Erosion & Sediment Control for Road Construction

Part 2:
Erosion and Sediment Control Plans & Bridge and Culvert Construction

Catchments & Creeks

August, 2017

Erosion & Sediment Control Field Guide for Road Construction – Part 2

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Disclaimer

Significant effort has been taken to ensure that this document is representative of current (2017) best practice erosion and sediment control practice; 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 as techniques and knowledge improve.

To be effective, erosion and sediment control measures must be investigated, planned, and designed in a manner appropriate for the given work activity and site conditions.

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

- compliance with any statutory obligations
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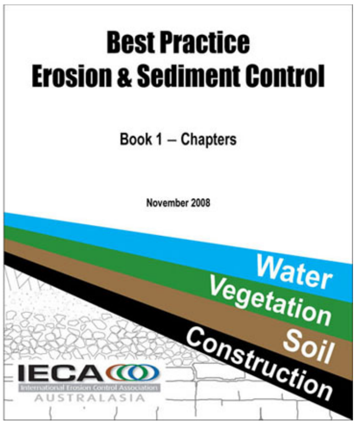
Principal reference documents:



IECA (2008) – Book 1

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

1. Introduction
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3. Site planning
4. Design standards and technique selection
5. Preparation of plans
6. Site management
7. Site inspection
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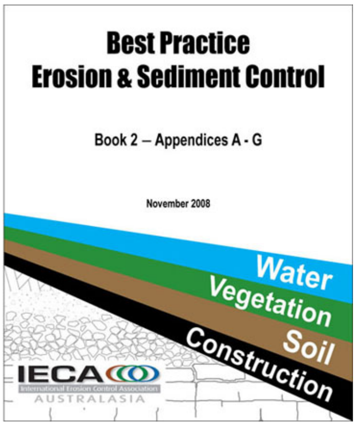

IECA (2008) – Book 2

Book 2: Appendices

A. Construction site hydrology and hydraulics
B. Sediment basin design and operation
C. Soils and revegetation
D. Example plans
E. Soil loss estimation
F. Erosion hazard assessment
G. Model code of practice

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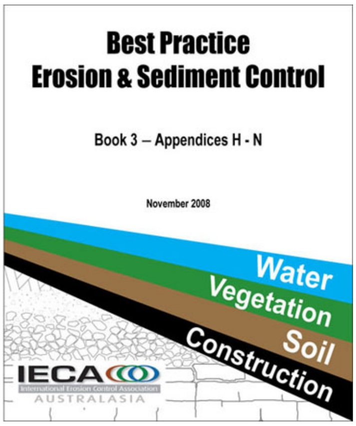
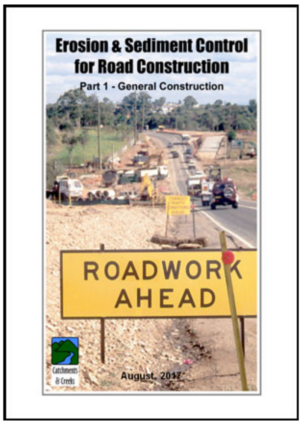


IECA (2008) – Book 3

Book 3: Appendices

H. Building sites
I. Instream works
J. Road and rail construction
K. Access tracks and trails
L. Installation of services
M. Erosion processes
N. Glossary of terms
P. Land-based pipeline construction
X. Index (Books 1 to 3)



Field Guide for Road Construction, Part-1

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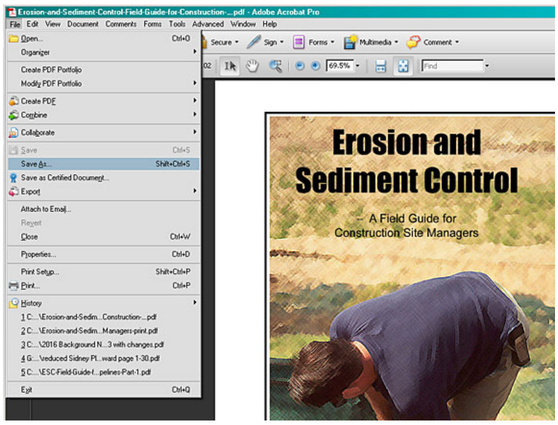

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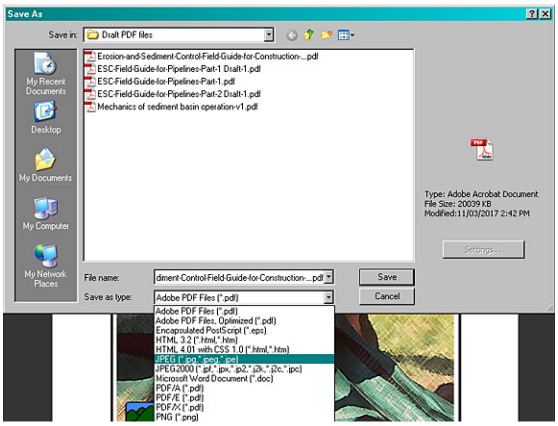

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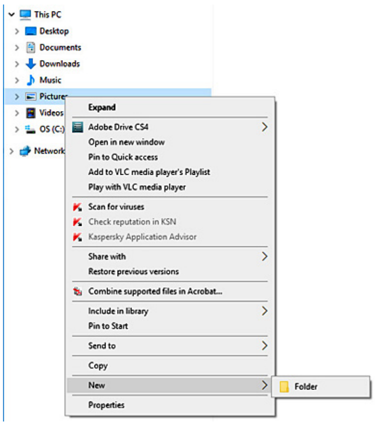

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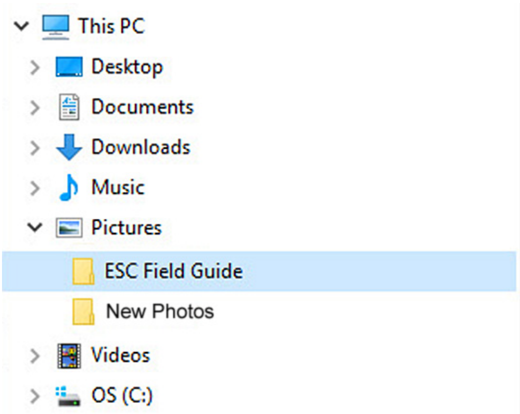

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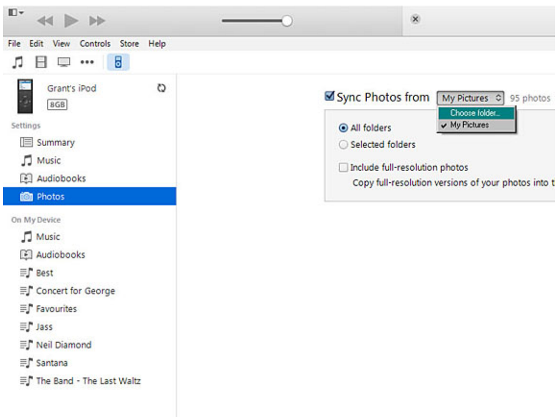

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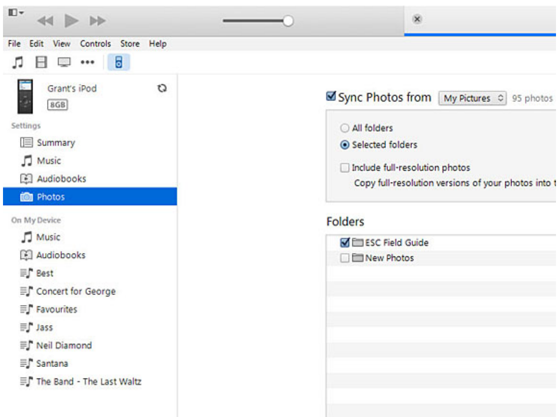

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Contents

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Purpose of field guide

Part 2 of this field guide has been prepared specifically to provide:

- the road construction industry with general information on the preparation of erosion and sediment control plans, and the management of bridge and culvert construction
- construction personnel working within the road construction field with an additional training tool on Erosion and Sediment Control.

This field guide has been prepared specifically for use on greenfield road construction and large rural road projects. Only parts of the document will be relevant to urban road construction.

This guideline has **not** been prepared for the purpose of being a site's primary guide to erosion and sediment control. Consequently, the recommendations provided within this field guide should **not** be used to overrule advice obtained from suitably trained experts, or the recommendations and/or requirements of locally endorsed ESC guidelines/manuals.

It is noted that approximately 64% of the photos presented within this field guide have originated from road construction projects.

About the author

Grant Witheridge is a civil engineer with both Bachelor and Masters degrees from the University of NSW. He has over 35 years experience in the fields of hydraulics, stormwater management, creek engineering and erosion & sediment control. Since 1995, Grant has conducted over 380 training courses in erosion and sediment control attended by some 6500 people.

Grant is the principal author of the IECA (Australasia) *Best Practice Erosion and Sediment Control (2008)* documents. In 2010 Grant was presented with the IECA (International) *Sustained Contributor Award*.

Introduction

Roadway crossings of waterways are complex construction activities that can pose a significant risk to waterway environments. Each waterway crossing can present a unique set of site conditions that requires a specific construction practice.

This field guide attempts to provide general advice and guidance on the construction of waterway crossings with respect to erosion and sediment control (ESC) issues. However, it should be noted that ESC issues represent only one of the many issues that need to be considered on any construction project.

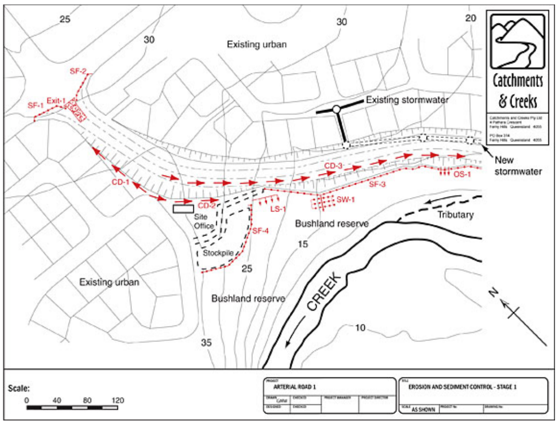
To a limited extend, guidance is also provided on related topics such as fish passage considerations during the construction phase, and the rehabilitation of waterways disturbed by construction activities.

The application of this field guide to a particular waterway crossing will depend on the type of roadway and the type of waterway crossing (i.e. bridge, culvert, causeway, ford). The appropriate application of this field guide requires the reader to have experience in civil construction. The recommendations presented within this document **must** be tailored to the conditions known to exist at a particular site, and **must** represent an appropriate balance between theory, past experience, and common sense.

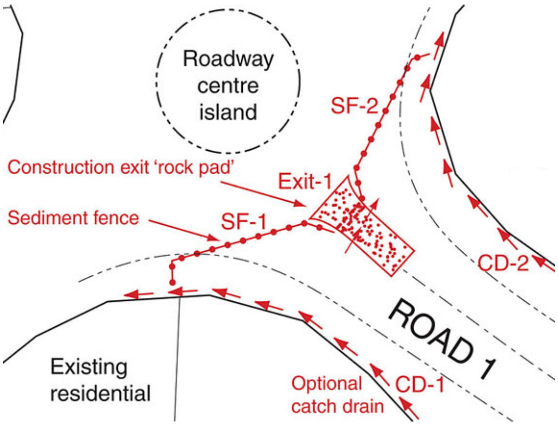
In general, the Erosion and Sediment Control industry relies on the combined experience of several professions, including construction personnel, geotechnical engineering, hydraulic engineering and revegetation specialists. The design and construction of waterway crossings introduces into the design team additional experts from a number of other professions, including river morphology, riverine biology, and experts in aquatic and terrestrial passage.

This field guide contains many examples of waterway culverts constructed in stages to allow uninterrupted flow bypass and fish passage. Such construction practices are currently not the 'normal' construction method, and in most cases would require the re-design of the culvert's structural components and steel reinforcing. It should be noted that 'best practice' does not mean 'the best of the best', it is a term that would have been better described as 'the most appropriate construction practice for a given set of circumstances relative to current national and international practices'.

Erosion and Sediment Control Plans

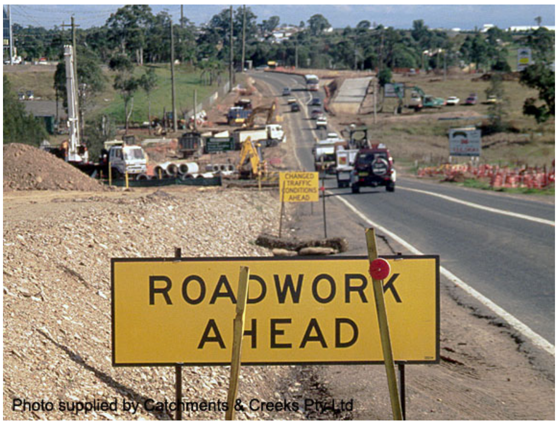


Primary ESCP



Progressive ESCP

Clean water cross-drainage system



Duplication of an existing roadway

Primary ESCP

- Major road projects can adopt a two-stage process to the development of Erosion and Sediment Control Plans (ESCPs).
- The first ESCP is the 'Primary ESCP', which is an overarching ESCP that provides generic drainage, erosion and sediment control procedures for the whole of the construction project.
- These plans set out key issues, such as the location of major sediment traps, so that they can be incorporated into the road design.

Progressive ESCP

- The second stage consist of the development of 'Progressive ESCP'.
- Progressive ESCPs are developed for each stage of the road works, and are also produced in response to changing site conditions.
- These plans provide details on the location and installation of ESC measures within each drainage sub-catchment, either hilltop to valley floor, or hilltop to hilltop.

Management of 'clean' run-on water

- Critical to the design of any ESCP is the management of both 'clean' and 'dirty' stormwater runoff.
- One option is to carry all run-on water along the up-slope edge of the road to the nearest drainage line or waterway.
- The alternative is to carry this clean run-on water across the road at regular intervals; however, this process may not be practical while 'boxing out' the road foundations because the road works effectively acts like a wide drainage channel.

