Erosion & Sediment Control Field Guide for Instream Works

Version 2, 2020

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Disclaimer

Significant effort has been taken to ensure that this document is representative of current best practice erosion & sediment control and waterway management; however, the author cannot and does not claim that the document is without error, or that the recommendations presented within this document will not be subject to future amendment.

To be effective, instream construction activities must be investigated, planned, and designed in a manner appropriate for the given work activity and site conditions.

No warranty or guarantee, express, implied, or statutory is made as to the accuracy, reliability, suitability, or results of the methods or recommendations.

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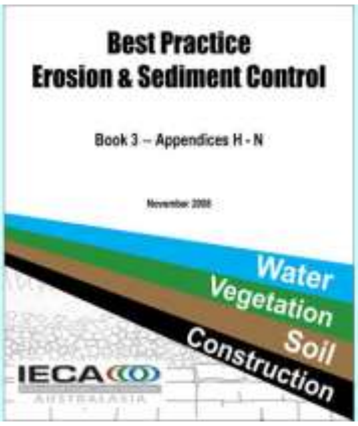
Specifically, adoption of the recommendations and procedures presented within this field guide will not guarantee:

(i) compliance with any statutory obligations;
(ii) compliance with specific water quality objectives;
(iii) avoidance of environmental harm or nuisance.

Principal reference documents:



IECA (2008) – Book 3

***Best Practice Erosion & Sediment Control*. International Erosion Control Association, (IECA) Australasia Chapter, 2008**

Book 1 – Chapters

Book 2 – Appendices A to G

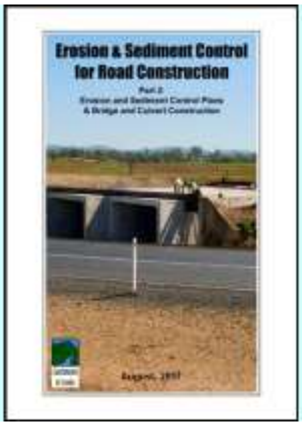
Book 3 – Appendices H to N, including:

- Appendix I: Instream works
- Appendix P: Land-based pipeline construction (electronic PDF)

Book 4 – Design fact sheets

Book 5 – Field Guide

Book 6 – Standard Drawings



Road Construction Guide, Part 2 (2017)

Erosion and Sediment Control for Road Construction – Part 2

Grant Witheridge, 2017, Catchments and Creeks Pty Ltd, Brisbane, Queensland, Australia

Down-load the field guide from:

www.catchmentsandcreeks.com.au

Pipeline Field Guide, Part 2 (2017)

Erosion and Sediment Control Field Guide for Pipeline Projects – Part 2

Grant Witheridge, 2017, Catchments and Creeks Pty Ltd, Brisbane, Queensland, Australia

Down-load the field guide from:

www.catchmentsandcreeks.com.au

Trow Consulting Engineering Ltd (1997)

Instream Sediment Control Techniques Field Implementation Manual

Trow Consulting Engineers Ltd. 1997, Nest Field Guide FG-007, Ontario Ministry of Natural Resources, Northeast Sciences & Technology

www.borealscience.on.ca

Contents

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Purpose of field guide

This field guide has been prepared specifically to:

- provide training on instream construction practices
- provide support to Appendix I of the IECA (Australasia) Best Practice ESC documents.

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

The caption and/or associated discussion should **not** imply that the actual site shown within the photograph represents either good or bad stormwater practice. The actual circumstances, site conditions and history of each site are not known in each case, and may not be directly relevant to the current discussion. This means that there may be a valid, site-specific reason why the designer chose the design or layout depicted in the photo.

Unlike general construction site erosion and sediment control, the accepted practices of instream work activities are changing on a regular basis as new techniques are developed. This means the photos presented within this field guide are likely to 'date' relatively quickly. Currently the document is reflective of the work practices observed between 2000 and 2015.

About the author

Grant Witheridge is a civil engineer with both Bachelor and Masters degrees from the University of NSW (UNSW). He has 40 years experience in the fields of hydraulics, stormwater management, creek engineering, and erosion & sediment control, during which time he has worked for a variety of federal, state and local governments, and private organisations.

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

Grant is the principal author of such publications as the revised *Queensland Urban Drainage Manual* (2007, 2013 & 2017), and IECA (Australasia) *Best Practice Erosion and Sediment Control (2008)* documents. In 2010 Grant was presented with the IECA (International) *Sustained Contributor Award*.

Introduction

The term 'sediment control' can have different meanings to different people. Within the Erosion & Sediment Control (ESC) industry the term refers to any system that directly collects (traps) sediment from stormwater runoff. In the waterway profession the term refers to any activity that aims to reduce unnatural sediment inflows into a waterway, which would include all drainage, erosion and sediment control measures that are applied while conducting an instream work activity.

The term 'instream sediment control' can evoke a strong reaction from many seasoned ESC professionals. Within the erosion and sediment control profession we are taught that most sediment traps should <u>not</u> be placed in areas of concentrated flow, especially <u>not</u> within a watercourse. But the logic here is that most sediment traps cannot possibly treat the volume of water that is passing down a watercourse during a storm event.

However, within this field guide, the suggested instream sediment traps are not installed within a waterway to treat wet weather flows, but to treat the trickle flows that exist within a watercourse during normal dry weather conditions. This means there is a fundamental difference between the operation and purpose of instream and off-stream sediment traps.

When conducting works within a watercourse it is often a legal requirement to regularly monitor water quality levels upstream and downstream of the work site. Even if there is just a minor trickle flow in the watercourse, a 10% change in water turbidity can register as a failed test result. Consequently, instream drainage and sediment control measures are required to minimise any contamination of these dry weather flows.

Types of instream work activities

Bridge construction (USA)

Construction of waterway crossings

- Instream work activities include both construction and maintenance work as discussed below.
- The construction of waterway crossings can include:
  - bridges
  - arch structures
  - culverts
  - causeways
  - suspended pipelines
  - footbridges

Pipeline installation (Tasmania Irrigation)

Installation of services under a waterway

- These installation activities include:
  - pipelines
  - telecommunication lines
- The installation of these services can involve:
  - directional drilling
  - trench rilling
  - open excavations

Bank stabilisation (Qld)

Waterway channel modifications

- Instream channel works can include:
  - channel relocation
  - channel reconstruction
  - post-flood waterway repairs
  - bed and bank erosion control
- These activities also include the construction of vegetated drainage channels as a part of urban development.

Creek de-silting (Qld)

Maintenance of instream structures

- Instream maintenance activities can include:
  - channel dredging
  - waterway de-silting
  - de-silting culverts and stormwater pipes and channels
  - post-flood scour control around engineered structures
  - flood-control waterway maintenance
  - in-bank weed removal.

Legal requirements

Court House, Barcaldine (Qld)

Local government (Qld)

Code-based instream works (Qld)

Water quality monitoring (Qld)

Introduction

- Each state has its own definition of what constitutes a watercourse, and in some cases these definitions will vary from region to region within the state.
- Approvals (sometimes more than one) are usually required from the state before works can be carried out.
- Owning the land does not mean that you don't need approval to build a house—similarly, owning a portion of a creek does not mean you can modify that waterway at your will.

Local government requirements

- The need to get local government approval depends on two key issues:
  - are the proposed works a controlled activity as identified within the Planning Scheme (Town Plan), or
  - will any of the works be conducted within land owned or managed by the local government.
- Note; getting local government approval may not negate the need to get state government approval.

State government requirements

- Instream works may trigger the following state-controlled legal requirements:
  - waterway permits
  - vegetation removal permits
  - fish barrier permits
  - permission to conduct works within land owned or managed by the state
  - general environmental duty.
- Note; approval from one department does not negate the need to get an approval from another interested department.

Legal requirements

- The approval to conduct instream work activities is normally associated with some essential outcomes, including:
  - water quality monitoring while the work activities are being conducted
  - time limits on when the works can occur, and the duration of the instream disturbance
  - requirements for the rehabilitation of the watercourse.

Types of waterways

Tidal waterway (Qld)

Introduction

- Government regulations associated with instream work activities can vary with the type of waterway.
- The proposed rehabilitation of a waterway can also vary significantly depending on the characteristics of the waterway.
- The following pages outline some general classifications of waterways.

Major waterway (Bremer River, Qld)

Major waterways

- Major waterways are most commonly referred to as 'rivers'.
- However, the upper regions of most rivers can be so narrow that their behaviour is more closely aligned with the behaviour of minor waterways.
- In major waterways, bank vegetation can play a major role in providing post-flood bank stability, but during a flood, it is the floodwater that usually dominates over the vegetation.

Minor urban waterway (Brisbane, Qld)

Minor waterways

- Within this field guide, the term 'minor waterway' is used to describe narrow-bed waterways where vegetation type and density is often the dominant factor in determining the size and stability of the channel.
- 'Springs', 'brooks' and 'creeks' are the types of waterways most likely to fall into this category.
- These waterways normally have a low stream order classification (i.e. 1, 2, or 3).

Well-vegetated drainage line (Qld)

Drainage lines

- A drainage line is a stormwater drainage pathway (or overland flow path) that carries concentrated flow (not sheet flow).
- These drains are likely to flow only while rain is falling, and for short periods (hours) after rainfall has stopped.
- Drainage lines are generally <u>not</u> considered to be waterways.
- The classification of waterways is usually a matter for state governments, while the mapping of drainage lines is more commonly done by local governments.

A waterway classification system applicable to minor waterways

Clay-based waterway (Qld)

Clay-based waterways

- The bed and banks of clay-based waterways are primarily formed from clayey soils.
- These are 'fixed bed' waterways, that typically have minimal natural sediment flow or bed movement—this allows mature woody vegetation to establish close to, or even on, the channel bed.
- Typically these waterways have a U-shaped or V-shaped channel profile (i.e. not a wide, flat channel bed).

Sand-based waterway (Qld)

Sand-based waterways

- Deep, loose sand dominates the make-up of the bed of sand-based waterways.
- The depth of the sand can exceed the depth of the root systems of much of the bed and bank vegetation.
- These are alluvial waterways that experience significant bed movement (sand flow) during both minor and major flood events.
- Bed vegetation (if any) typically consists of quick-response, short-lived, non-woody species.

Gravel-based waterway (NSW)

Gravel-based waterways

- Bed material is made-up mostly of well-rounded gravels, cobbles or boulders.
- These are alluvial waterways that often feature pools and riffles.
- The movement of the bed material during major floods means the channel bed is usually flat (similar to sand-based rivers).
- Woody vegetation can struggle to form on the channel bed if the bed movement is significant—which may not be the case in the upper reaches of the waterway.

Rock-based waterway (Tas)

Rock-based waterways

- The bed material of rock-based waterways is made-up of exposed rock outcrops, often separated by sections of clay, sand or gravel-based channels.
- These are fixed-bed, 'spilling' waterways usually containing waterfalls or riffles followed by deep pools within which energy dissipation occurs.
- These waterways are sometimes referred to as 'rocky-spilling' or 'steep pool-fall' waterways.

Other water bodies affected by construction and maintenance works

Torrens River lake, Adelaide

Freshwater lakes

- If construction or maintenance works occur within a lake, estuary or bay, then the principles of instream erosion and sediment control still apply.
- If work activities in or around a freshwater lake disturb a dispersive soil, then this action can cause significant changes to the clarity (colour) of the water.
- The task of de-silting a lake can result in the re-suspension of significant volumes of harmful pollutants into the water column.

The Entrance, Victoria

Estuaries and tidal lagoons

- Critical to the hydraulic operation of estuaries and tidal pools is the frequency and degree of tidal exchange, and the overall degree of water circulation.
- Dredging and construction works can generate significant volumes of sediment.
- The re-suspension of these bed sediments can affect the health of marine life, including essential micro-organisms.

Botany Bay, Sydney

Bays and harbours

- Hydraulically, bays operate in a manner similar to estuaries.
- The degree of tidal exchange and water circulation are critical to determining the recovery rate after a disturbance to the water quality.
- The potential impacts are not just to the aquatic life that we can see, but also to the micro-organisms that the larger aquatic fauna depend on.

Pacific Ocean, Queensland

Oceans and seas

- Oceans have an enormous natural ability to accommodate the inflow of pollutants, and for this reason the potential impact of construction and maintenance activities are often understated.
- The combined sciences of oceanography and coastal engineering are required to fully understand potential impacts, and to manage these impacts.

Where to get help and advice

Local government community centre

Introduction

- Land owners that are wishing to conduct instream work activities should always make use of the advice that is freely provided by many government and non-government organisations.
- Local governments and community groups can assist land owners in selecting the best plants for erosion control and stream rehabilitation.

Community training day (Qld)

Community groups

- Local community groups can be a good source of information, and they can also have good contacts within the private sector and within governments.
- Try your local:
  - Landcare and Envirolink group
  - Bush rehabilitation group
  - Coastal Landcare group
  - NRM (Natural Resource Management) organisation—usually linked to the local river system.

State government officers (SA)

Local and state governments

- The state government department that will most likely have an interest in waterway management will be a department with a title that includes the words: *Natural Resources*, or *Water*.
- Your state's environment department will likely be interested in general environmental issues, such as water quality and the protection of wildlife.
- Your state's fisheries department may be interested in any instream works that could impact fish habitats or fish migration.

Creek inspection (Qld)

Waterway consultants

- Private consultants can provide advice on a wide range of waterway issues, but the key is finding the right consultant.
- You may get help finding the right consultant by asking a local community group (see above) or by asking your local council or councillor.

1. Potential Impacts of Instream Works on Waterway Health

Potential environmental impacts of instream work activities

Sediment-laden stormwater runoff

Introduction

- Poorly managed instream works can result in various forms of environmental harm, including:
  - poor water quality resulting in harm to aquatic life
  - damage to aquatic habitats
  - damage to in-bank terrestrial habitats
  - damage to riparian flora
  - increased water supply treatment costs
  - increased risk of channel erosion.

Cement runoff from a work site

Changes to the water pH

- If the instream activities involve the pouring of concrete, then care must be taken to ensure this process does not:
  - release high pH water
  - change the pH of the receiving water body.
- It is the lime in the concrete that results in the elevated pH (alkaline) levels.
- Runoff pH problems can continue to occur even during the curing of the concrete.

Fish kill due to low oxygen levels

Changes in dissolved oxygen

- Bed sediments in many waterways can be rich in organic matter.
- If the bed sediment is disturbed, and this organic matter is released into the water body, then it can begin to be digested by aquatic organisms, which is a process that will remove oxygen from the water.
- An excessive reduction in oxygen levels can result in foul smells and fish kills.

Inflow of nutrient-rich stormwater runoff

Release of dissolved pollutants

- Dissolved pollutants can include, nitrogen, phosphorus and metals.
- These pollutants can be contained within the sediment often found in urban creeks and lakes.
- As discussed above, the release of nutrient-rich material into water bodies can begin a digestion process that ultimately removes oxygen from the water.

Potential environmental impacts of instream work activities

Inflow of coarse sediment (Qld)

Increased bed load (coarse) sediment

- Sediment released from a work site into a waterway or water body can cause an increase in both turbidity and bed load sediment.
- Bed load sediment consists of the coarser silts, sands, and gravels that move along, or close to, the bed of a watercourse.
- Coarse sediment can fill the voids between the stones within riffles and gravel beds, which significantly reduces their habitat value.

Ocean release of turbid stormwater runoff

Increased turbidity (fine sediment)

- Turbidity consists of the clay and fine silt particles that generally do not settle until they reach quiescent or saline waters.
- Unnaturally high turbidity levels can cause stress to aquatic life, such as:
  - damage to fish gill membranes
  - reduced ability for aquatic life to feed
  - the intrusion of non-native species
  - health problems associated with pollutants attached to clay particles such as metals and pesticides.

River bank stabilisation (NSW)

Loss of habitat

- The loss of riparian vegetation removes potential habitats and food sources from the waterway.
- The placement of rock and other hard engineering measures on river banks alters the habitat potential of the waterway, often favouring non-native species.
- Hard engineering measures also prevent burrowing animals, such as platypus, from nesting.

The remains of industrial runoff (Qld)

Visual pollution

- The appearance of highly visible pollutants in drains and water bodies can anger the local community.
- Highly visible sediment plumes entering urban lakes can also generate understandable anger from people that reside around the lake.

Assessing the potential impact of coarse sediment on waterways

Fern Creek (NSW)

Introduction

- Loose sediment is a natural component of most waterways; however, this does not mean that there can be no adverse effects caused by the release of coarse sediment while conducting instream work activities.
- The potential impacts of unnatural sediment releases depends on the type of watercourse, and more importantly, on the type and degree of natural bed sediment within the waterway.

Sediment deposited in a clay-based creek

Clay-based creeks

- In clay-based creeks, <u>coarse</u> sediment can:
  - smother essential bed vegetation
  - damage the habitat value of aquatic environments (e.g. pools and riffles)
  - smother natural pools
  - cause bank instabilities by altering the location of the low-flow channel, or by reducing the effective bed width.

Gravel-bed creek covered in sand (Qld)

Gravel-based creeks

- In gravel-based creeks, <u>coarse</u> sediment can cause all of the above impacts listed for clay-based creeks, plus:
  - damage the habitat value of the gravel bed
  - reduce the total submerged surface area of riffle systems, thus reducing the potential supply of food for aquatic life
  - eventually convert gravel creeks to clay-based creeks by completely smothering the gravel bed.

Sand slug on the bed of a sandy creek

Sand-based creeks

- The inflow of coarse sediments usually has the least impact on sand-based creeks.
- The potential impacts can be significantly less than in clay or gravel-based streams, especially if the introduced material has a similar grain size to the natural bed material.
- However, if the introduced sediment contains clay or organic material, then environmental harm can occur similar to other types of creeks.

Assessing the potential impact of coarse sediment on waterways

Sand deposited in a rock pool (Qld)

Wawirra Creek in flood (SA)

Sand deposited in a wetland (Qld)

Seagrass damaged by sediment (Qld)

Rock-based creeks

- The inflow of coarse sediments into rock-based creeks can settle within rock pools.
- Such sedimentation can reduce the habitat value of these essential rock pools (much of the aquatic life survives within these pools between storm events).
- In the clay, sand or gravel-based reaches located between the rock outcrops, the potential environmental harm caused by coarse sediment is the same as previously discussed for these types of waterways.

Inland waterways

- In Australia, many of the waterways that pass through arid or semi-arid regions are naturally highly turbid.
- Typically this countryside has pockets of dispersive soil, which can release large quantities of turbidity & coarse sediment.
- In very flat country, coarse sediment can cause waterways to meander and relocate.
- When working in such regions, authorities must set appropriate water quality objectives, usually unique to each region.

Lakes and wetlands

- Wetlands can be severely damaged by the inflow of coarse sediment.
- The initial impact of coarse sediment on lakes can be minor, but if the degree of sedimentation reaches a point where the lake needs to be dredged, then the full impact of the sediment can become obvious, especially to the residents that surround the lake.
- The dredging of urban lakes can cause the re-suspension of very harmful pollutants resulting in fish kills.

Estuaries, bays and tidal lagoons

- Coarse sediment can smother aquatic vegetation and bed habitats.
- Fine sediments can settle as a fine dusting over the seabed, causing the loss of seagrass through reduced photosynthesis, and damage to coral habitats.
- Fine sediments that enter such waterways can be constantly resuspended into the water column by tidal flows, resulting in elevated turbidity levels.

Assessing the potential impact of fine sediment on waterways

Floodwater entering a river (USA)

Protecting water quality during periods of low flow

- In many creeks it is common for the water clarity to decrease as the flow rate increases.
- Water clarity is usually highest (i.e. best) during those periods of low flow.
- Therefore, to minimise the harm caused to creeks, the aim should be to achieve the highest quality water standards during periods of low flow.

Examples of suspended solids content

Background levels

- The allowable discharge conditions from a work site may be linked to either:
  - long-term average background levels
  - or the immediate upstream water quality at the time of work activity.
- However, some instream work activities will have discharge conditions set by the state that are independent of the background turbidity (NTU), or suspended solids (TSS) levels, that exist within the receiving waters.

Floodwater entering Moreton Bay (Qld)

Catchment-wide approach

- In some drainage catchments, turbidity levels can vary significantly from location to location down the waterway.
- In such cases, it may not be appropriate to set water quality objectives (WQOs) based on the immediate receiving water; instead, WQOs should be based on a catchment-wide objective.
- For a waterway that flows into a bay, the WQOs may be based on the needs of the bay, rather than the needs of the waterway.

De-silting an urban creek (Qld)

Other impacts

- Additional impacts can include:
  - increased weed infestation of creeks and wetlands
  - pollution of water storages
  - increases in the frequency of maintenance dredging
  - decreases in recreational and commercial fishing
  - damage to the aesthetic, ecological, and recreational values of waterways.

2. Key Principles for Managing Instream Work Activities

Introduction

The focus of general ESC activities

Dry weather ESC measures (NSW)

Use of a filter tube to treat water (Qld)

Pumping water to a grass filter bed

Differences between instream and off-stream erosion and sediment control

- The fundamental principles of construction site erosion and sediment control (ESC) apply to all work sites, including instream work activities.
- However, for instream work activities there are some key differences in how these principles are applied to:
  - off-stream activities
  - instream activities.

A focus on dry weather conditions

- In general construction, the focus is on managing and treating stormwater runoff during periods of wet weather—the site is generally dry during dry weather.
- However, for instream activities the focus is on managing:
  - stream flows and de-watering activities during dry weather conditions
  - local stormwater runoff (lateral inflows) during wet weather conditions.

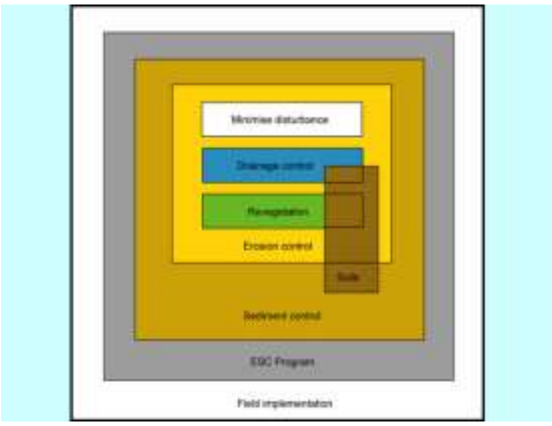
A focus on filtration processes

- In general construction, sediment control measures primarily utilise gravitational settlement to remove sediments from dirty water.
- However, for instream work activities, there is a greater use of filtration processes to clean dirty water, including:
  - passing water through filter tubes, and
  - allowing dirty water to infiltrate soil (e.g. discharging over grassed filter beds).

Better utilisation of soil infiltration

- In general construction, the soil that surrounds a work site is generally saturated at the time sediment control processes are activated (because of the wet weather).
- However, for instream work activities, there is a stronger possibility that the surrounding soil could be ‘dry’ and able to be used to infiltrate small volumes of site water, thus providing a highly efficient filtration process.

Key principles



Key tasks of erosion & sediment control

Site inspection (NSW)

Team meeting

Torrens River, Adelaide (SA)

Introduction

- The key principles for instream erosion and sediment control are:
  - appropriately plan work activities
  - minimise channel disturbances
  - control the movement of water
  - minimise soil erosion
  - minimise the release of sediment and sediment-laden water
  - promptly rehabilitate disturbed areas
  - design instream works to minimise the need for future disturbances.

Site inspections and data collection

- Construction and maintenance projects often start with a site inspection and the initial collection of site data.
- Chapter 3 discusses the typical observations required during early site inspections.
- Site data can be obtained from a variety of sources.
- An ecologist can be a very important member of a site inspection and data collection team.

Site planning

- Good site planning involves consideration of:
  - the appropriate scheduling of instream works
  - how the work activities will be conducted
  - the design and planning of the site rehabilitation.
- Chapter 4 provides further discussion on site planning.

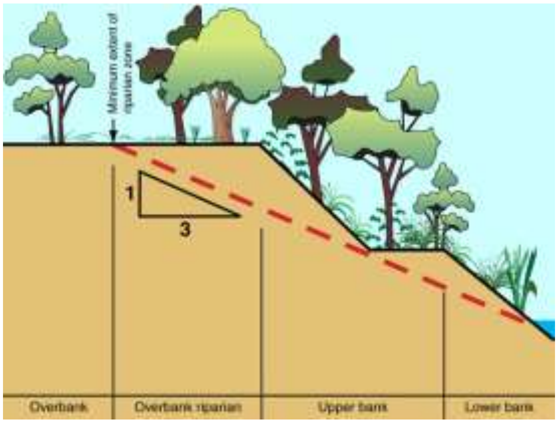
Scheduling instream works

- Scheduling issues include:
  - expected weather conditions and stream flow rates
  - periods of known fish migration
  - periods of aquatic bird nesting and/or migration
  - other relevant environmental factors.
- Chapter 4 provides further discussion on the scheduling of instream works.

Minimise channel disturbance

Site office located outside riparian zone

Maintenance of in-channel sewer pit



Minimum desirable riparian width

A bench formed to allow vehicle access

Introduction

- For instream work activities, the task of minimising soil disturbance involves:
  - minimising the number of access tracks cut through riparian areas
  - minimising the overall disturbance to established riparian vegetation
  - where possible, limiting disturbance to one bank of the waterway
  - and for channel and bridge maintenance, limiting the extent of channel disturbance to the minimum necessary.

Vehicle access

- Vehicle access tracks cut through established riparian vegetation should be limited to the minimum necessary.
- If equipment needs to move along the waterway, then determine if less environmental harm could be achieved by:
  - vehicles moving along the bank (which may require removal of riparian plants)
  - or vehicles moving along the channel bed (which will increase disturbance to the channel bed).

Disturbance to riparian areas

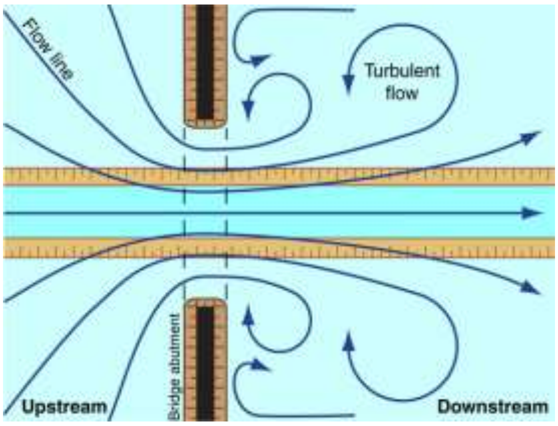
- Equipment and stockpiles should be located outside the riparian zone.
- Ideally, the riparian zone (measured from the water's edge) should be wider than the channel width, or three times the bank height, whichever is the greater.
- Performing a tree survey during the planning phase can help in minimising damage to important habitat trees.

Vehicle access into the channel

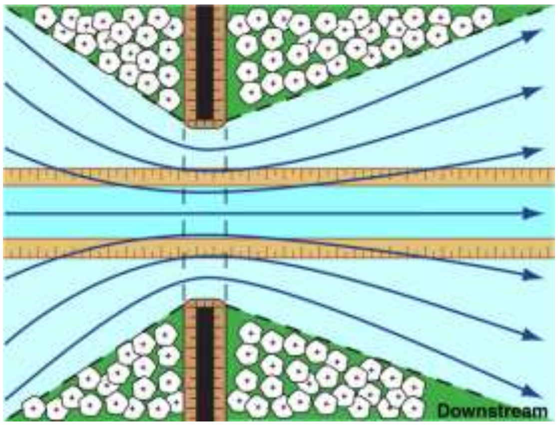
- Consider using long-reach excavators to remove sediment from channels, thus avoiding the need for equipment to move onto the bed of the channel.
- If rock is being placed on the banks of a waterway, then consider the benefits of forming a bench that would allow equipment to move along the bank, rather than within the main channel.

Selective removal of vegetation for reasons of flood control

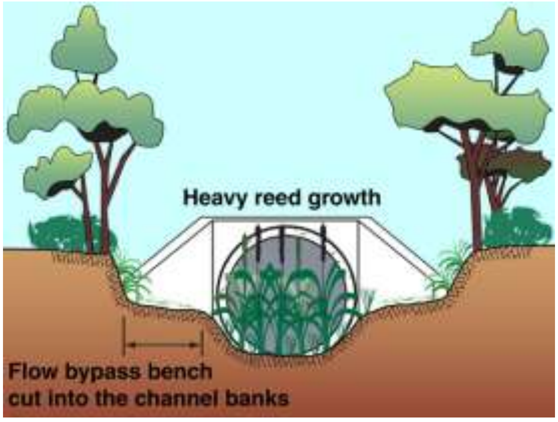
Woody vegetation near a bridge (Qld)



Typical flow conditions under a bridge



Ideal flow conditions under a bridge



High-flow bypass channels

Introduction

- Instream maintenance activities include:
  - de-silting culverts, storm drains, creeks, lakes and wetlands
  - dredging ports and shipping channels
  - weeding waterways
  - the selective removal of plants, sediment and debris to improve the flow conveyance of a culvert, bridge or waterway.

Clearing flow paths under bridges

- Significant energy loss can occur as floodwaters pass under bridges and through culverts.
- If strong woody vegetation establishes near a bridge it can increase the energy loss of flood flows and contribute to localised erosion around the foundations of bridge piers and abutments.
- The selective removal of certain plants can be an essential component of floodplain management.

Using plants to improve flow conditions upstream and downstream of a bridge

- There are some circumstances where dense vegetation planted in specific locations adjacent to a bridge or culvert can actually **improve** the hydraulics of the waterway crossing by allowing the gradual contraction and expansion of the flow.
- Floodplain vegetation located inside a 45-degree angle adjacent to the inlet embankment, or a 1:4 expansion adjacent to the outlet of a bridge, could actually benefit the structure's hydraulics.

Clearing vegetation downstream of stormwater outlets

- Stormwater pipes are often connected to a waterway via a short open channel.
- If reeds or mangroves establish in great numbers within these channels, then:
  - sediment can settle within the pipes
  - and backwater effects can reduce the flow capacity of the pipes.
- As an alternative to ongoing vegetation removal, consider the benefits of forming high-flow bypass channels to allow storm flows to bypass this vegetation.

Control the movement of water

Aqua-Barrier, HSI Services (USA)

Manage existing stream flows

- Wherever practical, instream flows should be diverted around the work area by isolating any channel disturbance.
- Appropriate consideration must be given to fish passage requirements during these periods of flow diversion.
- Consideration must also be given to:
  - the duration of flow diversion
  - the likelihood of fish movement, and
  - the cost/benefit of alternative construction procedures.

Cofferdam covered in filter cloth (Qld)

Manage elevated stream flows

- Ideally instream disturbances will be programmed to occur during periods of low flow; however the risk of local or distant storms elevating stream flows must be considered.
- Appropriately anchored erosion control blankets can be used to stabilise temporary embankments that could be overtopped by elevated stream flows.
- Filter cloth is often used in these cases as a temporary erosion control blanket.

Freshwater fish (Qld)

Manage trapped wildlife

- If part of the waterbody has been isolated by a barrier, then trapped wildlife must be managed in accordance with state guidelines.
- The capture and release of trapped fish may or may not require a permit (depending on state rules).
- Wherever possible, the handling of wildlife should be managed by licenced wildlife officers.

Temporary flow diversion bank (Qld)

Manage local stormwater runoff

- Appropriate measures must be taken to divert local stormwater runoff away from soil disturbances.
- On bridge and culvert construction, this may require the temporary diversion of table drains away from the construction site.
- Local stormwater runoff should enter the waterway in a non-erosive manner.

Minimise soil erosion during the construction period

Long-term stockpile cover with filter cloth

Erosion control during the construction phase

- During wet weather, erosion control measures should be applied to exposed soils, including soil stockpiles, in order to minimise sediment-laden runoff.
- Filter cloth is often used in these circumstances to control raindrop impact erosion.
- Filter cloth can also be used to form temporary batter chutes that carry lateral inflows down unstable creek banks.

Rock placement on a creek bank

Control vehicle movement

- Construction vehicles should not unnecessarily enter, or disturb the channel bed.
- Even if the channel bed has been isolated, and sediment-laden water is unable to flow into the bypassing flow, unnecessary disturbance to the channel bed:
  - increases the risk of bed erosion and water pollution once the isolation barrier has been removed, and
  - damage natural bed habitats.

Jute mesh pinned to a creek bank

Transitioning from temporary erosion control to permanent site stabilisation

- On finished earthworks, the temporary erosion control practices need to appropriately integrate with the proposed waterway rehabilitation.
- The use of sheet-like erosion control blankets can be problematic in waterways because of the risk of the blanket lifting during elevated flows.
- Jute or coir mesh is generally preferred, and can also be used to secure loose mulch on creek banks.

Coir log toe protection (Qld)

Managing erosion along the toe of disturbed creek banks

- The toe of disturbed creek banks may need additional protection during the revegetation phase.
- Rock and coir logs can be used to:
  - reduce the risk of soil erosion along the water's edge of recently disturbed creek banks
  - protect recently planted 'toe' vegetation from being disturbed by minor stream flows.

Minimise the release of sediment and sediment-laden water

Culvert construction in a dry creek bed

Planning of work activities

- All reasonable and practicable measures should be taken to schedule instream work activities such that:
  - the work occurs during a period of expected low stream flow
  - the work is conducted in a manner that minimises the need for instream sediment controls.
- The focus should always be on preventing water contamination, rather than the instream treatment of contaminated water.

