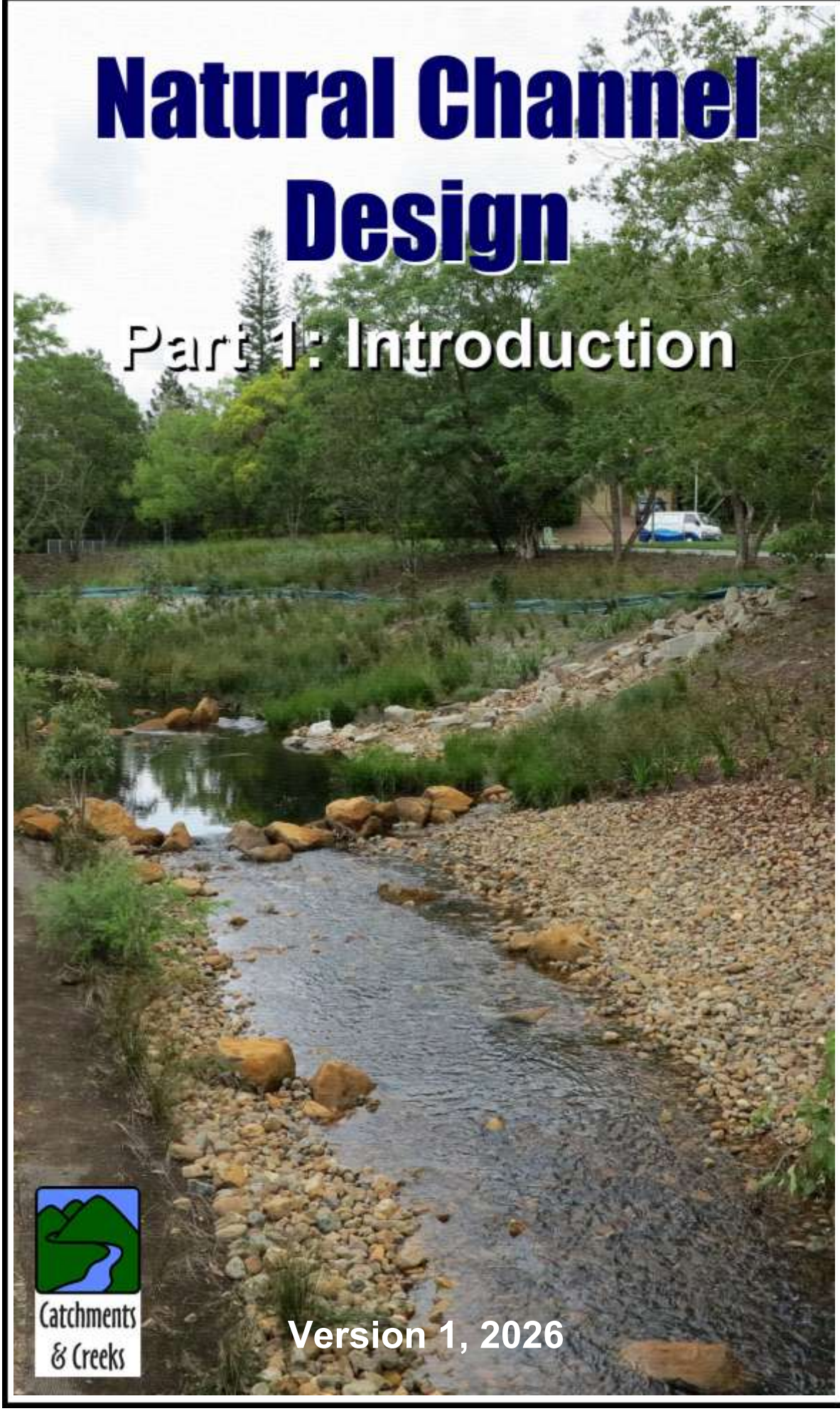
Natural Channel Design

Part 1: Introduction



Catchments & Creeks

Version 1, 2026

Natural Channel Design
Part 1 – Introduction

Version 1, April 2026

Prepared and illustrated by: Grant Witheridge, Catchments and Creeks

Published by: Catchments and Creeks, Bargara, Queensland

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Witheridge 2026, *Natural Channel Design Part 1 – Introduction*. Catchments and Creeks, Bargara, Queensland.

Copies of this document may be downloaded from: www.catchmentsandcreeks.com.au

Cover image: Rehabilitation of a channelised section of Cubberla Creek upstream of Moggill Road, Chapel Hill, Brisbane, Queensland.

Foreword

I believe that this publication will be one of the last instalments in my collection of what I have called, ‘field guides’. But his document should be a little different from the past field guides because I have decided, based your feedback, to include both nouns and verbs in the same sentence. A bit radical for an engineer, but I will try. Well, at least 50% of the time.

Thanks for reading. Enjoy.

Principal reference documents

Brisbane City Council, 2000

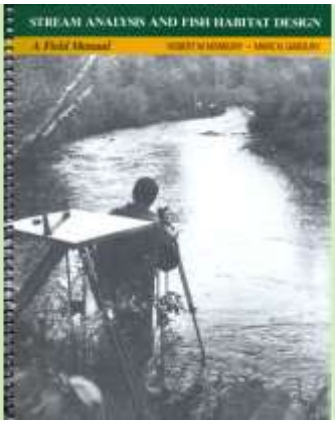
Natural Channel Design Guidelines

Brisbane City Council, 2000, Brisbane, Queensland.

Prepared in association with Catchments and Creeks Pty. Ltd.

152 page colour booklet (out of print).

PDF is/was available from the Council's website.



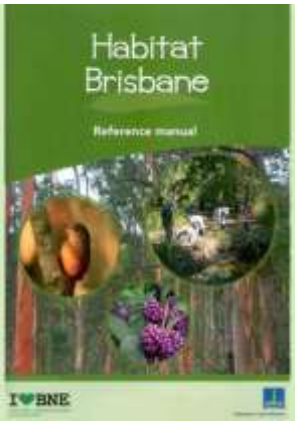
Newbury & Gaboury, 1993

Stream Analysis and Fish Habitat Design

Robert Newbury and Marc Gaboury

Published by Newbury Hydraulics Ltd. and The Manitoba Habitat Heritage Corporation, Manitoba Fisheries Branch, Gibsons, British Columbia, Canada, 1993

ISBN 0 969 6891 0 1



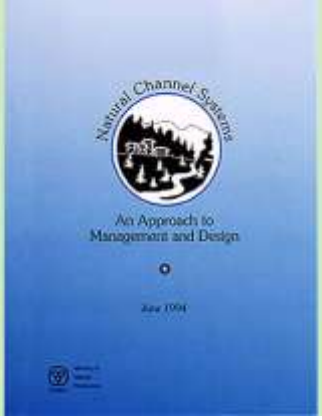
Habitat Brisbane, 2016

Habitat Brisbane – Reference manual

Brisbane City Council, 2016

CA15-454487-01-1500

A colour, hard copy document with limited release—supplied to Brisbane habitat volunteers.



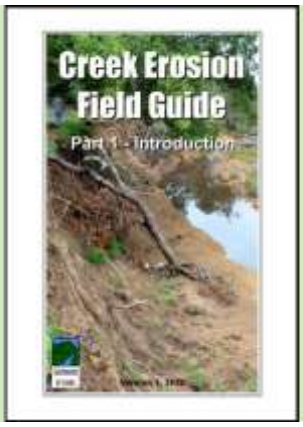
Natural Channel Systems, 1994

Natural Channel Systems – An Approach to Management and Design

Ministry of Natural Resources, Ontario, June 1994.

ISBN 0-7778-2669-0

Related *Catchments and Creeks* publications



Creek Erosion Field Guide, 2021

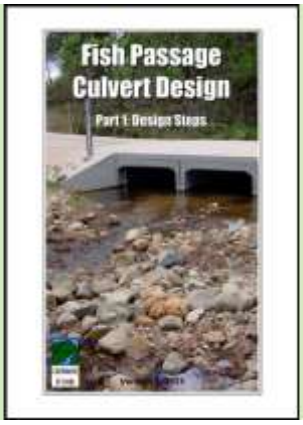
Creek Erosion Field Guide

Catchments & Creeks Pty Ltd, 2021, Bargara Queensland.

A four-part PDF document.

Version 1, April 2021

- Part 1: Introduction
- Part 2: Bed Stabilisation
- Part 3: Bank Stabilisation
- Part 4: Bank Treatment Options



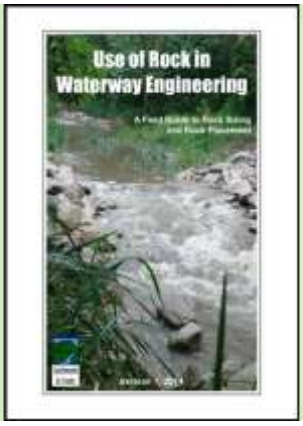
Fish Passage Culvert Design, 2026

Fish Passage Culvert Design

Catchments & Creeks, Version 2, 2026, Bargara Queensland.

A three-part PDF document.

- Part 1: Design Steps
- Part 2: Appendices A to F
- Part 3: Appendices G to M



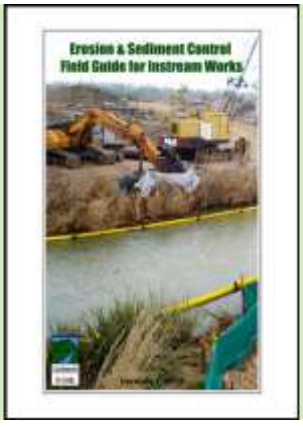
Use of Rock in Waterways, 2020

Use of Rock in Waterway Engineering

Catchments & Creeks Pty Ltd, 2020, Brisbane Queensland.

Version 3, 2020

A pictorial guide to the sizing and placement of rock within waterways.



ESC for Instream Works, 2020

Erosion and Sediment Control Field Guide for Instream Works

Catchments & Creeks Pty Ltd, 2020, Brisbane Queensland.

A pictorial-based guide to erosion and sediment control practices appropriate during the conduction of instream work, such as constructed drainage channels, and creek rehabilitation.

Contents

Purpose of this document

This document has been prepared specifically to:

- provide guidance on the principles and application of *Natural Channel Design*
- provide general education on creek engineering
- provide this information in a manner that is both visually attractive and easy to understand.

The document does not specifically address creek rehabilitation projects; however, parts of the document are relevant to creek rehabilitation and channel modification projects.

The photos presented within this document are intended to represent the current topic of discussion. These photos are presented for the purpose of depicting either a preferred or discouraged outcome (as the case may be). In many cases the photos do not represent current best practice, but are simply the best photos available to the author at the time.

The caption and/or associated discussion should **not** imply that the site shown within the photographs represents either good or bad waterway management. The circumstances, site conditions and history of each site are not known to the author, and may not be directly relevant to the current discussion. This means that the designer may have had a completely valid reason for the channel layout presented within the photo (i.e. don't be too quick to judge).

About the author

Grant Witheridge is a retired civil engineer with both Bachelor and Masters degrees from the University of NSW (UNSW). He has over 45 years experience in the fields of hydraulics, creek engineering, and erosion & sediment control, during which time he worked for a variety of federal, state and local governments, as well as private organisations.

Grant commenced his career at the UNSW Water Research Laboratory (1981) constructing and operating physical flood models of river floodplains. He later worked for Brisbane City Council on creek engineering and stormwater management issues, before ended his career working through his own company, Catchments & Creeks Pty Ltd.

Introduction

Natural Channel Design (NCD) is not a form of creek rehabilitation or creek restoration; however, it does share many values and design concepts with these activities.

Natural Channel Design is a channel design philosophy that aims to introduce sustainable hydraulic and ecological features of local waterways into the design of constructed channels.

Creek rehabilitation is a process of restoring the hydraulic, ecological, floral and/or channel-stabilising features of a waterway in a manner that is compatible with the altered channel or catchment conditions of the waterway.

Creek restoration is the process of restoring the original features and geometry of a waterway.

The principles of Natural Channel Design can assist, but not outright dictate, the rehabilitation of waterways that have been modified by past activities.

The typical uses of Natural Channel Design include:

- the design of vegetated drainage channels
- the relocation of waterway channels
- the design of flood mitigation works that may impact upon a natural waterway, such as channel expansion, floodplain modifications, or vegetation removal
- the rehabilitation of a heavily modified section of a waterway.

Constructed channels not only have to integrate well with the catchment hydrology and ecology, but they must also integrate well with the local community, and the values the community places on these waterways and drainage channels. The ultimate aim is for the community, and the local wildlife, to eventually treat the constructed channel as if it were a natural feature of the landscape.

Layout of Part 1 of this four-part document

Constructed drainage channel (Qld)

The Principles of Natural Channel Design

- Chapter 1 introduces the philosophy of Natural Channel Design (NCD).
- This chapter discusses:
  - the design team
  - the ideals of a 'creek whisperer'
  - water quality issues
  - some of the terminology used in Natural Channel Design.

Constructed drainage channel (Qld)

Application of Natural Channel Design

- Chapter 2 introduced the different types of waterway projects that can benefit from the principles of Natural Channel Design, including:
  - rehabilitation of a degraded waterway
  - stabilisation of an eroded waterway
  - channel expansion
  - design of vegetated drainage channels
  - replacement of old concrete drains.

Project meeting

Project Planning

- Chapter 3 discusses the potential steps involved in the planning of creek rehabilitation projects.
- Chapter 3 focuses on creek rehabilitation projects rather than the design of drainage channels (which is the focus of Part 2 of this four-part document).

Public consultation

Managing Public Expectations

- Chapter 4 introduces the types of discussion that need to be held with the public about creek projects.
- Discussions include the 'weedy phase', expected flood damage, the potential involvement of community groups, and planting schemes.

Policy Issues

- Chapter 5 discusses the issues that should be addressed within waterway management policies.

1. The Principles of Natural Channel Design

Introduction

Target

The aim

- The aim of Natural Channel Design (NCD) is to provide the required hydraulic conveyance, while maximising the channel's environmental values.
- This design approach combines the disciplines of:
  - hydraulic engineering
  - fluvial geomorphology
  - riparian-based biology and ecology
  - bushland restoration and landscape architecture.

Constructed drainage channel (Qld)

Application of Natural Channel Design

- The application of Natural Channel Design (NCD) can include:
  - design of vegetated drainage channels
  - channel expansion (widening)
  - channel relocation
  - waterway rehabilitation
  - restoration of aquatic habitats
  - restoration of terrestrial movement corridors.

A modified drainage catchment (Qld)

Limitations

- Unfortunately, it is not possible to have an all-natural waterway within and unnatural catchment.
- However, the principles of NCD can assist in the rehabilitation of a modified waterway through the adaptation of channel features that would likely have been associated with the original waterway.
- The fact remains—because a waterway is a product of its catchment, if you change the catchment, then you will change the waterway.

Caution!

A failed design approach

- The 'Field of Dreams' approach to channel design and creek rehabilitation is a design approach that focuses on encouraging wildlife to move into a created habitat, such as a constructed drainage channel.
- This approach can seen as legitimate when the aim is to replace habitat that has been lost from others parts of a city.
- However, we should never encourage non-native fauna or flora to inhabit a natural waterway.

The design team

Design team

The design team

- Wherever possible, the design team should consist of an:
  - aquatic ecologist
  - terrestrial ecologist or wildlife officer
  - creek engineer or river morphologist
  - local vegetation expert
  - soils expert (soil scientist).
- Certain members of the team may not be required if relevant guidance is provided within existing plans and reports.

Engineer

Hydraulic and fluvial engineering

- Creeks and rivers share many properties, but they also have their own characteristics.
- If the project involves a ‘creek’, then a creek engineer may be appropriate; however, if the project is dealing with a ‘river’ then a river morphologist could provide valuable guidance.
- A soils expert is often required if the area contains problem soils, such as sodic or acid sulfate soils.

Biologist

Riparian biology and ecology

- Natural Channel Design aims to preserve the integrity of a local ecosystem by conserving or promoting diverse communities and species that are appropriate for the local area.
- The two key areas of interest are:
  - aquatic habitats
  - terrestrial habitats.

Bushland habitat officer

Bush rehabilitation and landscape design

- Bush restoration is a very different ‘science’ from that of landscape architecture, but that does not prevent a landscape architect from having expertise in bush restoration and the management of riparian communities.
- The key knowledge is not ‘what previously grew in the area’, but what needs to grow there in the future given the changing conditions of the site, and/or the changing catchment.

The ‘Creek Whisperer’

Waterway specialist

Introduction

- The concept of a ‘creek whisperer’ originates from the Hollywood movie, *‘The Horse Whisperer’*.
- The term refers to someone that has the ability to read and understand what messages the waterway is displaying through its:
  - channel erosion and flood damage
  - meandering channel patterns
  - water quality and sedimentation
  - and its changing ecology.

Knowledge and training

Potential background of a waterway expert

- The key attributes of a waterway expert are (in the author’s opinion):
  - education
  - experience
  - willingness to admit that they don’t know everything, and their willingness to seek the advice of other experts.
- There is no profession that holds a monopoly on being a waterway expert.

Creek inspection (Qld)

Reading a waterway

- The science of river morphology can tell you what to expect in a typical waterway, but the two instruments that a waterway expert relies upon in order to understand a stressed waterway are:
  - their eyes, and
  - their experience.
- Practitioners should take every opportunity to observe that shape of a channel, the marks in the soil, the type of plant damage, and the movement of the water.

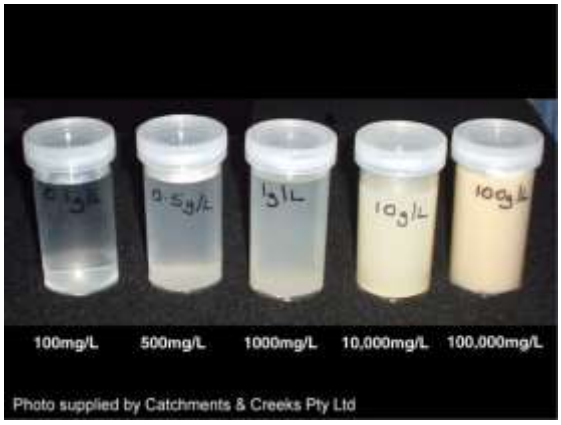
Waterway inhabitants (Qld)

Measuring the health of a waterway

- A ‘creek whisperer’ would never rank the health of a waterway solely on its water quality.
- The health of a waterway should be based on:
  - the long-term water quality
  - the diversity of aquatic life, including invertebrates
  - the health of the riparian zone and fauna
  - the stability of the waterway channel.