Base plan

- A <u>critical</u> aspect of road construction ESCPs is the selection of the 'base plan'.
- The base plan is the underlining road layout onto which the ESC measures are identified within the ESCP.
- In road construction, a separate ESCP should be prepared for each stage of earthworks and/or temporary road layout.
- If an existing road is being upgraded or replaced, then the existing road embankment can interfere with the flow of dirty water to specific sediment traps.

ESCP production team

Construction personnel

Construction personnel

- The preparation of *Erosion and Sediment Control Plans* (ESCPs) for road construction projects is not a one-person task.
- To avoid expensive, unpractical or ineffective outcomes, the design team must include a range of experts.
- **Key** to the production of practical outcomes is the inclusion of advice from experience construction personnel.
- Even the best ideas are wasted if they contradict specific contract conditions.

Engineering professionals

Engineering advice

- Individual engineers specialise in different fields of engineering, and not all engineers have appropriate construction experience.
- Engineering advice is typically required on:
  - catchment hydrology and hydraulics
  - geotechnical engineering and soil compaction requirements
  - structural engineering issues relating to the proposed staged construction of a waterway crossing.

Scientific officers

Science advice

- Specialist advice may be required on the following issues:
  - soil science
  - fish passage and fish biology
  - environmental protection
  - waterway ecology
- The knowledge base found within the soil science profession is different from that found within geotechnical engineering; however, specialist consultancies typically employ both professionals.

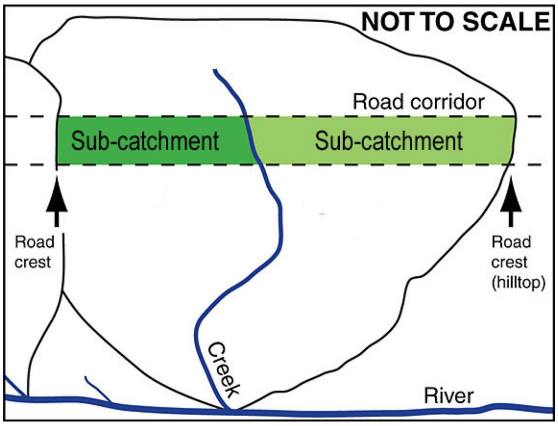
Revegetation contractors

Revegetation advice

- Revegetation contractors are different from landscape architects and botanists.
- Some revegetation contractors specialise solely in the operation of planting/seeding equipment, while others may also have specialist knowledge in plant selection and soil conditioning.
- The knowledge base and experience of the revegetation contractor will have a **significant** influence on both the rate of plant establishment, and the long-term revegetation outcomes.

Development of Erosion and Sediment Control Plans

Protection of a wetland habitat



Defining a drainage sub-catchment

Looking at the end of a staged urban road

Type 2 drop inlet sediment trap

Step 1: Identify environmental issues

- Identify local issues and concerns.
- Identify critical habitats and environmental protection issues along the road corridor.
- Local environmental values may be identified within an existing Stormwater Management Plan, or Catchment Management Plan.
- Identify potential risks to these environmental values.
- Review soil maps to identify high risk erosion hazards.

Step 2: Identify drainage catchments

- Identify drainage lines that cross the roadway, including:
  – minor drainage lines
  – creeks
  – rivers
- Divide the road corridor into individual drainage catchments, either 'hilltop to hilltop', or 'hilltop to valley floor.
- These drainage catchments will be used in the determination of the sediment control standard in Step 4.

Step 3: Identify construction stages

- Determine if the earthworks and/or road construction will be performed in stages.
- A staged construction program is likely to be utilised within large road construction projects, staged subdivision projects, or construction programs that require the re-routing of existing public roads.
- The staging of a project can influence the location and timing of the construction of proposed sediment basins.

Step 4: Sediment control standard

- Determine the sediment control standard (Type 1, 2 or 3) for each drainage catchment identified in Step 2.
- This analysis may required USLE/RUSLE calculations for each drainage catchment.
- The sediment control standard may also be determined by the existence of critical environmental habitats identified in Step 1.
- Specific soil testing is usually required prior to commencing this step.

Sediment control standard (Step 4)

Road construction works

Sediment retained in a sediment trap

Road construction works

USLE & RUSLE

- Soil loss rates are most commonly estimated using the *Universal Soil Loss Equation,* also known as USLE.
- Over its many years of use the parameters used within the USLE have been modified resulting in the formation of a revised equation.
- The Revised Universal Loss Equation (RUSLE) is now the more commonly used equation; however, both equations take the following form:

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

Equation terms

The terms used in the USLE equation are:

- A = soil loss rate (tonnes/ha/yr)
- R = rainfall erosivity factor
- K = soil erodibility factor
- LS = combined length-slope factor
- C = cover and land management factor
- P = erosion control practice factor

To determine the **tonnage** (t) of soil loss:

- – multiply by the area (ha) and time (yr)

To determine the **volume** (m^3) of soil loss:

- – divided by the soil density (t/m^3)

Application of RUSLE to construction sites

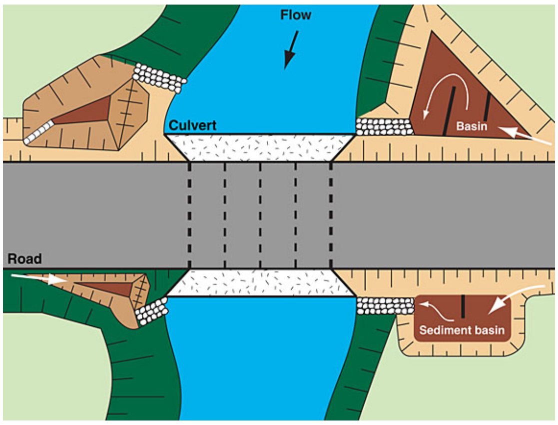
- The USLE/RUSLE formula was originally developed and calibrated for the assessment of erosion rates on **low-gradient** rural properties.
- The equation assesses only 'sheet' and mild 'rill' erosion.
- The equation does **not** take into account soil dispersion, gully erosion or erosion within creeks and drainage channels.

The erosion hazard is linked to the tonnage of soil loss, not the rate (t/ha/yr); thus, the sediment standard is related to both the soil loss rate and area of disturbance (ha), as set out below:

Area limit (m^2)	Soil loss rate limit (t/ha/yr)			Soil loss rate limit (t/ha/month)		
	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3
250	N/A	N/A	Special case	N/A	N/A	Special case
1000	N/A	N/A	All cases	N/A	N/A	All cases
2500	N/A	> 75	75	N/A	> 6.25	6.25
>2500	> 150	150	75	> 12.5	12.5	6.25

Table 1 – Example sediment control standard for general construction works

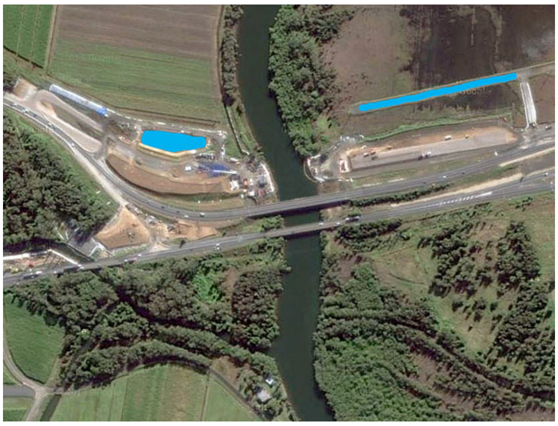
Locating major sediment traps (Step 5)



Culvert construction

Step 5: Locate major sediment traps

- Major sediment traps are most commonly located:
  - within the isolated 'islands' formed by motorway on/off access ramps
  - each side of the roadway, and each side of a watercourse crossing.
- Sediment basins are usually located away from active construction areas, which may require temporary drains to be constructed to carry sediment-laden water to these basins.



Bridge construction

Bridge construction

Culvert construction

Culvert construction

Rural road construction

Residential road construction

Development of Erosion and Sediment Control Plans

Site entry/exit

Step 6: Locate site entry/exit points

- Locate separate entry/exit points away from areas of significant cut or fill.
- On large projects it may be desirable to provide separate light and heavy vehicle entry/exit points if earth is being imported or removed from the site.
- Avoid locating entry/exit points at low points where they could interfere with the positioning of major sediment traps.
- Establish appropriate sediment controls and associated drainage controls around these entry/exit points.

Stockpile area

Step 7: Locate site office, stockpiles and borrow pits

- Identify the location of the:
  - site office
  - material storage areas
  - earth stockpile areas
  - borrow pits
- Establish appropriate drainage and sediment controls around such areas.

Temporary access road

Step 8: Identify temporary access roads

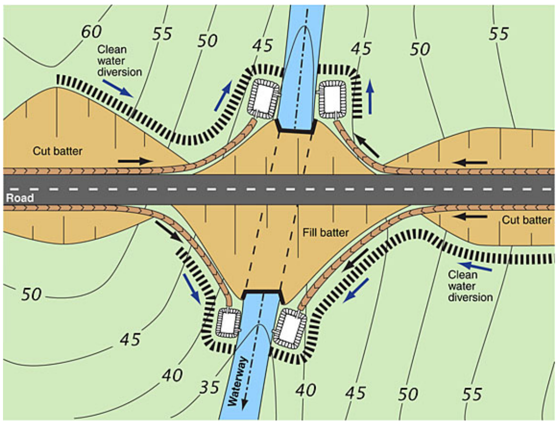
- It is recommended that a separate ESCP is prepared for each construction phase of complex intersections, especially if a public road system already exists.
- Identify temporary access roads required to enter the site and access borrow pits.
- Identifying all temporary roads, in addition to the new roadway layout, is essential prior to preparing *Construction Drainage Plans* to ensure that sediment-laden water can actually flow to the specified sediment traps.

Sediment fence located in bushland

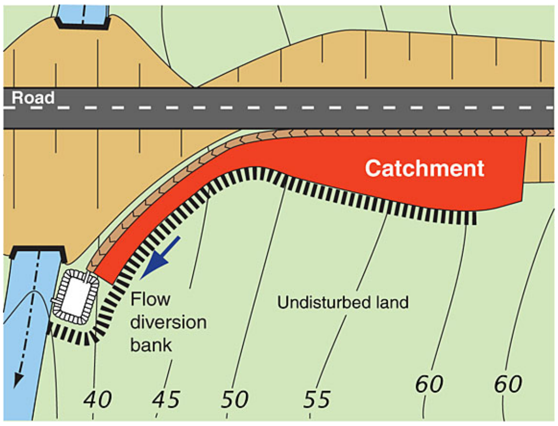
Step 9: Identify potential non disturbance areas

- At this stage of preparing an ESCP it is usually not possible to define the final limits of disturbance because not all of the ESC measures have been identified.
- However, it is important to 'clearly' mark on the plans those areas where land disturbance should not occur in order to avoid placing sediment traps or temporary drainage channels through these areas.

Development of Erosion and Sediment Control Plans



Construction Drainage Plan



Clean water diversion around a basin

Turf filter strips placed along the contour

Temporary batter chute

Step 10: Prepare Construction Drainage Plans

- Prepare *Construction Drainage Plans* for each phase of construction.
- The intent of these plans is to show:
  - flow entry and exit points (i.e run-on and runoff water)
  - areas of sheet flow
  - clean water flow diversions
  - dirty water collection and re-direction.
- These drainage plans are prepared in association with Steps 11 to 16.

Step 11: Identify 'clean' water flow diversions

- Ensure 'clean' run-on water is conveyed through the site in a non-erosive manner without allowing it to mix with sediment-laden water generated within the site.
- Wherever practical, clean water should be diverted around sediment traps in order to:
  - reduce the size and cost of these traps
  - improve the treatment efficiency of these sediment traps.

Step 12: Identify mid-batter drainage controls

- Identify the need for:
  - temporary, mid-bank drainage controls
  - inner-batter turf filter strips, or
  - stage batter revegetation.
- Mid-batter turf filter strips can be used to help maintain non-erosive, 'sheet flow' conditions down high road batters.
- Mid-batter catch drains can reduce the risk of rill erosion, but may not be practical if not apart of the permanent design.

Step 13: Identify location of temporary batter drains

- Newly formed road batters are vulnerable to sheet erosion and rilling during the revegetation phase.
- Temporary 'batter chutes' and 'slope drains' can be used to carry stormwater runoff down newly formed road batters.
- The spacing of these temporary batter drains depends on the maximum catchment area that can be connected to each drainage system.

Development of Erosion and Sediment Control Plans

Velocity control check dam

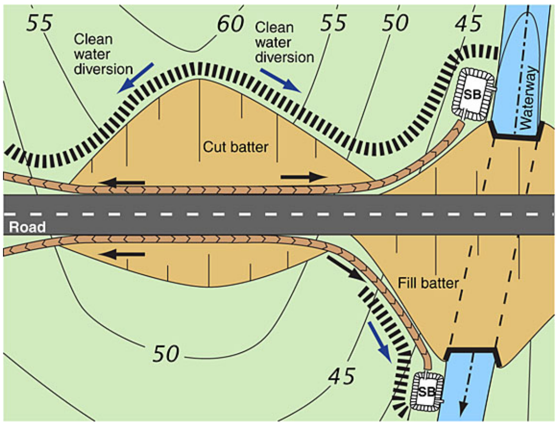
Step 14: Identify velocity control measures

- Ensure non-erosive flow conditions within clean water diversion drains and roadside table drains.
- Treatment options include:
  - reduce the flow velocity within the drain through the use of *Check Dams*, or
  - increase the scour resistance of the drain through the use of *Erosion Control Mats*.
- Avoid duplicating the use of both *Check Dams* and *Mats* within the same drain.

Drop inlet sediment trap

Step 15: Identify location of sediment traps

- Identify opportunities for the placement of sediment traps within the development site.
- Locate sediment traps:
  - up-slope of on-grade kerb inlets
  - around sag-type kerb inlets
  - around drop inlets located with medians
  - up-slope of stormwater pipe inlets
  - along the toe of fill batters
  - along the edge of the road reserve if runoff cannot be directed to a basin.



Drains directing water to sediment basins

Step 16: Identify 'dirty' water drainage

- Identify all necessary 'dirty' water drainage systems required to direct sediment-laden water to major sediment traps, such as *Sediment Basins*.