Upstream and downstream water samples

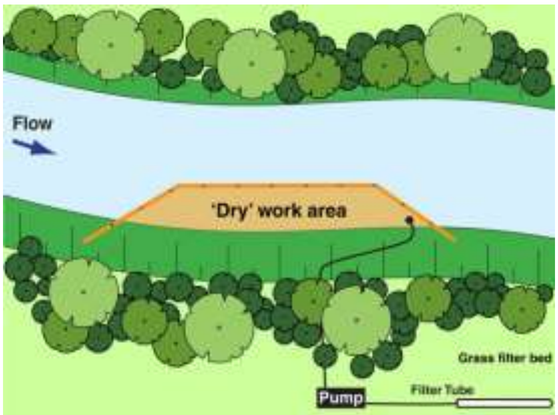
Water quality standard

- Sediment control systems, whether instream or off-stream, should aim to:
  - minimise environmental harm
  - minimise changes in water quality from upstream to downstream, and
  - where practical, achieve the highest instream water quality during periods of low flow.
- Understanding the complex relationship between water quality and environmental harm requires input from experts.

Sediment fence down-slope of stockpiles

Manage local stormwater runoff

- The management of local storm runoff involves:
  - the diversion of this runoff around the work site (i.e. drainage control)
  - the treatment of such water if it becomes contaminated while passing through the work site (i.e. sediment control measures).
- Appropriate off-stream sediment controls are discussed in the *ESC Field Guide for Construction Site Managers*.

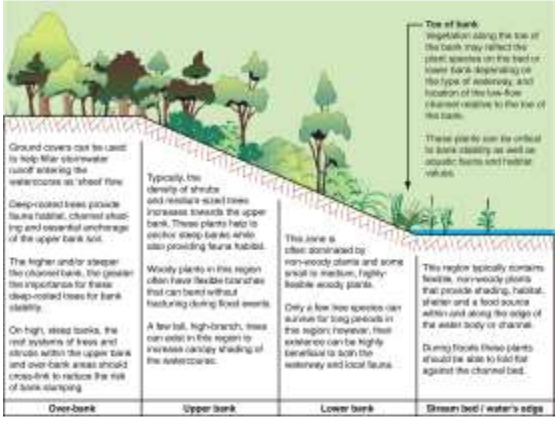


De-watering of a work site

Management of site de-watering

- All reasonable and practicable measures should be taken to appropriately treat all contaminated water pumped from excavations and the waterway channel.
- Wherever possible, the treated water should pass over a grassed filter bed before re-entering the waterway.

Rehabilitation of disturbed areas



Creek bank revegetation

Plants integrated into rock protection (Qld)

Constructed riffle u/s of a culvert (NSW)

Trimming a creek bank prior to planting

Site rehabilitation

- All disturbed areas should be stabilised and rehabilitated as soon as possible after the works have been completed.
- For waterways, the key to a successful revegetation plan is not just the use of native plants, but the use of the right plant in the right location (a larger version of this diagram is reproduced in Chapter 11).
- Plants placed along the water's edge can be critical for restoring aquatic habitats and fish passage.

Integration of plants into hard engineering scour control measures

- To the maximum degree practical, vegetation should be integrated into any erosion control and bank stabilisation works, including rock work.
- In cases where various scour control options exist, priority should be given to those measures that allow the successful integration of vegetation, especially adjacent to any permanent waters.

Channel rehabilitation

- If the construction works have disturbed the channel bed, then to the maximum degree practical, the bed 'form' and substrate should be returned to its original condition.
- If the construction work has altered the natural pool–riffle sequence, then the re-positioning and reconstruction of any pools and riffles should be done in consultation with a fisheries officer, freshwater ecologist, or suitably trained environmental engineer.

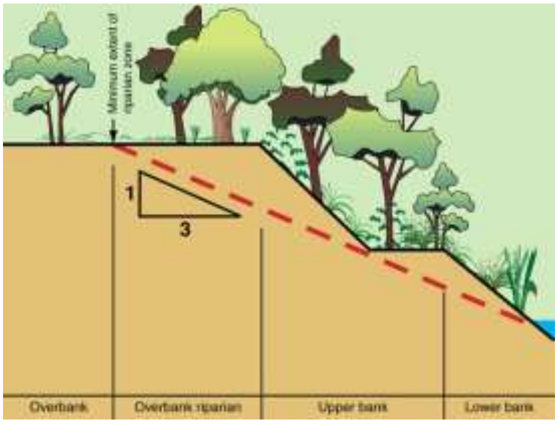
Rehabilitation of channel banks

- All reasonable and practicable measures should be taken to:
  - avoid the use of plastic-reinforced erosion control blankets in bushland areas, and to
  - leave the bank soil in an appropriate firm (i.e. not excessively compacted) condition that will assist in the quick establishment of vegetation.
- Compacting the soil to a 'hard' condition can significantly slow revegetation.

Designing waterways to minimise the need for future disturbances

Channel maintenance (Qld)

Constructed drainage channel (Qld)



Minimum desirable riparian width

Permanent sediment extraction ponds

Introduction

- The maintenance of waterways, whether through the actions of de-silting or weeding, can cause harm to the waterway and its fauna.
- Wherever practical, waterway structures should be designed in a manner that reduces the need for ongoing maintenance.
- Such actions not only benefit the waterway, they also reduce the ongoing costs of such maintenance work.

Design of constructed waterways

- Constructed waterways, including vegetated drainage channels, should be designed (sized) based on a minimum specified channel roughness.
- This minimum channel roughness should be based on **realistic** plant growth.
- It is unacceptable to assume that plant densities will remain at a constant value, or that the local authority will carry out ongoing maintenance of the channel in order to maintain an unsustainable vegetation density.

Locating structures near waterways

- If structures, such a roads or bikeways, are located close to creek banks, then active bank erosion can result in the need for stabilisation measures to be applied to the creek.
- Avoid placing assets:
  - adjacent to the outside of channel bends
  - within 15 m of the top of bank, or within a distance of three times the bank height from the toe of the bank (whichever is greater).

Permanent sediment extraction ponds

- If sediment inflows cannot be adequately managed through effective construction site erosion and sediment control, then sediment may need to be removed from urban waterways on a regular basis.
- As an alternative to disturbing large sectors of a waterway, consider the establishment of permanent sediment extraction ponds at key points along the waterway, such as upstream of culverts.

Minimising the inflow of sediments into lakes and wetlands

Creek bank stabilisation (Qld)

Introduction

- Urban lakes, wetlands, lagoons and estuaries can experience significant sedimentation problems that can eventually require the local authority to dredge the waterbody.
- Dredging these water bodies can result in the re-suspension of harmful pollutants.
- Actions can be taken to reduce the volume of sediment entering these waters.
- One of the first steps should be to actively stabilise all upstream waterways.

Building site ESC (Qld)

Building and construction site erosion and sediment control

- Effective erosion and sediment control practices must be applied to all building and construction sites within the catchment.
- Similar erosion and sediment controls need to be applied to all government projects.
- Key to the success of such activities is the policing policy, including the adoption of *Erosion and Sediment Control* officers.

Gross pollutant trap upstream of a lake

Gross pollutant traps

- Formal sediment traps should be established at major stormwater inflow points surrounding lakes and wetlands.
- The design of these 'gross pollutant traps' has changed significantly over the past few decades resulting in a growth of fully enclosed commercial products.
- A key design requirement is to minimise the annual cost of maintaining such pollutant traps.

Sedimentation pond adjacent a lake (USA)

Inflow sediment ponds

- Traditional gross pollutant traps combine the capture of coarse sediments and litter at one location.
- Alternatively, narrow ponds can be formed immediately upstream of urban lakes to act as sediment extraction ponds.
- The narrow width of the pond, and the design of the pond's embankment, allows the use of long-reach excavators (or other locally-available equipment) to easily de-silt the pond.

3. Site Assessment and Data Collection

Introduction

Site inspection (Qld)

Site inspection (Qld)

In-bank wildlife habitat (SA)

Fisheries construction code (Qld)

Introduction

- On construction projects, sufficient site data may have already been collected as a result of the design phase.
- However on maintenance projects, data collection may only commence in the weeks prior to the start of works.
- The timing of data collection will usually depend on what data is required in order to obtain the necessary government approvals.

Site assessment

- The following observations should be noted during the site inspection:
  - type of watercourse
  - site access points
  - stockpile and de-watering areas
  - dry-weather flow rate and water quality
  - flow depth (< or > 0.8 metres)
  - flow velocity
  - soil testing (as required).

Understanding the local environment

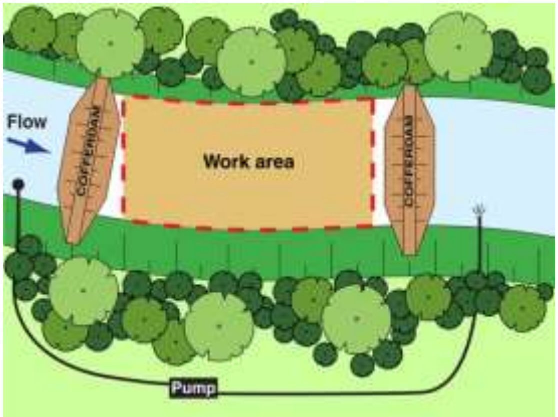
- Good environmental management requires an understanding of when the local wildlife moves, breeds and feeds both in and around the waterway.
- This information is needed in order to:
  - determine the environmental risks associated with the proposed works
  - determine if certain wildlife will need to be relocated
  - determine the rehabilitation requirements for the site.

Potential Fisheries issues

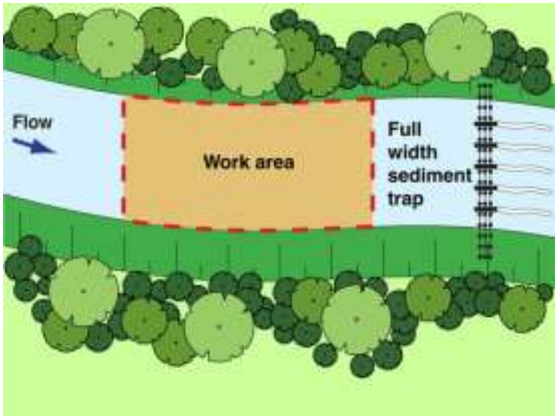
- Some states require Fisheries approval of any temporary waterway barrier, such as an instream sediment control system.
- Some states have produced self-assessable codes that must be applied if temporary instream barriers are installed, including the use of cofferdams.
- In Queensland, all waterways that require fish passage consideration have been mapped by the fisheries department.

Initial site assessment

Site inspection (Qld)



Full-width disturbance with cofferdams



Full-width instream sediment trap

Capture and relocation of fish (USA)

Site inspection

- It is during the initial site inspection that some key issues can be investigated.
- Issues such as:
  - Is there good access on both sides of the waterway?
  - Can the work be completed without having vehicles and equipment enter the waterway?
  - Will a tree survey or inspection be required to identify the best access points into the waterway?

Managing stream flows

- Site issues include:
  - Are stream flows expected while the instream works are being conducted?
  - If flows are possible, then can these flows be diverted around the instream disturbance?
  - If full-width bed disturbance is required, then can stream flows be ducted (gravity line) or pumped around the work activities?
  - Will the site need to be de-watered?

Managing sediment controls

- Site issues include:
  - Will it be necessary to incorporate instream sediment control measures (this should be avoided if possible)?
  - Will site de-watering require the water to be treated?
  - Will material de-watering require the water to be treated?
  - Will temporary sediment controls be required during the installation and removal of the main sediment trap?

Managing people and wildlife

- Site issues include:
  - Will it be necessary to maintain pedestrian access across the waterway?
  - Will it be necessary to maintain vehicle movement across the waterway?
  - Will it be necessary to maintain fish passage through the site while works are in progress?
  - Will existing wildlife (terrestrial or aquatic) need to be relocated?

Data collection

Inspection of gully erosion (Qld)

Floating silt curtain (Qld)

Limited site access (Qld)

Water pH testing (Qld)

The type of waterbody

- Knowing the characteristics of the watercourse, lake or wetland is important because:
  - it enables an assessment of the likely impacts that coarse and fine sediment will have on the waterbody
  - it can assist in the design of some flow diversion systems and instream sediment control measures
  - it can determine what types of government approvals and licences will be required.

Waterway characteristics

- Knowing the likely depth of the water will:
  - assist in the design of any flow diversion system
  - determine if silt curtains can be used.
- Knowing the velocity of the water can determine if floating silt curtains can be used.
- Knowing the flow rate will help in the design of any instream sediment control systems.

Riparian conditions

- A simple vegetation survey can assist in plant selection for site rehabilitation.
- Locating possible site access points can assist in determining how difficult it will be to transport materials into the site, and to remove waste products from the site:
  - Can the site be accessed from both sides of the waterway?
  - Is there space to de-water any earth or sediment removed from the site?
  - Is there good access for heavy machinery?

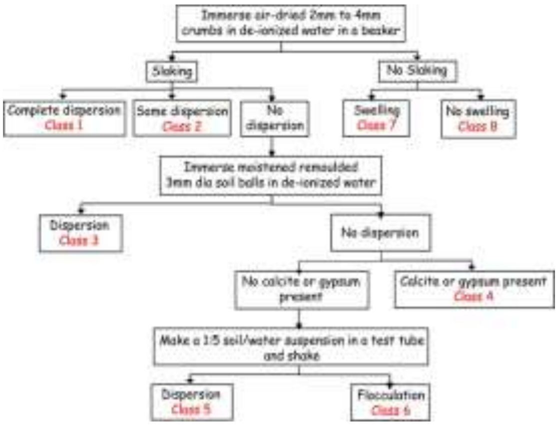
Water quality

- It is usually a government requirement that water quality testing must be performed:
  - before the works commence
  - while the instream works are occurring
  - and possibly after site rehabilitation reaches a specified condition.
- Water quality measurements may include: water pH, total suspended solids (TSS) and turbidity (NTU) readings.
- NTU is a better test because it allows instant results during on-site works.

Identifying problematic soils

ORGANIC MATTER		
Organic Matter	%	1.7
SALINITY		
Electrical Conductivity	dS/m	0.09
Chloride	mg/kg	28
Sodium	mg/kg	26
EXCHANGEABLE CATIONS		
Exchangeable Sodium	meq/100g	0.11
Exchangeable Potassium	meq/100g	0.37
Exchangeable Calcium	meq/100g	0.40
Exchangeable Magnesium	meq/100g	0.30
Exchangeable Aluminium	meq/100g	Not Applicable
Exchangeable Sodium Percent	%	9.6
Exchangeable Potassium Percent	%	31.6
Exchangeable Calcium Percent	%	33.4
Exchangeable Magnesium Percent	%	25.4
Exchangeable Aluminium Percent	%	Not Applicable
Cation Exchange	meq/100g	1.18
Calcium/Magnesium Ratio		1.32

Soil analysis



Emerson aggregate test

Water testing

Saline soils (SA)

Soil data

- It is not essential to get soil testing at every creek erosion site—in most cases just a visual inspection will provide all the necessary information.
- However, if the site inspection reveals possible ‘problematic soils’ (such as highly erodible soils, dispersive soils, slaking soils, or acid sulfate soils), then soil testing may be required.

Dispersive and slaking soils

- Dispersive soils can be identified through soil testing, such as:
  - exchangeable sodium percentage > 6%
  - Emerson aggregate classes 1 to 5, note classes 3(2), 3(1) and 5 have a slight risk of dispersive problems.
- A simple field test such as the Aggregate Immersion Test (see over page) can be used as an on-site indicator test.
- Dispersive soils may also be identified by their distinctive erosion patterns.

Acid sulfate soils

- Prior to the disturbance of soils below an elevation of 5 m AHD, the soil should be tested for its acid sulfate potential.
- Creek works that disturb acid sulfate soils can result in fish kills.
- Actual and potential acid sulfate soils must be managed in accordance with the state-approved guidelines.

Saline soils

- Saline soils can introduce complex revegetation problems.
- Saline soils can be identified through appropriate soil testing, such as:
  - electrical conductivity (EC) of either a 1:5 extract > 1.5 dS/m, or a saturated extract > 4 dS/m.
- Tree planting in saline soils requires expert advice.

Aggregate Immersion Test

Slightly dispersive soil

Non dispersive, non slaking soil

Dispersive soil

Slaking soil

Aggregate Immersion Test

- The ***Aggregate Immersion Test*** can be used as an 'indicator' of dispersive soils.
- The test involves filling a dish with distilled water (generally available at petrol stations and supermarkets) to a depth sufficient to cover the soil samples.
- Several dry hard clumps of soil are gently placed in the water.
- The water is then observed for colour changes (**after** all the air has escaped).

Non-dispersive soil

- If the water remains clear and the boundary of the soil clumps remains clearly defined, then the soil is likely to be non-dispersive.
- If the soil clumps are loose or otherwise heavily disturbed, then the soil will likely separate into smaller pieces when first placed into the water—this does not indicate that the soil is dispersive.
- Air escaping from the soil can also cause the clumps to fall apart—this also does not indicate that the soil is dispersive.

Dispersive soils

- If clay particles disperse both horizontally and vertically into the water, then the soil could be dispersive.
- Highly dispersive soils will collapse in less than 10 minutes.
- Caution; using tap, tank or groundwater can sometimes mask the dispersive reaction due to minerals and/or chemicals in the water; hence the need to use distilled water.

Slaking soils

- Slaking soils are soils that readily collapse in water, but do not necessarily 'colour' the water.
- If the water remains clear, and the clumps completely collapse and **spread horizontally**, then the soil could be a slaking soil.
- Slaking soils commonly occur within regions containing granite rock.
- These soils can be highly erodible, especially if disturbed by floodwater.

Dispersive and slaking soils

Fluting erosion

Fluting

- In dispersive or sodic soils the rills passing down steep banks and batters are normally deep, narrow and regularly spaced—a form of erosion known as 'fluting'.
- Dispersive soils are sometimes referred to as sodic soil (because of the high sodium content), or sugary soils (because they produce a lot of 'washed' sand when they erode).

Bank not exposed to direct rainfall

Textured surface

- Both dispersive and slaking soils can display textured patterns on soil surfaces that are <u>not</u> directly exposed to rainfall.
- These surfaces become textured as a result of raindrop splash bouncing off adjacent soil surfaces.

Deep rilling and tunnel erosion

Tunnel erosion

- Tunnel erosion is typically an indicator of dispersive or sodic soils.
- Tunnel erosion can initially appear as just another example of bank rilling, until further investigations discover that tunnel erosion exists further up the bank.

Rilling that extends to top of bank

Rilling that extends to the top of the bank

- If the rilling extends to the top of the bank, then this **may** indicate that the erosion is influenced by run-on water.
- In such cases, investigate the drainage conditions coming off the floodplain.
- However, this can also indicate that the soil is dispersive all the way to the top of bank.
- If the soils are dispersive (sodic) then they will need to be ameliorated with such chemicals as gypsum to reduce the dispersivity and help stabilise the soil.

Visual identification of dispersive and slaking soils

Caboolture, Queensland

Visual indicators of dispersive soils

- As previously discussed, dispersive soils can often be identified by the existence of regular-spaced rilling (fluting) or their often textured erosion patterns.
- In Australia, dispersive soils are more commonly associated with examples of gully erosion, but these soils can still be exposed by recent erosion activities on creek banks.

Brisbane, Queensland

Ipswich, Queensland

Springsure, Queensland

Miles, Queensland

Coverty, Queensland

Broken Hill, NSW

Site and performance monitoring

Site inspection (Qld)

Trapped wildlife (Qld)

Water pH testing (Qld)

Post-work site inspection (NSW)

Introduction

- Site inspections and water quality sampling must occur at regular intervals while instream disturbances are active.
- On high-risk sites, these inspections should be carried out by a separate body.
- On local government work sites, site inspections and water quality monitoring may need to be carried out by the council's environment or waterway division.

Site inspections

- Site inspections should check for:
  - safety issues
  - damage or movement of ESC measures
  - excessive sediment blockage of sediment controls
  - trapped wildlife
  - litter or rubbish dumped by people entering the site after hours.

Water quality sampling

- It is usually a government requirement that water quality testing must be performed:
  - before the works commence, and
  - while the instream works are occurring.
- Water quality measurements may include; water pH, total suspended solids (TSS) or turbidity (NTU) readings.
- Local governments should retain all water quality data in a central data base that should be professionally reviewed annually.

End-of-job site inspection

- A final end of project site inspection should be conducted by an experienced waterways officer.
- In some cases the state government will need to be notified so that they can carry out a similar site inspection as part of the waterway permit requirements.
- Site photographs should be stored on the council's central data base.

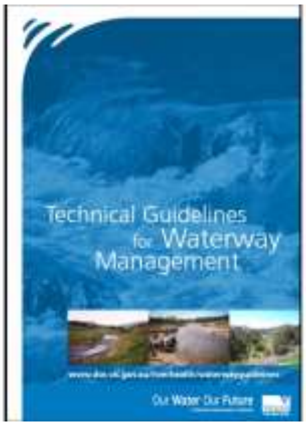
4. Planning Instream Work Activities

Introduction

Site inspection (Qld)

Introduction

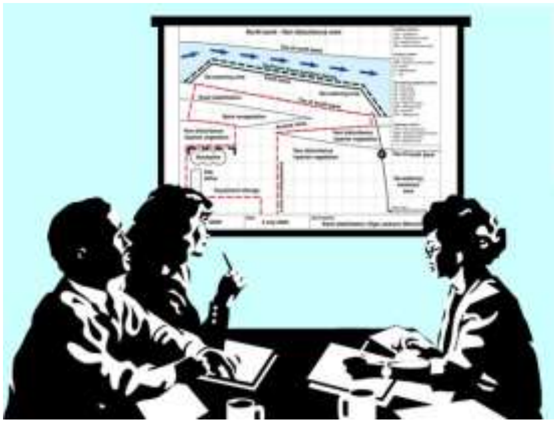
- Good site planning can help to minimise environmental impacts resulting from instream works.
- Site planning involves consideration of:
  - the appropriate scheduling of instream works
  - how the work activities will be conducted
  - design of the channel rehabilitation activities.



Victorian waterway management

Government guidelines

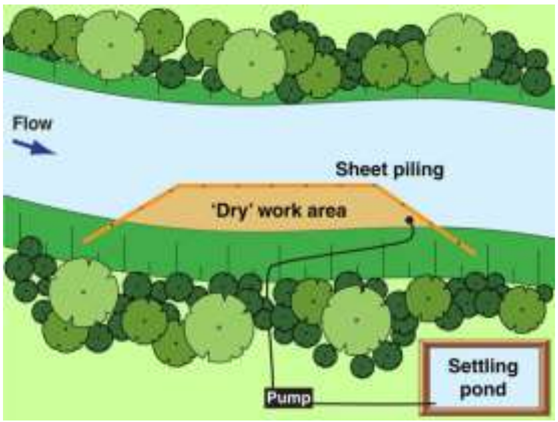
- Numerous federal, state and local guidelines exist on the management of waterways and on the design of engineered structures located in and around waterways.
- Where appropriate, these guidelines should be reviewed and followed when designing instream work activities.



Team meeting

The planning and design team

- Good site planning usually requires input from various professionals, including:
  - freshwater or marine ecologists to assess the environmental values and any potential threats to these values
  - waterway officers and/or hydraulic engineers to assess hydraulic risks and advise on site rehabilitation
  - revegetation or bushland officers to advise on site rehabilitation
  - construction or maintenance personnel to ensure practical outcomes.



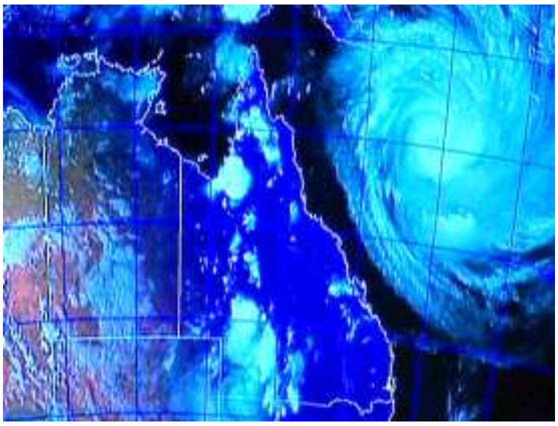
Standardised ESC plans

Standardised ESC plans

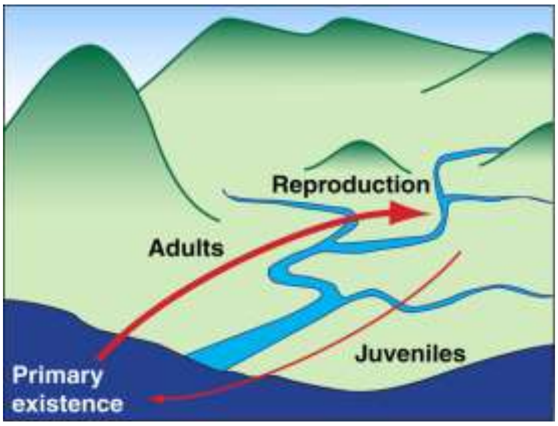
- Council's creek maintenance program often involves repeating the same work activity from site to site, and from year to year.
- In such cases it may be appropriate for the council to develop standard Erosion and Sediment Control (ESC) plans, or a maintenance manual.
- These plans can refer to separate fact sheets for the installation and use of common ESC measures.

Scheduling of instream works

Migrating fish (Qld)



Cyclone season (Qld)



Anadromous fish migration

Australian Ramsar wetlands

Introduction

- One of the keys to minimising environmental harm is to program instream works to occur at the least vulnerable times of the year.
- Issues include:
  - expected weather conditions and stream flow rates
  - periods of known fish migration
  - periods of annual aquatic bird nesting and/or migration
  - other relevant environmental factors.

Consideration of weather conditions

- In regions where there are clearly defined wet and dry seasons, instream works should, wherever practical, be scheduled for the dry season.
- The Bureau of Meteorology can provide information on typical weather conditions throughout a year.
- Similarly, instream disturbances should avoid periods when stream flows are expected to be high.

Consideration of fish migration

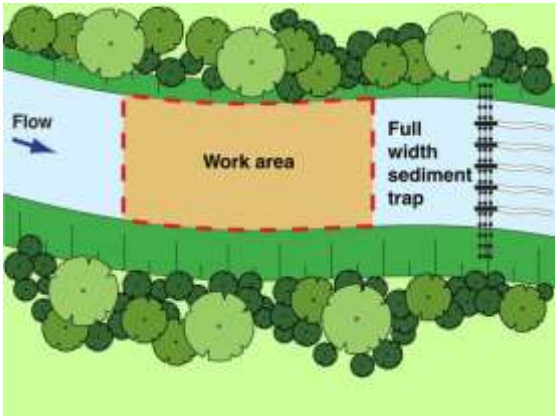
- There is a recognised difference between the terms ‘fish passage’ and ‘fish migration’.
- The term *fish passage* generally refers to the everyday movement of fish.
- The term *fish migration* refers to a specific aspect of fish passage where fish need to migrate along a waterway as part of their life cycle.
- Instream works should <u>not</u> occur during periods of fish migration.

Consideration of other factors

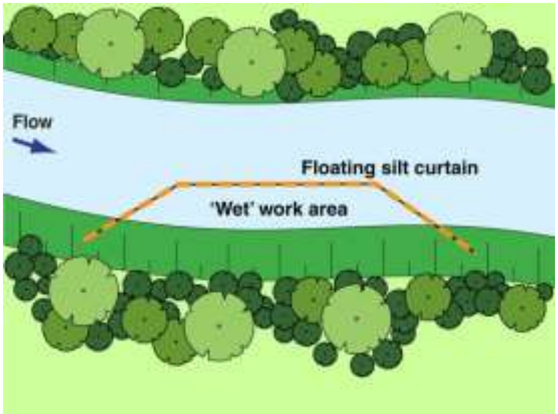
- Ecological activity in and around a waterway, both terrestrial and aquatic, is usually highly variable throughout the year; therefore, the potential impacts of instream disturbances also vary throughout the year.
- Instream disturbances should avoid known periods of bird nesting and migration.
- Works around Ramsar listed wetlands need special attention and the appropriate timing of such disturbances.

Consideration of alternative work procedures

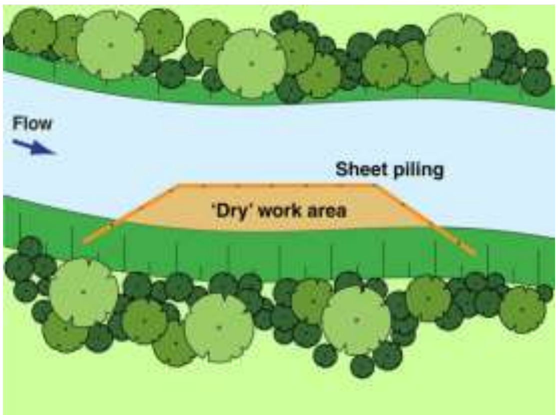
Site de-watering



Full-width bed disturbance



'Wet' work area



'Dry' work area

Introduction

- There is almost always more than one way of conducting instream work activities.
- Work options are typically based on:
  - is full-width bed disturbance required
  - can the works be isolated from stream flows
  - will it be necessary to create a dry work area
  - will site de-watering be required
  - will sediment de-watering be required.

Full-width bed disturbance

- If it is necessary to cause soil disturbance across the full width of the channel without staging the disturbance, then:
  - will it be possible to conduct the works during a period of zero flow
  - can stream flows be diverted around the disturbance (e.g. bypass channel or a pumped bypass)
  - in small waterways it may be possible to use a full-width instream sediment trap (usually the least preferred option).

Isolated work sites

- If only partial bed disturbance is required, or if the works can be staged into isolated areas of disturbance, then:
  - where possible, still try to conduct the works during a period of zero flow.

Otherwise:

- a porous flow diversion barrier could be used to isolate a 'wet' work area, or
- an impervious flow diversion barrier may be needed to form a 'dry' work area.

Dry work sites

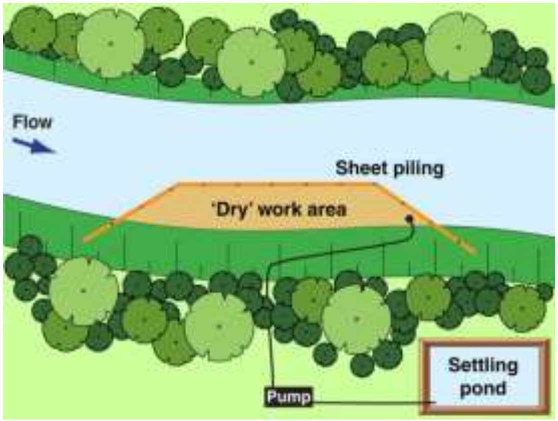
- If it will be necessary to establish a dry work area, then:
  - where possible, try to conduct the works during a period of zero flow.

Otherwise:

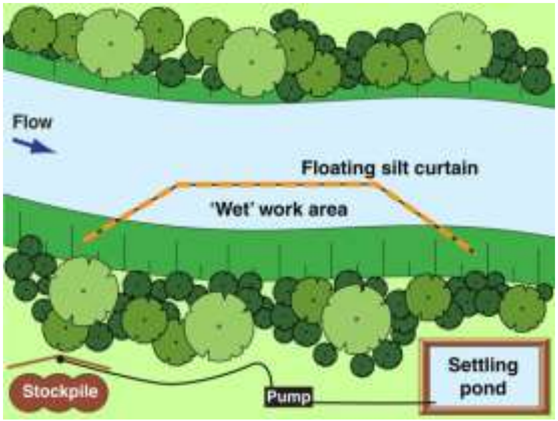
- use an isolation barrier to isolate the work area from the stream flow, and
- use pumps to de-water the area and direct such water to an off-stream sediment control system.

Consideration of alternative work procedures

Construction of a culvert base slab (Qld)



Site de-watering



Stockpile de-watering

De-watering filter pond (Qld)

Culvert construction

- The construction of waterway culverts usually requires full-width bed disturbance in order to construct the base slab.
- Even though it is technically possible to construct such base slabs in stages, such work practices are likely to be resisted because:
  - this will require a redesign of the slab reinforcing, and
  - increased construction costs.

Site de-watering

- If site de-watering is going to be required, then the treatment options include:
  - pumping the water to a point where it can be released as sheet flow over a well grassed area
  - pumping the water to a temporary irrigation system that can spread the water over a large vegetated area
  - pumping the water to an off-stream sediment control system, such as a settling pond.

Sediment de-watering

- Material removed from the waterbody usually needs to be de-watered before being transported off the site.
- Treatment options include:
  - initially stockpile the material within the isolation area so it can drain excess water (which is then treated with the rest of the site de-watering)
  - stockpile the material at a suitable off-stream location well away from the waterbody so that the draining water can infiltrate into the soil
  - stockpile the material in an off-stream location where the draining water can be collected within a sump pit, then pumped to a filtration system
  - stockpile the material in an off-stream location where the draining water passes through a Type 2 sediment control system before re-entering the waterbody
  - place the material directly in a truck that then moves to a suitable location away from the waterbody where it allows the material to slowly de-water through the trucks rear gate.