Water quality issues

Water quality testing



Water quality samples

Stormwater retention basin (Qld)

Urban development (Qld)

Introduction

- Humans typically have a blood test only when they are in poor health, which means an average of these test results will show a bias towards 'poor health'.
- Similarly, if we only test water quality when we expect a waterway to be in poor health, then the results can show a bias towards 'poor health'.
- **The lesson is:** Don't make conclusions from water quality results unless you have knowledge of the testing program.
- A water quality test is at best, an 'indicator' of an issue; not a conclusion.
- Remember: An person could use selective water quality results to make a healthy waterway appear to be unhealthy, or an unhealthy waterway to appear to be in a health condition.
- What is more important than a point-in-time water quality check, is the ability of a waterway to quickly improve its water quality after a flood event.
- It is also important to note that floodwater can fully drain from most creeks, but is largely retained within most rivers.

Maintaining groundwater inflows

- If a local authority wishes to encourage the adoption of Natural Channel Design within existing and future urban developments, then the authority should also encourage:
  - stormwater infiltration in order to maximise groundwater inflows (spring flows) into drainage channels and waterways, and the adoption of
  - stormwater retention systems that slowly release filtered water into the drainage system after storm events.

Sediment control

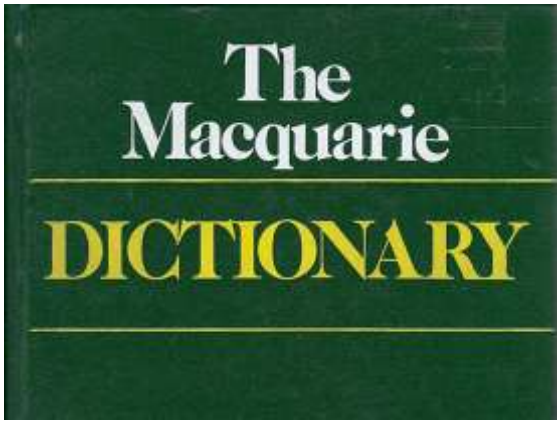
- Drainage channels that have been constructed with natural channel features can be completely destroyed if the drainage catchment does not have active *erosion and sediment control* practices on building and construction sites.
- Excessive coarse sediment (sand) can smother low-flow channels, and infill habitat pools.
- Excessive turbidity (clay) can severely impact the health of aquatic fauna.

Terminology

Gravel-based creek (Qld)

Sand-based creek (Qld)

Navigable waterway (NSW)



Macquarie dictionary

Introduction

- There are many ways to classify a waterway, and the profession of river morphology has its own terminology.
- This publication classifies springs, brooks and creeks as minor waterways, and most rivers as major waterways; however, it is noted that most rivers commence as a minor waterway.
- Minor waterways can be classified in accordance with the dominant bed material (i.e. clay, sand, gravel or rock).

The term: 'watercourse'

- A *watercourse* is a channel with defined bed and banks along which surface water flows on a permanent or semi-permanent basis, or at least under natural conditions for a substantial time following periods of heavy rainfall within its catchment.
- Constructed drainage channels are usually not considered to be watercourses; however, the adoption of *Natural Channel Design* principles in the design of drainage channels is beginning to change that status.

The term: 'waterway'

- Historically, the term *waterway* referred only to a navigable watercourse.
- In rural communities, the term 'waterway' can be used to describe a shallow drainage line that crosses farmland (in urban areas this would be called an 'overland flow path').
- In the fluvial (waterway) industry it is common for the terms 'waterway' and 'watercourse' to be interchangeable, which will be the case throughout this document.

The term: 'artificial'

- The term: *artificial* means:

'Made by human skill and labour *(opposed to natural)*; made in imitation of or as a substitute; not genuine.' [The Macquarie]

- Thus, an 'artificial wetland' is not a wetland made from plastic plants, but in fact any constructed wetland.
- Therefore, Natural Channel Design may be said to produce an artificial waterway, which may or may not be recognised as a watercourse by State authorities.

2. Application of Natural Channel Design

Introduction

Caution!

The focus of NCD is on rehabilitation, not restoration

- Natural Channel Design (NCD) **CANNOT** produce a 'natural' channel, only nature can do that.
- Natural Channel Design **CANNOT** be used to return (restore) a modified waterway back to its original condition.
- However, Natural Channel Design **CAN** be used to design a new channel, or to rehabilitate an existing channel in a manner that incorporates natural features.

Urbanisation (Qld)

Restoration of a natural waterway

- The process of returning a waterway back to its original, natural, condition is a process known as: 'restoration'.
- Designers should **NOT** attempt to restore the complete natural conditions of a waterway **if** the drainage catchment remains in a modified condition.
- A waterway is a product of its catchment—if you change the catchment, then you will change the waterway.

Rehabilitation of an eroded creek bank

Rehabilitation of a natural waterway

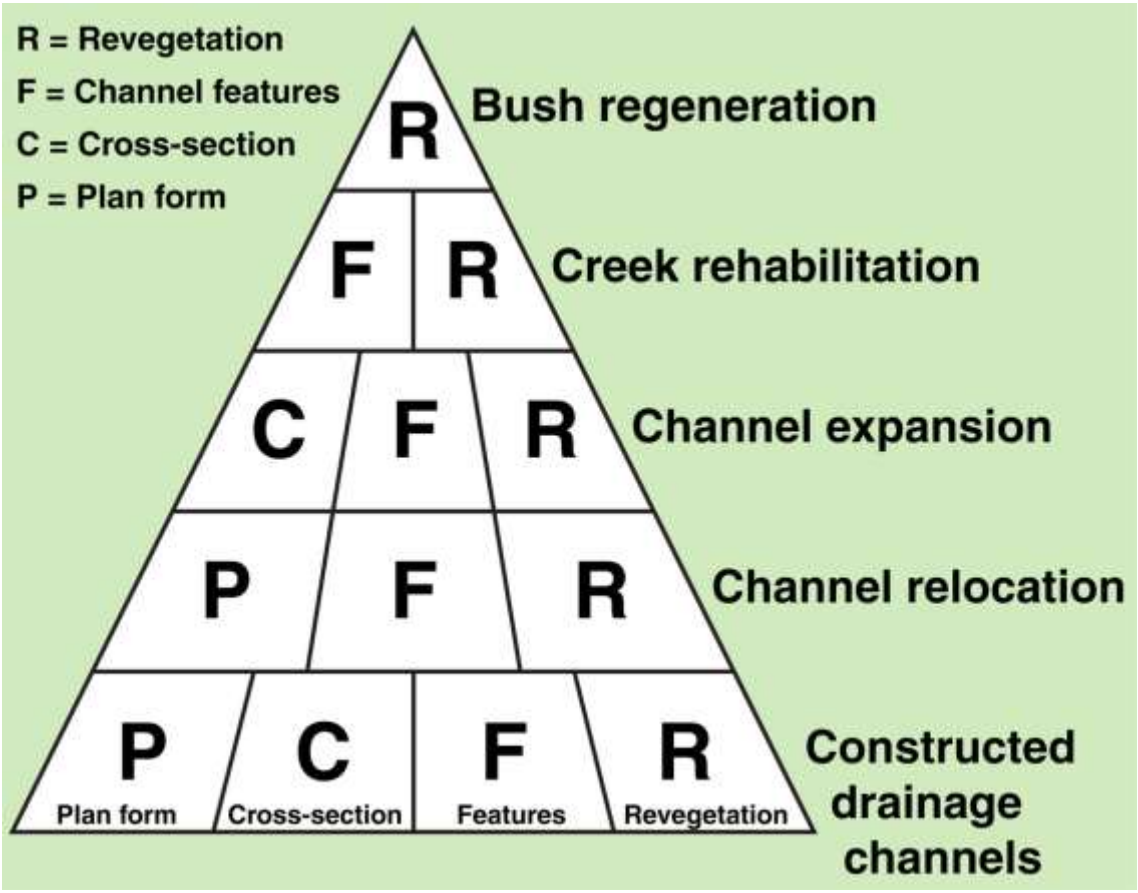
- The process of rehabilitating a waterway involves:
  - physically forming, or guiding a waterway towards the formation of a channel layout, alignment, and profile that is compatible with the catchment hydrology, soil conditions, riparian vegetation, and local fauna.
- The design procedures incorporated into Natural Channel Design are not normally used in creek 'rehabilitation', but they share many components.

The design process

Uses of Natural Channel Design (NCD)

- The principles of Natural Channel Design can be used in:
  - bush regeneration (low degree of involvement)
  - creek rehabilitation (mild degree of involvement)
  - channel expansion
  - channel relocation
  - the design of constructed drainage channels.

Application of Natural Channel Design (NCD)



The typical application of Natural Channel Design principles

Enlarge channel capacity (Qld)

Channel <u>expansion</u> (flood mitigation)

- The public demand for flood mitigation often results in the widening of selected reaches of a waterway channel, especially at channel constrictions.
- Much of the design process is performed through flood modelling; however, the principles of Natural Channel Design can be used to determine: the depth–width ratio, the form of the channel bed, the size of the low-flow channel, and the design of key channel features (channel furniture).

A relocated waterway channel (Qld)

Channel relocation

- In the past, waterway channels were relocated in order to optimise the layout of a new urban development.
- These days, a natural channel is only likely to be relocated if such actions are considered of significant benefit to the wider community.
- Channel relocation is similar to the design of drainage channel; however, the size of the channel must blend seamlessly with the existing upstream and downstream channels.

Application of Natural Channel Design to 'creeks' and 'rivers'

Bluff River (NSW)

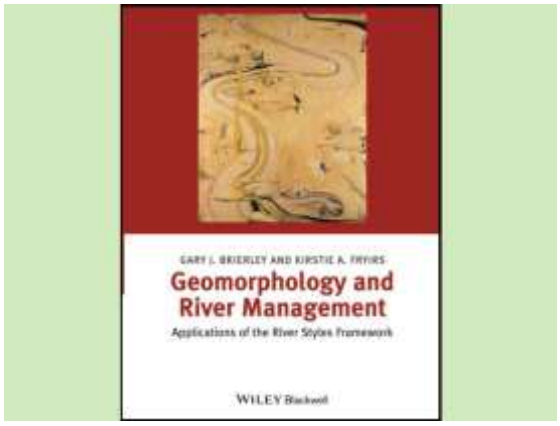
Introduction

- There are those that claim that the rules of geomorphology apply equally to both creeks and rivers, and there are those that know better!
- The terms: 'creek' and 'river' can be misleading because all rivers start out as creeks, but can still be posted as rivers.
- Even the terms: 'minor waterways' and 'major waterways' can be confusing when South Australian waterways are compared to Queensland waterways.

Minor, gravel-based waterway (Qld)

What makes a river different from a creek?

- In general:
  - the smaller the channel, the more important vegetation is in determining the channel's size and stability
  - if a major waterway wants to move, then no vegetation is going to stop it
  - most rivers experience some degree of natural sediment flow; however, some minor waterways can have almost zero natural sediment flow.



River Styles Framework, 2005

Application of NCD to rivers

- In river morphology, water flow and sediment flow will dominate over the riparian vegetation.
- Suggested reference documents include:
  - Geomorphology and River Management, 2005.
  - Geomorphic Analysis of River Systems.
  - Stream Analysis and Fish Habitat Design, 1993.
  - Natural Channel Systems, An Approach to Management and Design, 1994.

Fully constructed drainage channel (Qld)

Application of NCD to creeks

- The geomorphology of minor waterways represents the science that most closely aligns with the principles of Natural Channel Design as presented within this document.
- When Natural Channel Design is applied to the design of a vegetated drainage channel, then the choice of vegetation, and the arrangement of these plants, becomes a dominate factor in the design and performance of the channel.

2.1 Bush regeneration

2.1 Bush Regeneration

Bush regeneration program (Qld)

Introduction

- At first glance, there would appear to be very little connection between the science of bush regeneration, and the engineering of vegetated drainage channels, but the connection is very strong.
- The design of a vegetated drainage channel will almost certainly fail in the long-term if the design team does not incorporate the experience of revegetation experts.
- Good landscaping can turn a simple ‘drain’ into a delightful watercourse.

Ithaca Ck, Glenrosa Rd, Red Hill (2005)

Ithaca Ck, Glenrosa Rd, Red Hill (2014)

Cubberla Creek, Brisbane (Qld)

Torrens River, Adelaide (SA)

Approaches to bush regeneration

Removal of weed tree (Qld)

Introduction

- Ecosystem rehabilitation can be approached in four different ways:
  - natural regeneration
  - assisted bush regeneration
  - bush reconstruction
  - bush fabrication.
- Natural regeneration involves weed removal, and the regeneration of native plants from the existing in-soil seed bank.

Assisted bush regeneration (Qld)

Assisted bush regeneration

- Assisted bush regeneration is most useful when the in-soil seed bank has been depleted, and the species diversity is low.
- These programs involve weed removal and seed collection, which is used to propagate seedlings for later planting.
- After initial weeding, time is given to see if natural regeneration will occur, possibly over 12 months—if unsuccessful, then assisted planting can occur.

Reconstruction of a riparian zone (Qld)

Bush reconstruction

- Bush reconstruction occurs when the site is heavily modified, but the soil and hydrological conditions remain suitable for the original plant communities.
- The original plant communities can be identified through tree surveys of the site, and adjacent plant communities.
- Tree surveys of nearby bushland can be useful, but expert advice will be required to modify these survey results for the riparian conditions of the waterway.

A newly-constructed drainage channel

Bush fabrication

- Bush fabrication is the process that is often adopted when:
  - constructing a new drainage channel
  - replacing a concrete-lined drain with a vegetated drainage channel.
- Wherever possible, the fabrication process should mimic the above ‘reconstruction’ approach.
- Note: Any seed introduced into these drainage channels will likely migrate downstream into natural waterways.

The unexpected ‘enemy’ of our waterways

Drainage engineer

Introduction

- Most people would expect that the greatest threat to our waterways would come from the actions of engineers that still want to build concrete drains.
- However, engineering is a service industry, which means most engineers aim to build whatever the community wants, which means engineers will start to design and build vegetated drainage channels as fast as the community demands the existence of vegetated drainage channels within our suburbs.

Excessive weed removal

The stubborn weeder

- In the author’s opinion, the greatest threat to our waterways currently comes from the ‘stubborn weeder’.
- This is a council officer, or a public volunteer, who is so driven by the task of removing weeds that they fail to consider the wider impacts of their actions.
- Just to be very clear, removing weeds from a waterway can be a very good activity; however, there is no task that should ever be performed without appropriate planning and thought.

Excessive weed removal

Problems caused by uncontrolled weeding

- Weeds may be considered an undesirable plant, but weeds are still plants, and weeds do what most plants do—they help to control erosion, while also providing food, shelter and habitat.
- The rapid removal of weeds can increase the risk of channel erosion, which can undermine native vegetation.
- Rapid weed removal can also cause a short-term increase in flow velocities, which can trigger further channel erosion.

Staging program for weed removal

The correct way to remove weeds

- As a general rule, no weed should be removed from a channel unless there is a replacement plant that is ready to be planted, and that can provide the same erosion control benefits that the weed had previously provided.
- Extensive weed removal projects must be staggered along a waterway so that flow velocities are no altered in a manner that would cause uncontrolled channel erosion (i.e. a lot of thought and planning).

2.2 Rehabilitation of a Degraded Waterway

Norman Creek, Arnwood Place, (1999)

Introduction

- The rehabilitation of a degraded waterway usually does not involve major channel works; however, if the waterway has developed an unstable channel meander, or unstable banks, then major works may be required.
- If the waterway is severely degraded, then there may be little information available on the waterway's 'natural' features, in which case the principles of Natural Channel Design may assist in the development of a natural-looking waterway.

Rehabilitation of Norman Creek, Arnwood Place, (2014)

Rehabilitation of a degraded waterway (examples)

Cubberla Ck, Akuna St, Chapel Hill (1991)

Same view in 2014

Ithaca Ck, Glenrosa Rd, Red Hill, Qld (1992)

Same view in 2014

Kedron Brook, Mitchelton, Brisbane (1999)

Same view in 2014

Norman Ck, Willis St, Brisbane (2001)

Same view in 2014

2.3 Enhancing the Ecological Features of a Confined Channel

River Tiber, Rome, Italy

Kallang River, Bishan-Braddell, Singapore

Sandy Creek, Enoggera, Brisbane, Qld

Introduction

- A 'confined waterway' can be defined as a waterway, or drainage channel, that has banks formed from hard engineering materials, such as concrete, exposed rock, or block work.
- Existing infrastructure and property boundaries can make it impractical to fully rehabilitate the waterway, and so the focus now becomes 'making the best of what you have'.

The problem

- Over time, some waterways have been subjected to severe modifications; often resulting in the waterways being restrained between vertical walls.
- Existing public assets can prevent these waterways from being fully rehabilitated, so the next best thing is for the rehabilitated to focus on:
  - channel aesthetics
  - ecological values, and/or
  - human water-related activities.

Case study: Sandy Creek, Enoggera, Qld

- In a channelised section of Sandy Creek, Enoggera (left), the bed of the concrete channel was covered with firmly-grouted rocks, which helped to retain sediment, which enabled opportunistic vegetation (i.e. weeds) to establish, which shaded the water and encouraged aquatic life, which in-turned helped to control potential mosquito problems.
- The focus was not on 'aesthetics', but on an improvement in the waterways ecological values.

Examples of waterway rehabilitation in Singapore

Alexandra Canal, Singapore

Bukit Batok Canal, Singapore

Kallang River, Bishan-Braddell (early)

Kallang River, Bishan-Braddell (later)

Kallang River, Potong Pasir, Singapore

Pang Sua Canal, Singapore

Sungei Api Api, Singapore

Sungei Tampines, Singapore

2.4 Stabilisation of an Eroded Waterway

Non-vegetated rock placement (Qld)

Introduction

- The traditional treatment of creek erosion typically involved the placement of loose rock (riprap).
- The principles of Natural Channel Design now encourages the integration of native vegetation into this loose rock.
- This change in rock placement reduces weed growth, allows for a quicker recovery of the riparian zone, and provides benefits to both aquatic and terrestrial fauna through improved shelter and habitat values.

Vegetated rock placement, Kedron Brook, upstream of Ferny Way, Brisbane, Qld

Stabilisation of a waterway (examples)

Boss Ck, Kev Hooper Park, Inala (1995)

Same location in 2014

Cedar Creek, Closeburn (2015)

Same location in 2016

Downfall Ck, Rode Rd, Chermside (1991)

Same location in 2014

Kedron Bk, Ferny Way, Ferny Hills (2011)

Same location in 2014

2.5 Channel Expansion

Flood mitigation works (NSW)

Introduction

- Flood mitigation activities can take many forms, including:
  - channel widening
  - selective removal of vegetation from the channel and floodplain
  - the formation of grassed floodways within the floodplains
  - the removal of hydraulic choke points from the channel and floodplain.
- Natural Channel Design can be used to incorporate ecological features into these waterway activities.