Batter stabilisation

Step 17: Identify if temporary batter stabilisation is required

- If road batters are not scheduled to be immediately vegetated, then details must be supplied on the application of temporary erosion control measures.
- These measures can include:
  - mulching (straw mulching)
  - brushwood mulching
  - erosion control blankets
  - soil binders (e.g. Polyacrylamide)
  - gravelling (arid & semi-arid regions).

Development of Erosion and Sediment Control Plans

Identification of non disturbance area

Step 18: Identify non-disturbance areas

- After all drainage and sediment control measures have been identified, it is important to ensure that none of these devices have been located within land identified as a non-disturbance area.
- Where appropriate, non disturbance areas can be identified on the site with marker tape to avoid unnecessary land clearing.
- Do not rely on survey pegs to identify non disturbance areas.

Site revegetation

Step 19: Define site revegetation methods

- Site revegetation procedures may not necessarily appear within the ESCP, but may appear within a separate document prepared by the revegetation contractor.
- Landscaping plans typically do not detail the methods that will be used to achieve vegetation cover, but instead detail only the finished condition.
- The ESCP can include details on revegetation methods appropriate for various site locations and seasonal conditions.

Code	Item	Plan	Installed	Removed
Mark out initial limits of disturbance				
Exit-1	Construction Exit	DWG-001	Day one	When permanent internal roads are sealed
Exit-2	Construction Exit	DWG-001	Day one	When permanent internal roads are sealed
Site office		DWG-010	Day one	End of works
SF-1	Sediment Fence	DWG-001	Prior to land clearing	After site stabilisation
SF-2	Sediment Fence	DWG-001	Prior to land clearing	After site stabilisation
SB-1	Sediment Basin	DWG-002	After SF-3	After site stabilisation
CH-1	Chute	DWG-002	During construction of SB-1	During removal of SB-1
Clearing of Sediment Basin settling zone				
CD-1	Catch Drain	DWG-003	After construction of SB-1	After site stabilisation
SS-1	Sediment Trench	DWG-003	Prior to land clearing	After site stabilisation
CD-2	Catch Drain	DWG-003	After construction of SS-1	
CD-3	Catch Drain	DWG-003	After construction of SS-1	
SF-3	Sediment Fence	DWG-003	After land clearing	After site stabilisation

ESC installation sequence

Step 20: Prepare the installation sequence

- It is critical that the various drainage, erosion and sediment control techniques are installed in an appropriate sequence relative to other construction activities.
- The installation sequence should provide:
  - an identification number for each item
  - when the control measure is to be installed relative to other construction activities
  - when the control measure is to be decommissioned.

Stockpile essential ESC materials

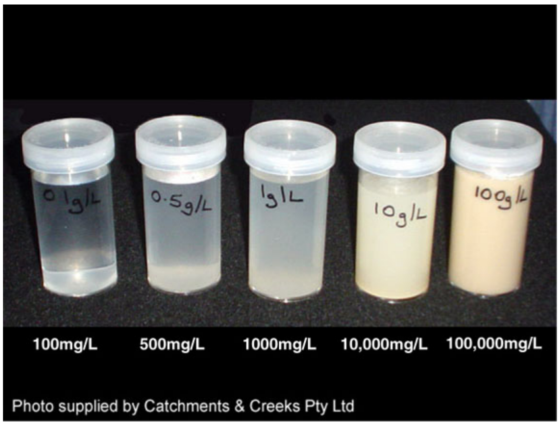
Step 21: Detail site establishment requirements

- *Technical Notes* can be used to specify:
  - ESC materials that need to be stored on site ready for an approaching storm.
  - ESC measures that need to be installed during the initial stages of construction project
  - method of identifying on the site any non-disturbance or exclusion areas.

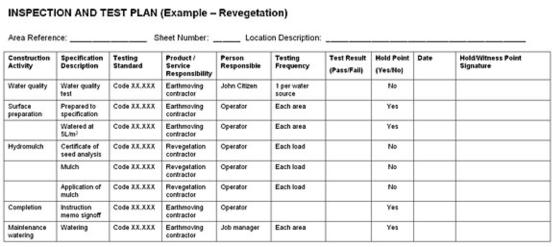
Development of Erosion and Sediment Control Plans

Water quality monitoring

Approaching storm



Examples of suspended solids content



INSPECTION AND TEST PLAN (Example – Revegetation)

Area Reference: ______________ Sheet Number: _____ Location Description: ______________________________

Construction Activity	Specification Description	Testing Standard	Product / Service Responsibility	Person Responsible	Testing Frequency	Test Result (Pass/Fail)	Hold Point (Yes/No)	Date	Hold/Witness Point Signature
Water quality	Water quality test	Code XX.XXX	Earthmoving contractor	John Citizen	1 per water source		No		
Surface preparation	Prepared to specification	Code XX.XXX	Earthmoving contractor	Operator	Each area		Yes		
	Watered at 5L/m²	Code XX.XXX	Earthmoving contractor	Operator	Each area		Yes		
Hydromulch	Certificate of seed analysis	Code XX.XXX	Revegetation contractor	Operator	Each load		No		
	Mulch	Code XX.XXX	Revegetation contractor	Operator	Each load		No		
	Application of mulch	Code XX.XXX	Revegetation contractor	Operator	Each load		No		
Completion	Instruction memo signoff	Code XX.XXX	Earthmoving contractor	Operator			Yes		
Maintenance watering	Watering	Code XX.XXX	Earthmoving contractor	Job manager	Each area		Yes		

Inspection and Test Plan

Step 22: Detail site management procedures

- *Technical Notes* can be used to specify:
  - the person responsible for ESC issues
  - monitoring and inspection procedures
  - information transfer procedures
  - procedures for reporting and acting on areas on non-compliance
  - procedures for amending an ESCP
  - procedures for responding to *Witness* and *Hold Points*.

Step 23: Detail emergency ESC procedures

- Specify ESC measures required in the event of rain or strong winds.
- These temporary measures are applied to a site to control soil erosion and the passage of water in the event an imminent storm.
- Typically these ESC measures are not detailed on the ESCP, but appear as technical notes within the supporting documentation (refer to Book 1, Section 5.8 of IECA, 2008).

Step 24: Prepare the Site Monitoring and Maintenance Program

- Prepare a list of the expected ESC materials and equipment required to be stored on-site to facilitate regular maintenance and repair activities.
- Prepare a Monitoring and Maintenance Program for the site and each drainage, erosion and sediment control technique.
- Maintenance requirements for the various ESC techniques are provided in the Book 4 fact sheets of IECA (2008).

Step 25: Prepare Inspection and Test Plans

- *Inspection and Test Plans* detail the inspection, testing and performance criteria for site revegetation.
- *Witness points* represent construction activities that are to be observed by a nominated 'witness'.
- *Hold points* represent stages in the construction program beyond which work must not proceed unless a specific activity has been completed, or the works have been authorised by an appropriate officer.

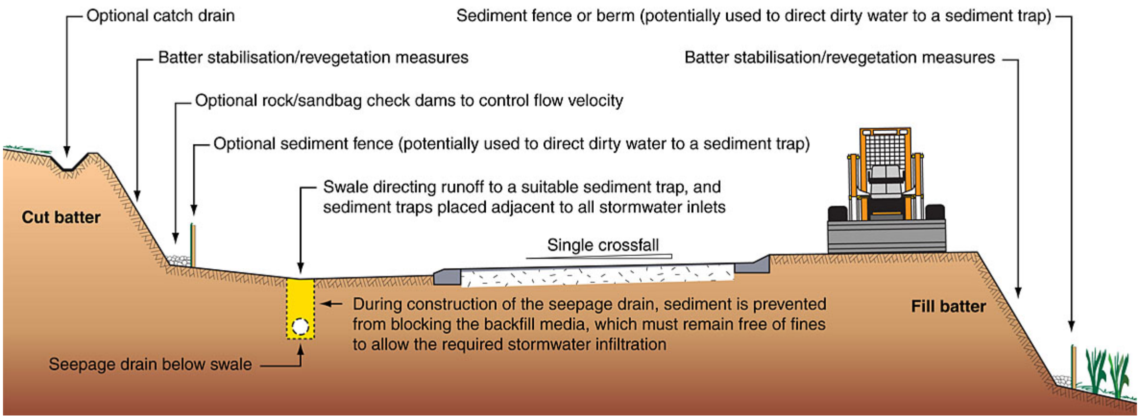
Typical ESC Management in Road Construction

Construction of a local road

Single crossfall local road

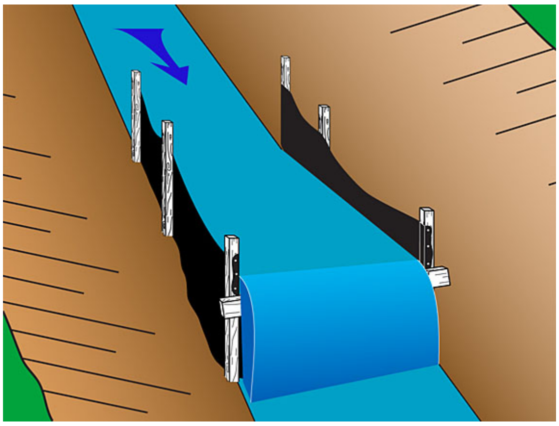
Erosion and sediment control practices

- It is often impractical to incorporate large sediment basins into the construction of local roads, unless these roads are apart of a larger subdivision project.
- Sediment controls are typically limited to Type 3 and supplementary sediment traps, with Type 2 sediment traps used at field inlets (i.e. not kerb inlets), and at waterway crossings.
- However, erosion control practices are normally **enhanced** from those adopted on rural construction projects.



Possible layout of erosion and sediment control measures on a single crossfall road

Check dam sediment trap



U-shaped sediment trap

U-shaped sediment trap on mild slope

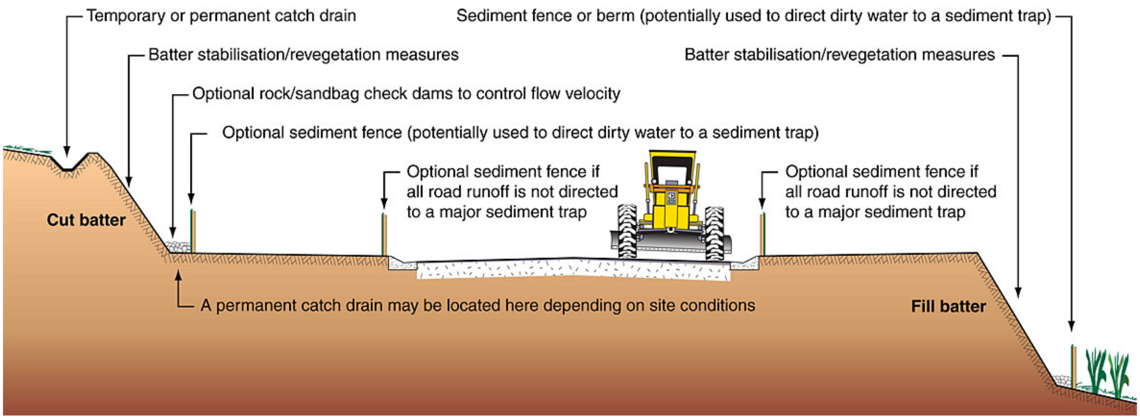
U-shaped sediment trap on steep slope

Construction of a neighbourhood road

Neighbourhood road

ESC practices on arterial roads

- Sediment basins often appear within these larger construction projects at waterway crossings, especially if wide parklands exist adjacent to the waterway.
- Type 2 sediment traps can be used at drainage line crossings (sag points).
- Sediment controls often rely heavily on controlling inflows into kerb inlets.
- Ideally, berms and drains are used to direct dirty water to sediment traps rather than relying on sediment fences.



Possible layout of erosion and sediment control measures on a crowned roadway

Check dams adjacent a sediment fence

Mulch berm sediment barrier

'On-grade' kerb inlet sediment trap

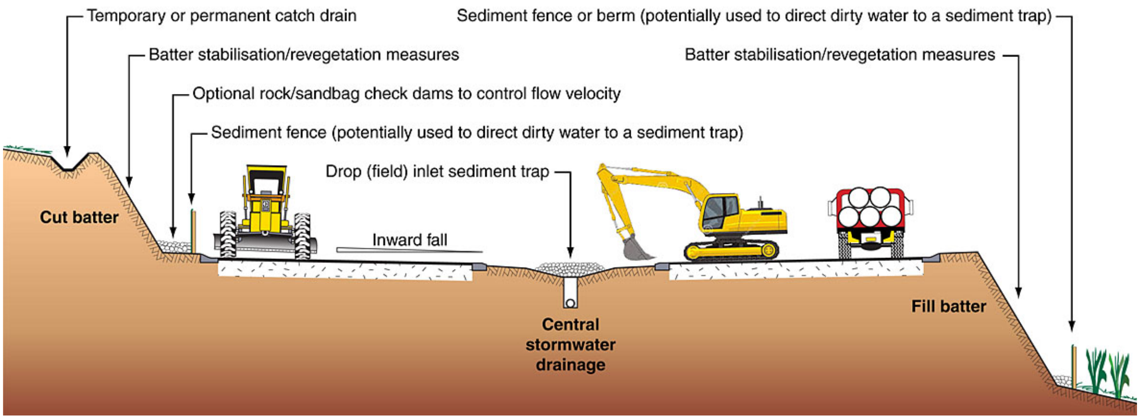
'Sag' kerb inlet sediment trap

Construction of a dual carriageway

Dual carriageway major road

ESC practices on motorways & highways

- Sediment control practices rely heavily on the use of sediment basins.
- The use of sediment fences is avoided in favour of drainage controls directing dirty water to major sediment traps.
- Significant use is usually made of bank stabilisation measures prior to, or incorporated into, bank revegetation.
- Extensive use of mulch berms to control the movement of both 'clean' and 'dirty' water.