Erosion and Sediment Control Plans

De-silting a storm drain outlet (Qld)

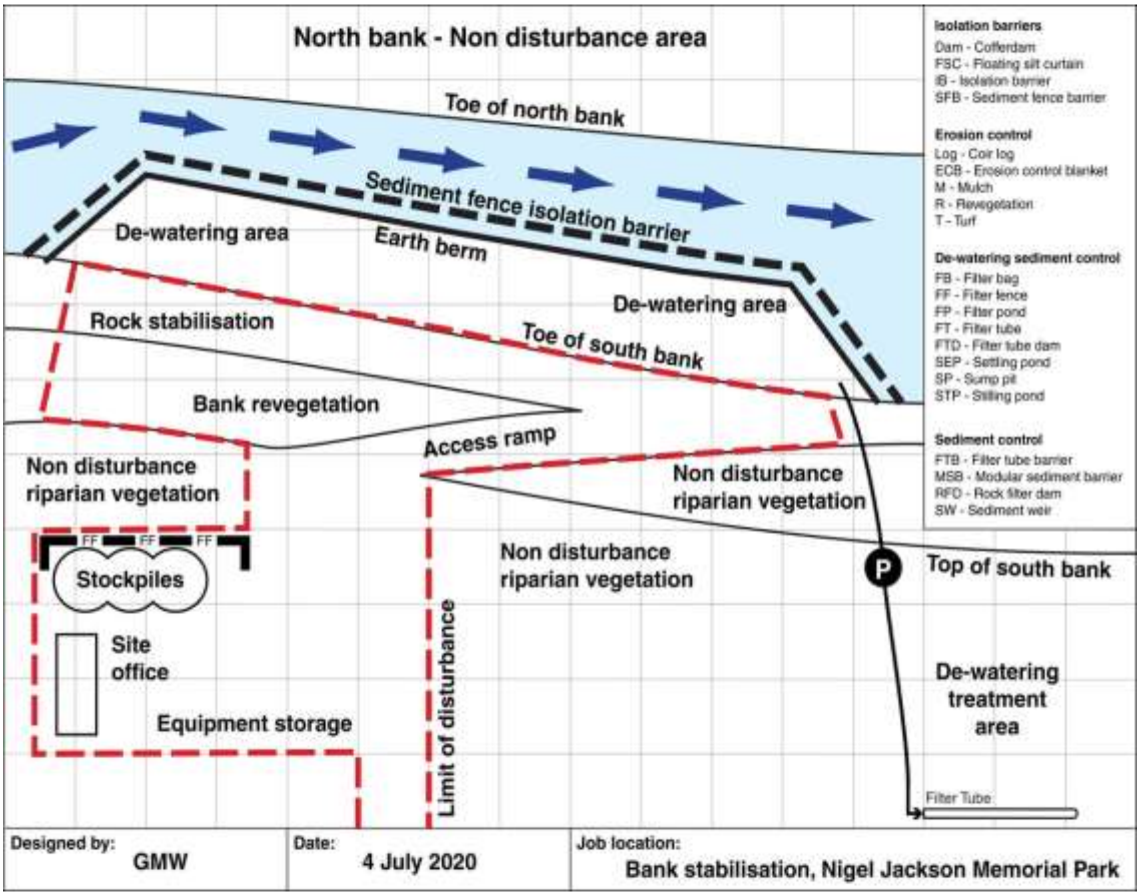
Creek bank stabilisation (Qld)

Minor instream works

- The level of detail supplied in the *Erosion and Sediment Control Plan* (ESCP) must be commensurate with the complexity of the proposal and the assessed environmental risk.
- On low-risk sites, such as routine council maintenance projects:
  - the plans may be simple sketches, such as shown below
  - alternatively, councils may choose to develop generic plans for those tasks that are repeated annually.

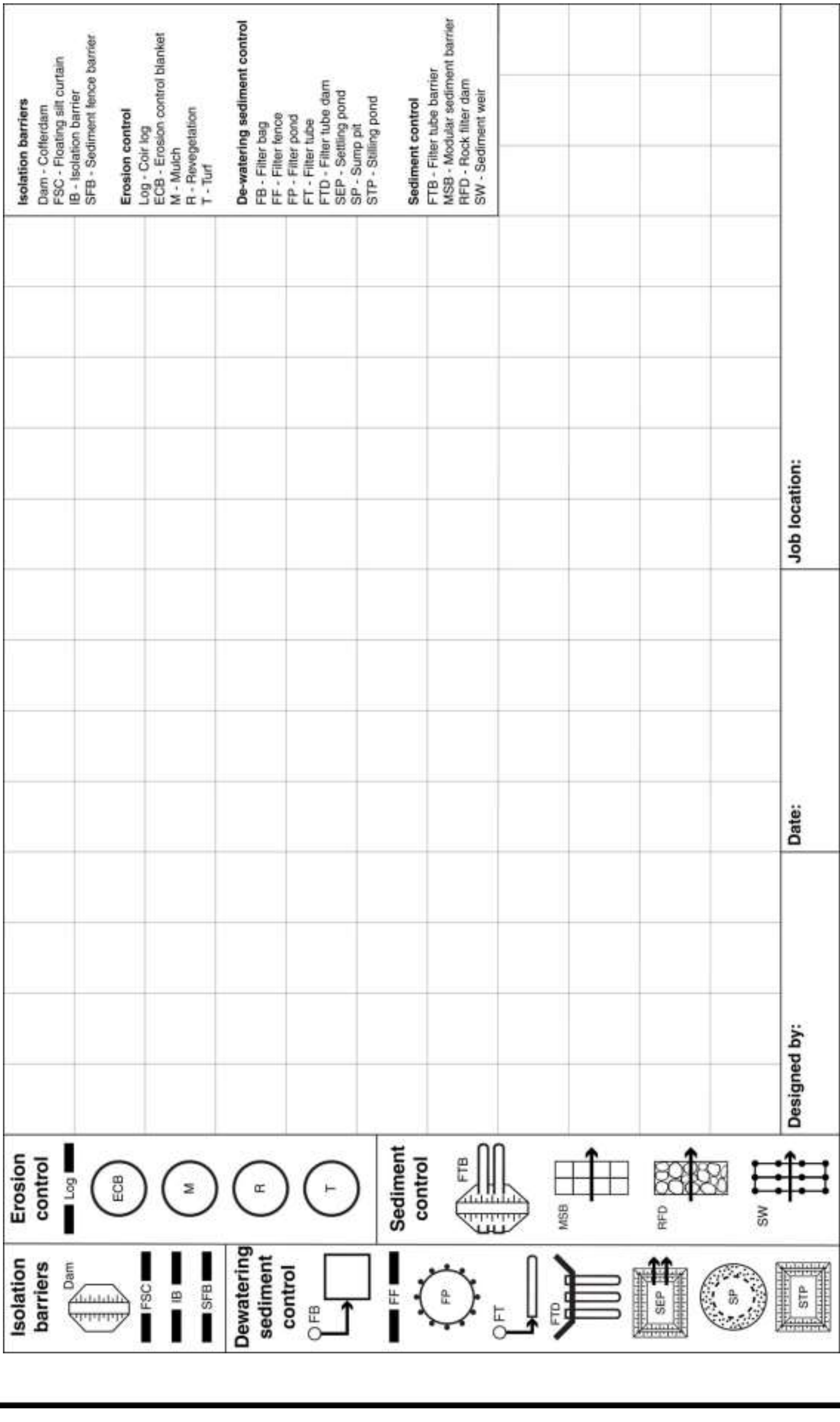
Major instream construction projects

- For major construction projects, the ESCP may need to consist of several plans, including:
  - limits of site disturbance
  - temporary ESC measures applied during site establishment
  - the primary ESC plans
  - site rehabilitation plans.
- Specialist advice may be required from a waterway ecologist if major channel disturbance is required.



Example Erosion and Sediment Control Plan for a bank stabilisation project

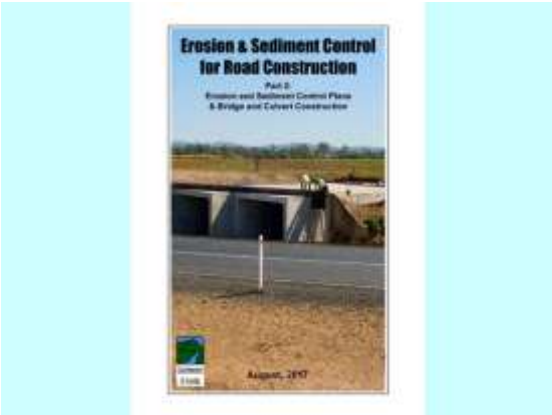
Erosion and Sediment Control Plan (example template)



5. Bridge, Culvert and Pipeline Construction

Introduction

Bridge construction (NSW)



Road Construction field guide, Part 2

Culvert construction (Qld)

Pipeline installation field guide, Part 2

Introduction

- Waterway construction projects typically consist of:
  - bridge and arch construction
  - waterway culverts
  - pipeline crossings
  - dams and weirs
  - constructed lakes and waterways
- Unlike waterway maintenance, these construction projects usually take several months to complete.

Bridge construction

- Expanded discussion on erosion and sediment control practices during the construction of roads, bridges and culverts can be found in a separate *Catchments and Creeks* field guide:
  - Erosion and Sediment Control for Road Construction (parts 1 and 2)
- Part 2 of this road construction field guide contains information on bridge and culvert construction.

Culvert construction

- Culvert designs include:
  - pipe culverts
  - box culverts
  - recessed culverts
- The construction of box culverts is complicated by the need to first form a base slab, which normally requires the temporary diversion of stream flows.
- Fish-friendly recessed culverts further complicate the issue by requiring deep excavation of the waterway bed.

Pipeline crossings of waterways

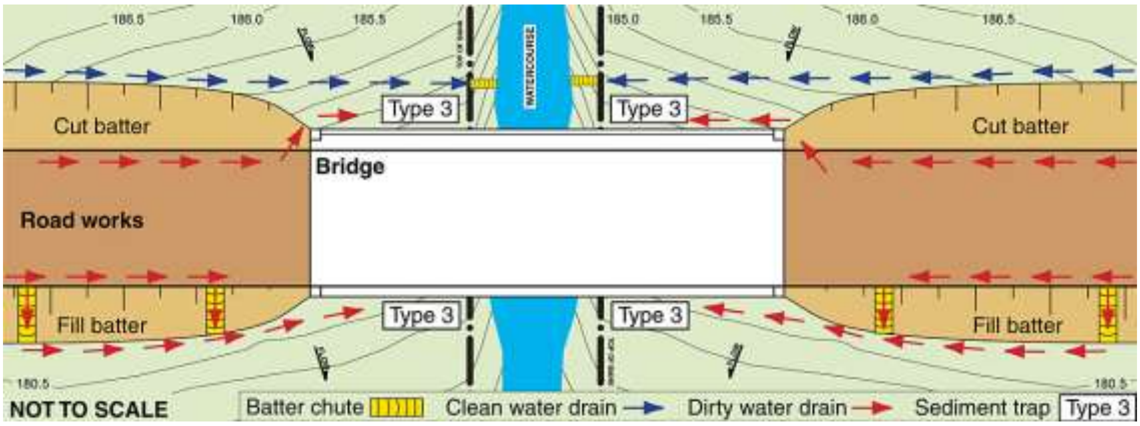
- Expanded discussion on erosion and sediment control practices during the installation of pipelines can be found in a separate *Catchments and Creeks* field guide:
  - Erosion and Sediment Control Field Guide for Pipeline Projects (parts 1 & 2)
- Part 2 of this field guide contains information on the construction of pipeline crossings across drainage lines and waterways.

Sediment controls for road construction over waterways

Sediment fence (Type 3 sediment trap)

Type 3 sediment controls

- The use of a Type 3 sediment trap is appropriate when:
  - total up-slope catchment (clean & dirty) is less than 0.25 ha, and
  - soil loss rate < 75 t/ha/yr.
- Typical Type 3 sediment traps include:
  - Sediment fence
  - U-shaped sediment traps

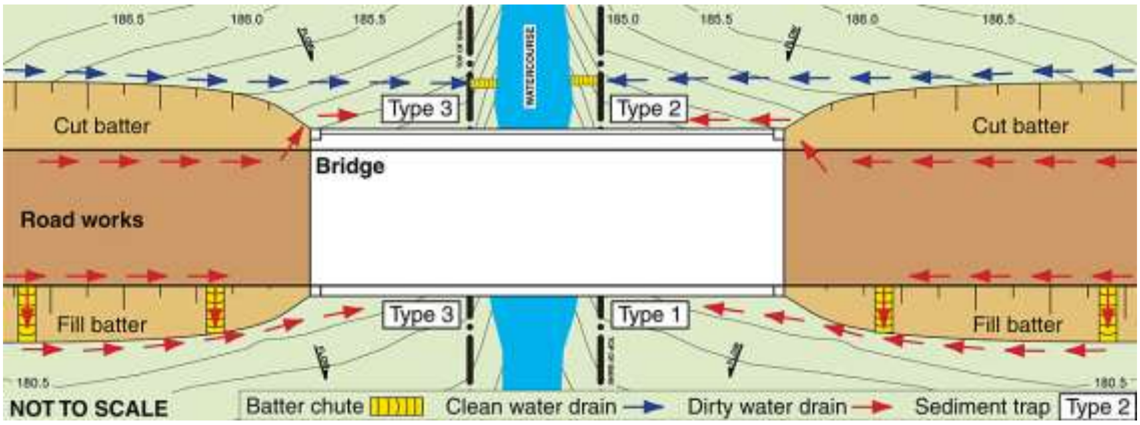


ESC measures for road works over a waterway with minimal road runoff catchment

Rock filter dams (Type 2 sediment trap)

Type 2 sediment controls

- Placement of Type 2 sediment traps each side of a bridge or culvert construction is appropriate when:
  - the contributing catchment area is less than 0.25 ha and the soil loss rate is greater than 75 t/ha/yr, OR
  - the contributing catchment area is greater than 0.25 ha and the soil loss rate is less than 150 t/ha/yr.
- Differences in the sub-catchment areas could mean different sediment traps are required in each quadrant.



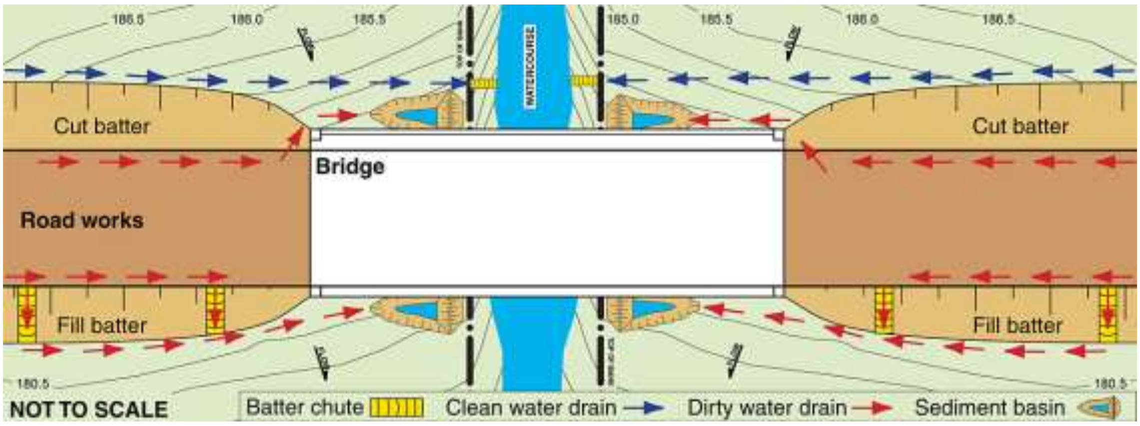
ESC measures for road works over a waterway with variable catchment areas

Sediment controls for road construction over waterways

Sediment basins (Type 1 sediment trap)

Type 1 sediment controls

- Placement of Type 1 sediment traps each side of a bridge or culvert construction is appropriate when:
  - the contributing catchment area is greater than 0.25 ha, or
  - soil loss rate > 150 t/ha/yr.
- Not all of the clean and dirty water drains shown below will be operational during each phase of the road construction.
- The contributing catchment area can include both the road and batter runoff.

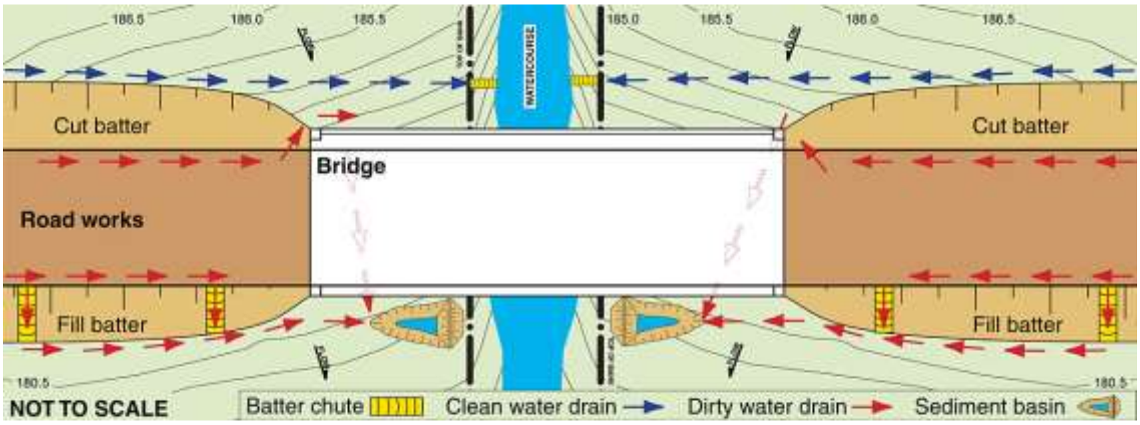


ESC measures for road works over a waterway with significant dirty water runoff

Sediment basin (Type 1 sediment trap)

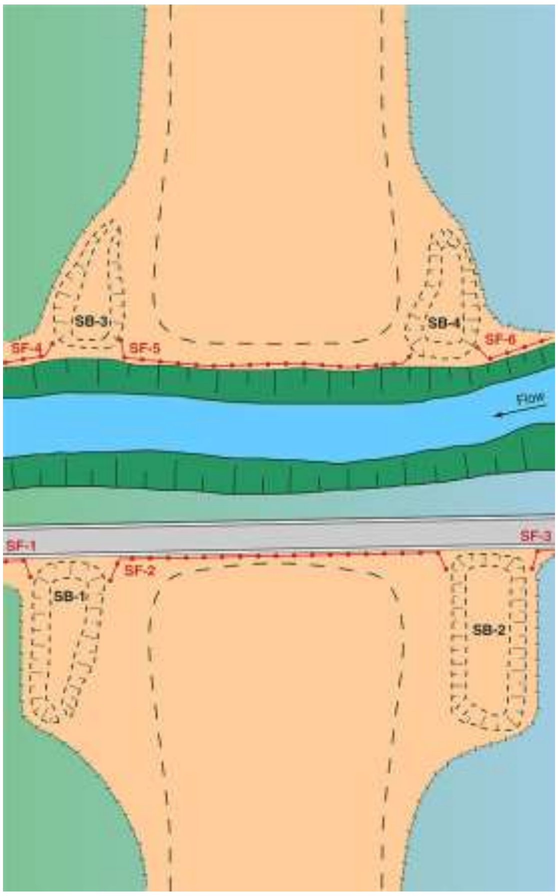
Alternative drainage layouts

- The number of required sediment traps can be reduced if sediment-laden runoff from both sides of the roadway can be diverted to a single sediment trap located each side of the waterway.



Alternative layout with dirty water directed under the bridge towards the basins

Example construction sequence

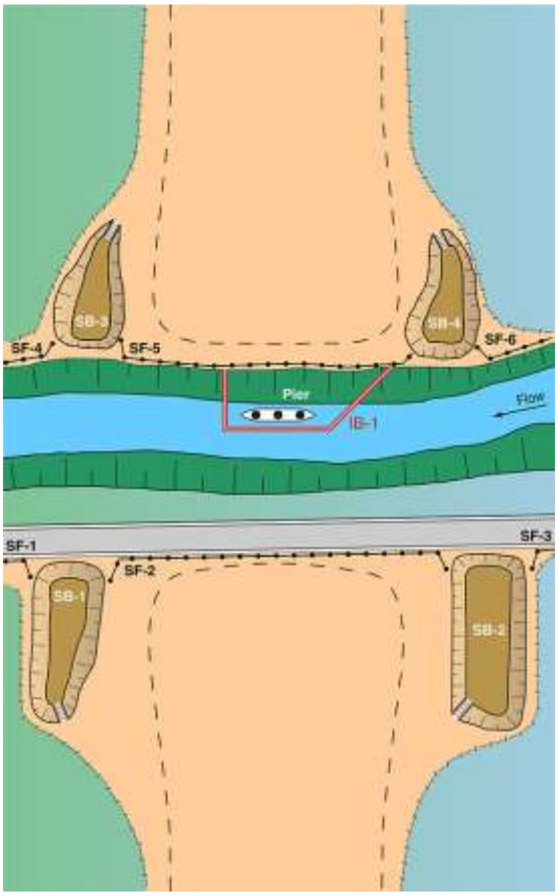


Stage 1

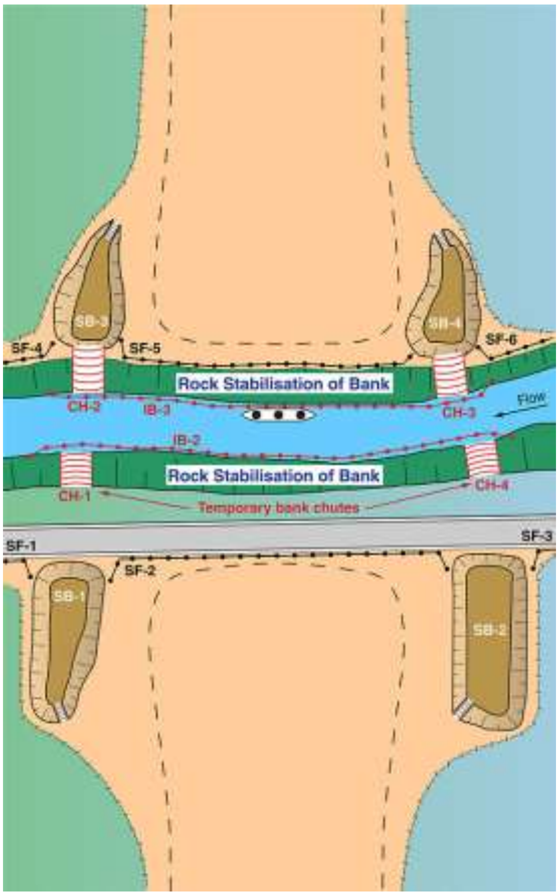
Bridge construction (NSW)

ESC practices for bridge construction

- Erosion and sediment control practices typically include:
  - marking out non-disturbance areas
  - sediment fence (SF) located along down-slope edge of land clearing (riparian vegetation should not be cleared unnecessarily)
  - construction of sediment basins (SB)
  - isolation barriers (IB) around piers
  - sediment fence isolation barrier or silt curtain installed along the water's edge.

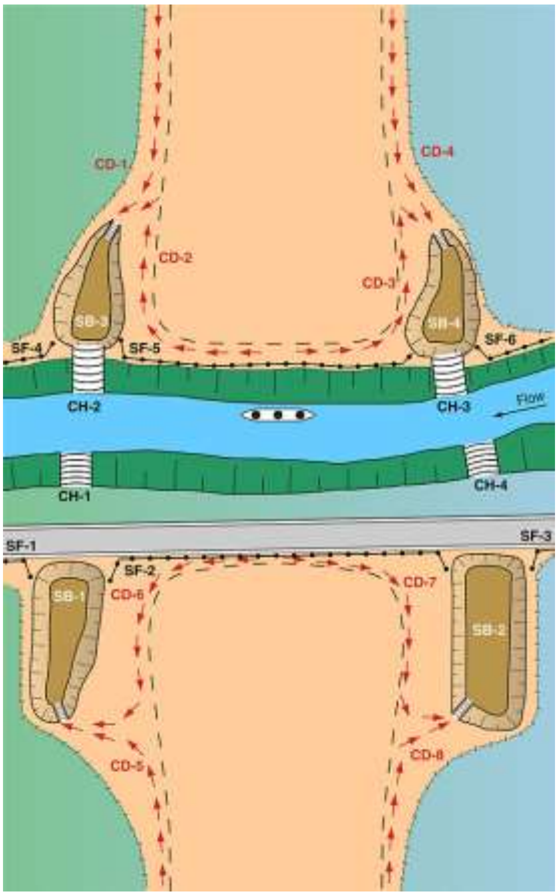


Stage 2



Stage 3

Example construction sequence

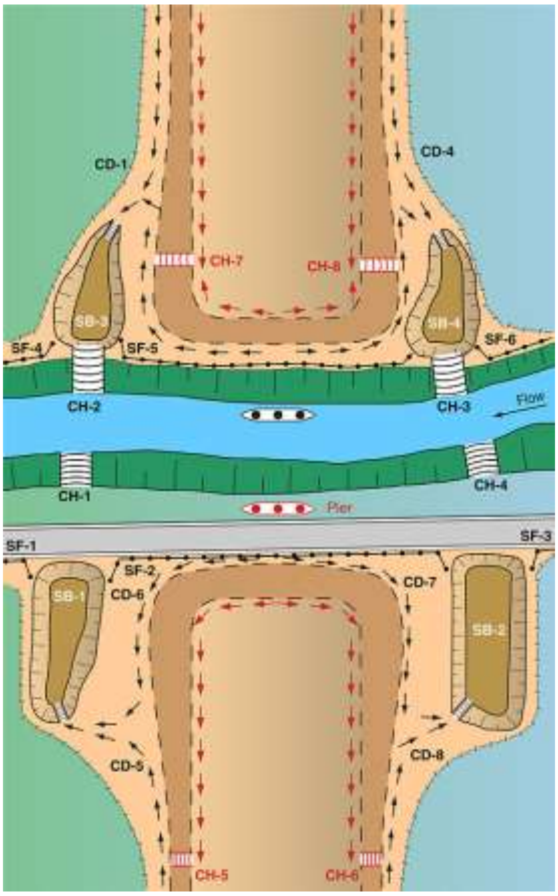


Stage 4

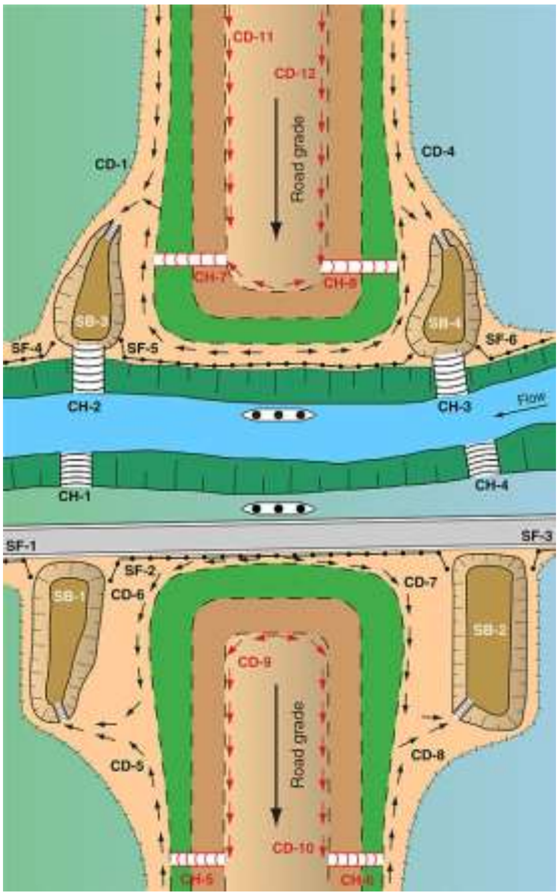
Bridge construction (Qld)

ESC practices for bridge construction

- Erosion and sediment control practices typically include:
  - temporary catch drains (CD) to direct dirty water to sediment basins
  - earth windrows formed along the edge of embankment works in the event of imminent rainfall
  - temporary filter cloth (or other) batter chutes (CH) to direct embankment runoff down recently formed fill batters.

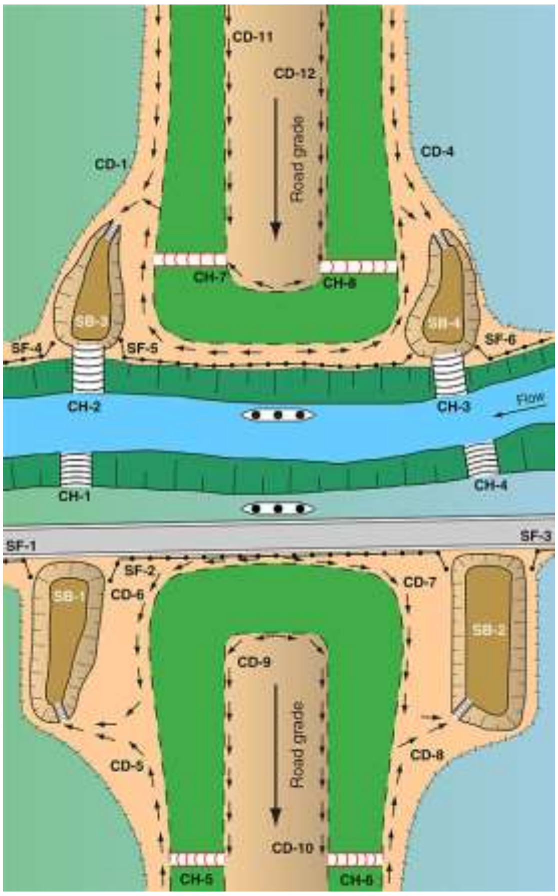


Stage 5



Stage 6

Example construction sequence

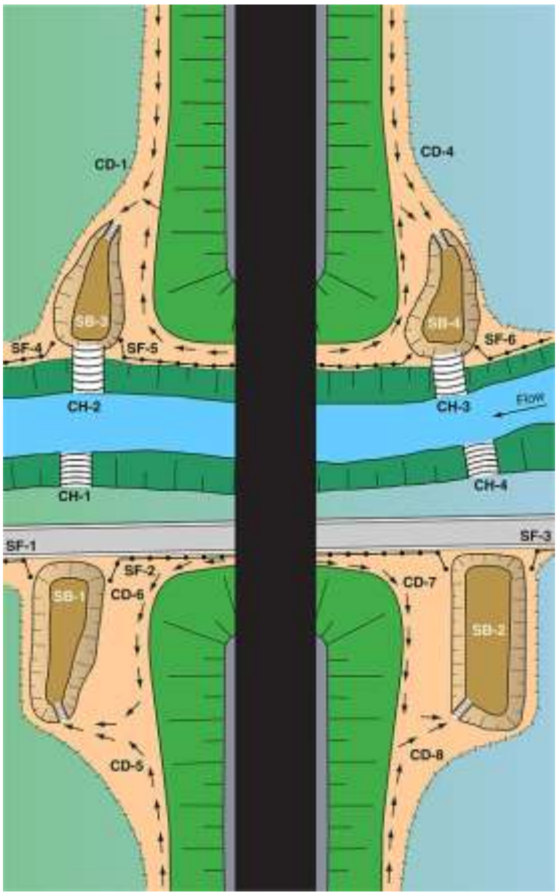


Stage 7

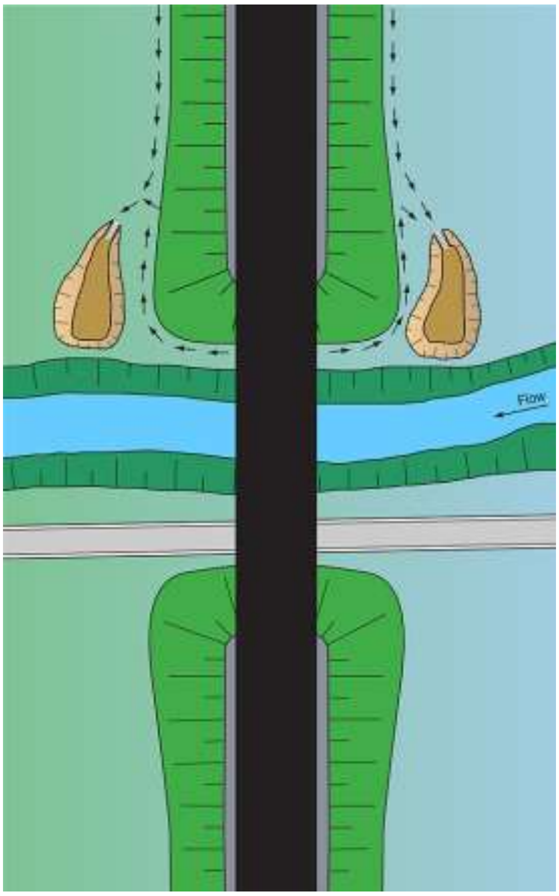
Bridge construction (NSW)

ESC practices for bridge construction

- Erosion and sediment control practices typically include:
  - batter stabilisation measures applied to fill embankments after the embankment exceeds a height of 3 m, and then after each further 3 m rise
  - batter revegetation applied as soon as practical
  - major sediment traps converted into permanent stormwater treatment ponds
  - disturbed areas revegetated.