Channel expansion for drainage improvement and flood mitigation works (1997)

Increasing the flow capacity of an existing channel

Floodplain flooding (Qld)

Introduction

- Local flooding concerns are commonly associated with three channel conditions:
  - the waterway has a known narrow section (choke), that restricts the movement of floodwater
  - the waterway has long sections (reaches) where the flow capacity is less than desirable
  - the waterway has experienced excessive urban encroach into the floodplain.

Removal of understorey weeds (Qld)

Selective plant removal

- The flow capacity of a waterway can be increased by:
  - reducing the density of in-channel and floodplain vegetation, and/or
  - the formation of grassed floodways.
- The problem with vegetation clearing is that the clearing must be repeated regularly, and public attitudes towards vegetation clearing may change over time.
- The problem with forming floodways is the annual cost of grass mowing.

Channel expansion (Qld)

Widening of the main channel

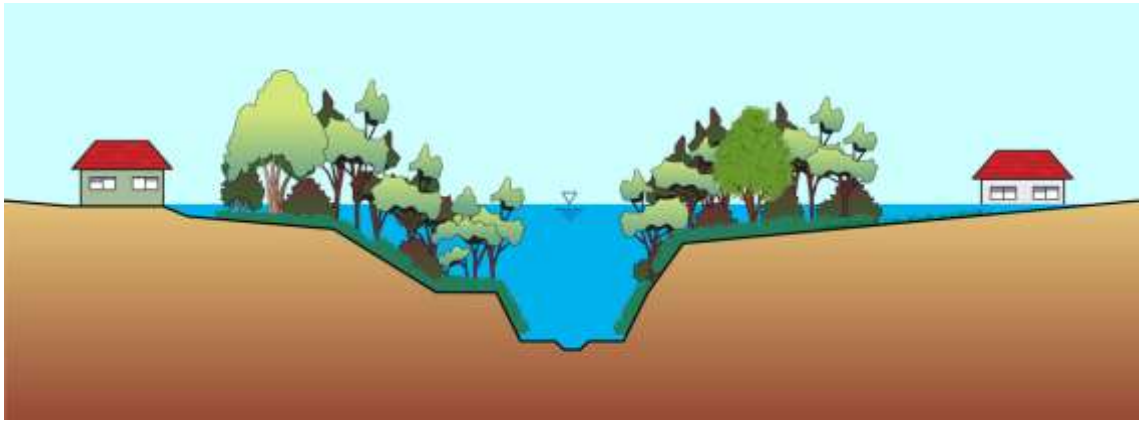
- The flow capacity of a waterway can also be increased by:
  - expanding the main channel
  - lowering or benching the floodplain.
- The problem with expanding the channel is the risk of weed and/or reed invasion, which can add to the maintenance costs.
- The problem with lowering or benching the floodplain can be the temporary or permanent loss of riparian vegetation.

Benched floodway (Qld)

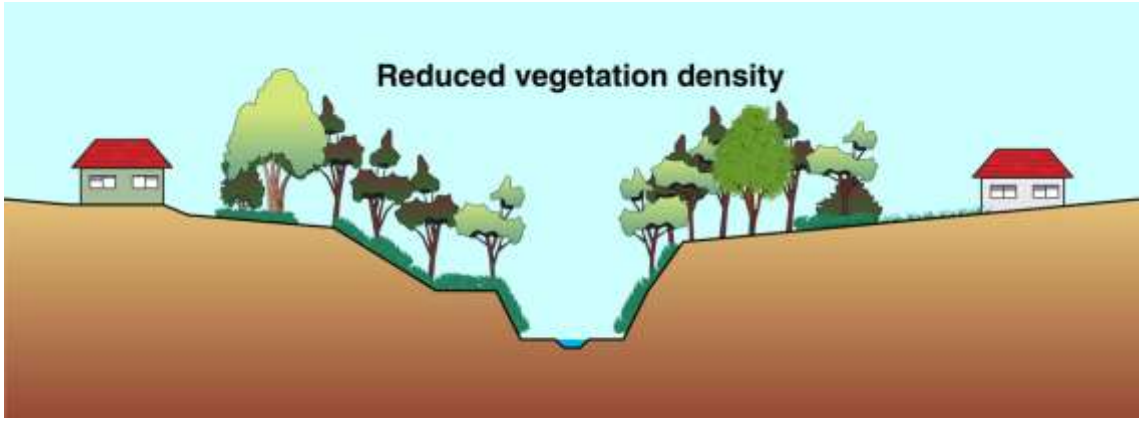
The formation of grassed floodways

- The flow capacity of a waterway can be further increased by:
  - benching the banks of the main channel
  - introducing a grassed floodway to the floodplain.
- The problem with benching the banks is the loss of the natural (original) riparian vegetation.
- The problem with forming grassed floodways is the loss of riparian vegetation and the cost of ongoing grass mowing.

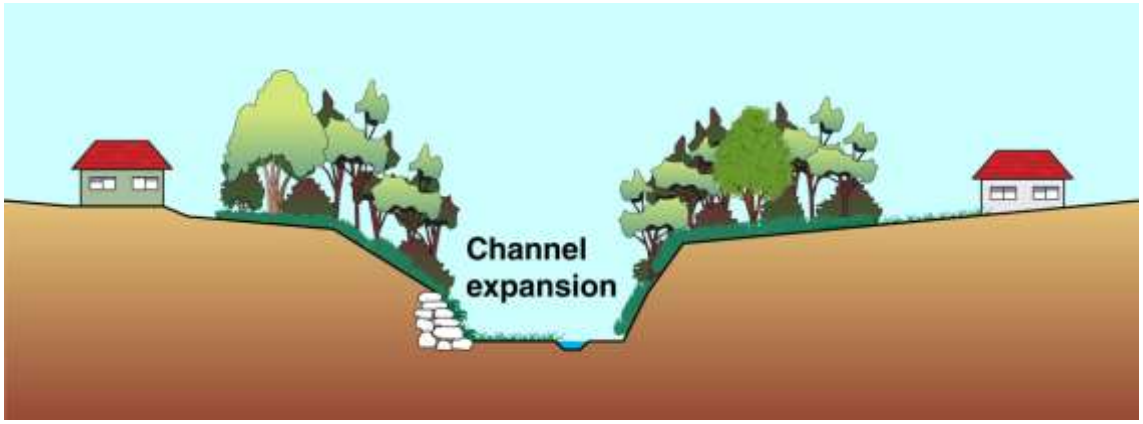
Options for increasing the flow capacity of an existing channel



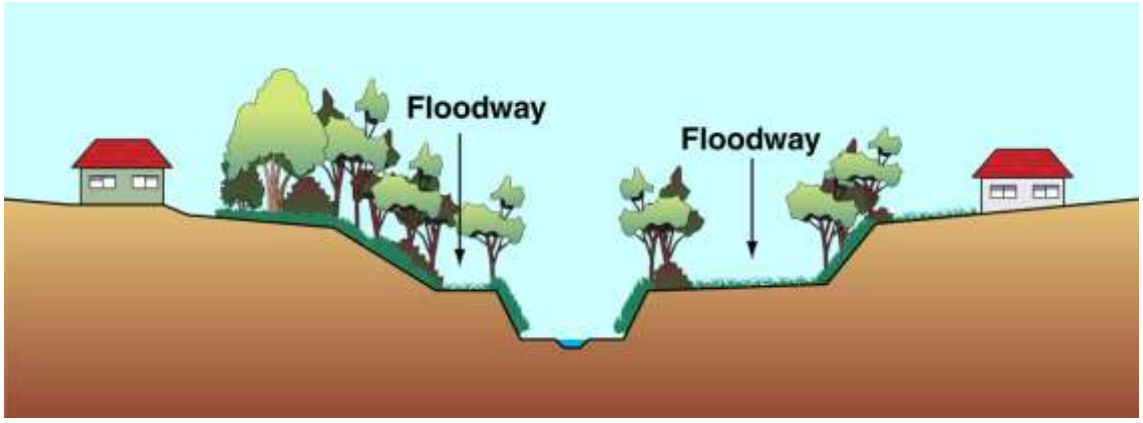
The existing channel with flooding problem



Option 1: **Reduced tree density and the removal of shrubs and some understorey plants**



Option 2: **Expansion of the channel**



Option 3: **Lower the channel bank/floodplain and forming grassed floodways**

The problems caused by reducing the density of vegetation (Option 1)

Tree clearing

Introduction

- Reducing the density of riparian vegetation is an obvious way of increasing the flow capacity of a waterway; however, this action can cause several complications, including:
  - increased risk of soil erosion
  - increased risk of flood damage to retained vegetation
  - increased risk of weed invasion.

Soil scour following weed removal

Excessive soil scour

- If weed removal results in the partial or complete exposure of the soil surface, then operators should expect ongoing soil erosion, unless appropriate controls are put in place, such as:
  - geo logs anchored to the soil to provide temporary surface roughness
  - shade cloth or wire mesh installed across the floodplains (Caution!).
- Erosion control mats can protect the exposed soil, but they can shift during flood events, and damage new plants.

Soil erosion at the base of a tree

The effects of increased flow velocities on the remaining vegetation

- If extensive weed removal results in some trees remaining as isolated plants, then:
  - high-velocity floodwater can generate turbulence and flow eddies immediately downstream of these tree trunks . . .
  - which can form an erosion hole downstream of the trees (left) . . .
  - which can eventually cause the tree to topple and fall into its own scour hole.

Companion planting around a tree

The protection of trees located in regions of high flow velocity

- The erosion problem described above, which can damage trees that are located in regions of high flow velocity, such as within a floodway, can be managed by companion planting placed around the trees, such as:
  - planting native stiff grasses around the base of the trees, such as *Lomandra*
  - planting understorey plants around the base of the trees.

The problems caused by widening an existing channel (Option 2)

A section of widened channel (Qld)

Introduction

- In Brisbane, several creeks were expanded or channelised in response to the extensive flooding of 1974.
- This action has allowed the city to witness the response of these creeks to this sudden and dramatic change in the width of these waterway channels.
- The two main outcomes were:
  - sedimentation problems
  - weed infestation.

Sediment deposition in a widened channel

Sedimentation problems

- There is a reason why a creek forms within a given valley, and why creeks normally have a channel and a floodplain.
- These reasons also govern why channels are formed with a given width and depth.
- If we choose to widen a natural channel, then we should not be surprised to find that 'nature' will try to return the channel back to its original width—and it does this through the process of sediment deposition.

Reeds choking a widened creek bed

Weed infestation problems

- Weeds are opportunistic plants that take advantage of any change in the natural conditions of an environment.
- Channel widening causes a reduction in flow velocity, which is an outcome that allows weeds to establish.
- Sedimentation is a process that forms new soil surfaces, which is another outcome that allows weeds to establish.
- Weeds help to trap sediment, which helps the channel to return to its original width.

Benching a waterway bank (Qld)

Preferred channel widening techniques

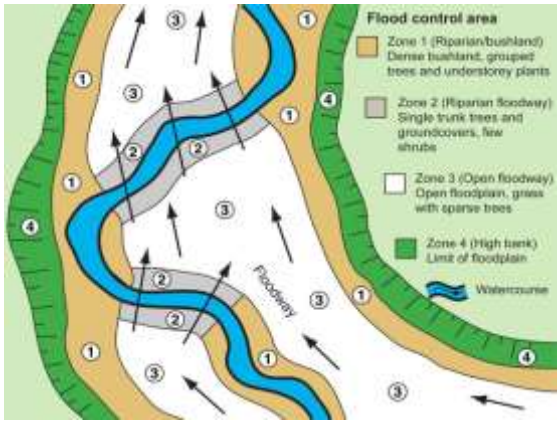
- Wherever possible:
  - the 'natural' width and depth of a channel should be retained
  - if a channel needs to be widened, then the existing channel should be retained as a 'low-flow channel'
  - try to form benches that are at least 1 m above the natural bed
  - if the existing channel bed must be lowered, then reform the bed as a low-flow channel.

The use of grassed floodways (Option 3 from page 31)

Fire trail and maintenance berm (Qld)

Introduction

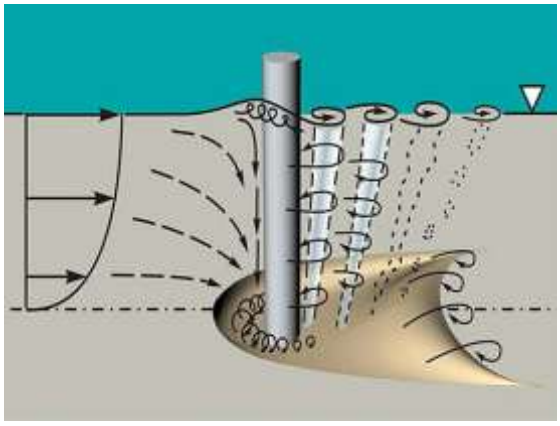
- Open grassed floodways can perform several functions, including:
  - increased flow conveyance
  - public access, footpaths, bikeways
  - maintenance access
  - fire breaks and fire trails.
- In addition to the above, these areas of open grass can discourage the movement of terrestrial wildlife (snakes) from moving between the riparian zones and residential properties.



Floodway passing over a channel

The use of floodways on meandering channels

- If the main channel meanders across the valley, then floodwater will be required to pass through the riparian vegetation (Zone 2 in the diagram shown left).
- In these regions of the riparian zone, the selection of plant species becomes critical—plants should consist of very flexible species, including smooth-trunk trees, stiff grasses, and groundcovers, but no shrubs with their low branches.



Soil scour at the base of isolated trees

Isolated trees located in riparian zones

- Once again, it is important to note the potential problems associated with high-velocity floodwater passing around isolated trees.
- Any trees located within these 'flow-through' regions of the riparian zone, need to be surrounded by stiff grasses and groundcovers to prevent soil scour at the base of the trees.

Soil scour downstream of a tree (Qld)

Isolated trees located in floodplains

- The erosion problem described above can also affect isolated trees located with floodplains and floodways.
- The large scour holes shown here (left) was formed downstream of a tree located in a grassed floodway of a Queensland waterway that was affected by severe flooding in 2011.

2.6 Relocation of an Existing Channel

Channel moved away from important trees

Introduction

- The principles of Natural Channel Design can be used in the design of a channel relocation projects.
- The relocation of a natural waterway should of course be avoided wherever possible; however, circumstances can exist that require such actions because:
  - the lateral movement (meandering) of a waterway is endangering critical assets
  - the realignment will allow the channel to avoid a public asset that itself cannot be moved.

Channel moved away from critical road works, Stable Swamp Creek, Brisbane

2.7 Constructed Drainage Channels

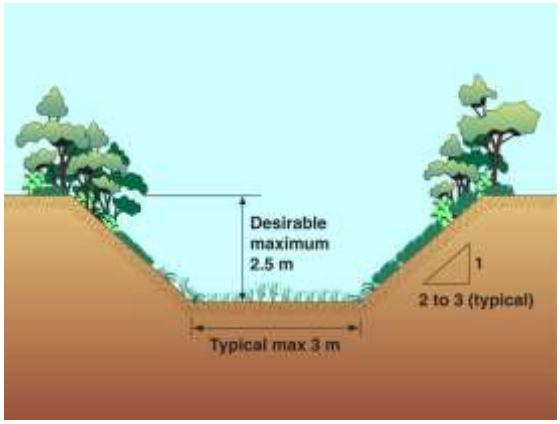
Settlement Road, The Gap (2012)

Introduction

- As a design tool, the primary use of the Natural Channel Design is in the design of vegetated drainage channels.
- These drainage channels are typically located in areas where a natural waterway did NOT previously exist.
- The drainage channels typically represent a reconstruction of an existing overland flow path, usually converting a wide shallow flow path into a channelised drainage reserve.

Constructed drainage channel, Settlement Road, The Gap, Brisbane (2015)

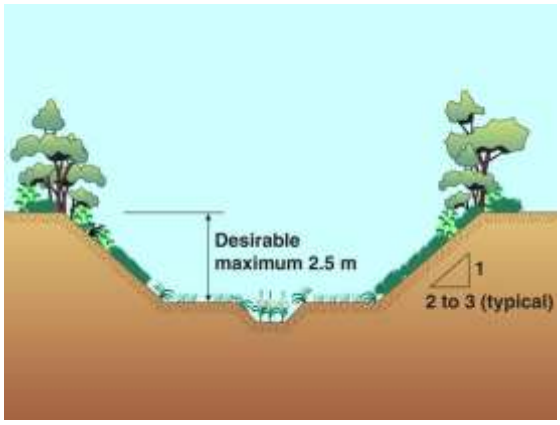
Constructed drainage channels (an expanded discussion is in Part 2)



Single-stage trapezoidal channel

Vegetated channels without a low-flow channel

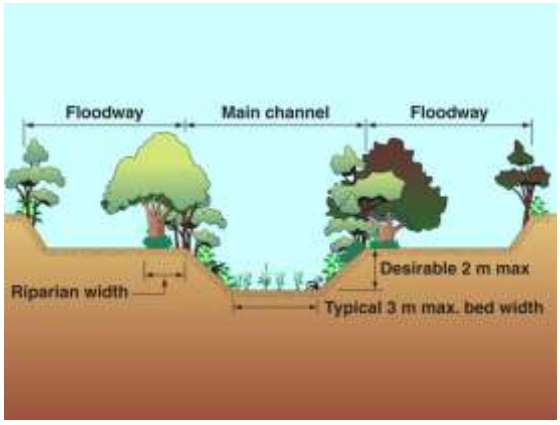
- A channel bed can become hydraulically unstable if the bed width exceeds approximately 3 m.
- As the bed width increases, the bed vegetation and bed roughness becomes less uniform, which can cause the concentration of flows along the channel bed, which can cause the formation of an incised low-flow channel.