Possible layout of erosion and sediment control measures on a dual carriageway

Block & aggregate drop inlet trap

Mesh & aggregate drop inlet sediment trap

Rock & aggregate drop inlet sediment trap

Rock & aggregate drop inlet sediment trap

Typical ESC Management for Road Construction Across Drainage Lines

Road construction across a drainage line

Natural drainage line

Road crossings of drainage lines

- Road profiles typically consist of a series of crest and sags, with sag points typically being located at points where the road crosses:
  - swales and drainage pipes
  - non-waterway drainage lines
  - streams, brooks and creeks
  - rivers

Urban stormwater pipe drainage line

Drainage lines

- A 'drainage line' is a natural or constructed stormwater drainage path that:
  - carries 'concentrated' rather than 'sheet' flow
  - is likely to flow only during periods of rainfall, and for short periods (hours) after rain has stopped
  - is a drainage path that has not been classified as a 'watercourse' based on a locally or state-adopted classification system.

Minor culvert crossing

Minor drainage culverts

- The existence of a drainage line is likely to result in the need for a small drainage culvert passing under the roadway.

Fauna passage culverts

Major culverts

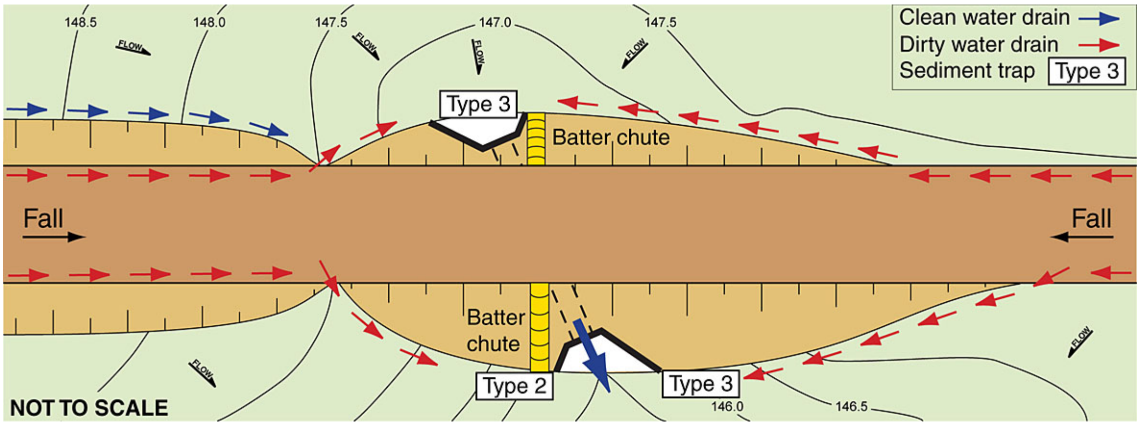
- On motorways, fauna passage culverts are often located at drainage line crossings.
- The size of these culverts does not necessarily indicate the size of the drainage catchment, but may be related to the minimum needs of terrestrial fauna passageways.
- The importance of the culvert type, and the size of the drainage catchment, is that it influences the type of sediment control practices adopted at these locations.

Road construction across a drainage line

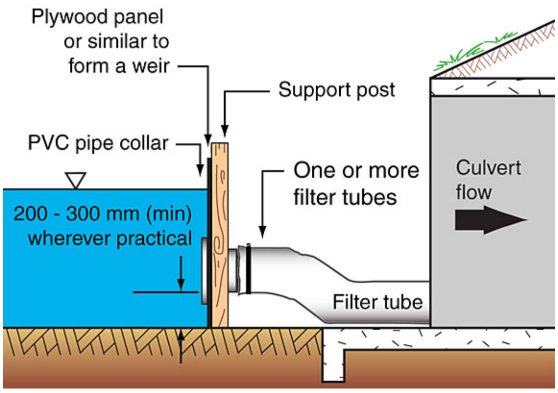
Sediment fence (Type 3 sediment trap)

Treatment option 1

- Placement of a Type 3 sediment trap across the **entrance** of a small drainage pipe (culvert) 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 with wire mesh backing
  - U-shaped sediment trap.



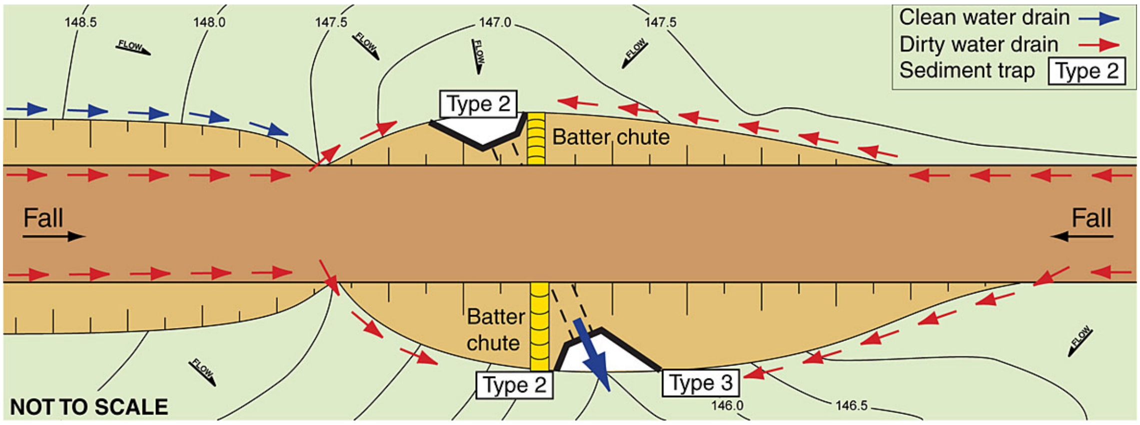
Example ESC measures for road works over a drainage line with minimal catchment area



Filter tube dam (Type 2 sediment trap)

Treatment option 2

- Placement of a Type 2 sediment trap across the **entrance** of a small drainage pipe (culvert) is appropriate when:
  - total up-slope catchment (clean & dirty) is less than 0.25 ha, and
  - soil loss rate < 150 t/ha/yr.
- Typical Type 3 sediment traps include:
  - Block & aggregate sediment traps
  - Filter tube dams
  - Mesh & aggregate sediment traps
  - Sediment weirs.



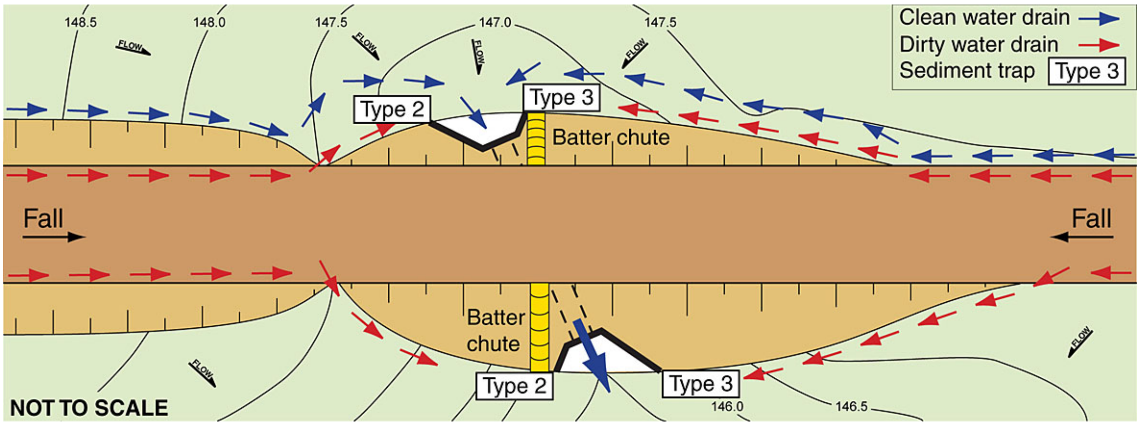
ESC measures for road works over a drainage line with modest up-slope catchment area

Road construction across a drainage line

Rock filter dam (Type 2 sediment trap)

Treatment option 3

- Placement of Type 2 sediment traps **each side of the entrance** of a small drainage pipe (culvert) 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, <u>OR</u>
  - the contributing catchment area is greater than 0.25 ha and the soil loss rate is less than 150 t/ha/yr.
- Use of Type 3 sediment traps is appropriate when the area < 0.25 ha and the soil loss rate < 75 t/ha/yr.

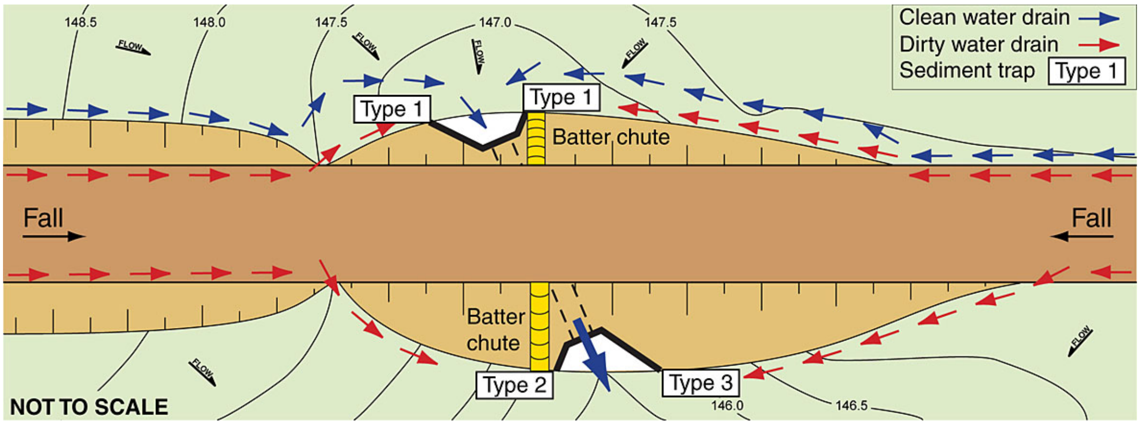


ESC measures for road works over a drainage line with significant up-slope catchment

Sediment basins (Type 1 sediment trap)

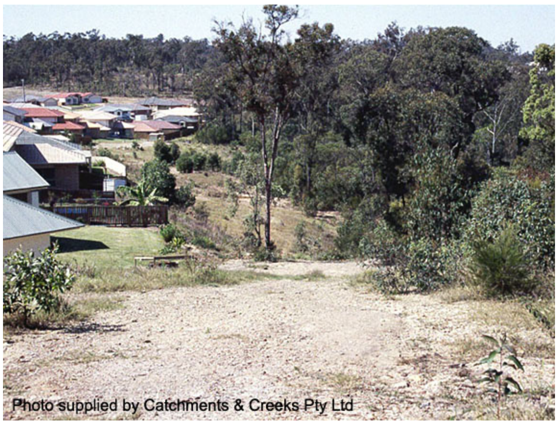
Treatment option 4

- Placement of Type 1 sediment traps **each side of the entrance** of a small drainage pipe (culvert) 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 includes both the road and batter runoff areas as appropriate.



ESC measures for road works over a drainage line with significant road runoff area

Case Study 1 – Road construction over a piped drainage line



Road reserve prior to road works

Project description

- This 1996 road construction project involved the construction of one stage of a multi-stage urban road corridor.
- The construction project involved significant cut and fill, and the crossing of a drainage line that involved the extension of an existing piped drainage system.
- The existence of the adjacent urban development meant that all sediment controls were located along the bushland side of the roadway.

