how to do this, and it seemed to get more support than the vague notions of 'environmental improvement'. After ten years, they knew that the stream was more stable and they thought it must be environmentally improved, but it was hard to know exactly what this meant.

Key points about goal setting

- Clearly defined goals serve as the foundation of a stream rehabilitation project.
- The goals will be most successful if they are expressed in such a way that you will know when they have been achieved.
- It helps to have goals that inspire the people involved.

1 Developing a vision for stream rehabilitation

The condition of many Australian streams is a sorry legacy of 200 years of European occupation. This manual argues that it is time to reverse the decline in the condition of our streams, in concert with an improvement in the condition of our environment generally. An appropriate goal for a stream rehabilitation project would be the following:

- This project aims to maintain existing natural physical and biological diversity in streams within the catchment, and return as much as possible of the diversity that has been lost from the catchment's degraded streams.

Why is it important to define a goal or vision for a stream rehabilitation project? Such a goal provides a foundation and a reference point. Most rehabilitation projects last for many years, so it is important to describe the underlying

motivation that sustains the effort. The goal may not even be achievable ultimately, but it provides a vision to work towards.

Also, streams have many attributes of value to humans, so they are natural hot-beds of conflict. If managers are not committed to environmental goals as being legitimate and valuable outcomes of their stream management, then the project could eventually fail in the face of inevitable opposition. This point may appear obvious. However, we would argue that stream rehabilitation will not progress, and your stream rehabilitation project will probably fail, if you are not clear about the fundamental purpose of your management, and committed to it in the face of opposition. In fact, a recent review of stream rehabilitation practice in Australia concluded that almost all stream management projects in Australia had goals relating to the

utilitarian or aesthetic values of the stream, with ecological values being much discussed but little applied (Rutherford et al. 1998). If ecological outcomes occur, it is often as much by luck as by design. The review concluded that “the absence of ecological rehabilitation as a legitimate goal of management is one of the major impediments to stream rehabilitation in Australia”. This is why we need to define concrete goals for stream rehabilitation projects.

In Step 5 (Setting Priorities), we discuss how much more efficient it is to protect the good reaches of a stream than to try to fix badly damaged reaches. Effectively applied, this principle means that most stream rehabilitation resources would often be directed at streams and problems that provide little direct economic, aesthetic or recreational benefits to people, because these streams, by escaping our notice, have also often escaped degradation. Thus, if the goal of the management really is ‘ecological rehabilitation’, then managing stock on a remote, remnant water-hole in western Queensland may have higher priority than patching-up bank erosion on a channelised urban stream.



Figure 1.1 Cooper Creek in south western Queensland. This river system is still in good condition—grazing and minor water diversions are the only major impacts. Maintaining this good condition should have a high priority.

2 What is a goal?

A good goal will have two elements. First, it will have some sense of an end-point, or a clear target. Second, it will be inspiring. People will give up their weekends to pursue this vision. Compare these goals, from the Don River in Toronto, Canada (Goal 1), and the vague statement (typical of many rehabilitation plans) in the example that introduced this step (Goal 2):

Goal 1. “The Don that we envision for the future is a revitalised river, flowing with life-sustaining water, through regenerated natural habitats and human communities. In its upper reaches the sparkling brooks and deep forest pools will flash with fish. Downstream in the older urbanised area of the city, the Don will ripple gently under shade trees, meander across its grassy plain, and merge into wetlands alive with waterfowl.”
(MTRCA 1994)

Goal 2. “After the project, the creek will be environmentally improved and attractive”.

The vision for the Don River is emotive, but it is vaguely measurable—you will know if the stream looks like this description. It is also an inspiring vision. It could carry the workers through the dark years of only creeping progress. Contrast this with the second example. ‘Environmentally improved’ is not only a vision that is too vague to measure, it is also boring.

Here is another example of some broad goals from a major rehabilitation project still under way in Europe:

- “The Rhine River was pronounced dead in 1970, its animal and plant life extinguished. In 1986 a fire in a Swiss chemical factory spewed toxic chemicals into the river, prompting a drinking-water alert for 50 million people. In 1987, five Rhine countries created the International Commission for the Protection of the Rhine, which called for cutting pollution in half, establishing a riverwide alert system, and restoring the Rhine’s flora and fauna.

Today, most of these goals have been met. Heavy metals and dioxins have been cut by 50-70 percent and improvements in water treatment plants have made the water potable. Last November, salmon and trout were spotted in the upper Rhine for the first time in 50 years."

(From Aleta Brown,
'World Rivers Review' V11:5)

Usually, the goal will relate to some 'template' of what the stream could be like. Examples would be:

- The stream will be returned to the same condition that it enjoyed in the 1930s (when the older residents of the valley enjoyed dense, shady riparian vegetation, deep swimming holes, and yabbies crawling across the bottom of the clear creek).
- The stream will be returned to its original, pre-European condition.

These specific goals can be good because at least you know that the stream was once like this. (Or do you? Upon closer investigation (at Step 3 of the procedure) you may find that the recollections of long-time residents may have changed with time. If this is the case, then you loop back to this step and update your goals.)

You may choose a narrower goal that relates to only selected elements of the ecological system. Examples would be:

- The return of attractive swimming holes that have silted-up.
- Return of sports fishing species.
- An attractive stream.

The major goal for rehabilitation projects in Europe and North America has usually been to develop larger populations of salmonid and other sports fish. While this has motivated a large amount of habitat creation work, it has also been criticised for not providing a sustainable 'eco-system' view of a stream system (National Research Council, 1992). In addition, providing favourable conditions for a limited range of species inevitably leads to other imbalances in the natural system. We would urge caution in defining narrow goals.

Although the statement of goals should include a recognisable endpoint, it does not have to be very detailed. Nor does it have to be completely achievable—it is an ideal vision to work towards. Note that the goals will be re-expressed in far more specific terms in Step 7, to form the measurable objectives for individual rehabilitation projects.

3 Summary

What are your goals?

- Are you clear what you want to achieve in your stream (eg. to return it to something like its original condition, be able to catch native fish, have swimming holes back again etc.)?
- Will you know when your goal has been reached?
- Is your goal expressed in a way that provides an inspiring vision of the stream?

4 Setting goals in Mythic Creek

The coordinator of the Mythic Creek Landcare group is strongly committed to the ecological rehabilitation of the creek. In fact, she is willing to make it her professional goal for at least the period of her three-year contract. She, and her Landcare group, have drafted the following broad goal for managing Mythic Creek:

- “Mythic Creek and its tributaries will be transformed into streams that support most of the plants and animals that originally lived in them. The stream will experience natural rates of channel change and flooding. They will be streams that we will be proud to pass on to our children”.

Note that it is unlikely that the vision will be achieved in all reaches of Mythic Creek. It is unlikely that the channelised Reach 4, for example, will have ‘natural rates of channel change and flooding’. This does not matter particularly, because the statement of goals represents a vision to work towards, rather than a prescription.

5 Reality Check

A stream rehabilitation plan is not linear, it is iterative, and often loops back on itself. This is the first example of one of these loops. The procedure will often bring you back to the goals of the project. When you come back to the goals from various steps, this is what you need to do:

From Step 2 (Who shares your goals for the stream?): You have found that you have insufficient support for the goals of your project as originally conceived. You can compromise on your goals, you can redirect your attention to another catchment, or you can give up.

From Step 3 (How has your stream changed?): One of the tasks in Step 3 is to investigate what the stream was like in pre-European times. You may learn new things about your stream that would encourage you to define more-specific and accurate goals. For example, you may have started with an image of your stream as being a sinuous pool-and-riffle stream. More detailed research shows that it was a swampy chain-of-ponds. This then becomes a more appropriate part of the goal.

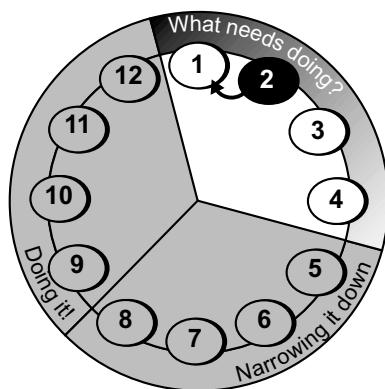
From Step 5: (Setting priorities) Comparing the objectives, feasibility and priorities, it appears that your project is not feasible (ie. there are too many fatally linked limiting variables to proceed). As with Step 2, at this point you can change your goals to reflect the realities of the situation, or you can take your visions of rehabilitated streams to other catchments.

Step 2:

Who shares your goals for the stream?

(Prepared with assistance from Neville Oddie, Jim Burston, and Michael Good)

AIM: by the end of this step you should have assessed whether other people, with interests in the stream, share your goal for the rehabilitation of the stream. You should also have decided on some strategies to increase the number of supporters.



A local community group, with support from the Department of Environment, and the local Shire, has been fencing and revegetating a good reach of stream. They had persuaded the farmers to remove their stock from the stream, and the group were excited about the prospects for the project. To their horror they discovered that an upstream landholder had won approval from the Department of Water Resources to pump a large volume of low flow (summer) water into an off-channel dam for irrigation. Despite many pleas to the Department of Water Resources, the licence conditions were not altered, and the stream remained dry for much longer periods through summer. The condition of the stream deteriorated. The community group became disillusioned and interest in the project waned.

Key points about gathering support for your goals:

- Most stream rehabilitation projects are at least as much about people as they are about science and construction
- From the very beginning of a project you need to identify the important people and groups who support or oppose your goals for the stream
- There is a variety of techniques that you can use to increase the number of allies and to resist or convert the opponents.

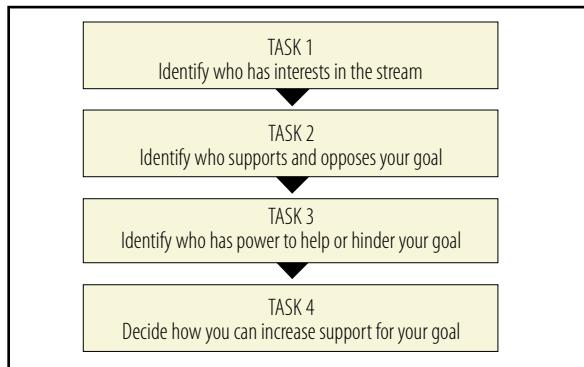
1 Getting people's support

It is difficult to protect and rehabilitate streams. Streams are long and thin, so they maximise the pressures placed on them from surrounding land, as well as from the catchment. Furthermore, they are often the focus of competing values. The many utilitarian values of streams (such as flood control, water supply, waste disposal, erosion control) might conflict with the environmental values of the stream. Thus, the battle for rehabilitation of streams often becomes a battle between continuing exploitation, and a growing conservation ethic. We are assuming, in this step, that you have embraced a conservation ethic in rehabilitating streams, acknowledging, of course, that many stream managers have to balance exploitation and conservation in their work.

"I went into the Mersey River study thinking that our work would be all about the environment. I came out realising that the real issues were about people" (Anderson 1999, p.9).

If you plan to join the battle, then it is well to have identified your allies, and those who might oppose you. It is certain that you will not be able to achieve your vision without the help of others. Do the groups and people that you will rely on for fulfilling your vision, share your vision?

This step consists of four tasks:



You have to identify all of the interests in the stream early in the procedure for two reasons. First, because your project could be scuttled very easily by the opposition of a single, powerful interest group. You have to be prepared for such opposition. Second, one of the best ways to encourage people to share your goals is by including them in this 12 Step planning procedure!

You may be thinking that this step is sounding combative and confrontational. Isn't catchment management about cooperation and compromise? It is, but remember, this is not a catchment or stream management manual. This manual is squarely about stream rehabilitation. Rehabilitation is only one of many competing demands on a stream. This step helps you to be realistic about the competition!

1.1 Task 1: Identify interested parties?

You may already be able to list the various groups and individuals in the district who would support and oppose your goals. Often you will be surprised by the huge number of groups and individuals with an interest in the project. Who owns the stream and the land (see *Legislative and administrative constraints*, in Miscellaneous planning tools, Volume 2)? Think about all of the utilitarian users of the stream: farm water supply, pollution disposal, irrigation, and so on. Who owns the infrastructure associated with the stream—the bridges, pipes, and pumps? Which government departments have a strong interest in the stream? Which departments have some responsibility for the stream, but do not exercise it? Who controls the water supply into the target reach?

In a large catchment, it may be necessary to advertise in order to identify all of the people affected by the rehabilitation. This will include not only all of the landholders along the stream, but also the interested people in the community who picnic, swim, fish or otherwise use the stream.

With all of the above, it is useful if you can name *people* who may be interested in the project, as well as organisations. So who in the Roads Board would be likely to be concerned with the project if culverts are involved? How would you expect that person to react? Removing the spectre of the faceless bureaucracy is often useful.

What about future users of the stream? Do future generations have an interest in the stream? Who will represent them?

1.2 Task 2: Who shares your goals?

Make a list of the names of all of the people and agencies with interests in the stream, and what their interests are. For example, some farmers may want access for stock, others may emphasise clean water. Anglers may want sports fish, while dam owners want freedom to regulate the flow. Divide the stakeholders into three groups—supportive, indifferent, and hostile—according to how you think they may respond to your goal. Try to identify exactly why each stakeholder holds their particular view.

1.3 Task 3: How much power does each group or individual have over the goal?

People and groups can exercise many types of power that could affect your goals: political, financial, control over land and water resources, legislation and regulation, or local popularity. Here are some examples of various groups and their interests.

- A government department administers legislation that provides a powerful weapon in your project.
- A national conservation group has expressed a special interest in some aspect of your goal, and thus may be considered a powerful lobby group supporting your goal.
- An influential local farming family (with strong political connections) could be considered a potentially hostile force because you could be planning to restrict its summer pumping from the stream.
- In Tasmania, it would be difficult to do much to larger streams without provoking the interest of the Hydro Electric Corporation because of its ubiquitous influence over streams in that State.
- While a single schoolchild may not be considered powerful, an entire school of committed students can be tremendously powerful—hence the influence of the Waterwatch program.

1.4 Task 4: How can you shift the balance of power in your favour?

You should now have listed your most powerful potential allies and opponents. Your first task is to shore-up support amongst the powerful allies. It is worth getting them involved in the project from the outset, or at least keeping them informed, so that they can help when needed. You also need to stop opponents of the project from jeopardising its success, and to turn the indifferent people and groups into enthusiastic allies. Over time, you should gradually increase the number of allies.

The next section explores how you can win allies, and bolster support amongst hostile or indifferent stakeholders.

2 How to win allies and resist opponents

2.1 How to win allies ...

Here are a few tips on how to create allies of your plan.

1. *Investigate the history* of streams in your region to develop a feel for the way the streams were. Find pictures, or vivid descriptions of their original condition, perhaps from explorers' journals or the diaries of early landholders. Such early images of the stream and landscape could provide you with a powerful vision of what the stream could be once again, and can influence people who are interested in the stream. This information will be used further in Step 3.
2. *Identify flagship species or communities* in your stream. Is there something special, endangered, or rare that can be used as the centre piece of a rehabilitation plan? Rare rainforest would be good; as would be cute, cuddly, or beautiful animals. The platypus (ironically, one of the tougher aquatic animals!) has been very successful as the flagship animal for several stream rehabilitation campaigns. 'Operation Platypus' in Western Victoria, and the Australian Platypus Conservancy in Melbourne, have had huge success with community and corporate support because of the status of this charismatic animal. We caution, however, that concentrating on one species should be avoided in the long run. North American experience has shown that concentrating on salmon habitat, while ignoring the broader condition of the stream and catchment, has not led to sustainable rehabilitation.
3. *Look for beneficial secondary effects* of rehabilitation of the stream to act as further impetus for the work. Providing more fish for fishermen has long been the impetus behind rehabilitation in the northern hemisphere. Rehabilitation of urban streams can be justified on the grounds that natural streams will require less maintenance than will channelised and engineered streams. You can argue that the project will benefit landholders as well as the general community, through changes such as increased shade, improved water quality, reduced erosion, increased property value (see *Why stakeholders may not support your plan* in Miscellaneous Planning Tools, Volume 2, for some ideas on this). There may be more direct incentives,

such as State and Federal agency incentive schemes, or tax concessions (this latter tends to be a weak incentive for many farmers who in some years aren't making enough to pay tax! It may be a useful incentive when you are trying to persuade a community 'leader' that he/she should start a demonstration project).

The above points relate to the *message* that you can bring to stakeholders in order to persuade them to support your goal. However, equally important is how that message is delivered. Here are some ideas for persuading others to support your vision.

1. Make sure that *your goal or vision is clear in your mind*, so that you can also describe it clearly, and so communicate your commitment to that goal. Remember the first rule of selling: "If you don't love the product—nobody else will". Stream managers must be as committed to their goals of stream rehabilitation as landholders (or any stakeholder) are committed to their private interests. In short, you will gain much more respect for your point of view if you are (a) well informed, (b) passionate in your commitment, and yet (c) remain capable of seeing the interests and perspective of other users of the stream.
2. *Develop the plan as a cooperative venture:* If a stream rehabilitation plan is developed from the outset as a cooperative venture between the managers and the landholders, then it has a much better chance of success than if it is simply imposed from above. Involving the community in the problem definition, and deciding on appropriate solutions, will develop ownership of the stream and the rehabilitation project. This is the best approach to community involvement, as a community with a sense of ownership will take responsibility for the project.
3. *Educate, rather than dictate.* Rather than simply telling landholders what you feel is wrong with their stream, you should provide them with the opportunity to identify the problems for themselves. For example, provide people with the original surveys of a stream, then help with resurveying the reaches. People will believe what they can see and work out for themselves.

4. **Develop demonstration sites.** Demonstration sites can be very important for inspiring reluctant landholders to rehabilitate the stream, as well as convincing people that a certain strategy will actually work. However, farmers may not always have the time to go touring rehabilitation sites, so a folder of photographs would also be useful.

5. **Find yourself a stalwart.** Anderson (1999) describes the importance of having a strong, inspirational community leader involved in any project. Such a person has been the key to successful stream rehabilitation projects in the Torrens catchment in SA, in the Mersey in Tasmania, and elsewhere. This person can also act as a go-between with the community and government agencies.



Figure 2.1. A Landcare Group on a field day on the Chetwynd River, Western Vic.

A sobering (true) story of support lost and gained

A catchment authority employed consultants to assess the condition of streams in a large catchment, and to develop priorities for managing them. Part of the task was to map and categorise the condition of all frontages on large streams. The consultants walked the length of the larger streams, categorising the frontages, and eventually produced a GIS map of priority and problem areas. The plan was technically sound and may even have worked except...

The GIS map was presented at a public meeting. Some influential farmers discovered, to their surprise, that the river frontage to their properties was coloured red and labelled 'very poor condition'. The farmers, predictably, were offended by this, and the river managers lost support for their plan even before it was fully presented. The issue here is not whether the assessment of frontage condition was correct (it probably was), but of how this 'fact' was managed. It will take a lot of work to get the affronted farmers back on side, let alone involved in the stream rehabilitation procedure. Without their support, the ambitious plans will not be achieved.

Meanwhile, another arm of government in the region was concentrating its efforts on supporting a leading farmer to establish some revolutionary approaches to managing streams. As a result, the farmer had fenced-out a wide strip of land along both sides of his stream frontage with rabbit-proof fence, and had constructed off-river watering. This was an expensive exercise, partly because the strip was wide enough to avoid flood damage. The farmer was delighted with the result because it allowed him to manage his stock (which used to wander between paddocks along the river), keep rabbits out of his paddocks, and it led to dramatic natural regeneration of vegetation along the frontage, and (anecdotally) much better condition in the stream with the stock out of it. Many local farmers now visit this property and are enthusiastically told of the benefits of the rehabilitation work by the farmer, who is seen as one of the most innovative and successful farmers in the district.

2.2 How to work constructively with opponents ...

"Prices are down, the costs of inputs are up, we have just had the worst drought in 50 years, and you are seriously asking me to fence off my most productive land so that we can have more bugs in the creek?"

You have mustered your allies around you, and are confident of their long-term support. Now you turn to the groups that are likely to oppose your goal. Again, the best approach to opposition is persuasion rather than force. Nevertheless, there may be times when you have to resort to regulations to support your plan. Some more ideas can be found in *Why stakeholders may not support your plan*, in Miscellaneous planning tools, Vol. 2.

You may come across the rare landholder who simply does not share your interest in environmental values. They could not care less if there were bugs and blackfish in the creek, so long as it does not flood their property. Most landholders will claim to care about the environment, and will remember fondly what the streams used to be like. However, the reality is that rehabilitating ecological values is usually not a high priority for them. Is this any surprise when they are often flat out just having their business survive from season to season? In such cases your options are to force compliance (usually a bad option), wait until somebody else takes on the farm, or attempt to gradually change their values using the methods discussed above (often a long process). It is almost always useful to know what legal support you have.

Investigate whether there is any legislation or other official directive to protect natural values of streams in your region. It is always easier to stand fast against the winds of opposition if you are tethered by official sanction. You may be able to find no more than by-laws of a local planning amendment or the statements of the Global Convention on Bio-diversity, but it all helps. Here are three examples of legislation that provides support for stream rehabilitation.

- The Victorian *Fauna and Flora Guarantee Act* (1988) protects certain threatened species or communities of species, by controlling 'threatening processes'. These include sediment input, desnagging and altering temperature regimes.
- Following detailed investigation and consultation, the Land Conservation Council of Victoria nominated various river reaches to be managed and protected (for

recreation as well as for ecological reasons). These recommendations were passed into law through the *Heritage Rivers Act (1992)* which restricts land and water uses affecting these reaches, and requires the preparation of management plans. Any activities in these areas must comply with these plans and with the Act. The result is that it is now quite clear to both managers and the community, that management efforts in these reaches are intended to preserve the existing values of the streams.

- Under the Victorian *Conservation, Forests and Lands Act (1987)* obstructions that could affect fish migration cannot be built without permission from the Department of Natural Resources.

Standing up to resistance

The catchment management officer had been in the job for only a few months. He was very nervous as he stood on the banks of the stream telling an angry landholder that his application to remove snags from the channel had been refused. The officer explained that the application had been refused because so many snags had been removed in the past that there was now little habitat left for fish. Also, the snags were important for macroinvertebrates in this type of sand-bed stream. When he told the landholder that macroinvertebrates were bugs, he seemed to get even more angry.

The landholder rang the regional manager of the department to complain about the decision. The officer had discussed the matter with the regional manager who told the landholder that he supported the decision, particularly in the light of some legislation and by-laws that restricted such damage to streams. In an effort to placate the landholder, the officer had copied some summary material that showed the value of snags in streams, and some other research that suggested that snags did not increase flood duration too much anyway. The landholder calmed down a little and said that the material looked interesting. Finally, the officer invited the landholder to come along to a demonstration that he had organised in which some biologists from the department were going to electrofish a reach with and without snags to compare the difference in fish numbers. They finished their meeting with the landholder describing the fish that he used to catch in the stream when he was a boy.

Regulations can be used to set the limits of the discussion, negotiations must start from the legislative requirement. For example, if a landholder wanted to divert water out of a stream, the manager could simply say “no—that is forbidden under a particular Act in this river, so there is little point discussing it further”. Again, the manager might say, “under such-and-such an Act, you have to remove your stock from the stream. Sorry, that is the situation. Now let’s talk about what can be done to mutual advantage by considering the benefits of off-channel watering. I just happen to have some information here...”.

2.3 Maintaining support for the goal

It is one thing to capture support for your goal, it is quite another to maintain that vision over the many years that it takes to rehabilitate a stream.

One of the greatest dangers of stream rehabilitation is *unrealistic expectations!* As was discussed in *Recovery of disturbed stream systems*, in Stream rehabilitation concepts (this volume), it can take decades, or even centuries, for some types of stream disturbance to recover. Promising that landholders will be catching endangered trout cod out of the stream next year, and welcoming eco-tourists the year after, is unlikely to win long-term support for the project when these predictions do not come true.

Support can wane over time if things don’t appear to be moving fast, and things typically will not move fast in a stream rehabilitation project. You need to keep people informed of what is happening, in order to maintain their interest in the project. This will be possible because of the evaluation project that you will be setting-up at Step 10 of the procedure.

3 Summary

Who shares your goals for the stream?

- What other people and groups have interests in the stream that you plan to work on?
- Are they likely to support or oppose your vision and goals?
- How powerful is that support or opposition likely to be?
- What can you do to increase the number of powerful allies and reduce the number of powerful opponents?

4 Gathering support for the Mythic Creek vision

We will illustrate this step using the Mythic Creek example, by running through the four questions in the above summary.

What other people and groups have interests in the stream that you plan to work on?

The Landcare coordinator sat down with some members of the Landcare group to identify all of the people and groups with interests in Mythic Creek. Although Mythic Creek is only a small rural catchment, the group was amazed by the number of people, government agencies and community groups with an interest in the stream. The Landcare

coordinator knows that she can achieve very little without the support of the community along the stream—especially with the poor resources at her disposal. Fortunately, many in the Landcare group are also deeply committed to the goals of rehabilitation. The support of some other agencies is also needed. The local shire manages all of the creek crossings, the Environment Protection Authority (EPA) may be involved in managing any effluent from the piggery, the local water authority is promoting the dam in reach 1a, and the Department of Environment & Gambling (DOEG) controls grazing licences. Members of the group were also surprised at the range of legislation that could potentially be used to support their work.

Are there powerful stakeholders who are likely to support or oppose your vision and goals?

About half of the frontage owners are in the Landcare group, and about half of these are committed to returning many of the original values to the stream. This leaves a majority of indifferent landholders, and a few hostile ones, along the creek. Fishing groups and community conservation groups will be strong supporters of the goal. The DOEG and EPA will be supportive, and the local member of parliament appears to be particularly supportive of the project. It is going to be a challenge to lever concessions out of the shire engineer who is known for his hostility to 'greenies'. The water authority will certainly be very hostile to any opposition to the proposed dam, as will the local Farmers' Federation representative.

How powerful is that support or opposition likely to be?

Some landholders were identified who could be expected to be fiercely for or against the rehabilitation goal. One of the opponents in particular is known to have strong political connections that could prove to be a problem. Intransigence from the shire and water board is daunting. The EPA has the regulatory muscle required to prosecute polluters (such as the piggery) if necessary. The coordinator is overjoyed to have found a 'stalwart' person

in the community who is passionately interested in rehabilitating the stream.

What can you do to increase the number of powerful allies and reduce the number of powerful opponents?

Broad public support is essential if the Landcare group is going to have any chance of influencing the shire engineer or the water authority. The Waterwatch program at the primary school is already paying-off as the kids begin putting pressure onto their parents about the condition of the creeks. The local member of parliament has taken advantage of several photo opportunities in the creek and is right behind the program. It is likely that projects on the properties of well-respected farmers will get priority, so as to become demonstration sites.

The group have asked the local DOEG officer (who strongly supports the goal) to investigate if there are any endangered species in the catchment, and if there is any specific legislation, or regulations, that can be used to support the project.

5 Reality Check!

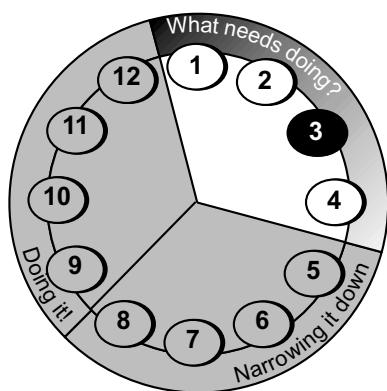
Now you will have thought about the many other groups with interests in the stream, and you may have a feel for the level of support and opposition that you will have in achieving your goals. Perhaps the opposition looks formidable, and the supporters few, so that you may be tempted to reassess your goals (ie. return to Step 1). Perhaps you are being over-ambitious? We would suggest, however, that you persevere with your ambitious goals at this stage, and begin to reassess them later in the

procedure. Otherwise you will end up with a compromised plan from the beginning. Nevertheless, it may be possible to slightly change the goals, or combine them with other complementary goals, so as to increase support among stakeholders. For example, you could express your goals in terms of angling fish numbers, or in terms of swimming holes, or pollution filtering. These will be only components of a stream rehabilitation plan, but they may generate more support for the project.

Step 3:

How has your stream changed since European settlement?

AIM: by the end of this section you should have divided your stream into reaches, developed a 'template' of the ideal state of the stream, and described the present stream.



The group had been working on the stream for a few years. They had a picture in their heads of what they thought the stream should look like, and they were using this picture as the target for their plan. However, when they started to do some more detailed investigation into the original character of the stream and catchment, they received some surprises. There were reports of crayfish living in the stream, the vegetation along the stream was quite different from what they had assumed, and the stream had a completely different form.

Key points for describing your stream:

- Use the linked-reach method to introduce a catchment perspective
- To know your stream you need to know its original condition, present condition and rate of change.
- Look for independent evidence or anecdotal information (don't believe everything you are told!) and avoid diagnostic errors (as described below)
- As well as describing the present condition, estimate the potential for recovery or deterioration of the stream (ie. trajectory).
- Identify and recognise rare (high value) assets

1 Introduction

In Step 1, you defined the goals for rehabilitation in terms of the environmental value of the stream. You need more detail about what this target stream really looks like, and how the present stream differs from that target. Armed with this knowledge, you can identify:

- *assets* (elements of a reach, or the entire reach, that are already close to the goal);
- *degraded assets* (elements of the reach that need to be rehabilitated in order to achieve the goal); and
- *problems* (something that threatens the assets, or something that has already damaged the degraded asset).

In this step, you will develop a detailed picture, or 'template', of the goal condition, from historical records, stream remnants that are still in good condition today, and generic models of healthy streams. You also describe the present condition of the stream. Finally, you produce a map showing the reaches, their template characteristics and their present condition. This will provide the information needed in Step 4, where you will identify the assets, degraded assets and problems.

1.1 Appropriate levels of effort

Assessing the condition of a stream can be as small or large a job as you can afford it to be. The detail that you go into for each of these steps depends upon the information available for the stream, the size of the project, and the cost of getting it wrong. It also depends on your rehabilitation goals.

Levels of effort — contrasting examples:

The Snowy River, Victoria and New South Wales

It has been proposed that the Snowy Mountains Hydro-Electric Scheme be privatised. In anticipation of this change, the Snowy River is being studied in detail to provide a firm basis for its rehabilitation in the future.

A small catchment in Qld

By contrast, the Upper Wombo Catchment Group has received a \$15,000 grant to prepare a rehabilitation plan for their 12,000 km² catchment. This will be far less detailed than the Snowy River plan.

2 Describing your stream

There are four tasks to complete in describing your stream (Figure 3.1): divide the stream into defined units (segments and reaches), construct a template of the goal condition, describe the present stream, and summarise all of the results in a map (Figure 3.2). This step is discussed in more detail in *Catchment review*, in Natural channel design, Volume 2.

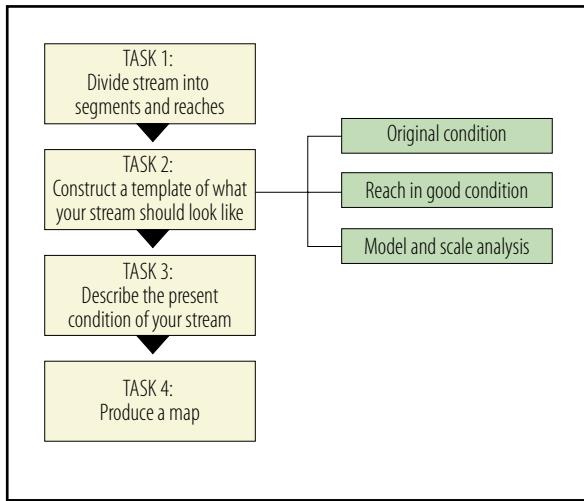


Figure 3.1.The tasks to be completed in Step 3.

2.1 TASK 1: Divide your stream into segments and reaches.

The fundamental units of stream management within catchments (or sub-catchments) are segments and reaches. When you draw a long-profile of a stream, you usually find either that the stream divides into logical segments based on slope (such as headwaters, valley, and floodplain), or that there are a few distinctive segments with their own set of slopes. These segments are then divided into reaches.

A *reach* is the basic stream management unit. It represents a length of stream with reasonably uniform characteristics. It can be seen as a unit of stream (with its riparian zone) subjected to a definable flow and sediment regime, that carries a characteristic set of geomorphic units (such as bars, channel width, bed material, etc.) (see Brierley, 1999) and a characteristic biological community (vegetation, macroinvertebrates, fish).

The reach can be defined on the basis of many criteria, including physiography, bed material, discharge, vegetation, biology (species present) etc. Reaches can also be defined in relation to point changes such as tributary junctions, dams, sewage treatment outlets, if these are important to your management objectives. Except in very large streams, a reach will seldom be longer than tens of kilometres. See Figure 3.2 for an example of how to divide a stream into segments and reaches, and *Catchment review*, in Natural channel design, Volume 2 for a detailed discussion of how to define reaches. The 'Index of Stream Condition' (DNRE 1997) also includes a good section on how to define reaches.

2.1.1 The catchment perspective: inputs into the reach from up and downstream

Using a reach-based description of a catchment does not fully encompass the condition of the catchment. Water quality is influenced by land use throughout the catchment, sedimentation is caused by erosion upstream (see Figure 3.4), a good reach can be threatened by a headcut migrating upstream, or depleted fish populations could be caused by a barrier downstream. However, the catchment context can be accommodated (Figure 3.3) by considering inputs to the reach that come:

- from upstream (water of a particular quality, seeds, sediment, etc.);
- laterally from the riparian zone (sediment, run-off, nutrients, large woody debris, etc.); and
- from downstream (erosion headcuts, barriers to fish passage).

You should keep this catchment perspective in mind while describing your stream in the following tasks.