Vegetated channel with low-flow channel

Vegetated channels with a low-flow channel

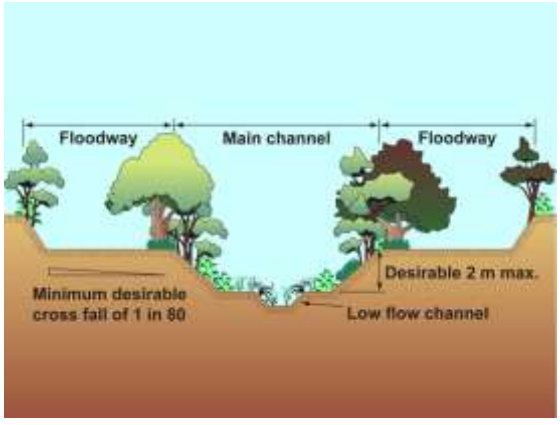
- A well-defined low-flow channel can assist fish passage, and can help to control soil moisture levels across the channel bed.
- The recommended maximum channel depth is 2.5 m, otherwise:
  - excessive erosion and vegetation damage can occur during high flows and/or
  - excessive sedimentation can occur during periods of low flows.



Single-stage channel with floodways

Channel with floodways

- Channel capacity (excluding floodways) is typically 1-in-1 year to 1-in-10 year ARI.
- A channel capacity in excess of 1-in-10 year ARI should be avoided.
- The recommended maximum main channel depth is 2 m relative to top of the lowest bank.
- Care must be taken to ensure that the meandering of the channel does not adversely affect the passage of floodwater along the floodways.



Multi-stage channel with floodways

Channel with floodways and low-flow channel

- Channel capacity (excluding floodway) typically 1-in-1 year to 1-in-10 year ARI.
- A channel capacity in excess of 1-in-10 year ARI should be avoided.
- The capacity of the low-flow channel is based on the dry-weather flow rate.
- The main channel is usually designed as a low-maintenance, heavily vegetated, closed canopy system.

Conversion of an overland flow path into a vegetated drainage channel

Natural drainage line (Qld)

Forest Lake, Brisbane, Qld (1994)

Sinnamon Rd, Sinnamon Park, Qld (2000)

Bowman Park, Bardon, Qld (2000)

Overland flow paths

- An overland flow path or drainage line is a stormwater drainage pathway that carries concentrated flow (not sheet flow), even though the flow path may be very wide.
- Natural bushland can contain numerous drainage lines.
- When undisturbed bushland is converted into an urban landscape, many of these drainage lines can be transformed (expanded) into constructed drainage channels.

Controlling legislation

- When developers deal with existing waterways they must comply with relevant State or Territory legislation, which would include reference to the State's Fisheries legislation.
- However, when developers are dealing with drainage lines, then there is usually no State or Territory legislation that deals with the treatment of these landscapes.
- It is typically the local government that controls the management of drainage lines.

Council Planning Schemes

- A council's Planning Scheme (Town Plan) can specify which principles of Natural Channel Design must be incorporated into the design of drainage channels.
- Typically:
  - a 1% or 2% flow capacity
  - a depth*velocity product; D.V < 0.6
  - integration into the urban landscape
  - low maintenance, or otherwise maintained by the estate.

Critical design objectives

- The critical design objectives are normally:
  - **AVOID** the formation of a high-maintenance drainage channel
  - the channel has the visual appearance of a 'natural' ephemeral waterway
  - the growth of vegetation controlled by canopy shading
  - fish passage and fish habitat is usually not required if the drainage channel is not recognised as a watercourse.

Constructed drainage channels (examples)

Browns Creek, Lismore, NSW (2003)

Same location in 2007

Hoben Street, Michelton, Brisbane (2005)

Same location in 2014

McCaskill Road, Pullenvale, Qld (2001)

Same location in 2014

Sinnamon Rd, Sinnamon Park, Qld (2000)

Same location in 2014

2.8 Replacement of a Concrete Drain with a Vegetated Channel

Bowman Park, Bardon, Brisbane (1998)

Introduction

- The principles of Natural Channel Design can be very useful when converting concrete-lined drainage channels back to a vegetated condition.
- These design projects are very similar to the design of constructed drainage channels.
- It is very rare for a 'drain' to be converted back to its original topography, because the catchments conditions have usually changed, but it should 'look' natural.

The rehabilitated drain as it appeared in 2001

Replacement of a concrete drain with a vegetated channel (examples)

Bowman Park, Bardon, Brisbane (1998)

The same location in 2010

Bowman Park, Bardon, Brisbane (1998)

The same location in 2005

Bridgewater Creek, Brisbane (2001)

The same location in 2003

Cubberla Ck, Moggill Rd, Chapel Hill (2010)

The same location in 2014

3. Project Planning

3.1 Design philosophy

Design Philosophy

What are you trying to do?

A creek 'in equilibrium' (Qld)

'Field of Dreams' movie poster

Introduction

- One of the first tasks that a design team should perform while commencing a new project is to clearly establish the project's aims, such as:
  - improving the waterway aesthetics
  - restoring natural features along the waterway
  - improving fish passage
  - flood management
  - erosion management, or
  - reducing maintenance costs.

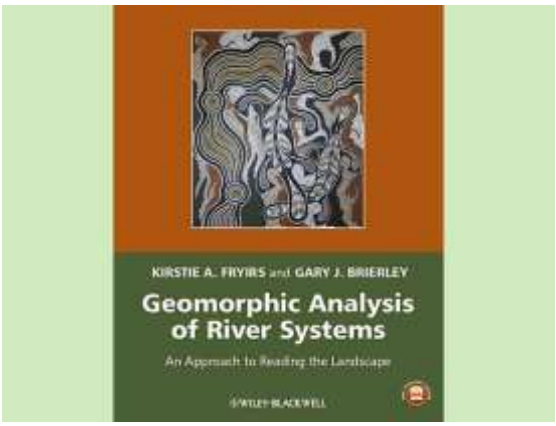
Regime theory

- As humans we are inclined to approach a task by focusing on the 'humans want', but the task of creek rehabilitation team is to focus on what the 'creek wants'.
- Regime theory is a design approach that uses our knowledge of waterways to predict what a waterway may 'want'.
- In rivers, this means finding a sustainable level of channel erosion and sediment deposition; however, in creeks this means finding a sustainable level of vegetation cover.

Field of Dream approach

- The Field of Dreams approach to channel design and creek rehabilitation is a process that focuses on encouraging specific wildlife to migrate towards, and inhabit, a waterway and its riparian zone.
- This could be viewed as a legitimate approach if the aim were to replace habitat lost from other regions of a city.
- However, this design approach is not recommended for the rehabilitation of waterways, and remains questionable for the design of drainage channels.

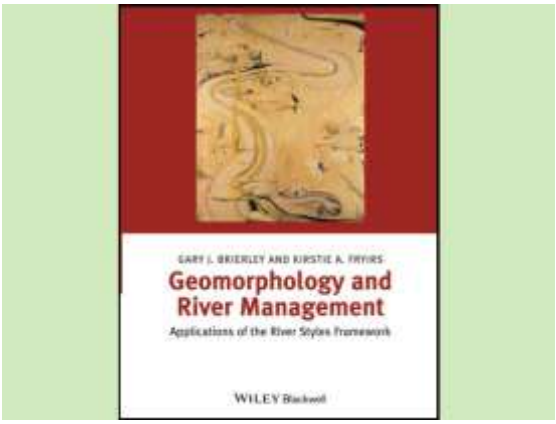
Regime theory



River Styles Framework, 2005

Introduction

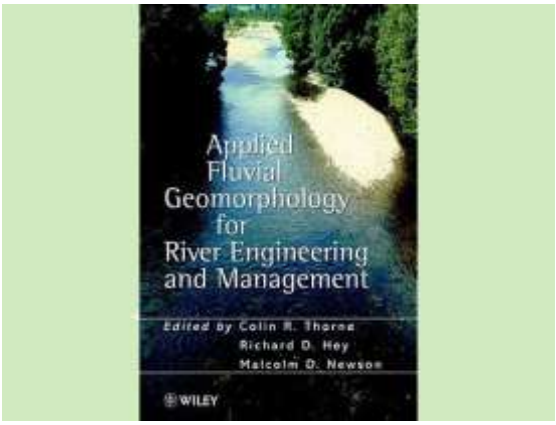
- In the author's opinion, drainage design, creek engineering, and river morphology, are three very different topics that happen to share several common properties.
- In the author's opinion, the River Styles Framework provides a very good approach to river rehabilitation in undisturbed catchments, but not for the design of vegetated drainage channels, or even some forms of creek rehabilitation.



River Styles Framework, 2005

River morphology

- In river morphology, 'channel hydraulics' dominates over the 'vegetation'.
- Suggested references include:
  - *Geomorphology and River Management*, 2005
  - *Geomorphic Analysis of River Systems*, 2005
  - *Stream Analysis and Fish Habitat Design*, 1993
  - *Natural Channel Systems, An Approach to Management and Design*, 1994



Applied Fluvial Geomorphology, 1997

River morphology based on the channel substrate

- In rivers, channel sizing should be based on the catchment hydrology and the type of bed material (substrate):
  - **Gravel:** Hey & Thorne Equations
  - **Clay:** Brisbane Equations
  - **Sand:** Simons & Albertson Equations

Brisbane City Council, 2000

Brisbane City Council guidelines for clay-based creeks

Channel width (W) & depth (D) for a bankfull flow rate (Q_f) less than 100 m^3/s:

- $W = 4.37\ (Q_f)^{0.373}$
- $D = 1.07\ (Q_f)^{0.224}$

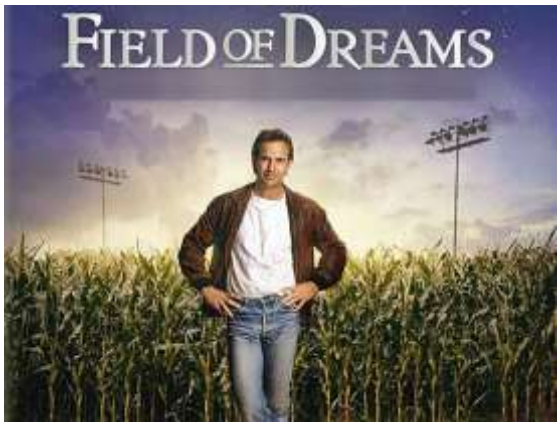
Typical range of:

- $4.33\ (Q_f)^{0.5} > W > 1.78\ (Q_f)^{0.5}$

Typical range of:

- $0.598\ (W)^{0.6} > D > 0.295\ (W)^{0.6}$

The ‘Field of Dreams’ approach to stream rehabilitation



‘Field of Dreams’ movie poster

The movie

- The >Field of Dreams approach is based on the principle:

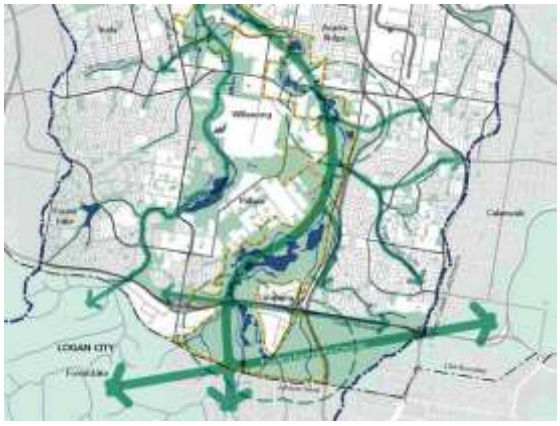
  ‘Build it and they will come.’

- This statement is a quote from the Kevin Cosner movie, *‘Field of Dreams’*.
- The idea being that if you build a vegetated drainage channel with features that attract wildlife, then you will be enhancing the ecological value of the drainage channel.

Introduced habitat log (Qld)

The problem

- The potential problem with this design approach can be summarised as:
  - it is not advisable to entice wildlife into environments they would not normally inhabit.
- **However**, it could be said that installing habitat boxes (possum boxes) in trees is just another example of the Field of Dreams approach, which remains a widely accepted approach to managing urban wildlife.



Wildlife Corridor Map

When should you introduce wildlife features to a new or rehabilitated channel?

- The types of channel features that should be incorporated into the design of a new channel are those that directly relate to the wildlife that are endemic to the area.
- New fish habitats can be introduced to replaced lost aquatic habitats, but only after consultation with Fisheries.
- A catchment-wide wildlife corridor plan can be developed to identify the terrestrial wildlife that are likely to pass along a new waterway corridor.

Problematic rock riffles (weirs)

Channel features that should only be adopted after careful investigation

- Pool–riffle systems generally only exist in gravel-based and rock-based waterways.
- Sand-based channels can develop a type of pool–riffle system, but these bed conditions will change with every flood event.
- Large habitat ponds should only be build if there is sufficient dry-weather flow to maintain the pond’s water quality.
- Habitat dens can attract wildlife that may be considered by the public to be vermin.

Is it a waterway, or just a water feature in a public park?

Active recreation park with waterway

Introduction

- Drainage engineers and public servants ultimately answer to the public, and as a result it is common for the 'public interest' to take priority over the interest of the waterway and its fauna and flora.
- In some projects this can result in waterways being transformed into decorative water features passing through a public park or urban landscape.
- The author hates seeing a waterway turned into an urban water feature.

Recreational park (Qld)

The problem

- In general, there are two types of open space: active recreation parks, and passive bushland.
- **The question is:** *Should the waterway be altered to match the function of the park, or should the park be designed around the natural function of the waterway?*
- Ponds, lakes, creeks and river can greatly enhance the aesthetics of public open space, but are we 'selling' the public a false concept of a waterway?

Recreational park (Singapore)

Integrating a waterway into an urban park

- In cities that have a heavily contoured topography, their waterways and associated riparian zones are often protected by the natural deep valleys.
- However, in cities with a relatively flat topography, flooding and drainage issues can become a major public concern, and waterways are expected to have a high flow capacity.
- In these flatter cities, natural waterways can be forced to function more like open floodways.

Golf course with zero riparian zone

Integrating a waterway into a golf course

- Over the 40 years that the author has worked as a creek engineer, he has rarely seen any golf course successfully integrate with the waterways that passed through the golf course.
- Obviously, a fairway cannot successfully pass through a healthy riparian zone.
- In addition to the vegetation issues, is the heavy use of lawn fertilisers that can, and do, cause significant water quality issues within downstream waterways.

Knowing what to focus on

In ship building, if you were commissioned to build a frigate or battleship, then you would know what you were required to build. In architecture, if you were commissioned to design a hospital or a primary school, then again you would know exactly what is required. But in creek engineering, if you were asked to rehabilitate a waterway, would you automatically know what your focus should be? Who is it in society that speaks on behalf of the waterway?

Natural Channel Design could be considered as just one of the design philosophies that could be used in the rehabilitation of a waterway. For some designers, the principles of Natural Channel Design should only be used in the design of drainage channels. So what role can it play in the rehabilitation of natural waterways? Whichever way you choose to think about these issues, the overriding question remains; *'What are you trying to achieve?'*

We can start to address this question by acknowledging that there are potentially six functions of a waterway corridor, those being:

- human movement (pedestrian and cycling)
- aquatic movement (fish passage)
- terrestrial movement
- arboreal movement
- water flow (drainage and flood control)
- riparian conservation.

A project team could then set about the task of ranking the relative importance (Essential, Important, Secondary or a Non-issue) of each of these six outcomes. Tables 3.1 to 3.6 provide examples of how the 'focus' of a creek rehabilitation project could be developed.

Table 3.1 – Human movement

Requirements	Essential	Important	Secondary	Non-issue
Continuous, dual purpose pedestrian and bike pathway on at least one side of the waterway, with regular waterway crossings. Alternatively, pathways on both side of the waterway.	**Yes**			
Dual purpose, pedestrian and bike pathways located in regions where these pathways do not detract from nominated essential functions of the waterway corridor.		**Yes**		
Pedestrian and bikeway conduits incorporated into the design of new culvert crossings.	**Yes**	**Yes**		
Regular access/exit ramps to adjacent roadways, bikeways and pathways.	**Yes**	**Yes**		
Pedestrian and bike pathways located beyond the top of bank.			**Yes**	
Pedestrian crossings of the waterway to link with existing off-stream pedestrian movement corridors.	**Yes**	**Yes**	**Yes**	
Pedestrian crossings of the waterway are limited to road crossings.				**Yes**

Table 3.2 – Aquatic fauna movement (typically not a priority on drainage channels)

Requirements	Essential	Important	Secondary	Non-issue
Identify and remove (rehabilitate) all artificial fish passage barriers from the full extent of the natural fish habitat.	**Yes**	**Yes**		
Identify and remove artificial barriers to the movement of other aquatic fauna (e.g. turtles).	**Yes**	**Yes**		
Develop a program for the staged rehabilitation of all artificial fish passage barriers from the full extent of the natural fish habitat.	**Yes**	**Yes**	**Yes**	
Provide suitable riparian vegetation, and continuity of vegetation, to support fish migration during flood events.	**Yes**	**Yes**	**Desirable**	
Replace all causeway crossings, and rehabilitate existing culvert crossings.	**Yes**	**Yes**	**Desirable**	
Preference given to bridge and arch crossings of the waterway, if not mandated by State Fisheries.	**Yes**	**Yes**		
Adopt fish friendly designs for all new and replacement culverts.	**Yes**	**Yes**	**Yes**	
Introduce skylights to the nominated 'wet' cells of long culverts.	**Yes**	**Yes**	**Desirable**	
Give appropriate consideration to the rehabilitation of habitat and the movement corridors of other aquatic fauna (e.g. turtles and eels).	**Yes**	**Yes**	**Yes**	**Yes**

Examples of aquatic habitat:

Shading of the water's edge (Qld)

Open voids in rocks below water level

Table 3.3 – Terrestrial fauna movement (example)

Requirements	Essential	Important	Secondary	Non-issue
Prepare a fauna corridor master plan for the region, which links waterway corridors with major bushland corridors.	**Yes**	**Yes**		
Provide 'dry' fauna pathways under bridges, arches, and through culverts.	**Yes**	**Yes**	**Yes**	
Identify and rehabilitate discontinuities in the terrestrial movement corridors.	**Yes**			
Develop a program for the staged rehabilitation of terrestrial movement corridors.		**Yes**	**Yes**	
Shield fauna movement corridors from the effects of street lighting.	**Yes**	**Yes**		
Introduce both low level (dry pathways) and high level (lizard runs) to culverts.	**Yes**	**Yes**		
Investigate opportunities to return native fauna to waterways and vegetated drainage channels.	**Yes**	**Yes**	**Yes**	**Yes**

Table 3.4 – Arboreal fauna movement (example)

Requirements	Essential	Important	Secondary	Non-issue
Establish appropriate canopy trees adjacent to permanent water bodies to assist birds safety accessing water.	**Yes**	**Yes**	**Yes**	
Identify and rehabilitate discontinuities in arboreal movement corridors.	**Yes**	**Unlikely to be an issue.**		
Investigate the overall advantages and disadvantages of introducing nesting boxes to riparian zones.	**Yes**			
Introduce additional nesting boxes to compensate for the loss of natural nesting hollows.	**Yes**	**Yes**		

Table 3.5 – Water movement (example)

Requirements	Essential	Important	Secondary	Non-issue
Prepare a flood study of the waterway.	**Yes**	**Yes**		
Prepare a long-term program to mitigate any unacceptable flood risks.	**Yes**	**Yes**		
Prepare a master floodway corridor plan for the waterway, which identifies the preferred channel profile for each reach of the waterway.	**Yes**			
Integrate the floodway master plan with the open space or parkland master plan.	**Yes**	**Yes**		
Prepare guidelines on the preferred planting schemes for each reach of the waterway.	**Yes**	**Yes**	**Yes**	

Table 3.6 – Riparian conservation (example)

Requirements	Essential	Important	Secondary	Non-issue
Riparian zones have a minimum width of 30 metres to minimise the risk of excess weed growth in the centre of the riparian zone (i.e. controlling edge effects).	**Yes**			
Active weed control within riparian zone.	**Yes**	**Yes**	**Yes**	
Weed control within land adjacent to the riparian zones.	**Yes**			
Riparian zones have a minimum width of 15 metres to minimise the risk of excess weed growth in the centre of the riparian zone.		**Yes**		
Riparian zones have a minimum width of 5 metres to minimise the risk of excess weed growth in the centre of the riparian zone.			**Yes**	
Markers or edge planting is use to separate mown grassland from riparian bushland.	**Yes**	**Yes**		

Defining the project's design objectives (example)

Worst bad outcome	Least bad outcome	Least good outcome	Best good outcome
Waterway channel exists within an open grassed floodway with no shade, shelter, or riparian values. Open plan on-line urban lake with no riparian values.	Full public access exists along the waterway, with only the minimum riparian corridor. Active bikeway and pathway located adjacent the riparian zone.	Regular bikeway and pedestrian crossings of the waterway. Primary bikeway and pedestrian corridor located along the adjacent roadway system.	Continuous bikeway and/or pathway located within the floodway, and outside a health riparian zone. Fish-friendly waterway crossings.