Topsoil cleared from road reserve

Sediment fence with rock check dams

Sediment fence with rock check dams

Spill-through weir outlet structure

Spill-through weir & aggregate filter

Case Study 1 – ESC Plans

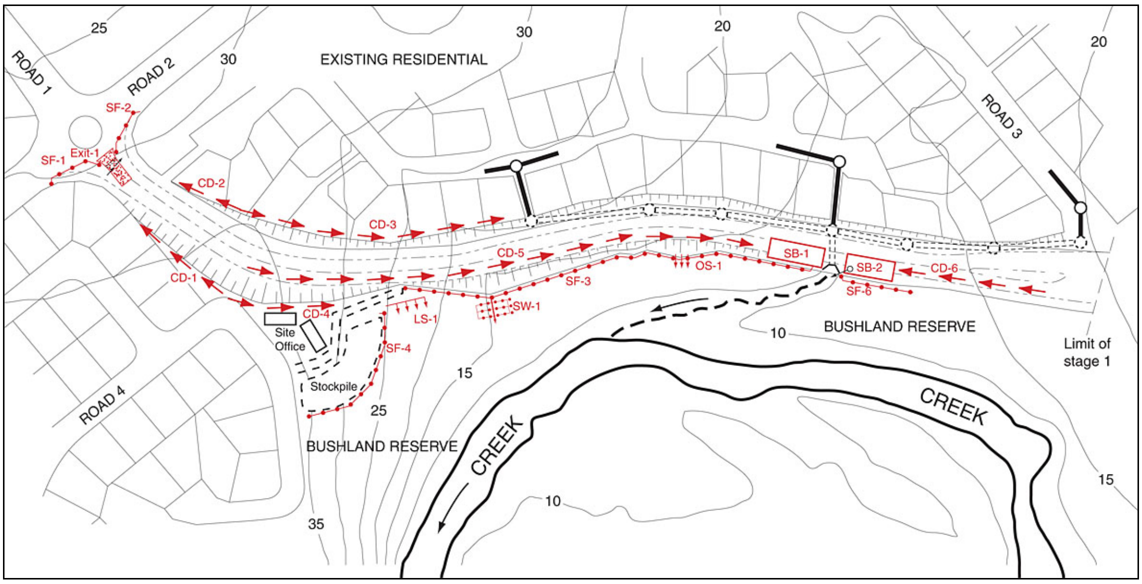


Figure 1 – Stage 1 Erosion and Sediment Control Plan

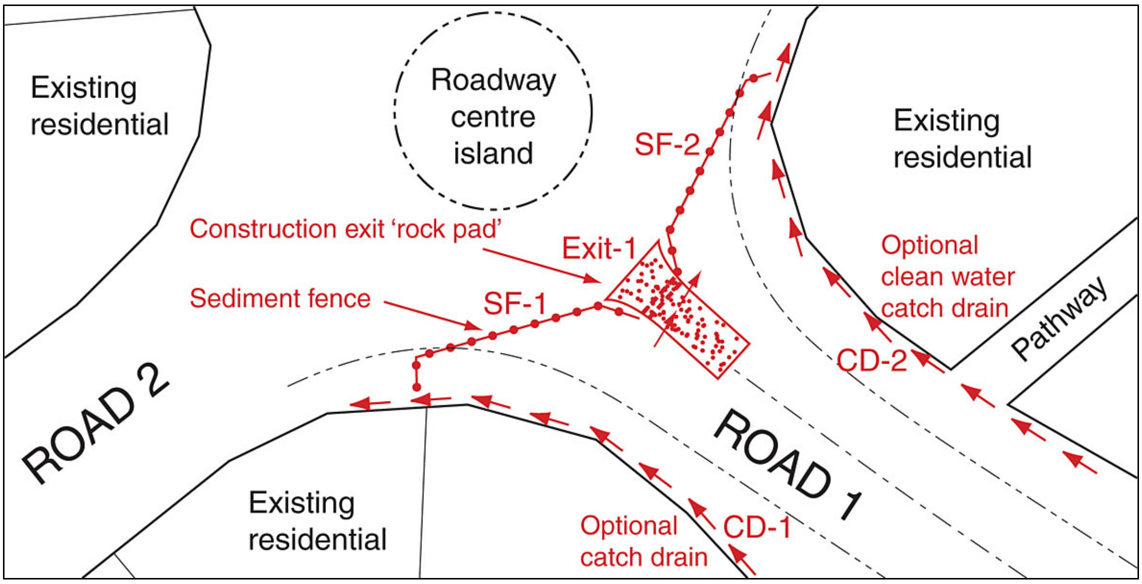


Figure 2 – Details of construction works ESCP at the road intersection

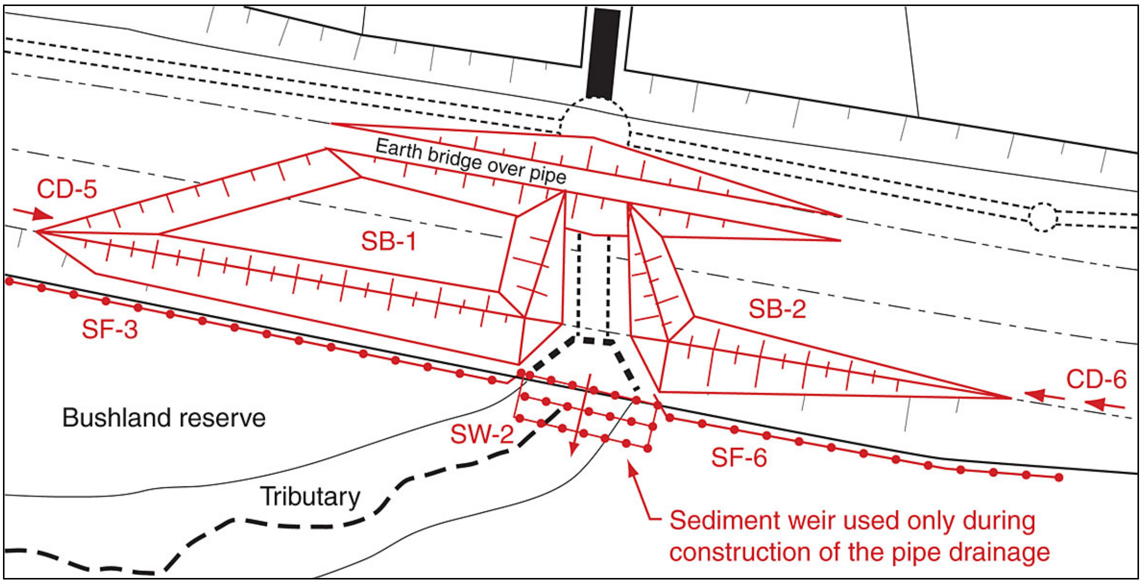


Figure 3 – Details of construction works ESCP at the pipe extension

Case Study 1 – Road intersection

Pre-construction T-intersection

Pre-construction condition

- Prior to the commencement of this stage of the road construction, the roadway corridor was partially cleared of vegetation, and the proposed mini roundabout consisted only of a T-junction.

Heavy vehicle site entry point

Rock pad with flow diversion berm

Straw bale of questionable value!

Site entry/exit point

- The site's main entry/exit point for heavy vehicles was located at the location of the proposed roundabout.
- A rock pad *Construction Exit* was installed.
- A raised flow diversion berm was formed within the rock pad consistent with the *Erosion and Sediment Control Plan*.
- The purpose of such berms is to divert sediment-laden runoff from the rock pad to a separate sediment trap (so that the rock pad does not become a source of sediment flow onto the public road).
- However, within the ESCP the location of the rock pad and adjacent sediment fences were marked in relation to the proposed roundabout (Figure 2), not the T-junction that currently existed.
- The consequences were:
  - the sediment fences were located in the positions marked within the ESCP
  - the rock pad was (correctly) re-positioned to abut with the existing T-junction
  - the flow diversion berm was positioned (incorrectly) such that it did failed to divert excess stormwater runoff towards the sediment fences, but simply diverted the flow around the berm and onto the public road.
- The 'correct' approach here would have been for the sediment fences and rock pad to be positioned as observed within the adjacent photos; however, for the raised flow diversion berm to have been located at the up-slope end of the rock pad such that sediment-laden run-on water would have been diverted towards one of the sediment fences.
- We do no know the 'purpose' of the straw bale!

Case Study 1 – Drainage line crossing

Pipe outlet pre-construction

Drainage line crossing

- At the drainage line crossing, the following ESC measures were employed:
  - the piped drainage system was extended across the road corridor early in the construction phase
  - an earth bridge was built over the new pipeline to allow the movement of construction vehicles
  - sediment basins were formed each side of the extended pipeline.
- Restrictions prevented the basins from being built within the bushland area.

Excavating a sediment basin

Location of sediment basins

Shallow Type-2 sediment basin

Rock filter dam outlet structure

Road construction corridor viewed from the eastern end of the project

Introduction to Road Construction Over Waterways

Defining waterways and watercourses

Gravel-based creek

Introduction

- The official classification of waterways, watercourses and drainage lines is usually a matter for the state.
- Some states use maps to identify waterways, or at least critical parts of waterways.
- Waterways are typically identified by the existence of a well-defined channel.
- This means the main waterway channel needs to have clearly defined bed and banks.

Dry, ephemeral waterway

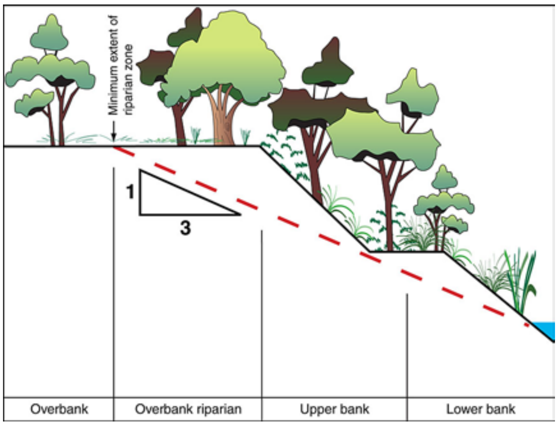
Ephemeral waterways

- In many locations within Australia, dry ephemeral waterways can look remarkably similar to ‘drainage lines’.
- Even experts can disagree on what is a ‘dry creek’, and what is a ‘drainage line’.
- The term ‘ephemeral’ simply means the waterway occasionally stops flowing, but could still contain permanent pools.
- It is noted that an ephemeral waterway may contain sub-surface groundwater flows even though the bed appears dry.

Navigable waterway

Waterways and watercourses

- Historically, the term ‘waterway’ referred only to a navigable watercourse.
- In farming communities, a ‘waterway’ is a shallow constructed drainage line that crosses either pasture or cropping land.
- In the road construction industry it is common for the terms ‘waterway’ and ‘watercourse’ to be interchangeable.
- Within this publication, the terms waterway and watercourse are considered to have the same meaning.



Minimum desirable riparian width

Riparian vegetation

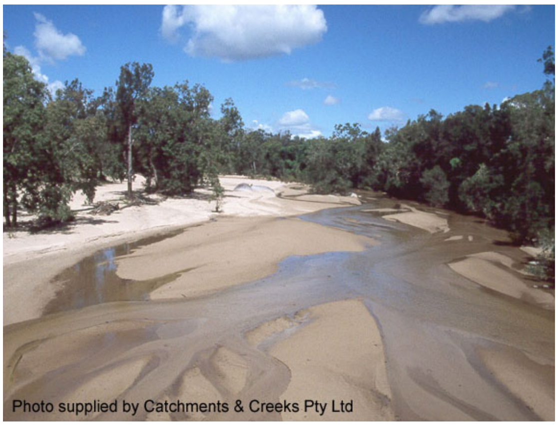
- The riparian zone is that part of the landscape adjacent to a waterway that influences, and is influenced by, the processes that occur within the waterway.
- This usually includes instream habitats, and the bed, banks and floodplains of a waterway (or parts of the floodplains).
- Ideally, the riparian zone (measured from the water’s edge) should be wider than the top-of-bank width of the waterway channel, or three times the bank height, whichever is the greater.

Types of waterways

Clay-based waterway

Clay-based waterways

- There are many types of waterways, and descriptions are often given based on the channel shape.
- Clay-based waterways contain clayey soils across the bed and banks.
- These are 'fixed bed' waterways, that should not have significant quantities of 'natural' sediment flow.
- Mature woody vegetation can often grow close to, or even on the channel bed.



Sand-based waterway

Sand-based waterways

- Sand-based waterways contain deep, loose sand across the channel 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 sand flow during both minor and major stream flows.
- There is normally a clearly defined change in plant species from those growing on the bed (if any) to those growing on the banks.

Gravel-based waterway

Gravel-based waterways

- In gravel-based waterways, the bed material is made-up of well-rounded gravels and boulders.
- These are also alluvial waterways that usually contain pools and riffles, which can completely reform from flood to flood.
- The channel bed of both sand and gravel-based waterways is usually 'flat', as compared to the U-shaped bed of clay-based waterways.
- Woody vegetation can struggle to form on the channel bed.

Rock-based waterway

Rock-based waterways

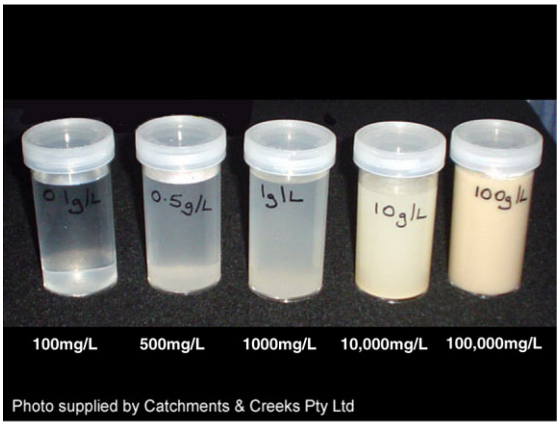
- The bed material of rock-based waterways is made-up of exposed rock outcrops often separated by sections of clay, sand or gravel-based channels.
- These are fixed-bed 'spilling' waterways usually containing waterfalls or riffles followed by deep pools to help dissipate water energy.

Assessing the potential impacts of sediment released into waterways

Sand deposited into a wetland

Coarse sediment v fine sediment

- The potential impact of sediment on aquatic environments depends on the type of water body and the type of sediment.
- Coarse sediments (e.g. sands and coarse silts) many cause adverse impacts to wetlands and small waterways, such as creeks.
- Fine sediment, such as fine silts, clays and 'turbidity', can cause adverse impacts to almost all waterways, including bays and estuaries.



Examples of suspended solids content

Background levels

- In some cases, the allowable discharge conditions from construction sites will be linked to either the:
  - long-term average background levels
  - or immediate upstream water quality conditions at the time of discharge.
- However, most construction projects have discharge conditions set independent of the background turbidity (NTU) and suspended solids (TSS) levels within the receiving waters.

Smaller turbid waterway entering a river

Catchment wide approach

- In some drainage catchments, natural 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 are based on a catchment-wide objective.
- An example of this would be waterways that flow into a bay, where WQOs may be based on the needs of the bay, rather than the needs of the immediate waterway.

Wawirra Creek in central NSW

Inland waterways

- In Australia, many waterways that pass through arid or semi-arid regions are naturally highly turbid.
- Typically the countryside is arid or semi-arid, and the soils often have dispersive properties.
- When working in such regions, authorities must set appropriate WQOs, usually a maximum of 10% above natural background levels.
- Conversely, most coastal streams have traditionally had very clean base flows.

Site issues that can influence the construction procedure

Culvert construction

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

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 ephemeral streams are either:
  - wet but not flowing (trench de-watering will be required), or
  - dry (preferred condition).

Elevated stream flow conditions

The risk of elevated stream flows

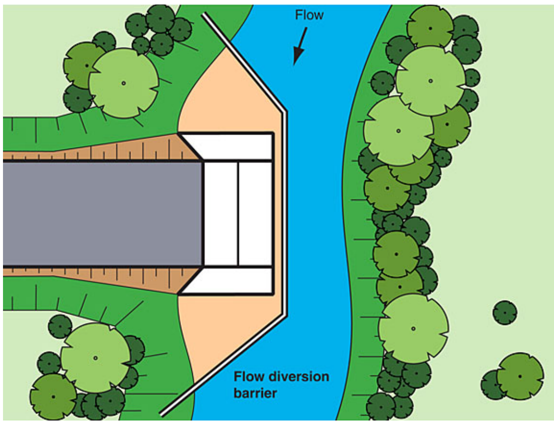
- Elevated stream flows can result from local or distant rainfall.
- Many parts of Australia experience only seasonal rainfall and stream flows, so different construction procedures will need to be employed during the dry and wet seasons.
- The methods for flow bypassing vary depending on the expected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

Construction of a culvert base slab

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 the construction procedure



Staged construction of a culvert

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 through the use of impervious 'isolation barriers'.
- Constructing culverts in stages while maintaining stream flows is a complex and expensive procedure that should only be considered in exceptional circumstances.
- The use of a bridge, instead of a culvert, is preferred in these circumstances.