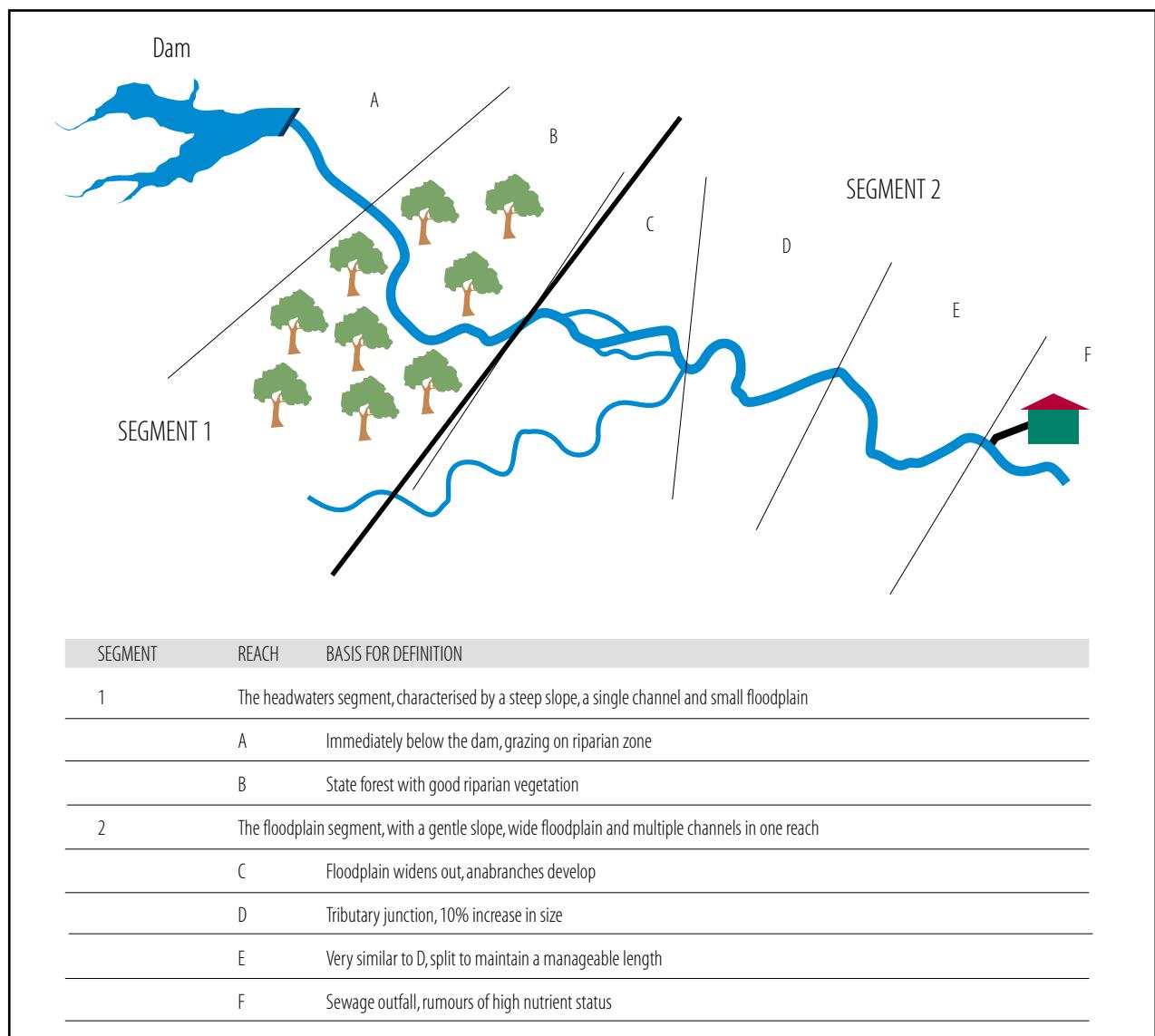


Figure 3.2. An example of how to divide a stream into segments and reaches.

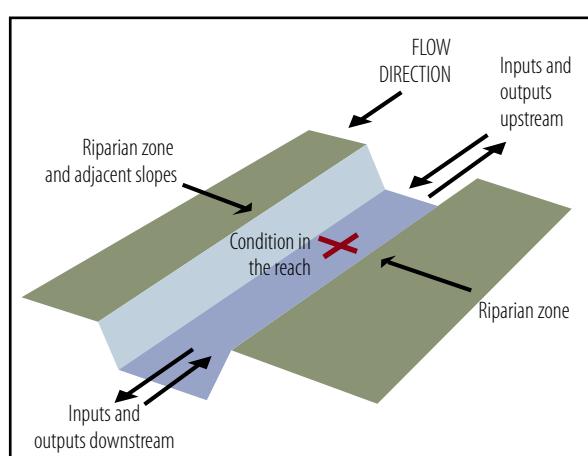


Figure 3.3. Sources of inputs and outputs to a stream reach. Identifying these will give you the catchment context of your reach.



Figure 3.4. Turbid water entering the Tarago River (Victoria) from its East Branch (on the right). The sediment has caused a water quality problem in a reservoir downstream.

2.2 TASK 2: Construct a template of what your stream should be like.

How do you assess the environmental condition of your stream? Stream managers tend to develop, in their minds, a picture of what the stream *should* look like. It should be this size, and have this type of vegetation, and this proportion of bare banks, and these fish species, etc. This picture has probably been built-up from all sorts of places, such as other streams that the manager has seen, from descriptions in old books, newspapers, and magazines, from descriptions of the stream by old-timers, from comparison with the next reach upstream that appears to be in good condition, and so on. The picture in the manager's head forms the template against which the stream is assessed. Here we simply formalise the development of the template so that it becomes clear to everybody what the target condition is.

Not only is it more accountable to have the template formally described, but it also means you will discover any faults in your template. For example, from your experience elsewhere you might have assumed that all streams should have a standard pool-riffle sequence, but after doing some work on a template for this stream, you discover that the stream was originally a chain-of-ponds and it never had true pools and riffles.

In Step 4 (What are your stream's main assets and problems), we define problems and assets in terms of how the present stream differs from the template. Thus, it is important to develop your template with care, because it is the cornerstone for the rehabilitation procedure.

Ideally, the template should be the original condition of the stream, since this is what our goal of rehabilitation relates to. However, given the difficulties of an accurate historical reconstruction (especially for variables such as water quality), the template will usually be based on a mix of:

- historical information;
- remnant features left in the field;
- comparable reaches that are still in good condition;
- empirical approaches (ie. comparison with large data sets of other streams); and
- generic models of 'good' streams.

For each source you should attempt to collect information on the following seven attributes.

1. The **diversity and populations of animals and plants**, as well as whole stream communities (eg. platypus, fish, macroinvertebrates, macrophytes): for example, “*we used to catch huge Bass here in the 1930s; this was a diverse wetland, and now it is just a muddy hole*”.
2. **Riparian vegetation**: diversity, structure (eg. forest or grassland), weed invasion, natural regeneration; for example “*all of the water gum were cut down by the turn of the century*”.
3. **Flow regime**: flow duration and magnitude, any regulation or water diversion; for example “*the creek used to take two days to peak, now it seems to take hours; there are hardly any big floods now because the dam takes all the water*”.
4. **Longitudinal connection along the river**: artificial barriers to movement of water, sediment and organisms along the stream; for example “*dams, diversions, weirs, willow encroachment*”.
5. **Lateral connections across the floodplain**: connection of the stream with the floodplain, including billabongs and anabranching channels. Things that change lateral connectivity include levees, channel enlargement, channellisation, changes to flow regime, blocked flood channels, connection with billabongs; for example “*The stream used to flood and fill those wetlands, but now a levee stops the flood waters, and the wetland is drained*”.
6. **Water quality**: turbidity, nutrients, oxygen, salinity, temperature, toxicants; for example “*we used to be able to see the bottom all year; in the great drought of 1890 the river became a chain of stinking green pools*”.
7. **Structural complexity and stability** in the channel: size of the channel, sediments, large woody debris; for example “*the deep pools filled with sand in the floods of the 1950s; the stream used to erode but at a slower rate*”.

Static versus dynamic assessment

Most assessments of stream condition can be described as 'static'. That is, they consider the condition at a point in time. It is much more useful if the assessment can be 'dynamic'. That is, it is also concerned with change over time. For example, bank erosion is often assessed on the basis of how 'raw' and bare the banks look. This may, in fact, be a poor indicator of erosion rates, and it is the rates that are of most interest. Thus, the most useful descriptions will allow some assessment of changes in condition over time. Such dynamic assessments are expensive and can be difficult to do, but they provide much more information.

2.2.1 Creating a template from historical information

Obvious sources of historical information are local landholders, aerial photographs, and historical descriptions. Other sources of information are described in *Catchment review* in Natural channel design in Volume 2. The great advantage of using historical data is the information that you can acquire on rates and direction of change in your stream, which will help you to understand the degradation processes taking place in the stream, as well as the processes of natural recovery. There are many examples of good studies that recreate the original condition of streams. Read, for example, Barry Starr's comprehensive report on the Numeralla River in the Murrumbidgee catchment (Starr, 1995).



Figure 3.5. A rare remnant pond in a chain-of-ponds in south-eastern NSW. Photo: Barry Starr.

Be careful of misdiagnosis

Landholders on the Snowy River believed that the bed was filling-up with sand since they diverted flow out of the river. In fact, the cross-sections have not changed much since regulation, it is just that there is less water so you can see more sand. If the stories about aggradation were taken on face-value, then the sand that was supposedly aggrading the bed would have been considered a threatening process.

You need to be careful when gathering historical information. A common mistake is to believe everything that you are told!

In your investigations you will be told all sorts of things have changed in the stream, or are happening in the stream. Such anecdotal information can be invaluable, but it should also be verified by independent evidence if at all possible. Finlayson and Brizga (1995) note examples of 'myths' about stream systems that have been perpetuated for many years.

The two questions to ask in verifying anecdotes are:

- is the trend that people describe real?
- is the cause that people blame correct?

Thus, you need to attach a level of confidence to the problems that you identify before spending vast amounts of time and money trying to fix them. This can be a very time-consuming task.

2.2.2 Creating a template from field remnants

It may be possible to reconstruct a great deal about the original stream from clues left around the present channel. Remnants of the original vegetation communities will usually survive along a stream, and it may be possible to piece these together to reconstruct what was there. Where a stream has been channellised and straightened, it is common to find pieces of the original channel preserved on the floodplain.

In many areas, community groups, Greening Australia, or government departments have attempted to reconstruct the local native vegetation from the fragments that remain. These efforts include, for example, the remarkable species lists developed for northern NSW streams by the NSW Department of Land and Water Conservation (eg. Raine and Gardiner 1997).

2.2.3 Creating a template with information from a comparable reach in good condition

You can create a template from remnants around the target reach, including remnants of the old channel, or remnants of vegetation (Figure 3.6). You can also create a template using a more complete remnant of a stream elsewhere in the catchment, or in a nearby catchment. The critical thing to remember when using templates developed further away from the target site is that you will probably have to ‘scale’ the template. That is, if the nearby reach has a different catchment area, then the dimensions and characteristics of the channel will need to be scaled up or down to be relevant to the target reach. Newbury and Gaboury (1993) provide detailed methods for describing nearby reaches, and also for scaling the dimensions of the nearby reach to the target reach. That is, streams tend to increase in size in a regular way as catchment size increases. So, if you know the rate at which a natural channel would change downstream, then you can take the dimensions of the template reach and adjust them for the difference in catchment area between the target and template reaches. These methods, as well as guidelines for selecting nearby reaches, are discussed in more detail in *Natural channel design*, Volume 2.

2.2.4 Creating a template by using empirical relationships

We noted in the preceding section (Creating a template from a comparable reach) that characteristics of the reach must be scaled for use in other sections of the stream. Extending this approach, it is possible to take a large sample of streams in good condition and measure a variable (such as suspended sediment, width, area, bed-material size, macroinvertebrate diversity, etc.) that can then be statistically correlated against an independent variable such as catchment area and discharge. The resulting relationship can be used to estimate what the value of a given variable *should be* in your target reach. It is important to note that such relations are accurate only for the stream type used to develop them. Here are some examples of this type of empirical template:

- Raine and Gardiner (1995) use an empirical relationship between stable channel morphology (particularly width) and catchment area to determine whether a specific stream is too wide or narrow. The relationship can be adjusted for vegetated or unvegetated banks. Such relationships can be developed for a region.



Figure 3.6. (a) a reach in poor condition, and (b) a nearby reach on the same stream that could be a potential template for the rehabilitation of the reach in poor condition.

- The AUSRIVAS water quality system uses statistical analysis of very large data sets from reference sites (ie. sites in good condition) to relate the composition of macroinvertebrate communities to habitat variables (such as altitude and substrate type). This means that you can then go to another site and see how the macroinvertebrate community compares with the predicted composition. If it is worse, it implies that something in your stream, such as water quality, is not right.

2.2.5 Creating a template using general models of condition

If you cannot find enough historical information, or you cannot use an empirical assessment, then a cruder way to reconstruct what the original stream should have been like is to use a general ‘healthy river model’. Thus, you would assume that a healthy river would have continuous riparian vegetation, low turbidity, an unregulated flow regime, and so on. If your stream does not have these characteristics, then it can be classified as being in poor condition.

A good example of this generic type of approach is the ‘Index of Stream Condition’ (DNRE, 1997). Definitions of condition in this approach are based on generic measures of what constitutes a good or bad condition for most Victorian streams. Thus, phosphorus concentration in a mountain stream in Victoria above 40 mg/m³ is considered to be rating zero (the worst of 5 ratings). Structural intactness of riparian vegetation is classified as continuous, patchy, and sparse, with continuous being best. By measuring all of these variables the condition of a stream can be compared with a hypothetical ‘ideal’ stream.

We provide a summary of water quality parameters that are considered biologically relevant in *Water quality problems*, in Common stream problems, Volume 2 . These can be considered to be ‘thresholds of concern’ for your template. If a water quality variable exceeds the threshold, then it can be considered unnaturally high.

2.3 Combining the results from the five methods to create a final template

We have described five related approaches that you can use to create a template of your stream reach. Your final template will be an amalgam of all of these methods. The way to create the template is to try to put a description of the original condition next to each of the characteristics in the following list.

- Animals and plants
- Riparian vegetation
- Flow regime
- Connection along the stream
- Connection with the floodplain
- Water quality
- Structural complexity and stability.

Under water quality, for example, you might write the following:

“Farmer Smith recalls the stream being clear at low flow in the 1930s. A comparable stream over the divide from the target reach is in forested stream and has low turbidity and pollution levels. Trigger points for concern about turbidity would be 30 NTU, and this level is often exceeded in the target stream.”

For connection with the floodplain:

“There are no gauge records, but Farmer Brown remembers the flood of 1931 covering the entire valley before the levees were built. A comparable reach across the hills with no levees is flooded a few times a year. Empirical relationships suggest that the stream should flood every year or two”.

These descriptions form the template for the natural stream. The condition of the present stream can then be compared with the list of features in the template in order to identify assets and problems. See the Mythic Creek example below for a full example of this procedure.

Creating templates for different stream types

It will be easier to develop templates for some stream types than others. The floodplains of most large streams have usually been developed for agriculture and other human activities. Larger streams also accumulate the effects of disturbance across large areas. By contrast, there are many more kilometres of small stream than large stream and so there is a greater chance of finding intact remnants for comparison. For this reason, the larger the stream the harder it is to find remnant templates, and the more likely it is that you will have to rely on historical reconstructions and generic models of condition in developing your template.

2.4 TASK 3: Describe the present condition of your stream.

2.4.1 Methods for describing the stream

In this task you compare the present condition of the stream reaches with the list of characteristics developed for the template. You can, of course, make this comparison in as much detail as you want. You could also use one of the existing stream condition assessment tools to make the comparison. They are discussed in more detail in *Catchment review*, in Natural channel design, Volume 2. None of these methods provides a full comparison with a detailed template, but they will be able to provide information for the comparison.

The methods available include the ‘Index of Stream Condition’ (DNRE 1997), the Brierley ‘catchment characterisation’ or ‘river styles’ approach (targeted at sediment problems) (Brierley *et al.* 1996), the Anderson ‘State of the Rivers’ system (Anderson 1993); the NSW ‘Rivercare’ approach (Raine and Gardiner 1995), and several others. There are other international methods such as the stream classification approach of Rosgen (1996), and the method of Newbury and Gaboury (1993). The Brierley and Rosgen methods attempt to predict the trajectory of your stream—that is, how the stream will improve or deteriorate if you do nothing.

In addition, there are various techniques available to describe macroinvertebrate populations, such as AUSRIVA’s and the ‘signal index’. These can be very useful for identifying water quality problems.

We recommend applying one of the Australian procedures to your stream in order to complete the first part of this step.

- If you want to produce a quick comparison between the condition of catchments (such as your template reach and your present reach), then use the ‘Index of Stream Condition’ (DNRE 1997). Importantly, this procedure assesses water quality and changes to flow regime. This method was developed for Victoria.
- If you want to assess stream stability in a small to medium-sized catchment, then use the Brierley catchment characterisation procedure. This method emphasises the recovery of stream systems following disturbance by major episodes of erosion, and is the only method that actively includes interaction *between*

stream reaches in the catchment (see also *Common stream problems* in Volume 2).

- If you are working on streams on the northern NSW coast, then consider the Rivercare methodology. This method uses channel shape, channel alignment, and particularly channel vegetation to assess stream condition. The approach is particularly strong on vegetation management.
- If you want a detailed general description of the condition of your stream, then consider the Anderson ‘State of the Rivers’ approach. This method produces large amounts of detailed information.

We stress that none of these methods will provide enough information to do a complete comparison between the template and present condition (eg. most do not consider animals in the reach).

It is important to stress that all of the above techniques have been developed with broader goals in mind than stream rehabilitation alone. So we are not suggesting that you will have to do more work than these methods describe. Instead you may have to use parts of each approach.

2.4.2 Collect information on known conservation values

At this point you should collect as much information as possible on any high-conservation assets associated with the stream. Examples would be remnant populations of rare animals or plants. (See Identifying valuable reaches in Volume 2).

Some will be common (eg. another forested riparian zone in a large forest full of vegetated streams). Others will be rare (eg. the last remaining habitat of the grunting frog, or the last reach of stream in the region that has not been damaged by sand slugs). State government agencies (eg. the Victorian Herbarium and the Department of Environment) often have databases of the rare plant species. Also, if there have been biological surveys of your stream, you can check species lists against lists of known rare species. It is also possible to search the Australian Heritage Commission’s Register of the National Estate to check for sites of national significance that may be relevant to your stream. It is important to note that ‘rare’ reaches do not necessarily have to have been classified as rare by others. You might note that this appears to be the last stream of its type in the region, then call it a high conservation value asset.



Figure 3.7. A salt affected stream in south-western Western Australia

These high value (rare) assets may be recognised by formal surveys, or you could allocate value by your local experience. Assets can be classified as having national significance (eg. the Baw Baw frog is found only in a few small streams on the Baw Baw plateau of Victoria), regional significance, or local significance.

3 Summary

Summary of tasks to identify how your stream has changed

At this stage, you have completed the following four tasks:

Task 1. Break the stream into segments and reaches.

Task 2. Develop a template of what the stream should look like (used to look like), based on five methods

- historical information;
- remnant features left in the field;
- comparable reaches that are still in good condition;
- empirical approaches (ie. comparison with large data sets of other streams); and
- generic models of 'good' streams.

You will be describing seven variables: animals and plants; vegetation; flow; connection along the stream; connection across the floodplain; water quality; and structural complexity.

Task 3. Describe the present condition of your stream using the same seven variables as were identified in the template (Task 2).

Task 4. Present your results on an annotated map.

Discovering conservation assets

- A check of State databases might reveal that the lower reaches of a small saline creek in WA (Figure 3.7) support an endemic frog.
- A talk with the local conservation agency reveals that an overflow from the creek in western Queensland feeds a wetland several kilometres away that supports one of the largest water bird populations in the region. Road culverts upstream of the effluent are diverting water in another direction and so drying-out the wetland.

2.5 TASK 4: Record everything and produce a map

At this stage you should produce a map of the stream showing segments and reaches, with annotations about the condition of each reach. Good approaches to this type of mapping are provided in the Rivercare approach (Raine and Gardiner 1995), and in Newbury and Gaboury (1993).

4 An example of the procedure: describing the condition of Durben Creek

Like Mythic Creek, Durben Creek is a hypothetical stream that we will use to illustrate the rehabilitation procedure. Durben Creek is an ephemeral stream 40 km long with a catchment area of 130 km^2 . It rises on gentle basalt hills before flowing into the urban area of a large city (south of Edge Road, Figure 3.8). The lower portion of the river passes through a gorge before joining the larger Drain River. There is considerable interest in rehabilitating the creek from organisations along its length.

Task 2: Construct a template of the original condition.

The condition of the creek was assessed using the following methods.

- The original morphology of the stream was reconstructed from old aerial photographs, and historical descriptions. Compared the morphology

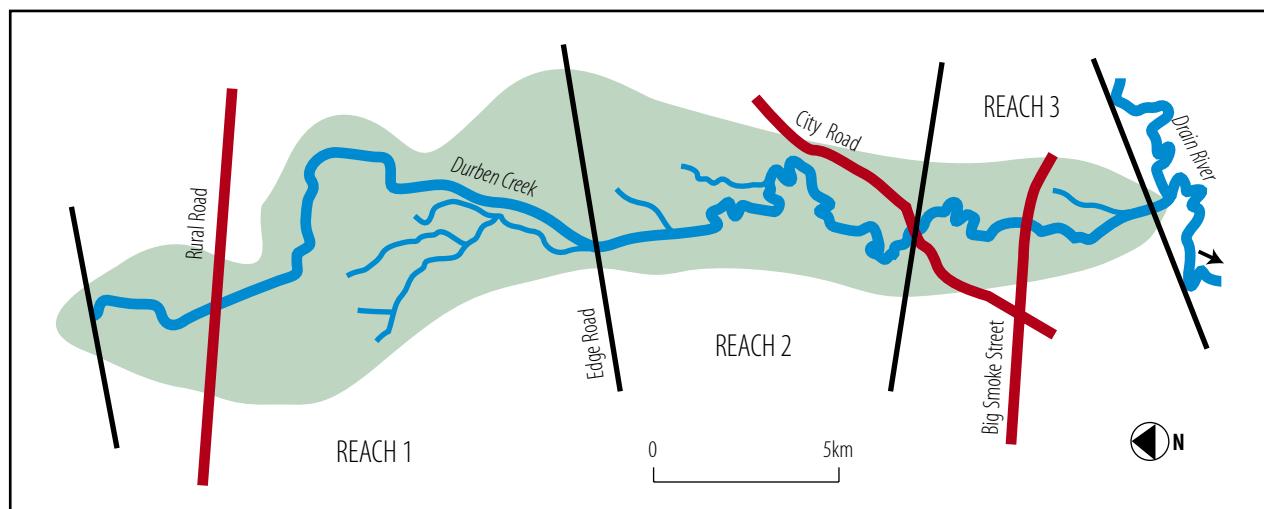


Figure 3.8. Schematic map of Durben Creek showing the reaches defined in the text.

Task 1: Divide the stream into reaches.

The stream was divided into three reaches (Figures 3.8 and 3.9): the upper, rural reach; a middle, urban reach; and the lower gorge reach through the city to the Drain River.



Figure 3.9a, b & c. Examples of the three reaches of Durben Creek.

(a = Reach 1, b = Reach 2, c = Reach 3)

- with a short upstream reach that retained its original morphology (but not vegetation). Scaled the morphology of the upstream reach to the target reaches downstream. Compared the vegetation and morphology with a similar creek nearby that remains in fair condition.
- Water quality was assessed by comparing sampled water with national standards, and also by a macroinvertebrate survey using a SIGNAL index (see *Bioassessment* in Catchment review, Volume 2).
- Task 3: Describe the present condition.**
- Remember, we are supposed to assess for the following features:
- animals and plants
 - riparian vegetation
 - flow regime
 - connection along the stream
 - connection with the floodplain
 - water quality
 - structural complexity and stability
- Reach 1 (Figure 3.8) is completely cleared and grazed; the middle reach (2) has been channelised; and the lower reach (the Durben Gorge) (Reach 3) is modified, but not channelised.
- ## 5 Describing the condition of Mythic Creek
-
- Task 1: Define segments and reaches.**
- The creek has been divided into five reaches (Figure 3.10): the predominantly granite North Branch, which has been only partly cleared (Reach 1a); the sedimentary South Branch, which has been extensively cleared, and has incised (Reach 1b); Reach 2, from the confluence of the North and South Branches to the beginning of the Gorge section; Reach 3, which is the Gorge; and Reach 4, from the bottom of the Gorge to the confluence with the major river downstream. Reach 4 is a channelised stream on a low-gradient floodplain.
- Task 2: Construct a template of what the stream should be like.**
- We need to consider each of the following seven variables for each of the five reaches.
- animals and plants
 - riparian vegetation
 - flow regime
 - connection along the stream
 - connection with the floodplain
 - water quality
 - structural complexity and stability
- See Figure 3.10 for a comparison of the template condition with the present condition for these variables. Information for the map came mostly from historical studies, and discussions with landholders. Early maps could verify the condition of reach 4, as could remnants of the old pre-channelisation channel preserved on the floodplain. Reach 1a appears to be in close-to-template condition.
- Task 3: Describe the present condition of the stream.**
- The ‘Index of Stream Condition’ (DNRE, 1997) was used as a rough guide for what should be measured in a description of a stream (with the exception of macroinvertebrates, as no one in the group had the expertise or time to survey these). However, the Landcare group stopped at the description stage, rather than using the ratings supplied in the Index. This was because they intended to compare this description to the original condition, rather than accept the generalised guidelines provided by the Index.

5.1.4 Task 4: Describe the stream and produce a map.

REACH 4	3	2	1A	1B
<p>TEMPLATE</p> <p>The Fenciful River</p> <p>Track crossing</p> <p>Falls</p> <p>2 km</p>	<p>1. Stream fringed with macrophytes. Four species of fish present. 2. Riparian vegetation is a dense redgum forest. 3. Natural flow regime. The annual flood inundates the floodplain for 2-3 weeks. 4&5. Good connectivity between the channel and floodplain. 6. Water quality was probably good - there appears no obvious reason for this not to be the case. 7. Stable channel, providing complex habitat including deep pools, undercut banks, woody debris, variation in substrate and hydraulics, macrophytes and riparian vegetation.</p>	<p>1. Lots of macrophytes present. Probably only 1 species of fish present above the falls. 2. Dense redgum on the floodplain. 3. Natural flow regime. 4&5. Connectivity with the floodplain is good. 6. Good water quality 7. Stable and complex channel, similar to reach 4, with the addition of riffles with large bed material.</p>	<p>1. Lots of macrophytes present. Probably only 1 species of fish present. 2. Riparian woodland. 3. Natural flow regime. 4&5. Connectivity with the floodplain is good. 6. Good water quality 7. Stable and complex channel, similar to reach 4.</p>	<p>1. Some macrophytes present. Probably only 1 species of fish present. 2. Riparian woodland, merging into the forest of the valley slopes. 3. Natural flow regime, smaller tributaries are ephemeral. 4&5. Connectivity with the floodplain is good. 6. Good water quality 7. Stable and complex channel, with pools, riffle, macrophytes, woody debris, hydraulic and substrate variation, and undercutts.</p>
<p>PRESENT CONDITION</p>	<p>1. Very few macrophytes remain, but some filamentous algae grow in shallow, slow flowing areas. Only 1 species of fish is present above the culvert. Cattle now graze the stream banks and wade in the stream to drink. 2. Riparian trees all cleared. Banks entirely covered with grassy weeds. 3. Flow regime is more or less natural, but floods pass more quickly through the channelised reach. Also, the dam proposed for reach 1A will impact on flow. 4&5. The more efficient channel, and levees along most of this reach mean the flood plain is rarely inundated, perhaps only every few years. 6. Moderately high nutrient and turbidity loads. 7. Stable channel, but a few areas of bank seem to be eroding. Very low complexity due to channelisation.</p>	<p>1. Some macrophytes present in pools. One species of fish present in low numbers. Cattle graze in and around the stream. 2. A narrow band of redgum lines the stream banks with the occasional willow and patches of blackberry. 3. Natural flow regime (but see reach 1A). 4&5. Connection with the flood plain is good (the gorge means the floodplain is very small). 6. Moderate turbidity and nutrient loads. 7. Stable and complex channel, possibly very similar to original condition. Some desnagging has occurred, and pools seem shallow.</p>	<p>1. Macrophytes and some slimy algae present in pools. One species of fish, in very low numbers. Cattle have access to the stream. 2. Riparian zone dominated by weeds, retains very few trees. 3. Natural flow regime (but see reach 1A). 4&5. Good connection with the floodplain. 6. Moderately high turbidity and nutrient loads. 7. Channel unstable in some areas, with actively eroding banks. Habitat complexity is relatively low. The reach has been desnagged, bank slumping has destroyed any undercutts most pools are only shallow and the substrate seems uniformly fine.</p>	<p>1. Macrophytes are still common around shallower portions of the pools. One species of fish is present. Cattle are grazed in the catchment, and have access to the stream. 2. Some weeds have invaded the riparian zone which is largely intact. 3. Natural flow regime. However, a dam is planned for this reach, which would be a severe disruption to the flow regime. 4&5. Good connection with the floodplain. 6. Water quality is still good. Turbidity and nutrients seem slightly elevated. 7. The channel is stable, and probably quite similar to the original condition.</p>

Figure 3.10. Map of Mythic Creek, noting the template condition and the present condition. The numbers in each column refer to the seven stream attributes to be compared: (1) animals and plants, (2) riparian vegetation, (3) flow regime, (4&5) flow connection, (6) water quality and (7) geomorphic stability and in-channel complexity.

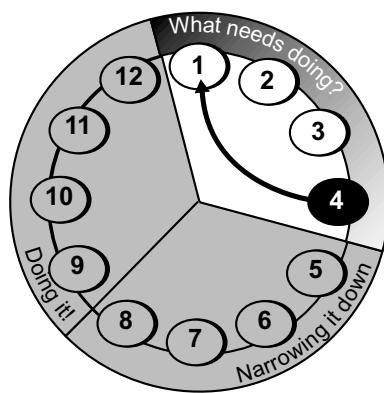
6 Reality Check

There is no reality check tasks at this point because Step 3 has only collated information. Even if you cannot find much information for the stream, the generic tools provide some assessment of condition.

Step 4:

What are the stream's main natural assets and problems?

AIM: by the end of this step you should have identified the remaining natural assets of the stream, as well as the degraded assets. You will then identify the problems that are degrading those assets.



When the government department compared the present condition of a stream with the template, they identified some important assets that needed protection, and the processes that were threatening those natural assets. For example, some of the last remaining wetland habitat of the swooping crane (a rare bird) is threatened by drainage from surrounding cotton developments. They were surprised to find, in the lowland portion of the catchment, a good quality remnant reach that still had good vegetation and channel form.

1 Introduction

In this step, you will assess the condition of your stream. This assessment is done by comparing the condition of the present stream with a ‘model’ condition (here called a ‘template’) that you developed in Step 3. Where some aspect of your stream is similar to the template (eg. water quality that is better than national standards, or original reed communities in the bed) then that ‘component’ of the stream is described as an asset (eg. Figure 4.1a). A reach of stream may contain many components that are assets, so that the entire reach becomes an asset in its own right. Often the original assets of the stream have been degraded. You also have to identify the processes that are degrading or threatening the stream’s assets (these processes are loosely defined here as ‘problems’) (eg. Figure 4.1b). Further, at the end of this step you should have identified the trajectory of the assets: is their condition getting better or worse? The procedure described above is broken down into four tasks (Figure 2). Techniques to help with these steps are described in more detail in *Natural channel design*, in Volume 2.

Stream managers have traditionally concentrated on identifying **problems** and **damage**. When stream managers want to rehabilitate a stream they should concentrate on identifying, preserving, improving and creating **natural assets** in streams. This is a fundamental change in perspective.

Key points for identifying assets in your stream:

- Identifying, protecting, improving and creating natural assets is the key task of stream rehabilitation.
- Assets are identified by comparing the present stream with the template stream (developed in Step 3).
- Assets are defined as elements of the present stream that are similar to the template.
- Some assets can also be artificially created.
- Problems are the processes that degrade or threaten assets (eg. pollution or clearing vegetation).
- We identify two questions that you can ask to identify problems, and three types of errors that you can make in identifying problems.
- The final task is to assess the trajectory of the assets and problems that you have identified. Will they improve if you do nothing?



Figure 4.1. (a) An *asset* of this reach is the dense riparian vegetation on the far bank. This vegetation will soon recover from the recent major flood. However, the sand slug (b) just downstream of the vegetated site (a) is likely to be a *problem* if it threatens assets downstream.

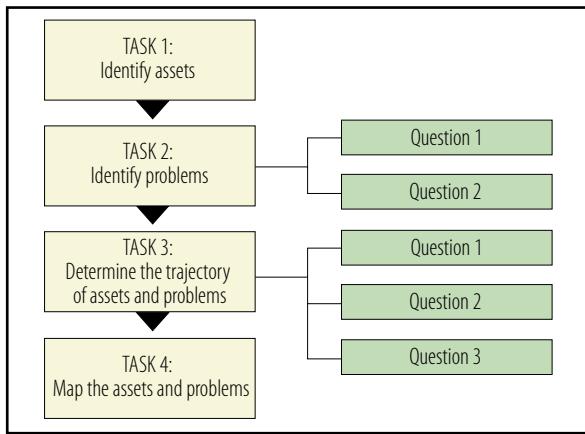


Figure 4.2. A procedure for identifying the problems in your stream.

Do not expect to find all of the answers in this manual...

One of the central problems facing stream managers is identifying why a particular asset has been degraded. You might know that the diversity of fish species in a stream has declined over the years. The real challenge is to know why it has. You might know that the gravel bed has filled-up with fine sediment, but there might be argument about where that sediment came from.

Knowing why an asset is being degraded is, of course, central to effective rehabilitation. There is no point restocking fish species into a reach if you do not know why the natural stocks declined.

It is important to emphasise that this manual cannot provide enough information for you to diagnose your problem or what caused it. Even after decades of intensive research and years of experience, people often misdiagnose the underlying cause of degradation in streams. It is dangerous to imagine that any manual such as this one, or any classification system, can provide the information required to diagnose the underlying causes of many problems in streams. You may well require the assistance of a professional stream ecologist, engineer, geomorphologist, botanist, etc. After all, if somebody was really sick, you would consider it foolhardy to consult a general medical manual. You would go to a doctor, often a specialist, for help. This manual can provide at most some generic assistance with the most typical erosion and water quality problems (see Volume 2).

1.1 TASK 1: Identify assets.

Identifying assets and problems is a matter of comparing your template (described in Step 3), with the present condition. As you do so you will find assets. These are characteristics of the stream that resemble the template. These assets can be entire reaches (eg. a reach that is still in close-to-natural condition), or they can be elements within a reach (eg. good stands of macrophytes or deep pools that remain in an otherwise degraded reach).

In Step 3 the rarity of assets was identified. This will identify the relative value of each asset. Some will be common (eg. another forested riparian zone in a large forest full of vegetated streams). Others will be rare (eg. the last remaining habitat of the grunting frog, or the last reach of stream in the region that has not been damaged by sand slugs). Rarity is important in Step 5 when we begin to set priorities.

1.1.1 Created assets

What happens when you compare the condition of a reach with the template and it is very different, but still provides environmental value? For example, trout cod were artificially introduced into Victoria's Seven Creeks system. The species is now endangered throughout Australia, and Seven Creeks holds one of the most important remaining populations. Because the fish were not naturally found in the stream systems, they would not be defined as an asset. However, because of their obvious importance for biodiversity, the introduced fish could be called a high value *created asset*.

Another example is Mathers Creek in western Victoria. Sand has filled this former meandering stream so that it is now a series of long pools and wetlands. The wetland now supports a tremendously diverse community of plants and animals in comparison to other streams in the region that have not been filled with sand, but have been damaged by clearing and grazing. Mathers Creek is now too swampy for much grazing and is an important regional asset.

Created assets will often require as much protection as natural assets, but natural assets would usually get precedence.

1.2 TASK 2: Identify the problems.

1.2.1 Identify the degrading and threatening processes

A problem is the threatening or degrading process that is having an impact on the assets (eg. changed flow regime, bed incision, exotic fish, etc.), and these are identified in Task 2.

In this task you have to identify what is damaging the asset. If you again compare your template list and your present condition list, you will note that there are numerous changes that could have led to the deterioration of the assets. Fish could have declined because of water quality, flow regulation, lack of shade and cover, loss of habitat, loss of access to the floodplain, and so on. As we mentioned earlier, we cannot provide much help in identifying the causes of degradation of assets, but we make two suggestions for questions that you can ask in order to identify the most important threat to an asset.