Human movement outcomes

Worst bad outcome	Least bad outcome	Least good outcome	Best good outcome
Waterway channel exists within an open grassed floodway with no riparian values. Regular barriers to fish passage along the waterway.	Non-continuous riparian zone. Fish passage along the waterway is restricted, but possible for some species. Minimal shading of the water.	Continuous, but restricted fish passage. Continuous riparian zone along one side of the waterway. Fish-friendly waterway crossings.	Continuous, unrestricted fish passage along the waterway. Healthy riparian zone on both sides of the waterway. No downstream barriers to fish passage.

Aquatic fauna outcomes

Worst bad outcome	Least bad outcome	Least good outcome	Best good outcome
The width of a near-continuous riparian zone (measured from the top of bank) is less than 3 metres.	The minimum width of a near-continuous riparian zone (each side of the water's edge) is 5 metres. Shields are placed on street lights to deflect the light away from riparian zones.	The minimum width of a continuous riparian zone (each side of the water's edge) is 15 metres for 1st order streams; 30 m for 2nd order streams; and 60 m for higher order streams.	The riparian zone is continuous along the waterway, and blends seamlessly with the adjoining bushland. A continuous corridor exists from the mountains to the sea.

Terrestrial fauna outcomes (linked to riparian width)

Worst bad outcome	Least bad outcome	Least good outcome	Best good outcome
Invasive and noxious weeds are not being controlled. Biodiversity of native plants is in decline. A single plant species is forming a mono-culture.	Aggressive weeds are replaced with non-aggressive weeds. Low-invasive grasses replace highly-invasive and noxious weeds.	Weeds are replaced with native plants. Some non-endemic native plants are being used to control high-risk erosion sites.	The risk of weed invasion is removed. Weeds are controlled on adjoining land. Riparian zones are dominated by locally endemic native plants.

Riparian values

3.2 Project planning

Project Planning

Park master plan

Park master plans

- Park master plans focus on the long-term goals of a park.
- These plans aim to identify the common outcomes so that maintenance work, community projects, and emergency flood repair works, are all aligned with these common outcomes.
- These plans allow local parks to align with the aims of a wider community, rather than just the aims of vocal personalities.

Wildlife corridor map

Wildlife corridor maps

- Wildlife corridor maps identify essential terrestrial and aquatic movement corridors that link wildlife habitat and breeding areas.
- These maps are generally influenced by the development of *Waterway Corridor Maps*, which also influences the preparation of *Floodplain Mapping* and *Stormwater Management Plans*.
- In urban areas, waterway corridors often act as important wildlife corridors.

Catchment management plan

Catchment management plans

Catchment Management Plans may address a wider range of issues, including:

- land use needs, often focused on open space requirements
- community needs, such as community education
- flora and fauna needs, including catchment and inter-catchment human and fauna movement corridors
- threats to sustainable land use and/or conservation needs, such as weed control.

Planning steps

Project meeting

Project map

16 steps to planning and design

Step 1 – Ranking of proposed sites

- Use a ranking system to determine the projects of greatest need or benefit.

Step 2 – Ownership

- Identify the ownership of the land through which the waterway passes.

Step 3 – Interested parties

- Identify the organisations that would like to have input into the project.

Step 4 – Data collection

- Collect data, but don't waste money collecting data that you don't really need.

Step 5 – Identify the issues

- Identify the issues and site restrictions that may apply to the project.

Step 6 – Type of channel works

- Determine the degree and extent of works.

Step 7 – Setting priorities

- Set priorities: human benefit, aquatic values, terrestrial values, riparian values.

Step 8 – Assess material options

- Identify the preferred materials: quarry rock, rounded rock, vegetation source.

Step 9 – Assess equipment options

- Assess equipment availability and site access.

Step 10 – Identify treatment options

- Determine the preferred option for the treatment of any channel erosion.

Step 11 – Impacts on fauna and flora

- Think about the needs of the creek.

Step 12 – Identify human access

- Assess the desired human interaction with, and access to, the waterway.

Step 13 – Identify the best treatment option

- Prepare a detailed design of the preferred treatment option.

Step 14 – Cost estimation

- Prepare a detailed cost estimation of the preferred treatment option.

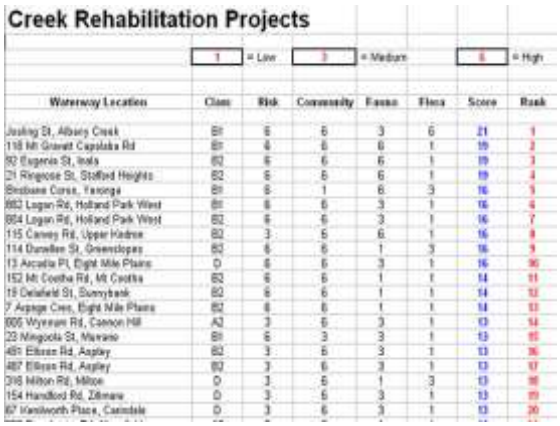
Step 15 – Recontact interested parties

- Communicate with the community what you are planning to do.

Step 16 – Obtain approvals and permits

- Obtain all necessary approvals for your proposed works.

Overview of planning steps 1 to 4



Creek Rehabilitation Projects

1 = Low 3 = Medium 5 = High

Waterway Location	Class	Risk	Community	Fauna	Flora	Score	Rank
Jasling St, Albany Creek	B1	6	6	3	6	21	1
118 Mt Gravatt Capalaba Rd	B1	6	6	6	1	19	2
92 Eugenia St, Inala	B2	6	6	6	1	19	3
21 Ringrose St, Stafford Heights	B2	6	6	6	1	19	4
Brisbane Corso, Yeronga	B1	6	1	6	3	16	5
882 Logan Rd, Holland Park West	B1	6	6	3	1	16	6
884 Logan Rd, Holland Park West	B2	6	6	3	1	16	7
115 Carvey Rd, Upper Kedron	B2	3	6	6	1	16	8
114 Dunellen St, Greenslopes	B2	6	6	1	3	16	9
13 Arcadia Pl, Eight Mile Plains	D	6	6	3	1	16	10
152 Mt Cootha Rd, Mt Cootha	B2	6	6	1	1	14	11
19 Delafield St, Sunnybank	B2	6	6	1	1	14	12
7 Aspage Cres, Eight Mile Plains	B2	6	6	1	1	14	13
605 Wynnum Rd, Cannon Hill	A2	3	6	3	1	13	14
23 Ningoola St, Murrarie	B1	6	3	3	1	13	15
481 Ellison Rd, Aspley	B2	3	6	3	1	13	16
487 Ellison Rd, Aspley	B2	3	6	3	1	13	17
206 Milton Rd, Milton	D	3	6	1	3	13	18
154 Handford Rd, Zillmere	D	3	6	3	1	13	19
67 Wentworth Place, Carindale	D	3	6	3	1	13	20

Ranking creek projects

Step 1 – Ranking of proposed sites

- Government authorities may choose to use a ranking system to identify which projects deserve funding.
- An example ranking system is provided over the following pages.

Fenced property (SA)

Step 2 – Ownership

- The second step to planning a creek project should be to determine who owns the land over which the creek flows.
- Be very careful when reviewing electronic mapping services (e.g. Google maps) because the location of property boundaries may not always be correct.
- In some cases (but rare), the land boundary is defined by the centre of the creek, which means the property boundary moves if the channel moves.

On-site community meeting (Qld)

Step 3 – Interested parties

- The third step should be to identify and contact all possible interested parties.
- Interested parties could include:
  - neighbours
  - traditional land owners
  - local government
  - State or Territory government.
- However, don't be surprised if you are the only interested party willing to inject time and money into the project.

Site inspection (Qld)

Step 4 – Data collection

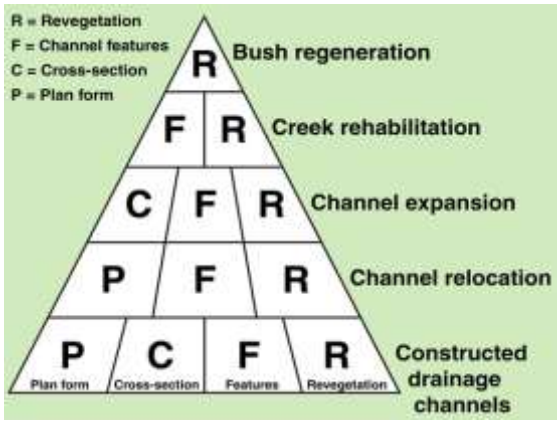
- Some data can be collected electronically from government files, but most of the data will need to be collected from the site.
- Data collection could include:
  - catchment hydrology
  - soil types
  - fauna and flora surveys (contact your State Fisheries)
  - location for site access
  - availability of materials, such as rock.

Overview of planning steps 5 to 8

Catchment plan

Step 5 – Identify the issues

- Try to think of at least one issue from each of the following categories:
  - water movement (drainage and flooding)
  - human movement
  - aquatic fauna movement
  - terrestrial fauna movement
- It is important to refer back to any current planning schemes, such as park master plans, and wildlife corridor maps.



Application of NCD

Step 6 – Type of channel works

- Identify the extent of the works, and the type of work activity.
- The mathematics of Natural Channel Design is most commonly used in the design of vegetated drainage channels.
- However, the principles of Natural Channel Design can be applied to several different types of instream work activities.

Bed and bank scour (Qld)

Step 7 – Setting priorities

- If the site is experiencing both bed and bank erosion, then as a general rule, the first priority should be to stabilise the channel bed.
- However, it is possible to design bank stabilisation measures that can work with unstable bed conditions.
- If there are several erosion problems along a given reach, then a scoring system can be used to rank the relative importance of each site.

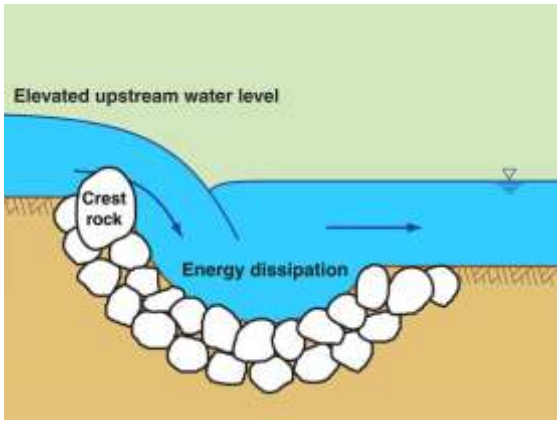
Local rock quarry (Qld)

Step 8 – Assess material options

- In most cases, the treatment options will not be limited by the availability of materials.
- However, when dealing with creek erosion on farm land it may be advantageous to utilise only those materials that are readily available to the landowner.
- In some arid areas there may be a limited supply of suitable rock.
- Similarly, some mechanical equipment, or plant species, may not be readily available in certain areas.

Overview of planning steps 9 to 12

Access ramp cut down a creek bank (Qld)



Rock-lined plunge pool

Questionable environmental outcome

Access to bush regeneration site (Qld)

Step 9 – Assess equipment options

- The choice of treatment options may depend on:
  - what equipment is available, and
  - whether suitable access exists at the site for large or heavy machinery.
- On a farm it may be preferable to utilise only general farming equipment.
- Long-reach excavators, or telescopic equipment, may be needed to reach over, or through, riparian vegetation.

Step 10 – Identify treatment options

- In some cases it can be useful to develop at least three options for the treatment of the creek erosion:
  - a low cost option that could be built with local equipment (such options usually have a higher risk of failure if unfavourable weather conditions occur)
  - a medium cost and medium-risk option
  - a high cost option that has enhanced fauna and flora features, and/or increased long-term channel stability.

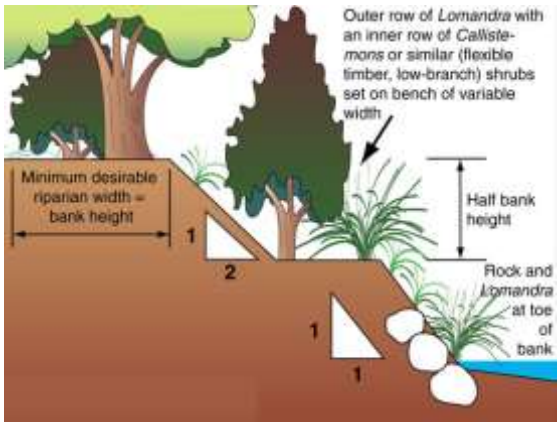
Step 11 – Impacts on fauna and flora

- Each treatment option should be assessed with respect to its potential environmental impacts, including:
  - impacts on fauna habitats
  - impacts on fauna movement corridors
  - potential damage to, or removal of, established habitat trees
  - the risk of causing excessive instream sedimentation during construction
  - impacts on the waterway aesthetics.

Step 12 – Identify human access

- Identify:
  - worker access
  - public access (if required)
  - public bypass (if required)
  - equipment access
  - off-street parking (if required).

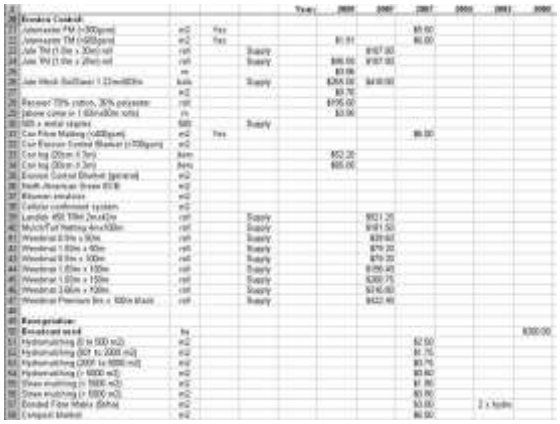
Overview of planning steps 13 to 16



Bank stabilisation proposal

Step 13 – Identify the best treatment option

- In some cases it will be the client or landowner that chooses their preferred treatment option.
- However, in most cases there will be a need to rank the options, then provide the client with the chosen treatment option.
- Critical issues can include:
  - cost (initial estimate)
  - risk of short-term failure, usually as a result of a subsequent flood
  - what works best for the waterway.



Unit cost spreadsheet (example only)

Step 14 – Cost estimation

- During my career I have found that most people believe that engineers should be able to calculate the cost of any project to the nearest dollar—that is not so!
- Cost estimation is a very specialised task, and rarely is it more accurate that +/- 20%.
- The cost of supplying materials and constructing earthworks can also vary significantly between urban and rural areas.

On-site meeting of interested parties

Step 15 – Recontact interested parties

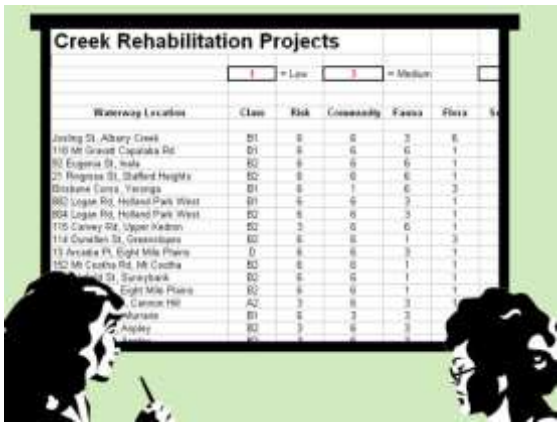
- Finally, all interested parties should again be consulted—this time notifying them of the proposed works.
- On rural properties it is likely that the only interested parties are those that sit around your kitchen table on a daily basis.

Queensland Water Act, 2000

Step 16 – Obtain approvals and permits

- Government approvals (plural) may be required in order to:
  - conduct any works within a creek
  - disturb native vegetation.
- It is noted that freshwater creeks and saltwater estuaries may be managed by different government departments.
- The local Fisheries office may be required to issue a permit for any instream disturbance, or for the installation of temporary waterway barriers during construction.

Example ranking system (Step 1)



Ranking rehabilitation creek projects

Ranking the relative importance of potential projects

- Ranking systems need to be developed for the specific needs of the local community.
- Issues that appear within the ranking system will vary from region to region depending on local issues.
- Below is an example scoring system used in the ranking of community-based creek rehabilitation projects that were seeking local government funding.