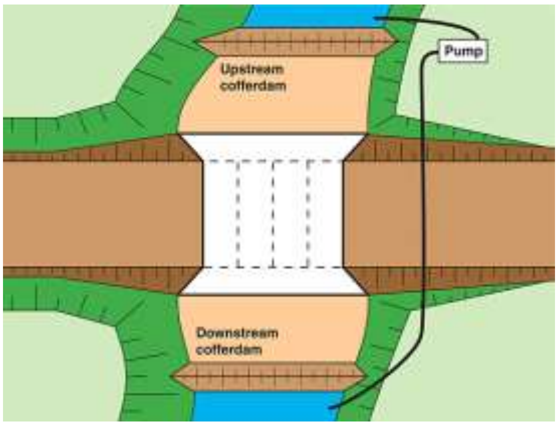


Stage 8

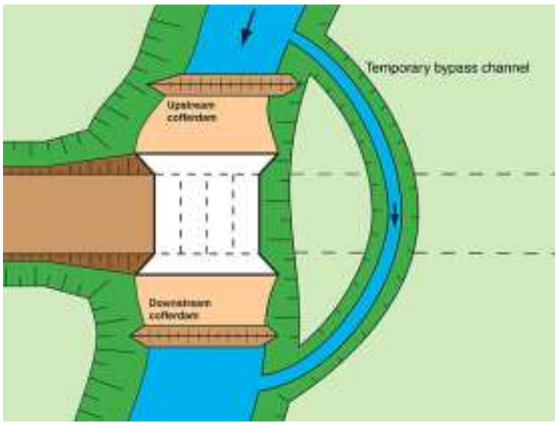


Final road layout with retained basins

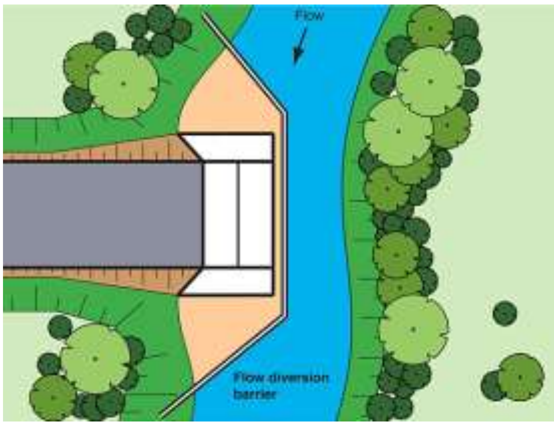
Culvert construction



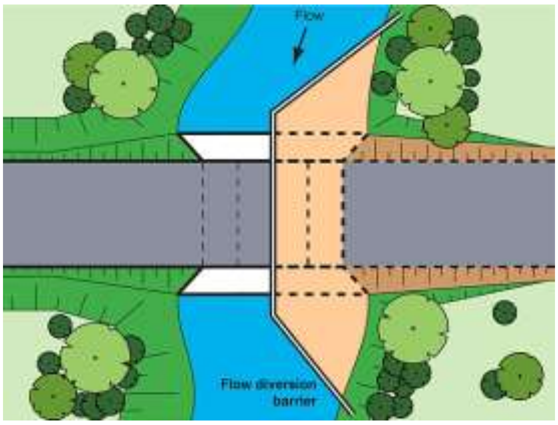
Use of cofferdams



Construction of a bypass channel



Stage 1



Stage 2

Usage of cofferdams

- The degree of complexity of the culvert construction increases significantly if it is necessary to maintain stream flows, fish passage, and/or public access during the construction phase.
- Stream flows can be maintained by:
  - providing a pumped bypass
  - installing a gravity-flow pipeline that can be easily relocated
  - constructing a bypass channel
  - staging the instream disturbance.

Bypass channels

- If base flows within the waterway are significant, then it is preferable for the waterway crossing to consist of a bridge rather than a culvert.
- If a culvert is to be constructed across such a waterway, then the construction practice may involve the construction of a temporary bypass channel.
- However, such bypass channels may not provide suitable fish passage conditions.

Staged construction

- The staging of a culvert construction is not currently considered normal practice because of the construction difficulties and expense.
- Advice on the practicality of such construction methods must be obtained from experienced personnel prior to adopting such a construction process.
- The 'staged' construction of a culvert will likely require a re-design of the base slab reinforcing.
- Such complex construction practices can be avoided by:
  - constructing bridges or arch structures over critical fish habitats
  - constructing culverts during the dry season
  - constructing culverts during periods when fish are not migrating along the waterway
  - considering the option of a pipe culvert instead of a box culvert.

Site issues that can influence culvert construction

Culvert construction (Qld)

Construction procedure

- There is more than one way to build a culvert, causeway or bridge.
- The method of construction can be influenced by many factors, including:
  - available funds
  - the type of structure
  - flow conditions within the waterway
  - fish passage requirements
  - land use adjacent to the structure
  - the existing road structure and the need to maintain traffic flow.

Culvert construction in a dry channel (NT)

Stream flow conditions

- The construction procedure is critically dependent on the expected stream flows.
- The construction of a base slab is obviously much easier and cost-effective if the works are scheduled for periods when stream flows are either non existent or easily managed.

Elevated stream flow conditions (Qld)

The risk of elevated stream flows

- Elevated stream flows can result from local or distant rainfall.
- Many parts of Australia experience only seasonal rainfall and stream flows, so different construction procedures will need to be employed during the dry and wet seasons.
- The methods for flow bypassing vary depending on the expected stream flow.

Construction of a culvert base slab (Qld)

The need for bed disturbance

- Bridge and arch construction has the advantage of requiring minimal disturbance to the bed of the waterway.
- Pipe culverts also have the advantage of reduced bed disturbance (relative to box culverts); however, the waterway bed still needs to be isolated from stream flows.
- The construction of box culverts requires the construction of a base slab, which requires the bed to be isolated from stream flows.

Site issues that can influence culvert construction

Isolation barrier (HSI Services, USA)

Maintaining stream flows

- If it is necessary to maintain stream flows during the construction period, then it may be necessary to construct the culvert in stages isolated from stream flows.
- The use of impervious isolation barriers is discussed in Chapter 6.

Freshwater fish passage (SA)

Maintaining fish passage

- Potential impacts on fish passage can vary significantly across the country.
- Further discussion is provided on the next page.

Temporary bypass road (Qld)

Maintaining public access across the waterway

- Bridge and culvert construction is often preceded by the construction of a temporary bypass road to allow ongoing traffic movement.
- The fish passage requirements for the temporary culvert placed under these bypass roads can vary significantly from location to location.

Temporary stream crossing (Qld)

Construction of vehicle access across the waterway

- A temporary stream crossing may also be needed to allow the movement of construction vehicles across the waterway.
- Temporary stream crossings may consist of:
  - piped culvert
  - culvert 'bridging slab'
  - ford crossing (alluvial streams).

Fish passage considerations

Estuary fish (NSW)

Signage at in-stream works (Qld)

Retention of tree root system (Qld)

Natural bank vegetation (Qld)

Fish passage

- Fish passage considerations and management strategies need to be discussed with the local Fisheries office.
- Some states may have specific legislation or self-assessable codes that address issues such as:
  - the maximum allowable duration of instream works and/or the existence of temporary fish barriers
  - the time of year when works can occur
  - required bank rehabilitation measures.

Notification and signage of works

- Requirements for on-site signage of approved works vary across the country.
- In some states, all instream works will require both pre-works and post-works notification with the local Fisheries office.
- Such rules may also apply to works conducted under self-assessable codes.
- It is important to note how rules can change during periods of 'fish migration' as compared to general 'fish passage'.

Vegetation clearing on bed and banks

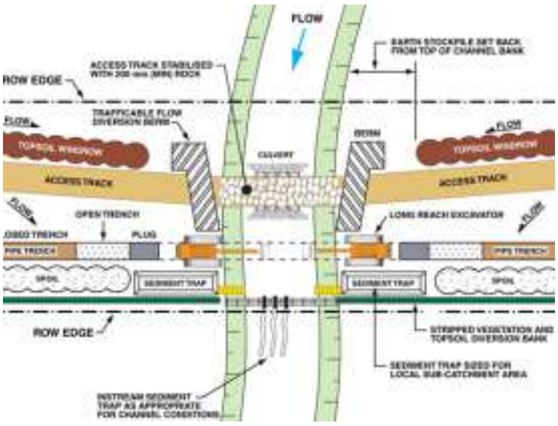
- If it is necessary to remove vegetation (marine, aquatic or riparian) from the bed and banks; then wherever practical, this vegetation should be cut no lower than ground level, with the roots left in the ground to aid soil stabilisation.
- Ideally, roots should only be removed within the region of any required engineering works.
- The application of such environmental practices will vary from site to site.

Bank rehabilitation

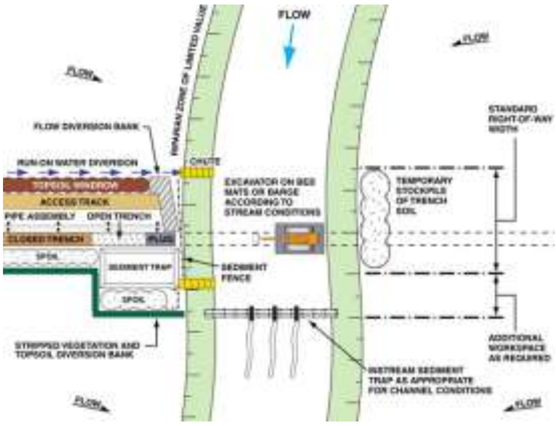
- In some cases it may be a requirement to re-establish native vegetation over the channel's bed and banks.
- However, this may not be appropriate with respect to establishing vegetation under a bridge deck, or integrating vegetation into the abutment and bank stabilisation measures.
- It is important to understand how certain plants can assist in providing beneficial fish passage conditions under a bridge.

Pipe crossings of waterways

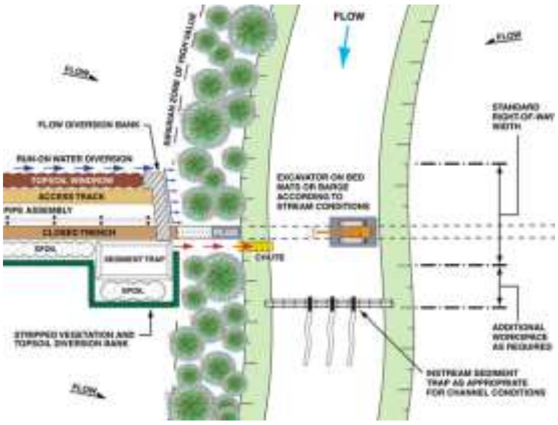
APIA Code of Environmental Practice



Minor waterway



Shallow-bed waterway



Protection of a riparian zone

Pipeline crossings

- An expanded discussion on the construction of pipeline crossings can be found in:
  - Erosion and Sediment Control Field Guide for Pipeline Projects – Part 2, Catchments and Creeks (2017)
  - Code of Environmental Practice – Onshore Pipelines, Australian Pipelines Industry Association Ltd (2013)
  - Pipeline Associated Watercourse Crossings, Canada (2005)

Open cut across a small waterway

- This construction method may be suitable for drainage lines, dry-bed waterways, and non-flowing shallow (typically, < 1 m) water bodies.
- Suitable for alluvial (sand or gravel-based) waterways where the excavator can reach well below that part of the substrate that is likely to migrate during severe floods.
- May not be suitable if the waterway bed contains large boulders or shallow bedrock.

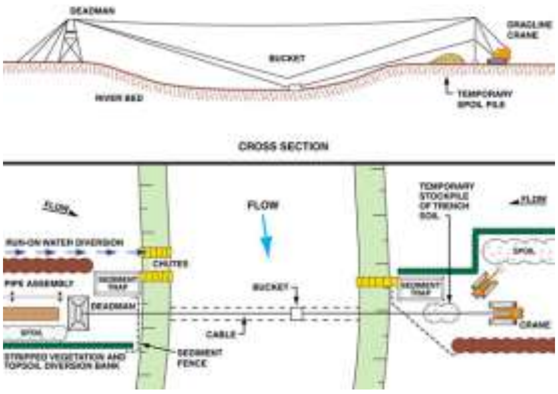
Open cut across a large ephemeral waterway

- Suitable for the crossing of large dry-bed waterways, and non-flowing shallow (typically, < 1 m) water bodies.
- Suitable for alluvial (sand or gravel-based) waterways where the excavator can reach well below that part of the substrate that is likely to migrate during severe floods.
- May not be suitable if the waterway bed contains large boulders or shallow bedrock.

Open cut across a waterway with existing riparian vegetation

- Riparian vegetation plays an important role in the function of natural waterways, including bank stability, terrestrial habitat, and fish passage during flood events.
- Construction practices should aim to minimise overall disturbance to the riparian zone.
- The critical width of the riparian zone varies from waterway to waterway—refer to local guidelines.

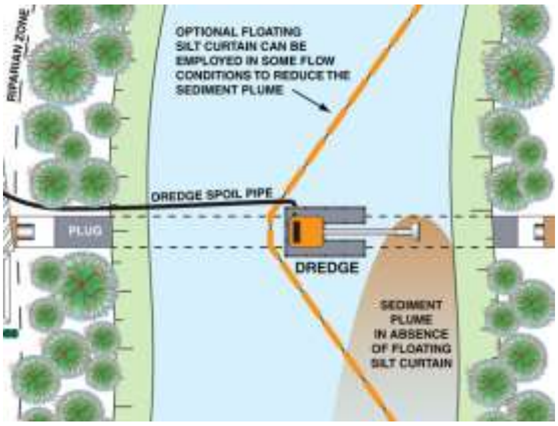
Pipe crossings of waterways



Dragline pipe trenching

Dragline

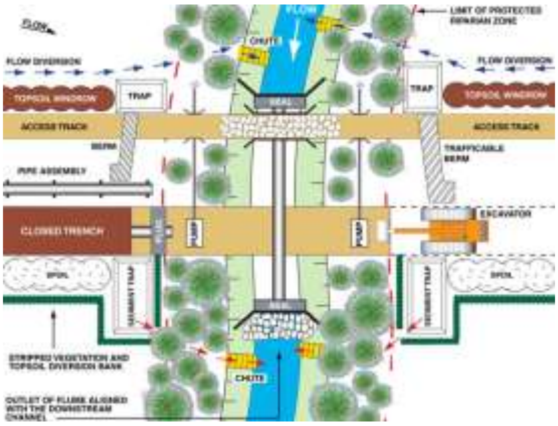
- This construction technique may be suitable for wide and deep waterways with soft substrate and limited navigational traffic.
- Not suitable if the waterway bed contains large boulders or shallow bedrock.



Dredge

Dredging

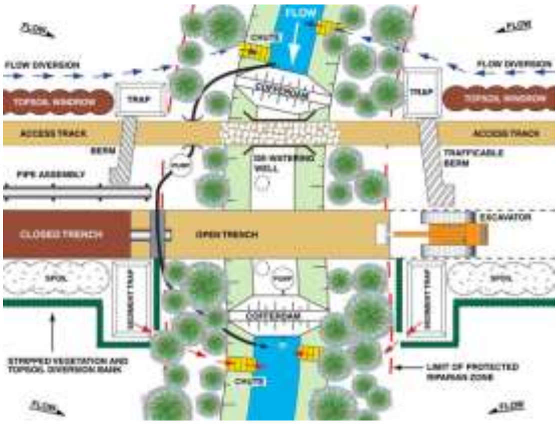
- This approach may be suitable for wide and deep waterways with soft substrate.
- Not suitable if the waterway bed contains large boulders or shallow bedrock.



Cofferdams with gravity bypass

Cofferdams with gravity bypass

- Suitable for minor, narrow waterways with minimal base flows, and during those periods when flood flows are unlikely to occur, and fish passage is not critical.
- The bypass pipe may be augmented with a pumped bypass.

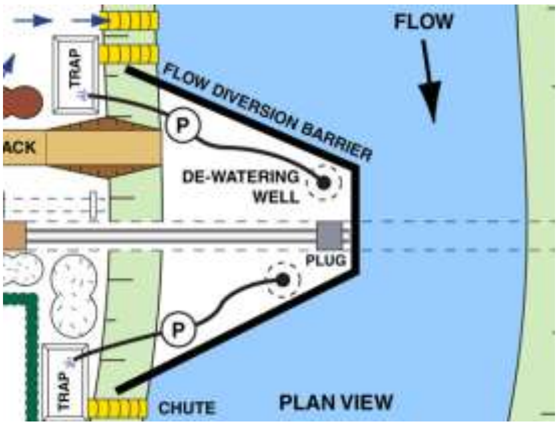


Cofferdams with pumped bypass

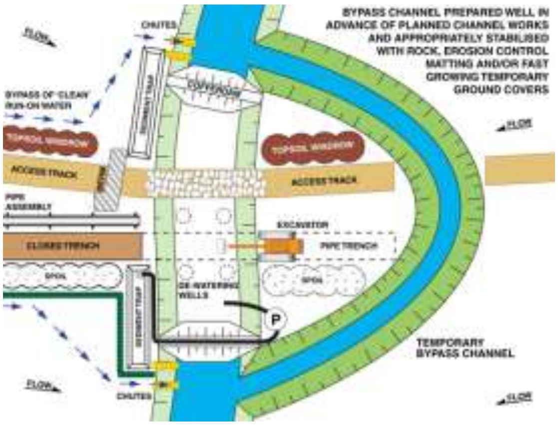
Cofferdams with pumped bypass

- Suitable for waterways with minimal base flows, and during those periods when flood flows are unlikely to occur, and fish passage is not critical.

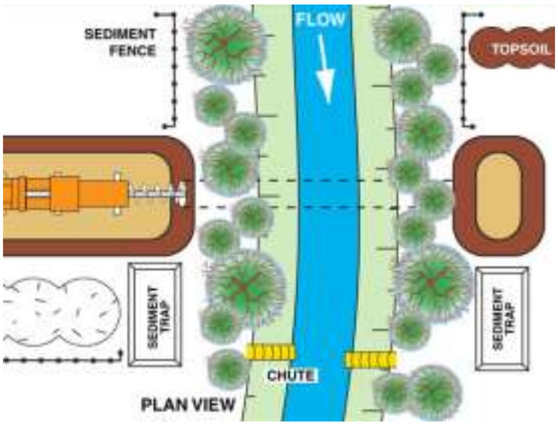
Pipe crossings of waterways



Two-stage open cut installation



Temporary bypass channel



Horizontal boring

Horizontal directional drilling

Two-stage open cut crossing of a waterway

- Applicable to the larger waterways, and waterways where maintaining fish passage is critical.
- May be difficult to apply to some gravel-based (alluvial) waterways due to the difficulty of anchoring/punching the barrier into the gravel bed, and creating a watertight seal.
- Flow diversion or isolation barriers may be constructed using either floating or land-based machinery.

Constructed bypass channel

- Extreme care must be taken if the bypass channel is to be constructed through unconsolidated sandy soil because ongoing channel erosion can occur, even after the bypass channel is backfilled and rehabilitated.
- The bypass channel may need to be lined with erosion control mats, or similar, depending of the expected flow velocity.

Horizontal bore and punch, or pipe jacking

- Best suited to passing pipelines under narrow, sensitive waterways containing impermeable substrates.
- The process is not suited to all waterway substrates due to excessive borehole slumping and water seepage.
- Borehole length possibly limited to around 100 m (boring) or 50 m (pipe jacking).

Horizontal directional drilling

- Best suited to passing pipelines under sensitive waterways.
- The maximum approach angle of the pilot hole is around 10–20 degrees.
- Success depends on the type and consistency of the substrate (bed material).

6. Managing Stream Flows

Introduction

Temporary drainage chute (Qld)

<u>Off-stream</u> erosion and sediment control

- In traditional off-stream erosion and sediment control, the task of 'drainage control' consists of:
  - transporting external stormwater runoff through the work site in a manner that avoids contamination of the water
  - directing 'dirty' water to sediment traps
  - carrying stormwater runoff down newly-formed earth slopes
  - diverting stormwater runoff away from recently vegetated areas.

Diversion of stream flows (Qld)

<u>Instream</u> erosion and sediment control

- For instream work activities, the task of drainage control consists of:
  - diverting dry weather stream flows through or around the work area
  - where practical, diverting lateral inflows (i.e local stormwater runoff) away from disturbed areas
  - and where the above is not practical, managing lateral inflows to minimise damage to the work site and contamination of this runoff.

Temporary flow diversion bank (Qld)

Diversion of lateral inflows

- The diversion of lateral inflows is recommended in the following cases:
  - when rainfall is expected or likely; and
  - soil stockpiles contain clayey, silty or otherwise harmful material, and any material washed from these stockpiles is likely to wash into the waterway; or
  - the lateral inflows are likely to flow over exposed soil, or cause bank erosion within the work area.

Filter cloth stabilisation of a cofferdam

Managing elevated stream flows

- Ideally instream disturbances will be programmed to occur during periods of low flow; however, local or distant storms can still cause elevated stream flows.
- Appropriately anchored erosion control blankets/mats can be used to stabilise any temporary embankments that could be overtopped by elevated stream flows.
- Filter cloth is often used in these cases as a temporary erosion control blanket.

Diversion of lateral inflows

Coir logs protect new plants (Qld)

Jute and coir logs

- Catch drains or flow diversion banks can be used to divert up-slope stormwater runoff around stockpiles, revegetation areas, and other soil disturbances.
- Jute and coir logs are durable and quick to install.
- Logs that incorporate plastic mesh should not be used because such mesh may strangle reptiles or be used by birds to form their nests (potentially entangling their newborn).

Mulch flow diversion bank (NSW)

Mulch berms

- If the work site generates mulch as part of the vegetation clearing, then this mulch can be used to form temporary flow diversion banks.
- Alternatively, if mulch is to be delivered to the site and used as part of site revegetation, then initially this mulch can be used to form flow diversion banks.
- However, it is noted that compost berms are much more stable than freshly chipped mulch.

Mulch/compost flow diversion berm (Qld)

Compost berms

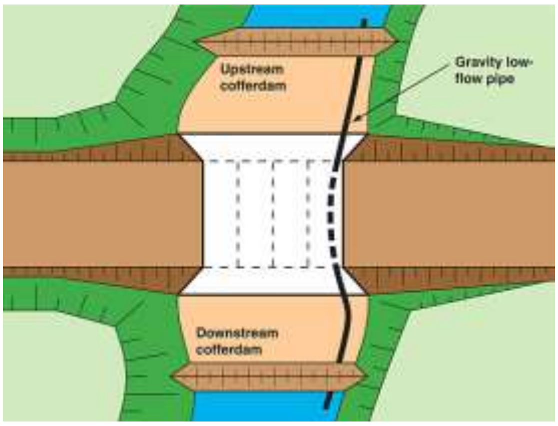
- Composted organic matter has much greater bonding properties than fresh mulch.
- Compost berms can be formed with mechanical 'slides', but can also be formed manually as per traditional mulch berms.

Straw bale flow diversion bank (Qld)

Straw bales

- Straw bales can be used to form **temporary** flow diversion banks to protect exposed soils and excavations from imminent storms.
- Straw bale berms should **not** be used for periods longer than a week during wet weather.
- The straw bales can be wrapped with filter cloth to increase their stability and durability.

Managing stream flows



Cofferdams with gravity-flow bypass

Stream flows pass through the steel pipe

Bypass channel in a gravel-based creek

Bypass cut through a sandy bench (Qld)

Introduction

- Dry weather stream flows can be managed through the use of:
  - cofferdams with a gravity-flow bypass
  - cofferdams with a pumped bypass pipeline
  - a temporary bypass channel
  - an isolation barrier.

Bypass pipeline

- Minor (trickle) flows can be bypassed using flexible, small diameter PVC pipe, or lay-flat nylon pipe.
- Larger flows can pass through corrugated steel pipe work.
- This photo (left) shows the rehabilitation of Cherry Creek in Denver, Colorado, with stream flows carried within the large diameter steel pipe anchored to the creek bank.

Bypass channels

- Temporary bypass channels can be formed by:
  - isolating part of the low-flow channel
  - cutting a temporary channel through a wide channel bench (sometimes referred to as the lower bank, or lower floodplain)
  - cutting a channel through the main floodplain (extreme caution must be exercised in such cases).
- Rock check dams can be used to control flow velocities within the bypass channel.
- If the bypass channel is to be used for temporary fish passage, then expert advice will be required.
- Special care must be taken in the rehabilitation of these channels to prevent the waterway from re-opening (eroding) these channels during subsequent floods.
- Pile fields or rock check dams can be placed in the bypass channel before backfilling to minimise the risk of uncontrolled erosion.

Use of cofferdams

Earth cofferdam with bypass channel (Qld)

Types of cofferdams

- Cofferdams can be formed from a variety of materials, including:
  - sandbags
  - earth
  - water-filled rubber dams
  - sheet piling
  - sheet metal (narrow channels)
- Filter cloth can be used to stabilise earth cofferdams.

Sandbag cofferdam (USA)

Structural integrity

- In urban areas, the failure of a cofferdam could result in flash flooding and possible loss of life.
- The design and construction of high-risk cofferdams needs to be appropriately regulated and supervised.
- Design storms should be based on the assessed risks.

Floodgates prior to their installation

Managing inflows

- Floodgates can be incorporated into the downstream cofferdam to:
  - allow the work area to drain in the event of heavy local rainfall, or elevated stream flows
  - prevent tidal backwater from flooding the work site.

Cofferdam with tide gates (Qld)

Tidal waters

- Working in tidal waterways can introduce additional complexities.
- In most cases, waterway permits will be required in order to conduct works within tidal waters.
- It is also common for specific legislation to apply to the damage and/or removal of marine plants.

Use of isolation barriers

Sheet piling isolation barrier (NSW)

Use of isolation barriers

- Ideally, isolation barriers should isolate no more than 30% of the stream width at any given time, but this is not always practical.
- Velocity checks must be carried out to ensure:
  - channel erosion is not increased
  - fish passage is not impacted.
- Steel sheet piling is a traditional instream isolation barrier, which can be used in relatively deep water.

Water-filled dams, HSI Services (USA)

Transportable water-filled dams

- Transportable water-filled dams can be used to isolate large areas at low cost.
- Generally limited to relatively wide and shallow waterways.

Earth bund

Earth bunding

- Earth bunding can vary from minor earth banks used to divert trickle flows around bank stabilisation works (as shown at the beginning of this chapter), to large earth embankments used in rivers and estuaries (left).
- The installation and removal of these earth bunds can result in water quality problems, which can be managed through the use of temporary sediment control barriers.

A-frame Aqua Barrier, HSI Services (USA)

A-frame water barriers

- Various commercial products are available.
- These techniques are generally limited to shallow water bodies.
- Possibly best used when working within concrete lined drainage channels.

Isolation barriers – Floating silt curtains

Riverwall repairs (Qld)

Floating silt curtains

- Silt curtain fabric should not be confused with sediment fence fabric.
- Floating silt curtains are not sediment filters.
- Silt curtains are used in low velocity, deep water conditions (>1 m depth) as a flow diversion barrier to isolate a work site.
- Special care must be taken when they are placed in tidal waters to allow the normal tidal movement without causing the release of sediment-laden water.

Bridge construction (NSW)

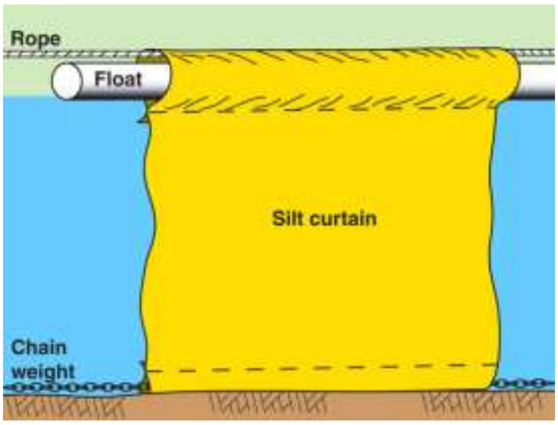
Two stage sediment control

- In bridge construction, floating silt curtains can be partnered with a traditional sediment fence (or other sediment trap) to form a two stage sediment control system.
- The land-based sediment trap acts as a Type 2 or Type 3 coarse sediment trap.
- The silt curtain:
  - acts as a flow diversion barrier, and
  - forms a stilling pond adjacent to each bank to settle out fine sediments.

Construction of a stormwater outlet (USA)

Allowing for lateral inflows

- Silt curtains can be used as an isolation barrier during the construction of a stormwater outlet headwall.
- Consideration must be given to how the curtain will manage inflows from the stormwater pipe in the event of a storm.
- The curtain should not be installed so close to the stormwater outlet that it results in the curtain being partially submerged as a result of pipe flows or excessive sediment deposition (as is the case in this photo).

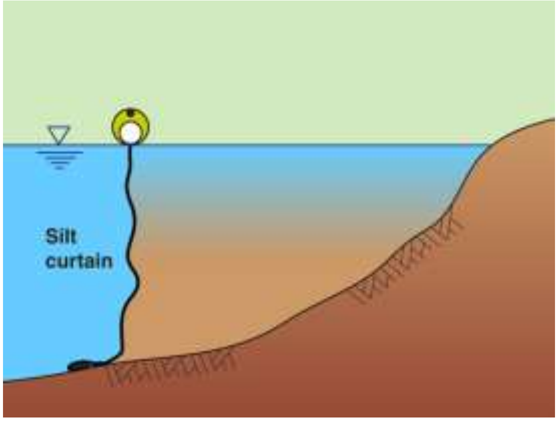


Floating silt curtain

Components of a silt curtain

- The components of a floating silt curtain vary from manufacturer to manufacturer.
- Each curtain must be made to order (length and fall) as required for the work site.

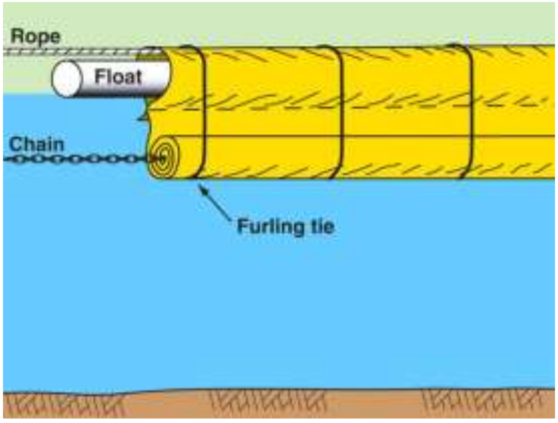
Isolation barriers – Floating silt curtains



High tide condition

Sizing silt curtains

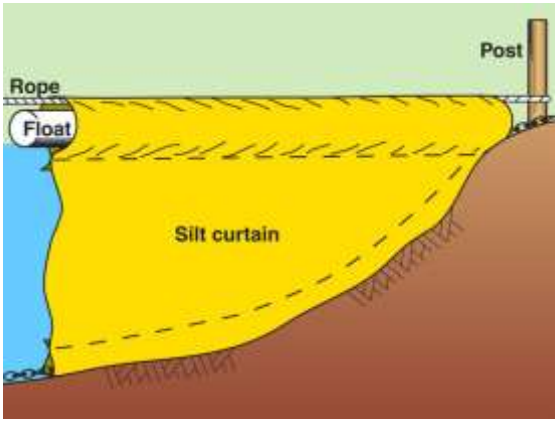
- The 'fall' of the silt curtain must allow for:
  - peak water level during high tide, and
  - sufficient capacity to retain all sediment-laden water during low tide.
- If low tide conditions fully expose the river bed, then it becomes impossible to retain water behind the silt curtain—in such cases the design and operation of the silt curtain must be based on minimising overall environmental harm.



Initial floating of a silt curtain

Installation procedure

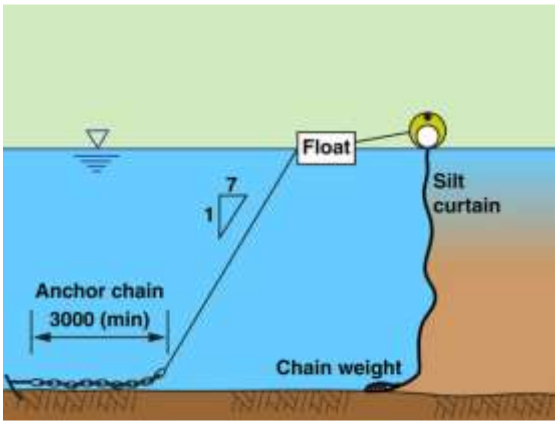
- Silt curtains are initially floated into position while in a 'bundled' condition.
- Once in position and suitably anchored, the furling ties are released to extend the curtain.



Land anchor

Land anchor

- Land anchors need to be appropriately secured to prevent dislodgment of the curtain in the event of elevated stream flows.



Marine anchor

Wet anchors

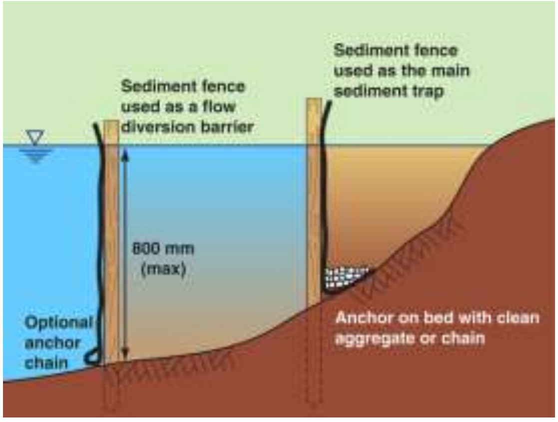
- Example of a marine anchor.
- Silt curtains can also be held away from a river bank using a floating A-frame formed from fallen trees (caution), or PVC pipe filled with expanding foam.

Isolation barriers – Sediment fence barriers

Sediment fence isolation barrier (NSW)

Introduction

- A sediment fence barrier is used instead of a floating silt curtain when the maximum water depth is less than 0.8 metres.



Sediment fence isolation barrier

Two stage sediment control

- A sediment fence barrier (left) can be partnered with traditional sediment fence (right) to form a two stage sediment control system.
- The landward sediment fence acts as a Type 3 coarse sediment trap.
- The outer (instream) barrier:
  - acts as a flow diversion barrier, and
  - forms a stilling pond adjacent to each bank to settle out fine sediments.