Common Stream Problems

At this point it may be useful to browse the *Common stream problems* section of Volume 2. These provide some summaries of typical degrading processes.

1.2.2 Question one: Does experience or knowledge of the problem suggest a likely cause?

Animals or plants can be absent from a stream for three reasons. First, there may be a requirement of day-to-day life that is, for at least some of the time, missing from the stream; second, plants and animals are unable to (or have not yet) migrated into the reach; third, individuals are not managing to produce sufficient offspring to maintain the population (some element that is essential for the life cycle is missing). Ideally, we would know enough of the requirements of any species to be able to pinpoint what was lacking from an environment. Unfortunately, the day-to-day life-cycle requirements of most organisms are poorly understood. For example, we may not know what triggers spawning in fish, or what happens to particular macroinvertebrates at certain salinities. However, there is often enough known about the kind of impacts that cause problems for different types of organisms to narrow down

which of the many changes to the stream may be important. *Common stream problems*, in Volume 2, offers some advice on some common problems, including when water quality may be a problem. You may be able to pinpoint specific problems, such as very bad water quality during summer, or a culvert blocking fish migrations (such as that in Figure 4.3). If you are able to form such a theory as to the cause of a stream problem, the next step is to use Question 2, below, to check that your theory makes sense. Question 2 will help, even if you have been unable to form such theories.

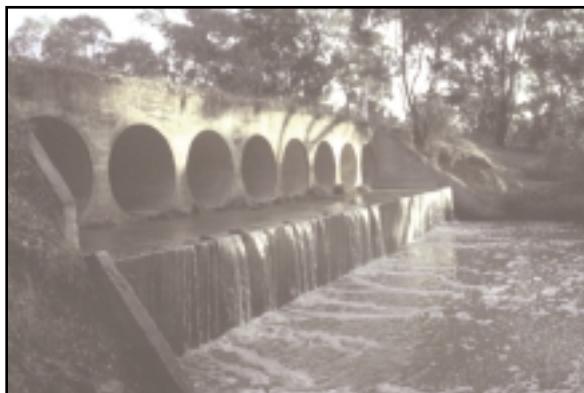


Figure 4.3. A culvert that could pose a barrier to fish passage.

1.2.3 Question two: Are there clues to the problems in the distribution of organisms?

The distribution of a plant or animal is largely driven by the availability of suitable conditions—that is, the *lack* of problems. By comparing a reach where you can find an animal or plant, with a reach where it is absent, you may be able to deduce the problem that has caused that distribution. For example, check if there is a difference in organisms above and below a point source of pollution. Look at existing riffles to see if artificial ones could increase species diversity. If, from Question 1, you have a theory as to what were the important problems, Question 2 may be able to test that theory.

There is one important limit to this technique. Accessibility will also restrict distribution, for example, a fish species may be absent from your reach, not because of bad water quality, or a lack of habitat, but because it is absent from the entire catchment. Before you conclude anything from the distribution of a species, you should make sure it can actually get to both of the areas that you compare.

Some examples of identifying problems:

The Murrumbidgee River in the ACT is a good example of using existing remnants to identify real problems. The river is slowly transporting a large slug of sand. Fishermen will tell you that you will find native fish in the few remaining pools, but most of the stream is a featureless sheet of sand. That fish are present in the reach shows water quality is not the important problem. They have access to the whole reach, but are usually found in the pools. This suggests the absence of pools is the problem causing the fish to be absent from the rest of the reach.

Another example is on the Yarra River in Victoria. The richness of macro-invertebrate communities increases whenever the banks have good riparian vegetation, and where the bed is a coarser substrate (eg. Figure 4.4). By contrast, wherever the banks are covered in willows, and the bed and banks are mud, the macro-invertebrate diversity plummets (Tim Doeg, personal communication). This pattern suggests either that native riparian vegetation provides good habitat, or that willows are poor habitat.



Figure 4.4. A psephenid beetle larvae, one of the many species of invertebrates you might find on a coarser substrate, but not in the mud that deposits under willows. (© Gooderham and Tsyrlin)

1.2.4 Errors to beware of when identifying problems ...

While considering the stream's assets and problems, you should bear in mind the more common ways to make mistakes. There are four types of error that are typically made.

Type 1: Identifying as a problem something that is actually a natural attribute of the stream (eg. a naturally sandy stream with a low diversity of macroinvertebrates).

Type 2: Wasting time treating problems that would have fixed themselves with time (eg. the stream would eventually have stabilised and developed structural complexity).

Type 3: Treating something that is not actually a real, threatening problem for the plants and animals in your stream (eg. putting great effort into reducing turbidity when it is not actually causing problems).

Type 4: Identifying the wrong problem (eg. a Landcare group clears trees from a river bank because they blame them for causing bank slumping, when really the stream bed is deepening, causing the banks to collapse despite the trees).

Reading this manual will not stop you from making these errors, which are frequently caused by the fact that often we simply do not yet know enough about aquatic systems to get the diagnosis right. However, having stressed the complexity of the issues, the problems in your stream could often be pretty obvious.

1.3 TASK 3: Determine the trajectories of your assets and problems.

Over time, the condition of a reach, individual asset or problem, can improve, stay the same, or deteriorate. Considering how both the assets and problems of your stream will develop in the future is an essential exercise for any management strategy. Such information will be invaluable when you come to consider what assets might need protecting, how to speed the recovery of an asset, or if the natural rate of recovery is satisfactory and there is no need for intervention at all. It is the trajectory of the assets and problems which is of interest to us. The section *Disturbance and recovery in streams* in the Stream rehabilitation concepts of this volume, provides some conceptual information for predicting recovery rates.

There are three questions to ask yourself when determining the trajectories of your problems and assets.

1. How has the asset or problem developed over time?

By looking at a series of historical records such as air photos, or repeated biological or physical surveys, you can see how problems have developed. For example, you might find that the catchment and riparian zone has been cleared since the 1940s. Similarly, records of the biological condition of the stream, such as fish catches, may show the population of a certain fish (an asset) has been steadily declining for some years.

2. **Will the problem change in the future?** Problems will change over time through the natural recovery of the stream, or through changes in stream management (Table 4.1). Gully erosion is a good example of the first situation. As discussed in *Recovery of disturbed stream systems* in the Stream rehabilitation concepts section of this volume, gullies have a predictable recovery path. The condition at first gets worse as the headcut moves upstream, producing large quantities of sediment. Eventually, the gully will stabilise, and the problem will improve. Understanding these changes in the trajectory of the problem could be very important if you were attempting to manage a sediment sensitive ecosystem downstream of a gully.
- Changes in management can also change the trajectory of a problem. For example, plans to build a dam mean the creation of all the impacts associated with construction and presence of the dam. Alternatively, changes in farming practise from cropping to grazing may reduce the need for levees on the stream banks, allowing greater connectivity with the floodplain and better access to nursery habitat for fish.
3. **How will assets respond to problems that are stable?** There are many situations where the impacts on our streams are quite stable. A dam that blocks fish passage is a good example of this. Once in place, the effect is the same year after year. A riparian zone that is regularly grazed is another example. However, the degradation of assets that is caused by these problems, may *not* have a stable trajectory. Although the fish barrier has been in place for some years, the fish population may still be in gradual decline. Eventually, when the fish species is extinct above the dam, the asset (the fish population) will also have a stable trajectory. Although the grazing pressure (the problem) is the same each year, the seed stored in the soil is dying, so the ability to regenerate naturally (the asset) is in decline. But if grazing had continued for many years, there would be no seed left in the soil, in which case, the asset, as well as the problem, would have a stable trajectory.

1.4 TASK 4: Map the assets and problems.

Update the map produced in Step 3 to include descriptions of the assets and problems. See the Mythic Creek map on page 106 as an example.

Table 4.1. Examples of recovery or deterioration of stream problems

Problem	Example of recovery or deterioration
A barrier across the stream prevents bass from migrating.	Bass can live for over 20 years, so fishermen may not notice a decline in populations for some years. They may notice that they only catch mature fish! This problem will not fix itself, and will get worse.
Seeding willows have been found in a stream reach.	The willows will spread by seed and the impact on riparian vegetation will become exponentially more difficult to control. Native riparian vegetation will continue to decline.
Stream bed is scouring due to clear-water releases from a dam.	There is plenty of gravel available from tributaries below the dam, so it is likely that the bed will armour and scour will cease.
Rising nutrient levels appear to have eliminated many species in a small stream.	There is good potential for recovery of populations because of good remnant populations up and downstream of the impact area. Nutrients are coming from a few dairy sheds, so there is a good chance of controlling the source. However, nutrients are stored in the sediments, so it will take several years to cycle this nutrient through.
The stream has widened and deepened dramatically following channelisation. The stream is now a sterile clay channel.	The stream will progressively stabilise over decades and develop new complexity in the bed.

2 Summary

So, at this stage, you will have a map showing segments and reaches of your stream, with descriptions of the assets and problems in each reach. You will have established if the changes over time are real, and will be fairly confident that if you know what problems have caused them. For each

problem, you will have thought about what will happen if you do nothing, and what is the minimum that you can do to accelerate recovery. Now you are ready to start setting priorities for action, but first consider these case studies that illustrate how to define problems and assets.

Summary questions for identifying problems and assets

- Have you compared the present condition of the stream with the template in order to identify assets (aspects of the stream that are similar to the template) and problems (different to the template).
- Have you been able to verify that any anecdotal changes are real?
- Have you questioned your theories as to what problems are affecting your stream assets?
- What is the trajectory of the assets that you have identified? Will they improve or degrade if you do not do anything?
- Have you produced a map of the problems and assets?
- Is the stream similar to one of the *Common stream problems* described in Volume 2?

3 An example of the procedure: identifying assets and problems in Durben Creek

Assets and problems in Durben Creek are shown in Table 4.2.

Table 4.2. Assets and problems in the three reaches of Durben Creek.

(Note that the symbols in the trajectory column mean the following: + improving, = stable condition, - deteriorating).

Reach	Task 1a Identify assets (from comparison with template)	Task 1b Identify degraded assets	Task 2 Identify problems	Task 3 Assess trajectory (+,=,-)
Rural headwaters (Reach 1)	Almost original structure and morphology	Riparian vegetation partly cleared and invaded by weeds Low macroinvertebrate diversity	<ul style="list-style-type: none">Poor water qualityGrazingLack of regeneration of riparian treesWeed invasionHydraulic changes?	= = - - =
Urban mid reach (Reach 2)	Some structural value from scour and erosion of pools and riffles	Very poor macroinvertebrate diversity Riparian vegetation largely cleared (although some revegetation has occurred)	<ul style="list-style-type: none">ChannelisedLow morphological complexity (therefore low habitat diversity) because of channellisationVery poor water qualityContaminated substrateWeedsVery flashy floods	= + - =
Downstream gorge (Reach 3)	Original structural complexity In places, good riparian vegetation	Poor macroinvertebrate populations and diversity	<ul style="list-style-type: none">Very poor water qualitySubstrate contaminated by pollutantsWeeds in riparian vegetationLack of natural regeneration of riparian vegetation	- =

Note that most problems are stable, but some are improving (eg. channel complexity). Also, the assets in each reach were assessed for 'rarity'. The rural reach is the closest to having some rarity value because such unconfined basalt streams in good condition are rare. Reach 1 has some interesting sections that preserve the original chain-of-ponds morphology.

4 Identifying problems on Mythic Creek

4.1 TASKS 1 AND 2: Identify assets and problems.

A comparison of the template and present conditions shown in the map of Mythic Creek (Figure 3.10 at the end of the previous step) revealed the assets and problems shown in Figure 4.5, along with the major problems identified. For example, the widespread reduction in macrophyte density can be attributed to cattle grazing and trampling. The cattle can be seen eating some plants (*Question 1*), and these are found in much greater density in reach 1a where cattle numbers are lower (*Question 2*). The piggery effluent is considered the main source of nutrient pollution, because of the presence of nuisance algae only downstream of the outfall (*Question 2*). Grassy weeds dominate the riparian vegetation, because grazing has made it difficult for native trees to regenerate (*Question 1*). In reach 1a, which was never cleared and where grazing pressure is lower, there is more regeneration of riparian plants (*Question 2*).

4.2 TASK 3: Determine the trajectory of assets and problems.

The trajectory of the assets and problems is indicated by symbols in Figure 4.5.

4.3 TASK 4: Map the problems and assets.

The map of Mythic Creek is found in Figure 4.5. On this map are the distribution of assets, their trajectories and the problems that threaten or damage the assets.

5 Reality Check

After assessing the condition of the stream you may decide that there is too much difference between the template and the present condition for the stream to be salvaged. In other words your goal of ecological rehabilitation may be simply impossible. If this is so, then you should return to your goals at Step 1 and either reassess them, or go and work on a different stream.

Consider this example:

A community group has assessed the condition of their stream and have come to the startling conclusion that it no longer has any characteristics that can be described as assets. It is in appalling condition. At this point in the process the group have a few choices.

1. Return to Step 1 and reassess the goal of the work. Perhaps improving aesthetics with revegetation is a more realistic goal than biological rehabilitation.
2. Persevere with the planning procedure (ie. move on to Step 5: Setting priorities) in order to see if something can be salvaged from the stream.
3. Consider working on a different stream with more potential for successful rehabilitation.

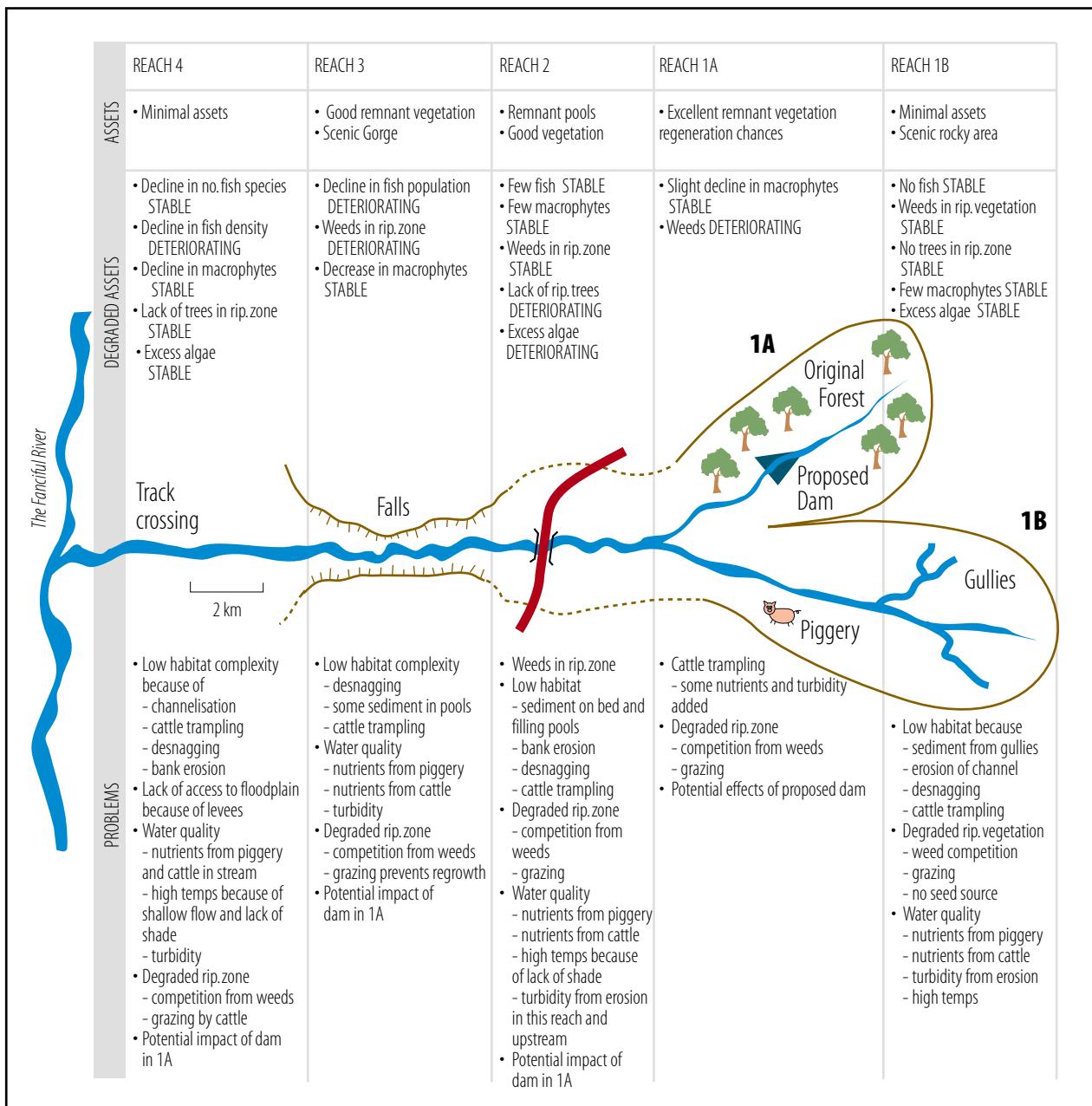
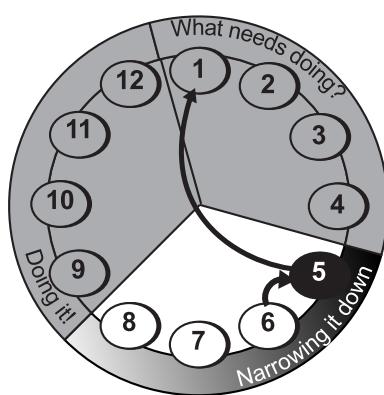


Figure 4.5. A map of Mythic Creek, showing the assets, problems, and trajectories.

Step 5:

Setting priorities: Which reaches and problems should you work on first?

AIM: by the end of this step you should have a list stating the order in which you are going to manage reaches and problems in your stream.



Members of a Rivercare group in NSW have received a grant of \$50,000. Their aim is to rehabilitate as much of their stream as possible with that money. With their last grant they built three rock chutes in their degrading, incised stream. They are now planning to spend this new money on two more chutes, and some revegetation and fencing for the degraded stream. But there are some concerns in the group that they may not be getting the most value for their rehabilitation dollars. Are they targeting the right sections of stream, or the critical problems, or should they be doing something else altogether?

Key points on setting priorities for action

- Priorities should be set in terms of how much natural biodiversity (or some other measure of stream health) you can get for your money or effort.
- Do not automatically start rehabilitation at the most damaged reaches. In terms of stream health it is usually more effective to protect (preserve) reaches of stream that remain in good condition, than to spend huge amounts of money trying to rehabilitate reaches that are already damaged.
- Similarly, it is usually more efficient to stop a stream deteriorating than to try to fix it later.
- When the major assets of the stream have been protected, then you can begin to improve the stream condition
- When protecting or improving a reach, you should be careful to identify any fatal and limiting problems, and treat these first.
- Priorities should ideally be set within a regional framework; ie. priorities should be set hierarchically from national down to the local scale, from large catchments down to subcatchments and reaches of sub-catchments.

1 Introduction

From Steps 3 and 4 (How has your stream changed?, and What are the streams main assets and problems?), you should now have a list or map showing the following information:

1. the assets and degraded assets in each reach;
2. any assets that are high value because of rarity;
3. the problems that are threatening or degrading any of the assets; and
4. the trajectory of the assets.

Of the many problems you identified, which should you fix first? Obviously, we would like to rehabilitate all reaches of all streams. Unfortunately, there are not enough resources for this, so we have to have some way to allocate resources

between streams, reaches of streams, and problems. There are many techniques around for describing the condition of streams, but few of these offer much guidance on what the order in which you should attack problems. This is like a doctor confirming that you are sick. OK, so now you know that you are ill—but what do you do about it? In stream rehabilitation, the usual assumption is that you should attack the most obvious problem in the worst reach first, but is this the best strategy if you are aiming at sustainable ecological diversity, or a return of the reach to an original state?

In this step, we argue that it is far more efficient to preserve streams and reaches that are still in good condition, rather than concentrating on fixing what is already degraded. It is also very important to attack the right problem in each reach, which may not be the most obvious (such as erosion) or the easiest to fix (such as riparian revegetation).

2 On what basis do you set priorities?

Let us consider an analogy that will help us to set priorities for stream rehabilitation.

2.1 Saving the *Titanic*

Imagine that you are in a small rescue boat on the sea. You are watching the *Titanic* sink. The ship is doomed, but you can save a pitiful number of passengers in your little boat. Whom do you save? This is a tough problem because some of the passengers are cute and attractive, others are rich, most are poor. Which ones most deserve rescue? The ‘Spirit of Heroism’ in Figure 5.1 is suggesting that women and children should get priority.

But you look around and suddenly notice that the *Titanic* is not alone on the sea. In fact, as far as the eye can see there are ships of all sizes in different kinds of trouble. Some have only their funnels above water, some are burned to the water-line, but are still limping along with survivors on board. There is a damaged ship that is full of school children, and another that is full of convicted murderers. You look again and see a large ocean liner in good condition, with thousands of people on board, heading towards an iceberg! You are faced with a terrifying dilemma. Do you stay and save a few passengers on the *Titanic* or do you save

many thousands more lives by rushing to warn the other ocean liner of its danger? There isn’t time to do both.

The situation in stream rehabilitation is analogous. Imagine that the ships are stream catchments and reaches, and the passengers are the biological communities that they support. There are many more streams that are damaged, and at risk of deteriorating further, than we can hope to save with the resources available. How do you decide where to start? It is possible to identify similar priorities for managing catchments for biodiversity, as for saving passengers.

At sea, you base your priorities on how you can **save the most lives**: in streams, you should base your priorities on how you can **save the most biodiversity**. It is more efficient to keep the ships afloat, rather than trying to rescue some important passengers from them. Similarly, it is most efficient to save entire reaches, than to attempt to rescue individual species or communities and leave the reaches to be destroyed. Just as it may be tempting to save the attractive, cute person in the water, it may be just as ‘unfair’ to expend all of your resources on a cute family of platypus in a degraded stream, when you could be saving whole communities of organisms for the same expenditure of resources elsewhere.



Figure 5.1 The Spirit of heroism defining priorities on the sinking *Titanic* (from Marshall Everett, *Wreck and Sinking of the Titanic*)

What is the currency of stream rehabilitation?

The basic measure for deciding priorities is the amount of **sustainable natural biodiversity that can be gained per dollar, or per unit effort, and usually in the shortest time**. The emphasis should be on achieving this for the greatest possible length of stream.

Table 5.1 shows six principles, in order of priority, for deciding what actions to take to save the most people at sea, or the most biodiversity in our streams.

Table 5.1 Six principles for saving ships and rehabilitating streams

Rescuing the <i>Titanic</i>	Rehabilitating Australia's streams
1. Save ships with more valuable passengers (the children) before those with possibly less valuable passengers (convicted murderers?).	Save reaches that support valuable organisms or communities (rare or endangered) before you turn to less valuable reaches that support common organisms and communities.
2. Make sure that the ships that are in the best condition stay in that condition, before you try to fix the ones that are already sinking.	Protect the streams that are in the best general condition (Figure 5.2a) before trying to improve those that are in poor condition. (Figure 5.2b)
3. Stabilise the ships that are beginning to get damaged, but are not yet sinking, and so do not yet need many repairs.	Stop streams deteriorating, rather than waiting for them to stabilise and then trying to accelerate recovery.
4. Accelerate the rate of repair of ships that have been damaged, starting with those that need the least repairs, and so are easy to save.	Improve the condition of reaches that are damaged, beginning with those that are easy to fix.
5. So long as there are still ships that need protecting or repairing, don't bother raising the <i>Titanic</i> once it has sunk!	While there are still reaches that need protecting or improving, don't bother trying to fix reaches that are already extremely degraded.
Note! Identify the most important problem! A big hole in the side of the ship might be the obvious problem, when a smaller hole hidden below the water line is causing the ship to sink.	Identify the most important problems. Raw banks and erosion may seem obvious problems, but the real problem could be water pollution in storm run-off.

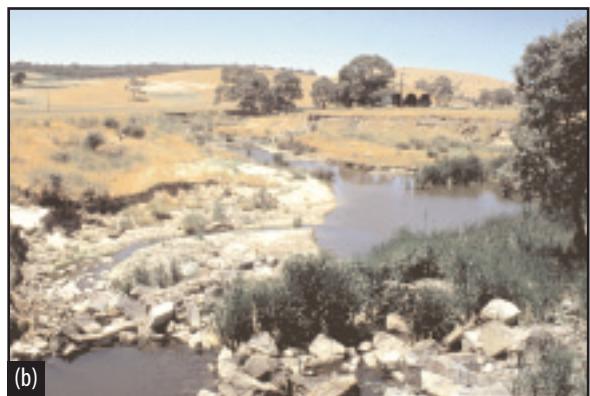


Figure 5.2 a & b: The stream in (a) is in good condition (middle reach of the Torrens River, SA), and so deserves to have a high priority for rehabilitation. In contrast, photograph (b) shows another reach of the Torrens that is in generally poor condition. Rehabilitation of this reach may be a lower priority, because it would take a great deal of effort, money and time, for a far smaller return than you would get for preserving the reach in photograph (a). Of course you might need to manage weeds in (b) that could damage reach (a).

Setting regional priorities by applying these principles

Ideally, stream rehabilitation planning should proceed downwards from the national or at least regional scale. In practice, this means comparing the condition of whole catchments rather than just reaches. The six principles for setting rehabilitation priorities for stream reaches work equally well for catchments.

For example, the Thurra River in East Gippsland is one of the few coastal streams in SE Australia that is in close to original condition throughout its length (Figure 5.3a). It receives little attention compared with its neighbouring stream, the Cann River (Figure 5.3b), which has suffered from dramatic erosion (Erskine and White 1996). In terms of stream rehabilitation, at a national level, the Thurra River should be a high priority stream. Then, within the Thurra catchment, the stream would be divided into reaches that would themselves be ranked according to the criteria described below.



Figure 5.3 a and b: The Thurra River (Figure 3a) is still close to its original condition. As such, it is worth preserving, and should have a high priority for rehabilitation. The Cann River (Figure 3b) was once similar to the Thurra, but has been disturbed by human impact. The Cann now receives much more management attention than the Thurra, because of its degraded condition.



Preservation is more effective than repair

A premise of this section is that it is better to preserve what remains than to try to salvage what is doomed. It is important that we establish the truth of this. The first argument is that it is very difficult, if not impossible, to artificially recreate a functioning physical and biological system. As discussed in *Recovery of disturbed stream systems in Australia*, (Stream rehabilitation concepts, this volume), it is much easier to destroy a biological and physical system than it is to re-create it. You can do it without trying! The second argument is that attempts at re-creation are usually prohibitively expensive. The correct way to look at this issue is in terms of long-term efficiency. You want to get the maximum natural biodiversity for your dollar over a period of decades. On the assumption that you would eventually like to rehabilitate all of the reaches in a stream, the relative value of spending money to protect a reach *now* is *usually* much less than the cost of attempting to rehabilitate it in the future. Here is a hypothetical example.

Consider a small catchment in North Queensland that has vegetated headwaters in the top half of the catchment (10 km of frontage), and is cleared and channelised in the lower half (10 km of frontage). The goal is to rehabilitate the streams with appropriate riparian vegetation, snags, etc. You decide to fence out the lower reach to allow regeneration from vegetation upstream. But while you are busy doing this sensible thing, you do not realise that a permit has been issued to clear most of the upper section of the catchment to establish banana plantations.

What has been the cost of losing the upper half of the catchment and stream? There are three monetary costs. The first is the large cost of having, at a later date, to attempt to recreate the original stream. The second is the *extra* cost of rehabilitating the *lower* reach in the absence of a good seed source, and colonisation source of animals. The third is the opportunity cost of spending money rehabilitating the upper reach that could have been spent elsewhere. Table 5.2 shows some hypothetical costs for this example

Ideally, the stream manager would have ensured that the agency issuing land-use permits knew that the upper half of the catchment was valuable, so that appropriate protection could be built into the development permits.

Table 5.2. The hypothetical cost of the failure to protect stream assets

Cost with protection of upstream reach	Cost without protection of upstream reach		
Upstream protection	Upstream rehabilitation		
Administrative cost of developing planning controls	\$4,000	20 km of fence (\$1,000/km, each side)	\$20,000
		Replanting with tubestock	\$40,000
Downstream rehabilitation	Downstream rehabilitation		
20 km fence (\$1,000/km each side)	\$20,000	20 km fence (\$1,000/km each side)	\$20,000
Weed control	\$2,000	Weed control	\$2,000
		Replanting with tubestock	\$40,000
Opportunity cost	Opportunity cost		
		Extra cost up and downstream	\$96,000
Total cost	\$26,000	Total cost	\$218,000
		Extra cost	\$192,000

From Table 5.2, the cost of fencing and weed control in the downstream reach will remain the same, regardless of the upstream condition.

Protecting the upstream reach only costs an extra \$4,000. But if the upstream reach is cleared, then fencing and replanting that area, along with extra costs downstream and the lost opportunity cost, will cost \$196,000, just to get back a juvenile riparian vegetation, where before there was mature forest. Thus, the benefit-cost ratio of protecting the upstream reach first is very high: 48 to 1! (\$192,000 versus \$4,000).

In purely economic terms, one would also include in the above example the value of the bananas produced from the cleared land over time.

However, in terms of stream rehabilitation, the currency is natural biodiversity, not economic production from bananas. Thus, it does not matter what use the land is put to if it reduces biological condition, unless the profit from the use goes toward rehabilitation elsewhere.

2.2 Protecting valuable reaches

Protecting and preserving means the control or removal of any processes that pose a threat to an asset, or are already causing the asset to deteriorate. Such threats can come from within the reach (such as weed infestations, or erosion), but can just as easily come from up or downstream (for example, bad water quality from upstream, or erosion heads from downstream). Threats may not come from the stream at all, but from other activities in the catchment. Whatever form the threat takes, and from wherever within the catchment it comes, it must be dealt with as a part of asset protection, even if this means treating some catchment-wide problems. Often, however, protection will be relatively cheap and easy.

Some examples of asset protection would be:

- declaring a high conservation value area to be a ‘special conservation zone’, and establishing suitable planning regulations;
- stabilising headcuts that are moving upstream and threatening valuable reaches; and
- specifying strict design guidelines for culverts built within high priority areas.

Of course, we are not suggesting that you be overly pedantic about protecting small details in one reach, while major damage is occurring elsewhere. For example, you would not want to be wasting time haggling over a tiny increase in turbidity in a good reach, while a downstream reach in moderate condition has 200 cattle drinking directly from the stream.

3 Setting reach priorities

Setting priorities is an ongoing process!

Please note. The procedure for setting priorities is a dynamic planning process. You do not sit down one day and set the exact priorities for the project and these will not change for the next ten years. You can set the general thrust of the priorities, but the details will change.

Where to find more information...

A process for assigning reaches to the categories in section 3.1.1 can be found in Volume 2. It is perfectly acceptable to categorise reaches simply by using the list to follow. However, if you have a large catchment, you may find it easiest to keep track of the relative value of reaches using the ‘Reach Priority Shuffle’ that can be found in *Setting priorities for stream rehabilitation*, in Miscellaneous Planning Tools in Volume 2.

The aim of this step is to produce a list of reaches and their problems, in the order of priority for treatment. We have here seven tasks that you need to complete to develop this list. Tasks 1-3 relate to ranking the reaches themselves, tasks 4-6 relate to prioritising the problems that threaten or damage each reach, and the final task involves putting some reaches in more than one place in the rankings.

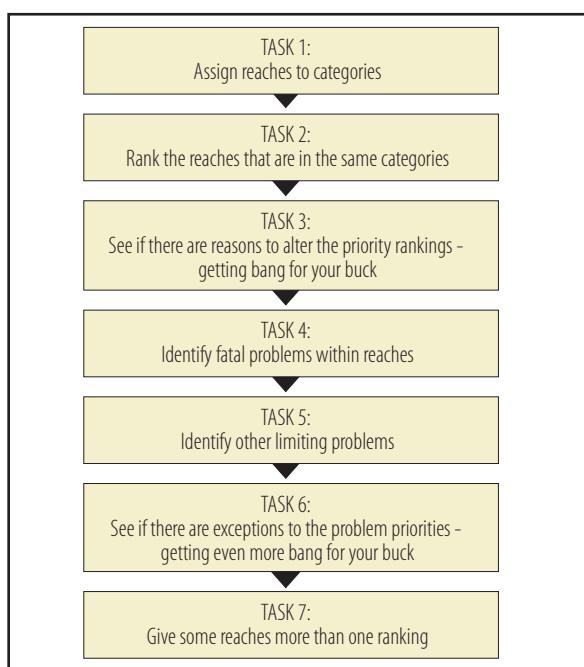


Figure 5.4. The tasks to be completed in Step 5.

3.1 TASK 1: Assign reaches to the categories listed below.

How do you decide which reaches deserve immediate attention, and which can be left for another day? Using the principles demonstrated in the *Titanic* analogy, you can rank a reach according to its **rarity** (rare reaches have higher priority than common), its general **condition** (reaches in good condition are easier to fix than those in bad condition), its **trajectory** (deteriorating reaches should at least be stabilised before you improve reaches that are improving of their own accord), and finally **ease** (reaches that are easy to improve, before those that are hard). This gives you the nine categories that are listed in order of priority in section 3.1.1 below. You should now allocate each reach to one of the following nine categories.

3.1.1 Reach priority categories

Category Zero: *Reaches in good condition throughout, that are already protected.* Reaches in this category need nothing done to them. There are no active threats, and they have been protected against potential threats. All the assets in these reaches are in good condition. All this reach needs is a watchful eye, to check for the development of new threats in the future. The aim of rehabilitation is to move all reaches into this category.

Category One: *Protecting Regional Conservation Value reaches.* The highest priority is to preserve those reaches with assets that are important nationally or regionally. These could contain endangered species or communities, or be a good quality remnant of a once common stream type (such remnant reaches may have been chosen as templates in Step 3). For example, the riparian vegetation on the lower LaTrobe River in eastern Victoria is mostly cleared, as it is on almost all rivers in the area. However, one 10 km reach on the LaTrobe has escaped clearing, and retains fairly natural riparian vegetation, providing natural densities of large woody debris to the stream. Because so few lowland rivers in Gippsland retain a healthy riparian zone, this reach has Regional Conservation Value.

Often you may have no reaches in this category. Alternatively, you may have more than one reach (for example, a rare fish species could be found through half a river system). The chapter *Identifying valuable reaches*, in Common stream problems, Volume 2, discusses how to go about identifying known populations of vulnerable, rare

and endangered species. Protecting these reaches, and preventing any decline in condition, is the highest rehabilitation priority. **Protection should include identifying and fixing threatening problems that come from other reaches** (how to identify such problems is described below). These threatening reaches may themselves have little value, but it is important to prevent them from causing deterioration elsewhere.