Table 3.7 – Example waterway project ranking system

Waterway attribute	Rating	Points	Score
Aesthetics	Low improvement Medium improvement High improvement	0 2 4	
Asset protection	No threat to assets Low improvement Medium improvement High improvement	0 3 6 10	
Construction cost	Low Medium High	0 3 6	
Channel stability	Low risk of bank failure Medium High risk of bank failure	0 3 6	
Community interest	Low Medium High	0 2 4	
Ecology	Low improvement Medium improvement High improvement	0 4 8	
Maintenance costs	Low Medium High	0 3 6	
Public safety	Low improvement Medium improvement High improvement	0 8 16	
Public usage	Low Medium High (highly visible)	0 2 4	
Riparian vegetation	Low improvement Medium improvement High improvement	0 2 4	
Water quality	Low improvement Medium improvement High improvement	0 2 4	
Use of natural materials	Low (hard engineering) Medium High (all natural)	0 2 4	
		Total score =	

Example ranking system – Background notes

Aesthetics

- Aesthetics can be an important attribute for the public, even though it may not be important to the ecology that lives in and around the watercourse.
- Waterway rehabilitation projects that can be seen and enjoyed by many people provide a greater value to the city than works that will be viewed by just a few.
- However, creeks are not supposed to look like gardens or parks, and not all creeks should look like babbling brooks.

Construction cost

- Councils should always give priority to those projects that provide the greatest value for money, or benefit/cost ratio.
- Factors to consider include:
  - the cost per metre length of channel
  - the total cost of the project
  - the likely escalation in costs if the project were to be delayed another year or two (i.e. the 'cost' of not doing the work this year).

Channel stability

- In this context, the term 'channel stability' refers to:
  - the overall stability of the channel within the floodplain with respect to active channel meandering
  - the likelihood of the long-term success of the proposed erosion control measures.
- Short-term success is often governed by weather conditions (i.e. the timing of the next flood), but long-term success is usually governed by how well our designs integrate with the long-term behaviour and characteristics of the waterway.

Community interest

- Waterway rehabilitation is not always done purely for the benefit of the public.
- In some cases it is performed to prevent or minimise environmental harm.
- Community support and community participation is a very important aspect of any proposed council activity.
- Waterway rehabilitation projects can also have an educational component.
- Articles in local newspapers can help to make the wider community aware that they live within a waterway catchment, and that their council recognises the value of healthy waterways.

Public safety

- Factors to consider include:
  - is the area accessible to the public
  - does the existence of a unstable bank increase the risk of a person falling into dangerous waters
  - is the safety risk new to the area
  - is public access new to the area
  - will children, especially non-supervised children, visit the area.

Public usage

- Increased public access to waterways can be a key objective of a council; however, the public does not need direct access to every part of the waterway.
- Factors to consider include:
  - should a given area of the waterway be protected from the public
  - should public access be encouraged
  - should the creek works be used as a means of improving public access.

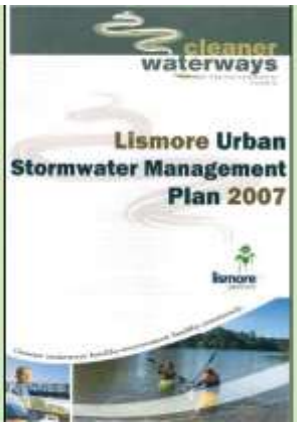
Riparian vegetation

- Factors to consider include:
  - does the project minimise the loss of existing habitat trees
  - is the revegetation phase adequately funded
  - does the proposal incorporate weed control measures
  - does the project enhance overbank riparian values
  - does the project incorporate lower, middle and upper storey planting.

Water quality

- Factors to consider include:
  - will the works improve ongoing water quality
  - will the project incorporate water quality improvement systems
  - will the works ultimately improve shading of the water's edge
  - will the works reduce ongoing channel erosion
  - will the works stabilise a dispersive soil.

Community consultation (Step 3, also refer to Chapter 4)



Stormwater management plan (NSW)

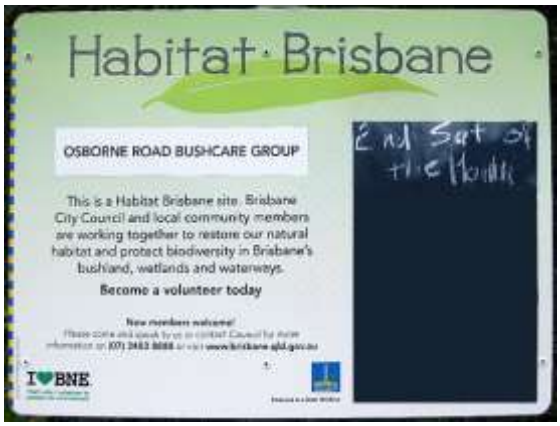
Introduction

- The local community is obviously one of the most important of the 'interested parties' because they have a direct connecting with waterway and the politicians that govern the finances.
- When conducting waterway projects, the local community can often express very different objectives from that of the wider community.
- Achieving a balance between local and regional expectations is a task for managers and politicians.

On-site community meeting (Qld)

Community meetings

- Community consultation can consist of:
  - public notices
  - public meetings
  - the involvement of community groups.
- Community meetings can be held at the start of a project to gather community input, and at the launch of a project to explain the design features and expected long-term outcomes of the project.



Local Bushcare group (Qld)

Community involvement

- In the author's opinion, community involvement is best achieved through the use of government liaison officers (State or local government), possibly:
  - National Parks officers
  - Landcare officers
  - Council Bushcare or parks officers.
- Typical activities are usually centred around ongoing maintenance, such as weed removal, track maintenance, and minor erosion control.

'Weedy phase' of plant growth (Qld)

Community expectations

- It is very important that the community consultation process adequately informs the community about the aims of a project, and the changes in vegetation that they should expect to see over the following years.
- All vegetated systems will pass through a 'weedy phase' while they progress to full maturity, and the public should not be uninformed about this outcome.
- Waterway projects are not 'parks', nor are they maintained like city parks.

Data collection (Step 4)

The data collection phase is very important, but if poorly managed, it can become an enormous waste of money.

Try to remember how things were back in your school days; when you were given an assignment or an examination question, you would have been given all the data that you needed in order to complete the task. But in the real world things are not so simple. When dealing with a creek erosion problem it will be up to you to decide what data is needed in order to assess the problem, and design any treatment.

If you ask the landowner what data they want you to collect, their first response is likely to be: 'the more the better'. But data collection costs time and money, and your client may not be willing to pay the full cost of data collection, or be willing to wait the extra time needed in order to collect all the available data.

The data collection phase of a project should focus on collecting only the data that is considered necessary to complete the design, and to make sure the design is compatible with the dynamics and characteristics of the waterway.

In creek engineering, the three most important design 'tools' are your eyes, your training, and your experience. In many cases there will be very little need to collect vast amounts of numerical data. Your eyes should be able to collect most of the information you will need simply by visiting the site.

Catchment hydrology:

Do you really need to set-up a complex hydrologic model of the drainage catchment?

Do you really need to know the 10 year, 50 year, or the 100 year flow rate for the waterway, or do you just need to know an estimate of the bankfull flow rate?

Maybe you don't need to know any flow rates. Maybe you just need an estimate of the average flow velocity in the waterway during those conditions that are likely to cause further erosion.

Channel hydraulics:

Do you need a complex hydraulic model of the channel in order to estimate the flow velocity, or can you estimate the flow velocity by using a simple Manning's calculation based on an approximation of the bankfull discharge?

In many cases you can estimate the bankfull discharge (m^3/s) by multiplying the bankfull flow area (m^2) by your best guess of the flow velocity (m/s). You can then use Manning's equation to check if your first guess of the flow velocity was close enough. If your first guess isn't good enough, then repeat the process until you are satisfied with the result.

River morphology:

Do you really need to calculate the 'stream power', or the 'shear stress'? If you are dealing with a dynamic river system, and you don't know the answers to these questions, then you may need the assistance of an experienced river morphologist.

Extensive data collection:

Extensive data collection is likely to be required in the following circumstances:

- if it is suspected that the waterway is highly unstable, and that any bed or bank stabilisation measures will likely fail during the next flood event
- designing the rehabilitation of an instream extractive industry site
- designing a major road or railway crossing of a highly mobile waterway
- ranking the importance of several proposed waterway rehabilitation projects.

Identify the needs of the community (Step 5)

Pathway located along a floodway (Qld)

Introduction

- Urban waterways should not be treated as simply an extension of somebody's backyard.
- An increase in human activity along a waterway almost always comes at a cost to the local fauna.
- An urban waterway should not be viewed by the public as an active recreation area, as a garden park, or as an excuse to have a 'water view'—its a 'waterway', and that is its function within an urban setting.

Low-level footbridge (SA)

Public access

- The public should have access to urban waterways, just as they have access to urban bushland.
- But, this access must be managed in a way that provides an appropriate balance between the competing objectives.
- In the author's opinion, access should be concentrated along open floodways, with appropriately located waterway crossings (stepping stones and footbridges, but not causeways).

High-level footbridge (Qld)

Waterway crossings

- In the author's opinion, the preferred types of waterway crossings, in order of preference, are:
  - pathways integrated into road crossings
  - low-level footbridge without handrails
  - high-level footbridge with handrails
  - culvert crossings.
- It is noted that all of these crossings can adversely affect fish passage.

failed boardwalk crossing a creek

Boardwalks

- Boardwalks consist of low-level, elevated pathways that usually pass over wet ground that is otherwise unsuitable for the construction of a traditional footpath.
- As a general rule, boardwalks should **only** be located within regions of low velocities, such as wetlands.
- If located in areas subjected to high-velocity flood flows, the flow turbulence generated around the piers can cause excessive soil erosion, and cause a new channel to form under the boardwalk.

Typical erosion control materials (Step 8)

Jute or coir blanket (organic)

Jute or coir mesh (organic)

Filter cloth (100% synthetic)

Erosion control mat (composite material)

Gravel (which includes fines)

Aggregate (near-uniform in size)

Gabions (during construction)

Rockfall netting (anchored to rock)

Equipment options (Step 9)

Mini loader

Skid steer (skid-steer loader, *Bobcat*)

Backhoe loader

Rock grab

Excavator

Longreach excavator

Feller buncher

Telehandler (telescopic handler)

Revegetation equipment (Step 9)

Seeder

Scarifier

Straw mulcher

Straw mulcher with bitumen spray

Hydromulcher (hydromulch)

Hydromulcher (Bonded Fibre Matrix)

Deep ripper (for ripping hard soil)

Skid-steer topsoil leveller/spreader

Assessing impacts on riparian vegetation (Step 11)

Restoration of a site access pathway

Introduction

- Erosion control projects can either:
  - enhance riparian areas as part of the project's overall aims, or
  - result in a net loss of riparian values as a result of providing access to the work site, or the battering of creek banks.
- Obviously the preferred outcome is an enhancement of riparian values, or at least the protection of existing values.
- Such outcomes require appropriate planning and funding.

Open-void rock work can attract weeds

Impacts on weed control

- The process of repairing creek erosion can provide opportunities for weed control in the local area.
- Ideally, new vegetation will be introduced as part of the channel stabilisation works.
- Significantly fewer weeds are generated if the area is actively planted, instead of relying on natural regeneration.
- Ideally, rock-stabilised banks should be planted immediately after rock placement.

Retention of a mature habitat tree (Qld)

Protection of endangered species

- Endangered plant species and critical habitat trees should be identified and adequately protected from damage.
- If significant vegetation clearing is required in order to provide access for earthmoving equipment, then adjacent vegetation should be protected wherever possible.
- If the creek erosion is endangering the stability of mature trees, then the advice of an arborist may be required.

Multi-layer planting (Qld)

Blending lower, middle and upper storey vegetation

- Most people readily accept that there is an important link between animal species and plant communities.
- It is also noted that there are many links between the different types of plant communities, from ground covers to middle storey to upper storey plants.
- Creek rehabilitation should not focus solely on the planting of trees.

Assessing impacts on aquatic fauna (Step 11)

Diverse aquatic habitat (Qld)

Loss of aquatic habitats

- Like all living creatures, aquatic life needs a place to live, food to eat, a place to shelter from predators and extreme weather conditions, and the ability to interact for the purpose of reproduction.
- The control of bed scour can sometimes result in a change in water levels and the size of permanent pools, which can directly impact upon the aquatic life that depends on these pools.

Open voids between submerged rocks

Impacts of food supply

- It can be difficult to recognise potential food sources for aquatic life.
- Critical factors are:
  - aquatic plants
  - total surface area of submerged surfaces, including plants and rocks
  - species diversity.
- There are a lot of little things that can be done in erosion control that can make a big difference to aquatic habitats.

Shading of the water's edge (Qld)

Impacts on shelter and water temperature

- Plants placed along the water's edge should partially cover and shade the water in order to:
  - control the water temperature
  - hide fish from terrestrial predators.
- The voids between submerged rocks are generally left open in order to:
  - allow fish to shelter during flood events
  - protect small fish from larger fish.

Inadequate bank vegetation

Impacts on fish passage

- Adverse impacts on fish passage can result from:
  - the creation of steps in the channel bed (i.e. mini waterfalls)
  - non-fish-friendly grade control structures (e.g. steep rock chutes)
  - changes in the vegetation and hydraulic roughness of channel banks that: (i) reduces the ability of fish to shelter from high-velocity flows, and (ii) reduces the ability of fish to swim upstream during floods.

Assessing impacts on terrestrial fauna (Step 11)

Habitat diversity (Qld)

Impacts on terrestrial habitats

- For aquatic life, the three most important factors affecting their habitat are: food supply, water quality, and good company.
- For terrestrial life, the three most important factors are likely to be:
  - habitat diversity
  - plant diversity
  - habitat continuity (i.e. a continuous migration path between areas of bushland).

Natural food chain (Florida, USA)

Impacts on food supply

- For terrestrial wildlife, food supply is closely linked to the diversity of native plant species.
- Plants not only provide a source of food for some animals, they also attract a wide range of wildlife.
- The use of just rock and grasses to stabilise a creek bank can be a cheap and easy option, but such simplistic solutions can severely deplete the value of terrestrial habitats.

Terrestrial habitat (Qld)

Impacts on shelter and roosting areas

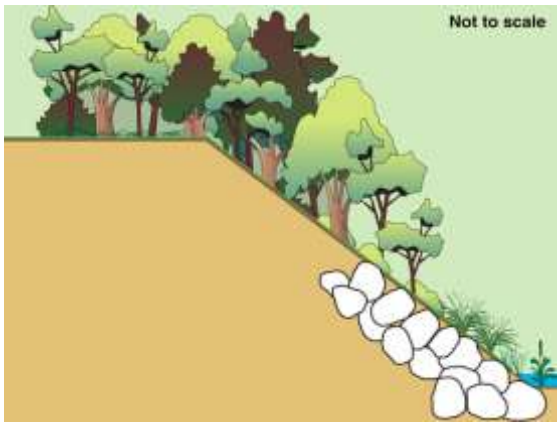
- Terrestrial wildlife typically needs access to:
  - sun and shade
  - a place to be seen, and a place to hide
  - places of low and high elevation.
- The aim is not to build a 'zoo', or an extension of someone's backyard.
- The aim is to appropriately integrate natural features into the site's rehabilitation measures.

Terrestrial movement corridor (Qld)

Impacts on movement corridors

- Ideally, the bushland that surrounds an urban waterway should be linked to adjacent bushland reserves using suitable movement corridors.
- Corridor mapping (e.g. *Mountain to Mangroves*) can help governments and communities recognise and protect essential terrestrial movement corridors.

Selecting the preferred treatment option (Step 13)



Bank stabilisation design sketch

Introduction

- Ideally, more than one treatment option should be investigated for each project site.
- This means that eventually a preferred treatment option will need to be selected.
- Typically this selection process will occur before detailed designs are prepared.

Community meeting (Qld)

Assessing impacts on the community

- The task of selecting the preferred option involves considering the relative importance of the:
  - needs of the community
  - wants of the community
  - needs of the waterway (a waterway cannot 'want' an outcome).
- In order to be effective, waterway managers need to be good communicators, and good people managers.

Well-maintained parkland (Qld)

The importance of aesthetics

- Most healthy creeks look 'messy', while most parks look well-maintained.
- A messy creek positioned in the middle of bushland can look natural and pleasing to the eye.
- A messy creek passing through a well-maintained council park can look neglected and unsightly.
- Waterway managers should avoid turning a creek into a 'decorative water feature' just to keep adjacent neighbours happy.


Creek Rehabilitation Projects

1 = Low 3 = Medium 5 = High

Waterway Location	Class	Risk	Community	Fauna	Flora	Score	Rank
Jacaranda St, Albany Creek	B1	6	6	3	6	21	1
118 Mt Gravatt Capalaba Rd	B1	6	6	6	1	19	2
92 Eugenia St, Inala	B2	6	6	6	1	19	3
21 Ringrose St, Stafford Heights	B2	6	6	6	1	19	4
Brisbane Corso, Fassifern	B1	6	1	6	3	16	5
882 Logan Rd, Holland Park West	B1	6	6	3	1	16	6
884 Logan Rd, Holland Park West	B2	6	6	3	1	16	7
115 Carney Rd, Upper Kedron	B2	3	6	6	1	16	8
114 Dunellen St, Greenslopes	B2	6	6	1	3	16	9
13 Arcadia Pl, Eight Mile Plains	D	6	6	3	1	16	10
152 Mt Cootha Rd, Mt Cootha	B3	6	6	1	1	14	11
19 Delafield St, Sunnybank	B2	6	6	1	1	14	12
7 Agape Cres, Eight Mile Plains	B2	6	6	1	1	14	13
605 Wyreema Rd, Cannon Hill	A2	3	6	3	1	13	14
23 Mingoola St, Mawarra	B1	6	3	3	1	13	15
481 Ellison Rd, Aspley	B2	3	6	3	1	13	16
487 Ellison Rd, Aspley	B2	3	6	3	1	13	17
316 Milton Rd, Milton	D	3	6	1	3	13	18
154 Handford Rd, Zillmere	D	3	6	3	1	13	19
67 Kenilworth Place, Carindale	D	3	6	3	1	13	20

Example of project ranking

Ranking systems

- Ranking systems can be developed for a variety of purposes, including:
  - ranking the preferred treatment option at a given location
  - ranking the importance of various sites along a waterway
  - ranking the priority of repairs after a flood event
  - ranking community-based rehabilitation projects prior to the allocation of government funding.

Assessing likely maintenance costs (Step 13)

Channel maintenance (Qld)

Introduction

- From a local government perspective, one of the most important design considerations is to reduce the need for ongoing maintenance of the waterway.
- High maintenance costs are a 'drain' on government funds, which ultimately is a drain on the finances of all rate payers and tax payers.

Weed control of rock mattresses (Qld)

Weed control

- The failure to appropriately revegetate a site will enable weeds to invade the area.
- An increase in weeds often results in an increase in public complaints about the waterway, which can lead to ongoing weed control programs, and ongoing maintenance costs.