Bridge construction (NSW)

Flat bed waterways

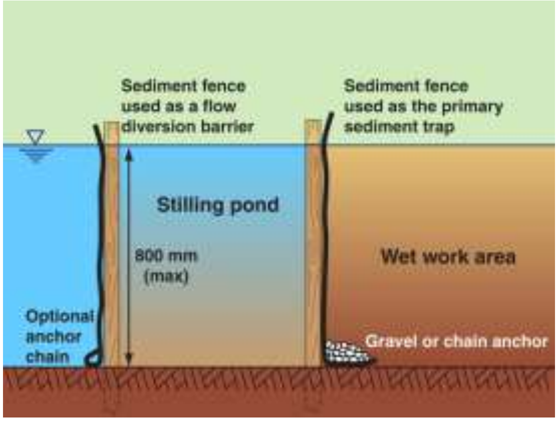
- Alluvial waterways, such as sand-based and gravel-based creeks, often have a relatively flat bed, which means the water depth is near-constant across the channel.
- However, it can be difficult, if not impossible to 'stake' a sediment fence into the bed of a gravel-based waterway.

Flow diversion system (Qld)

Flow diversion channels

- Sediment fence barriers can also be used in conjunction with earth banks to form an in-bank bypass channel.

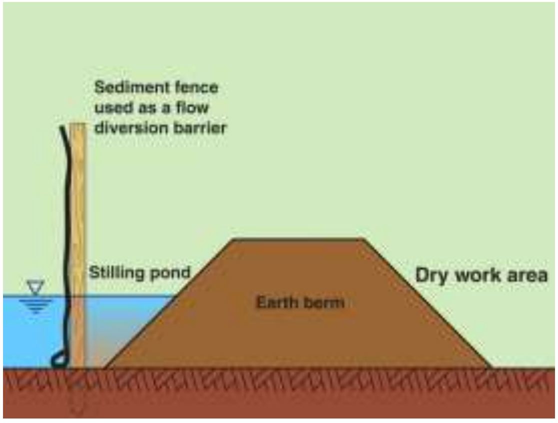
Isolation barriers – Sediment fence barriers



Wet work area

Isolation of a 'wet' work site in a shallow waterway

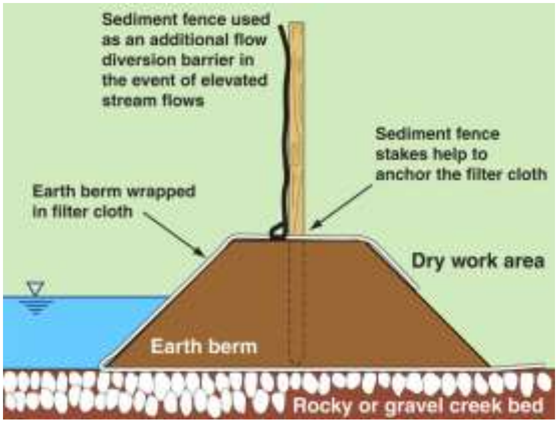
- A twin sediment fence isolation barrier can be used to create a 'wet' working area within a shallow (< 0.8 m) stream.
- The landward sediment fence acts as a Type 3 coarse sediment trap.
- The outer barrier:
  - acts as a flow diversion barrier, and
  - forms a stilling pond that allows the settling of fine sediments.



Dry work area

Isolation of a 'dry' work site in a shallow waterway

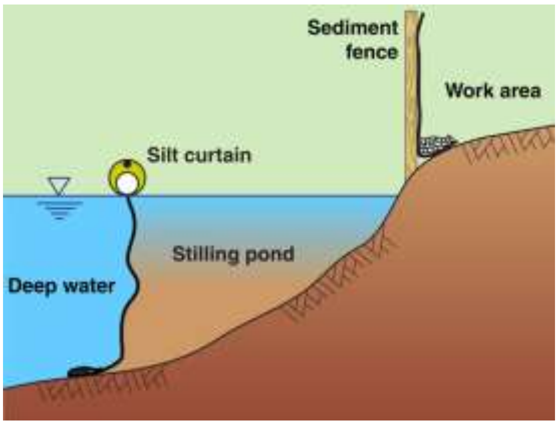
- If a 'dry' work area is required, then an earth berm can be formed behind a staked sediment fence isolation barrier.
- The sediment fence is installed first, which helps to control sedimentation during the formation of the earth berm.
- Alternatively, a temporary cofferdam can be installed to stop stream flows while the berm and sediment fence are installed.



Placement in a gravel-based creek

Isolation of a 'dry' work site in a rocky or gravel-based waterway

- In rocky or gravel-based waterways it can be difficult, if not impossible to 'stake' a sediment fence isolation barrier.
- As an alternative, the sediment fence can be staked into a filter cloth wrapped earth berm.
- The sediment fence helps to anchor the filter cloth, and helps to minimise damage to the work area in the event of slightly elevated stream flows.



Deep water floating silt curtain

Deep water alternative

- If the waterway is too deep to install a sediment fence (depth > 0.8 m), then the outer sediment fence isolation barrier can be replaced by a floating silt curtain.

Management of aquatic life

Freshwater habitat (Qld)

Trapped fish (Qld)

Fish eggs (USA)

Fish capture prior to relocation (USA)

Introduction

- Fisheries advice and/or approval may be required in the following circumstances:
  - disturbance to critical aquatic habitats
  - works within fish migration zones
  - disturbance to, or removal of, riparian vegetation that is known to assist fish migration during flood events
  - construction of a temporary flow bypass
  - installation of a temporary weir or cofferdam.

De-watering operations

- Site de-watering often results in the concentration of aquatic life within isolated pools.
- Licenced (or otherwise approved) wildlife/fisheries officers will usually be required to plan the relocation of all trapped animals.
- In some cases, Fisheries legislation regulates only the release of introduced aquatic life, thus allowing any trapped fish to be released back into the stream (check your Fisheries guide).

Site inspections

- The best way to avoid causing environmental harm is to first obtain an adequate understanding of the environment.
- Consult your state Fisheries office/web site before works commence to identify likely fish species and habitat areas.
- Critical aquatic life is not restricted to fish that can be seen from a distance, but may include turtles, eels, frogs, snakes and fish eggs.

Capture and release

- On large construction projects it may be necessary to capture and release a large number of trapped fish which will require a well planned process.
- It should be noted that in most states the capture and release of trapped wildlife, both terrestrial and aquatic, is strictly regulated by the state, and may only be done by registered wildlife handlers.

7. Short-Term Erosion Control Measures

Introduction

Flows overtop a rock filter dam (Qld)

Works conducted during the dry season

Embankment stabilised with filter cloth

Jute mesh pinned to a creek bank

Introduction

- In construction site ESC, erosion control practices primarily focus on the control of raindrop impact erosion, which is a major contributor to runoff turbidity.
- For instream work activities, erosion control practices focus on:
  - controlling soil erosion caused by elevated stream flows (i.e. an unexpected flood event)
  - controlling soil erosion caused by lateral inflows that cannot be diverted.

Instream erosion control

- Undesirable bed erosion can result from:
  - the installation of isolation barriers that isolate too much of the channel bed
  - excessive flow velocities within a temporary bypass channel.
- Bed erosion can be controlled by:
  - scheduling works to occur during periods of low flow
  - ensuring appropriate hydraulic investigations are carried out prior to the commencement of works.

Off-stream erosion control

- Filter cloth is often used to control soil erosion on temporary embankments and earth cofferdams.
- Filter cloth can also be used to form temporary batter chutes that carry lateral inflows down unstable creek banks.

Transitioning from temporary erosion control to permanent site stabilisation

- On finished earthworks, erosion control practices need to appropriately integrate with the final bank stabilisation measures.
- The use of erosion control mats and blankets can be problematic in waterways because of the risk of the whole mat lifting during elevated flows.
- Jute or coir mesh is generally preferred, and can be used to secure loose mulch on creek banks.

Erosion control mats, blankets and mesh

Jute mesh

Jute or coir mesh

- A 'mesh' is an open weave blanket made from rope-like strands such a hessian (jute) or coir rope (coconut fibre).
- It has a design life of around 12 to 24 months.
- Jute mesh can be anchored with pegs, staples or rocks.

Jute blanket

Biodegradable mats and blankets

- Organic-based blankets have low shear strength, and thus a low allowable flow velocity.
- Jute blankets have a service life similar to that of a hessian bag placed on the ground (i.e. approximately 3 months).
- Coir blankets have a service life similar to that of a domestic coir doormat that has been placed directly on the ground.

Synthetic-reinforced blanket

Synthetic-reinforced blankets

- Erosion control blankets with temporary, synthetic reinforcing have a low to medium shear strength.
- These temporary (non UV stabilised) blankets have a design life generally less than 12 months.
- As a general rule, these blankets should <u>not</u> be used in, or around, waterways.
- The plastic mesh can represent a threat to fauna, potentially entrapping wildlife such as lizards, snakes and birds.

Synthetic weed control blanket

Weed control blankets

- Weed control blankets that incorporate synthetic mats should <u>not</u> be used adjacent to waterways.
- Alternative weed control options are:
  - loose mulch anchored with jute or coir mesh
  - thick organic-based (jute) blankets can be used to suppress weeds during site revegetation (a short-term control only).

Blanket anchorage systems

Timber stakes

Timber pegs and stakes

- Short timber pegs can be used in a wide variety of soils.
- Stakes are typically used to anchor turf placed in areas likely to experience high-velocity flows soon after turf placement.
- They can also be used to anchor erosion control blankets, especially if storms or strong winds are imminent.

Metal staples

Metal staples

- Metal staples/pins are best used on firm to hard (compacted) clayey soils.
- Anchorage of these pins is partially by friction, and partially through the rusting of the pins; therefore, conditions must exist that will allow the pins to rust.
- Initially (i.e. prior to the pins rusting) metal pins provide only marginal anchorage, and as such, erosion control blankets can be displaced by strong winds unless also anchored by rocks, sandbags or tree debris.

Barbed plastic pins

Barbed plastic pins

- Barbed plastic pins are best used in soft to firm clayey soils, but generally <u>not</u> very sandy soils.
- They can be difficult to use if the soil is heavily compacted or natural (i.e. undisturbed).
- Care must be taken when used to anchor a 'mesh' to ensure the pin adequately captures or twists around the mesh.

Jute mesh with additional rock anchors

Rock anchors

- In riparian areas, rock can be used as a supplementary anchorage system for erosion control blankets.

Common problems experienced with erosion control blankets

Blankets displaced by winds

Poor anchorage of blankets

- Erosion control blankets have traditionally been anchored with metal staples (pins).
- Metal pins largely achieve their anchorage to the soil through the 'rusting' of the metal.
- Blankets anchored solely with metal pins are susceptible to disturbance by strong winds while the pins are new (i.e. not rusted).
- Additional anchorage can be provided by placing rocks or tree debris on the blankets.

Jute mesh anchored with rocks

Brushwood used to stabilise a batter

Inappropriate anchorage pegs

Blankets placed directly over a dispersive or slaking soil

- Erosion control blankets are **<u>not</u>** the solution to all soil erosion problems.
- Dispersive and slaking soils require appropriate amelioration and/or sealing with topsoil **prior** to the placement of blankets or site revegetation.
- Slaking soils (left) are likely to require barbed pins or timber pegs in order to secure the blankets.

Mats overlapped in the wrong direction

Blankets and mats overlapped against the direction of flow

- Erosion control blankets **<u>must</u>** be overlapped in the direction of stream flow.
- On creek banks, the upstream blanket must overlap the downstream blanket.

Use of coir logs

Coir log (field day demonstration site)

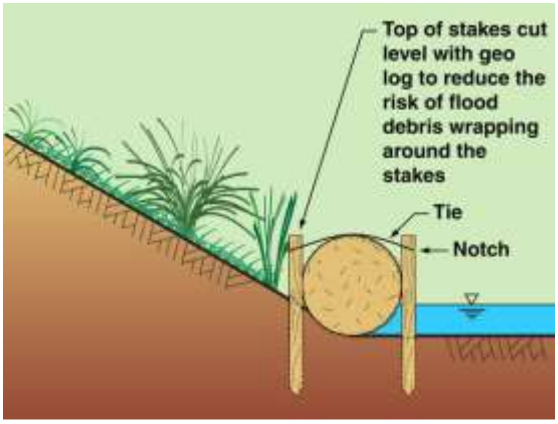
Toe protection (NSW)

Introduction

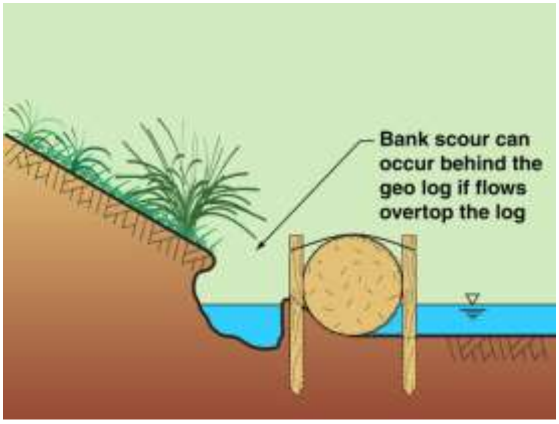
- Geo logs can be made from jute or coir.
- Coir (coconut fibre) logs generally have a longer working life.
- Geo logs can be used to:
  - reduce the risk of soil erosion along the water's edge of recently disturbed creek banks
  - protect recently planted 'toe' vegetation from being disturbed by minor stream flows.

Toe stabilisation

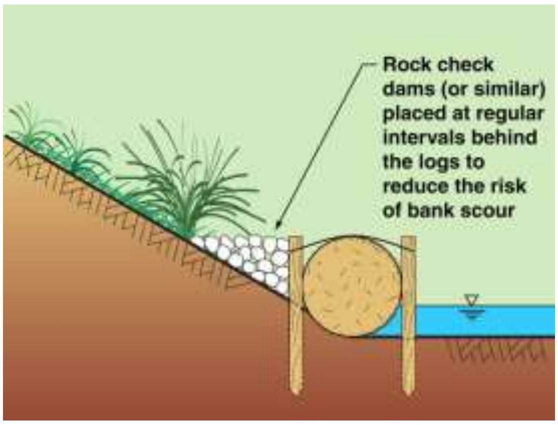
- Geo logs on their own cannot prevent all forms of erosion while creek banks are being revegetated.
- Appropriate use must also be made of jute mesh, and the like, to control bank scour caused by elevated stream flows.
- A common problem is the occurrence of bank erosion immediately adjacent to the logs—this erosion can be controlled using the techniques shown below.
- Note the bank erosion immediately behind the geo logs in the photo (left).



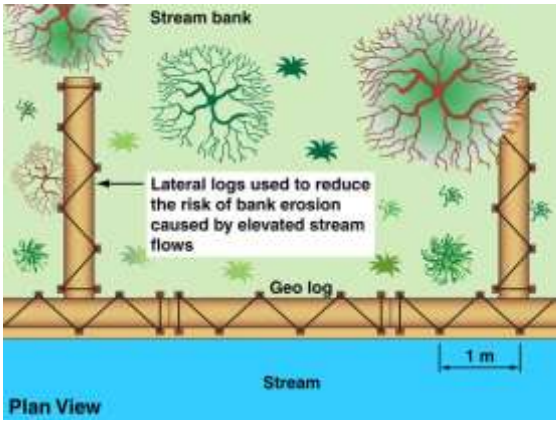
Typical placement along toe of bank



Potential bank scour problem



Use of rock check dams to control scour



Use of lateral logs to reduce bank scour

8. Instream Sediment Control Measures

Introduction

Type 2 (off-stream) sediment trap (NSW)

Off-stream sediment control

- In traditional construction site ESC, sediment control measures primarily treated the stormwater runoff that occurred during periods of wet weather.
- Typically these sediment traps are designed to treat the runoff generated by a specified storm event, such as half the peak discharge of the 1 in 1 year storm.

Instream filter tube sediment trap (Qld)

Instream sediment control

- Instream sediment traps are not designed to treat stream flows during periods of wet weather, but instead the base flow that occurs during dry weather.
- If stream flows are elevated by wet weather, then these elevated flows should be allowed to pass over the instream sediment trap without causing damage.
- However, during periods of wet weather, off-stream sediment traps are required to still perform their traditional roles.

Off-stream de-watering settling pond (Qld)

Overbank sediment control

- Overbank sediment controls consist of:
  - traditional sediment controls placed around the site office and stockpile areas
  - sediment traps used in the de-watering of any excavated material
  - sediment traps used in the de-watering of the instream work area.
- The design flow rate for these off-stream sediment controls usually depends on the required flow rate for the de-watering pumps.

Site de-watering (Qld)

De-watering sediment control

- De-watering sediment controls typically rely on 'filtration' techniques in order to achieve the required water quality.
- Unlike traditional sediment control systems, which are prone to failure if such filtration systems are used, these de-watering sediment control systems allow the de-watering pumps to be turned off, and any system blockages to be quickly rectified.

Types of <u>instream</u> sediment traps

Failed sediment fence (north of NSW)

Rock filter dam (Qld)

Straw bales placed on a rocky creek bed

Floating litter trap (NSW)

Introduction

- Wherever possible, instream work practices should be organised such that the need for <u>instream</u> sediment traps is avoided.
- Wherever possible, the focus should be on the use of <u>off-stream</u> sediment traps.
- Instream sediment traps are generally:
  - easily overburdened by high sediment loads or elevated stream flows
  - inefficient in their treatment of water turbidity.

Types of instream sediment traps

- Instream sediment controls include:
  - filter tube barriers
  - modular sediment barriers
  - rock filter dams (instream design)
  - sediment filter cages
  - sediment weirs (instream design)
- The design of the *rock filter dams* and *sediment weirs* presented in this chapter is **<u>different</u>** from how such structures are used in off-stream construction.

Short-term sediment traps

- Short-term sediment traps include:
  - sediment filter cages
  - staked sediment fences
  - straw bale barriers
- These short-term sediment traps are generally not very durable, and cannot be relied upon to produce the desired treatment standard.
- Further discussion on these sediment traps is provided at the end of this chapter.

Floating silt curtains

- Floating silt curtains are generally <u>not</u> considered suitable for use as instream sediment traps.
- However, floating silt curtains have been used for the following purposes:
  - isolation barriers (refer to Chapter 6)
  - floating litter and debris traps
  - floating oil skimmers
  - pollution containment systems (in the event that a sediment plume enters a large waterbody).

Filter tube barriers

Filter tube embankment (Qld)

Embankment overtopped during a storm

Filter tubes

- Filter tubes can be attached to a variety of instream sediment traps, including:
  - earth embankments (d/s cofferdam)
  - sandbag embankments
  - rock filter dams
  - sediment weirs
  - modular sediment barriers
- Filter tubes operate as Type 2 sediment traps, meaning they capture only sands and coarse silts, while clays and water turbidity can pass through the fabric.

Design features

- The hydraulic design of filter tube barriers is similar to the design of rock filter dams and sediment weirs:
  - the embankment is designed to be overtopped by elevated stream flows
  - the hydraulic properties of the embankment are 'ideally' designed to achieve a specified pond surface area at a specified flow rate
  - the flow capacity of the filter tubes must exceed the stream's dry weather flow rate.

Initial testing of the filter tube concept in Brisbane

Filter tube barriers

Inlet of solid pipe covered with screen

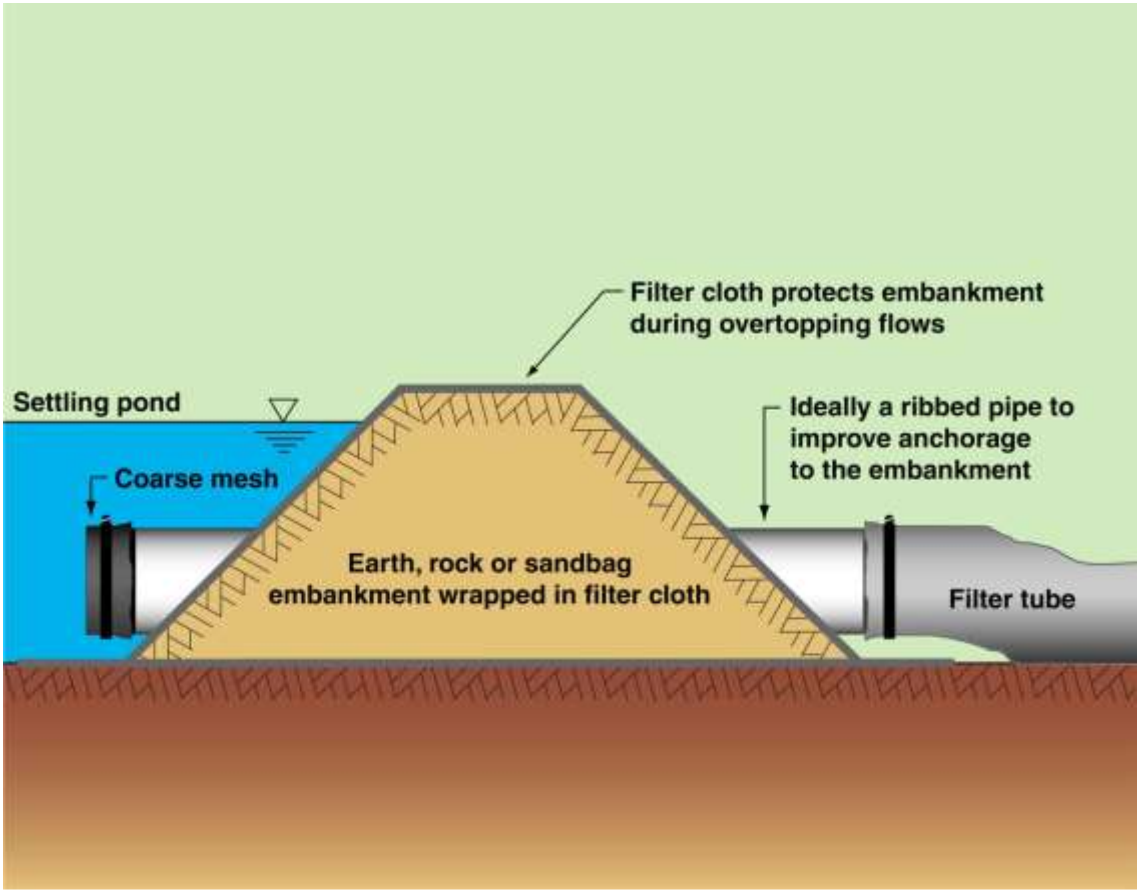
Inlet protection

- The inlet of the filter tube should be covered with a coarse screen in order to prevent aquatic life entering the filter tube.

Outlet of solid pipe connected to filter tube

Use of ribbed pipes

- The use of ribbed pipes improves the anchorage of the pipe to the embankment.
- Several filter tubes may need to be used in parallel in order to achieve the desired hydraulic flow capacity.



Filter tube attached to a downstream earth cofferdam

Modular sediment barriers

Modular sediment barrier being installed

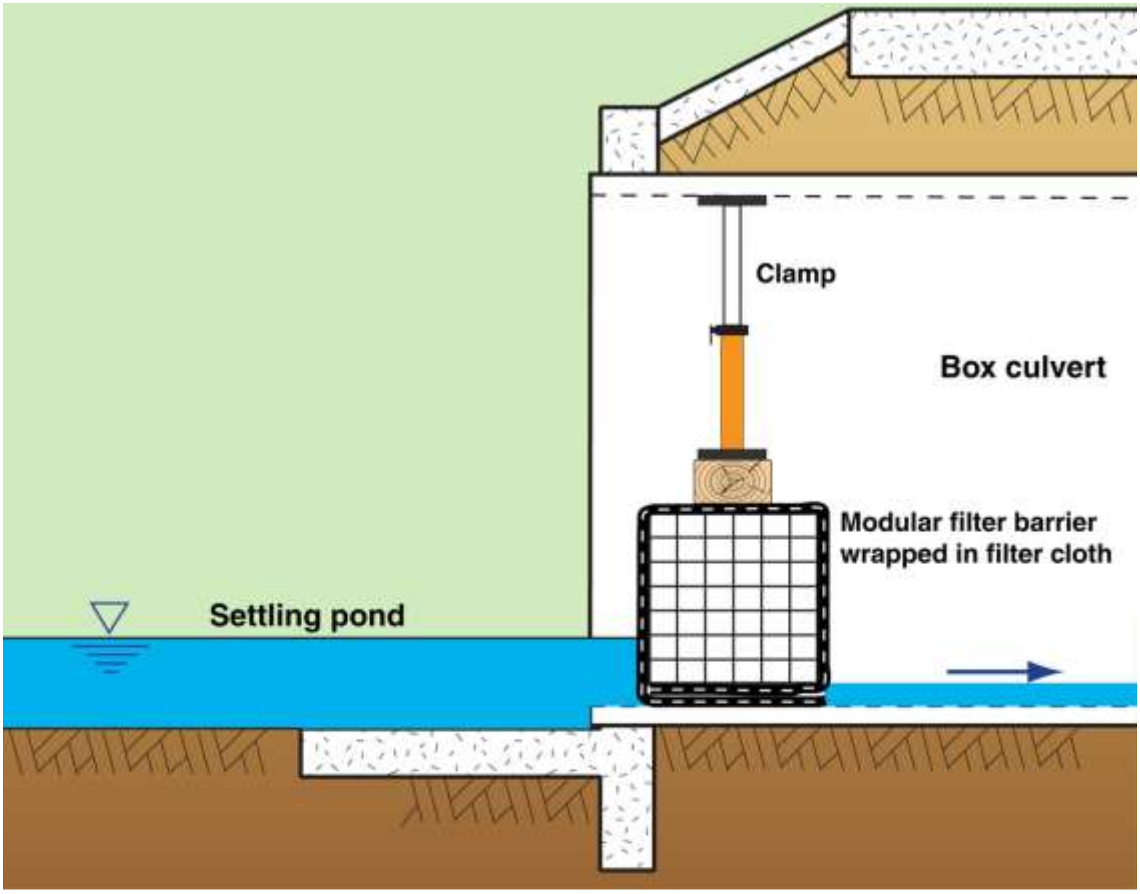
Modular barrier in an overland flow path

Modular sediment barriers

- The concept of modular sediment barriers was initially developed as:
  - a durable and reusable replacement for straw bale barriers
  - a sediment trap that could be used in concrete channels and grassed overland flow paths (dry channels).
- The plastic crates can be modified to allow the installation of filter tubes.
- Some designs allow geotextile or granular filters to be installed within the crates

Limited practicality

- Modular sediment barriers generally have a limited range of practical uses because of their high installation cost.
- When installed in concrete drains and under box culverts, the modular units can be clamped in place with timber planks and adjustable props (below).



Modular filter barrier installed inside a box culvert

Rock filter dams (instream)

Rock filter dam (Qld)

Rock filter dams

- Rock filter dams are generally used in constructed or heavily modified drainage channels.
- Significant bed and bank damage can occur if installed within natural (vegetated) waterways.
- Ideally the rock filter dam should be wrapped in filter cloth to aid in the complete removal of the dam from the channel at the end of the job.

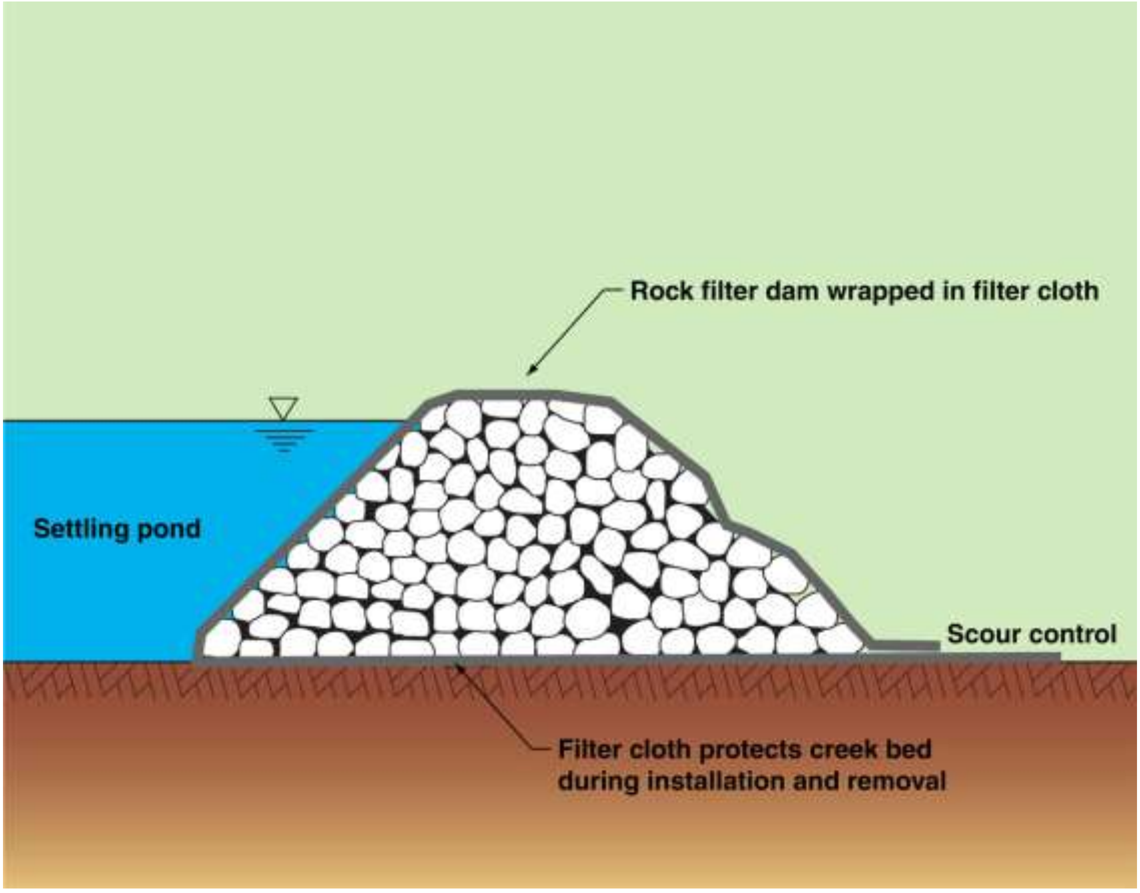
Embankment could easily wash away

Design features

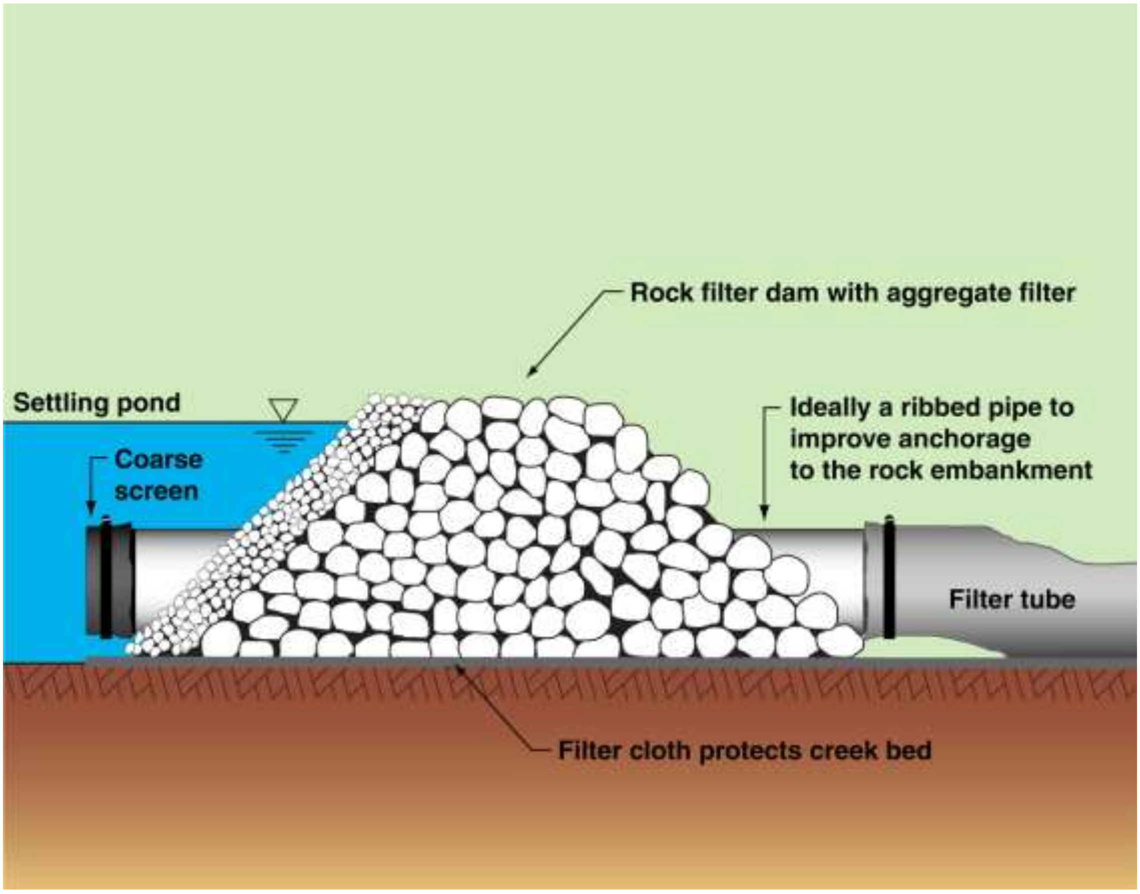
- The hydraulic design of rock filter dams involves:
  - the embankment being design to be overtopped by elevated stream flows
  - the hydraulic properties of the embankment being designed to achieve a specified pond surface area at a specified flow rate
  - the flow capacity of the embankment must exceed the stream's dry weather flow rate.