Category Two: Protecting Local Conservation Value reaches. These are reaches in so good a condition that they can be considered to be surviving remnants of the original stream (a possible template reach). Unlike the remnant reaches in Category One, however, local conservation value reaches will be common in the region, although they may be rare within the catchment. For example, the headwaters of the LaTrove River are forested, affected only by logging and road construction. These tributaries have Local rather than Regional conservation value, because many of the headwater streams in surrounding catchments are also forested. Such remnants should be the second priority for protection. Once again, **protecting these reaches from deteriorating involves treating all threatening problems, including those from outside the reach.**

Category Three: Protecting and improving deteriorating reaches. Some reaches will already be damaged, but their condition is continuing to deteriorate. As with categories One and Two, it is usually more efficient to stop further deterioration than to wait for the damage to plateau-out, and then try to fix it. Consider, for example, a river with a large weir that prevents fish passing. Upstream of the weir, the fish populations are declining, and will eventually disappear altogether. It is better to provide fish passage now, while some fish remain, than wait till later and have to re-establish the population from nothing. **Note that this category does not include any reaches already in extremely bad condition. These basket-case reaches have low priority (categories seven and eight below).**

Note that the emphasis of categories 4 to 8 changes from protection of assets, to improving assets.

Category Four: Expand good reaches. At this stage you should have *protected* all of your important assets, and you now begin to *improve* the condition of the stream. It is easier to do this by expanding an area in good condition, than by trying to create a new island of improved stream amongst the degraded reaches. There are two reasons for this. First, although quality assets can exist isolated within an otherwise degraded setting (a healthy riparian zone

beside a stream with a sand slug, for example), their value is greatest when combined with other assets to form a complete stream community. Secondly, the recovery of plant and animal communities is generally fastest when there is a healthy community close by. This is because colonising individuals will find the new habitat faster where there is no barrier of inhospitable degraded reach (see *Recovery of disturbed stream systems in Australia*, in Stream rehabilitation concepts, this volume, for a discussion of this). In order of priority, you should work on:

- reaches with some high quality assets and some degraded assets;
- poor quality reaches that link two asset-rich reaches; and
- poor quality reaches connected by one end to an asset-rich reach.

The lower Hopkins River in western Victoria has various reaches that are in quite good condition because they run through basalt gorges. The reaches between the gorges are on sedimentary geology. They are cleared and heavily grazed, and are in poor condition (see Figure 5.5).

Normally, these generally degraded sedimentary reaches would not receive high priority, but because they are a link between good reaches, they should receive higher priority.



Figure 5.5: A reach of the Hopkins River, running through sedimentary geology. Though in fairly poor condition, this reach is a Category Four priority because it links two basalt reaches in good condition.

Category Five: Improve impeded recovery reaches (easily fixed reaches). These are reaches in poor, but stable condition (ie. although degraded, their condition is not deteriorating). A natural recovery process ought to be occurring, but some stream problem prevents this (see *Recovery of disturbed stream systems in Australia*, in Stream rehabilitation concepts, this volume, for a discussion of natural recovery). If you identify and fix that problem, you can allow the natural recovery to do the hard work of improving the stream condition. An example would be a reach degraded by nutrient enrichment from a point source such as the outfall from a trout farm. Improving the water quality will pave the way for a rapid recolonisation of the reach by stream animals.

Category Six: Improve moderately damaged reaches (more difficult to fix). These are reaches that are damaged by human impact, but have good potential to recover at reasonable cost. They differ from category five streams, in that they require several, rather than a single, intervention. They are typified by many lowland and floodplain streams. For example, they may be cleared of riparian and in-channel vegetation, with marginal water quality and some fine sediment deposition in the channel. Simply revegetating these streams will not rehabilitate them.

Category Seven: Improve basket-case reaches. These are reaches that are in very poor condition, that do not threaten other reaches, and have little chance of recovering by themselves over time. An example would be a channelised stream that has such a low-slope, and low energy, that it cannot cut a new course (Brookes, 1987) (see Figure 40, *Recovery of disturbed stream systems in Australia*, in Stream rehabilitation concepts, this volume). These reaches have serious problems and need intervention to recover.

Category Eight: Improve basket-case reaches with hope. These are reaches that are in very poor condition, that do not threaten other reaches, but that have some chance of recovering themselves with time. An example would be the high energy reaches of rivers emerging from mountainous terrain, that tend to get damaged by large floods. Such streams are very expensive and difficult to artificially rehabilitate, and have a pretty good chance of recovering themselves over time. Many lowland streams in coastal NSW could fall into this category. Note that these reaches may get bumped up the priority list if their instability threatens downstream reaches.

Present priorities for stream management work in Australia

Do stream managers in Australia follow these priorities when they are reputedly doing stream rehabilitation projects? No! Most stream management work in Australia concentrates on controlling erosion in our most degraded streams, such as gullies, urban streams and the dramatically eroded coastal streams of south eastern Australia. While this work is usually successful at protecting human assets such as bridges, the work cannot be seen as a high priority for rehabilitation, according to the scheme described above. In fact, most erosion control work is carried out on streams that would be classified as 'Basket case' streams (Category Seven or Eight) (Figure 5.6). Thus, adopting this ecologically based priority system would represent a major departure from past practices in Australian stream management. Note, however, that you may have to work on basket-case reaches in-order to protect higher category reaches from deterioration.



Figure 5.6: This river in NSW is an example of a category Eight stream which is presently undergoing rehabilitation.

3.2 TASK 2: Rank reaches that are in the same category.

Where more than one reach falls into a single category, you will need to decide which has the highest priority. This is done in the same way as the original categorisation, on the basis of **rarity** (rare before common), **condition** (good before bad), **trajectory** (deteriorating before improving), and **ease** (easy before hard). Thus, if two reaches are of the same rarity, then the one in best condition gets preference for protection. If they are in the same condition, the one at risk of deterioration is a higher priority. Finally, if their trajectory is the same, you would work on the reach where improvements are easier to achieve.

3.3 TASK 3: See if there are reasons to change the reach priority rankings.

There are four reasons to work on a reach with low priority before one with high priority. So far, our emphasis has been on extracting the largest ecological gains for the effort invested. In reality, there are other important criteria that may also be used to make sure you get the most bang for your buck in the long term. After considering these, you may decide to rearrange your reach priorities.

Community support: Sometimes a reach is given higher priority because of the influence that it will have on the community, or on decision-makers. The selected reach may be a highly visible section of degraded stream near to a bridge or an urban centre, or support a charismatic animal, like platypus. You may reason that improvements to this reach will influence decision-makers as to the value of stream rehabilitation, and so lead to rehabilitation of the rest of the stream. Again, a reach may be given higher priority than it would otherwise deserve because it is owned by a particularly keen landholder and community leader. So, re-examine your reaches to see if any of them will produce more long term bang-for-your buck in terms of community or political sentiment that will make achieving future rehabilitation easier.

Potential regional conservation value reaches. There are some stream types that are so widely degraded, that there are few or no reaches left in good condition. The unconfined streams of Victoria's basalt plains are a good example of this. These streams are almost totally cleared and grazed. In this situation, you might decide that it is worth the cost and difficulty of rehabilitating a degraded reach, because if you succeed, you will have created an asset of regional conservation value.



Figure 5.7. Jacksons Creek, to the north of Melbourne, is an example of an unconfined basalt stream. These streams are usually cleared and grazed, and not many are left in good condition. This reach, in the Organ Pipes National Park, has been revegetated over the last 15 years. It is of high conservation value because of the scarcity of reaches of this type in good condition.

Upstream reaches. It can be best to start rehabilitation in the headwaters, or at a reach already in good condition, and work downstream. Many stream problems such as weed seeds, sediment, and water quality problems, get transported downstream with the flow. But in the upstream reaches, you can tackle the sources of the problem in the reach you are currently working in, without having to worry about the problem continuing to enter the reach from upstream.



Figure 5.8. Damage to the Queen River, at Queenstown, Tasmania. The Queen is a major tributary of the King River. For a century, nearly a million cubic metres of copper-rich mine tailings were dumped into the river each year (Locher 1996).

Think about where the water and sediment are going.

In setting priorities, we have to think also about the final fate of water from reaches. The condition of a lake, estuary or wetland may also be threatened by problems in a stream. For example, the King River in Tasmania is clearly a basket case (see category 7 above) after receiving over a million tonnes of mine tailings per year, for a century, from the Mt Lyle copper mine (Locher 1996). However, efforts are being made to rehabilitate this stream because of the possible threat that the toxic mine tailings stored in it could pose for Macquarie Harbour, into which it flows.

4 Setting problem priorities

Within your highest priority reach, you have to decide which *problems* are important. To preserve an asset, you have to know what threats it needs to be protected from. To improve a reach, you have to know which problems have caused it to degrade, and which are stopping it from recovering. More often than not, you may find that each asset is being threatened or damaged by more than one problem. For example, in a typical rural stream, the fish population could be affected by high turbidity, high nutrient loads, habitat simplification caused by erosion, trampling by cattle, desnagging, large quantities of sediment derived from erosion upstream, the presence of exotic fish species such as carp, and possibly changes to the hydrology. This list could easily be longer. You must decide which of these problems demands attention now, and which can be safely ignored, at least for a while. Remember that problems that threaten or damage a reach may not actually be based in that reach. For example, polluted water can be a problem for many kilometres downstream from

where it enters the reach, or, erosion upstream of your reach could be causing fine sediment deposition in your reach. Such problems are most efficiently treated at the source.

How do you decide which problem is most important? You need to identify the hierarchy of problems, from **fatal** problems that are so bad that they exclude the animal or plant from the reach, to **limiting** problems that stress the species in question, to **nuisance** problems, that have minor effects on the population. For the stream community to fully recover, all these problems need to be fixed, but in order to see the fastest improvements along the way, the problems should be tackled in that order. Finally, you should keep track of interactions between problems, so that you know when the success of fixing one problem will be **linked** to the condition of another problem.

Tasks four, five and six help you to identify the order in which you should work on the problems.

4.1 TASK 4: Check for fatal problems.

Fatal problems are so severe that they exclude assets from the stream. They must be fixed first—there is no point doing anything else in the stream until the fatal problem is fixed. Sand ‘slugs’ are a good example of this. A sand slug is a huge deposit of sand in the bed of the stream, travelling slowly downstream. Sand slugs can fill a stream, swamping all the in-stream habitat, and leaving very shallow water flowing over a smooth sheet of mobile sand. Not surprisingly, such a stream will not support many aquatic plants or animals. Until the sediment has moved through the reach (this can take many decades) or has been stabilised in some way, it will continue to swamp any habitat, including any added to the stream artificially. Any work on the stream must tackle the sand slug first. Extremely bad water quality, or a major barrier to fish passage, are other examples of fatal problems.

A fatal problem

Dartmouth Dam releases cold water to the Mitta Mitta River in NE Victoria (Figure 5.9). The cold water has dramatically reduced the number and diversity of native fish in the reach below the dam (Koehn et al., 1997). If your goal is to return native fish populations to their original size and diversity, then there is little point planting riparian vegetation (presently dominated by willows), and improving in-stream habitat, when the water will still be too cold for the target fish. You either fix the fatal problem of water temperature, or you go and work elsewhere if these native fish are your rehabilitation goal.



Figure 5.9. The Mitta Mitta River below Dartmouth Dam, Victoria. Cold water released from the dam is the limiting problem in this river.

4.2 TASK 5: Check for other limiting problems.

A limiting problem is the one that most severely affects an asset (*An introduction to stream ecosystems* in Stream rehabilitation concepts, this Volume, contains a discussion of limiting variables). If you don’t fix the limiting problem, the target of your rehabilitation cannot recover, even if you fix other problems. Fatal problems are an extreme example of limiting problems.

Take the example of River Blackfish. These fish love woody debris—they shelter under it, and spawn amongst it. Imagine a reach with a very small blackfish population, and three relevant problems—there is some nutrient enrichment, only moderate density of macroinvertebrate (the main food), and only one piece of LWD. It is probably the lack of debris that would be the limiting problem; that is, all the available debris is used by fish, and no more fish can live in the reach, because there is no room under the debris. If a rehabilitation project focused on increasing food supply to this reach, or improving the water quality, it would have no effect on the fish, because there are already as many fish as there is habitat. So, if there is no fatal problem, the most *limiting problem* threatening or degrading an asset needs to be fixed first. Then you should proceed down the hierarchy of limiting problems.

In some cases, one stream problem is the cause of another problem. For example, substrates contaminated with heavy metal is a problem that can limit macroinvertebrate populations. This, then, would be classified as a high priority limiting, or even fatal, problem. These metals are typically transported in the water column in low concentrations, and gradually accumulate to subtoxic or toxic levels in the sediment. The water quality probably has little direct effect on many invertebrates, but because it is the cause of the substrate contamination, it must be treated first.

You should identify where problems are ‘linked’, either in a hierarchy of limiting problems, or where one problem causes another. If two problems are linked, then there may be little point fixing only one. You can use these links to check that you are not wasting time and effort by treating problems in the wrong order (see the case studies at the end of this step for examples of linking reaches).

4.3 TASK 6: Exceptions to the problem priorities: getting more bang for your buck.

Just as there are reasons to work on a low priority reach before one with a high priority, there are reasons to take a problem that is not the most fatal, or limiting, and work on it anyway. In the long run, these may give you more bang for your buck.

Fix problems that damage a large reach of stream.

Where possible, work on problems that affect a large reach of stream, before you work on site-specific problems. Where the cost is the same, fixing these large-scale problems can give more benefit to the stream than smaller scale, site-specific works. For example, a point source of pollution can affect water quality for many kilometres downstream. A barrier to fish passage will affect the fish populations through all of the upstream reaches. Treating these problems would improve more stream than, for example, adding a few pieces of woody debris to one reach.

Time for recovery. Some stream assets will take a long time to recover. Although improving such assets may not be a high priority now, it is sometimes wise to start the recovery process now, so that the asset is there when it is needed. Riparian vegetation is a good example of this. In the drier temperate regions, it could take over 10 years for trees to reach a size where they stabilise the banks and shade the stream. It will take even longer before they start to contribute large woody debris. The lack of riparian vegetation may presently be less critical than, for example, an overload of fine sediment. However, when the sediment has been stabilised or flushed through the reach, a healthy riparian zone may be important. By starting revegetation now, as well as measures to bring the sediment under control, then the trees will be there when you need them.

Community support: As with reaches, it is sometimes worth giving a problem higher priority than might otherwise be the case because of the influence its solution would have on the community, or on decision-makers. These may be problems that will lead to quick improvements in the stream appearance, such as replanting degraded riparian vegetation, or problems that cause trouble for the landholder, as well as the stream, such as water quality. Though these problems may not be fatal, or the most limiting, in some situations fixing them will give good bang for your buck in terms of support for future projects.

At this point you should have a list of reaches in order of priority, and beside each reach a list of problems, also prioritised, with any links between problems noted. Only one more task remains before you have a workable set of priorities.

4.4 TASK 7: Check if some reaches should have more than one rank.

You may be under the impression that the way to use the priority list is as follows. Take the first priority reach, protect its major assets, improve its degraded assets, and keep on working on that one asset-rich reach until it is perfect. Then you can re-categorise the reach as Category Zero, and move on to the next highest priority reach. Well, things are not that simple.

One reach may contain some assets that need to be protected, but the same reach will also contain some degraded assets that are in poor condition. It will often be more effective to protect the threatened assets, then move on to protect assets in other reaches before trying to improve the degraded assets in the 1st reach. So what then happens to those degraded assets in the first reach? The answer is to re-classify the reach by comparing it with all other reaches, assuming that the quality assets have been protected. As a result you can have the same reach appearing as, for example, a Category One ‘Regional Conservation Value’ reach, but then appearing again later (ie. lower in the priorities) as a Category Four ‘Expand Good Reaches’ reach. Here is an example.

The upper reaches of Seven Creeks in Victoria contain one of the few remaining populations of the endangered trout cod, and so are of Regional Conservation Value. However, the reaches where the trout cod live are in only moderate condition. Thus, the trout cod reach of Seven Creeks would appear once as a high priority Category One, to allow you to protect the trout cod, and once as a lower priority Category Four, where you will enlarge on the good assets and improve the condition of the whole reach. In between, you would treat any reaches in categories 2 and 3. A 3-step procedure for identifying where each reach will fit is described below.

1. In each reach that falls under Categories One to Three, just do the work that is implied by the title of each category. So, for a Category One reach, you protect the Regional Conservation Value asset, in Category Two reaches, you protect Local Conservation Value assets, and in Category Three reaches, you protect any deteriorating assets. Our reach in the Seven Creeks example is Category One, because the trout cod are endangered. Therefore, the first priority is to protect the population of trout cod.

2. Reconsider the quality of the reach, now that you have protected the asset (ie. trout cod). What needs to be done now? Are **all** the assets in good condition? Are they **all** protected against future threats?
 - If you answer yes, then congratulations, the reach is now upgraded to Category Zero!
 - If you answer no, then there is still work to be done in the reach. You need to consider what priority this work would have, compared to all the other reaches in your stream.
3. Categorise the reach again. The trout cod reach would no longer be Category One, because the fish have now been protected. The rest of the reach is in moderate condition, but would fall into Category Four: Expanding good reaches, because the reach has at least one high quality asset (the cod). So, you will treat any reaches in Categories Two and Three, before you return to the trout cod reach.

5 Summary

Summary of Prioritising Rehabilitation Activities

- Preserve what is good, before trying to fix what is bad.
- Where possible, use this prioritisation procedure to select catchments to work in, before selecting reaches to work on.
- Work on your reaches and problems in the following order: rare reaches before common ones; good condition before bad; deteriorating reaches before stable or improving; and easy reaches to fix before hard.
- Recognise basket-case reaches for what they are, and spend your effort on other reaches where you have more chance of success.
- Within a reach, fix fatal problems first.
- Identify links between problems in a reach.

6 Case study: Durben Creek

The three reaches of Durben Creek were described in Step 3. In this step, we fit those reaches into the priority categories, and then decide which are the important problems in each reach. Table 5.3 shows which categories the reaches fall into (in order of priority), the relative importance of the problems and the links between problems. Note that the rural reach has been given higher

priority than would be expected from its category. This is because the reach has the potential to become a high conservation value reach. Also, note that the gorge reach appears twice, once as category one, to protect the local conservation asset, and once as category four, to improve the other assets in the reach.

Table 5.3: The reach priorities in Durben Creek (linked problems need to be tackled together)

Reach	Priority Category	Description of reach	Problems in order of priority, and links between problems
Priority 1 Downstream Gorge (Reach 3)	Category 2: Local conservation value	The integrity of the stream morphology and the riparian vegetation give this remnant reach local conservation value, despite the very bad water quality (there are too many similar streams in similar condition for this reach to have regional significance). The stream morphology and riparian vegetation should be protected as a first priority.	1. Weeds in riparian vegetation There are no immediate threats to the stream morphology.
Priority 2 Rural headwaters (Reach 1)	Bang for your buck: potential conservation value	Without the potential conservation value, this reach would be Category 6: Moderately damaged. However, if this reach were rehabilitated, it would be a high conservation value reach. Because of this potential bang for your buck, this becomes a higher priority.	2. Grazing (linked to 3—if you stop grazing, without starting weed control, you will encourage weeds) 3. Weeds (linked to 2—grazing will continue to encourage weeds) 4. Lack of regeneration (linked to 2 & 3—regeneration is limited by the impacts of grazing and competition from weeds. Without treating these, replanting is likely to be unsuccessful) 5. Poor water quality 6. Water quality from the Urban reach (linked to 7, 8, 9 & 10) 7. Water quality problems from this reach (linked to 6, 8, 9 & 10) 8. Hydrology (linked to 6, 7, 9 & 10) 9. Substrate contamination (linked to 6, 7, 8, & 9) All these problems are interlinked. The hydrology contributes to the water quality problems, the water quality contributes to the contaminated sediment. They also all contribute individually to the degraded macroinvertebrate community. It is uncertain if you would get any benefit from treating only one of these problems.
Priority 3 Downstream Gorge (Reach 3)	Category 4: Expand good reaches	This reach has good morphology, but the water quality, contaminated sediments and altered hydrology mean that stream animals cannot take advantage of the habitat. If you did fix these problems, you ought to get a good response from the stream biota.	
Priority 4 Urban mid reach (Reach 2)	Category 7: Basket case without hope	This reach is in bad condition. Channellisation has reduced morphological complexity and connection with the floodplain. Urbanisation has changed the hydrology and polluted the water. Although the channel may recover some morphological diversity over time, there is no hope of the water quality improving without intervention.	10. Riparian weeds 11. Lack of native riparian vegetation 12. Water quality from rural reach (linked to 13 & possibly 16) 13. Water quality from this reach (linked to 12 & possibly 16) 14. Contaminated substrate (linked to 12, 13 & possibly 16) 15. Changes to hydrology (linked to 12, 13 & possibly 16) 16. Low habitat diversity (linked to 12, 13, 14, & 15) Again, these in-stream problems are interlinked, and you are unlikely to have much rehabilitation success unless you treat all of them. However, the riparian zone is more independent, and so could be successfully rehabilitated on its own.

7 Mythic Creek

Here we will run through the seven prioritisation Tasks to describe how we arrived at the final priorities for Mythic Creek, as shown in Table 5.5.

Task 1: Assign reaches to categories.

Table 5.4 summarises the first priority sweep.

Table 5.4: Initial reach priorities for Mythic Creek

Reach (in order of priority)	Description (condition, trajectory, relation to other reaches)	Category
Reach 1a	In pretty good condition, a remnant reach of local value (ie. there are examples of similar reaches in the region, but no others in the catchment).	Category one
Reach 3	In good condition with respect to morphology and habitat complexity.	Category one
Reach 2	In poor condition—simplified habitat, sediment aggradation, poor riparian zone, and erosion.	Category two
Reach 4	In bad condition—fish barrier, poor riparian condition (infested with weeds), lack of habitat complexity, poor water quality. Is unlikely to recover without intervention.	Category seven
Reach 1b	In bad condition. Erosion, poor habitat complexity, considerable nutrient enrichment from piggery, poor riparian condition. May slowly recover habitat complexity.	Category eight

Task 2: Rank the reaches that are in the same categories.

Both reaches 1a and 3 are categorised as Local Conservation Value reaches. Which one should have the higher priority? Remember we compare the reaches on the basis of:

1. **rarity** (both reaches similar, so compare on the basis of condition);
2. **condition** (Reach 1a is in better condition than 3 because there are more threats to 3);
3. **trajectory** (Reach 1a gets the higher rank again because it is most directly threatened by the proposed dam); and
4. **Ease** (Again Reach 1a is the higher rank because it is relatively easy to oppose the dam, but it is more difficult to control pollution from Reach 1b that enters reach 3).

Task 3: See if there are reasons to alter the priority rankings-getting bang for your buck.

To do this task we considered the four reasons why we should possibly elevate one of the lower priority reaches (see Task 3 above), and none of them applied to Mythic Creek (see the Durben Creek example above to see where one of these corrections was applied).

Task 4. Identify fatal problems

Unless you fix fatal problems, it is not worth doing much else to the stream. Are there any fatal problems in Mythic Creek? The proposed dam in Reach 1a is potentially fatal because of its great effect on summer flow (water is being diverted out of the catchment). Similarly, the high nutrient flow from the piggery may be a fatal problem in Reaches 1b and 2. Sand in the bed of Reach 2 is also probably fatally limiting.

Task 5: Identify other limiting problems and link them.

Several other limiting problems are shown in Table 5.5, along with several links. Weeds, for example, are linked to grazing. There is no point trying to control weeds if you have not controlled grazing, because the stock will just spread the weeds again and restrict regeneration. There is not much point going to huge effort to remove sand from pools if water quality remains poor.

Task 6: See if there are exceptions to the problem priorities-getting even more bang for your buck.

The priorities can be slightly changed to accommodate some of the suggestions made in the section above. For example, revegetation in Reach 2 should probably proceed at the same time as efforts are made to clear sand from the reach. This is because it will take decades for the trees to grow.

Task 7: Giving some reaches more than one ranking.

You will note from Table 3 that Reaches 1a and 3 appear

twice, first as Category One, then as Category Four reaches. This is an example of Task 7. Once the assets in Reach 1a are protected, the next highest priority is to protect the assets in Reach 3, not to keep improving Reach 1a. After the protection phase of the work on the creek is completed, work begins on improving degraded assets. The first priority here is to expand good assets (see the description for Category Four above). The newly protected reaches are assessed again in relation to all of the reaches. Again the criteria are condition, trajectory and ease (rarity has been dealt with). By these criteria, Reach 1a again gets highest priority and becomes the first of the three Category Four reaches.

The lowest priority reaches for treatment are 4 and 1b. Please note that reach 1b has reversed its order in Table 5.5 when compared with Table 5.4. The reason for this is that so many improvements will have been made to Reach 1b in order to protect assets in other Reaches (eg. nutrients and erosion), that 1b will be in much better condition by the time the Landcare group get around to it! This means it could be considered as an 'Easily Fixed' Category 5 reach instead of a 'Basket Case' Category 8 reach.

Table 5.5. The reach priorities in Mythic Creek.

Priority	Reach Category	Description of reach	Problems in order of priority, and links between problems (in brackets and bold)	
PROTECTION	Reach 1a	Category 2 Local Conservation Value	The integrity of the stream morphology and the vegetation identify this as being of Local Conservation Value. Major threats are a proposed dam, as well as continuing grazing and weed infestation.	1. Proposed dam 2. Stock grazing (3) 3. Woody weeds and vines (2)
	Reach 3	Category 2 Local Conservation Value	As for Reach 1a, but includes some deep pools containing good fish populations. Threats from upstream include nutrient pollution and sediment.	4. Effluent from piggery in Reach 1b 5. Grazing 6. Weeds (linked to 2—grazing will continue to encourage weeds) 7. Sediment moving through Reaches 1b and 2
IMPROVEMENT	Reach 1a	Category 4: Expand assets	If threats to the reach are controlled then improving the riparian vegetation is the next priority (ie. expanding the already good vegetation, first by natural regeneration).	8. Encourage and assess regeneration of vegetation
	Reach 3	Category 4 Expand assets	If threats to the reach are controlled then improving the riparian vegetation is the next priority (ie. expanding the already good vegetation, first by natural regeneration).	9. Encourage and assess regeneration of vegetation
	Reach 2	Category 4 Expand assets	Reach 2 has a cleared frontage, bank erosion, and low channel complexity (note that the problem of sand in the pools will have been addressed in Problem 6 above in order to protect Reach 3).	10. Grazing 11. Pasture weeds (9) 12. Poor vegetation (9, 10) 13. Minor erosion control (9, 11)
	Reach 1b	Category 5 Easily Fixed Reach	Several of the problems in Reach 1b will have been addressed when protecting reach 3 (see above). The incised reach can recover reasonably quickly if grazing is controlled and the reach is revegetated.	14. Grazing control 15. Revegetation (14)
	Reach 4	Category 7 Basket Case Reach	This channelised, low energy reach has little hope of recovery without substantial intervention. Water quality entering the reach should have been corrected by works described above.	16. Erosion 17. Poor habitat and hydraulics (16) 18. Lack of native riparian vegetation 19. Poor connection with floodplain

8 Reality check!

The first time you visit this step there is no reality check, so you are free to move straight onto Step 6. However, after having identified solutions to your priority one problem (Step 6), set your objectives (Step 7) and checked the feasibility (Step 8), you may find that it is not possible, unfortunately, to fix that problem. This may be because the technology needed is not available, or it is too expensive, or there isn't the support you need from government and the community, or the side-effects of the project would be too great. You have searched for compromises, and found none. You are forced to admit that tackling this problem is not an option. If this happens, you get sent back to this prioritisation step.

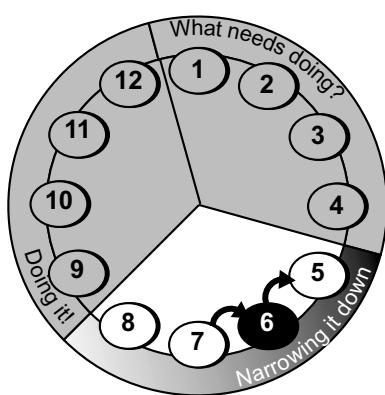
There are three possible outcomes when you find that you cannot fix your top priority problem:

1. In the reach you are working on, you find a problem that you can treat successfully because it is not linked to the insoluble problem. Focusing on this problem, you move onto Step 6 (What are the strategies?).
2. All of the important problems are linked to the insoluble problem. You move to the next priority reach, where you identify the most important problem, and move onto Step 6.
3. You decide that the insoluble problem was fatal to the whole stream. You return to Step 1 (What are your goals for this stream?), and reassess your goals.

Step 6:

What are your strategies to protect assets and improve your stream?

AIM: by the end of this section you should have identified preferred strategies to tackle the highest priority problems identified in Step 5



A Landcare group is concerned about the decline in golden perch numbers in the favourite fishing holes near town. The water quality in the river seems fine for this species, but the group thinks there may be a lack of suitable habitat for juvenile fish. Their priorities are first to protect the remaining fish population, and second to create suitable habitat for the young fish, and thus improve the fish population.

Possible strategies to protect the remaining fish include organising with the Department of the Environment to institute fish bag limits, and putting up signs at the fishing holes, explaining the situation and asking fishermen to throw all golden perch back.

Strategies to create juvenile habitat include fencing stock out of the stream, and replanting riparian vegetation and macrophyte beds.

Key points about developing strategies

- A strategy is the approach you will take to protect and improve assets.
- Strategies could involve changing *processes* in the stream by altering inputs into the stream.
- Strategies may also involve changing the structure of the stream itself by either adding or removing things from the stream
- Most strategies will also involve changing the behaviour of people who use the stream.

1 Identify the range of options to solve the problems

1.1 Introduction

In Step 4, you produced a list of **assets, degraded assets and problems** in each reach. On the basis of those characteristics, in Step 5 you sorted the reaches into order of priority, and identified the important assets and problems in each reach. So you know which assets need protecting and which problems need to be fixed. It is now time to think about the possible strategies for protecting the assets and fixing the problems. The purpose of this step is to identify the range of possible solutions to the highest priority problems. In the following two steps, you will (in Step 7) identify the rehabilitation objective for each option, and (in Step 8) assess its feasibility.

At this stage, we are interested in general strategies for treating problems, rather than detailed designs (these come later, in Step 9: How will you achieve your objectives?). For instance, you may have decided that macroinvertebrate populations in your stream are limited by an absence of riparian vegetation, and therefore a lack of leaf litter in the stream. In this step, you might decide that a suitable rehabilitation option is to fence the stream to exclude stock, and revegetate the riparian zone. You do not have to consider how feasible the strategy is until Step

8 (How feasible are your objectives?). You do not have to consider what type of fence you will use, or which species you will plant using what planting techniques, until you get to Step 9 (What is the detailed design of your project?). The purpose of this step is simply to identify a general strategy, or range of strategies, to solve the problems.

It is worth explaining why you should wait until Step 8 to consider the feasibility of different strategies. It is too easy to discard strategies because they seem too hard, when they may be the best, or even the only, treatment available for a certain problem. Where this is the case, it may well be worth fighting for the money and support necessary to go ahead, despite the difficulties. For example, consider the difficulties of rehabilitating a reach just below a dam, where the cold water released from the dam is a fatal problem. The options for treating this are knocking down the dam, or constructing a high level offtake, so the upper, warm waters can be released. Both of these strategies sound expensive (millions of dollars) and unlikely. However, if you discard them, you are left with a fatally limited reach, and no means of treating it. Having said all this, there is no point in identifying strategies that are downright silly, and involve, for example, bulldozing and revegetating half a city, to improve the water quality of an urban creek.

1.2 Possible strategies

The rehabilitation priorities you identified in the previous step will relate to **protecting** some assets, and fixing problems to **improve** the condition of other assets. The strategies you develop will often be different, depending on whether you wish to protect or improve. However, it is important to put just as much effort into strategies to protect assets from harm (Figure 6.1), as into fixing assets that have already been damaged.

What makes a suitable strategy for protecting or improving stream assets will depend on the problems that are threatening or causing the damage. Often, the problem will relate to the physical character of the stream. For example, an erosion head is moving upstream, or there is a lack of fish habitat because erosion has destroyed undercutts and the woody debris has been removed from the stream. In this case, your strategy will be physical intervention in the stream—such as a rock ramp to stabilise the erosion head, or the introduction of large woody debris to the stream. However, in other cases, the threat to the stream comes from human activities, such as recreation, or stream management with goals other than rehabilitation. In this situation, your strategies will involve convincing people **not** to do things in streams. For example, recreational fishing is depleting fish stocks, or water extraction means the stream stops running

for a much longer period in summer. You need a strategy to change people's behaviour—such as bag limits and an education campaign for recreational fishing, or reducing the volume of water extracted, and building small dams to store winter flow, so allowing the natural summer flow regime to return. Most stream rehabilitation projects should include both types of strategies. For example, consider the reintroduction of woody debris mentioned above. If landholders are continuing to remove timber from streams in order to improve flood conveyance, there would be little point artificially adding wood to the channel. The first strategy would be to persuade stream managers or landholders to stop removing the wood that is already there, which would be followed by adding more timber.

Table 6.1 lists some examples of strategies for physical intervention in the stream, and also tells you where more information is available in this manual. You should also check the descriptions in *Common stream problems*, and *Intervention tools* in Volume 2. Table 6.2 lists ways to change people's behaviour. You should also check Step 2 (*Who shares your goals for the stream?*) and *Why stakeholders may not support your plan* in *Miscellaneous planning tools*, Volume 2, for suggestions on strategies to involve people in rehabilitation. Think of as many options as you can, and list them all. Do not be afraid to combine strategies, and be ready to think laterally. After Table 6.2, we present some case studies of identifying strategies.



Figure 6.1. This drain is the new course of a creek in central Victoria. Digging a ditch like this might be good management if your goal is flood management, but if your goal is to protect the health of the stream, then this is an example of a management activity that should have been stopped because of the damage caused to the stream environment.

Table 6.1. Some examples of strategies for fixing problems by intervening in the stream.
Where strategies are required to change peoples behaviour, there is a reference to Table 2.

Problem	Examples of strategies for preventing problems	Examples of strategies for fixing problems and accelerating recovery	Where to find more information in this manual
<i>Plants and animals (including riparian zone)</i>			
Willows and other weeds	Remove plants that could be a source of invasion. Eg. trees that are upstream of the area and that produce seed.	Some combination of poisoning the plants and physically removing them.	Willow infested streams and Exotic weed infestations in Intervention in the riparian zone, Vol. 2.
Feral animals	Identify and eradicate populations that could invade the reach.	Identify and eradicate populations in the reach.	Not covered in this manual.
Damage to stream by grazing animals	Define buffer zones around streams.	Define and fence buffer zones around streams, offer off-channel watering.	<i>Stock management</i> in Common stream problems, Vol. 2., <i>Managing stock access to streams</i> in Intervention in the riparian zone, Vol. 2
Poor riparian vegetation	Prevent clearing or grazing of native vegetation (see Table 5.2).	Revegetate by encouraging natural regeneration, direct seeding, or planting tube stock.	<i>Vegetation management</i> in Intervention in the riparian zone, Vol. 2
<i>Flow regime</i>			
Flow regime and amount of water	Prevent water abstraction (see Table 5.2).	Return critical elements of natural flow regime by remove regulating structures, modify flow releases or modify the channel to produce desired flow characteristics.	This manual does not consider environmental flow management. However, Natural channel design in Planning tools, Vol. 2, can be used to create the channel that you want!
<i>Longitudinal connection</i>			
Longitudinal barriers (eg. fish barriers)	Discourage construction of any structures across streams (see Table 2).	Provide passage through the length of the stream by removing barriers or building fishways. Restock fish above barrier (not ideal).	<i>Barriers to fish migration</i> in Common stream problems, Vol. 2 <i>Overcoming barriers to fish passage</i> in Intervention in the riparian zone, Vol. 2
<i>Lateral connection</i>			
Lateral (floodplain) barriers	Control levee construction and changes to effluent channels (see Table 2).	Provide sufficient area and frequency of natural flooding on the floodplain by moving or removing levees. Restore connectivity to floodplain wetlands and channels by altering flood gates and other barriers to floodplain flow . Alter flow regime to provide flooding.	No detailed information provided on lateral connectivity.
<i>Water quality</i>			
Pollution	Identify possible sources of pollution and prevent them from reaching the stream Eg. preventing erosion of polluted sediment (also see Table 2)	Treat pollution in the stream by intercepting with wetlands. Identify the source, and stop the addition of more pollution (easier with point sources).	Some information is provided in Water quality in Common stream problems, Vol. 2. This manual does not discuss solutions to water quality impacts in any detail.
High temperatures	Prevent discharges of hot waste water. Prevent the development of shallow water without any shade.	Allow waste water to cool before discharging into stream. Replant riparian vegetation to shade stream Construct pools in the stream.	As above.