Selective tree removal (Qld)

Controlling vegetation in flood control areas

- Creek rehabilitation plans often specify a recommended tree spacing, which is based on an allowable channel roughness, which is based on flood modelling.
- However, trees don't know when to stop growing, and when to stop seeding.
- Intelligent waterway design can help to avoid the ongoing cost of removing plants—the key is knowing how to establish the right plant communities.

Local community group (Qld)

A watch and act approach

- Some councils, such as Brisbane City Council, operate very successful community-based Bushcare groups that carry out voluntary maintenance of creeks, wetlands and bushland reserves.
- In effect, the council manages the community groups, that in-turn manage their own local waterways and bushland.
- Community groups are more likely to recognise and act upon problems before the cost of repairs becomes excessive.

Cost estimation (Step 14)

Paying the bills

Introduction

- Estimating the cost of a project is a difficult task that usually requires experience.
- Project costs can include:
  - investigation and design phases
  - the provision of site access
  - supply of materials
  - equipment (and operator) hire
  - temporary erosion and sediment control during the construction phase
  - site revegetation, including watering.

Site investigation (NSW)

Cost of investigation, design and construction management

- Project costs don't start at Step 14, they start at Step 1, from the first moment that someone is being paid to investigate the project.
- Reducing or removing the investigation phase can reduce costs, but it can put the whole project at risk.
- If the project team lacks experience, then consider employing a project manager to run the project.

Construction materials (Qld)

Cost of materials and equipment

- The cost of delivering rock to a project can vary **significantly** from city to rural areas, and from region to region.
- A significant part of the supply cost can be the cost of delivery.
- Some equipment can only be hired on a daily basis, and the hire costs may not include the supply of an operator.
- Special equipment may be required just to move materials through the riparian zone without causing damage to trees.

Site revegetation (Qld)

Cost of revegetation

- Project managers can be tempted to save costs at the end of a project by reducing the proposed site revegetation.
- It is obviously much cheaper to simply dump loose rock onto a creek bank than it is to integrate the rock into the final site revegetation.
- However, such cost savings can ultimately harm the creek.
- Project funding should also include the cost of short-term watering, and subsequent site inspections and weeding.

Government approval of proposed works (Step 16)

Fisheries Act (Qld)

Introduction

- Lesson 1: Every State and Territory has its own approval and permit systems.
- Lesson 2: State government agencies are themselves required to meet all State government policies and permit systems.
- Lesson 3: Local government approvals do not extinguish the need to obtain State government approvals.
- Lesson 4: An approval from one State government department does not extinguish the need to obtain all necessary State government approvals.

Works within the riparian zone

Approvals and permits required for works conducted within the riparian zone

- Each State and Territory has a different definition of what constitutes a 'waterway' and a 'watercourse'.
- Most legislation recognises that the riparian zone is a component of a waterway.
- Changes to riparian vegetation may require Fisheries approval and Natural Resources (DPI, Waterways) approval.

Fisheries permit (Qld)

Approvals and permits for works conducted within the waterway channel

- Works conducted within a waterway may require local government approval if such works are recognised in the councils Planning Scheme as a controlled activity.
- Any works conducted within a recognised fish habitat, even if temporary, will usually require approval from Fisheries.
- Any works that 'pen' water, or alter the flow conditions will usually require approval from Natural Resources (DPI, Waterways, or similar).

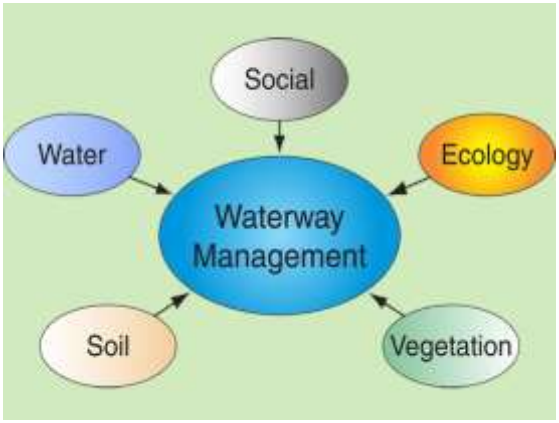
Dredging of marine waters (Vic)

Approvals and permits for works conducted within marine waters

- Most States and Territories have separate legislation for freshwater habitats and marine waters.
- Work activities conducted within marine waters may require:
  - Fisheries approval
  - Natural Resources (DPI, Waterways or similar) approval
  - Department of Environment (or similar) approval.

4. Managing Public Expectations

Introduction



Holistic design approach

Introduction

- Throughout this document, an emphasis has been placed on the consideration of multiple objectives supported by multiple participants.
- Natural Channel Design does not just focus on 'drainage', or the 'environment', but it is a holistic design approach that considers:
  - water and sediment movement
  - fauna and flora movement
  - human movement.

Pre-works public meeting (Qld)

Communicating the aims of a project with the local community

- Difficulties can arise if parts of the community believe the aim of the project is to reduce flooding, while others believe the works are focused on stream rehabilitation.
- These issues are best addressed through effective public consultation.
- Ideally, the project should start with public consultation, and finish with a public information session.

Public meeting (Qld)

Public consultation

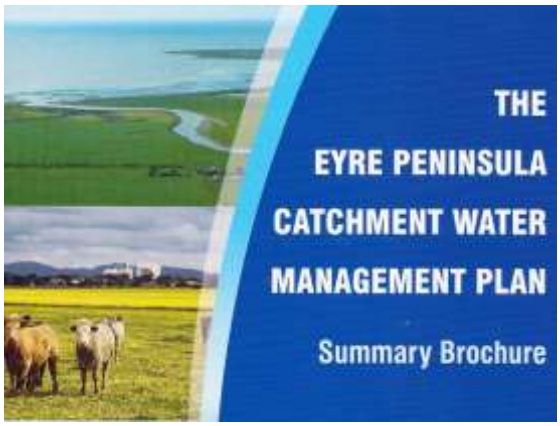
- Public consultation is a two-way communication process.
- However, only a fool walks into a public meeting with an empty mind—it may sound romantic to enter a meeting with a blank-sheet approach, but it shouldn't partner with an empty mind!
- Just as a barrister shouldn't ask a question that they don't already know the answer, a design team shouldn't ask for public input without being prepared to address the public's questions.

Educational field day (Qld)

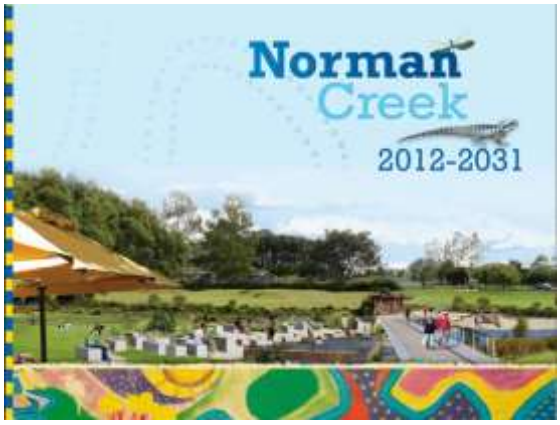
Public information

- Public information sessions largely consist of an initial one-way communication, followed by questions and answers.
- It is critical for the public to be informed about the dynamic properties of waterways, and what changes they should expect to see over time.
- Waterways are not like 'garden parks' or 'community centres' where the visual appearance of these centres do not change over time—a rehabilitated waterway can change significantly as the vegetation matures.

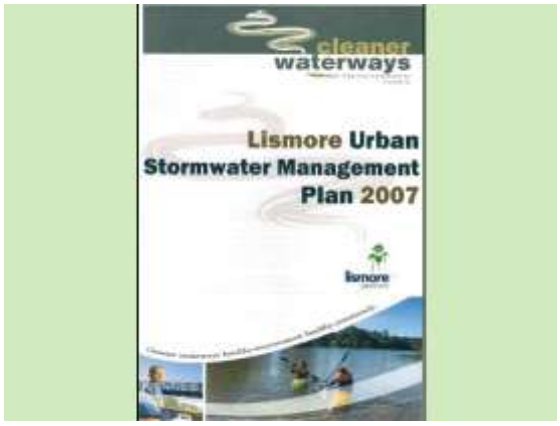
The value of policies and planning



A Catchment Management Plan (SA)



Creek master plan (Qld)



Stormwater management plan (NSW)

Waterway management program (Qld)

The value of policies and planning

- In our cities, police are not seen as law makers, but as the enforcers of the laws that have been written by other people.
- This means that complaints about these laws are primarily directed towards politicians, rather than the police.
- Similarly, without a waterway management plan, public complains are often directed towards council officers; however, the development of a plan can cause these complaints to be directed towards the 'plan'.
- If a design team is solely responsible for the outcomes of a project, then that team will rightly receive all the community feedback.
- However, if the outcomes were based on government policies, or a waterway master plan, then the feedback will be directed towards these policies and plans.
- Developing master park plans and waterway policies does not reduce the number of complains, but it can allow a better management of these complains.

Waterway policies (refer to Chapter 5)

- The development of a regional waterway policy increases the likelihood of common outcomes in:
  - private waterway developments
  - public waterway projects
  - waterway maintenance activities.
- It is important for waterway policies to be closely linked to:
  - catchment management plans
  - stormwater management plans
  - building site erosion control.

Waterway management plans

- It has been said that: *'The city does not have a waterway problem; rather, it is the waterway that has a city problem'.*
- The development of waterway management plans allows common outcomes for:
  - creek rehabilitation projects
  - emergency post-flood bank repairs
  - reduce cost and time delays associated with new projects
  - the design of new waterway crossings.

Informing the public of the ‘weedy phase’

Sandy Creek, Enoggera, Brisbane in 1997

The reality of weed infestation

- By definition; weeds are plants that are unnatural to a given region.
- The arrival of weeds is nature’s response to a rapid change in site conditions, AND, the eventual replacement of those weeds with native vegetation is the ideal way of achieving long-term stability and canopy growth.
- All creek rehabilitation projects will pass through a ‘weedy phase’, and with appropriate care, the worst of this phase should last less than 5 to 10 years.

Site condition in 1998

Site condition in 2007

Site condition in 2014

Informing the public of future flood damage

Damage to infrastructure (Qld)

Designing to 'fail'

- In most fields of engineering there is the fear that a built structure will either bend or break.
- However, in creek engineering we know that our waterway designs will both bend and break during flood events.
- Unlike a garden park, creeks operate within a damage–repair cycle.
- The aim is not to design a waterway that will never change, but a waterway that will achieve a desirable outcome.

Flood damage to new plants (Qld)

Loss of plants submerged by floodwater

Natural sediment movement (Qld)

The damage–repair cycle

- This damage–repair cycle applies to all aspects of a typical waterway:
  - sediment accumulates for several years and then moves on
  - vegetation grows, then flood events either bends, breaks, or removes excessive plant growth
  - rocks are moved in order to optimise their energy dissipation benefits.

Lesson 1: Always expect changes to occur!

Flood-induced vegetation damage (Qld)

Movement of rocks (Qld)

Informing the public of the importance of flood events

Flood-control dam (Qld)

Introduction

- Nothing that is said here disputes the devastating effects that floods can have on a community and the personal lives of many people.
- However, it is important to remember that the occurrence of regular flood events is important for the health of many of our waterways, especially rivers.
- It is for this reason that the health of a river often declines once a dam is constructed.

River dredging (Qld)

Floods help to mobilise sediment deposits

- All waterways experience the deposition of sediments from time to time.
- In a healthy waterway, the natural deposition of sediments is balanced by the mobilisation of those sediments during flood events.
- When a dam is placed on a river, an excessive build-up of sediment can occur within parts of the river, which may require dredging to occur along the river.

Organic-rich flood sediment (Qld)

Floods help to prevent anaerobic conditions developing along a riverbed

- People that have experienced a flood often comment on the foul smells of floodwater.
- This smell is unlikely to be due to sewage inflows, but rather to the re-suspension of anaerobically-digested organic matter that has been resting on the river's bed for many years.
- This odour problem can be made worse if a dam has reduced the frequency of flood events.

Flood-induced damage to plants (Qld)

Floods help to remove plants that are growing in the 'wrong' location

- A common mistake made by vegetation surveys is the reporting that certain tree species can be planted close to the river edge simply because that species has been observed growing in such a location.
- It is important to remember that plants can establish in almost any location, and only time will tell if that was the 'right' location for that plant.
- Flood events help to remove plants that are growing in the 'wrong' location.

Community-based Landcare/Bushcare groups (Community involvement)

On-site working bee notice board (Qld)

Introduction

- Within the city of Brisbane, there is at least one council-supported community group associated with the rehabilitation of virtually every creek and wetland.
- These groups are coordinated and supported by the Habitat Brisbane section of the Council.
- Each group meets on a regular basis to continue the work of weed removal and the treatment of minor erosion issues.

Community training (Qld)

Guidance by experts

- The community groups are given training in:
  - plant identification
  - weed identification
  - weed removal
  - creek rehabilitation
  - bush regeneration
  - erosion control.
- Community centres provide similar advice and education for the general public.

Provision of plants (Qld)

Provision of materials

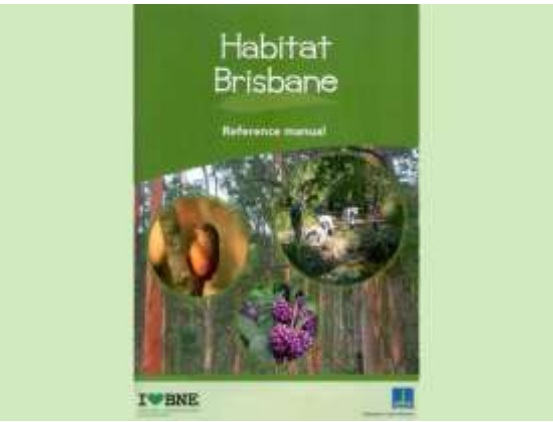
- The Council supplies these community groups with:
  - an assigned coordinator (bushland officer)
  - plants
  - planting scheme
  - mulch
  - erosion control products.
- Major erosion control projects are listed as scheduled items for council maintenance.

Weeds ready for removal from a site

Waste disposal services

- The Council also provides the service of removing all waste materials from project sites, including woody weeds.

Providing training for community working groups



Habitat Brisbane, 2016

Introduction

- Brisbane City Council provides its community groups with:
  - an initial induction day
  - on-site training
  - a reference manual (not available to the general public).

Riparian vegetation (Qld)

Riparian plants

- Community groups are trained in the use of plants to control different types of erosion issues.
- In general, the more flexible the plant, the closer to the waterway the plant can be located.
- Trees and shrubs that are located near the water's edge often have:
  - very flexible branches
  - a root system that can be partially exposed to air without dying.

Staging program for weed removal

The staging of work activities

- Community groups are taught about the hydraulic effects of mass weed removal, which can cause a temporary increase in flow velocities.
- In large projects, weed removal may need to occur in a staged pattern to avoid this activity causing erosion problems elsewhere along the waterway.
- The Council can support this process with through the flood modelling of the waterway.

Weed identification (Qld)

Identification and control of weeds

- A plant can be declared a 'weed' because:
  - it does not belong in Australia
  - it does not belong to a given waterway
  - it does not belong to a given reach of a waterway.
- Native plants sold by a local nursery, or even listed on a government website, may be considered to be a 'weed' simply because they don't belong along a given reach of a waterway.

Engineering aspects of riparian plants

Caution!

Introduction

- The author stresses that he is not a revegetation expert, he is just a civil engineer that has spent 25 years working on creek projects.
- Therefore, the advice provided in this chapter should be treated with appropriate caution.
- That said, the following are some of the lessons the author had learnt over his working life.

Mass planting of *Lomandra* (Qld)

Stiff grasses used as a monoculture

- A mass planting of stiff grasses can be an effective way of dealing with very high flow velocities; however, ecological values can be diminished by such landscaping.
- The mass planting of stiff grasses can be useful in the following circumstances:
  - high-velocity channels
  - lower bank region on the outside of a channel bend
  - around the base of 'objects' located in floodways, such as isolated trees.

Water's edge (Qld)

Lomandra (mat rush)

- *Lomandra* is possibly the most important erosion control plant in Eastern Australia, but many would suggest that it is also one of the most over-used plants.
- *Lomandra* is most effective when floodwaters overtop the plant (i.e. when located within the lower bank region).
- They are not suited to high-velocity, shallow-water conditions, such as dam spillways.

Vetiver grass (full growth)

Vetiver grass

- *Chrysopogon zizanioides* is commonly known as 'vetiver grass'.
- Vetiver grass grows in tall clumps, with tall, thin, and rather rigid leaves growing to a height of 2–3 metres, and a root system that can grow to a depth of 2–4 metres.
- The plant can survive deep water flow conditions and temporary submergence.
- The most commonly used commercial genotypes of vetiver are sterile, meaning the plant can be propagated only by breaking the clumps.