Freshwater fish migration

Maintaining fish passage

- Potential impacts on fish passage can vary significantly across the country.
- The best option is to approach the local Fisheries Office for guidance on fish passage sensitivity and the critical periods of fish migration.
- Some states may have specific legislation or construction codes.
- Issues include: time of year, duration of works, the extent of the fish barrier, and proposed bank rehabilitation measures.

Temporary bypass road

Maintaining public access across the waterway

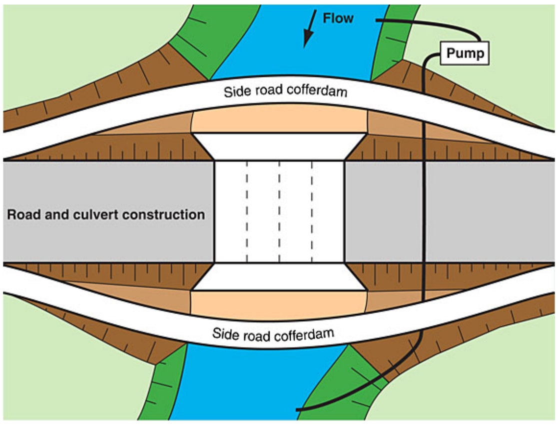
- Bridge and culvert construction is often preceded by the construction of a temporary bypass road to allow ongoing traffic movement.
- The fish passage requirements for these temporary structures can vary significantly from location to location.

Temporary stream crossing

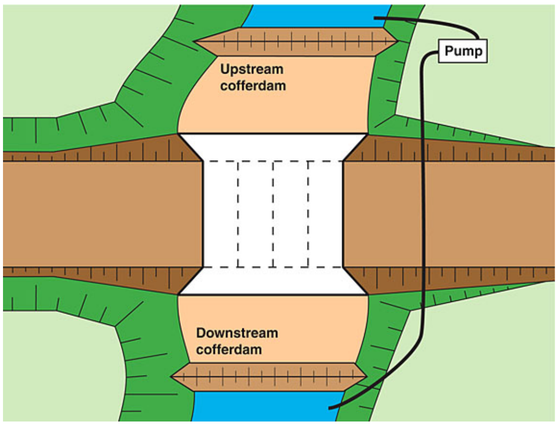
Construction of temporary bypass roads

- 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)
- The use of temporary stream crossings is discussed later in this field guide.

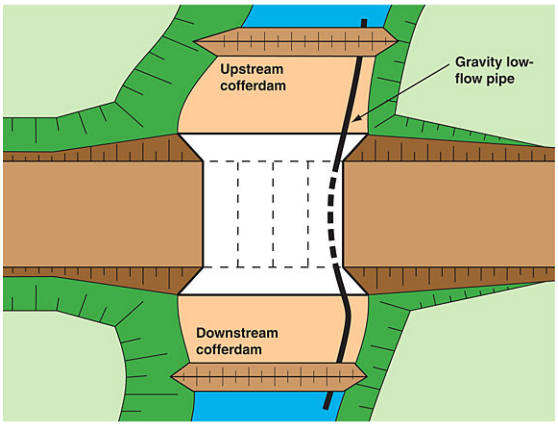
Use of cofferdams



Bypass roads used as cofferdams



Cofferdams with pumped bypass



Cofferdams with gravity flow bypass

Instream works with piped-flow bypass

Use of cofferdams

- Cofferdams are commonly used to isolate a section of a waterway.
- Cofferdams can be formed from a variety of materials, including:
  - sandbags
  - earth
  - water-filled rubber dams
  - sheet pilling
- Cofferdams can also operate as temporary bypass traffic lanes.

Cofferdams with pumped bypass

- Flow bypassing is most commonly achieved using a pump.
- These pumps need ongoing maintenance (fuel supply, removal of blockages) during their operation (including non-work days).
- Bypass pump hoses can interfere with the construction process.
- Pumps can be blocked or damaged by natural sediment flows during flood events.

Cofferdams with gravity flow bypass

- If the waterway contains significant base flows, then a large-pipe gravity system may be preferable (see image below in which bypass flows are contained within a large, relocatable steel pipe).
- These in-channel bypass pipes can interfere with the construction process.
- Both pumped and gravity systems will result in significant short-term impacts on fish passage during the construction period.

Other design issues

- A de-watering system will usually be needed to manage both groundwater and local stormwater inflows.
- Floodgates can be incorporated into the cofferdam to allow the work area to drain in the event of heavy local rainfall or elevated stream flows.
- Working in tidal waterways can introduce additional complexities with different state legislation being applied to works within tidal waters.

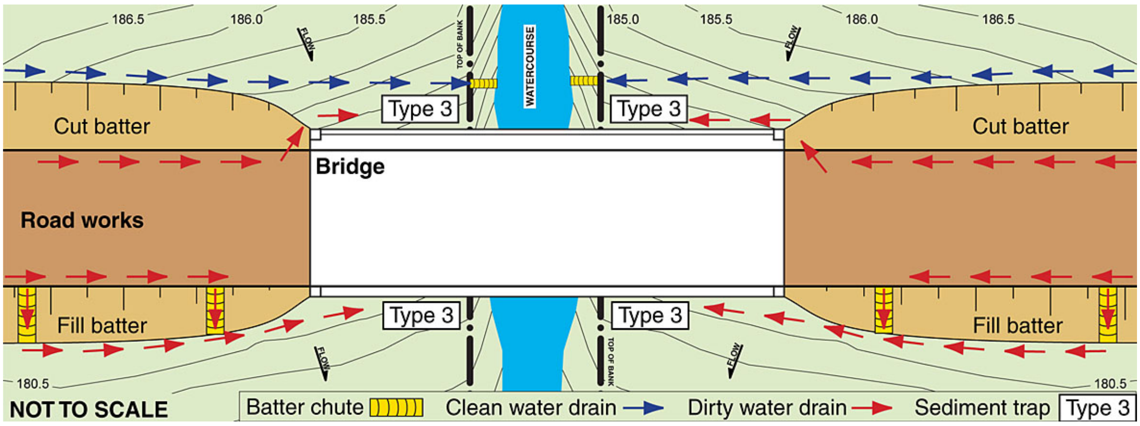
Typical Sediment Control Practices for Road Construction Over Waterways

Sediment controls for road construction over waterways

Sediment fence (Type 3 sediment trap)

Type 3 sediment control

- Placement of a Type 3 sediment trap across the entrance of a small drainage pipe (culvert) 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 trap.

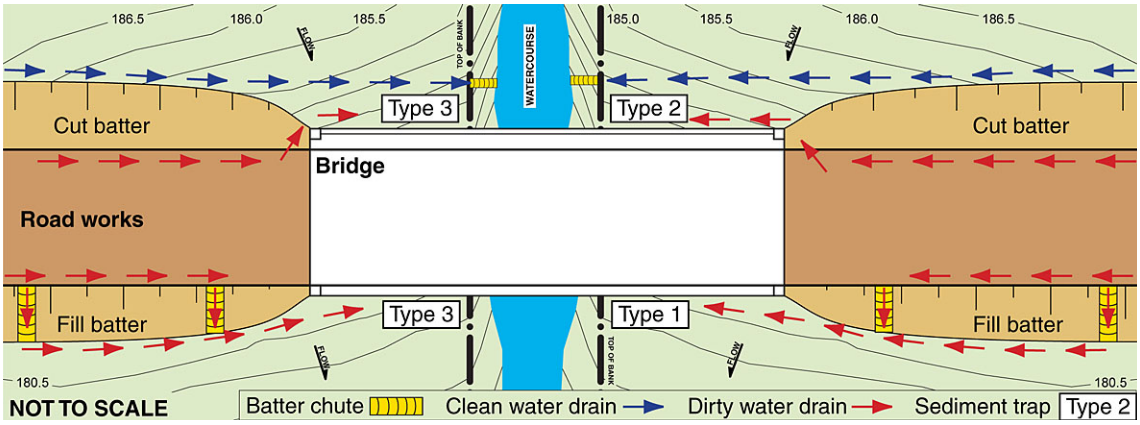


ESC measures for road works over a waterway with minimal road runoff catchment

Rock filter dams (Type 2 sediment trap)

Type 2 sediment control

- Placement of Type 2 sediment traps each side of a small drainage pipe (culvert) 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, <u>OR</u>
  - 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.



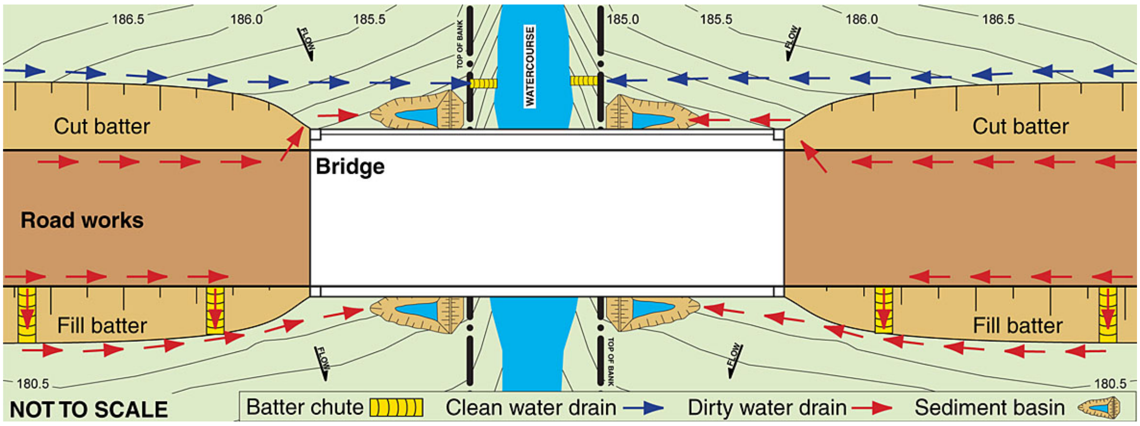
ESC measures for road works over a waterway with variable catchment areas

Sediment controls for road construction over waterways

Sediment basins (Type 1 sediment trap)

Type 1 sediment control

- Placement of Type 1 sediment traps each side of a small drainage pipe (culvert) 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.

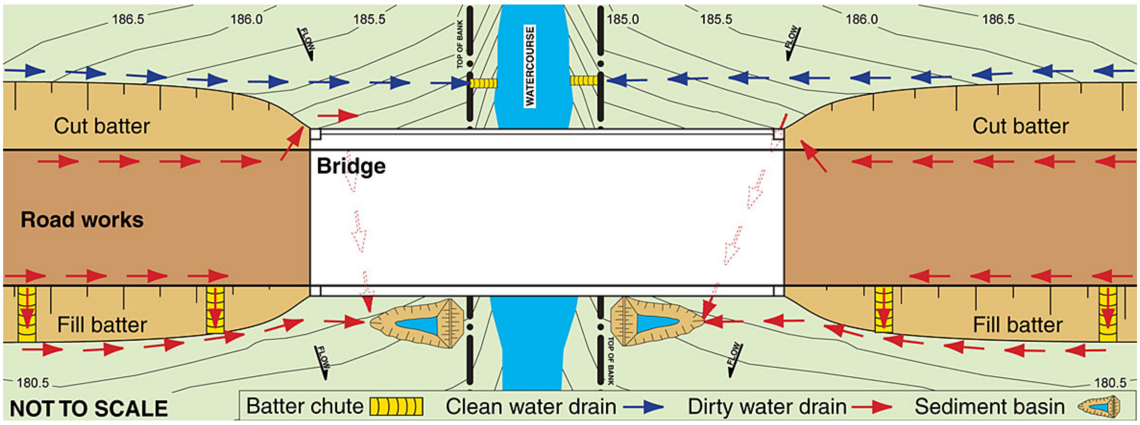


ESC measures for road works over a waterway with significant dirty water runoff

Sediment basin (Type 1 sediment trap)

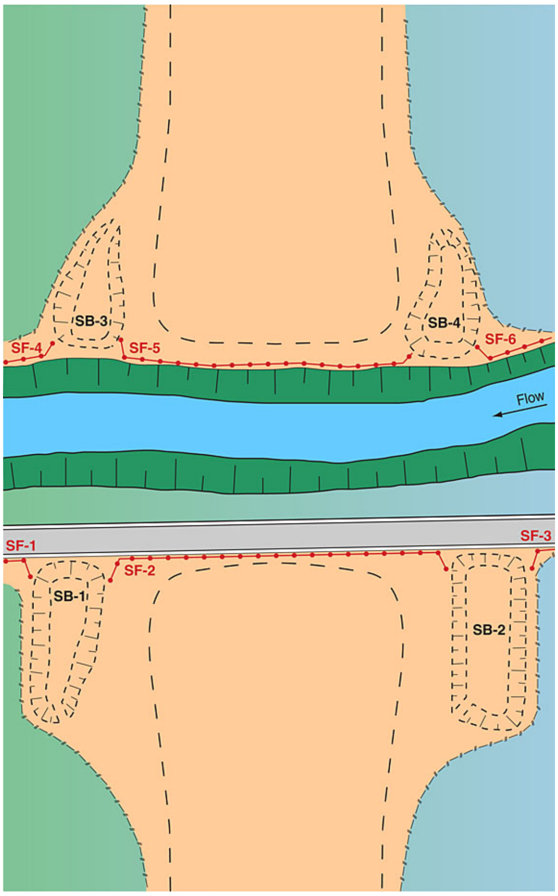
Alternative drainage layouts

- The number of 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.
- The above examples apply equally to the construction of bridges and culverts; however, this alternative drainage layout (below) can only be employed on bridge construction.