Table 6.1. Some examples of strategies for fixing problems by intervening in the stream.

Where strategies are required to change peoples behaviour, there is a reference to Table 2. (*Continued*)

Problem	Examples of strategies for preventing problems	Examples of strategies for fixing problems and accelerating recovery	Where to find more information in this manual
<i>Water quality (cont'd)</i>			
Fine sediments and turbidity	Control input of fine sediment to the stream. Intercept or flush through the reach sediment coming from upstream.	Identify and treat sources of fine sediment (eg. road crossings, forestry, farm run-off, bed and bank erosion). Intercept or flush through the reach sediment coming from upstream.	As above.
<i>Structural and hydraulic complexity</i>			
Sediment slugs	Prevent erosion in areas where the sediment will be delivered to the stream. Prevent in-stream sediment from reaching good reaches by removing sediment from stream .	Stabilise sediment in position to reduce impact of slugs on stream. Remove sediment from stream.	<i>Sediment slugs</i> in Common stream problems, Vol. 2 <i>Sand and gravel extraction as a management tool</i> in Intervention in the channel, Vol. 2
Large woody debris	Ensure that no woody debris is pulled out of the stream for flood or erosion management (see Table 2).	Add large woody debris to the stream. Revegetate riparian zone to promote natural additions of debris.	<i>Large woody debris</i> in Common stream problems, Vol. 2 <i>Management of large woody debris</i> in Intervention in the riparian zone, Vol. 2
Instability and changes to gross channel form	Prevent channellisation or other disturbance (see Table 5.2).	Accelerate recovery of 'natural' channel using structures to control bed and bank erosion, and stabilise sediment in the channel.	<i>Geomorphic problems</i> in Common stream problems, Vol. 2 <i>Instream structures</i> in Intervention in the channel, Vol. 2.

Table 6.2. A few strategies for changing people's behaviour (see also Step 2 (Who shares your goals for the stream?) and *Why stakeholders may not support your plan* in Miscellaneous planning tools, Volume 2)

Strategy	Examples of the strategy
Education and Persuasion	Developing the rehabilitation plan cooperatively Waterwatch Field days Advertising on local radio, newspapers or television Public meetings Political campaigns
Legislation and regulation	Bag limits on fishing Altering the status of the stream and adjacent land (ie. zoning land uses) Water quality controls

2 Summary

Summary of how to identify strategies

- You need to identify a general strategy to protect and improve assets, and to fix problems. The feasibility of these general strategies will be assessed in Step 8.
- Strategies to protect assets need as much thought as strategies to fix problems and repair damage.
- The condition of streams can be improved both by changing the stream (eg. building things such as rock ramps), or by changing people's behaviour in the stream (eg. water extraction).
- Almost every project should include some strategies for changing human behaviour.

At the end of this step, you should have a table that has the reaches ranked in order of priority, with the major assets, and potential assets, in each reach identified. Next to each

asset you will have identified any potential and problems. Now you will have defined strategies for reducing the impacts of those problems. You will also have developed strategies for improving the potential condition of assets (eg. stabilisation, revegetation).

The next step is to turn these general strategies into specific rehabilitation objectives.

Here is a summary of the priority reaches for treatment in Durben Creek (from Step 5).



Figure 6.2. Weeds in an upstream reach of Durben Creek.

3 Case study: Durben Creek

Table 6.3. Impacts on Durben Creek with possible strategies for reducing the impact

Reach and priority	Problems in order of priority, and links between problems	Possible strategies for treating the problems
Priority 1 Downstream Gorge (Reach 3)	1. Weeds in riparian vegetation	<ul style="list-style-type: none">• Weed control• Revegetation
Priority 2 Rural headwaters (Reach 1)	2. Grazing (linked to 3) 3. Weeds (linked to 2) 4. Lack of regeneration (linked to 2 & 3) 5. Poor water quality	<ul style="list-style-type: none">• All of the following: control grazing (fencing); weed control, revegetation.
Priority 3 Downstream Gorge (Reach 3)	6. Water quality from the Urban reach (linked to 7, 8, 9 & 10) 7. Water quality problems from this reach (linked to 6, 8, 9 & 10) 8. Hydrology (linked to 6, 7, 9 & 10) 9. Possible substrate contamination (linked to 6, 7, 8, & 9)	<ul style="list-style-type: none">• Identify and manage diffuse sources of pollution• Manage diffuse sources of urban pollution (investigate how the urban growth in the catchment can occur without damaging the stream)• Increase the roughness of the channel with vegetation and increased structural complexity• Test for contamination of substrate
Priority 4 Urban mid reach (Reach 2)	10. Riparian weeds 11. Lack of native riparian vegetation 12. Water quality from rural reach (linked to 13 & possibly 16) 13. Water quality from this reach (linked to 12 & possibly 16) 14. Changes to hydrology (linked to 12, 13 & possibly 15) 15. Low habitat diversity (linked to 12, 13, & 15)	<ul style="list-style-type: none">• Weed removal, fencing , off-channel watering for stock, revegetation.• Assess sources of pollution, control point sources from farms.• Increase roughness with vegetation• Improve macrophyte vegetation, and in-channel complexity

4 Possible solution strategies in Mythic Creek

Table 6.4 summarises the order in which impacts would be tackled in Mythic Creek, and the possible strategies for solving the impacts. Note that these are strategies for solving the problems (ie. treating the impacts) not specific, detailed ideas on the design of the solution (eg. the slope of the riffles, or the vegetation species).

Table 6.4. Priorities set in the Mythic Creek example

Reach Priorities	Assets & associated problems in order of priority	Possible strategies
Reach 1a	1 Proposed dam 2 Weed infestation	<ul style="list-style-type: none">Prevent dam being builtControl weeds
Reach 3	3 Proposed dam 4 Sediment from upstream 5 Grazing 6 Nutrients from piggery 7 Weeds (linked to 2)	<ul style="list-style-type: none">Prevent dam being builtAttempt to intercept sand in reaches 1b and 2.Fence, revegetate, and exclude stockReduce effluent releases (investigate storage in sediments?)Control weeds
Reach 1a	8 Degraded vegetation	<ul style="list-style-type: none">Revegetate, or assess natural regeneration
Reach 2	9 Sediment from Reach 1b 10 Poor riparian vegetation (linked to 2*) 11 Poor instream habitat (linked to 9) 12 Erosion control	<ul style="list-style-type: none">Intercept sedimentFence and allow to regenerate from Reach 1aImprove habitat, in long term revegetateRely on vegetation or stabilise banks
Reach 1b	13 Nutrient from piggery 14 Poor riparian condition 15 Poor habitat in incised streams	<ul style="list-style-type: none">Reduce pollution levelsFence and revegetateStabilise bed
Reach 4	16 Culvert is limiting barrier to fish passage 17 Poor riparian condition 18 Nutrient enrichment 19 Weed infestation	<ul style="list-style-type: none">Overcome barrier (remove, fishway, modify structure)Fence and revegetateIdentify rural sources of nutrientsControl weeds

* If there are still weeds in Reach 1a, seeds of these pest species and of native species will be washed downstream to colonise Reach 2.

5 Reality check

You should now have some options for fixing or protecting each asset and problem in your stream. If this is the case, you are free to proceed to Step 7 (What are yourspecific and measurable objectives?). However, if there are some problems for which you have been unable to identify any options, then the problem may be impossible to fix. You will need to return to Step 5 to consider the next highest priority problem. In some circumstances, you may need to consider working on a different reach (if there are no possible strategies for treating a fatal problem).

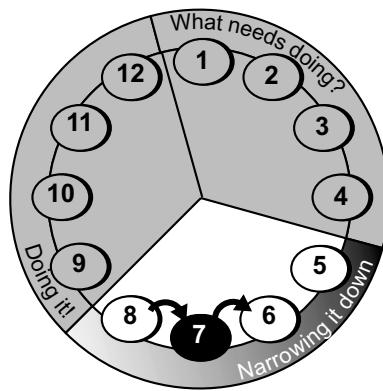
Steps 6, 7 and 8 (strategies, objectives and feasibility) are actually a tight loop. If your first set of objectives are not feasible at Step 8, then you return to Step 6 to search for alternative strategies, and to Step 7 to set new objectives. This can be demonstrated with the Mythic Creek example. If it is not feasible to stop the construction of the dam in Reach 1a, there may be some other strategy that will reduce the impact of the dam, such as ensuring it has large release valves to allow for environmental flow releases, combined with the negotiation of an acceptable environmental flow.

Step 7:

What are your specific and measurable objectives?

AIM: By the end of this step you should have defined objectives for your project that:

1. you can measure; and
2. have time limits attached to them.



A Catchment Management Board representative is meeting with one of the growing number of major grape producers in the valley. Routine measurements by a Waterwatch group, and inspections by the Board, have shown that turbidity below the drain outfall from the producer's vineyard is double that above the outfall (Figure 7.1). Turbidity is seen as a priority impact on downstream reaches. The farmer is keen to solve the problem.

The catchment management officer gives the landholder some literature on how to manage erosion in vineyards. She then proposes that they set an objective for reducing the turbidity. In the last three measurements the turbidity below the drain was double that above. Within a year, getting this down to only 30% greater would be satisfactory progress, and down to a 10% increase would be outstanding. After five years, the target would be to never exceed a 5% increase. The farmer agrees enthusiastically to these targets. Finally, the officer gives the landholder a calibrated turbidity bottle that he can use to monitor his progress himself.



Key points about setting objectives:

- Your general strategy for rehabilitation has to be turned into objectives that specify what you want to achieve in your rehabilitation project.
- Objectives are the small steps on the path to achieving the goal you identified in Step 1.
- Objectives should be measurable, so you can evaluate how successful you were.
- You should describe the range between what you would consider a very disappointing result, and what would be a great success.
- Objectives should specify the area of the stream to which they apply.
- Objectives should include a time limit within which they should be achieved.

Figure 7.1. Turbid water from a single road drain entering a small stream in western Victoria.

1 What are specific objectives, and why do you need them?

Your objective should be a clear, precise, and measurable statement of what you aim to achieve in your attempt to fix the top priority problems identified in Step 5 (Setting priorities), using the solution you identified in Step 6 (What are your strategies?). Objectives differ to the goals you identified at Step 1 (What are your goals?). Your goal is the vision that you are working towards for the stream. In the turbidity situation above, for example, the catchment management officer has visited the landholder because one of the goals of the management board is to provide "a stream environment that is adequate for populations of native fish to flourish". The board has identified the

reduction of peak turbidity to be a high priority task to achieve this goal. Their objective, therefore, is to reduce peak turbidity to somewhere between 40 and 70 NTU* (a great result and a disappointment, respectively), and low flow turbidity to between 5 and 15 NTU within five years. This specific objective for managing turbidity then translates into specific objectives for the drain from one of the farms that contributes to the problem. Objectives, then, are the specific aims of a rehabilitation project. They are usually only small steps along the path towards your general goal for stream rehabilitation.

*Nephelometric turbidity units which are standard units for measuring turbidity.

The benefits of setting objectives are:

1. They force you to work out exactly what you would consider a success. Once your project is finished, you will need a clear statement of what you set out to achieve, to allow you to assess the success of your work. In fact, having measurable objectives is a prerequisite for designing your evaluation in Step 10 (How will you evaluate your project?).
2. They make you set the scope and scale of the project. Are you going to treat all of the reach, or just parts? Are you going to completely fix the problem, or are you just trying to reduce its severity?
3. They reveal where objectives are contradictory. For example, revegetation is likely to reduce channel capacity for floods.

Defining measurable objectives adds rigour and accountability to the entire stream rehabilitation process.

2 How do you set objectives?

Setting objectives is a simple continuation of Steps 5 and 6. In Step 5, you identified the problems you are going to try to fix, and in Step 6, you identified how you might go about it. To complete Step 8 (Are your objectives feasible?) you need to have clear objectives. They will be needed again when planning the evaluation of your project (Step 10).

Setting objectives is a matter of considering the five tasks shown in Figure 7.2.

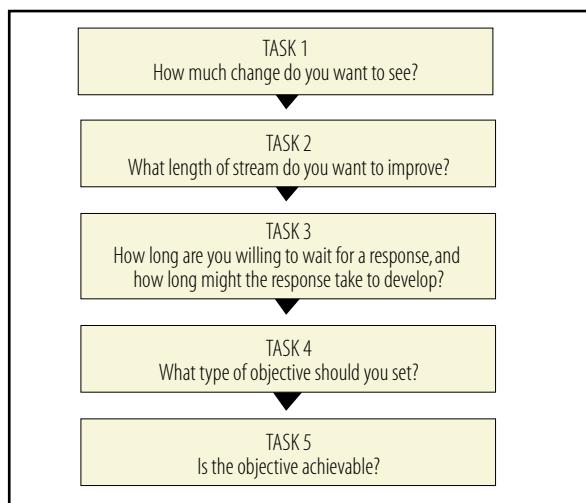


Figure 7.2. The tasks to be completed in Step 7

2.1 TASK 1: Defining the amount of change you want to see.

It is important to specify exactly what you want your rehabilitation project to achieve. For some projects, this will be a simple question of presence or absence. For example, the new factory will not discharge wastewater into the river, or the erosion head will not move upstream of the stabilising works. However, most of the time, the problems you tackle will not lend themselves to objectives that are so readily definable. Rather than either existing or not existing, they may improve a little, or a lot. For example, in a shallow river, the lack of deep pools could be a high priority problem. You might set as your objective that over five years, the pool will become a metre deeper. But what if the depth only increased by 90 cm? Is that a failure? Maybe even a 20 cm increase would be better than nothing, so although this result would be disappointing, it is not a total failure. In such situations, you should express your objective as a range between the best success you could possibly expect, and what would be a great disappointment, or the smallest useful improvement. A complete failure would be defined as no improvement, or even a worsening in condition. The objective for the increase in pool depth could be an increase in depth of at least 20 cm, or as much as 100 cm.

Alternatively, objectives can be set in terms of ‘maintenance’ rather than improvement. That is, when protecting an existing asset, the objective is whether its condition has not deteriorated. For example, “the number of cattle access points to the creek will not have increased after five years”.

2.2 TASK 2: Defining the spatial scope of the objective.

The length of stream you want to improve will depend on the problem you are treating, as well as the cost of the treatment and what length of stream you need to treat to get a response. If you are returning woody debris to a stream, you may see an improvement in the fish or invertebrate communities with the addition of only a few logs. However, if you are revegetating the riparian zone, with the hope that the extra shade will reduce water temperatures, or to develop a self-sustaining plant community, you will probably need to treat a considerably longer reach.

2.3 TASK 3: Setting the time frame.

To evaluate a stream rehabilitation project, you have to set the time over which you expect stream improvements to occur and be sustained. This will depend on the problem you are treating. *Recovery of disturbed stream systems in Australia* in Stream rehabilitation concepts, this volume, discusses how long one can expect to wait for a system to recover. You need to leave sufficient time for the stream to respond to your rehabilitation. You also need a short enough time frame to keep people interested. Having a series of objectives may help with this. These can track the recovery of the stream, as in the example at the start of this step, where the objectives called for an improvement in turbidity after one year, and further improvements after three years. Alternatively, two complementary objectives might be to complete any work on the stream (outputs) in a year, and to measure the effects of that work (outcomes) after 5 years (see Step 10 How will you evaluate your project?, for some more suggestions on this).

2.4 TASK 4: Determining the type of objective.

Objectives can be defined as **outputs** of the project, that are built, stopped, or modified with the intention of creating the desired **outcomes** in the condition of the stream. For example, building a fence is an output. Achieving natural vegetation regeneration is the outcome of the fence. Your objectives can be phrased in terms of outputs, so long as you are confident that the outcomes you desire will follow. Ideally, both sorts of objective are useful. Output objectives are usually easy to measure, and quick to show a result, but they can evaluate only implementation. You assume that the outcomes will follow. For example, we got the fencing and

planting done on schedule, so the revegetation should be successful. Outcome objectives allow evaluation of change in the stream condition, which is far more important, but also can be more difficult to measure, and usually far slower to show a result. As suggested above, a combination of both sorts of objectives is often most useful.

In Table 7.1 we suggest five general types of objective. Execution and survival objectives relate to outputs of rehabilitation—did you build what you planned, and did it survive the design flood, respectively. Objectives relating to outcomes can be based on aesthetics (eg. the stream looks better), change to the physical condition of the stream (eg. more pools developed because the sand bars have stabilised), or changes related to organisms (eg. there are more fish, more diversity of macrophytes and macroinvertebrates since we did such-and-such to the stream).

Types of objectives, and how you would evaluate them, are discussed in Step 10, and in the *Evaluation tools* in Planning tools, Volume 2, where there is a table that lists numerous measurable objectives that you could use to achieve some typical goals. This may provide you with ideas for setting objectives for your own project.

2.5 TASK 5: Check that the objective is achievable.

Experience shows that nothing kills the enthusiasm of participants in a project more quickly than objectives that can never be met. A successful project can appear unsuccessful because of over ambitious objectives. *Recovery of disturbed stream systems in Australia* in Stream rehabilitation concepts (this Volume) discusses this issue. Most recovery is measured in years, and often geomorphic recovery relies on a series of floods of the appropriate size (Figure 7.3). It is essential that objectives reflect the time that it is likely to take for recovery, and that all participants are fully aware of that time. Using objectives that specify a range of outcomes, from great disappointment to great success (as discussed above), is one way to make sure your objectives are achievable.

Table 7.1. Types of objectives for stream rehabilitation.

Output / outcomes	Type of objective	Example of objectives
Output	Execution of the project.	<ul style="list-style-type: none"> Fence 7-10 km of stream, and provide two off stream watering points by next summer.
Output	Survival of the project.	<ul style="list-style-type: none"> Flood gates in the fence survived a 5 year flood.
Outcome	Aesthetics of the stream.	<ul style="list-style-type: none"> Revegetation inside the fence makes the stream look much more attractive after 5 years.
Outcome	Physical condition of the stream. (May relate to the riparian zone, the physical form, the hydrology or the water quality).	<ul style="list-style-type: none"> After five years, the pools would be between 20 and 50 % deeper. The riparian vegetation will provide between 1 and 10 fragments of woody debris per kilometre of stream per year, after 20 years.
Outcome	Improvement or maintenance of stream ecology	<ul style="list-style-type: none"> The range of species present (diversity) in the riparian zone will be between 50 and 100% of that found in the template reach after 5 years. The numbers of a particular organism (eg. platypus, fish, macroinvertebrates, redgum) will increase to between 20 and 60% of populations found in the template reach, after four years.



2.6 Caveats

Objectives should have an escape clause covering unforeseen (but not unlikely!) events that are outside the design parameters. For example, it does not mean your project failed if structures that were designed to survive a 20-year flood, were destroyed by a 100-year flood soon after construction.

Figure 7.3. A bankfull flood in Dandenong Creek in Melbourne. Geomorphic recovery of streams often depends on floods like this.

3 Summary questions for setting objectives

Clearly stated objectives are at the core of a stream rehabilitation project

- If you achieve all of your objectives, will the stream be closer to your goal?
- What sort of objectives have you set? Will they measure what you are going to do, a response in the physical structure of the stream, or a response in the plants and organisms in the stream?
- Do all your objectives specify a level of change in a stream attribute?
- Do all your objectives describe the spatial extent of the project?
- Do all of your objectives have a time limit attached to them?
- Is the time limit realistic given the likely rate of recovery?
- Can all of your objectives be measured in some way?

4 Case study: a turbidity objective for the Patuxent River, USA

In front of the waiting throng of media, Senator C. Bernhard Fowler waded into the Patuxent river in southern Maryland, USA. He was looking down at his white sneakers. At the point where his sneakers could no longer be seen, he measured the depth—44 inches (112 cm). “In five years time”, he declared, “the efforts of my department will have improved water quality so that I will be able to wade to twice this depth before I can’t see my sneakers” (paraphrased from *New Scientist* ‘Feedback’, July 26, 1997).

This is an example of a clear objective (so to speak), with a time-frame and a measure defined. Even better, the objective grabs the imagination, and is easy to measure.

However, it is important to emphasise that the sneaker turbidity test is an objective, not a goal. The reason to reduce turbidity is to achieve the goal of improved ecological condition. Turbidity may be a limiting variable in achieving that goal.

In addition, we should emphasise that Senator Fowler’s measure needs more definition to be truly useful. The ‘Sneaker Index’ should be measured at the same discharge, in the same place, and wearing the same sort of sneakers. It would also be worth checking if it is, in fact, possible to reduce turbidity by that amount. Suspended sediment is a notoriously difficult pollutant to control.

5 Case study: Specific objectives for the rehabilitation of Durben Creek

In Table 7.2, we remind you of the priority problems identified in Durben Creek (see Step 5), possible solutions to those problems (Step 6), and then present some possible measurable objectives for a rehabilitation project aiming to fix those problems.

Table 7.2. A summary of the problems present in Durben Creek, strategies to solve those problems, and the measurable objectives for a project trying to fix these problems.

Reach	Problems in order of priority, and links between problems	Strategy	Objectives
Priority 1 Downstream gorge (Reach 3)	1. Weeds in riparian vegetation	• Weed control • Revegetation	<ul style="list-style-type: none">At the end of five years, have established a native vegetation community comprising 50-100 % of the diversity and density of the template community. Woody weeds should be only 0-30 % of the total non-grass vegetation.
Priority 2 Rural headwaters (Reach 1)	2. Grazing (linked to 3) 3. Weeds (linked to 2) 4. Lack of regeneration (linked to 2 & 3) 5. Poor water quality	• Fence off riparian zone • Revegetate • Reduce levels of pollution released into the stream	<ul style="list-style-type: none">Fence both banks of the 10 km of stream in this reach, by February next year.See revegetation objective for Gorge reach above.Identify and control the main point sources of pollution in this reach. Median, peak and low flow pollution levels should be reduced between 30-80 % by year ten.The SIGNAL index measure of macroinvertebrate population health should increase from probable severe pollution to probable moderate pollution by year 5

Table 7.2. A summary of the problems present in Durben Creek, strategies to solve those problems, and the measurable objectives for a project trying to fix these problems. (*Continued*)

Reach	Problems in order of priority, and links between problems	Strategy	Objectives
Priority 3 Downstream gorge (Reach 3)	6. Water quality from the Urban reach (linked to 7, 8, 9 & 10) 7. Water quality problems from this reach (linked to 6, 8, 9 & 10) 8. Hydrology (linked to 6, 7, 9 & 10) 9. Substrate contamination (linked to 6, 7, 8, & 9)	• Create artificial wetlands to absorb pollutants and retard flow • Reduce levels of pollution released into the stream	<ul style="list-style-type: none"> • By year 2, complete construction of a wetland upstream of the gorge. By year five, low flow, pollution levels downstream of the wetland should be between 40-80% of the upstream levels. • Identify and control the main point sources of pollution in this reach, as well as the urban and rural reaches upstream. Median, peak and low flow pollution levels should be reduced between 30-80% by year ten. • The SIGNAL index measure of macroinvertebrate population health should increase from probable severe pollution to probable moderate pollution by year 5
Priority 4 Urban midreach. (Reach 2)	10. Riparian weeds 11. Lack of native riparian vegetation 12. Water quality from rural reach (linked to 13 & possibly 16) 13. Water quality from this reach (linked to 12 & possibly 16) 14. Contaminated substrate (linked to 12, 13 & possibly 16) 15. Changes to hydrology (linked to 12, 13 & possibly 16) 16. Low habitat diversity (linked to 12, 13, 14, & 15)	<ul style="list-style-type: none"> • Weed control • Replanting • Reduce pollution, consider scarifying to remove sediment • Manage urban pollution • Increase roughness in channel and on floodplain • Wait for recovery of disturbed channels 	<ul style="list-style-type: none"> • Fence both banks of 7-10 km of stream in ten years. • In the fenced area, at the end of five years, have established a native vegetation community comprising 40-100 % of the diversity and density of the template community. Woody weeds should be only 10-50 % of the total non-grass vegetation. • Fence and revegetate 10 km in 10 years • Median pollution levels decreased by 50-80% in 5 years. Maintain this up to year ten • Scarifying experiment completed in 1 year (removing 70-90 % of pollutants from stream bed would be considered a success) • The SIGNAL index measure of macroinvertebrate population health should increase from probable severe pollution to probable moderate pollution by year 5 • Increase instream roughness (measured by Mannings 'n') to between 0.04-0.1 within 10 years • Assess change in hydraulic habitat using recognised measure, after 5 and 10 years.

6 Developing measurable objectives for the Mythic Creek rehabilitation

Table 7.3 shows the objectives set for the Mythic Creek project. They measure project outputs as well as physical and biological responses of the system (outcomes).

Importantly, the objectives specify when a response is expected, and the design flood that structures are expected to survive.

Table 7.3. Objectives set for the Mythic Creek Project (the low priority reaches 4 and 1b have been left out for brevity)

Reach Priorities	Assets & associated problems in order of priority	Possible strategies	Measurable objectives
Reach 1a	<ul style="list-style-type: none">• Proposed dam• Weed infestation	<ul style="list-style-type: none">• Prevent dam being built• Control weeds	<ul style="list-style-type: none">• No dam in 10 years time• Cover of weeds reduced to 20-60 % of pre-project cover by year 5• Fence both banks for 10 to 15 km of stream by end of year 1*.
Reach 3	<ul style="list-style-type: none">• Proposed dam• Sediment from upstream• Grazing• Nutrients from piggery• Weeds	<ul style="list-style-type: none">• Prevent dam being built• Attempt to intercept sand in reaches 1b and 2• Fence and revegetate• Reduce effluent releases (investigate storage in sediments?)• Control weeds	<ul style="list-style-type: none">• No dam in 10 years time (see dam related objectives in Reach 1a)• Experimental extraction completed year 2 (experiment to be considered a success if the pools in Reach 3 stop filling with sand—that is, depth at least remains the same, at best depth increases)• Both banks fenced for 15-18 km of stream by end of year 1*.• Vegetation diversity and density should be between 50-80 % of the template by year 5.• Effluent releases from piggery in Reach 1b meet EPA requirements in 18 months.• Monitor piggery effluent releases with Waterwatch• Cover of weeds reduced to between 0 and 30% of pre-treatment cover by year 5
Reach 1a	<ul style="list-style-type: none">• Degraded vegetation	<ul style="list-style-type: none">• Revegetate, or assess natural regeneration	<ul style="list-style-type: none">• Assess natural revegetation at year 5. Should have increased vegetation density and diversity to 75-100 % that of template reach.
Reach 2	<ul style="list-style-type: none">• Sediment from Reach 1b• Poor riparian vegetation• Poor instream habitat• Erosion control	<ul style="list-style-type: none">• Intercept coarse sediment and reduce turbidity• Fence and allow to regenerate from Reach 1a• Improve habitat, in long term revegetate• Rely on vegetation or stabilise banks	<ul style="list-style-type: none">• Experimental sediment extraction completed after 5 years (successful if median pool depth in the reach has increased by 50-200 %)• Reduce turbidity from Reach 1b by 50 - 80 % in five years• Fence both banks of the reach within 3 years.• Riparian vegetation should, by year five, have 50-80% of the diversity and density of native species found in the template reach.• Determine if natural regeneration is as efficient as direct seeding• Median pool depth in the reach has increased by 50-200 % after 5 years, and maintains depth up to year 10.• Bank erosion rate should match template five years after vegetation is established on the banks.

*Note that the floodgates on the fences should survive a five-year flood.

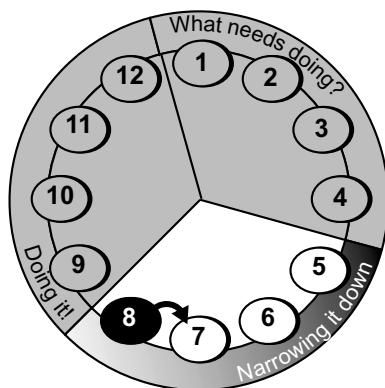
7 Reality check

The first time you run through this step, there is no reality check, so you move straight on to Step 8 (How feasible are your objectives?). However, in Step 8, you might find that your objectives are not feasible, and in this situation you return to this step. There are two alternatives when you find that your objectives for your top priority problems are **not** feasible.

1. Consider compromising on your objectives. Maybe you won't be able to be as thorough as you'd hoped, but by lowering your expectations a little, you may still be able to improve the condition of the stream with a compromise. Move onto Step 8 again to check the feasibility of this new objective.
2. You may decide that no compromise is possible—if you cannot achieve your objective, then there is no point fiddling around the edges of the problem. If this is the case, then you should return to Step 5 (Setting priorities) and identify the consequences of not treating the problem.

Step 8: Are your objectives feasible?

AIM: At the end of this step you should have decided on the feasibility of your stream rehabilitation plan based on the financial cost, other constraints, and possible undesirable side effects.



Members of a Rivercare group are trying to restore the native fish fauna of their stream. They have identified two high priority problems, a weir that forms a barrier to fish passage near the bottom of their catchment, and an absence of fish habitat throughout the stream because of widespread desnagging in the past.

They identified three possible strategies to achieve their objective of overcoming the barrier to fish passage, and examined the feasibility of each of these.

1. Demolishing the weir is **not** feasible, because the town water supply is pumped from the pool. The town has to get its water from somewhere, and the group would be unable to convince the shire council that letting fish into the river upstream is worth the expense of shifting their pumping station.
2. Constructing a fish ladder past the weir is also **not** feasible, because such structures cost more than the group can afford.
3. Building a rock ramp fishway up to the crest of the weir **is** feasible. This is a much cheaper option than the fishway, and does not interfere with the function of the weir.

The group also want to get the snags back into the river, to provide habitat for the fish that are already there. However, some landholders believe this is **not** feasible, because the debris will cause erosion in the channel, and increase the length of floods. The group decides to do a **pilot** study of the effects of debris, to see if the negative side-effects really do outweigh the benefits of the extra habitat.

Key points about the feasibility of actions

- Many of the things that you would, ideally, like to do in your stream rehabilitation plan are not feasible because of cost, legislative or administrative constraints or the side-effects of the work.
- You must think about **all** of the consequences of your stream rehabilitation project, not just the 'good' things that you want to happen. Stream rehabilitation work can lead to increased erosion and flooding, and even damage to biological systems that it was intended to enhance.
- Your willingness to pay high costs for a rehabilitation treatment will depend partly on how risky that treatment is. You may be willing to spend the money if the risks are small.
- Whilst feasibility is usually measured in terms of costs, it is equally measured in terms of resolve and passion. Things become feasible if you want them enough.

1 Feasibility—an introduction

At Step 6 you identified strategies for solving the problems that were considered to be priorities at Step 5. In Step 7 you wrote measurable objectives that specified the extent of your proposed rehabilitation actions. You should now have a list of problems, and your objectives for fixing them, in order of priority. It is now time to check the feasibility of each of those objectives. At the end of this step, you will decide which of these objectives you will pursue, with the resources available.

A feasible objective has three characteristics. Firstly, you can afford it—the cost of the project is less than the

money and resources available. Secondly, you are allowed to do it—it is not illegal, and you can get permits for the work where required. Finally, and most importantly, it is worth doing—the benefits of the project would outweigh any negative side effects. If you are confident your objectives meet these criteria, then you can go ahead without changing your plans. If, however, your objectives failed on one or more counts, you must consider modifying your plans. You may need to review your objectives (Step 7), strategies (Step 6), and even your priorities (Step 5).

2 Assessing the feasibility of your objectives

2.1 Task 1: Can you afford it?

Feasibility is evaluated according to the 5 tasks in Figure 8.1.

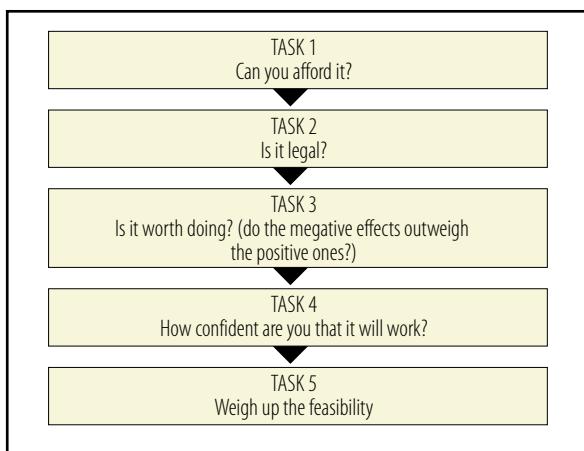


Figure 8.1. Five tasks for determining the feasibility of planned rehabilitation

Rehabilitating streams can be a frighteningly expensive business. When we think about stream management work we usually consider the **implementation costs** of the work. These are the obvious costs of doing things in streams, such as building fish ladders or fences, or planting vegetation (some typical costs of rehabilitation work in streams are provided in *Some costs of stream rehabilitation work*, in Miscellaneous Planning Tools in Volume 2.). What we do not often think about are the other monetary costs of planning and completing the project. Some of these extra costs are discussed below.

2.1.1 Implementation costs

- **What are the planning costs?** Stream rehabilitation can be a specialist task. It is possible to get free advice from government departments or committed experts. However, you may well have to pay for a diverse range of advice from people such as lawyers, engineers, or ecologists. Consulting fees of professionals are usually between \$500 and \$1,500 per day. Because stream rehabilitation work is not yet a 'cookbook' problem, you will probably find that the planning cost is higher than if you were doing a simple erosion control project.

Engineering firms often charge 10-20% of the overall project cost for their planning and design work. Planning is not cheap!

Table 8.1. Some examples of information costs you might encounter while planning a rehabilitation project in Victoria (as at 1999)

Information	Cost
Copies of parish plans from council archives	\$8.50 each
Stream gauging data	Free to community groups, but could be many hundreds of dollars to professionals
Aerial photographs	\$40-70 per photograph

- **What are the information costs?** The cost of gathering the basic information you need to plan a project quickly escalates. Table 8.1 gives some examples of useful information you will probably have to pay for.
- **What are the establishment costs?** One of the major costs of your project could be in getting machinery and material to the site. For example, the establishment costs for the reinstatement of meander cut-offs by the Wellington River Authority on the La Trobe River (Victoria) were approximately 80% of the total cost of the project, with the actual construction work in the stream comprising the other 20%. The sites were so inaccessible that roads and cuttings had to be made to get the machinery to the sites. In this situation, the River Authority was able to get permission to work on the land. The biggest establishment cost will occur in the extreme case where you have to buy the land in order to complete your rehabilitation project.
- **Will you have to compensate other stream users?** Compensating other stream users may be another type of establishment cost incurred. For example, you might be permitted to fence-out and revegetate a stream frontage so long as you provide, and pay for, off-channel watering points for stock.
- **Will vandalism add to the cost of your project?** Anything that looks to be of monetary or social value, including stream rehabilitation projects, will be a prime target for vandals. We have often seen fences cut, monitoring equipment stolen, and revegetation sites destroyed.