Rock filter dam wrapped in filter cloth (Qld)

Rock filter dams (instream)



Rock filter dam wrapped in filter cloth



Rock filter dam with aggregate filter and filter tube

Sediment filter cages

Sediment filter cage (Qld)

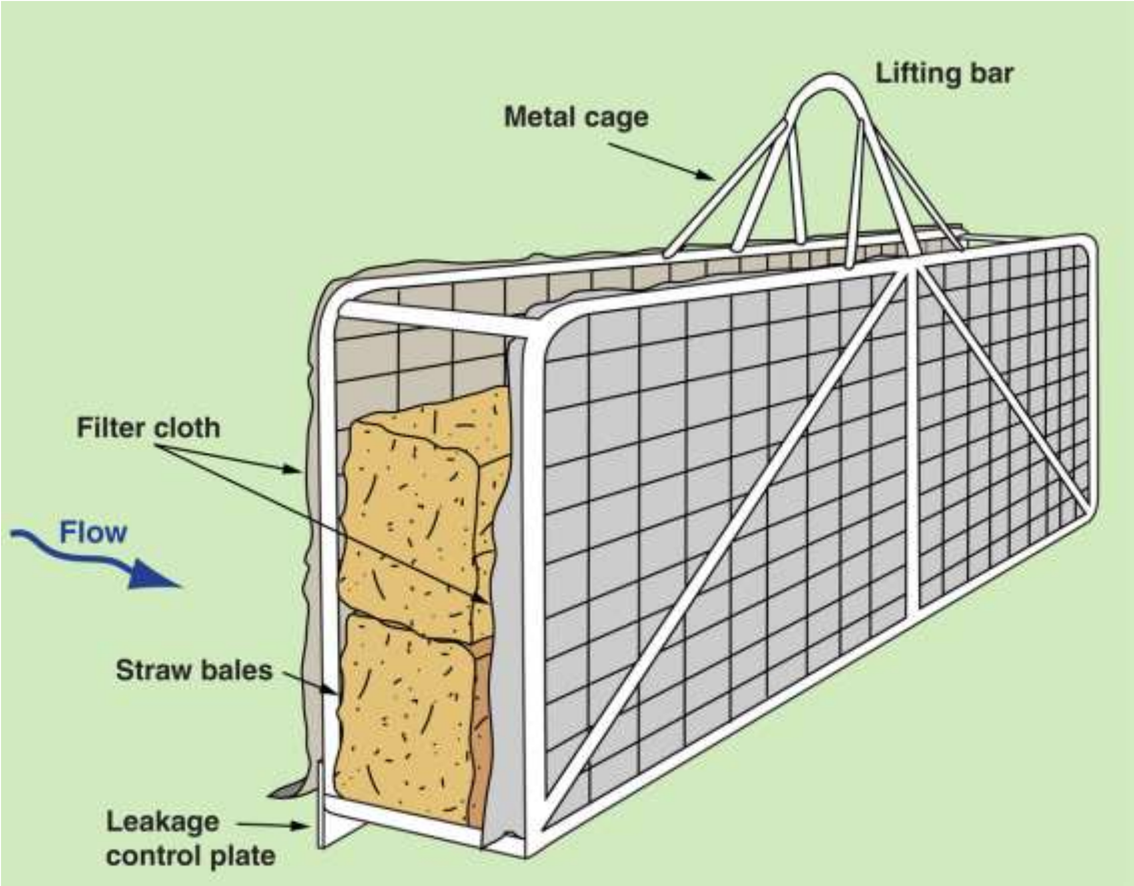
Sediment filter cage (Qld)

Sediment filter cage

- Sediment filter cages are used for short-term maintenance work within narrow, flat-bed channels.
- The cage can be fitted with a variety of filtration systems, including:
  - straw bales
  - filter cloth
  - compost-filled bags
- In general, these sediment traps are not very effective.

Control of flow bypassing

- It is important to control the leakage of unfiltered water:
  - under the cage (hence the use of a leakage-control plate)
  - around the ends of the cage.



Filter cage

Sediment weirs (instream)

Installation of a sediment weir (Qld)


Sediment weir (Qld)

Sediment weir

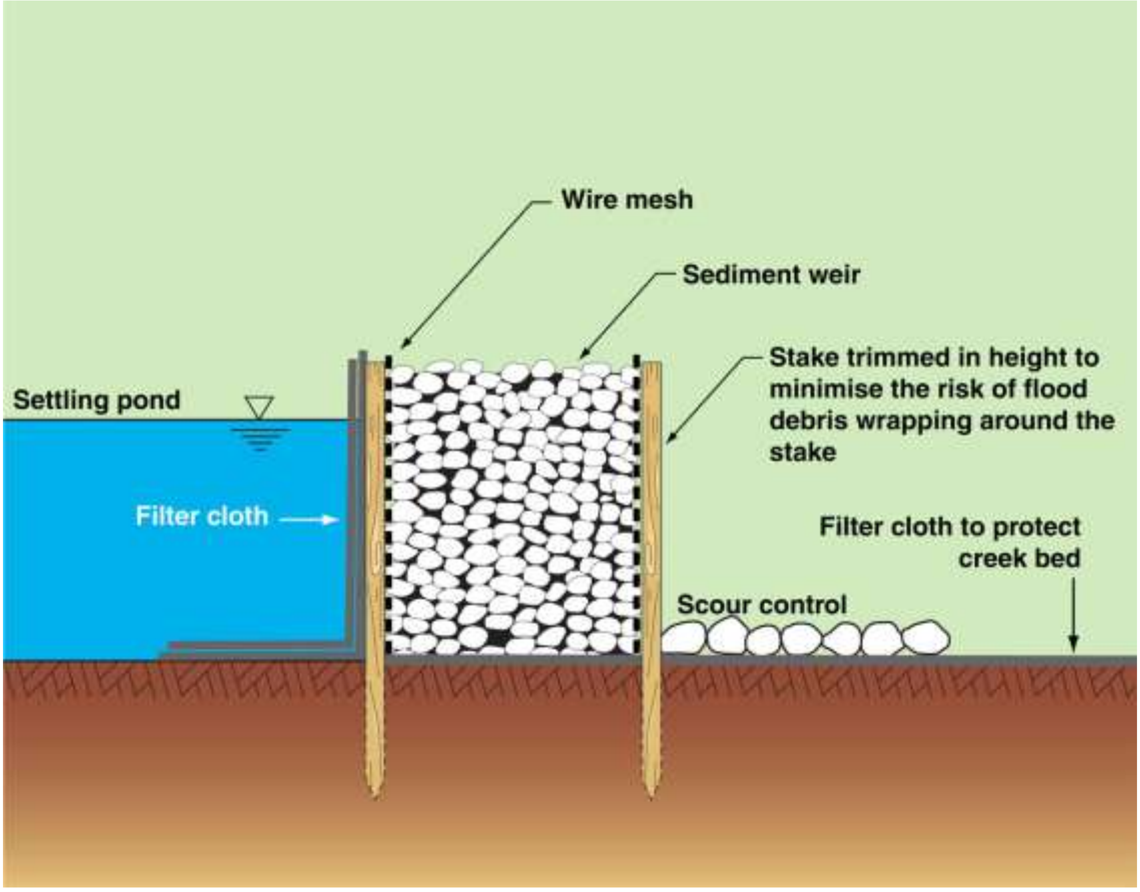
- Instream sediment weirs may be suitable for use in the following circumstances:
  - natural waterways
  - sites with poor machinery access where all the equipment needs to be brought in by hand (straw bales replace the use of an aggregate filter)
  - drainage channels that have an irregular bed.
- The weir can be filled with aggregate, compost-filled socks, or straw bales.

Design features

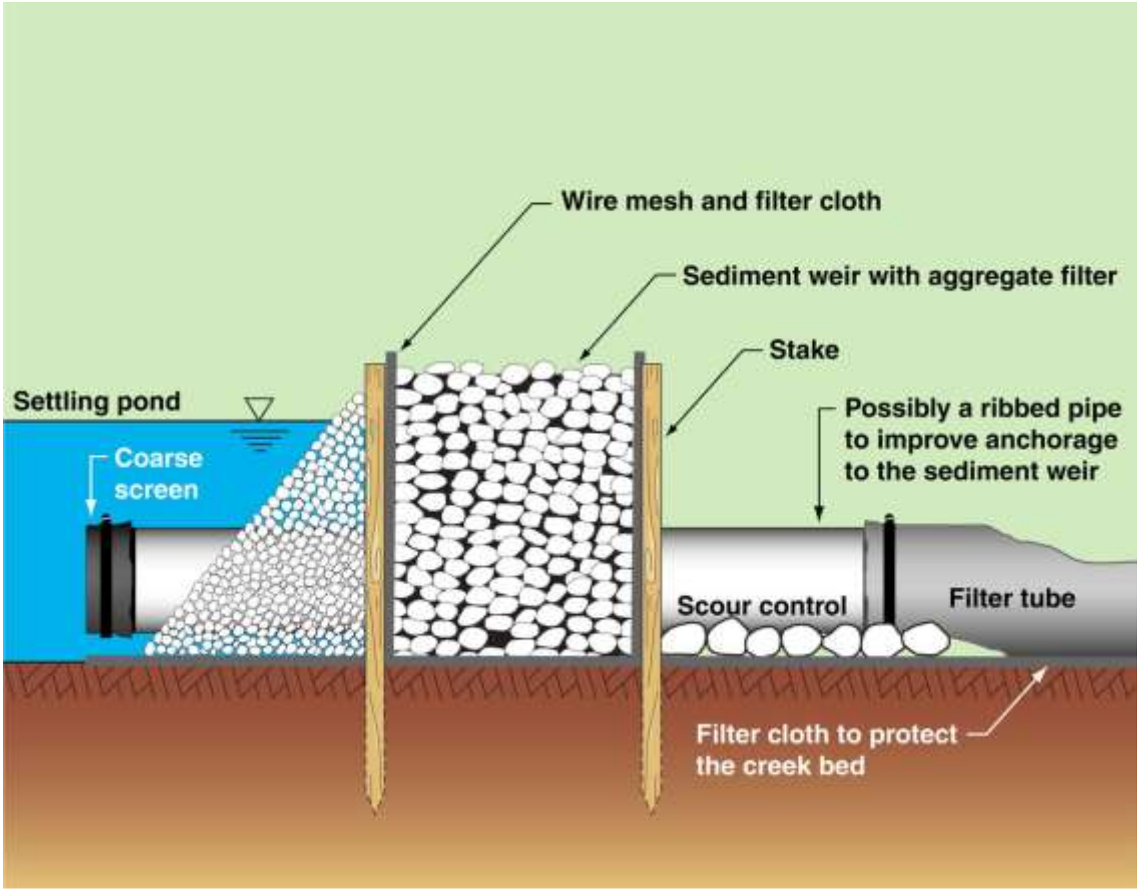
- The hydraulic design of sediment weirs involves:
  - the weir being designed to be overtopped by elevated stream flows
  - the hydraulic properties of the weir being designed to achieve a specified pond surface area at a specified flow rate
  - the flow capacity of the weir (with or without filter tubes) must exceed the stream's dry weather flow rate.

Sediment weir with aggregate filter (looking downstream)

Sediment weirs (instream)



Sediment weir with filter cloth and aggregate filter



Sediment weir with filter tube

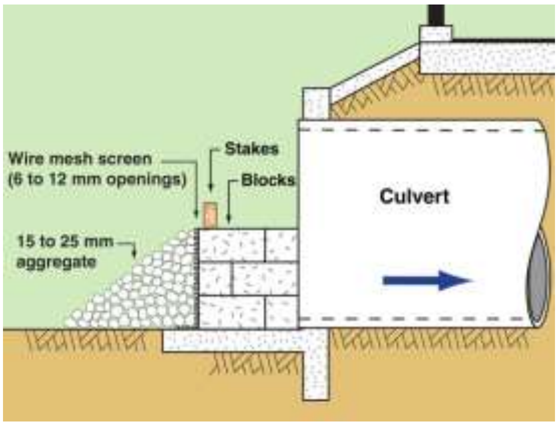
Table 1 – Selection of instream sediment control (guide only)

Site Condition	Technique	Comments
Short-term works (1 to 2 days)	Various	Preferred choice of sediment control device depends on site conditions and knowledge gained from past practices.
Default device for medium to long-term works (> 2 days)	Filter tubes	The *Filter Tubes* may be used in association with an earth embankment (wrapped in filter cloth), *Rock Filter Dam, Sediment Weir,* or *Modular Sediment Barrier* in accordance with the expected base flow rate and the environmental sensitivity of the watercourse.
Deep water drain or waterway	Floating silt curtain	Used as an isolation barrier or a pollution containment system.
	Isolation barrier	If significant channel flows exist, then preference should be given to the use of an *Isolation Barrier*.
No machinery access	Filter tube barrier	Used on medium to long-term works. Needs suitable site conditions so the *Filter Tubes* (when full) can be winched or otherwise removed from the channel. The *Filter Tubes* need to be incorporated into an in-situ *Modular Sediment Barrier, Sediment Weir* or other portable frame.
	Modular sediment barrier	Most components, except filter cloth, are reusable. Can be used in association with *Filter Tubes* to increase the allowable flow rate and/or increase service life.
	Sediment weir	Possible use of straw bales as the filter media within the *Sediment Weir*, or compost-filled socks.
	Sediment fence	Only suitable if channel flows are highly unlikely. Used as short-term control while installing the main instream sediment trap.
Small, constructed storm drain	Filter tube barrier	The *Filter Tubes* need to be incorporated into an in-situ *Modular Sediment Barrier, Sediment Weir* or other portable frame.
	Rock filter dam	Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
	Modular sediment barrier	Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
Low-flow concrete drain or rocky channel	Off-stream de-watering techniques	Consider the feasibility of pumping contaminated water to a *Filter Bag* or other off-stream de-watering sediment control system.
	Modular sediment barrier	Modular units must be wrapped in filter cloth and anchored to the channel bed. Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
	Filter tube barrier	*Filter Tubes* incorporated into modular filter units or an impermeable weir securely anchored to the channel bed.

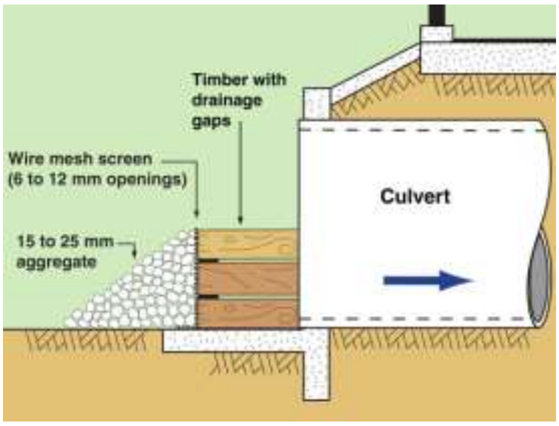
Table 2 – Selection of instream sediment control (guide only)

Site Condition	Technique	Comments
Significant sediment flows (in volume) are expected such as in a sandy bed channel	Sediment cage	Used in narrow, flat-bed channels or during low flow.
	Sediment weir	A *Sediment Weir* is a possible option if a *Sediment Cage* could not be suitably installed.
	Filter tubes	The preferred option if high turbidity levels are expected.
	Rock filter dam	Not suitable if there is a high risk of failure caused by high stream flows. Generally only suitable for constructed or modified channels where heavy machinery access exists.
Channels with existing turbid low-flows	Sediment cage	Used in narrow, flat-bed channels or during low flow.
	Sediment weir	Possible option if no heavy machinery access exists.
	Rock filter dam	Suitable for constructed or modified channels where heavy machinery access exists. May not be suitable if significant stream flows are likely.
Coarse gravel bed channels	Filter tube barrier	The preferred option if the *Filter Tubes* can be installed without causing irreversible or unacceptable bed damage.
	Rock filter dam	May require the use of a thick filter cloth to separate the gravel bed and *Rock Filter Dam*. May not be suitable if significant stream flows are likely.
Natural dry-bed waterway where stream flows are most unlikely	No instream controls	Site conditions may allow instream works to occur without the need for instream sediment controls if the risk of stream flow is sufficiently low.
	Modular barrier	Most components can be reusable from site to site.
	Sediment weir	Use of straw bales as the filter media may allow the bales to be reused if flow does not occur.
Natural dry-bed waterway where stream flows are possible	Isolation barrier	Stage disturbance across the channel to allow the free, uncontaminated bypass of likely stream flows, or lateral inflows resulting from local storms.
	Sediment weir	Use of compost socks or straw bales as the filter media may allow the filter to be reused if flow does not occur. Otherwise consider the use of a *Modular Sediment Barrier*.
Natural waterway with minor base flow	Delay works	1st option: delay works until a suitable low-flow period.
	Isolation barrier	Stage disturbance across the channel to allow the free, uncontaminated bypass of stream flows with minimal impact on aquatic fauna passage.
	Filter tube barrier	The *Filter Tubes* need to be incorporated into an in-situ *Modular Sediment Barrier,* or *Sediment Weir*.
Narrow channels with significant base flow	Delay works	1st option: delay works until a suitable low flow period.
	Isolation barrier	Stage channel disturbance wherever practical.
	Cofferdam	Cofferdam with gravity base-flow bypass pipe.
Wide channels with significant base flow	Delay works	1st option: delay works until a suitable low flow period.
	Isolation barrier	Stage disturbance across the channel and isolated from the main channel flow.

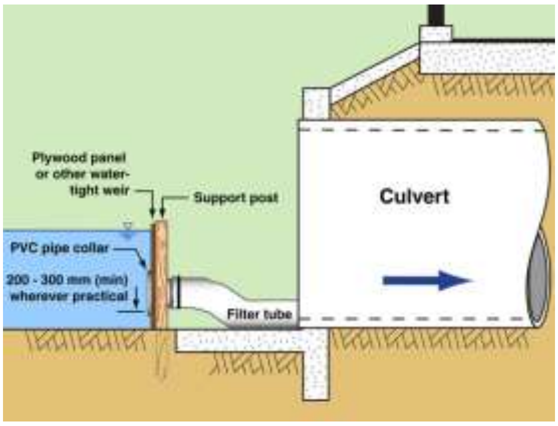
Sediment control suitable for placement at pipe and culvert inlets



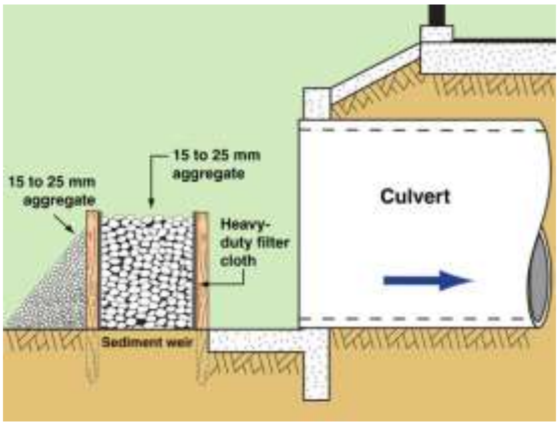
Block and aggregate sediment trap



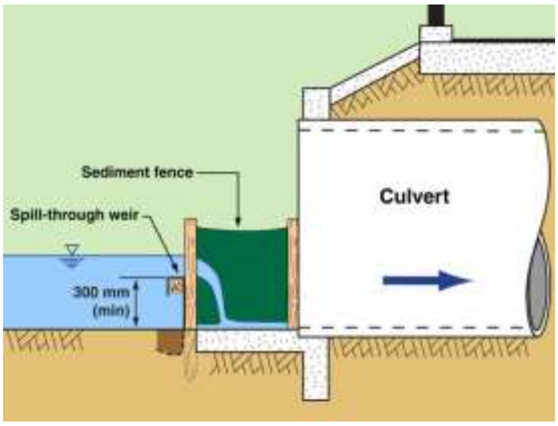
Plank and aggregate sediment trap



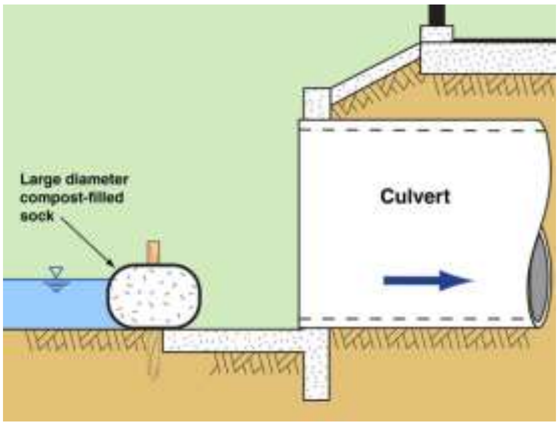
Filter tube dam



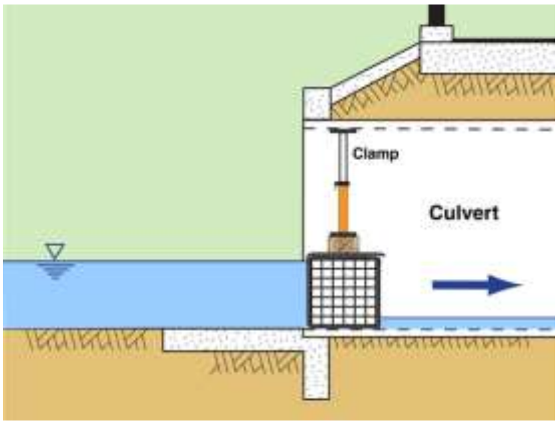
Sediment weir



Sediment fence with spill-through weir



Compost-filled filter sock



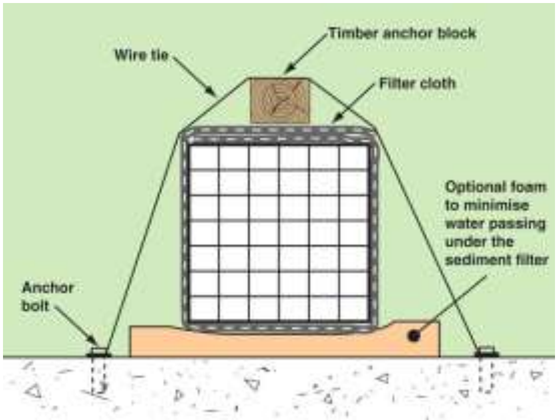
Modular sediment barrier

Inappropriate sediment control

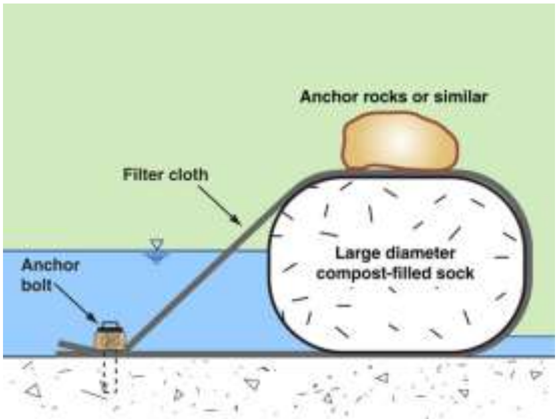
Instream sediment trap placed in concrete drains

Water leakage past sandbags

Simple filter wall (Qld)



Modular sediment barrier



Compost filter sock

Introduction

- The placement of sediment traps in concrete drains can result in the following complications:
  - leakage of unfiltered water
  - difficulty in anchoring the sediment trap to the concrete.
- It is noted that if water quality testing is required upstream and downstream of the sediment trap, then minor water leaks can result in a test 'failure' being recorded, even though the flow rate is very small.

Filter fence

- Filter fences are formed from heavy-grade filter cloth.
- Woven (sediment fence) fabric should <u>not</u> be used.

Modular sediment barriers

- Modular sediment traps are largely reusable (except for the filter media).
- The details of the installation needs to be fine-tuned for the actual site conditions.

Compost socks

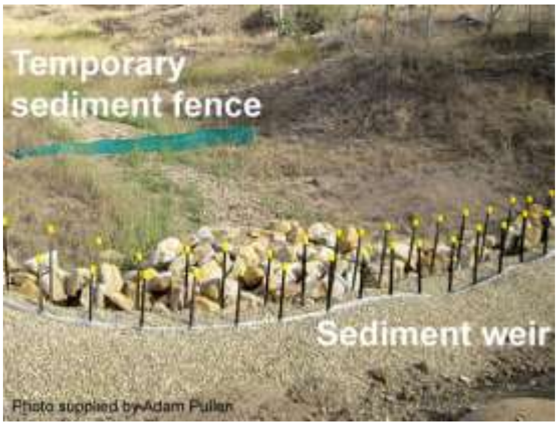
- Compost-filled socks can provide high treatment (filtering) standards, provided water leaks can be controlled.
- Anchorage of the socks to the concrete can become a complex issue that usually requires lateral thinking.

Short-term sediment traps

Sed-fence used during drain maintenance

Introduction

- Short-term sediment traps are used as a sediment control system while the primary instream sediment control system is being installed or removed.
- The need for such short-term sediment traps must be assessed on a case-by-case basis.



Sediment fence in an overland flow path

Staked sediment fence (filter fence)

- Sediment fences can be used with caution in dry drains and overland flow paths, but <u>not</u> within flowing waterways.
- Non-woven fabrics are preferred, including filter cloth.

Temporary straw bale barrier

Straw bale barrier

- Straw bale barriers should only be placed in wet environments for very short periods (1 to 2 days).
- Wrapping the straw bales in a filter cloth blanket can improve the sediment trap's durability.

Straw bales placed on a concrete apron

Inappropriate use

- Straw bales should <u>not</u> be:
  - placed, unsecured, on a concrete or rocky surface
  - used as the primary instream sediment system for instream disturbances conducted over more than 2 days
  - in areas of high flow velocity.

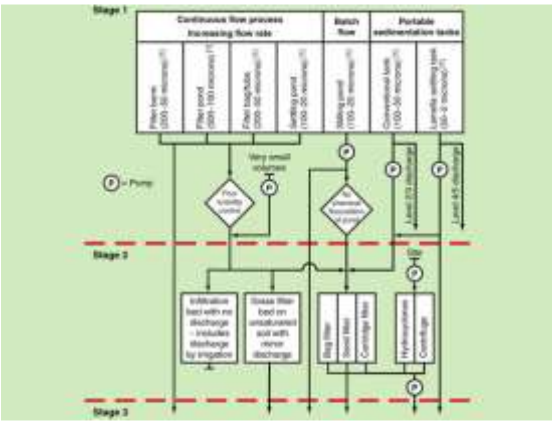
9. Sediment Control During Site De-watering

Introduction

Site de-watering (Qld)

Excavated material placed on creek bank

Site de-watering (Qld)



(see over page for larger diagram)

Introduction

- Site de-watering can be an important component of the ESC measures applied to instream work activities.
- As with all aspects of instream works, these de-watering activities should not allow sediment-laden water to enter the waterway.
- Site de-watering can consist of the:
  - de-watering of excavated material
  - de-watering of the instream work area.

De-watering of excavated material

- Material excavated from waterways typically has a high water content, and as such will require de-watering before the material can be stockpiled or removed from the work site.
- If the adjacent waterbody has been isolated from the bypassing stream flow, then in theory, the draining water can flow back into the waterbody for later collection and treatment, but in general this practice is not recommended.

De-watering the work site

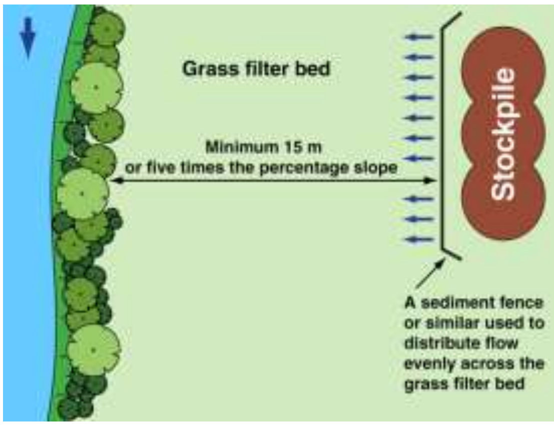
- Site de-watering is a common task carried out during instream work activities, especially when cofferdams and berms are used to isolate the work area.
- Trapped aquatic life needs to be managed in accordance with local policies, and should be protected from the inlet pipe.
- The inlet valve can be placed in a screened PVC pipe or bucket specifically modified to protect wildlife and the inflow of bed sediment.

Multi-stage sediment control

- The removal of sediment from water often requires a multi-stage treatment process.
- Stage 1 usually focuses on the removal of coarse sediments, similar to Type 3 sediment traps.
- Stage 2 usually incorporates some type of filtration process, similar to a Type 2 sediment trap.
- Stage 3 involves high quality filtration, and is often the only step that can fully treat water turbidity.

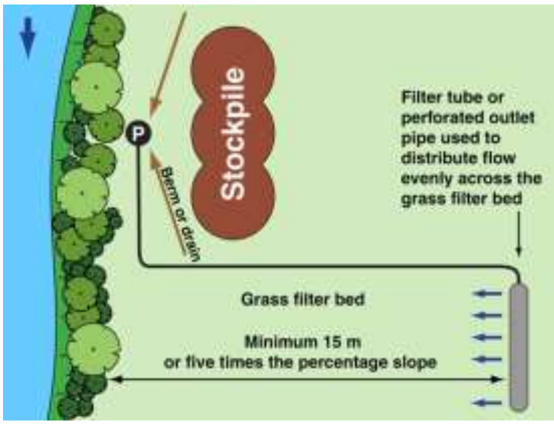
De-watering excavated material

De-silting a storm drain (Qld)



Typical layout of a grass filter

Type 2 sediment filter (compost berm)



Water collection and treatment

Introduction

- Instream construction works and channel maintenance can result in the stockpiling or transportation of large quantities of wet material.
- Allowing the sediment-laden water to drain into the surrounding soil can be one of the best ways of treating the water, provided:
  - the soil is not already saturated as a result of recent rainfall
  - the soil is not so porous that it allows turbid water to leak back into the waterway.

Discharge onto a grass filter bed

- If sediment-laden water is allowed to flow over a grass filter bed, then:
  - the flow must be evenly distributed as sheet flow
  - the grass bed should ideally have a flow length of at least 15 metres, or 5 times the land slope (whichever is the greater)
  - vehicles should be prevented from passing over this area (to avoid forming tyre depressions within the ground that could concentrate the flow).

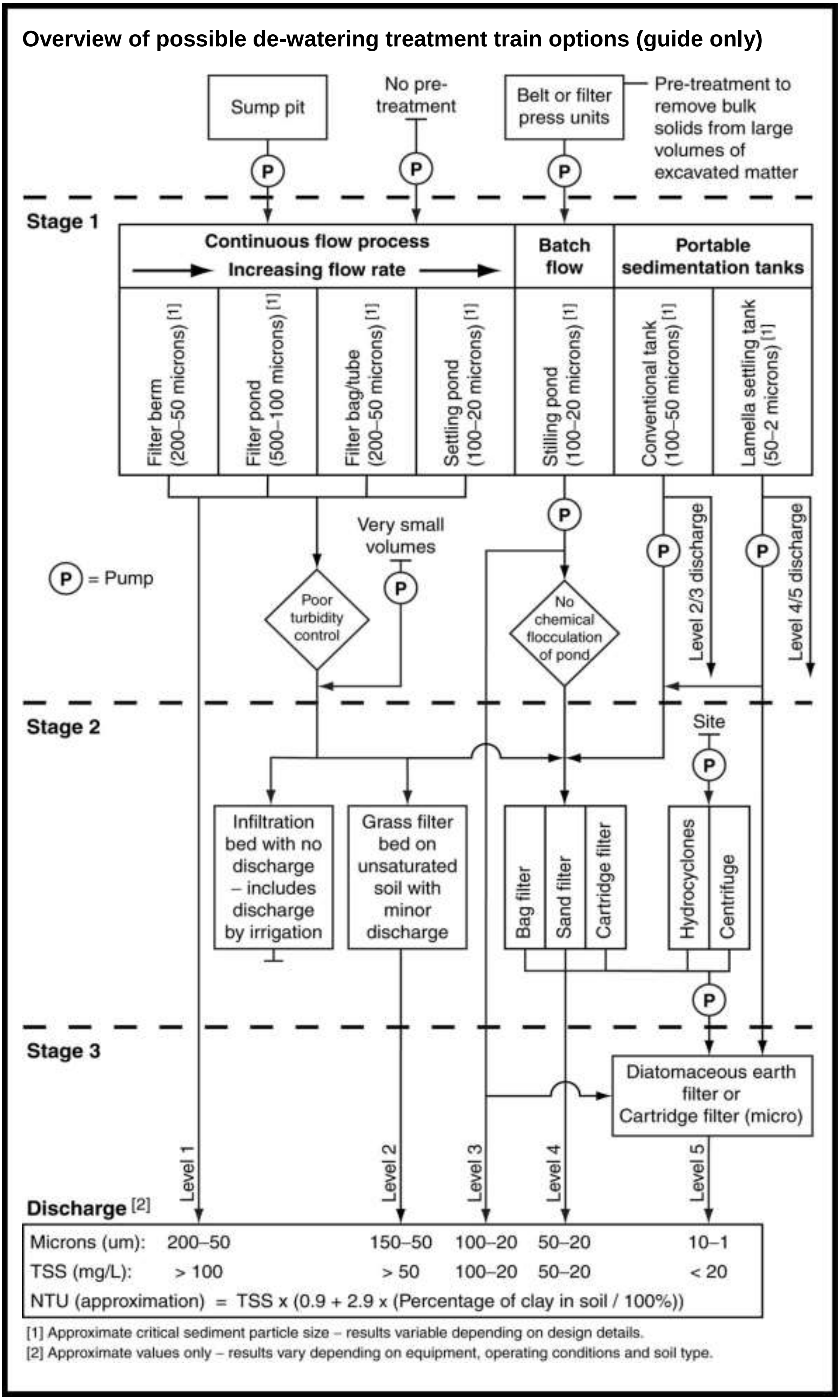
Use of Type 2 sediment filters

- A Type 2 sediment trap can be installed down-slope of the stockpile area.
- Suitable Type 2 sediment traps include:
  - compost berms
  - sediment weirs

Note: Type 2 sediment traps refers to the ranking system established for off-stream sediment control, not to the Stage 1, 2 & 3 treatment systems previously discussed in this chapter.