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

Case Study 2 – Bridge construction

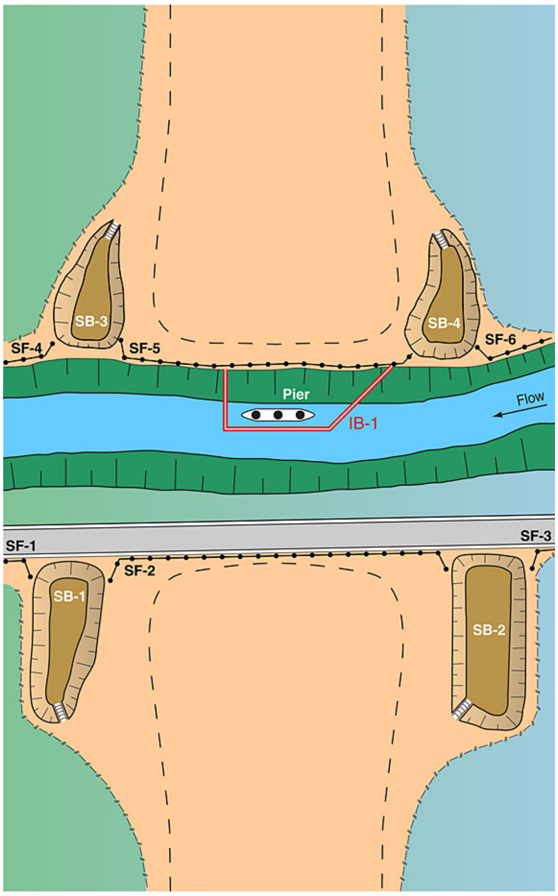


Stage 1

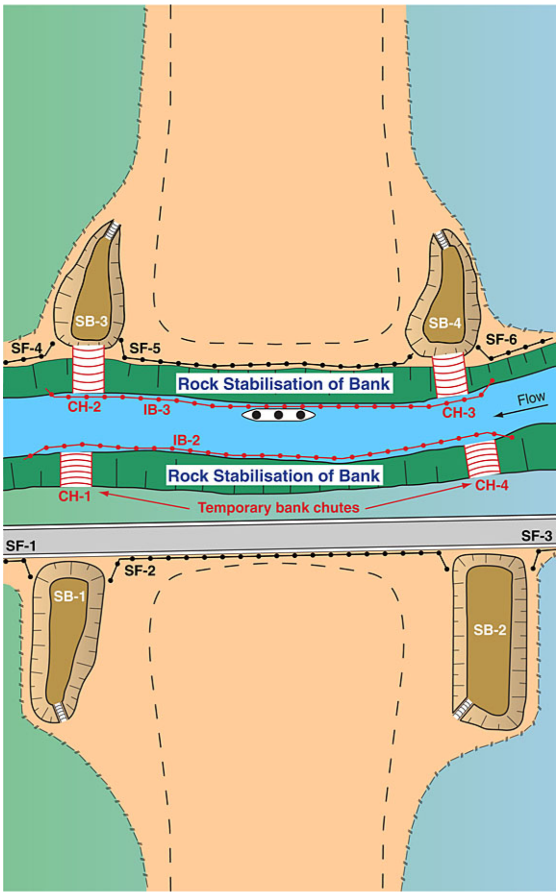
Bridge construction

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.

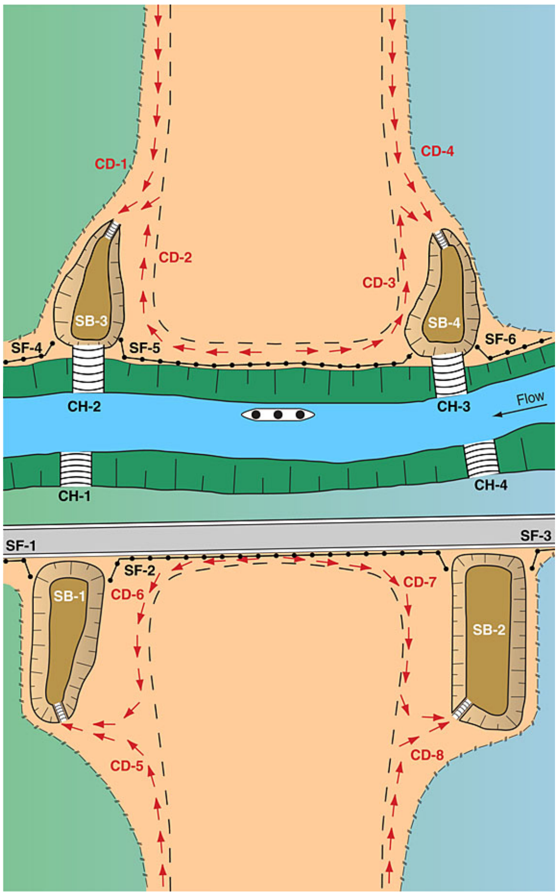


Stage 2



Stage 3

Case Study 2 – Bridge construction

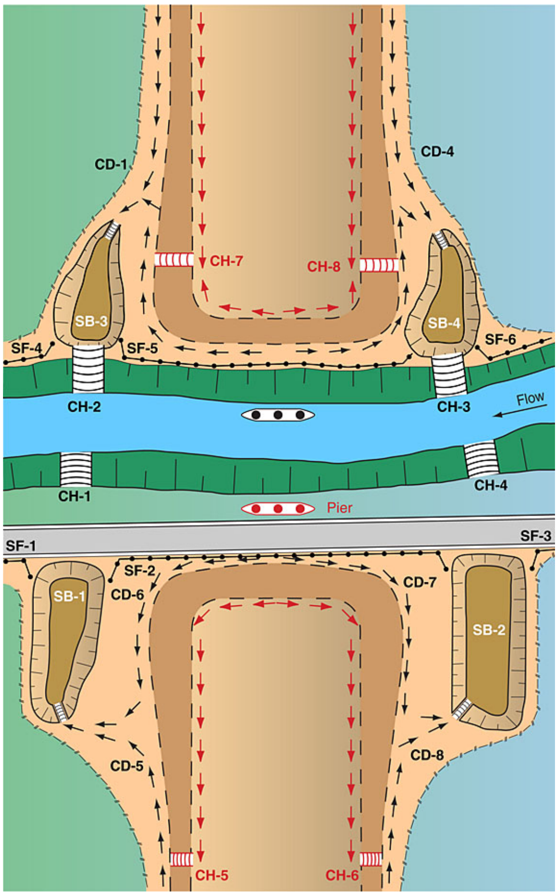


Stage 4

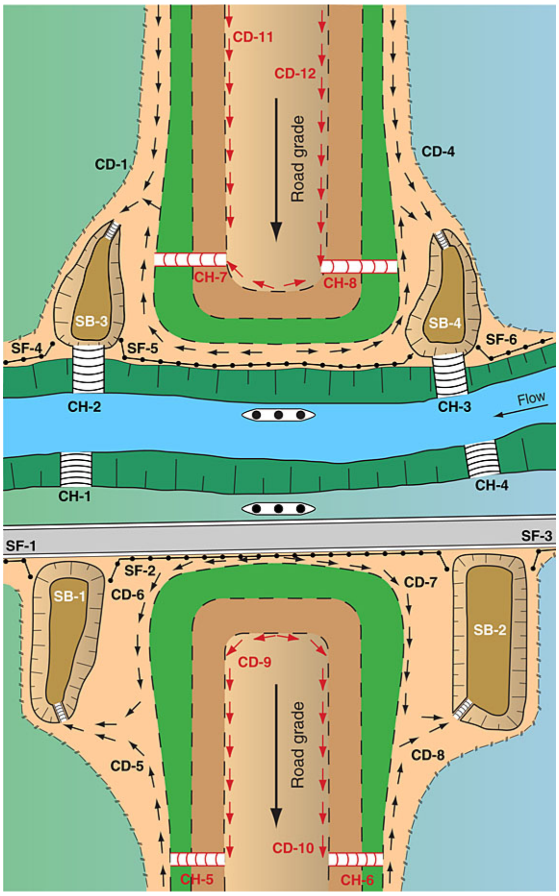
Bridge construction

ESC practices for bridge construction

- Erosion and sediment control practices typically include:
  - temporary catch drains (CD) to direct dirty water to sediment basins
  - earth windows 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.

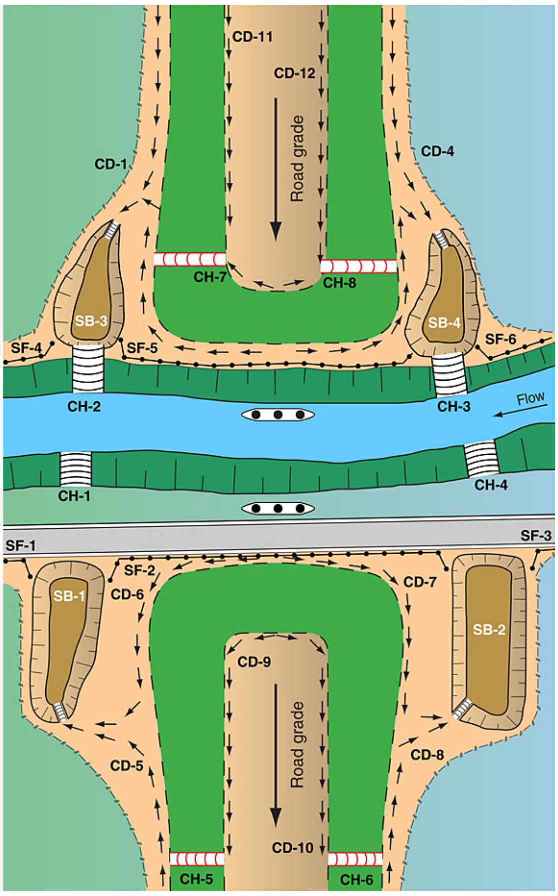


Stage 5



Stage 6

Case Study 2 – Bridge construction

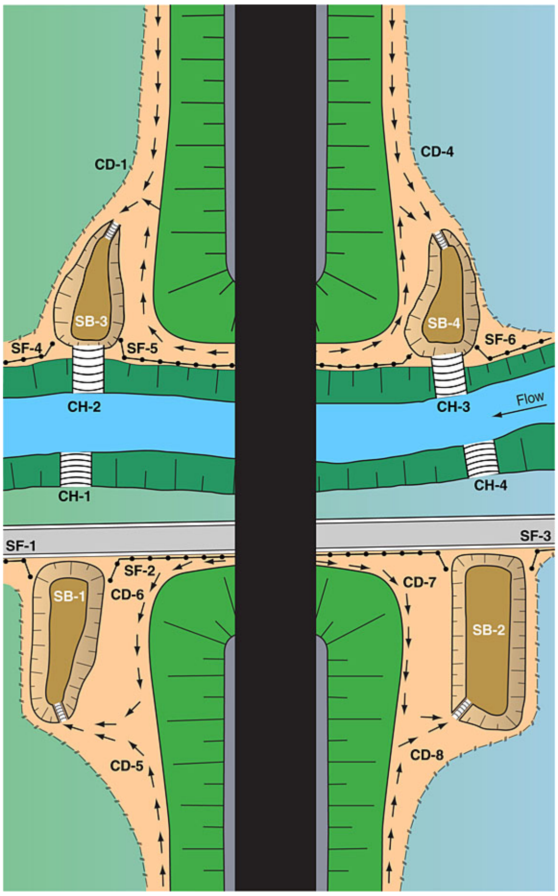


Stage 7

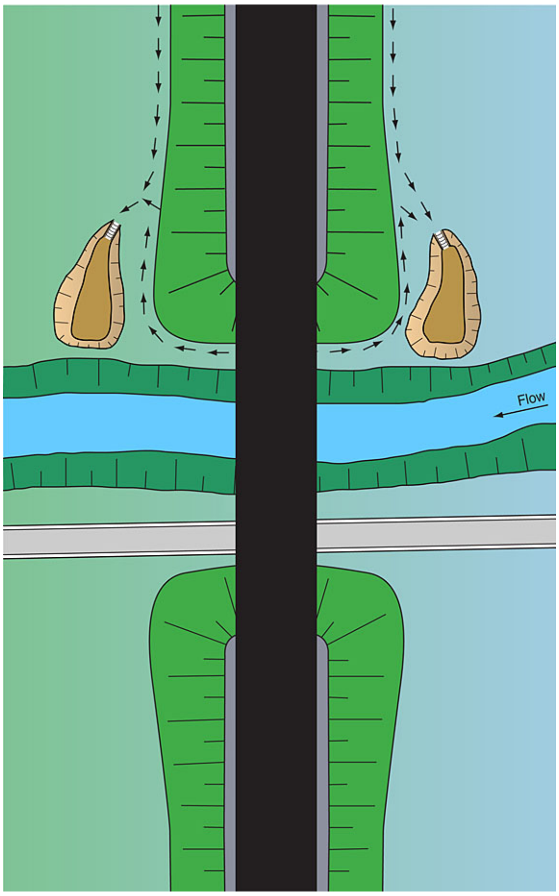
Bridge construction

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 (see over page)
  - disturbed areas revegetated.

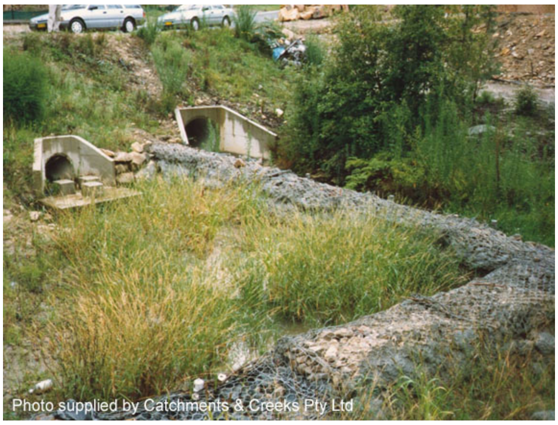


Stage 8



Final road and bridge layout

Conversion of basins to permanent stormwater treatment ponds



Roadside bio-retention system

Permanent stormwater treatment ponds

- After the construction phase, sediment basins can be converted into:
  - permanent road runoff treatment ponds or wetlands
  - pollution containment traps (for the collection of pollution spills resulting from traffic accidents)
  - farm dams.
- 'Stop board' outlet structures can be installed in order to allow emergency services to trap and hold pollution spills.