Three defences against vandalism are:

1. Make the work vandal proof (eg. it is so big it can't be moved) (Figure 8.1).
2. Make the work inconspicuous so that it is not found.
3. Prominently advertise the reason for the work so that even potential vandals will recognise its worth and leave it alone. This option will benefit from including potential vandals (eg. high school students) in the project from its inception.

2.1.2 Post project costs

- **What are the maintenance costs?** Building a structure is never the end of the project, because any construction work will need maintenance. In general, modern stream rehabilitation designs using 'soft engineering' and vegetation will require substantial maintenance. For example, rock chutes are designed to move around at high flows, rather than completely resist the flow. This will usually mean that some maintenance is required after floods.
- **How much will the evaluation cost?** As discussed in Step 10 (How will you evaluate your project?), a detailed evaluation program can cost more than the rehabilitation project itself. Most of this cost comes from the monitoring and measurement required to see if your project really has made a difference to the stream. You may have to abandon a low priority component of your project, in order to pay for a complex evaluation of the high priority elements of the work.

2.1.3 Other costs of the project

Many possible consequences of a project might be unrelated to the goal of the work. Some consequences could be expensive. Consider a project that revegetated stream banks and added large woody debris to the stream. In a major flood, the debris is washed downstream where it jams against a small bridge. The combined weight of the debris and flood water cause the bridge to collapse. The road authority is now planning to sue the community group for the cost of a new bridge. Such legal liabilities can prove cripplingly expensive.

In summary, to assess the feasibility of a project, stream managers have to assess all of the potential costs, including planning, implementation and after-project costs.



Figure 8.1. Some well constructed, vandal-resistant monitoring equipment (Ripple Creek, central Tasmania)

2.2 Task 2: Is it legal (what are the legislative and administrative constraints)?

Up to now we have been assuming that you will be permitted to implement the project if you want to. In fact, there is a raft of institutional and planning controls over what you can and cannot do on streams and rivers. These controls differ between States. Permits may be required for some activities. At this point you might want to check the list of Acts and other planning controls over stream work that are listed in *Legislative and administrative constraints* in Miscellaneous planning tools, Volume 2.

2.3 Task 3: Is it worth doing? What are the side-effects of the project?

The objectives of your rehabilitation project state clearly the benefits to the stream that you expect to result from your work. However, there will be some physical and biological side-effects to almost any project, and there are effects on other uses and users of the stream. These side-effects will not always be bad. However, for the project to be worth doing, the benefits must be greater than the negative side-effects.

2.3.1 Implications of physical side-effects for other stream users

Stream rehabilitation often involves walking a fine line between the opposition and support of local communities. If revegetation, in-channel works, or any other 'environmental' work along a stream produce unintended effects such as erosion or flooding, then support for stream rehabilitation activities may be set back by many years.

Some examples of legislative and administrative constraints

- Members of a community group decide to do some extensive rehabilitation works in a reach of stream on the Canning River in WA. They discover that the stream forms part of the Swan River Trust Management Area, and they will need permission from the management authority before they can proceed.
- * In Tasmania, plans to remove a small weir that is restricting fish passage will lead to a flush of sediment downstream. This will require a licence from the State EPA because the flush is likely to exceed 25 mg/L suspended sediment.
- * Under the *Victorian Water Act (1984)*, you do not have to pay for water that your stock drink directly from the stream. However, if you fence the creek, and force the farmers to pump water to an off-channel storage, then they could incur the cost of a diversion licence and other fees.

After all, many of the changes to our streams over the last 150 years were made deliberately—to reduce flooding, to provide grazing, or to reduce erosion. We should think very carefully before we blindly reverse these efforts.

Here are a few examples of the consequences of stream rehabilitation work on other users. Note that *Planning tools* and *Intervention tools* in Volume 2 provide detailed information for estimating the consequences of stream rehabilitation works on flood levels and on erosion. There is also some information in the detailed planning step of the procedure (Step 9: What is the detailed design of your project?).

- **Will the option cause erosion or deposition?**
Vegetation, snags, macrophytes, and in-stream structures are often central to stream rehabilitation projects. Sediment may collect in the backwaters of some structures (Figure 8.2). This could be the intended effect, but in some circumstances this deposition is detrimental to the stream. It can also cause clearwater scour downstream. Changes in the stream channel can also deflect or concentrate flow, and cause some bed or bank erosion. This is often of great concern to landholders, and can threaten assets such as bridges, culverts, and roads.
- **Will the option influence flood height or duration?**
As with erosion, putting things into streams can affect flood height and duration by blocking the channel and increasing roughness. *Natural channel design* in Planning tools, Volume 2 presents some methods for predicting the effect of stream rehabilitation on flooding.



Figure 8.2. Native phragmites reeds on a tributary of the Hopkins River. Macrophytes such as these are usually a welcome natural addition to a stream, but they can grow in dense stands through shallow water, sometimes encouraging the deposition of fine sediment and deflecting flow into the bank.

Flooding and erosion are not inherently bad

Flooding and erosion are in fact, an essential part of a naturally functioning stream. However, in some circumstances, they are bad because of their effect on the other users of the stream, and thus on the support for stream rehabilitation. It is unrealistic to expect that efforts to rehabilitate streams will never increase flooding and erosion. These effects of rehabilitation will eventually be a compromise between the need for floods, and the damage done by floods.

- **Will the option affect the performance of hydraulic structures?** Providing fish passage over structures in streams could compromise the purpose of the structure. For example, gauging stream discharge often relies on a weir built across the stream. The accuracy of the gauge depends upon having either a consistent crest form on the weir or on a special 'V' notch in the weir, and on having critical flow over the crest. The accuracy of the gauging can be jeopardised by trying to maintain fish passage over the structure (Figure 8.3). For example, piling rocks up to the weir crest (as is recommended in *Overcoming barriers to fish passage*, in Intervention in the Channel, Volume 2) will mean that the flow over the crest or notch will no longer measure the discharge accurately. Modifying culverts to allow fish passage provides another example of unintended consequences. It could reduce the capacity of the culvert, leading to more frequent flooding of the road.



Figure 8.3. The weir for a gauging station on the Wando River, Victoria. Providing fish passage over this weir could reduce its accuracy as a gauge.

- **Will the option affect practices of riparian landholders?** Fencing-out and revegetating riparian zones has many implications for adjacent landholders. It is always difficult to maintain fences on floodplains, and this may make landholders reluctant to fence riparian zones. Also, it is often necessary to provide off-channel watering for farmers if they have lost access to the stream (Figure 8.4), and to manage weeds and vermin that may shelter in the riparian vegetation. For example, there has been strong resistance to riparian revegetation in the sugarcane regions of Queensland because it is believed to harbour rats that damage the cane.



Figure 8.4. A nose pump providing an off-channel watering point for cattle on the Torrens River, South Australia.

- **Will the option affect recreational uses of the stream?** Many people think that natural streams look messy and untidy, and so may resist efforts to return the stream to a natural condition. Furthermore, fishermen may not thank you for planting dense swards of phragmites at the edge of the stream, because it can limit access for casting. Also, snags can tangle fishing lines, and may be a hazard for boats. Many fishermen would certainly be hostile to the suggestion that the government should stop stocking trout, or some other freshwater sport fish, despite the impact these introduced fish can have on native species.
- **Will the option affect other uses of the stream?** Streams are widely used as sources of water for irrigation and town water, and for disposing of waste products. Many rehabilitation projects will affect one or more of these uses. For example, improving water quality by tackling any point sources of pollution can be expensive for the farms or industries involved. In many regulated rivers, rehabilitation will relate to extracting environmental flows from dams, or demolishing dams or weirs that form barriers to fish passage. This can have serious ramifications for people who want to use that water for other purposes.

2.3.2 Undesirable biological side effects

Your well-intentioned stream rehabilitation plans could actually do more harm than good to the biological systems that you are trying to help. Table 8.2 gives some examples of this.

Table 8.2. Undesirable biological side-effects of some rehabilitation strategies

Rehabilitation method	Possible undesirable biological side effects
Riparian revegetation	<ul style="list-style-type: none"> Species that are not naturally found in an area may become weeds after being introduced in revegetation programs. Willows are the classic example of this, but it can also happen when Australian species are moved outside their natural range.
In-channel macrophyte planting	<ul style="list-style-type: none"> As with riparian vegetation, there is also the possibility of introducing weeds to the stream. Encouraging macrophyte growth risks being too successful. Overly vigorous macrophytes can choke the channel, reducing habitat and flow complexity by swamping riffles and slowing flow. This can potentially lead to low dissolved oxygen levels. Such macrophyte infestation is symptomatic of high nutrient levels, fine sediment deposition, and low flows.
Sediment extraction	<ul style="list-style-type: none"> During the period of sediment extraction there will be increased turbidity, and local destruction of in-stream habitat. There is the risk of over-deepening the bed, resulting in bank instability with its associated turbidity and fine sediment pollution.
Adding full width structures (eg. for controlling bed stability)	<ul style="list-style-type: none"> Structures that span the full width of the channel are potential barriers to fish passage. See <i>Barriers to fish migration</i> in Common stream problems, Volume 2, for a description of what constitutes a fish barrier. There is also a risk that too many full-width structures could flood-out all of the riffle habitat, and transform the stream into a series of slow moving pools. As well as decreasing habitat diversity, this can lower dissolved oxygen levels. Creating slow flowing pools can potentially trigger macrophyte growth which could choke the channel, particularly where there are already problems with nutrients and fine sediment deposition.
Removing barriers to fish passage	<ul style="list-style-type: none"> By removing barriers, you may allow exotic pest species, as well as desirable native fish, access to upstream reaches. Where this would threaten healthy populations of sensitive species of native fish, or delicate macroinvertebrate communities, it could be better to leave the barriers intact and live without the migratory native fish.
Bank revetment	<ul style="list-style-type: none"> This might remove bank habitat for burrowing creatures, and increase flow velocities near the bank.
Disturbing stored sediments (eg. when reinstating cut-off meanders or removing weirs)	<ul style="list-style-type: none"> When bends are reinstated, there may be some turbidity and fine sediment problems as material stored in the cut-off is remobilised. If this sediment includes pollutants (eg. heavy metals), this pollution could be released into the stream as a slug when the bends are reinstated. A similar pulse of sediment will be flushed downstream when dams or weirs are removed.

2.4 Task 4: How confident are you that a rehabilitation option will work?

The final issue to consider when deciding about the feasibility of your options is how much confidence you have that the options will work. One option may be very expensive, but you are almost certain that it will lead to dramatic improvement in biological condition. Another option may be cheap but you are sceptical about its effectiveness. This question is really: ‘How willing are you to gamble on your rehabilitation?’ If you are going to stake a lot of money, or risk some serious side-effects, you will probably want to be confident that your project will work.

2.5 Task 5: Weighing up feasibility.

The feasibility of a project depends on whether you can afford it, whether it is legal, and whether the benefits will outweigh the costs. If your objectives have met these three criteria for feasibility, then you can move on through the rehabilitation planning procedure. If, however, you decide an objective is not feasible, then you have three options.

You can compromise on your objectives, do a small scale trial of the project, or recognise the terminal unfeasibility of the project, and move on to your next priority.

- **Compromise!** You can try to change your project so that it becomes feasible, by reducing the cost, the side-effects, conforming with legislative requirements, or making it more palatable to community members. You might be able to achieve this by modifying your objectives (return to Step 7 to consider this). For example, you might reduce the amount of improvement you expect, or the length of stream you will treat. Alternatively, you can try to find some other, less costly or less damaging strategy for achieving your objectives (return to Step 6 to consider this). For example, constructing fish ladders is very expensive, and you may find that a cheaper rock-ramp fishway will do just as well to provide fish passage over low weirs.

If it is not possible to reach a compromise that still leaves the project with a meaningful outcome, you must turn to the second option.

Hypothetical example of a low confidence project

It has been suggested in a journal article that a particular fish species lays its eggs on the floodplain, and that a limiting step in its life-cycle is the narrow floodplain that has been produced by levees built along the banks. Should you move the levees 20 metres back from the bank-top to provide spawning area in this reach? This would be expensive, and you may not be overly confident of the outcome. Is it really the limiting variable for this fish? You might, in fact, decide to do a pilot study to test the plan before committing to a big project.

Hypothetical example of a high confidence project

An AUSRIVAS assessment shows a much better macroinvertebrate community above the outfall from a trout farm than below the outfall. You are very confident that controlling nutrient levels from the outfall will be effective in improving the macroinvertebrate populations below the pipe.

- **If in doubt, do a trial run.** For a high priority problem that is expensive to fix, and where you are not confident of the result, it may be possible to do a pilot study of the effectiveness before committing yourself to a major expense (see *Evaluation tools* in Planning tools, Volume 2 for more information on such an experiment). Trialing your project on a small scale will allow you to check if the benefits are as large, or the side-effects as bad, as people expect. Getting opposition groups involved in the evaluation of the trial is a powerful way to convince them that the undesirable effects were small and the benefits large (or to convince you of the reverse!).
- **Recognise terminal unfeasibility.** Treating some problems will produce consequences that are so bad, or cost so much, that a compromise cannot be made, and the project should not be considered further. It is terminally unfeasible. For example, in some situations removing a barrier to fish passage will not only allow native fish into the upstream reaches, but also an invasion of exotic species such as carp. There is no way to let the native fish through without also furthering the spread of carp. In situations like this, you must acknowledge that the problem cannot be fixed, and move on to your next priority problem (return to Step 5 to consider this).

You now know which of your individual objectives are feasible. However, the chances are that you don't have the money or resources to do all of them, and rehabilitate your stream entirely. You will have to decide which parts of your rehabilitation plan will actually happen. Generally, you

Real feasibility

This step in the stream rehabilitation procedure has considered the issue of feasibility. Whether or not a project goes ahead has been couched in terms of the monetary cost, legality of the work, the effects of the project on other users and so on. It is important to stress that, in the final analysis, feasibility is not really about these things, it is about how much people want things to happen.

Things become feasible in direct proportion to how much people want them to happen.

As a result, the most important question for rehabilitators to ask themselves is not, 'how much will this cost?'; or 'who won't like our proposal?' Instead, you ask: 'How much do I want this project to go ahead? What am I willing to give up (in terms of time, energy, anguish and money) to see this project go ahead?' At the end of the day, stream rehabilitation is about people and what they value. As a result, it is also about politics.

should be guided in these decisions by the original reach and problem priorities you worked out in Step 5 (Setting priorities). However, you should bear in mind that related problems need to be treated in order of importance, and that leaving a fatal or limiting problem unfixed will mean there is no point in treating other, linked, problems.

3 Summary

Questions for judging the feasibility of your stream rehabilitation objectives:

- Can you afford your rehabilitation objectives?
- Have you checked legislative and administrative constraints to see if you will be allowed to do the things that you want to do?
- Will the project create more benefits than negative side-effects (including the effects on other users of the stream, and on the stream biology)?
- How confident are you that the option will actually solve the problem?
- Can you modify the plan to minimise impacts on other uses of the stream? You may be able to do a small-scale trial of your proposal in order to test its effects.

Once you have answered these questions, you will be ready to review your priorities for action, based on the feasibility of your objectives. This may mean you don't treat some high-priority problems, because they are too expensive, or cause side-effects that are worse than the original problem. On the other hand, it may focus you on one expensive but

fundamental problem at the expense of some others. Be aware that high-priority problems are often fatal or limiting in that reach. If it is not feasible to treat such problems, there may be no point treating other problems in the reach. In these circumstances, you should return to Step 5 and review your reach and problem priorities.

4 Case study: the feasibility of rehabilitating Durben Creek

Table 8.3 summarises the cost and confidence of treating problems in Durben Creek. The most important problem in the high priority Gorge Reach of Durben Creek is poor water quality from urban areas. It will cost at least half-a-million dollars to investigate and manage all sources of poor water quality in the mixed urban-industrial catchment, and even then we would have little confidence that the problem could be solved. Thus, we might conclude that water quality cannot be treated. This decision also means that it is not worth worrying about substrate composition in the reach, because this is fatally linked to water quality (ie. it is no use having good substrate without good water!). Alternatively, we might decide that it is so important to have good water quality that we are going to persevere despite the cost and risk. Other problems on the creek may have to be sacrificed to pay for water quality. Which problem is given highest priority is really a political issue.

Table 8.3. Feasibility of rehabilitation options for Durben Creek

Reach Priorities (in order)	Problems in order of priority	Possible solutions	Estimated Cost (to treat full reach)	Confidence	Other costs
1. Downstream gorge (10 km) (reach 3)	1. Water quality	• Manage diffuse sources of urban pollution	• \$0.5 million	• Low	• inspection costs
	2. Substrate contamination (Linked to 1)	• Upstream sediment traps	• \$20,000	• Low	• Downstream scour
	3. Weeds and riparian veg (Partially linked to 1)	• Revegetation	• \$25,000	• High	• Minor loss of flood capacity
2. Rural headwaters (15 km) (reach 1)	4. Riparian zone condition (Linked to 5)	• Frontage management	• \$50,000	• High	• Minor loss of flood capacity
	5. Water quality (Linked to 4)	• Identify and manage diffuse sources of pollution	• \$30,000	• medium	• inspection costs
3. Urban mid-reach (8 km) (reach 2)	6. Water quality	• Identify and manage diffuse urban pollution sources	• \$100,000	• Low	• management and inspection costs
	7. Channellisation (Linked to 6)	• Structural controls on bed erosion, new meandering structure	• \$40,000	• Medium	• Minor loss of flood capacity
	8. Riparian zone	• Revegetation with native species	• \$40,000	• High	• maintenance costs

Note that if we decided that treating water quality was not possible, then revegetating the riparian zone would become less of a priority in the Gorge Reach too. It could be justified only on the grounds of aesthetics and riparian values. As a result, we might turn to our next highest priority problem, which is managing the riparian zone in the Rural Reach. This option is cheap, and we are confident it will work. However, this problem is linked to problem priority 6, managing water quality, so we then have to decide if we can afford to do both jobs. This process of pragmatically reassigning priorities will continue down the list. Overall, it will almost certainly be worth doing a trial on a sub-catchment to see if water quality could really be improved.

5 The feasibility of the Mythic Creek rehabilitation plan

This step describes the many reasons why a project may not be feasible. You can make a compilation like Table 8.4 by simply running through the list of points made in the

step above. Only items that may constrain the feasibility are mentioned in the 'Other costs' column.

Table 8.4. Feasibility of objectives set in the Mythic Creek example (reaches 2 and 4 excluded for brevity)

Reach priorities	Measurable objectives	Estimated cost	Legality	Confidence	Other costs and benefits
Reach 1a	<ul style="list-style-type: none"> • No dam in 10 years time • Cover of weeds reduced to 20 - 60 % of pre-project cover by year 5 • Fence both banks for 10 to 15 km of stream by end of year 1. 	<ul style="list-style-type: none"> • Low cost public campaign • \$30,000 for weed control • \$24,000 	<ul style="list-style-type: none"> • It is legal to challenge dam licences. • Access to land depends on land tenure • Access to land depends on land tenure 	<ul style="list-style-type: none"> • Moderate • High • High 	<ul style="list-style-type: none"> • Major secondary consequences for irrigators if the dam is not built. • Danger of stream pollution from weed control • Loss of grazing land along the stream • Cost of off-channel water supply for stock (add \$10,000)
Reach 3	<ul style="list-style-type: none"> • No dam in year 10 • Experimental extraction completed year 2. • Both banks fenced for 15- 18 km of stream by end of year 1. • Vegetation diversity and density should be between 50 - 80 % of the template by year 5. • Effluent releases from piggery in Reach 1b meet EPA requirements in 18 months. • Monitor piggery effluent releases with Waterwatch • Cover of weeds reduced to between 0 and 30% of pre-treatment cover by year 5 	<ul style="list-style-type: none"> • As above • No cost—commercial • \$28,000 • Low cost—volunteers • Cost to piggery • Low cost—volunteers • \$20,000 	<ul style="list-style-type: none"> • As above • Sediment extraction from stream requires a licence from DOEG • Access to land depends on land tenure • Access to land depends on land tenure Can get EPA to enforce guidelines • Effluents can be controlled by the EPA • Access to land depends on land tenure 	<ul style="list-style-type: none"> • As above • Low - moderate • High • Moderate • High • High • Moderate 	<ul style="list-style-type: none"> • As above • Possible effect of upstream bed erosion on reach 1b • Possible downstream bed degradation • Loss of grazing land along the stream • Cost of off-channel water supply for stock (add \$10,000) • Higher costs for piggery owner • Beneficial community activity Potentially large cost to farmer to comply with EPA regulations • Danger of stream pollution from weed control
Reach 1a	<ul style="list-style-type: none"> • Assess natural revegetation at year 5. Should have increased vegetation density and diversity to 75-100 % that of template reach. 	<ul style="list-style-type: none"> • Low cost—volunteers 		<ul style="list-style-type: none"> • Low - moderate 	<ul style="list-style-type: none"> • Reduced rough agistment

Table 8. Feasibility of objectives set in the Mythic Creek example (*continued*)

Reach Priorities	Measurable objectives	Estimated cost	Legality	Confidence	Other costs and benefits
Reach 2	<ul style="list-style-type: none"> • Experimental sediment extraction completed after 5 years • \$6,000 • Reduce turbidity from Reach 1b by 50 - 80 % in five years • \$20,000 • Fence reach within 3 years • \$48,000 • Riparian vegetation should, by year five, have 50-80% of the diversity and density of native species found in the template reach. • Determine if natural regeneration is as effective as direct seeding • Median pool depth in the reach has increased by 50 - 200 % after 5 years, and maintains depth up to year 10. • Bank erosion rate should match template five years after vegetation is established on the banks. 	<ul style="list-style-type: none"> • Sediment extraction from stream requires a licence from DOEG • Landholder permission, • Low licence form DOEG • requires permission from landholders • Low cost — volunteers and natural regeneration • Low cost • No cost • Low cost 	<ul style="list-style-type: none"> • Moderate • High • Moderate • Moderate • Moderate • Moderate • Moderate 	<ul style="list-style-type: none"> • Possible erosion downstream may undermine structures? • High maintenance cost with weed control. • Loss of some grazing land • Cost of stock watering points 	

So, in summary of the feasibility step for Mythic Creek, we can say that all of the options are financially feasible, so long as the group can get more funding. The major secondary effects relate to stopping the dam. This will have consequences for the irrigators who were planning it. There may also be costs involved for the piggery owner in improving discharge quality (he has talked about going broke!). Other extra costs will be the off-channel watering when reach 2 is fenced off, downstream scour below the sediment trap in reach 2, and possible damage to the levee in reach 4 with trees growing on it. The costs of evaluation should be small, because few measurements need to be made.

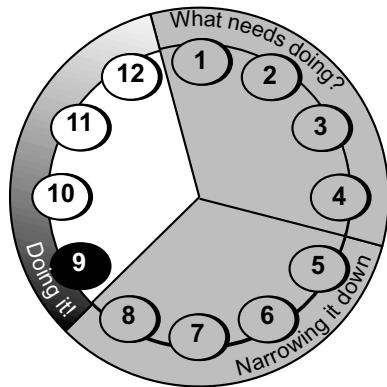
6 Reality check

This reality check is a summary of Task 5. Weighing up ‘feasibility’, and is just to remind you that revisiting previous steps is an essential part of assessing feasibility. If you are lucky, all of your objectives are feasible, and you can move on to Step 9 and do the detailed design of your project. However, if you find some of your objectives are not feasible, you can:

1. Return to Step 6 (What are your strategies to protect assets and improve the stream), and try to find a strategy for fixing your problem that costs less, or has fewer side-effects, and thus makes your objective feasible. For example, if the Mythic Creek Landcare group decided it was not feasible to stop the dam being built, they would return to Step 6 and consider compromise strategies, such as securing environmental flows that would minimise the effect of the dam.
2. Return to Step 7 (What are your specific objectives), and attempt to alter your objectives to find a feasible compromise between what you would like to achieve in the stream, and what is possible. You may find this is not possible, in which case treating that particular problem is terminally unfeasible. In this situation, the Reality check in Step 6 will send you back to Step 5 (Setting priorities), where you will consider the implications of not treating that particular problem.

Step 9: **What is the detailed design of your project?**

AIM: when this step is completed, you should know the details of your rehabilitation strategy.



A Landcare group is considering the rehabilitation plan for its reaches of a river, which lie just downstream of a dam. Although the basic morphology of the reach is still in good condition, the banks have been cleared and grazed, and the dam has a major impact on water temperatures and the flow regime. The group has decided to fence and revegetate the reach. Members of the group also plan to mount a campaign to extract some environmental flows from the dam (their original objective was to get the water authority to agree to the environmental releases, but this proved to be unfeasible). They are now doing their detailed planning.

- The fence along the riparian zone will be a permanent, five-strand electric fence, powered by mains electricity. They will construct the fence a minimum of 20 m from the stream. The riparian landholder will use an electric pump to supply water to his stock.
- The tree seedlings will be bought from a local wholesale nursery. They will be a mix of the three most common riparian species in the area.
- The campaign for environmental flows will start with media releases to the local newspapers, radio and television. A public meeting will be held once there is sufficient awareness of the issue in the community. The group will put together a school information kit on environmental flows, and will get the local primary school involved in the campaign.

Generally, the Landcare group is feeling pretty optimistic as the details of the plan come together and they begin to feel the project gather momentum.

Key points about designing your project:

- Whether you aim to change the behaviour of the stream, or the people that use the stream, you should plan the details of your project with care.
- List each strategy to be used in the project and describe in detail how you would do it.
- Aim to cause long-term change.
- Think about the sources of threats to your work.

1 Designing your project to achieve your objectives

In Step 8, you identified which of your objectives were feasible. You should now know which of the stream problems you want to work on (Step 5: Setting priorities), what strategies you will use (Step 6: What are the options to protect assets and improve the stream), and exactly what you want your rehabilitation to achieve. Now it is time to take those general strategies and state in detail how you will achieve the objective.

Whether your project aims to change the physical or biological character of the stream, or to change the behaviour of people who influence the stream, it is important to design the details of your strategies with care. However, this is not a design manual, either for

physical instream structures, or for social engineering. For detailed information on these topics, you will have to consult one of the many texts devoted to them (although Step 2 does contain some suggestions for changing people's behaviour). Note that in this step, we are concerned with the detailed design of the structures you will build, or the actions you will take. We are not yet concerned with exactly who will do what, when, and how much it will cost. A detailed plan of this type will be developed in Step 11. Before that, you need to have designed the evaluation for your project (Step 10). Here in Step 9 we make some suggestions about basic principles that you should use in designing your project.

2 Some principles for intervening in streams

Here are some important general principles and ideas that could help with detailed designs for stream rehabilitation. Many of them relate to influencing people, a subject already discussed in Step 2. We recommend you return to that step if changing people's behaviour forms part of your project. The rest of this step describes some general principles relating to changing the physical character of the stream.

2.1 Will your stream rehabilitation strategy still be successful in 20 years time?



Figure 9.1. Successful long-term revegetation on Jacksons Creek west of Melbourne.

Stream rehabilitation is only really successful if it improves the stream for decades after it is implemented. Some stream rehabilitation approaches can show a dramatic initial improvement, but this may wane over time for some of the following reasons.

- **Are you changing processes operating in the stream?** Recovery can often be best achieved by altering the inputs to a stream (eg. flow, nutrients, sediment, carbon) that will then alter processes operating in the stream (eg. erosion, nutrient cycling, and so on). The stream will then develop its own 'stable state' without you having to directly interfere with the structure of the stream (eg. by building structures).
- **Is your plan 'working with the stream'?** Helping the stream to gradually recover is more efficient, in most cases, than trying to build the final product that you want. This view is the general consensus of American and European rehabilitators who, for decades, have been building 'natural' streams from scratch. This type of design is giving way to a gradual process of cajoling the stream into a desirable, equilibrium form. So design your project to enhance the stream's natural recovery.

- **In the long term, structures that are built in streams do not fundamentally change the character of the stream.** All in-stream structures have a finite design life. Good stream rehabilitation work will have long-lasting effects on the stream form well after the structure has failed. Consider the use of retards in an overwide stream to trap sediment and provide low-velocity conditions for vegetation growth. Ultimately the retards will rot away. If the vegetation is well established by that stage, this will preserve the new channel alignment even after the retards have gone. If the vegetation was absent, the bench deposited behind the retards would be remobilised once the structures are gone.
- **Treat a reach and not a point of the stream.** You are more likely to have a permanent impact on the character of a stream reach if you treat the reach as a whole rather than just treating a few discrete problems within it. This may involve using a range of different structures and approaches within the reach. Often, the same is true of the next scale—it is better to treat the catchment than the reach.
- **Other factors in the catchment may jeopardise the success of the works in the long term.** For example, continuing high loads of coarse sediment can often swamp in-channel habitat structures over a few years. This point was made in Step 5 (Setting Priorities), in which you noted such 'links' between different assets and problems.

2.2 Is vegetation an integral part of your stream rehabilitation strategy?

As an extension of the previous points, the most successful way to maintain an equilibrium channel is to reinstate the natural vegetation. Vegetation not only helps to maintain channel alignment but also provides valuable stream habitat. Most rehabilitation works should include some form of revegetation whether it be natural recolonisation, planting seedlings or direct seeding. Having said this, vegetation alone is often not sufficient to rehabilitate a stream. In some rehabilitation projects in North Queensland, for example, spectacular growth of vegetation has not been accompanied by recovery of macroinvertebrate populations because fine sediment continues to choke the bed.



Figure 9.2. Healthy revegetation in this stream has had little effect on the fine sediment moving through the stream bed from logging operations upstream.

2.3 What are the threats to the project?

- **What is the cost of failure?** The cost of failure of a stream rehabilitation activity is critical to determining the appropriate level of design of any proposed structure (that is, what sized flood it should survive), and the effort that should go into its design. The cost of designing and building a structure should be roughly proportional to the consequences of its failure (though there are many exceptions to this). For example, where high-value assets are threatened by erosion, it is especially important that the erosion control structure protecting them does not fail.

If the cost (financial, biological, social) of failure would be high, then seek professional advice. If the cost of failure would be low, then local design and construction may be suitable.

- **Are there any major assets nearby** (roads, bridges, etc.) that are likely to be threatened in the event of a failed rehabilitation attempt? For example, if your artificially placed woody debris comes adrift, could it damage bridges or pumping stations as it moves downstream?
- **What is the value of the biological communities that are to be protected?** Are they rare or endangered? How is the project going to help them and what will happen if it fails (as many fish habitat enhancement projects in the US have: Kondolf *et al.* 1996)?
- **What are the potential causes of failure?** When planning a stream rehabilitation project it is important to consider the worst possible scenarios for failure, and assess the likelihood and acceptability of each scenario.

Look upstream and downstream for threats to the project. From upstream, the threats might include a sand slug which will bury the work, a high debris load which may get caught up in the structure, increase the hydraulic load and cause failure during a flood, or a source of weeds to colonise your riparian zone. From downstream the main threat to rehabilitation work is bed instability (headcuts moving upstream). In addition to looking upstream and downstream, assess the stream in terms of the following questions.

- What is happening to other structures in the stream—are they working as designed? If not, what has caused them to fail?
- What is the propensity of the stream for avulsion—is there evidence of old river courses on the floodplain, is there frequent out-of-bank flow?
- Are there direct human threats to the work, such as vandalism.



Figure 9.3. A sand slug in south-eastern New South Wales threatening downstream reaches.

2.3.1 The threat of floods

- **What sized flood do you expect your works to survive?** Doing anything in streams is a gamble. It is always possible that a large flood could sweep away all of your good work and we have to accept that risk. It is important that managers overtly accept this risk and specify the size of flood they expect their works to survive. Thus, it is unrealistic to design works around the bankfull flow, then be surprised when they are destroyed by a ten-year flood. If you have specified the flood size a structure is expected to survive, although its loss in a larger flood is a shame, it does not constitute failure.

The same argument can be used for droughts as well as floods. Long periods of low flow can lead to failure of certain rehabilitation measures, particularly revegetation.

- **Will unexpected things happen at high flows?** To ensure an instream structure is successful, it has to withstand the force of water, at least in the design flood specified. The hydraulic forces on a structure vary according to the type of structure, and the characteristics of flow around it. It is important to note that structures designed to be highly permeable may become like impermeable groynes by trapping the debris of just one flood. For more detailed information, see *Intervention in the channel*, in Intervention tools, Volume 2.

2.4 Are you using the right tools?

- **Should you use the same design repeatedly (put all of your rehabilitation eggs into one basket)?** The same rehabilitation outcome can often be achieved with a range of approaches. For example, you can stabilise a stream bed using a rock ramp, gabions, log sills, or pin weirs, to name a few options. It can be tempting to settle on a design or approach, and use it exclusively, because it feels familiar, safe, and easy. However, there have been cases in Australia and overseas where a single type of structure has been installed at many sites through a stream system, only to have them all fail for similar reasons. A more flexible approach that tailors the structures to the stream may be safer. It may also be wise to use a variety of structures, particularly since many of the techniques being used in stream rehabilitation are still experimental.
- **Will the proposed tool work on your stream specifically?** One of the core problems with managing streams is that they are all slightly different. This means that managers have to think very carefully

whether a technique or approach that is enthusiastically embraced in one stream is appropriate in another. This may appear obvious, but fads and fashions come and go in stream management as much as anywhere. Make sure that you are not swept along in the latest fad when it is not appropriate for your stream. For example, you would not build artificial riffles in the lower Darling, a clay-bed lowland river where riffles are naturally absent.

Before applying a technique that has been successful elsewhere, you should ask yourself if your stream differs, in terms of:

- Fauna (fish, macroinvertebrates)
- Vegetation (riparian and macrophytes)
- Sediment load
- Bed and bank material type
- Erosive potential of streambanks
- Stream power and size.
- History of disturbance and history of management (often the same thing!)
- Hydrology (eg. how steep is the flood frequency curve? ie. steep curve = high frequency of large events)
- **Should you experiment to check that you are using appropriate tools?** A pilot project using different styles of structure would allow you to assess the merits of the different designs. The problem with this, of course, is that you may have to wait 5 or 10 years for a big flood to come along, which is a long wait between starting your study, and getting a result. One way to get around this is to have the same structure in several trials in several streams. This increases the chance of at least one structure being exposed to a flood.

3 Useful information in the Management tools section of Volume 2

In the feasibility section of the procedure we discussed the undesirable side-effects of a rehabilitation project. Some of these undesirable effects (particularly flooding and erosion) can be reduced (if necessary) by modifying the design of instream structures. Both *Natural channel design*, in Planning Tools and *Intervention tools*, in Volume 2, provide valuable information for designing your project to minimise any undesirable impact on the stream.