Pumping dirty water to a treatment system

- Dirty water collected from a de-watering process can be pumped onto a grassed filter bed.
- A wide distribution of the released flow can be achieved by:
  - pumping the water into a filter tube that has been placed along the contour
  - releasing the water through an outlet manifold formed by cutting regularly spaced holes in a section of pipe.


Overview of possible de-watering treatment train options (guide only)
Sump pit
No pre-treatment
Belt or filter press units
Pre-treatment to remove bulk solids from large volumes of excavated matter
P
Stage 1
Continuous flow process
Increasing flow rate
Batch flow
Portable sedimentation tanks
Filter berm (200–50 microns) [1]
Filter pond (500–100 microns) [1]
Filter bag/tube (200–50 microns) [1]
Settling pond (100–20 microns) [1]
Stilling pond (100–20 microns) [1]
Conventional tank (100–50 microns) [1]
Lamella settling tank (50–2 microns) [1]
P = Pump
Very small volumes
Poor turbidity control
No chemical flocculation of pond
Level 2/3 discharge
Level 4/5 discharge
Stage 2
Site
Infiltration bed with no discharge – includes discharge by irrigation
Grass filter bed on unsaturated soil with minor discharge
Bag filter
Sand filter
Cartridge filter
Hydrocyclones
Centrifuge
Stage 3
Diatomaceous earth filter or Cartridge filter (micro)
Level 1
Level 2
Level 3
Level 4
Level 5
Discharge [2]
Microns (um): 200–50 150–50 100–20 50–20 10–1
TSS (mg/L): > 100 > 50 100–20 50–20 < 20
NTU (approximation) = TSS x (0.9 + 2.9 x (Percentage of clay in soil / 100%))
[1] Approximate critical sediment particle size – results variable depending on design details.
[2] Approximate values only – results vary depending on equipment, operating conditions and soil type.

Pre-treatment processes

Gravity draining of stockpiles (Qld)

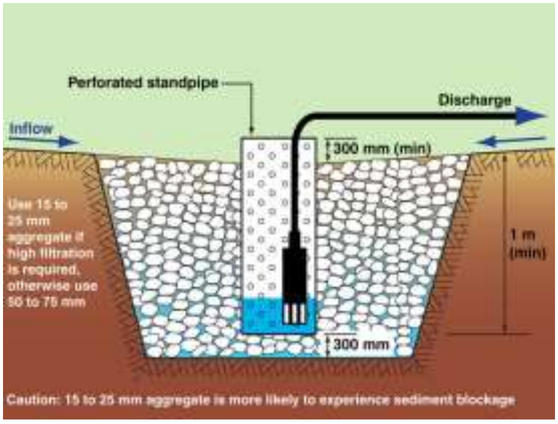
Gravity de-watering of stockpiles

- Pre-treatment processes can be used to initially de-water excavated material.
- In many cases this process will de-water the material to a condition that will allow it to be transported off the site.
- Placing excavated material in mounds (stockpiles) often allows water to quickly drain from the material.
- The released water is then collected and pumped to a suitable water treatment system.

Belt press (NSW)

Mobile belt press

- Mobile belt presses are often used to de-water fine sludges, such as the de-watering of sludge lagoons in wastewater treatment plants.
- It would be unusual for such a system to be employed on a waterway construction project, but it may have a use in the de-silting of urban lakes and stormwater treatment ponds.



Sump pit layout

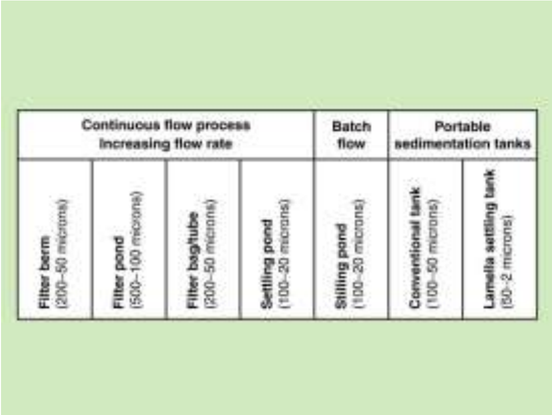
Sump pits

- Sump pits can be used to collect sediment-laden water that drains from a material stockpile, allowing it to be pumped to a suitable treatment process.
- Sump pits can also be formed in the bed of a creek or drainage channel to act as a central water collection sump.

Sump pit (Qld)

Standpipe (foreground) prior to installation

Stage 1: Coarse particle settlement and/or filtration



Continuous flow process Increasing flow rate				Batch flow	Portable sedimentation tanks	
Filter berm (200–50 microns)	Filter pond (500–100 microns)	Filter bag/tube (200–50 microns)	Settling pond (100–20 microns)	Stilling pond (100–20 microns)	Conventional tank (100–50 microns)	Lamella settling tank (50–2 microns)

Stage 1 treatment options

Introduction

- The treatment efficiency of the following Stage 1 treatment systems varies significantly, as does the potential hydraulic capacity of these treatment systems.
- Some techniques, such as the compost berms, can generate a high quality discharge under the right flow conditions.

Mobile clarifier tank

Clarifier tanks

- The use of clarifiers is well established within the water and wastewater treatment industries.
- It would be unusual for such a system to be employed on a waterway construction project, but it may have a use in the de-silting of urban lakes and stormwater treatment ponds.

Compost filter berm

Compost berms

- Free-standing compost berms and compost-filled socks can provide good filtration and turbidity control.
- The leakage of unfiltered water must be controlled.
- The performance of this process can be improved by integrating it with a substantial grass filter bed (e.g. placement on a wide floodplain).

Filter bag contained in a rubbish skip

Filter bags

- Commercial filter bags are suitable for the treatment of low flow rates.
- These bags collect only coarse-grained sediments (they provide minimal control of turbidity levels).
- It is important to ensure that there is a suitable means of removing and disposing of these bags once they are full.
- Placing the filter bags in a rubbish skip (drainage plug removed) can aid in the removal of the bags from the work site.

Stage 1: Coarse particle settlement and/or filtration

Filter fence water treatment system (Qld)

Filter fence

- Filter fences are formed from non-woven fabrics, such as filter cloth.
- Filter fences are suitable for the removal of coarse and fine-grained sediments, but not for turbidity control.
- An aggregate filter can be placed adjacent to the filter fence to reduce the risk of fabric blockage.
- The overall performance can be improved by placing the fence well away from the creek.

Filter pond (Qld)

Filter ponds

- Best used on flat or near-flat ground.
- Most effective for the treatment of water containing coarse-grained sediment.
- Limited control over turbidity unless the pond is placed on highly porous soil.
- The diameter of the pond and the composition of the filter wall depends on the sediment type and the flow rate.
- The performance can be improved by placing the pond on a grass filter bed.

Filter tube dam (Qld)

Filter tube dams/tanks

- Filter tube dams are similar to normal filter tubes, except the sediment-laden water is first pumped into a pit or tank before gravity feeds the water into the attached filter tubes.
- Steel or PVC tanks/drums can have filter tubes fitted as a filtered discharge system.
- The process provides minimal control over water turbidity.
- The performance can be improved by placing the tank on a grass filter bed.

Water pumped directly into a filter tube

Filter tubes

- De-watering hoses can be directly connected to a filter tube.
- Filter tubes collect only coarse-grained sediments, with minimal control of water turbidity.
- It is important to ensure that there is a suitable means of removing and disposing of the bags once they are full of sediment.
- The performance can be improved by laying the filter tube across a grass filter bed.

Stage 1: Coarse particle settlement and/or filtration

Lamella settling tank

Lamella settling tanks

- Lamella settling tanks utilise laminar flow conditions to optimise the settlement of non-dispersive soil particles.
- Controlling the inflow rate is critical for good performance.
- These tanks can be rented for short-term construction and maintenance projects.

Modified mini skip settling tank (Qld)

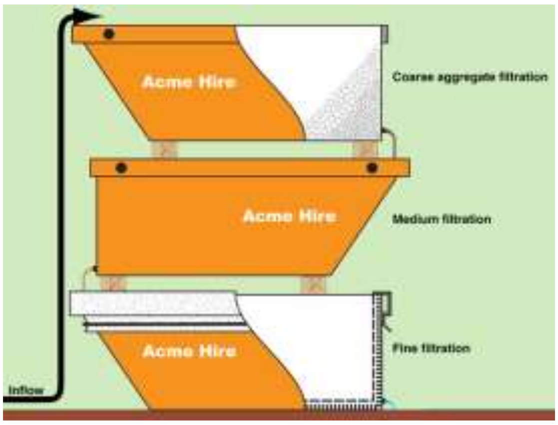
Mini skip settling tanks

- Rubbish skips can be modified to act as portable settling traps.
- With a bit of lateral thinking, treatment towers can be formed from stacked skips, each performing a different degree of water filtering.

Truck-mounted filter press

Mobile treatment units

- Small mobile 'Stage 1' treatment units can be assembled from a variety of swimming pool filters mounted on a car trailer.
- Mobile water storage tanks can be used to collect and transport sediment-laden water off a work site for specialist treatment.

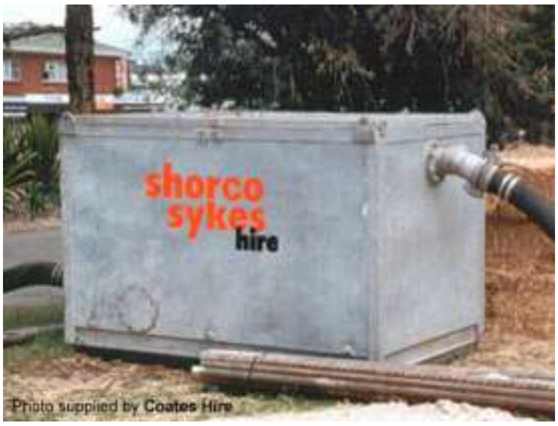


De-watering tower

Multi-stage water treatment towers

- Complex tower-type water treatment systems are often used on major tunnelling operations.
- Simple treatment systems can be developed with a bit of lateral thinking.
- A key feature of such systems is the ability to quickly remove and replace units once they reach their sediment storage capacity.

Stage 1: Coarse particle settlement and/or filtration



Portable sediment tank

Portable sediment tanks

- Various types of portable settling tanks can be hired.

Sediment basin (Qld)

Sediment basins

- If sediment basins exist on the construction site, then sediment-laden water can be pumped to these basins.

Settling pond (Qld)

Settling ponds

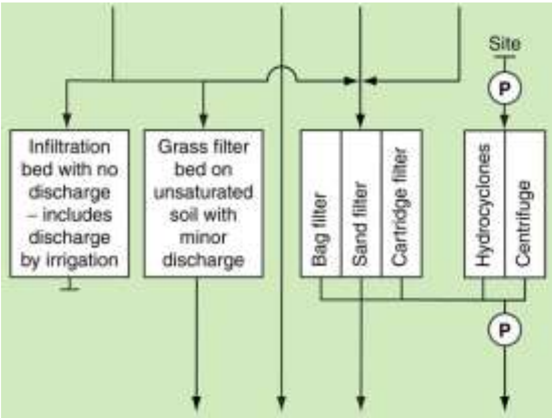
- Settling ponds incorporate a free-draining outlet system, usually consisting of a *Rock Filter Dam, Sediment Weir,* or a series of *Filter Tubes*.
- This process is only suitable for waters containing fast settling (coarse) and non-dispersive sediments.

Stilling pond (USA)

Stilling ponds

- Stilling ponds treat batch flows with the discharged water quality equivalent to a Type 1 sediment basin.
- Stilling ponds do not incorporate a free draining outlet system, but instead the treated water is removed once the water reaches a specified water quality.
- Turbidity control may require the use of flocculants.

Stage 2: Fine particle filtration systems



Stage 2 treatment options

Introduction

- Stage 2 water treatment systems vary significantly in their relevance to general instream construction and maintenance activities.
- Some of the techniques, such as bag filters (different from ‘filter bags’) are most unlikely to be associated with general de-watering practices.
- Some of the following techniques have been presented only to assist in pre-construction brain storming.

Bag filters

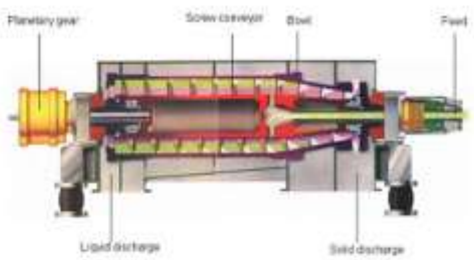
Bag filters

- Bag filters provide very fine filtration, and as such are only likely to be relevant to very unique situations.

Cartridge filter (rainwater filter)

Cartridge filters

- Cartridge filters are commonly associated with the operation of rainwater tanks.
- Several of these filters could be setup in parallel, and in series, on a portable trailer as a mobile water polishing system.



Centrifuge layout

Centrifuge

- Mobile (truck mounted) centrifuges can be used to treat recirculating cooling water used in directional drilling operations.
- Similar to belt presses, this is a treatment system that has been designed for one specific process, but can be used for other de-watering activities in the right circumstances.

Stage 2: Fine particle filtration systems

Filter press (USA)

Filter press

- Filter presses can be mounted on trucks in order to become a mobile system.
- Filter presses provide very fine filtration, and as such are only likely to be relevant to very unique site conditions.

Grass filter bed (Qld)

Grass filter beds

- Grass filter beds can be very effective provided:
  - the soil is <u>not</u> already saturated as a result of recent rainfall
  - the soil is not so porous that it allows turbid water to leak back into the waterway.
- Further details on the use of grass filter beds is provided at the end of this chapter.

Truck-mounted centrifuge (Qld)

Mobile units

- Mobile Stage 2 treatment systems include vacuum drum filters, filter presses, and truck-mounted centrifuges (left).

Sand filter (swimming pool filter)

Sand filter

- Sand filters are regularly used as domestic swimming pool filters.
- Similar to cartridge filters, several small sand filters could be set up in parallel and/or series on a portable trailer as a mobile water polishing system.
- Large (in-situ) sand filter are regularly used in stormwater treatment (e.g. filtration, bio-filtration and bio-retention treatment systems).

Stage 3: Ultra fine particle filtration

Diatomaceous earth filter

Diatomaceous earth

- These are high filtration systems.
- These filters provide very fine filtration, and as such are only likely to be relevant to very unique circumstances.

Granular water filter

Granular water filters

- Granular (cartridge) water filters are used in stormwater treatment.
- Similar to sand filters, several of these granular filters could be setup in parallel and/or series on a portable trailer as a mobile water polishing system.

Hydrocyclones

Hydrocyclones

- Hydrocyclones are used to extract particulate matter in a manner similar to a modern bagless vacuum cleaner.

Gravel soakage (infiltration) pit (USA)

Soakage pit

- Aggregate soakage pits (infiltration trenches) can be used as a final treatment process.
- In-situ sand filters can also act as soakage pits.

Problems associated with the use of grass filter bed

Pump discharging onto filter cloth

Grass filter beds

- To achieve the efficient treatment (infiltration) of sediment-laden water, the pumped discharge needs to be distributed evenly over the ground.
- In most cases this means the pump's discharge should not consist of a single-point outlet (left), but a multi-point outlet.
- Placing filter cloth over the ground at the outlet helps in the final removal of sediment from the grass at the end of the de-watering process.

Single-point outlet

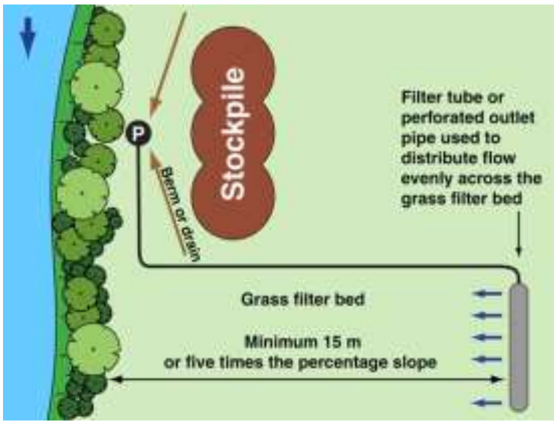
The problem of a single-point outlet

- Ideally, the discharge should not be to a single-point outlet.
- Steps should be taken to spread the discharge evenly over as wide an area as possible.

Sediment passes over saturated soil

The problem of saturated soil

- Once the ground becomes saturated, infiltration stops, and the sediment-laden water simply passes over the grass.
- The process shown here (left) has totally failed in its task of treating the discharged water.



Multi-point outlet system

Using outlet systems to spread the discharge over a wide area

- In order to achieve a wide and even distribution of the outflow:
  - form a multi-hole outlet manifold by cutting a series of well-spaced holes in a section of nylon hose, with a knot tied into the far end of the hose, or
  - pump the water into a filter tube that has been laid across the full width of the available grass.

10. Material Transport and Stockpile Management

Introduction

ESC for Site Managers

Delivery truck (Qld)

Vehicle passing over creek bed (Qld)

Stockpile area (Qld)

Introduction

- Instream construction projects typically involve significant off-stream vegetation and soil disturbance, potentially leading to soil erosion and water pollution issues.
- Site offices, stockpile areas and access roads need to be managed in accordance with the general principles of construction site erosion and sediment control.
- Readers should refer to the separate field guide prepared for general construction activities.

Material delivery and disposal

- An Erosion and Sediment Control Plan prepared for an instream construction project must identify:
  – site office area and associated ESC
  – stockpile areas and associated ESC
  – vehicle access points and associated ESC measures.
- The need for a stabilised entry/exit pad must be assessed on a case-by-case basis (noting that some instream work activities can be relatively small).

Temporary watercourse crossings

- Ideally a work site should be accessed from both sides of the waterway so that vehicles will not need to pass over the creek bed, but again this must be assessed on a case-by-case basis.
- Temporary watercourse crossings can consist of:
  – temporary bridge crossings
  – temporary culvert crossings
  – causeways
  – bed level (ford) crossings.

Stockpile management

- Ideally, material stockpiles that contain clayey or silty material should be managed with the use of Type 2 sediment control systems.
- <u>Woven</u> sediment fence fabric (which is a Type 3 sediment trap) is largely ineffective in controlling the type of sediment-laden runoff that discharges from stockpiles.
- Compost and mulch berms can provide better treatment of stormwater runoff released from soil stockpiles.

Temporary vehicular crossings of waterways

Mud generated by vehicular traffic

Clay-based waterway crossings

- The design of temporary vehicle crossings is strongly influences by the type of bed material found within the watercourse.
- Clay-based waterways are almost impossible to cross at bed level because the bed can quickly turn into mud.
- Temporary vehicle crossings of clay-based waterways normally require a temporary culvert, or possibly a rock-lined causeway if the bed is dry.

Sand-based ford crossing (NSW)

Sand-based waterway crossings

- Sand-based waterways can experience significant sediment (sand) flows during both minor and major floods.
- These waterways can often be crossed by vehicles at bed level (ford crossing) with minimal release of sediment into the water (assuming the vehicle tyres are clean).
- If necessary, these bed-level crossings can be reinforced with a cellular confinement system, but this synthetic mat <u>must</u> eventually be removed from the waterway.

Gravel-based ford crossing (Qld)

Gravel-based waterway crossings

- Gravel-based waterways usually contain a series of pools and riffles along the channel bed.
- The channel bed is typically flat, and bed-level crossings (fords) are normally located at riffles where flows are shallow.
- It is **important** to avoid sand and fine sediments entering the riffle, so drainage and track stabilisation measures are usually required on the approach roads.

Rock-based creek bed (Qld)

Rock-based waterway crossings

- Rock-based waterway beds are normally very stable, and few restrictions apply to the location of vehicle crossings other than to avoid disturbance to important riparian vegetation.
- In between the individual rock outcrops, these waterways may contain sections of clay, sand, or gravel-based channels, in which case the above rules apply as appropriate for the type of bed material.

Temporary vehicular crossings of waterways

Barge acting as a bridge crossing (Qld)

Barge crossings

- A barge can be used as a mobile transportation system to cross estuaries and protected waterways.
- Barges can also be used as a fixed bridge structure within narrow estuary inlets (as was the case in this image).

Temporary access construction bridge

Temporary bridge crossings

- A temporary bridge crossing is used when it is important to maintain fish passage during the construction period.
- Pre-case culvert bridging slabs (left) can be used to form a temporary bridge deck across a narrow low-flow channel.
- It is important to control stormwater drainage on the access roads leading to watercourse crossings in order to minimise the risk of sediment-laden water entering the watercourse.

Temporary pipe culvert (Qld)

Temporary culvert crossings

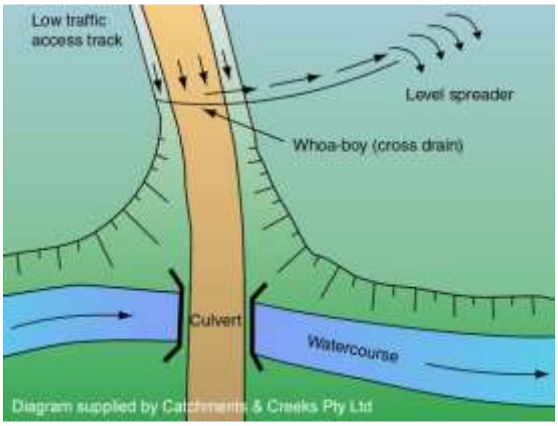
- Temporary culvert crossings are typically used on wide stream beds.
- They are best used when fish passage is not critical; however, suitable fish passage can be achieved through appropriate design.
- Recycled steel pipes are commonly used for this purpose.

Ford crossing of a sandy creek (NSW)

Temporary ford crossings

- Ford crossings are used on alluvial creek and river crossings when stream flows are not expected.
- The regular crossing of 'wet' creek beds by construction vehicles should be avoided.
- These crossings are typically used in shallow, intermittent streams that are expected to have negligible base flow during the construction period.

Design of approach roads



Diversion of road runoff

Drainage control

- Critical to the management of temporary watercourse crossings is the appropriate management of road runoff adjacent to the waterway.
- Road runoff must be diverted off the approach roads such that any sediment-laden runoff does not discharge, untreated, into the waterway.
- Cross drainage berms (cross banks) can be used to divert runoff into a sediment trap, or into the adjacent bushland, in order to filter sediments from the runoff.

Flows diverted off access track

Cross bank placed at top of descent

Recessed approach road

Alignment of approach roads

- Preference is normally given to aligning approach roads perpendicular to the waterway.
- Recessing permanent approach roads into the channel bank can provide both positive and negative outcomes.
- The exposed banks formed by recessing the approach roads must be appropriately stabilised against the erosive forces produced by eddies formed when floodwaters pass over these banks.

Rock stabilised vehicle crossing

Stabilisation of the road surface

- The need to stabilise the road surface with rock or gravel depends on:
  - the intended service life of the road
  - the type and number of vehicles
  - the likelihood of wet weather.
- Ideally, hard engineering surfaces (e.g. concrete) should be avoided within the waterway and riparian zone, especially if the waterway is unstable or mobile (i.e. subject to natural lateral movement).

Stockpile management

Material stockpile area (Qld)

Location of stockpiles

- Sand and soil stockpiles should not be located in a position where the material could cause harm, or be washed into the waterway.
- Do not locate stockpiles:
  - on a road pavement
  - within an overland flow path
  - on unstable stream banks
  - within the 'drip zone' of protected trees (long-term stockpiles).

Soil stockpile covered with hessian (NSW)

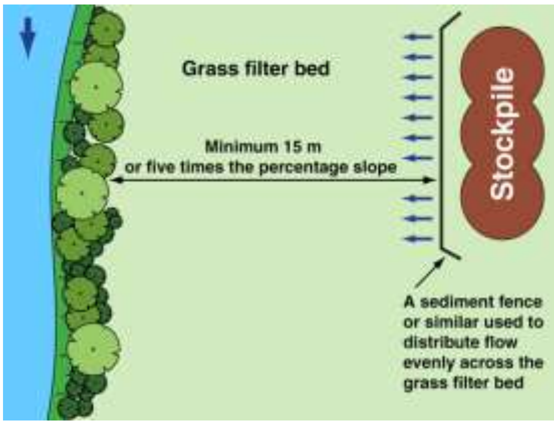
Erosion control measures

- Long-term stockpiles of clayey material should:
  - ideally be covered with an impervious cover (this may not always practical)
  - otherwise covered with mulch, hessian, or filter cloth.

Sediment control down-slope of stockpile

Sediment control measures

- Appropriate sediment controls should be located down-slope of sand/soil stockpiles, such as:
  - filter fence or compost berm for clayey soils
  - woven sediment fence for washed sand.



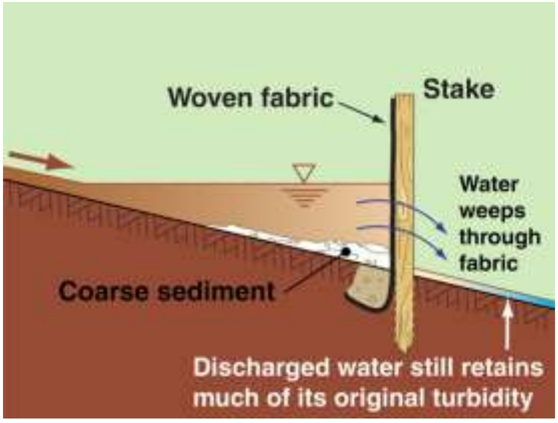
Typical layout of a grass filter

Use of grass filter beds

- If stockpile runoff is allowed to flow over a grass filter bed, then:
  - the flow must be evenly distributed as sheet flow
  - the grass bed should ideally have a flow length of at least 15 metres, or 5 times the land slope (whichever is the greater)
  - vehicles should be prevented from passing over this area (to avoid forming tyre depressions within the ground that could concentrate the flow).

Limited effectiveness of woven fabrics placed around soil stockpiles

Woven sediment fence fabric



Fluid mechanics of a sediment fence

Raindrop impact erosion

Non-woven filter cloth

Introduction

- Sediment fences are manufactured from woven fabrics because these fabrics provide the following hydraulic properties:
  - high strength and tear resistance making them suitable for a rough working life on construction sites
  - a very low flow rate, which causes water to pool up-slope of the fabric, and it is the creation of this pooling that allows coarse sediment to settle
  - a low risk of sediment blockage.

Performance of a traditional woven sediment fence

- The most important hydraulic property of a woven sediment fence is its ability to force sediment-laden water to pool up-slope of the fence.
- It is this temporary pooling of the water that allows coarse sediments to settle under gravity.
- This also means the bulk of the sediment settles on the ground, rather than on the fabric (which would otherwise have caused blockage of the fabric).

Sediment runoff from soil stockpiles

- Woven fabrics are useful in the manufacture of sediment fences because the sediment-laden runoff typically found on construction sites contains significant volumes of coarse sediment.
- Construction site runoff contains coarse sediment because these work sites are subjected to sheet and rill erosion (i.e. velocity-induced soil scour).
- However, soil stockpiles are only likely to experience raindrop impact erosion, which means the sediment-laden runoff from stockpiles is likely to contain only fine sediment in the form of water turbidity.
- The best way to treat the runoff from soil stockpiles is to use a 'filtration' system (such as a Type 2 sediment trap), instead of a gravity-settling system.
- The types of filtration systems that work best down-slope of soil stockpiles includes:
  - filter fences (non-woven fabric)
  - compost and mulch berms.

11. Post-construction Stream Rehabilitation

Introduction

Site revegetation (Qld)

Introduction

- Disturbed surfaces must be rehabilitated as soon as practicable to prevent, or at least minimise, the risk of environmental harm caused by long-term soil erosion.
- Waterways should be actively revegetated rather than just waiting for natural regeneration.
- Hard engineering measures should be avoided wherever possible.

Edge planting (NSW)

Ecological benefits of vegetation

- Instream ecology is greatly enhanced by the re-establishment of riparian vegetation, especially bank vegetation.
- Riparian vegetation provides:
  - shading for water temperature control
  - the establishment of habitat diversity
  - the creation of snags, which can provide habitat, shelter, and trap food
  - the linking of aquatic and riparian habitats.


Riparian wildlife (Qld)

Shelter for terrestrial wildlife

- In an urban setting, creeks can become popular areas for people to walk, exercise their dogs, and for children to play.
- This increased human activity means that terrestrial fauna needs certain types of vegetation, particularly ground covers, in order to provide shelter (somewhere to hide).
- Wherever possible, bank revegetation should extend to the water's edge to increase the value and linkage of the aquatic and terrestrial habitats.

A turtle in need of riparian shelter (Qld)

Shelter for aquatic wildlife

- The adopted scour protection and revegetation measures need to be compatible with the fish habitat and fish passage needs of the waterway.
- Understanding how to make scour protection measures 'fish friendly' requires expert advice.
- Minimising the hydraulic roughness of a waterway (to improve flood conveyance) can adversely affect fish passage during flood events.

The importance of vegetation in controlling creek erosion

Riparian vegetation (Qld)

Introduction

- In the early days of waterway assessment, waterway health was judged solely on water quality outcomes—this meant that a glass of pure water could have been classified as a Class A waterway!
- Obviously there is more to waterway values than just water quality.
- A key component of most non-arid waterways is *vegetation*, including ground covers, mid-storey and upper storey plants.

Ground covers (NSW)

The role of groundcovers

- With respect to erosion control, groundcovers are the primary plants used to control soil ‘scour’.
- Groundcovers can also reduce erosion around the base of isolated trees.
- Besides their erosion control benefits, groundcovers provide:
  - a food source
  - shelter for small ground-dwelling wildlife
  - boundary layer development that aids fish passage during floods.

Mid-storey shrubs on a river bank (Qld)

The role of middle storey plants

- Middle storey (or mid-storey) plants are often the forgotten heroes of our riparian landscape.
- Yes they make it difficult for humans to walk along a creek (which can be a good thing for the creek and wildlife), and they can have an adverse effect on flood levels, but it is their ability to slow water velocities that allows them to reduce flood damage to many upper storey trees.
- They also provide food and shelter for many birds.

Upper storey trees with minimal shrubs

The role of upper storey plants (trees)

- Tree roots provide the primary anchoring system for the soil, which allows creeks to have steep and/or high banks.
- The upper canopy can help control temperatures, shade the stream, help to control weed growth (through shading), and in some cases help to form a micro-climate within the riparian zone.
- Besides their erosion control benefits, trees provide food, habitat and shelter for wildlife.

The 'right' plant in the 'right' location

Site revegetation (Qld)

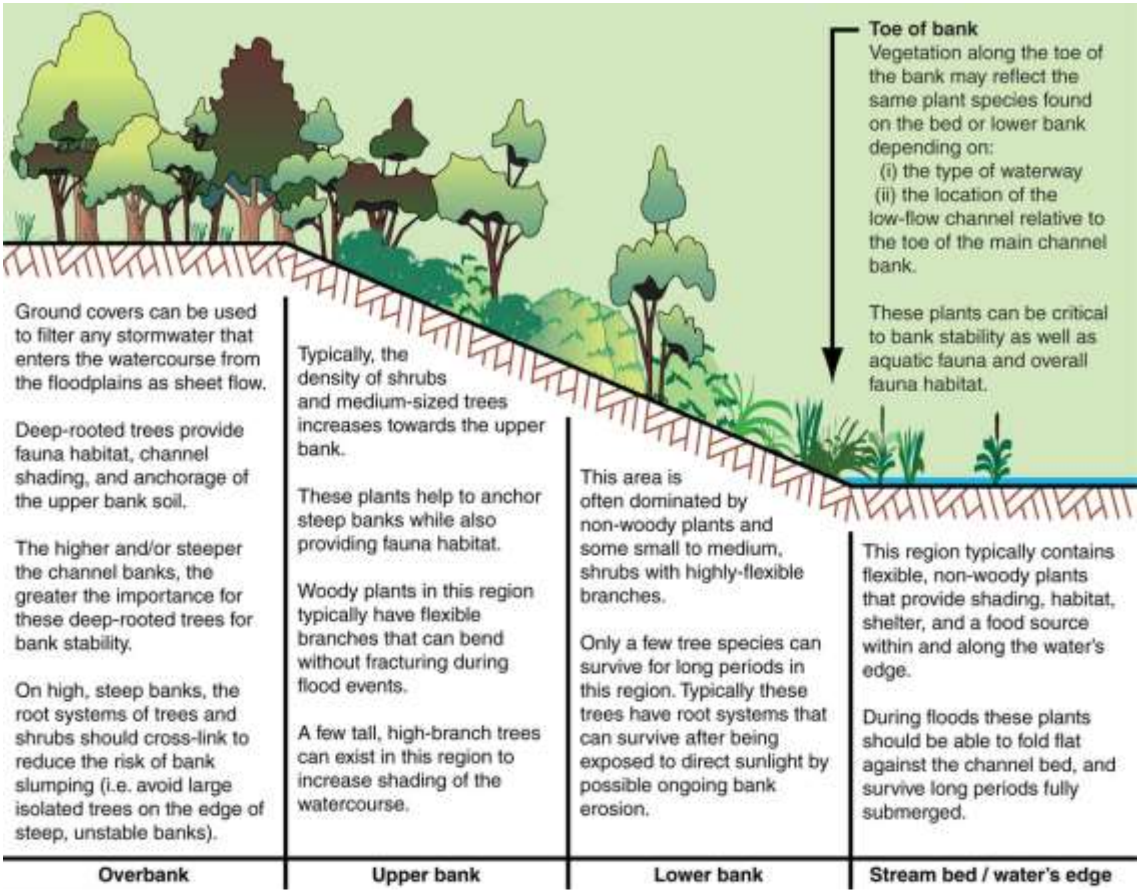
Site revegetation (Qld)

Introduction

- Site revegetation is <u>not</u> a case of delivering a truck-load of native plants to a site, and then planting them evenly 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 place, which means following a plan, or ensuring that the revegetation is carried out by suitably trained people.