The 'right' plant in the 'right' location (also see Part 2 of this document)

Site revegetation (Qld)

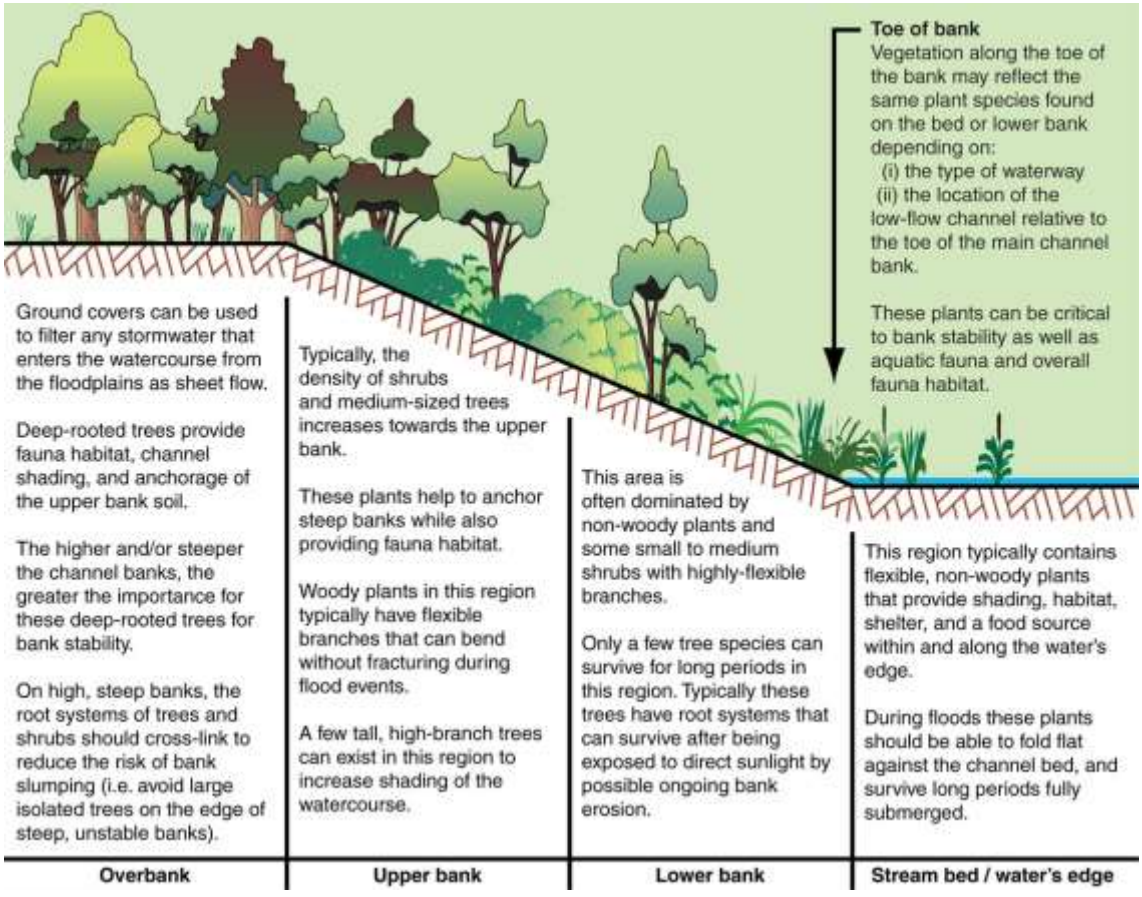
Introduction

- Creek rehabilitation is <u>not</u> a case of simply delivering a truck-load of native plants to a site, then planting them randomly over the disturbed ground.
- Plants play an important role in the stability and everyday functioning of our creeks.
- In order to perform these tasks, the right plant needs to be planted in the right location, which means following a plan, or ensuring that the revegetation process is supervised by a suitably trained person.

Site revegetation (Qld)

Planting along the water's edge

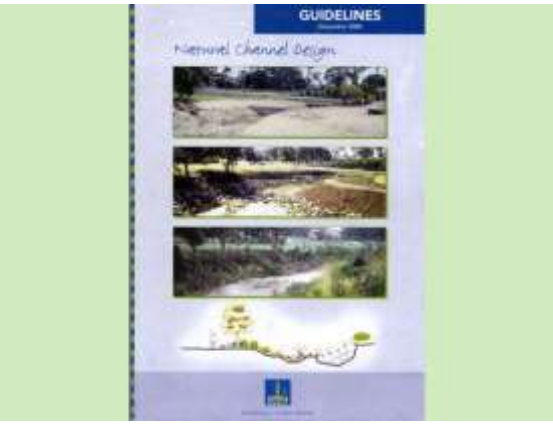
- The shading of the water's edge provides the following benefits:
  - control of water temperature (especially in tropical regions)
  - sheltering aquatic life from predators
  - controlling the boundary layer and local stream velocity adjacent the bank
  - providing a food source for aquatic fauna
  - providing favourable fish passage conditions during flood events.



Desirable characteristics of riparian vegetation

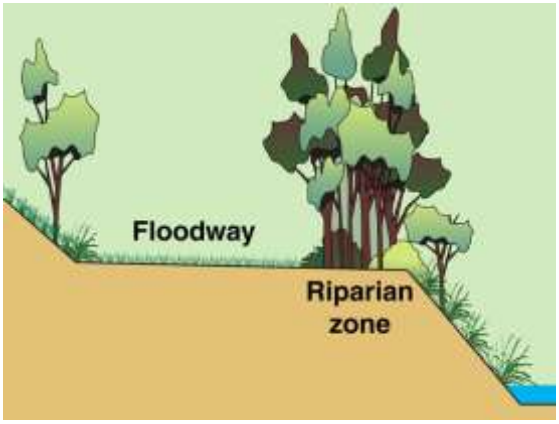
5. Policy Issues

Introduction



Brisbane City Council, 2000

Catchment-wide opportunities (Qld)



Variable planting structure

Corridor map

Introduction

- The application of Natural Channel Design principles to the design of drainage channels, and the rehabilitation of waterways, works best when supported by appropriate legislation and policies.
- Specifically policies dealing with:
  - design objectives
  - minimum surface roughness
  - minimum waterway corridor width
  - catchment management, and
  - fish passage.

Setting regional objectives

- The reality is that a mission statement, a design guideline, and community focus, are all useless items unless adequately supported by either:
  - political support
  - legislation, and/or
  - planning schemes.
- These official documents need to clearly define the objectives of drainage design, bush regeneration, and waterway management.

Nominating minimum design roughness

- It is a false belief by some designers that they can control the hydraulic roughness of a waterway by simply adjusting the spacing of trees.
- The reality is that bushland does not know when to stop growing—this means that the long-term control of the hydraulic roughness of bushland requires regular tree clearing.
- To avoid these issues, waterway designs should be based on roughness values that correspond to mature bushland.

Nominating minimum corridor width

- Policy documents should specify:
  - minimum riparian width (with allowances and exceptions)
  - minimum waterway corridor width (total channel and floodplain width).
- These policies normally refer to a government endorsed corridor mapping scheme, which defines the recommended corridor width for different reaches of a waterway.

Setting regional design objectives

Setting catchment-based goals

Introduction

- There is no denying that each city of Australia has its own character and treatment of urban waterways.
- There is nothing fundamentally wrong with design objectives that vary from region to region, and waterway to waterway.
- Some regions may choose to place a greater emphasis on bikeways, while others may focus on fish passage, and others on flood control.

Low-level footbridge (SA)

Drainage and flood control

- Objectives may include:
  - minimum 300 mm freeboard for habitable floors above the 1% flood
  - a depth*velocity product not exceeding 0.6 for all bikeways during a 1-in-2 year (40%) flood event
  - no depth*velocity limit for low-level pedestrian crossings of a waterway.

Wildlife corridor map

Fauna habitat objectives

- Objectives may include:
  - establishing connectivity from mountains to the sea (or similar)
  - establishing connectivity of bushland reserves with riparian corridors
  - conducting fauna surveys along all waterways every ten years
  - funding of a program for the rehabilitation of all artificial fish passage barriers.

Bushland connectivity (Qld)

Bushland conservation objectives

- Objectives may include:
  - establishing connectivity from mountains to the sea (or similar)
  - establishing connectivity of bushland reserves with riparian corridors
  - establishing fire trails between residential properties and bushland reserves
  - achieving a 90% reduction in designated high-priority weeds within 10 years.

Nominating minimum assumed surface roughness

Waterway management in Victoria, 2007

Introduction

- Most States and Territories have guidelines and/or policies on the management of waterways.
- For example: *Technical Guidelines for Waterway Management*, (2007) Department of Sustainability and Environment, Victoria.
  - ISBN 978 1 74152 794 0.

Manning's Roughness for Grassed Channels (50–150mm Blade Length)

Hydraulic Radius (m)	Swale Slope (%)					
	0.1	0.2	0.5	1.0	2.0	5.0
0.1	—	—	—	0.105	0.081	0.046
0.2	—	0.091	0.068	0.057	0.043	0.030
0.3	0.078	0.064	0.053	0.043	0.031	0.030
0.4	0.063	0.054	0.044	0.033	0.030	0.030
0.5	0.056	0.050	0.038	0.030	0.030	0.030
0.6	0.051	0.047	0.034	0.030	0.030	0.030
0.8	0.047	0.044	0.030	0.030	0.030	0.030
1.0	0.044	0.044	0.030	0.030	0.030	0.030
>1.2	0.030	0.030	0.030	0.030	0.030	0.030

QUDM (2017) Table 9.3.4

Mown grassland

- Recommended Manning's roughness (n) for short-cut grass is provided in numerous drainage design documents, including the *Queensland Urban Drainage Manual*.
- Otherwise, adopt:
  - **n = 0.035** for well-maintained overland flow paths
  - **n = 0.04** for mown floodways
  - **n = 0.05** for grassed floodplains.

Lomandra (Qld)

Stiff grasses

- The hydraulic roughness of stiff grasses should not be treated the same as short-length mown grasses.
- The appropriate Manning's roughness depends on the depth of flow.
- Manning's roughness can be determined from grass roughness charts based on a grass length of 280 to 600 mm (Chart B).

Riparian bushland without vines (Qld)

Bushland

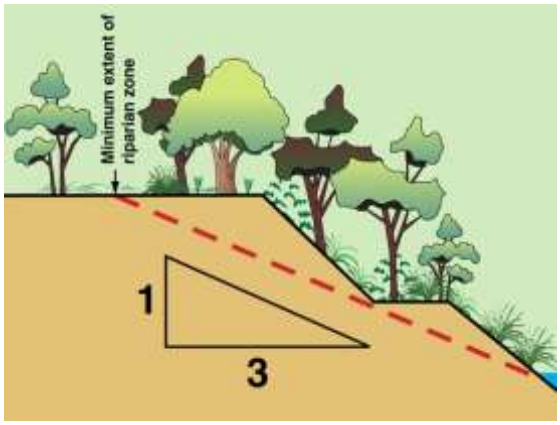
- Recommended minimum 'design' Manning's roughness vales for bushland and riparian vegetation is:
  - **n = 0.15** for bushland without vines
  - **n = 0.20** for bushland with vines.

Nominating minimum riparian and waterway corridor width

Riparian zone and grassed floodway (Qld)

Minimum width of riparian zone

- The suggested minimum width is 5 m.
- However, specifying a minimum width can become problematic if it results in only this minimum width ever being provided.
- In order to filter pollutants from stormwater inflows (sheet flow runoff) the minimum width of the combined riparian zone and grassed floodway is the greater of:
  - 15 m (minimum)
  - 5 times the land slope (i.e. 25 m width for a 5% land slope).



Minimum width based on bank stability

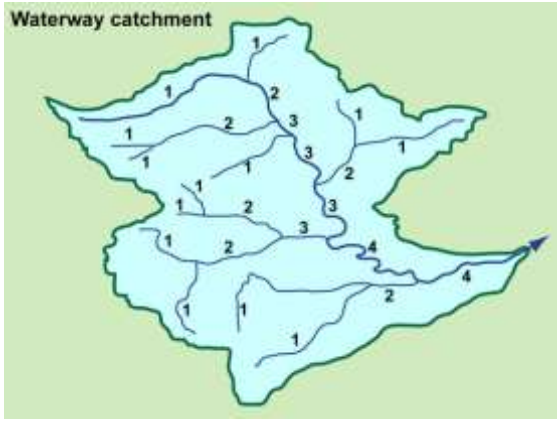
Minimum riparian width based on bank stability

- The minimum width of the riparian zone depends on numerous local factors, including bank stability.
- It is suggested that the riparian zone should extend at least three (3) times the bank height from the toe of the bank.
- Alternatively, some guidelines recommend a minimum riparian width (*measured from the top of bank*) equal to the height of the bank.

Corridor mapping

Minimum waterway corridor width

- Some authorities prepare *Waterway Corridor Maps* that identify which land must be excluded from development.
- The nominated corridor width is often measured from the centre of the creek (but may be a different distance each side of the creek)—suggested widths are:
  - 1st order streams = 15 m (each side)
  - 2nd order streams = 30 m (each side)
  - larger waterways = 60 m (thus the full width would be 2 x 60 = 120 m)

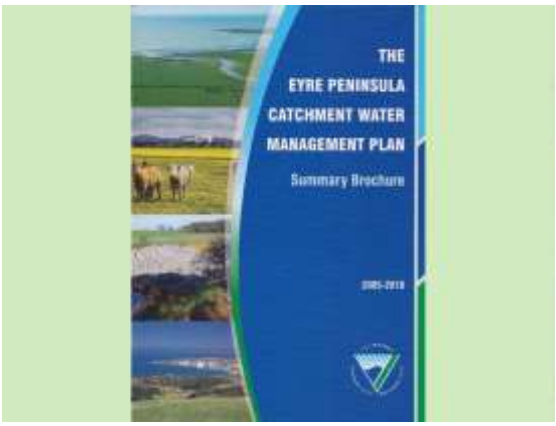


Horton's stream order system

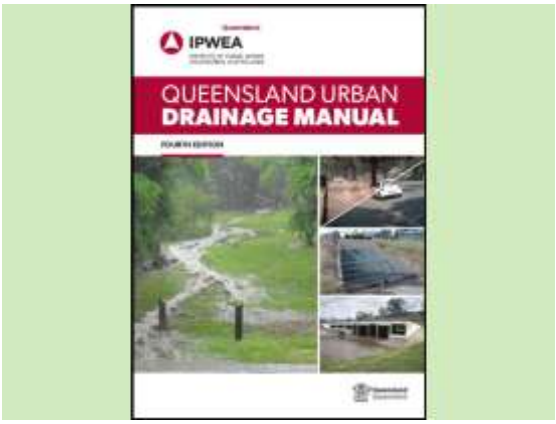
Existing corridor width recommendations

- Some guidelines nominate a minimum riparian width based on the stream order (based on 1:25,000 mapping):
  - 1st order streams = 5 m (Vic, 2008), or 10 m (NSW, 2012)
  - 2nd order streams = 10 m (Qld, 2001), or 20 m (NSW, 2012)
  - 3rd order streams = 15 m (Vic, 2008), or 30 m (NSW, 2012)
  - 4th order streams = 15 m (Vic, 2008), or 40 m (NSW, 2012).

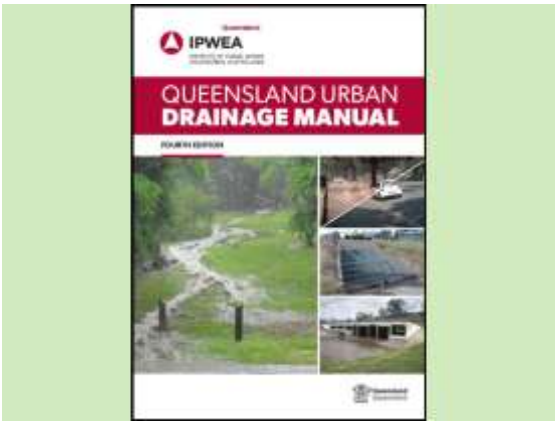
Catchment management issues



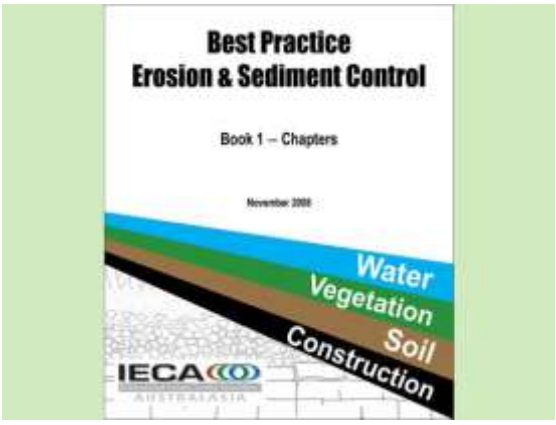
Catchment Management Plan (SA)



QUDM (2017)



QUDM (2017)



IECA Australasia (2008)

Introduction

- Waterways are the drainage systems of catchments.
- If you change the catchment, then you will eventually change the waterway.
- You cannot have a 'natural' waterway in an unnatural catchment.
- You cannot have a healthy waterway unless you have a healthy catchment.
- The pollution that you accept in a stormwater drain, is the pollution you accept in a waterway.

Directly connected impervious surface area percentage

- Waterway health is greatly improved by minimising the total impervious surface area that is directly connected to the waterway.
- Ideally, the runoff from impervious surfaces should pass through a pervious soil filter before entering a waterway.
- **Reference:** *Queensland Urban Drainage Manual,* Institute of Public Works Engineering Australia, 2017, Brisbane, Australia.

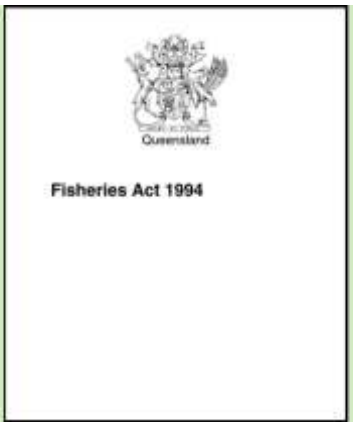
Setting targets based on Initial Loss

- The long-term stability of waterways can be improved by minimising changes to the 'initial loss' characteristics of the drainage catchment.
- Detention systems can reduce the effects of urbanisation on local flooding, but retention systems are the best means of controlling the flood risk, while also minimising adverse effects on the waterway.
- The retention volume should equal the change in initial loss of the development.

Erosion and sediment control (ESC)

- Effective erosion and sediment control on building and construction sites is critical for the long-term viability of vegetated drainage channels.
- Sediment control measures help to reduce the inflow of coarse sediment, which can fill ponds and damage riffles.
- Erosion control measures help to reduce adverse health issues for aquatic life.
- Drainage control measures help to reduce storm damage to a site's erosion and sediment control measures.

Fish habitat and fish passage



***Queensland Fisheries Act*, 1994**

Introduction

- Most States and Territories have guidelines and/or policies on the management of fish habitats.
- These policies and guidelines apply to all aquatic fauna, not just 'fish'.

NSW Policy and Guidelines, 2013

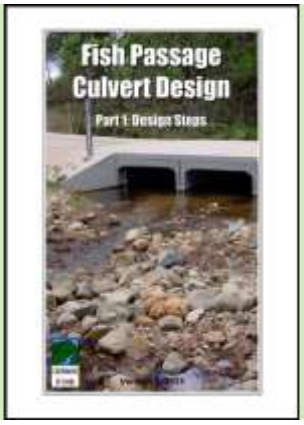
Protection of fish habitats

- The protection of fish habitats usually starts by the survey and mapping of the State's fish habitats.

Fish Passage at Small Structures (Vic)

Removal of barriers to fish passage

- From a fish passage perspective, the critical issues are likely to be:
  - potential blockage of essential fish migration during those limited times when fish migration is likely to occur
  - potential blockage of day-to-day fish movement if flood debris is not removed timely after each flood event
  - the design of debris control structures so as not to interfere with fish passage.



Fish Passage Culvert Design, 2025

Fish passage at waterway crossings

- Weirs and waterway crossings are currently the major cause of fish passage barriers.
- Waterway rehabilitation should prioritise the following in this order:
  - weirs
  - grade control structures
  - causeways
  - culverts
  - bridges.