Natural channel design:

Natural channel design has a large amount of information related to designing ‘natural’ channels. There is information on: how to design a natural stream, computational approaches to designing stable channels, predicting the scour associated with instream structures, flood estimation, and predicting the effects of channel changes on flood height and duration.

Intervention tools:

Intervention tools considers the types of structures that are used in stream rehabilitation, including a discussion of the effects of each design on flooding and erosion.

4 Summary

Summary questions about designing the details of your project

We cannot provide much help with detailed design. However, there are some principles that are important to designing a stream rehabilitation project. How does your planned project shape-up on the following questions?

- Will your project still be making a difference in 20 years time? (eg. will it still work when the structures have been destroyed by a flood?). In most cases this will occur only if you have treated basic processes at a catchment scale, and if vegetation has been encouraged to grow and modify the channel. Appropriate vegetation is often the key to successful stream rehabilitation.
- Is the project going to enhance the recovery trajectory of the stream, or work against it?
- Have you anticipated the threats to the project?
- What extreme events is the project designed to survive (floods and droughts)?
- Is your proposed project big enough? Does it treat a reach and not just a point?
- Are the tools that you are using appropriate for the stream and the problem?
- Have you designed your project to minimise any undesirable consequences of the project?

5 Detailed design for the Mythic Creek project

Table 9.1 shows a detailed description of the tasks involved in rehabilitating reaches 1a and 2 in Mythic Creek. Please note that we are only including these two reaches because otherwise the Table would get too long! Reach three would

be the second preference after 1a, but the problems in reach 3 and 1a are similar so we discuss reach 2 instead. Many of the problems in Reach 1b need to be treated in order to protect reaches 2 and 3, which is why reach 1b is also discussed here.

Table 9.1. The tasks involved in rehabilitating two reaches in Mythic Creek

Reach Priorities	Measurable objectives	Detailed description of the strategy
Reach 1a	<ul style="list-style-type: none">• No dam in 10 years time• Cover of weeds reduced to 20-60 % of pre-project cover by year 5• Fence both banks for 10- 15 km of stream by end of year one.• Assess natural revegetation at year 5. Should have increased vegetation density and diversity to 75-100 % that of template reach.	<ul style="list-style-type: none">• Dispute the licence for the dam with the Dept. of Water Resources• Develop a network of experts to provide advice on the up and downstream impacts of the dam• Consider appealing to the Land and Environment court• Consider incorporating the Landcare group to avoid liability problems• Run a campaign in the local media• Consider water supply options for the irrigators that want the dam.• Investigate options for weed control (eg. spraying, hand removal etc.)• Negotiate to cancel grazing licences along the stream• Construct 14 km of three plain/two barb fencing along catchment divide• Provide two off-channel stock watering points (nose pumps) after discussions with landholders• Survey vegetation at year 5. If natural regeneration has not sufficiently increased the species diversity and density, plan manual replanting program.
Reach 2	<ul style="list-style-type: none">• Experimental sediment extraction completed after 5 years (successful if median pool depth in the reach has increased by 50-200%)• Reduce turbidity from Reach 1b by 50-80 % in five years• Fence both banks of the reach within 3 years.• Riparian vegetation should, by year five, have 50-80% of the diversity and density of native species found in the template reach.• Median pool depth in the reach has increased by 50- 200% after 5 years, and maintains depth up to year 10• Bank erosion rate should match template five years after vegetation is established on the banks.• Improve water quality from the piggery in Reach 1b	<ul style="list-style-type: none">• Develop plan for experimental extraction of sand.• Approach commercial companies to do the extraction• Investigate experimental sediment trap at the bottom of reach 1a.• Identify and stabilise key sources of turbidity in Reach 1b.• Negotiate landuse change for 20-30 m along each side of the stream• Fence (electric) along 12 km of stream (both banks)• Investigate options for weed control (eg. spraying, hand removal etc)• Develop an experiment to assess natural regeneration of vegetation. Direct seeding trial on one side of the creek, weed control only on the other (except for the few eroding banks, that will all be direct seeded).• Relies on the sediment extraction described above• Revegetate eroding banks with native vegetation using direct seeding methods.• Encourage the EPA to monitor the effluent quality• Set up a Waterwatch program on Reaches 1a and 1b• Involve the piggery owner in the Waterwatch program, so he can appreciate the impact his wastewater has on the stream.

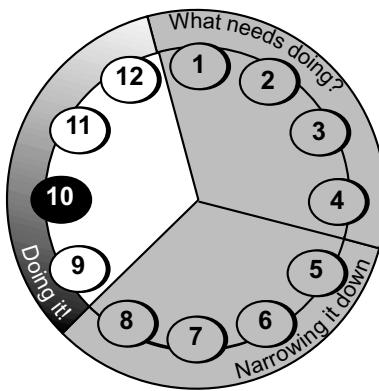
6 Reality check

It is possible that you did not realise the true cost of your strategy until you developed the detailed plan. You might now find that the plan is too expensive or unfeasible for other reasons. If this is the case you will return to Step 5 to reassess your priorities, or Step 6 to reassess your objectives.

Step 10:

How will you evaluate your project?

AIM: At the end of this step you should have a grasp of why it is necessary to evaluate stream rehabilitation projects, and what level of evaluation is required for your project. To design an evaluation program, you will also need to look at Evaluation tools in Planning Tools, Volume 2.



The members of a Landcare group are discussing their next project. Two years ago, they built two artificial riffles to stabilise the bed of their stream, and provide more instream habitat. Shortly after construction was completed, a big flood damaged one structure, but the other riffle survived unscathed. Now the group is arguing about whether to spend the money and fix the damaged riffle, or to try some other method of stabilisation.

Those landholders arguing that the riffle should be fixed say that:

1. such structures have been very successful in North America; and
2. the other riffle survived the flood, so it should be possible to make this one just as stable.

Those landholders arguing for a new technique say:

1. riffles might encourage American fish, but they don't know how successfully it will encourage Australian species; and
2. they don't know why the riffle failed, so how will they know how to fix it so it won't fail again?

During the discussion, both sides realised they had no facts to back up their arguments, just vague feelings about the best action to take. They decide that they will fix the riffle, but this time they will evaluate its progress. That way, they will know if it does encourage fish and, with careful monitoring, if it does fail again, they may be able to work out why.

Key points about evaluation

- Stream rehabilitation is fraught with uncertainty. The best way to increase our confidence and develop better techniques is by evaluation.
- Every stream rehabilitation project should have some form of evaluation—without it, you will never know if your project was worth the bother, and you will never learn how to improve your techniques.
- Evaluation need not be difficult. You may not need to measure whether your treatment made a difference to geomorphology and biology, you could simply measure aesthetic change, whether the works survived, or whether you did what you said you would do.
- The more complex evaluation plans must be prepared carefully, to avoid wasting your time, money and effort.
- We suggest five levels of evaluation to identify change. Which one of these you use depends upon how confident you already are that your rehabilitation will be successful, and upon who you want to convince that it was successful. Evaluation is more about confidence levels than it is about absolute truth.
- Good evaluation will commence before works begin, and will often incorporate a control site against which the treatment site can be compared.

1 What is evaluation, and why is it important?

A very common complaint about stream rehabilitation is that existing projects are not evaluated. Are there really more fish; is there better water quality or less erosion than before the project began? There are many good reasons to evaluate projects.

- Most importantly, evaluation ensures that you, and others, can learn from the experience of the project. As you have probably realised by this stage, stream rehabilitation is an uncertain business. While we can be confident of our techniques of erosion and flood control, in many cases we are still not confident that we know what needs to be done for rehabilitation, or how to go about it. Evaluation is the best way to improve our knowledge of stream rehabilitation. Remember, just as

your project is being completed there are hundreds of others starting up; any advice or guidance you can offer will accelerate the rehabilitation of our streams (not to mention bringing you fame and fortune).

- Evaluation ensures that you, funding agencies, and the public, will know if the project has achieved its aims
- Monitoring (continuous evaluation) means the project can be adjusted and improved as it goes along (ie. protecting the rehabilitation investment.) Many expensive projects have started positively but eventually foundered because of poor maintenance. (Note, however, that continually adjusting and improving your project may make it difficult to assess its effects.)

The importance of evaluation

Without evaluation, a lot of time and money can be spent using techniques that a simple evaluation could have shown to be unsuitable for that application. For example, Frissell and Nawa (1992) reviewed the rates and causes of physical impairment or failure of 161 fish habitat structures built in 15 streams in South-West Oregon, USA. The program assessed the physical integrity of the structures after a moderate flood event (2-10 year return flood) and found that almost 80% of structures either sustained some damage or were completely destroyed. This means that only 20% of the original structures were functioning as designed. The value of the remaining structures for fish habitat was not evaluated. Even though this was quite a coarse evaluation program (you will see below that it was a type 2: evaluation of survival), it provided important information about the suitability of certain structures in particular stream conditions.

Given that evaluation is so useful, why is it so rare? There are two main reasons projects are not evaluated. The first is that natural systems are complex, and they are also often slow to respond to changes. This means that evaluation can be difficult, slow and expensive. People who fund projects can't usually wait the years it can take to get results from evaluation, or commit money to such a drawn-out process.

This section raises the issues you should consider when planning the evaluation of your project. We believe that all projects should be evaluated in some way. But the key point that we emphasise here is that there are **different levels of evaluation**. Not all projects need to be major scientific experiments. The level of evaluation that you require depends first upon how confident you are that what you have done will work, and second, who you want to convince that your project has worked. You need to decide on the level of evaluation at the start of the project, and remain committed to it for a few years.

Evaluation can be a complicated and expensive business. This step summarises the procedure which is developed in more detail in the *Evaluation tools* in Planning tools, Volume 2.

Stream rehabilitation projects are experiments

In reality, with our limited present level of knowledge, every stream rehabilitation project should be considered an *experiment* (Kondolf and Micheli 1995). If all projects were considered as experiments, this would reduce the pressure for 'success' at all costs, and would increase the pressure for evaluation. We learn much more from failure than from success. Natural systems are so complex it is hard to demonstrate exactly what has caused success, but failure is usually easier to explain.

1.1 The parable of the two Landcare groups

A government agency gave the same amount of money to two adjacent Landcare groups on the east and west branches of Enlightenment Creek. Progress on the two projects would be assessed in two years time.

The east branch group particularly aimed to return native fish to the stream. To that end they wanted to remove three low weirs that they were certain limited fish passage through the reach. There was great resistance to removing the two top weirs, but they were able to remove the lower one, as well as narrow the eroding creek below this lower weir with small permeable log groynes (similar to Figure 10.1). The aim of the groynes was to protect the banks and create pools along the narrower, confined channel. Because the group were keen to remove the other two weirs, they wanted to demonstrate to landholders and to the government the great increase in fish numbers that removing the lower weir produced. So they did some electrofishing and macroinvertebrate surveys in cooperation with the local Department of Environment and Gambling office. They did these in November, before the works were done, and again a year later. They surveyed three reaches, an untreated (control) reach downstream of the weir and the permeable groynes, the narrowed reach below the remaining weirs, and above the remaining weirs.



Figure 10.1. A log groyne in the Broken River, NE Victoria.



Figure 10.2. A fenced and revegetated gully in the Inman River catchment, SA.

The results showed that there were many fish immediately below the weir before the works, and none above. After the works, there were slightly more fish overall, including in the downstream control reach, suggesting that it had been a good year for fish. However, there were also slightly more fish in the narrowed reach (that cross-section surveys also showed had narrowed considerably since the works went in) than in the control reach, and lots more macroinvertebrates. Above the old weir, there were many fish of several species, where previously there were none. Overall, the results showed that removing the weir dramatically improved fish numbers. The narrowing works had had only a small effect so far, but the increase in macroinvertebrates suggested that the reach now had the potential to support more fish.

Meanwhile, the west branch group had fenced and revegetated their stream reach (as in Figure 10.2), and constructed artificial rock riffles to stabilise the bed. They were completely confident that the riffles would stabilise the bed if they survived floods. A moderate-size flood did come through and one riffle failed and was rebuilt with an improved design. Also, they were interested to find out whether they would get good revegetation if they just left one section of frontage alone. They had heard that burning the frontage might help. They left one fenced reach unvegetated and burnt the grass. To their surprise they got a good strike of river red gums after the flood. They had heard about the fish surveys on the east branch and decided to survey their reach for fish after the works had gone in. They found they had many fish, far more than had been caught in the east branch. They thought that this large fish population was a reflection of their completely successful rehabilitation strategy, and that riffles were obviously the best technique.

After the two years was up, the Minister for Environment and Gambling did a tour of the works. The Minister was impressed with progress on the west branch project. Large blow-ups of before-and-after photos were striking. The revegetation plots were doing well and looked good, and the Minister was particularly impressed with the regeneration plot—it looked like a real money saver. He was also very impressed by the numbers of fish found in the west branch survey. However, there was a scientist on the government's review panel who pointed out that fish numbers were higher in the west branch than the east branch, because there was better habitat throughout the west. In fact, the survey results in the west branch showed the rehabilitated reach had only an average fish population for that stream.

The Minister was not impressed with the east branch work. There wasn't much to see except piles of logs in the creek. They had even forgotten to take any photos of the old weir and channel. Fortunately, they had put together a poster showing the difference in fish numbers before and after the works. The scientist was excited by these results and explained them to the Minister, who was also impressed. The scientist was convinced by the control section used in the sampling.

At the end of the day the Minister recommended that each project receive extra funding, and he promised to bring pressure to bear on the Minister for Water Resources and Racing to support the removal of the remaining weirs and subsidise some off-channel storage for the landholders pumping from the weirs.

This idealistic example illustrates some key lessons for stream rehabilitators in terms of evaluating their projects.

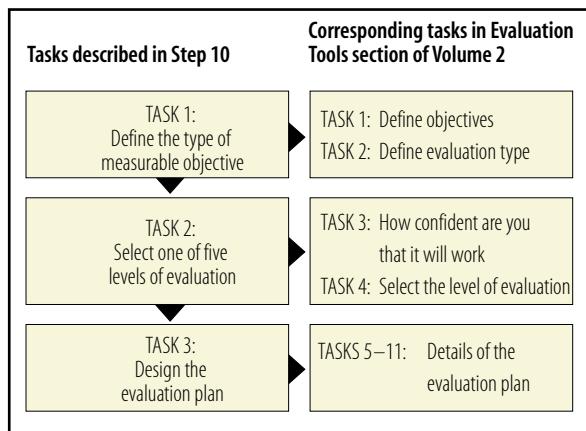
- Prepare your evaluation program before you start. The west branch Landcare group wasted their time and money on the fish survey, because that one survey was not enough to tell them if fish numbers had increased.
- More complex evaluation can be more convincing. The east branch fish survey convinced the scientist, while the west branch survey did not.
- Not all evaluations need to be complex. The before and after photos were enough to show the success of the revegetation on the west branch.

- Different people will be convinced by different styles of evaluation (compare the scientist with the politician).
- People are more easily convinced by treatments which look good, like revegetation, but this does not necessarily mean that pretty treatments are always best.
- Some effects of rehabilitation will take some time to become clear. In the narrowed reach of the east branch, the increase in macroinvertebrates suggests that fish numbers might increase, but it is still too early to tell.

In the remainder of Step 10, we outline the tasks in preparing a good evaluation plan. To make sure your evaluation program targets accurately what you intend it to, refer to the *Evaluation tools* in Planning Tools, Volume 2.

2 Tasks in the evaluation procedure

The three major tasks described in this step are broken into 11 tasks in the *Evaluation tools* section of Volume 2. The corresponding tasks are summarised below.



2.1 Task 1: Define the type of objective.

When it comes to evaluation, it is vitally important to have very clear and measurable project objectives. If you are not sure what exactly you want from your project, how can you tell if you have got it? How will you even know what to measure? In the example above, the east branch Landcare group was clear from the start that they wanted fish back, while the west branch group only thought of that half way

through the project. The effect on the two evaluations is obvious. Because it wasn't clear that increasing fish numbers was an objective, the west branch group were unable to evaluate this effectively. They were clear about their revegetation objective though, and that evaluation of that objective gave a clear result.

As described in Step 7 (What are your objectives?), evaluation can measure outputs (what you did) or outcomes (change that occurred because of what you did). The temptation is to believe that all of your objectives need to relate to outcomes—changes in the stream (eg. decreased erosion rate), change in creatures in the stream (eg. more fish), or even aesthetic improvements. In reality, outputs, such as execution of the project, and survival of the works, can also be evaluated (see Table 10.1). For example, the Minister in the Enlightenment Creek example was influenced by aesthetics, but he was also impressed by the fact that the works had been completed. The type of evaluation you choose will depend upon the confidence that you have in the outcome, and on whom you are trying to convince with your evaluation, and how much time you are willing to invest, as discussed below. *Evaluation tools*, in Planning Tools, Volume 2 describes typical objectives for a project and how they could be evaluated.

Table 10.1.Types of stream rehabilitation objectives

Objective type	Generic objectives	Typical measures
1. Execution outputs	To successfully complete our plan of works.	<ul style="list-style-type: none"> • Did you build three structures and 500 m of fencing, and complete 2 ha of revegetation; as per the plan?
2. Survival outputs	To install works that will withstand expected natural events.	<ul style="list-style-type: none"> • Did the structure survive its design flood (eg. 10-year flood)? • Did the vegetation survive the summer?
3. Aesthetic outcomes	To produce a more attractive environment To promote recreational use.	<ul style="list-style-type: none"> • Does the reach look better than it did before? • Has the number of recreational users doubled?
4. Physical/ structural outcomes	To improve habitat by increasing physical and hydraulic diversity.	<ul style="list-style-type: none"> • Is the reach more stable? • Does it have more varied hydraulic habitat, narrower, coarser bed material, reduced velocity? • Are there more snags?
5. Ecological outcomes	To improve the population size, diversity and sustainability of plant and animal communities.	<ul style="list-style-type: none"> • Has the mean population size of a range of macroinvertebrates increased over 5 years? • Have platypus have returned to a reach from which they were absent?

An example of evaluation types 4 and 5: physical and biological outcomes

With the aim of increasing habitat complexity and therefore fish populations, 22 full-width gabion or rock and log structures and 10 partial-width structures and boulder clusters were built in a 1.5 km reach of a small (width 9-12 m) coastal stream in Oregon (House, 1996). Checking that these structures had actually been built would be a Type 1: execution evaluation. Checking they had survived any floods since construction would be a Type 2: survival evaluation. However, the researchers were interested in whether the structures had had the expected effect on habitat, and if those changes had a corresponding effect on the fish populations (Types 4 and 5: evaluation of physical and biological outcomes).

It was hoped to improve habitat complexity (pool area, riffle area, pool volume, bed material size, spawning gravel area, and maximum depth) and fish populations (House and Boehne 1985). Surveys of habitat showed that within two years of installation, the area of pool habitat in the rehabilitated reach had increased by 53%. During the same period pool areas in an untreated reach (the control) had increased by only 23%. Unfortunately, the effect of habitat change on fish numbers was inconclusive due to flow conditions and poor fish survey techniques (House 1996).

2.1.1 How confident are you that your project will succeed?

If you are completely convinced that your goals will be achieved by what you intend to do, then a simpler type of evaluation is sufficient. For example, if returning blackfish to a reach is your goal, then there is lots of good evidence that placing snags back into a stream will increase the population. Thus, you are so confident that the treatment will work that all you need to evaluate is that the snags remain where you put them (survival objective in Table 10.1). If, on the other hand, you are using an experimental technique that you are not sure will produce a change, then you may need a detailed evaluation (one that tests ecological objectives). In the parable of two Landcare groups, the west branch group are convinced that the rock riffles will stabilise the creek and improve ecology. All they need to do is to check that they survive (type 2 evaluation). On the other hand, the east branch group are not confident that narrowing the channel will lead to improved biology, so they set out to measure the biological effect of the work, as well as the physical effect. The type of objective you evaluate is therefore decided by the confidence you have in your rehabilitation techniques.

You must be very careful that your confidence is not misplaced, particularly if you are investing a lot of time and money in the project. Remember that a strategy that is successful in one area may not be successful when transplanted to your stream. If you are uncertain, consider a pilot study, a trial run of the strategy, to see if it suits your conditions.

2.1.2 How much effort and time can you put into your evaluation?

Different types of evaluation require different monitoring times (Tim Doeg, personal communication). Execution can be checked as soon as construction has finished. Survival must wait until the design flood has occurred. To evaluate aesthetics, you need to give the trees time to grow. Physical changes may also take time to form, particularly if you have to wait for a flood. Biological outcomes may take longer still, because they can occur only once the physical changes have taken place. This has two implications. First, you must be prepared to wait, if you wish to evaluate the biological outcomes of your work. Second, if you are doing a higher type of evaluation, you can keep involved with the progress of your rehabilitation by evaluating outputs, while waiting for the physical or biological outcomes to develop (Figure 10.3).

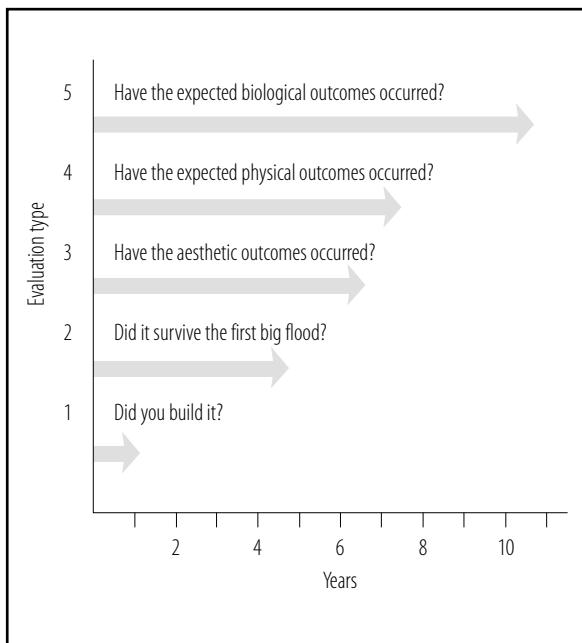


Figure 10.3. Some typical times taken for the various outputs and outcomes of a rehabilitation project to develop. You would evaluate each output or outcome at the end of its arrow.

2.2 Task 2: Choose the level of evaluation required.

If, from Table 1, you decide to evaluate the physical or biological outcomes of your work in a stream, then you need to think very carefully about the design of your evaluation program. Basically, you want to see if what you have done to the stream has made any difference to the geomorphology of the stream, or to its biology. To answer this you have to determine: (1) that something has

changed after the rehabilitation work (in the east branch example there were more fish); and (2) that your rehabilitation work caused the change (ie. that there are more fish because you removed the weir, rather than for some other reason). These are not easy questions to answer, because streams, like all natural systems, are constantly changing in response to climate and numerous other variables. Sorting out the change that **you** produced from all of the other changes going on is no easy task, and is the sort of thing that scientists spend much of their time doing. There are some key elements of evaluation design that allow you to isolate, with confidence, the real effects of your work. You need to know what these are, so that you can judge what level of complexity to include in your evaluation.

Your evaluation job is to sort out the change that you produced from all of the other changes going on.

2.2.1 Important elements of evaluation

You do not have to include in your evaluation all, or even any of the features below. However, you should be aware that including or excluding these elements will have an impact on the confidence you have in your evaluation.

- **Sampling before and after rehabilitation.** This is the main way to tell if your rehabilitation really caused a difference to the stream. You have to know what was there before, to see if there is any difference after. Unfortunately, there is seldom much time for repeated sampling before rehabilitation, but at least once is essential.
- **What is a control?** A control is a site that is as similar as possible to where you do your rehabilitation, but is **not** influenced by your rehabilitation. By comparing the two sites, you can check that any changes you see at the rehabilitation site are the result of your work, rather than because of some stream-wide change that would have happened anyway. Having a control site is possibly the most important aspect of your evaluation.
 - If the rehabilitated reach changes after your works, but the control reach doesn't, then you can be fairly sure you caused that change.

- If the control reach changes in the same way as the rehabilitated reach, then the change is most probably not because of your work, and you can't take the credit. For example, without the control site downstream, the east branch Landcare group (from our introductory parable) could not be sure that an increase in fish numbers wasn't a stream-wide increase that had nothing to do with them removing the weir and stabilising the banks.
- Controls help explain failure as well. Suppose there had been fewer fish after the instream works. A control would tell you if you had discouraged fish from living in the reach, or if the decrease reflected a smaller fish population in the whole stream, and so did not represent the failure of your rehabilitation.
- **What is replication?** Replication means having multiple sites that you use as controls, and multiple sites that you rehabilitate. At first glance this seems quite excessive, but replicates can be important if you want to apply the results of the evaluation to other rivers with a high level of confidence.
 - You need a control site to check that any changes you observe at the rehabilitation site are caused by your rehabilitation treatment, and not a change happening to the whole stream. But is one control site really enough to tell you that? It is possible that the control was different to the rehabilitation site for some other reason. If this is the case, you would be wrong to conclude your rehabilitation caused any differences that you see. Replicate control sites mean you can be more certain that you actually caused the observed difference, because there is less chance that both sites were different.
 - For the same reason, it is also good to have more than one rehabilitation site in your evaluation. Having replicate sites means you can tell the difference between natural variation, and improvements you have caused. However, it is obvious that this will not always be possible. Having no replicates does not mean that your evaluation is worthless, it just reduces the confidence you can have in the results.

2.2.2 Choosing a level of evaluation

If you want to evaluate the changes that your project has caused (ie. the outcomes of the project), then we have identified five levels of evaluation that you can use (Table 10.2). These range from Level 1, the unconvincing 'it-looks-better-now' style (only someone wanting to believe it would not want further evidence) to Level 5, a full, detailed scientific study (even a dedicated sceptic would have trouble arguing with its conclusions). Obviously, a Level 1 evaluation will be very easy and quick, while a Level 5 evaluation will take a great deal of time and effort. The cost could be as great as that of the project itself! The Enlightenment Creek east branch project used a Level 4 evaluation (Silver Medal). In practice, most existing stream rehabilitation work in Australia is evaluated to Level 1 or 2, if at all.

How do you decide which level of evaluation to use? The answer depends on: (1) how big an effect you would consider a success; (2) how difficult it will be to convince the people you want to convince that your evaluation was correct; and (3) how long you can support an evaluation (in terms of money and people). These points are expanded below.

- **How big an effect do you expect?** If you are expecting the results of your rehabilitation work in the stream to be startling and obvious, then you may not require a subtle study design. In the east branch example there were almost no fish before the weir was removed, and there were many after. A crude bronze medal design would pick up this type of change. However, if the effect is expected to be less dramatic, say there was 10 fish before, and 15 after, then the more detailed gold medal design, using a control site, would have been needed to be sure this was a real increase in fish numbers, rather than a chance variation.

Table 10.2. Levels of evaluation

Evaluation level	Description	Example	Level of confidence
Level 1: Plastic medal	Unreplicated, uncontrolled, anecdotal observation after rehabilitation	"I saw lots of platypus after we had done the work"	Very low
Level 2: Tin medal	Unreplicated, uncontrolled, sampling after rehabilitation	"There was a gradual increase in the number of platypus in the two years after the work"	Low
Level 3: Bronze medal	Unreplicated, uncontrolled, sampling before and after rehabilitation; OR Unreplicated, controlled, sampling after rehabilitation	"There were more platypus after the work than before" "After rehabilitation, there were more platypus in the control reach than in the treated reach"	Moderate
Level 4: Silver medal	Unreplicated, controlled, sampling before and after rehabilitation	"The number of platypus increased after rehabilitation in the treated reach, but not in the control reach"	High
Level 5: Gold medal	Replicated sampling, replicated controls, sampling before and after rehabilitation	"The increase in the number of platypus in the treated reach was greater than any increase at either control reach"	Very high

- **Who are you trying to convince?** The complexity of your evaluation depends not only on what would convince you, but also on what would convince others (Table 10.3). Here are some examples:

The audience might be the funding body, landholders, another Landcare group, or local journalists and politicians. In some cases, higher level evaluations may be written up and published in scientific journals.

- **Do you have the resources available to support your evaluation?** Evaluation can be time-consuming and expensive, particularly if you are using a high-level design. It can be difficult to obtain sufficient funding to support a long evaluation, and to keep the money safely stored away for work that must be done in 8 or 10 years. You should bear in mind the evaluation of physical or biological outcomes may well be a long-term project!

There is no such thing as truth in evaluation, only levels of confidence. In science, these levels are expressed in statistical terms. The key questions are: 'How much confidence do you need to convince somebody?' and 'How much confidence can you afford to buy with the resources available?'

Table 10.3. Examples of evaluation levels required to convince particular groups

- In the east branch example, the Landcare group wanted to convince the government that the other weirs should be removed. In fact, they had to convince the scientist on the review panel, so they had to have a pretty convincing design.
- You want to convince the community of how much better the river looks after rehabilitation than before, so you organise a tour for journalists with before and after photos.
- The lone farmer on the stream wants to demonstrate to his neighbours up and down the stream that putting snags back into the stream will not cause more bank erosion. So he sets up surveys in his reach with snags, and in a neighbour's reach without snags (as a control).
- You want to convince fishermen that your rehabilitation design produces more fish, so you sponsor a fishing competition in treated and untreated reaches.
- Gold medal evaluation
- Bronze medal evaluation (aesthetic type of objective)
- Bronze medal evaluation
- A risky tin medal evaluation

2.3 Task 3: What should be included in an evaluation plan?

Having decided what type of objectives you will evaluate, and the level of evaluation you will use, you now need to work out the detail of your evaluation plan. An elegant evaluation can be cheap, efficient and convincing. Furthermore, a well-designed evaluation may be able to tell you not only if your project succeeded or failed, but also the **reason** for that success or failure. *Evaluation tools*, in Planning Tools, Volume 2, describes in detail how you design your evaluation. The issues discussed in the Tools section are summarised below.

- **What should you measure?** As a minimum, your evaluation needs to indicate if you have met the objectives of your project. Thus, you have to measure anything that is related to those objectives. For example, if you proposed to increase numbers of a certain fish species by adding woody debris to the stream, then you need to monitor the numbers of those fish. However, a good evaluation will go further than this, and also tell you **why** you have succeeded or failed. This is far more useful, but unfortunately often more difficult than simply measuring success. To work out why a change occurred in the stream, you must measure not only elements directly related to your objectives, but also the stream elements that caused that change. So, as well as surveying the fish population, you might also measure anything that could influence the fish, such as water quality, stream discharge, populations of competing fish species, and so on. That way, if fish numbers did not increase, you may be able to suggest reasons, such as that low water levels in a hot summer killed many juveniles.
- **How frequently should you measure?** You don't want to waste time and money on frequent monitoring if it isn't necessary. On the other hand, you don't want to risk being misled by results which aren't typical of the stream. There are two possible sampling strategies:
 1. You sample at regular intervals, which will show up trends and variation in the data. This is good for things that respond slowly but steadily to your rehabilitation, such as a fish population.
 2. You sample after any flood events greater than a certain size. This strategy is appropriate for projects that involve structures which are really tested only during high flows, such as log weirs.
- **How long should your evaluation go?** Ideally, you should monitor until the stream has responded in full to the rehabilitation project. It can be difficult to know how long this will be. For ideas on suitable monitoring periods, it is best to look at what other people have found sufficient in similar systems. (See *Evaluation tools*, Volume 2)
- **Who will take the measurements?** For evaluation to be worth the bother it is important that you can trust your results. The people responsible for the evaluation must have the necessary expertise to use the chosen techniques, the persistence, and objectivity.
- **How will they record the results?** It is very important to have a standard recording sheet for data collection, especially during fieldwork. Without one it becomes very easy to forget to take some measurements at the end of a long day. A standard recording sheet also makes collating the results far easier.
- **How you will analyse the information.** For the simpler types of evaluation, the analysis of the results will be fairly straightforward—a matter of comparing photographs or plans of an instream structure with surveys of the structure. However, for types 4 and 5, evaluation of physical or biological effects, analysis may be a lot trickier. In fact, it may involve some form of statistical analysis. In such cases, it is vitally important to have considered the analysis at the planning stage of your evaluation, as many statistical techniques are restricted in the sorts of data they can handle. Realising you cannot analyse the plethora of information you have collected can be an unpleasant experience!

3 Summary

Summary questions from planning evaluation

To check that you have designed an evaluation appropriate for your needs, ask yourself these questions:

- Do you want to evaluate the completion of the project (outputs), or the influence of the project on the physical or biological character of the stream (outcomes)?
- Will the level of evaluation design convince the people that you want to convince about the success or failure of the project?
- Have you worked out the details of your evaluation plan? (What you will measure, how frequently and for how long you should measure it, who will measure it, how they will record the measurements, and how you will analyse the results?)
- Will your evaluation tell you why the project succeeded or failed?

4 Evaluating the Mythic Creek rehabilitation project

Table 10.3 lists some of the objectives of the Mythic Creek rehabilitation project, and the corresponding evaluation. An addition to this evaluation scheme would be to survey macroinvertebrates and water quality below the proposed dam site. If the construction goes ahead, this will provide a useful baseline data set for assessing the impact of the dam. It could also provide ammunition in the fight to stop the dam.

5 Reality check

You may find that evaluating your project to the level that you require will be so expensive that you have to reconsider some of the expenditure that you had planned in Steps 6 to 9 (strategies to detailed design). If you are certain you do not want to compromise your evaluation, return to Step 8 (Are your objectives feasible?), and consider which parts of your project to sacrifice.

Similarly, the evaluation may require a control reach to be set aside. Go back to Step 9 (What is the detailed design of your project?), and adjust your design to incorporate the evaluation.

Table 10.3. The evaluation scheme for the Mythic Creek rehabilitation project
 (Note that only reach 1a and 2 are considered, in order to save space.)

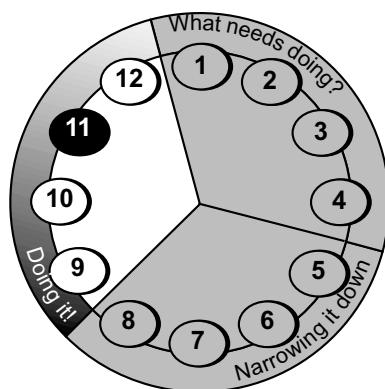
Reach priorities	Measurable objectives	Evaluation measures	Evaluation type	Evaluation level	Who are you trying to convince?*
Reach 1a	<ul style="list-style-type: none"> • No dam in 10 years time • Cover of weeds reduced to 20-60 % of pre-project cover by year 5 • Fence both banks for 10-15 km of stream by end of year one. • Assess natural revegetation at year 5. Should have increased vegetation density and diversity to 75-100 % that of template reach. 	<ul style="list-style-type: none"> No dam built. Cover of weeds in quadrats sampled before, and once yearly, after weed control Length of stream fenced (both banks) Photographic comparison before and after rehabilitation works. 	<ul style="list-style-type: none"> Execution output Biological outcome Execution output Biological outcome / Aesthetic outcome 	<ul style="list-style-type: none"> - Bronze - Bronze 	<ul style="list-style-type: none"> Other similar groups Funding body Funding body Funding body
Reach 2	<ul style="list-style-type: none"> • Experimental sediment extraction completed after 5 years (successful if median pool depth in the reach has increased by 50-200%) • Reduce turbidity from Reach 1b by 50-80 % in five years • Fence both banks of the reach within 3 years. • Riparian vegetation should, by year five, have 50-80% of the diversity and density of native species found in the template reach. • Determine if natural regeneration is as efficient as direct seeding. • Median pool depth in the reach has increased by 50-200 % after 5 years, and maintains depth up to year 10 • Bank erosion rate should match template five years after vegetation is established on the banks. • Improve water quality from the piggery in Reach 1b 	<ul style="list-style-type: none"> Pool depth before and after extraction Look for trends in turbidity over time, as the sources of sediment are treated Length of stream fenced Count the number, size and diversity of tree seedlings each year. Compare the number, size and diversity of seedlings on each bank Pool depth measured before works, at five years and at 10 years Measure erosion rate each year relative to fixed points at target bends and control bends. Sample water quality (or macroinvertebrates) above and below the outfall, before and after any changes to management. 	<ul style="list-style-type: none"> Physical outcome Physical outcome Execution output Biological outcome Biological outcome Physical outcome Physical outcome Physical outcomes (or biological) 	<ul style="list-style-type: none"> Bronze Bronze - Tin Tin Bonze Bronze Silver 	<ul style="list-style-type: none"> DOEG, and funding body Funding body Funding body Funding body Other stream managers DOEG Funding body, other management groups, landholders Yourself, EPA and the piggery owner

*Note that we assume you also need to convince yourself of the effectiveness of all actions.