Planting density

- An appropriate balance between ground cover, mid-storey and canopy plants is:
  - 50% ground cover species
  - 30% middle storey species
  - 20% upper storey (canopy) species
- Planting density in non-flood control areas could be:
  - 0.5 to 1 m spacing for ground covers
  - 2 to 4 m for mid-storey plants
  - 4 to 5 m for upper storey plants



Desirable characteristics of riparian vegetation

The hydraulic roughness of different plants

Lomandra plant with fibrous root system

Introduction

- Plants help to control creek erosion in two ways:
  - their root system help to anchor the soil, which is very important during and immediately after floods
  - the leafy and woody matter above the ground can help to slow flow velocities, which reduces the erosion risk immediately upstream of the plant.

Trees without middle storey plants

Trees (upper storey plants)

- I love trees, especially eucalypts, but I am afraid trees are often credited for a lot of the erosion control work that is actually performed by shrubs and groundcovers.
- Trees are soil anchors, they are the plants that allow our waterways to have steep and high banks.
- The right tree, planted in the right place, at the right density, can be a very powerful force in creek engineering; however, their hydraulic roughness may not be as much as some people fear.

Riparian shrubs

Shrubs (middle storey plants)

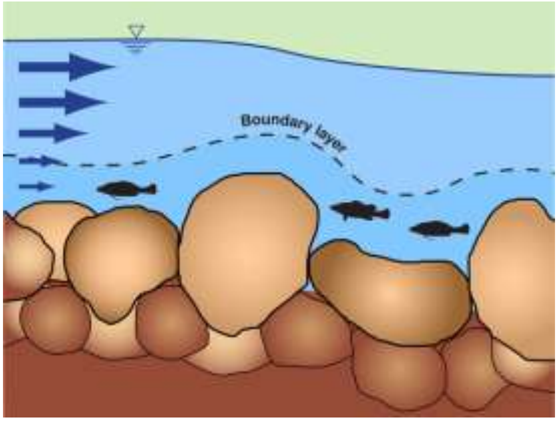
- As previously mentioned, shrubs are often the undervalued plants of our bushland and waterways.
- Shrubs can contribute significant hydraulic roughness to a channel (which can increase flood levels), but it is the existence of these shrubs that can help protect many of our riparian trees.
- The ability of a shrub to bend with the flow, and then quickly recover after a flood, is a very important attribute for a riparian plant.

Groundcover plants

Groundcovers

- Groundcovers can consist of living plants and discarded leaf litter.
- It is the groundcovers, such as the various native grasses and vines, that slow flow velocities close to the ground, and help to prevent soil erosion during floods.
- What primarily stops soil scour is not the part of the plant that lies within the soil (the root system), but the part of the plant that stands above the soil.
- Groundcovers generally do not add much to the overall channel roughness.

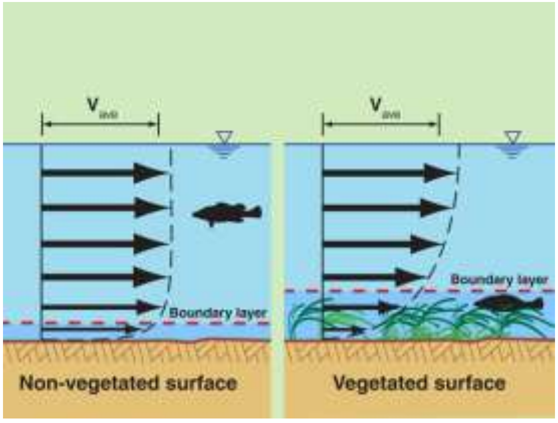
Fish passage considerations



Variation in velocity with depth

The benefits of channel roughness for fish passage

- Flow velocities are never uniform across the width and depth of flowing water.
- Close to the surface of the bed and banks of waterways, water velocities decline rapidly to form a layer of slow-moving water known as the boundary layer.
- The thickness of this boundary layer is directly related to the degree of surface roughness, and it is within this boundary layer that fish movement often occurs during periods of high flow.



Effects of channel roughness

Different vegetation causes different boundary layer and turbulence conditions

- Woody vegetation, such as trees and shrubs, cause extensive flow turbulence, and a general slowing of the water column, which can result in increased flood levels.
- Stiff grasses, such as Lomandra, are ideal for producing a thick, fish-friendly, boundary layer.
- Soft grasses, however, can fold flat in high velocity flows resulting in a thin, non fish-friendly boundary layer.

Planting along the water's edge (Qld)

The importance of plants along the water's edge

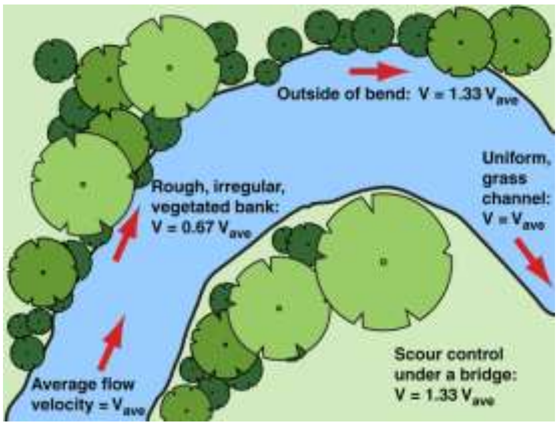
- Plants placed along the water's edge should partly shade the water.
- These plants:
  - shade the water and reduce water temperature during the heat of the midday sun
  - shelter fish from terrestrial predators
  - provide beneficial boundary layer conditions.

Adverse under-deck planting conditions

The importance of establishing vegetation under bridge decks

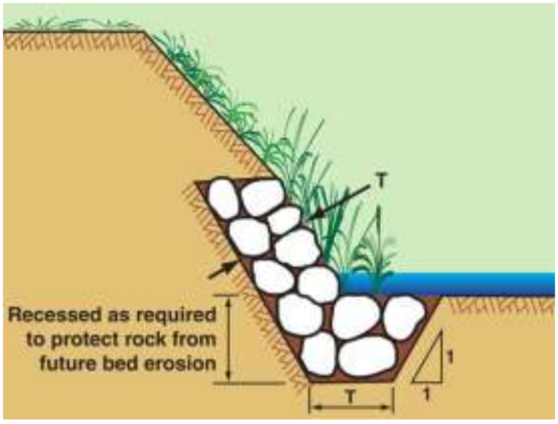
- Fish passage not only occurs within the main waterway channel, but it can also occur across overbank areas during flood events.
- Appropriate vegetation can aid fish passage during different flow conditions:
  - channel bed (ephemeral streams)
  - channel banks (moderate flows)
  - overbank areas (minor floods)
  - bridge abutments (major floods).

Use of rock in bank stabilisation



Placement of rock on channel bends

Partial vegetated bank stabilisation



Typical rock placement at toe of bank

Rock stabilisation on channel bend

Design velocity (V_{design}) adjacent to banks

- In grass-lined channels with a uniform cross-section, adopt a design velocity equal to the calculated average flow velocity ($V_{design} = V_{average}$).
- In irregular, natural, woody/scrubby waterways, adopt a design velocity of two-thirds (67%) the average flow velocity.
- In all cases, on the outside of significant channel bends, adopt a design velocity adjacent to the outer bank of 133% of the average flow velocity (1.33 $V_{average}$).

Rock type and grading

- Crushed rock is generally more stable than natural rounded stone.
- A 36% increase in rock size is recommended for rounded rock.
- The rock should be durable and resistant to weathering.
- Neither the breadth nor the thickness of a given rock should be less than one-third its length.
- In waterways the nominal rock size is usually between 200 mm to 600 mm.

Recessing rock below the toe of bank

- In most cases, rock stabilisation only needs to extend **below** the bed level if:
  - the rock is placed on a steep bank, and there is a risk of the rocks slipping down the bank during floods
  - deep movement of bed material is likely to occur during floods, or
  - long-term lowering of the bed level (bed erosion) is likely to occur.
- Otherwise, the toe protection can rest on the channel bed.

Elevation of rock placement on banks

- Rock placement often does not need to extend to the top of the bank.
- A simple guide to rock placement is:
  - straight reaches: 1/3 to 1/2 bank height
  - channel bends: 2/3 lowest bank height on the outside of bends; and 1/3 the lowest bank height on the inside of bends.
- In most cases, the upper bank area only needs to be stabilised with suitable vegetation.

Use of rock in bank stabilisation

Larger rocks forming toe protection

Rock placement over filter cloth (Qld)

Stacked boulder wall

Vegetated rock stabilisation of bank

Thickness of rock protection

- The thickness of the armour layer should be sufficient to allow at least two overlapping layers of the nominal rock size.
- The thickness of rock protection must also be sufficient to accommodate the largest rock size.
- It is noted that additional thickness (i.e. placing more than two layers of rock) will **not** compensate for the use of undersized rock.

Backing material or filter layer

- Non-vegetated armour rock must be placed over a layer of suitably graded filter rock, or geotextile filter cloth.
- The geotextile filter cloth must have sufficient strength, and must be suitably overlapped, to withstand the placement of the rock (which normally results in movement of the fabric).
- Armour rock that is intended to be vegetated by appropriately filling all voids with soil and pocket planting, will generally not require an underlying filter layer.

Maximum bank slope

- Maximum batter slope is typically 1:2 (V:H) for non-vegetated, and 1:2.5 (V:H) if vegetated—the flatter slope being desirable (but not essential) to provide safe conditions for planting operations.
- Steeper banks can be achieved with the use of slacked boulders, but the rocks must sit on a stable bed.
- Steep high banks can represent a safety hazard to revegetation teams—seek advice from revegetation contractors.

Establishment of vegetation

- The establishment of vegetation over rock-lined surfaces is generally encouraged.
- Common revegetation problems that may need to be addressed during the design phase include:
  - poor aesthetics due to poor plant selection or weed invasion
  - steep banks that can be difficult to maintain and weed
  - reduce the flow capacity of waterway crossing if woody species are allowed to establish in critical areas.

Examples of vegetated rock armouring

Sandy Creek, Enoggera, June 1997

Sandy Creek, Enoggera, October 2014

Sheep Station Gully, July 1999

Sheep Station Gully, September 2008

Farley Creek, Inala, January 1995

Farley Creek, Inala, July 2004

Kedron Brook, Ferny Hills, July 2011

Kedron Brook, Ferny Hills, September 2014

Common problems associated with rock stabilisation of waterways

Bank erosion at d/s end of rock work

Bank erosion at downstream end of rock-lined banks

- In the absence of a vegetative cover, rock-lined surfaces can act as 'hydraulically' smooth surfaces that can induce high flow velocities to exist adjacent to the rock-lined surface.
- These same high velocities can cause erosion on the unprotected waterway bank immediately downstream of the rock-lined surface.
- Erosion along the adjacent creek bed is also common.

Tunnel erosion under rocks

Rock placed on dispersive or slaking soils

- Rocks should **not** be placed directly onto a dispersive, sodic, or slaking soil.
- Tunnel erosion is a common outcome when rocks are placed directly on dispersive soils.

Collapsed dispersive soil bank

Placement of rock over dispersive soils

- If the rock is to be placed over a dispersive soil, then **prior** to placing the filter cloth, the exposed soil **must** first be covered with a layer of non-dispersive soil, typically minimum 200 mm thickness, but preferably 300 mm.
- It is noted that filter cloth, no matter how thick, cannot seal a dispersive soil, and thus should not be relied upon as the sole underlay for rock placed on a dispersive soil.

Poorly placed rocks on creek bank

Rock not integrated into the bank

- Rocks should not be placed on a creek bank in a manner that detracts from the natural aesthetics of the waterway.
- Wherever possible, the rocks should be recessed into the soil, and appropriately vegetated.
- The exception being when the establishment of vegetation would adversely affect local flood levels.

Temporary erosion control measures during site rehabilitation

Flood damage to site revegetation

Temporary bank stabilisation during site revegetation

- Temporary erosion control measures are often required during the revegetation phase.
- These erosion control measures are used to:
  - reduce damage to newly planted surfaces
  - reduce the loss of soil in the event of increased stream flows within the waterway.

Jute erosion control blanket

Erosion control blankets

- The use of 'fine' or 'thick' jute blankets is potentially undesirable in waterways because of the risk of elevated stream flows lifting and washing away the blankets, along with several plants.
- If jute blankets are used, then these blankets are more likely to be the thicker blankets to help suppress weeds.
- Erosion control blankets can be anchored to the soil similar to 'meshes' (below).

Jute mesh with additional rock anchors

Jute and coir mesh

- Jute or coir mesh is the most commonly used and recommended erosion control mat for waterway environments.
- These meshes are less likely to be disturbed by elevated stream flows, and are easier to plant into.
- The mesh is commonly anchored with traditional metal or plastic pins, plus additional rock weights.

Synthetic reinforced erosion control mat

Caution the use of synthetic reinforced erosion control mats

- Mats differ from 'blankets' because they typically incorporate a synthetic mesh that allows them to withstand higher flow velocities.
- These synthetic reinforced mats should not be used in bushland and waterway environments because ground dwelling animals, such as lizards, snakes, and seed-eating birds, can become entangled in the mesh.

12. Case Studies

Case Study A: Sediment removal from a city drain, Brisbane, Qld

Site map

A cofferdam isolates the work area

Sediment removed from the storm drain

Gas monitoring

Introduction

- The job involved de-silting a storm drain that extended from the suburb of Woolloongabba to Norman Creek, East Brisbane.
- The work occurred during February 2000.
- It is noted that the author did not play a role in the design or operation of this project, and the project was largely successfully completed without the aid of any state or local guideline on how such instream works should be conducted.

Isolation of the drain from downstream waterway

- A sandbag and earth-fill cofferdam was formed at the end of the drain to isolate the drain from Norman Creek's tidal waters.
- The cofferdam included three discharge pipes with tide gates fitted.

Excavation of sediment from drain

- Highly polluted, stormwater sediment was removed from the partially enclosed stormwater drain.
- Sediment extraction occurs from one side of the storm drain at a time, with the parallel cell temporarily isolated.
- This sediment would have collected over several years as a result of stormwater runoff and the normal sedimentation process that occurs at the tidal limits of the many tidal inlets connected to the Brisbane River.

Safety warning

- Gas monitoring is used because of the confined spaces.

Case Study A: Sediment removal from a city drain

Sediment stockpiled inside the drain

Initial material de-watering

- The excavated material is initially de-watered in the drain by mounding the sediment up against the sidewall of the drain.
- The draining water is temporarily contained within the storm drain.

Truck loading area

Disposal of sediment

- At regular intervals, an excavator collects the partially de-watered sediment from the drain and loads it into sealed trucks for removal to a waste disposal depot.
- Prior to the truck's arrival, filter cloth is placed over the loading area as a form of 'drop cloth' to collect any spills (this action will aid in the final clean-up of the park).
- The photo shows only a service vehicle on the site, with the filter cloth partially folded away.

De-watering the storm drain

Site de-watering

- Sediment-laden water that has drained from the sediment is pumped from the storm drain to a settling pond.
- A small sandbag cofferdam (bottom-left) is used to prevent this water from flowing into the adjacent storm drain.

Settling pond

Settling pond

- Sediment-laden water removed from the drain is pumped to a settling pond constructed in the adjacent park.
- The settling pond was fenced off from the public area.

Case Study A: Sediment removal from a city drain

Stage 1 of settling pond (inlet)

Settling pond inlet

- The settling pond was divided into three cells using two porous walls formed from sandbags.
- Spill-through weirs were formed at opposite ends of the two dividing walls to reduce the risk of short-circuiting.
- Gypsum was added to the first cell to improve the settling properties of the sediment-laden water.
- Given the saline nature of the water, the benefits of adding gypsum may be questionable (unknown by the author).

Subdivided settling pond

Settling pond

- Unlike a 'stilling pond', which relies on a plug flow (start/stop) process, a 'settling pond' uses a continuous flow process.
- Water passes from cell to cell by either filtering through the sandbag walls (which will quickly block with sediment), or spilling over the spill-through weirs (which will eventually becomes the only ongoing flow condition).
- Various types of internal 'filter walls' can be used.

Outflow from the settling pond

Discharge from the settling pond

- After passing through the settling pond, the treated water is released onto a grassed filter bed before passing through the creek's riparian zone and then into the creek.
- Ideally, the settling pond is constructed several metres from the waterway in oder to gain as much benefit as possible from the grassed filter bed.

Receiving waterway (tidal)

Receiving waterway

- The receiving waterway, a tidal inlet of Norman Creek.

Case Study B: Creek bank stabilisation, Grovely, Qld

Location map

Background

- This project involved the rebuilding of a creek bank that had been severely eroded during the flood events in 2009, 2010 and 2011.
- The eroded bank presented a safety risk to the adjacent park and school, plus a source of sediment for the creek.
- The site is located immediately upstream of the Dawson Parade bridge over Kedron Brook in the suburb of Grovely, Brisbane.
- The works were conducted in late 2012.

Site conditions in 2010

Erosion visible on the left bank, 2012

Site office and stockpile area

Site office

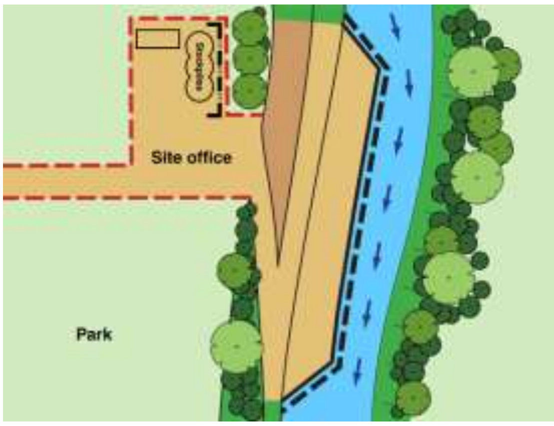
- A site office, equipment storage area and stockpile area was established in the park adjacent to the creek.
- The site office was surrounded with temporary fencing.
- It is noted that the author did not play a role in the design or operation of this project.

Stockpile area

Stockpile area

- A sediment fence was installed between the creek and the stockpiles.

Case Study B: Creek bank stabilisation, Grovely



Approximate layout of work site

Erosion and Sediment Control Plan

- This sketch demonstrates the general layout of the site and the proposed erosion and sediment control measures.

Isolation of the work area

Bypass of the creek flow

- Vegetation was cleared from the bank and a vehicle access ramp was formed down the bank.
- An earth berm was formed on the creek bed to divert the low-flow channel to the northern side of the creek.
- Filter cloth (white) was placed over the upstream end of the earth berm.
- The isolated section of creek bed was de-watered to allow equipment to access the base of the eroded creek bank.

Flow diversion berm

Flow diversion berm

- The flow diversion berm was formed from earth obtained from the formation of the vehicle access ramp.

Rock filter dam

Instream sediment trap

- A minor rock filter dam was installed across the low-flow bypass channel at the downstream end of the work area to control sediment during the formation of the flow diversion berm.
- The rock filter dam remained in place until construction vehicles finally left the channel and the vehicle access ramp was removed and replaced with rock.

Case Study B: Creek bank stabilisation, Grovely

Reconstruction of the eroded bank

Earthworks

- Earth is imported to reconstruct the eroded creek bank.
- Sediment-laden water generated by the movement of vehicles is isolated from the creek flow by the earth berm.

Sediment fence isolation barrier

Sediment fence isolation barrier

- A sediment fence isolation barrier was installed above the earth berm to provide additional flow protection to the work area.
- An alternative would have been to first construct a sediment fence isolation barrier in the live stream, then construct an earth berm behind the sediment fence.
- However, the ability to successfully construct a sediment fence isolation barrier in a creek depends on how much bed rock exists in the creek.

Upstream rock stabilisation

Placement of rock

- Rock stabilisation is placed over the newly formed creek bank.
- Earth fill is introduced to the rock during its placement in order to fill all voids prior to pocket planting.
- Ideally, filter cloth should not have been placed under the rocks as this cloth can interfere with the root growth of the established bank vegetation.
- The isolation barrier is removed from the creek bed.

Removal of rock filter dam

Removal of materials from creek bed

- All materials are removed from the creek bed.

Case Study B: Creek bank stabilisation, Grovely

Downstream rock stabilisation

Rock placement

- The vehicle access ramp is removed and the creek bank is reshaped prior to placement of the rock stabilisation on the downstream section of creek bank.

Site revegetation

Site revegetation

- All voids in the rock work are filled with soil.
- The creek bank is covered with jute mesh.
- Bank revegetation is established within the rock work and overbank area.
- The overbank area is also covered with jute mesh.

Turfing of overbank disturbance

Rehabilitation of site office area

- The site office, equipment storage area and stockpile area are turfed.
- All vehicle-compacted soil must be ripped before placement of the turf in order to allow the turf roots to freely establish within the underlying soil.

Post-construction, 2014

Post-construction

- Shortly after the works were completed the site experienced a significant stream flow which disturbed much of the jute mesh.
- Some bank vegetation was lost during this storm event.

Case Study C: Creek bank stabilisation, Ferny Hills, Qld

Vegetation clearing and weed removal

Site conditions prior to flood event

- In 2008, extensive weed removal occurred along the bank of Kedron Brook without associated revegetation.
- The bulk of the disturbed area was either covered with turf or loose mulch.
- It is noted that the author did not play a role in the design or operation of this project.

Post November 2008 flood

2008 flood event

- Shortly after the weed removal program, the creek experienced a minor flood event in late 2008.
- The flood washed away most of the loose mulch, and eroded the creek's northern bank.

Site office

Site office

- In late 2014 a project was undertaken to rebuild and stabilise the creek bank.
- A site office was established between the road and the creek.

Upstream cofferdam

Earth cofferdam

- An earth cofferdam was established upstream of the work area.
- Minimal dry weather flows exist in the creek, so a flow bypass was not required.
- The isolated section of channel was de-watered to a filter tube that was located at the downstream end of the work area.

Case Study C: Creek bank stabilisation, Ferny Hills

Bank reconstruction

Earthworks

- Deposited sediment was removed from the creek bed and the eroded creek bank was reformed.
- The full site could be accessed from the northern creek bank.

Rock placement

Bank stabilisation

- The reconstructed creek bank was covered with rock.
- All voids in the rock work were filled with soil.
- The overbank area was covered with jute mesh.

Rehabilitation of overbank area

Rehabilitation of site office area

- The overbank area outside the riparian zone was turfed.

Site revegetation

Revegetation

- Vegetation was established within the rock work and overbank area.

Case Study D: Creek bank stabilisation, Closeburn, Qld

Bank scour (January 2015)

Site conditions

- The eroding creek bank is located within private property.
- The creek is a gravel-based waterway with a medium-sized rural catchment.
- The eroded bank is located on the outside of a significant (approximately 90-degree) channel bend.
- The bank experienced significant scour during the floods of 2010, 2011 and 2013.

Access ramp down creek bank

Site establishment and temporary flow diversion

- The creek bank was to be stabilised with vegetated rock.
- A heavy vehicle access ramp was formed down the section of creek bank that was going to be stabilised.
- A temporary bypass channel (below) was formed on the opposite side of a vegetated 'island' that exists in the centre of the creek bed.

Cedar Creek with the bypass channel on the left and the work site on the right

Case Study D: Creek bank stabilisation, Closeburn

Rock filter dam downstream of work area

Instream rock filter dam

- Formation of the bypass allowed the work site to be isolated from any dry weather stream flows (i.e. natural base flow).
- An impervious cofferdam was formed at the upstream end of this isolated section of channel.
- A rock filter dam (formed from the natural bed gravel) was constructed at the downstream end of the isolated section of channel to treat any discharges originating from the work area.

Placement of rock (November 2015)

Rock placement

- Isolating the section of channel adjacent to the work site allowed the excavator to move across the gravel creek bed.
- The rock stabilisation consisted of layers of rock topped with sufficient soil to fill all voids, thus helping to encourage deep root growth for the eventual revegetation.

Hydromulch seeding (December 2015)

Initial seeding and mulching

- The finished bank was seeded with a hydromulch in order to achieve a rapid ground cover, thus protecting the bank from possible summer storms.

Early plant establishment (2016)

Early plant establishment

- Once a healthy ground cover was established over the bank, appropriate native riparian vegetation (predominantly shrubs) was planted across the bank.

13. Glossary of terms

Alluvial waterway	A waterway formed primarily from flood-laid deposits of sand, silt and gravel.
Aquatic wildlife	Animals that inhabit or frequent aquatic environments.
Armour rock	The upper layer of rock that is exposed to the hydraulic forces of waves and water flow.
Base flow	The stream flow that cannot be directly attributed to storm events, and is present during part or all of dry periods.
Clay	[1] Soil particles less than 0.002 mm in equivalent diameter. [2] A soil texture group in which the soil contains at least 35% clay and no more than 40% silt.
Clay-based waterway	A watercourse where clayey soils dominate the make-up of the channel bed.
Clean water	Water that either enters the property from an external source and has not been further contaminated by sediment within the property; or water that has originated from the site and is of such quality that it does not need to be treated in order to achieve the required water quality standard.
De-silting	To remove settled or collected sediment from a waterbody.
De-watering	The permanent or temporary removal of water from a given location.
Dirty water	Water not classified as clean water.
Dispersive soil	A structurally unstable soil that readily disperses into its constituent particles (clay, silt and sand) when placed in water. Most sodic soils are dispersive, but not all dispersive soils may be classified as sodic.
Drainage line	A natural or constructed stormwater drainage path that carries ‘concentrated’ rather than ‘sheet’ flow, and is likely to flow only during periods of rainfall, and for short periods (hours) after rain has stopped, and is a drainage path that cannot be classified as a ‘watercourse’ based on a locally or state-adopted classification system.
Elevated stream flow	A stream flow that is greater than the normal dry weather flow (base flow) expected for a given time of year.
Ephemeral waterway	A watercourse that only flows during and for short periods after storms.
Environmental harm	Any adverse effect, or potential adverse effect (whether temporary or permanent) on an environmental value.
Environmental risk	The potential of an activity to cause harm, whether material, serious, reversible or irreversible, to an environmental value. It includes potential nuisance caused to a person or property.
Erosion and Sediment Control (ESC)	The application for structural and non structural measures to control stormwater drainage, soil erosion and sediment runoff during the construction and building phases of land development. Some of these measures may be retained as part of the permanent site rehabilitation.
Erosion and Sediment Control Plan (ESCP)	A site plan, or set of plans, including diagrams and explanatory notes, that demonstrate proposed measures to control stormwater drainage, soil erosion, and sediment runoff during the active work phase.

Erosion control blanket	A blanket of synthetic and/or natural material used to cover and protect soil against erosion caused by wind, rain, and minor overland flows. In this document, the term 'blanket' also includes 'mats' and 'mesh'.
Erosion control mat	A mat of synthetic and/or natural material that is primarily used to protect soil against erosion caused by concentrated surface flows.
Erosion control mesh	An open weave blanket formed from synthetic or natural twine, such as hessian rope (jute) or coconut fibre (coir), primarily used to protect soil against erosion caused by concentrated surface flows.
ESC	Erosion and sediment control.
ESCP	Erosion and Sediment Control Plan.
Fish barrier	Any instream structure or other obstruction impeding the free passage of fish.
Fish barrier permit	A government permit to install, usually for a specified period, a water structure that may act as a fish barrier, such as a cofferdam.
Fish migration	The progressive seasonal movement of fish and other aquatic organisms up or down a watercourse as part of their life cycle.
Fish passage	General movement of fish and other aquatic organisms up and down a watercourse.
Filter cloth	[1] Industrial grade, non-woven synthetic fabric traditionally used to separate soils and rock of different textures or grain size. [2] A short-term filter for the removal of medium to coarse sediment from a liquid (usually water).
Fixed bed waterway	A waterway that does not have significant loose bed material that can migrate down the waterway during flood events.
Ford	A shallow place in a stream where the bed may be crossed by traffic.
Gravel	A mixture of coarse mineral particles larger than 2 mm but less than 75 mm in equivalent diameter.
Gravel-based waterway	Bed material is made-up of well-rounded gravels and boulders. These are 'alluvial' waterways usually containing pools and riffles that completely reform during severe flooding.
In-bank	The part of a channel, including bed and banks, below the channel bank elevation above which the water would spill out of the channel or begin to enter the floodplain.
Instream	Any area between the banks of a constructed drainage channel, watercourse or waterway.
Instream works	Any construction, building or land-disturbing activities conducted between the banks of a constructed drainage channel, watercourse or waterway.
Lateral inflow	Local stormwater runoff that spills into a waterway at a given location.
Moving bed waterway	A waterway that has significant natural loose bed material (substrate) that can migrate down the waterway during flood events. Most alluvial waterways have a moving bed.
NTU	Nephelometric Turbidity Units. A measure of water turbidity.
Off-stream	Relating to being away from the main stream channel.
Overbank	Relating to not being located between the top of the banks of a channel.

Overbank flow	The portion of a flood flow that flows outside the main river channel at relatively small depths over part of, or the full width of, the floodplain and in a direction essentially parallel with the main channel.
Ramsar wetland	A wetland identified as internationally important for the protection of migrating birds by the Ramsar Convention on Wetlands of 1971 held in the Iranian town of Ramsar, which resulted in a United Nations treaty enacted in 1975.
Riparian zone	That part of the landscape adjacent to a watercourse that influences, and is influenced by, watercourse processes. Usually includes the instream habitats, beds, banks and floodplains of watercourses, or their parts.
Rock-based waterway	Bed material is made-up of exposed rock outcrops separated by sections of clay, sand or gravel-based channels. Bank stability is governed either by bank vegetation or exposed rock walls. These are fixed-bed 'spilling' waterways usually containing riffles and waterfalls followed by deep pools.
Sand-based waterway	Waterways in which deep, loose sand dominates the make-up of the stream bed. The depth of the sand typically exceeds the depth of the root systems of some bed and lower bank vegetation. These are 'alluvial' waterways that experience significant sediment (sand) flow during both minor and major stream flows. The bed material can be highly mobile during floods, thus bed vegetation is normally dominated by quick-response species.
Sediment pond	A natural or purpose-built pond or sediment trap that is used as a regular sediment extraction point within an urban waterway.
Stream order	Stream order is a system for ranking the individual reaches of a waterway. There are a number of these ranking systems. In the Horton system a first-order stream has no contributing branches based on a specified mapping scale (the choice of map scale is critical). A second-order stream has at least two contributing first-order branches. A third-order stream has at least two contributing second-order branches, etc.
Terrestrial wildlife	Animals that inhabit or frequent land environments. Depending on its usage, terrestrial fauna may or may not be further distinguished from two subgroups, arboreal (living in trees) and aerial (pertaining to the air space).
Toe of bank	The junction of the base of a channel bank with the channel bed.
TSS	Total Suspended Solids, usually reported in units of mg/L.
Turbidity	A measure of the clarity of water. Commonly measured in terms of Nephelometric Turbidity Units (NTU).
Type 1, Type 2, Type 3 sediment traps	A classification system used to rank sediment control measures based on their ability to trap a specified grain size. Type 1 sediment traps are designed to collect sediment particles less than 0.045 mm in size. Type 2 sediment containment systems are designed to capture sediments down to a particle size of between 0.045 and 0.14 mm. Includes rock filter dams, sediment weirs and filter ponds. Type 3 sediment containment systems are primarily designed to trap sediment particles larger than 0.14 mm. These systems include sediment fences, grass buffer zones, and certain stormwater inlet protection systems.

Watercourse	Any natural or constructed drainage channel with well-defined bed and banks, including constructed drainage channels of a natural appearance, creeks and rivers, but not grass-lined or hard-surface constructed drainage channels void of ecological values. Within this document, the term can be interchanged with 'waterway'.
Waterway	Any natural or constructed drainage line, watercourse with well-defined bed and banks, including creeks and rivers, and any water body including lakes, wetlands, estuaries, bays and oceans. Within this document, the term can be interchanged with 'watercourse'.
Work area	The area that will be disturbed by building or construction works, including the area that fully encloses any soil disturbances, the building activities, materials stockpiles and vehicle pathways.
WQO	Meaning: Water Quality Objective. Usually a water quality standard set by a regulating authority.