Step 11:

How will you plan and implement your project?

AIM: Implement the project as efficiently as possible.



Members of a newly established Landcare group are about to start work on their first project. They plan to stabilise a bank with jacks (see *Interventions in the channel*, Volume 2), remove camphor laurel weed trees from the banks, revegetate the reach, and pile some rocks up against a culvert to provide fish passage. Although the project was eventually a success, it was made much more difficult by the following problems in the scheduling and detailed planning of the project.

- The group missed the deadline for the major government funding scheme. This set back the project by a year and put a much greater burden on local resources.
- Most of the work was done on one community field day. Unfortunately, the timber for making the jacks was not delivered. There was some disenchantment amongst the many volunteers who were standing around waiting for the timber to arrive. So, as an alternative to the jacks, the group decided to use the felled camphor laurel trees as bendway weirs to protect the stream bank (see *Interventions in the channel*, Volume 2). An excavator was available to help with this task. Camphor laurel timber rots quickly, so the weirs had to be replaced with the jacks within 2 years.
- After the site was cleared of weeds, the revegetation could not go ahead because not enough seed had been collected to justify hiring the direct seeding machine.
- The culvert that was acting as a barrier to fish passage collapsed when the excavator drove onto it. The shire council agreed to replace the old culvert with a fish-friendly design, but the incident did not help the relationship between the Landcare group and the council.
- When it came to reviewing the project it was discovered that nobody had taken any good photographs of what the stream was like before the work. It had not been clear who was supposed to do this.
- After the project had been completed there were continuing problems with maintenance because it had not been made clear before the project who would be responsible for the various aspects of maintenance.

Key Points

- Break the project (including evaluation) into individual jobs
- Decide the order in which the jobs should be completed
- Decide who will complete each job

1 Developing your project plan

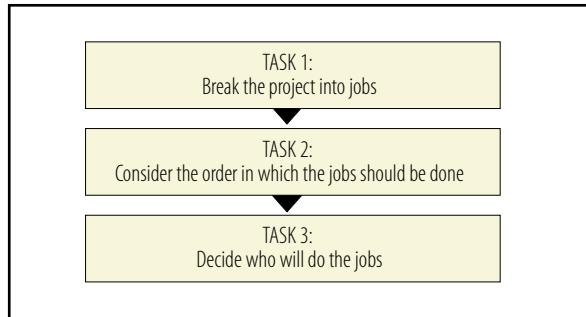
In Step 9, you worked out the detailed breakdown of all the solutions and strategies involved in your rehabilitation project. In Step 10 you planned how you would evaluate the success of those strategies. This step is where you plan when each task will happen and who will be responsible for making it happen. This includes the work itself, and any monitoring and evaluation tasks that are required before, during and after the work.

This planning of the project is important because it forces you to think through exactly what needs to happen. This helps avoid budget overruns, makes the ongoing management easier, and keeps the people involved

committed to the project. The start of each task is scheduled so that work in each area flows logically. For example, it is more sensible to revegetate after you have finished with earthmoving equipment. It will save time to have some tasks running concurrently. For example, establishing a seed bank for revegetation could occur at the same time as doing a fish survey, without causing site congestion.

Having an implementation plan also helps with assessing the project because each step can be ticked-off as it is completed, and each step can be budgeted.

The implementation plan has three tasks:



We then conclude this step with some general suggestions.

1.1 TASK 1: Break-up the project into jobs.

The project is currently defined as a set of solutions and strategies that you have decided on to meet your objectives. Each of these solutions and strategies should now be broken down into a series of jobs, each of which embodies one ‘deliverable’ of the project. This is illustrated in the Mythic Creek example below. Complex projects that require a large amount of work may have to be broken up into several subprojects, then into individual jobs.

The aim is to make each task simple enough for its duration and cost to be estimated.

1.2 TASK 2: Order the jobs to create your project plan.

- **Check for prerequisite jobs.** Take each job that you have identified and ask yourself “are there any other jobs that need to be done before this one?” How will the excavator get to the site? Should photographs of the site be taken for later evaluation before any works are done? Finish with earthmoving equipment before starting revegetation.
- **Identify any ‘key’ jobs.** Key jobs are the ones that have to be done, or you might as well as abandon the project. All of the jobs are critical to success, but if you cannot get permission to do the job at all, then that becomes fatal to the rest of the project.
- **How long will each task take.** Be realistic with this one!

- **Can any jobs be done simultaneously?** Are there any jobs that could be done at the same time without causing congestion at the site? For example, revegetation of the left bank could proceed at the same time as fencing on the right bank.

- **Draw up a chart of the project.** There are many tools that you can use to help you plan your project. Perhaps the most intuitive is the Gantt chart, or bar chart, which is simply the table of tasks to be completed with some columns showing the timing of jobs. Further information and training courses on project planning methods are available, for example see Meredith and Mantel (1995). Large projects may be more efficiently planned using project management software such as Microsoft Project, though in our experience these programs have seldom proven of much help.

An important thing to put on the chart are major milestones that you can tick off. These might be the completion of a sub-project, such as ‘rifflle construction’.

1.3 TASK 3: Who will be responsible for each job?

Deciding who actually does the jobs is one part of the project plan that is often overlooked. It is important to be specific about this. The responsibilities column is very useful for maintaining enthusiasm because it ties people to the project for its duration. They can see how long the project goes for and what is expected of them. They will also be able to see if they have too many simultaneous tasks to complete.

- **How much will each task cost?** Remember to account for all of the costs here, including travel, planning, getting gear to sites, and maintenance.

Project implementation simply means ‘do what you said

2 Project implementation

you were going to do in the project plan'. Project plans are not a stagnant document. If you appear to get all of the estimates correct first time, and your plan is not covered in crossings out and corrections then you are probably not using your plan properly. For small projects that run pretty smoothly, or are implemented over a short time frame, you may not need to revisit the project plan after you have completed your budget and resource estimates. However, for large or long-term projects it is easy to spend your hard fought project money in the first year of the project on 'extras'. You need to keep focused on the long-term plan by keeping your project plan up to date.

There are, however, a few key issues you should keep in mind when implementing a project.

1. Do you have the right contractor for the job?

A contractor with extensive experience in river work can be invaluable to your project. They will know how to get the job done as quickly and cheaply as possible, as well as providing you with some great ideas from their experience. There are many contractors (mainly in south-eastern Australia) that work almost exclusively on rivers.

2. Does your contractor share your vision?

Many stream rehabilitation projects will require an excavator or some other earthmoving equipment. The operators of this equipment might not share your passion for a rehabilitated stream or know a great detail about stream forming processes (even though they are one). Where you can't get an experienced 'stream contractor', then it is important to give them simple and explicit instructions and supervise them throughout the job. This is not to say that contractors cannot be trusted: the best stream rehabilitation work is done by experienced machinery operators. However, a lot of damage with long lasting repercussions can be caused by a half-a-day of poorly conceived work with an excavator in the bed of a channel (Figure 11.1).



Figure 11.1. The impact of an over-enthusiastic contractor. This bank was meant to be only slightly battered, and the groynes should have been on the toe of the bank, protruding into the base flow.

3. Are landholders and stakeholders involved in the project?

As we have emphasised many times, one of the keys to project success is to have the local people involved at all stages of the project. In particular, local people can take some responsibility for the long-term survival of works. Imagine a project that involves fencing and revegetating a riparian zone. For some years after the initial work of fencing and planting, follow-up weeding and watering are needed. If the volunteers involved lose interest, instead of a revegetated stream, all you may get is a fenced-off weed patch along the creek. Deciding who is responsible and writing that responsibility down on the project plan helps to avoid this failure. You don't need contract documents, just a simple note that so-and-so has agreed to help with this phase of the project. This ties them to the project, making it much harder for them to escape their responsibilities once the project loses its excitement.

Implementation plans are long, detailed, and tedious to prepare. If we were to present the entire plan for the Mythic Creek project, it would take several pages of table.

3 Summary

Summary of planning and implementation:

- Have you broken the project (including evaluation) into individual jobs?
- In what order should the jobs be completed?
- Who should complete each job?

4 Planning and implementing the Mythic Creek rehabilitation project

So here (Table 11.1) we just present some implementation details for Reach 1a. As presented here, we assume that the group already has funding to carry-out its plans. In reality, funding applications, and the time-lags associated with funding, would have to be factored into the implementation plan.

People involved in the project (and their designation in the table) are: Landcare coordinator (Coord.), key Landcare members (Liz, John, Tom and July), all of the Landcare Group (LGC), the Department of Environment and

Gambling (DOEG), the Environment Protection Authority (EPA), and school groups (School).

In developing your project plan you may get some surprises. When you actually schedule the work that needs to be done, you might find there is much more of it than you thought and, indeed, that you do not have enough people or resources. If this is the case, then you may need to reassess your priorities (Step 5) or how long your objectives will take to achieve (Step 8: Are your objectives feasible?).

Table 11.1. Some details of implementing the plan for Reach 1a of Mythic Creek

Reach	Measurable objectives	Implementation jobs in order	Who will do it?	Duration
Reach 1a	• No dam in 10 years time	<ol style="list-style-type: none">1. Find procedure for disputing the dam licence2. Gather experts to assist in dispute3. Meeting to discuss strategy4. Gather information on effect of dam5. Survey condition of the stream above and below the dam6. Prepare and review draft submission7. Deadline for submission of document to the Water Authority8. Develop a contingency plan in case dam goes ahead (eg. valve size on dam)9. Organise a meeting of the Landcare Group to discuss this plan.	<ul style="list-style-type: none">• Coord.• Coord.• LG• Experts + LG• Coord. + John, July• Experts + Coord.	<ul style="list-style-type: none">• 1 week• [Date here]• 2 trips of 2 days• 2 weeks[Date here]• 1 Week[Date here]

Table 11.1. Some details of implementing the plan for Reach 1a of Mythic Creek (*continued*)

Reach priorities	Measurable objectives	Implementation jobs in order	Who will do it?	Duration
	<ul style="list-style-type: none"> Cover of weeds reduced to 20-60 % of pre-project cover by year 5 Fence both banks for 10-15 km of stream by end of year one. Assess natural revegetation at year 5. Should have increased vegetation density and diversity to 75-100 % that of template reach. 	<ol style="list-style-type: none"> 1. Discuss weed control with DOEG in detail 2. Training day for volunteers 3. First spray 4. Second spray 5. Evaluate kill rate 1. Negotiations with landholder about fence route, watering points & responsibilities 2. Lay out route 3. Order and buy materials 4. Construction 1. Find a template reach 2. Do survey of template reach with DOEG officer 3. Survey reach 1a 4. Re-survey 1a (year 1, 2, 3) 	<ul style="list-style-type: none"> • Coord. • Tom • LG • LG • Coord., John & DOEG • Coord. • LG with landholder • Liz • Liz • Liz 	<ul style="list-style-type: none"> • [Date here] • [Start date, 2 days] • [Start date, 2 days] • [Date here] • July July [Date] [By this date] [Date] [Date] [Date] [Do at same time as weed survey]

5 Reality check

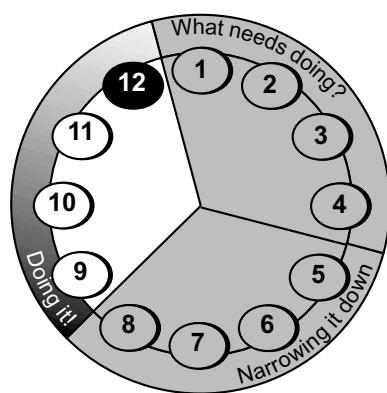
You might not be able to achieve some of the tasks that you have identified in your plan. For example, you might not succeed in getting funding, or you might fail to get the cooperation of key people or organisations, and so on. It is important to identify these ‘key’ steps so that you can

develop contingency plans, or move onto the next priority. If you do abandon a priority objective, then there will be a cascade of linked consequences. These links should have been identified in Step 5, Priorities.

Step 12:

Has your project worked?

AIM: In this step, you should assess whether your project succeeded or failed, and more importantly why, so that you can do better in your next project.



The Rivercare group stands on the bank of their stream, looking at the work done to stabilise the opposite bank. Three years ago, the outside of the bend was eroding rapidly, creating a shallow overwide stream, and producing large quantities of fine sediment that were depositing in the pools downstream. The group have trained the river back into its old course using log groynes. They have planted trees between the groynes, hoping to encourage deposition against the toe of the eroding bank. The work was completed two years ago, and the group is discussing the success of the project. They have decided that:

- The groynes have worked well at realigning the channel, which now flows more or less along the thalweg. However, they are aware that the structures have not yet been tested by a large flood.
- The banks were probably battered to a shallower angle than necessary (largely due to an over-enthusiastic bulldozer drivers). The Rivercare officer says that next time, she will take the time to supervise the heavy machinery in the stream.
- The vegetation between the groynes is growing well, but the officer acknowledges that this is largely due to the dedication of the landholder, who has watered the seedlings regularly through the summers.
- There was not enough vegetation planted between the groynes to keep the depositional bench stable in a small flood. Next time, the group will plant more and faster growing shrubs, such as bottlebrush and tea tree, rather than just the eucalypts planted here.

Over all, the group is pleased with the project. They decide to hold a field day at the site, because they want to share what they have learnt with the Rivercare group in the next catchment, which is planning some similar work.

Key points on assessing the success of your project:

- Have a definite endpoint, where you assess the success of your project.
- Don't just work out how successful the project was, also work out why, and how you can improve your next project.
- Always report what you find, so that other stream rehabilitators can learn from your experience.

1 Introduction

In Step 10, you worked out the evaluation strategy for your project. In Step 11, you planned exactly who would do what and when. Now, the project is finished. You have implemented the plan, and are collecting the data for your evaluation (this may be anything from photos to fish surveys). At some stage, you have to stop monitoring, and complete your evaluation by assessing your results. Ideally, you will not just find out if you succeeded or failed, but also what caused that result, and what lessons you can take from this project to increase the success of your next project. Sharing these lessons with others working in stream rehabilitation is the final task.

It is very important to have some well-defined time limit for completing your evaluation. Many evaluation plans are open-ended, and some preliminary evaluation is never followed up or analysed. This is a terrible waste of a chance to improve our knowledge of stream rehabilitation. Part of a good evaluation plan is knowing when to finish and examine the information you have collected.

2 Did your project succeed?

How you will analyse the results of your monitoring should have been decided in Step 10 (How will you evaluate the success of your project?). There is a range of techniques available for doing this analysis, from intensive, detailed statistical analysis, to a simple comparison of before and after photos, or a count of the kilometres of fence constructed. The analysis must suit the style of monitoring you have done, which depends on who you want to convince with your results (as described in Step 10 where you designed your evaluation). However, all analysis is based around one simple question—“Did the project achieve the objectives you set in Step 7?”

For example, a community group has decided to fence and revegetate a reach of their stream that had been totally cleared. They carry out the plan and 10 years later there are some healthy young trees in the riparian zone, though almost half of the young seedlings had died during a very hot dry summer the year after planting. There is still a weedy understorey, and no sign of any natural regeneration. Whether or not the project succeeded depends on what the group had aimed to achieve. Table 12.1 shows some examples of some possible objectives, and their implications for the assessment of this revegetation project.

This example highlights the role of your objectives in assessing the success or failure of a rehabilitation project. However, it also shows that success and failure are usually not absolute. Even if the aim was 70% survival, and only 50% of the seedlings lived, the riparian zone has still come

Table 12.1. Some typical assessments of objectives

Objective	Assessment
• Fence 2 km of stream, 20 m from the bank top, and plant 5,000 seedlings within a year of commencement.	The project succeeded
• After 10 years, there is some natural regeneration, showing that the riparian vegetation can be self sustaining	The project failed
• The stream is more attractive after 5 years	The project succeeded
• Between 35 and 90% of seedlings survive the first 10 years	The project was a moderate success

a long way from the cleared and grazed area it used to be. An objective that specifies a range of acceptable results, from very disappointing to the best possible outcome, allows you to take this into account in your assessment of your completed project

This example also shows that success and failure should be only one small part of the final assessment. The interesting question is what caused the success or failure, and what could you have done differently to make the project more successful? Why did almost half the seedlings die? How much more effort would have been needed to increase the proportion that survived? What lessons can we learn from our results? Was the ‘failure’ caused by unrealistic objectives? Were there any surprise benefits?

3 Why did your project succeed or fail?

As we discussed in Steps 7 (What are your objectives) and 10 (How will you evaluate your success), a project has **outputs** that are built, stopped, or modified with the intention of creating the desired **outcomes** in the condition of the stream, or the stream plants and animals. Erecting the fence and planting the seedlings are outputs of a revegetation project. Developing a healthy, self-sustaining riparian community is the outcome of that project. Failure can occur at either the output or outcome level.

3.1 What caused the outputs to fail or succeed?

Outputs can succeed or fail because of either good or bad design, human input or the weather.

3.1.1 Design and construction:

Sometimes structures will fail because they were poorly built, or because they were simply not appropriate for that particular situation. This is not to say that every failure of a stream structure is due to poor design—extreme weather conditions are often responsible. However, when an instream structure fails under normal conditions, this may be because they were under designed, or had flaws in construction.

3.1.2 Human input

Human input relates to the degree of interference we have in the post-project period. For example a revegetation project may fail, not for technical reasons, but because vandals have destroyed all the seedlings. In another case, revegetation may have been successful but only because one dedicated volunteer watered the plants every weekend over the height of summer. The human input that contributes to project success or failure is likely to be related to the success of a project because of adequate follow-up maintenance. For example, if a log sill is damaged by a large flood, and if we do not do some remedial work, every small flood will further degrade the structure.

3.1.3 The weather

Meteorological conditions play a huge role in determining the success or failure of rehabilitation. For example, did the low maintenance revegetation project succeed only because it was unseasonably wet during the 12 months after seedlings were planted? Or in another case, did the structures fail because they were under-designed, or because we got a 1 in 40 ARI flood two months after construction (Figure 12.1)? What gets the credit for the success or failure, the design of the project, or the climatic conditions, for being unusually favourable or unusually harsh?



Figure 12.1. A flood on the Perry River, Victoria, well on the way to destroying a fence.

3.2 What caused the outcomes to succeed or fail?

If the **outputs** of a project fail, then the **outcomes** are unlikely to succeed. That is, if something has gone wrong with the construction side of the project, the desired stream response will not occur. However, in the situation where the outputs have been successful, the fate of the outcome is determined by the weather, design issues, and sometimes the evaluation itself.

3.2.1 Design issues

The biological outcomes will not eventuate if the project did not target the limiting problems in the stream (see *An introduction to stream ecosystems* in Stream rehabilitation concepts for stream rehabilitation, this volume, for a discussion of limiting problems). For example, say you installed grade control structures to increase the pool habitat, as well as some woody debris, with the objective of getting native fish back into the reach. However, the truly limiting problem was actually that lack of shade resulted in warmer water and reduced dissolved oxygen content during summer. This doesn't mean that the new habitat was not needed, but rather that this water quality problem was more immediately important.

3.2.2 Evaluation

Sometimes a project is successful, but because of the timing, the evaluation suggests otherwise. For example, for a fish that spawns successfully only every couple of years, a monitoring program going for less than 5 years is worthless for detecting long-term trends in the population.

3.2.3 The weather

Again, climate and weather play an important role in determining the success of the project. Floods and droughts are natural disturbances that can set back the recovery of both the stream and the stream organisms.

4 Let people know the outcome

Our knowledge of the interaction of stream process and biology increases as the project goes on, so at the end of a project it is not uncommon to feel that you could solve the same problem next time with half the effort or at least more success. It is important to record these findings, because just as you are completing your project there are hundreds of other budding stream rehabilitators out there just starting theirs who could benefit from your experience. So—tell someone!! We all need to know what works and what doesn't, and why, so that we can continue to refine stream rehabilitation projects to make them cheaper and more successful.

To get your experience out there, aim your results at an appropriate forum. Consider your evaluation design and how reliable your conclusions are—your target audience and publishing forum should be a reflection of the degree of certainty in your evaluation design. Possible forums may be: speaking at an open day, publishing the results in internal government reports or Landcare annual reports, making contributions to manuals like this one, a national newsletter like *Waternotes Rip-Rap*, or, for those extra special BACI designed evaluation projects you may even be able to publish in the national or international scientific literature. It is best to target as many levels of publication as you can so that your results reach as many audiences as possible.

5 Summary

Final assessment questions:

- Did your rehabilitation project achieve your objectives?
- What contributed to that success or failure?
- What would you do differently next time?
- Have you made sure that you, and other people can learn from your experience?

6 Assessment of the Mythic Creek rehabilitation project

Five years after the start of the famous Mythic Creek project, members of the Landcare group meet at a one-day workshop. The aim of the workshop is to assess progress over the last half decade, and consider the lessons they have learned. The assessment is pretty easy, because clear objectives were defined at Step 7 (Table 12.2).

Overall, the project has achieved its highest priority objectives, although much remains to be done. In hindsight, the group wishes it had started more biological monitoring (eg. macroinvertebrates and fish surveys) before it began its main works. Though the many physical objectives were met, it is still not clear if the stream is responding biologically.

Another general lesson is the importance of involving, right from the beginning, everybody with an interest in the stream in the planning and assessment. Because the piggery operator was included in the planning and monitoring, he became convinced that action was required.

In addition, the group have an extra celebration after the evaluation meeting. The relationship between the Landcare coordinator and the piggery operator blossomed as they met regularly to take water quality measurements together. Their wedding celebration was held on the bank of the creek in Reach 2. Everybody agreed that the rehabilitated reach formed a beautiful backdrop for the happy couple's celebrations!

Table 12.2: The assessment of the Mythic Creek rehabilitation of reaches 1a and 2

Reach priorities	Measurable objectives	Assessment	Lessons learned
Reach 1a	<ul style="list-style-type: none"> • No dam in 10 years time • Cover of weeds reduced to 20-60 % of pre-project cover by year 5 • Fence both banks for 10-15 km of stream by end of year one. • Assess natural revegetation at year 5. Should have increased vegetation density and diversity to 75-100% that of template reach. 	<ul style="list-style-type: none"> • The scrutiny forced by the Landcare group's challenge to the dam proposal revealed that groundwater pumping was more efficient than the dam for supplying water to irrigators. The dam proposal has been shelved. • One vine species has resisted all attempts at control, but cover of major woody weeds has been reduced by 70%. • 14 km of fence constructed • Photographic comparisons demonstrate sufficient natural regeneration for manual replanting to be unnecessary. 	<ul style="list-style-type: none"> • Calm, professional and passionate resistance can sometimes use the available administrative procedures to protect stream assets.
Goal for Reach 1a	<ul style="list-style-type: none"> • GOAL: protection of Reach 1a 	<ul style="list-style-type: none"> • The overall goal has been achieved. The reach has been protected, and natural recovery is commencing 	
Reach 2	<ul style="list-style-type: none"> • Experimental sediment extraction completed after 5 years (successful if median pool depth in the reach has increased by 50-200%). • Reduce turbidity from Reach 1b by 50-80% in five years (by comparison between reaches 1a and 1b.) • Fence both banks of the reach within 3 years. • Riparian vegetation should, by year five, have 50-80% of the diversity and density of native species found in the template reach. • Determine if natural regeneration is as effective as direct seeding. • Median pool depth in the reach has increased by 50-200% after 5 years, and maintains depth up to year 10. 	<ul style="list-style-type: none"> • Despite some access problems, the sediment extraction has dropped pool depth by about 60%. Extraction ceased after two years, and the bed seems to be building up again. • The variability in the Waterwatch turbidity data, plus the possible improvements in Reach 1a, meant that no conclusion could be reached from the results of the monitoring. Some major sources of sediment were found. • Frontage fenced to over 30 m wide, except for one 500 m section where the landholder would not cooperate. This reach was turned into a 'control' section for vegetation recovery in the fenced sections. • Revegetation on both banks was successful. • Macrophytes returned quickly once stock were removed. • The vegetation experiment suggests that, with weed control, natural regeneration can be as rapid as direct seeding where there is a very close source of seed (in this case, reach 1a). • Pools are now only just over 50% deeper than five years ago. This just classifies as a success, though it is a disappointment. Unfortunately, it seems unlikely that even this depth increase will be maintained for the next five years. 	<ul style="list-style-type: none"> • Although sediment delivery to the stream has slowed, continuing supply from stored sediment within the stream is a problem for downstream work. • It can be difficult to monitor changes in water quality without having long data sets. Walking around the catchment in the rain can be a great way to identify sediment sources. Some key road drains were found this way, and treated. • It is possible to devise simple and useful experiments that do not jeopardise the project, but will provide useful information. Natural regeneration will be the reeve. method of choice wherever possible.

Table :The assessment of the Mythic Creek rehabilitation of reaches 1a and 2 (*Continued*)

Reach priorities	Measurable objectives	Assessment	Lessons learned
	<ul style="list-style-type: none"> • Bank erosion rate should match template five years after vegetation is established on the banks • Water quality from piggery to reach EPA standards in 5 years 	<ul style="list-style-type: none"> • This proved difficult to assess, but shrubs and grass are growing down the banks and reeds are growing at the toe of the bank. This appears to be reducing the erosion rate. • The glare of Waterwatch publicity encouraged the piggery owner to invest in a land disposal system. The release of wastewater to the river has now ceased. 	<ul style="list-style-type: none"> • Community scrutiny can influence commercial uses of the stream
Goal for Reach 2	<ul style="list-style-type: none"> • GOAL: Protection of Reach 3 (downstream), and improvement of a linking reach. 	<ul style="list-style-type: none"> • Reach 1a has proved a valuable source of seed for natural regeneration of vegetation in the reach. Water quality may have improved with control of the piggery effluent, but coarse and fine sediment from Reach 1b remain a problem 	<ul style="list-style-type: none"> • Benefits of working downstream from good quality reaches and using natural recovery. • Benefits of concerted community monitoring program • Importance of controlling upstream sediment sources • Disappointment that they did not set up some form of monitoring to measure changes in biological outcomes.

The outcomes of the assessment of the Mythic Creek project will be disseminated by:

- An article in the Landcare Journal
- A paper at the National Stream Management Conference
- A final inspection organised as part of the regional Landcare meeting
- Local newspaper articles
- Information on the LWRRDC Internet WebPage.

7 Reality check

You have now finished your rehabilitation project! Return to Step 1 for your next project, taking with you all that you have learnt.

Bibliography

Anderson, J., 1993. *State of the Rivers: Maroochy River and Tributary Streams*. Maroochy Shire Council & Department of Primary Industries, Maroochy, QLD.

Anderson, S., 1999. The "Science of Consultation: a Tasmanian Experience. In I. Rutherford and R. Bartley (eds.), *Second Australian Stream Management Conference, Adelaide*. Cooperative Research Centre for Catchment Hydrology, pp. 9–13.

Brierley, G., 1999. River styles: an integrative biophysical template for river management. In I. Rutherford and R. Bartley (eds.), *Second Australian Stream Management Conference, Adelaide*. Cooperative Research Centre for Catchment Hydrology, pp. 93–100.

Brierley, G.J., K. Fryirs and T. Cohen, 1996. *Geomorphology and River Ecology in Southeastern Australia: An Approach to catchment Characterisation: Part One: a Geomorphic Approach to Catchment Characterisation*. Working Paper, 9603. Graduate School of the Environment, Macquarie University, Sydney, Australia.

Brookes, A., 1987. The distribution and management of channelized streams in Denmark. *Regulated Rivers*, 1: 3–16.

Danley, H.D., M.J. Eubanks and C.L.J. Jernigan, 1995. *Twenty-mile Creek Habitat Restoration Project*. US Army Corps of Engineers, Mobile, Alabama.

DNRE, 1997. *Index of Stream Condition : User's Manual*. Department of Natural Resources and Environment, Victoria, 67 pp.

Erskine, W.D. and L.J. White, 1996. Historical river metamorphosis of the Cann River, East Gippsland, Victoria. In I.D. Rutherford and M.R. Walker (eds.), *First National Conference on Stream Management in Australia, Merrijig*. Cooperative Research Centre for Catchment Hydrology, pp. 277–82.

Finlayson, B.L. and S.O. Brizga, 1995. The oral tradition, environmental change and River Basin Management: Case studies from Queensland and Victoria. *Australian Geographical Studies*, 32(2): 180–92.

Frissell, C.A. and R.K. Nawa, 1992. Incidence and causes of physical failure of artificial habitat structures in streams of western Oregon and Washington. *North American Journal of Fisheries Management*, 12: 182–97.

House, R., 1996. An Evaluation of Stream Restoration Structures in a Coastal Oregon Stream, 1981–1993. *North American Journal of Fisheries Management*, 16: 272–81.

House, R.A. and P.L. Boehne, 1985. Evaluation of Instream Enhancement Structures for Salmonid Spawning and Rearing in a Coastal Oregon Stream. *North American Journal of Fisheries Management*, 5: 283–95.

Hupp, C.R. and A. Simon, 1991. Bank accretion and the development of vegetated depositional surfaces along modified alluvial channels. *Geomorphology*, 4: 111–24.

Kapitzke, I.R., R.G. Pearson, S.G. Smithers, M.R. Crees, L.B. Sands, S.D. Skull and A.J. Johnston, 1998. *Stream Stabilisation for Rehabilitation in North-East Queensland*. Land & Water Resources Research & Development Corporation, Townsville, 216 pp.

Koehn, J., T. Doeg, D. Harrington, and G. Milledge, 1997. Dartmouth Dam: effects on the downstream aquatic fauna. In R.J. Banens and R. Lehane (eds.), *Proceedings of the 1995 Riverine Environments Research Forum of the MDBC Natural Resource Management Strategy Funded Projects*.

Kondolf, G.M. and E.R. Micheli, 1995. Evaluating Stream Restoration Projects. *Environmental Management*, 19(1): 1–15.

Kondolf, G.M., J.C. Vick and T.M. Ramirez, 1996. Salmon spawning Habitat Rehabilitation, on the Merced River, California: An Evaluation of Project Planning and Performance. *Transactions of the American Fisheries Society*, 125: 899–912.

Locher, H., 1996. Response of the King and Queen Rivers, Tasmania, to Dramatic Changes in Flow and Sediment Load. In I.D. Rutherford and M.R. Walker (eds.), *First National River Management Conference, Merrijig*. Cooperative Research Centre for Catchment Hydrology, pp. 271–5.

- Meredith, J.R. and S.J. Mantel, 1995. *Project Management: A Managerial Approach*. John Wiley and Sons, New York.
- MTRCA, 1994. *Forty steps to a new Don: The report of the Don Watershed Task Force*, Metropolitan Toronto and Region Conservation Authority, Toronto.
- National Research Council, 1992. *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy*. National Academy Press,, Washington DC, 552 pp.
- Newbury, R. and M. Gaboury, 1993. *Stream analysis and fish habitat design—a field manual*. Newbury Hydraulics Ltd., British Columbia.
- Raine, A. and J. Gardiner, 1997. *Revegetating streams in the Bellinger Catchment. A guide to species and planting methods*. New South Wales Government.
- Raine, A.W. and J.N. Gardiner, 1995. *Rivercare: Guidelines for Ecologically Sustainable Management of Rivers and Riparian Vegetation*. Occasional Paper, 03/95. Land and Water Resources Research and Development Corporation, Canberra.
- Rosgen, D.L., 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, Colorado.
- Rutherford, I.D., A. Ladson, J.T. Tilleard, M. Stewardson, S. Ewing, G. Brierley and K. Fryirs, 1998. *Research and development needs for river restoration in Australia*. Report to the Land and Water Resources Research and Development Corporation, Canberra.
- Starr, B.J., 1995. *Numeralla—River of change*. Report to the Numeralla and District Landcare Group, by the Department of Water Resources, NSW, Bredbo.

A Rehabilitation Manual for Australian Streams, Volume 1

We need your feedback!

We want to know what you think of this manual: what parts of it you find most useful; what parts are least useful; what might be added; how the presentation might be improved. On the matter of presentation, please note that the manual was first published (in colour) on the World Wide Web, where can be accessed at <www.rivers.gov.au>. For economy and convenience, the pagination of the Web version has been retained here.

We also want to know about your experiences in stream rehabilitation, so we can develop a data bank of case studies in stream work in Australia. Please use the space on the other side of this form to tell us what you have done or are doing.

Sharing your experiences will help. The stream rehabilitation industry is in its infancy, but it will grow and mature. We hope that this manual will foster this and will itself evolve as we learn from each other about the business of stream rehabilitation. By sharing, evaluating and recording the successes and failures of our stream rehabilitation efforts we will gain the confidence needed to begin roll back the many decades of degradation that our streams have suffered.

Please complete this two-page questionnaire (we suggest you use a photocopy), providing as much information as you can. Return the completed form to: Dr Siwan Lovett, Program Coordinator, River Restoration & Riparian Lands, LWRRDC, GPO Box 2182, Canberra ACT 2601; Fax: (02) 6257 3420; email: <public@lwrrdc.gov.au>.

QUESTIONNAIRE

The parts of the manual which I found most useful were:

.....

The parts of the manual which I found least useful were:

.....

General comments on content:

.....

An updated version should contain more or new information on:

.....

I found the information in the manual was well-organised and easy to navigate (please tick appropriate box):

Yes No

General comments on presentation:

.....

The presentation of an updated version could be improved by:

I would purchase a copy of a new edition of the manual if it were available as a:

book
 CD-ROM (please tick preference)

I have looked at the World Wide Web version of the manual:

Yes No

If 'yes', please comment on its usefulness or otherwise:

I AM OR HAVE BEEN INVOLVED IN STREAM REHABILITATION OR RELATED ACTIVITIES (PLEASE TICK APPROPRIATE BOX)

Yes No

If 'Yes' please provide, in the box below, a brief account of the aims and outcomes of the work in which you are/were involved.

Name:Affiliation:

Postal address:

Fax:Email:

Please return the completed form to: Dr Siwan Lovett, Program Coordinator, River Restoration and Riparian Lands, LWRRDC, GPO Box 2182, Canberra ACT 2601; Fax: (02) 6257 3420; email: <public@lwrrdc.gov.au>.