Stormwater treatment pond (2009)

Same pond (left) in 2017

Type 2 sediment trap (1994)

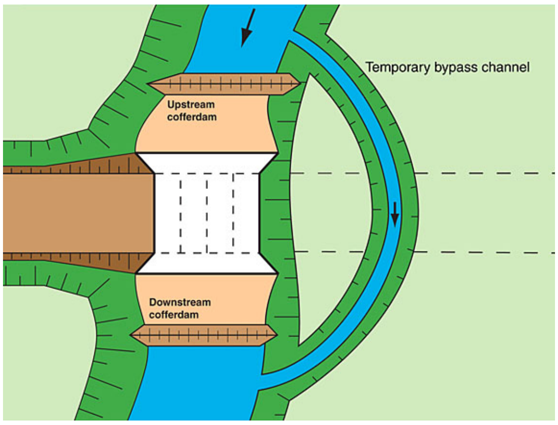
Same sediment trap (left) in 1997

Roadside pollution containment pond

Removable stop boards

Culvert Construction while Maintaining Stream Flow and Fish Passage

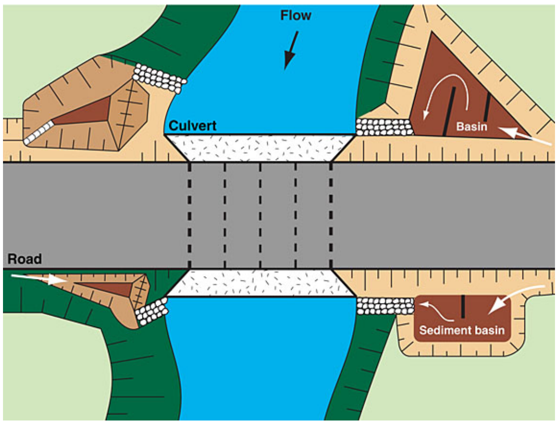
Introduction



Temporary bypass channel

Fish migration

Construction of a culvert base slab



Sediment control practices

Maintaining stream flows

- If base flows within the waterway are significant, then it is common 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 traditional construction practice would normally have involved the construction of a temporary bypass channel.
- However, such bypass channels may not provide suitable fish passage conditions.

Maintaining fish passage

- Fisheries authorities often give approval for the short-term interruption of general fish passage conditions within a waterway to allow construction activities.
- However, ‘fish migration’ and ‘fish passage’ are often viewed as two separate issues.
- Fish migration is a specific type of fish movement that is critical to the life cycle of certain fish species, and if construction activities are to occur during such periods, then strict rules can apply.

Construction difficulties

- The following construction procedures should not be considered as normal construction practice—these procedures are complex, difficult, expensive, and in some cases, impractical.
- Creditable advice must be obtained from experienced construction personnel prior to adopting any of the following construction procedures.
- The ‘staged’ construction of a culvert will require a re-design of the culvert, including the concrete reinforcing.

Sediment control practices

- Sediment basins have not be shown in the following two case studies in order to avoid the figures looking too complex.
- In each case, sediment basins would normally be located on each side of the roadway each side of the waterway (as shown left).

Fish passage considerations

Freshwater fish migration

Signage at in-stream works

Retention of tree root system

Natural bank vegetation

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 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.
- In Queensland such requirements also apply to works conducted under their self-assessable codes.
- It is important to note how rules can change during periods of 'fish migration' as compared to general 'fish passage'.

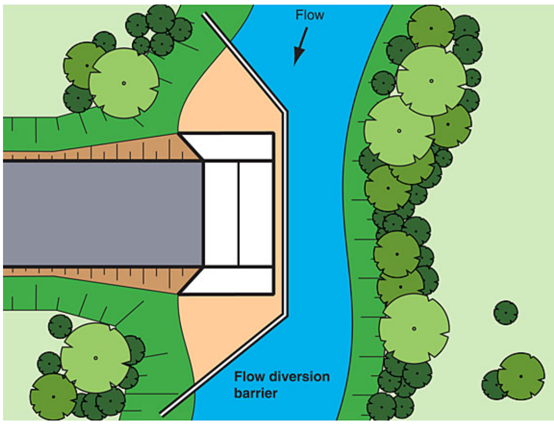
Vegetation clearing on bed and banks

- 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 hard engineering works.
- In reality, the application of environmental requirements such as this will vary from site to site.

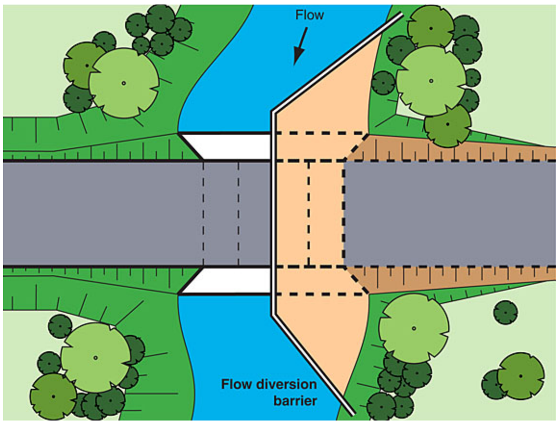
Bank rehabilitation

- In some cases it may be a requirement to re-establish natural vegetation cover 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 with the required abutment and bank stabilisation measures.
- It is important to understand how certain plants can assist in providing beneficial fish passage conditions under a bridge.

Case Study 3 & 4 – Culvert construction using isolation barriers



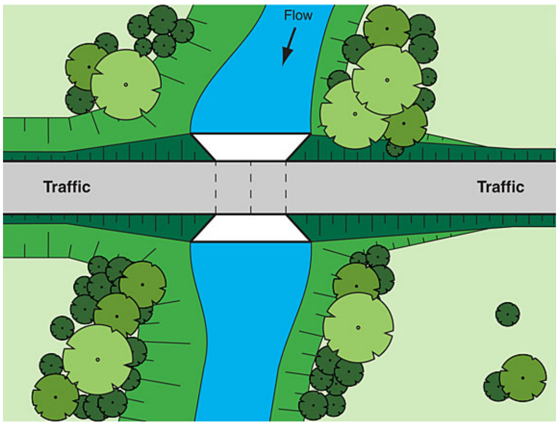
Case Study 3 – Stage 1 of construction



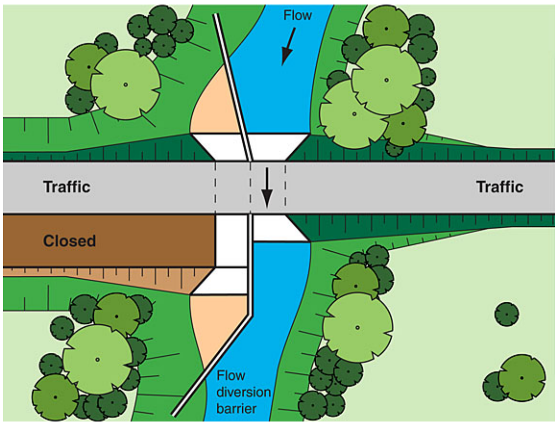
Stage 2 of new culvert construction

Case Study 4 – Culvert expansion

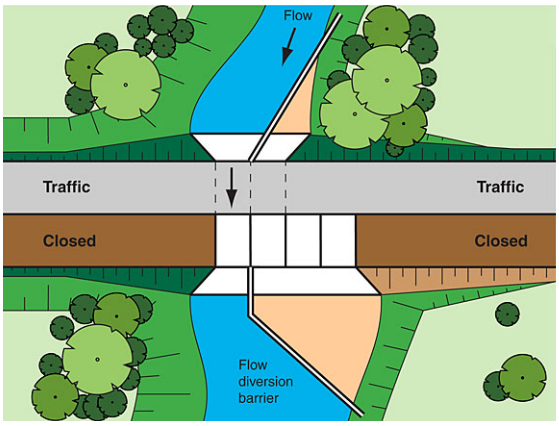
- The degree of complexity and construction difficulties increase significantly if it is necessary to maintain stream flows, fish passage, and/or public access.
- Construction difficulties include:
  - providing a watertight seal on the isolation barriers
  - attaching the isolation barriers to the culvert
  - constructing the culvert aprons.



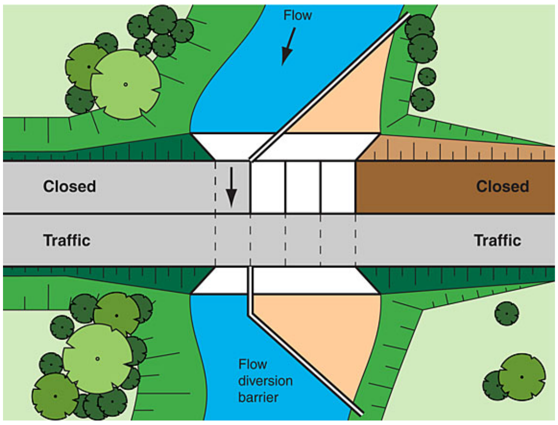
Case Study 4 – Existing culvert



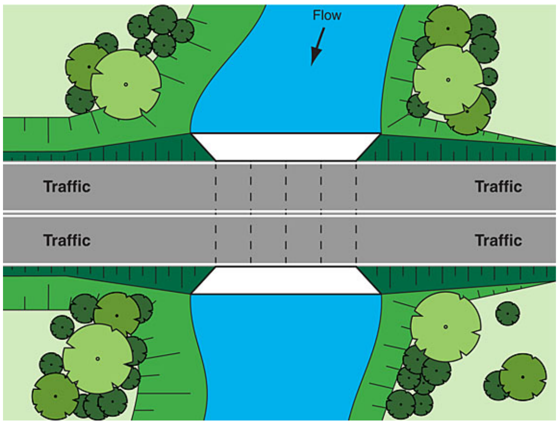
Stage 1



Stage 2



Stage 3



Finished waterway culvert

Types of isolation barriers

Sheet piling isolation barrier

Sheet piling

- Steel sheet piling is a traditional type of instream isolation barrier.
- This technique can be used in relatively deep water.

Water-filled dams

Transportable water-filled dams

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

Earth bund

Earth bunding

- Earth bunding can be a slow and expensive construction method.
- Significant sediment disturbance can occur during installation and removal of the earth bunds.

A-frame Aqua Barrier

A-frame water barriers

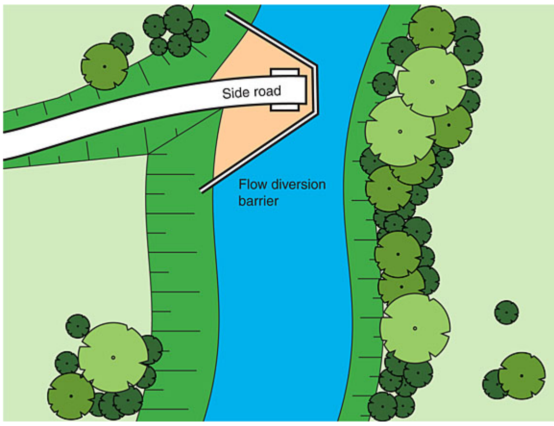
- Various commercial products are available.
- These techniques are generally limited to shallow water bodies.
- Possibly best used when working within concrete lined drainage channels.

Case Study 5 – Culvert construction with public bypass road

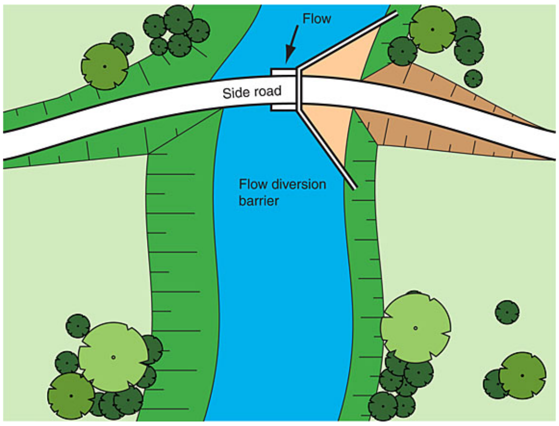
Temporary bypass road

Case Study 5 – Use of temporary bypass roads

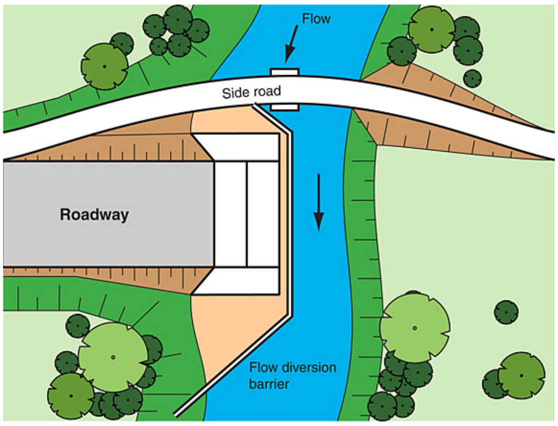
- In certain circumstances, the culvert placed under the temporary bypass road will also need to be fish friendly (consult with the local Fisheries officer).
- Construction difficulties include:
  - providing a watertight seal on the isolation barriers
  - constructing the culvert aprons
  - providing suitable fish passage through the temporary road culvert (if required).



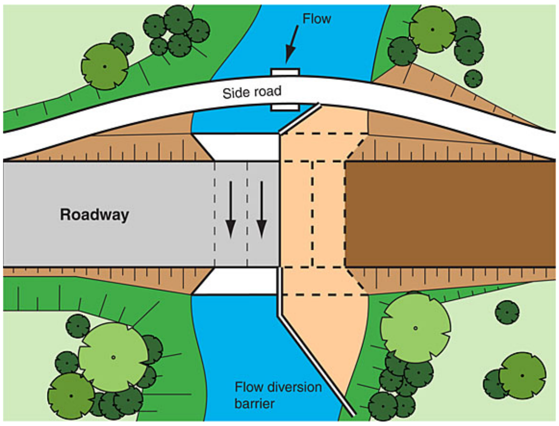
Stage 1



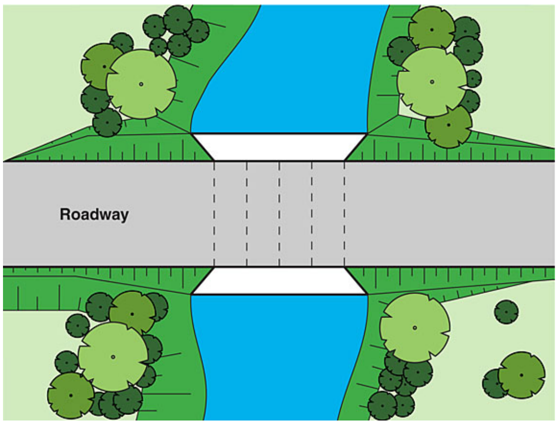
Stage 2



Stage 2



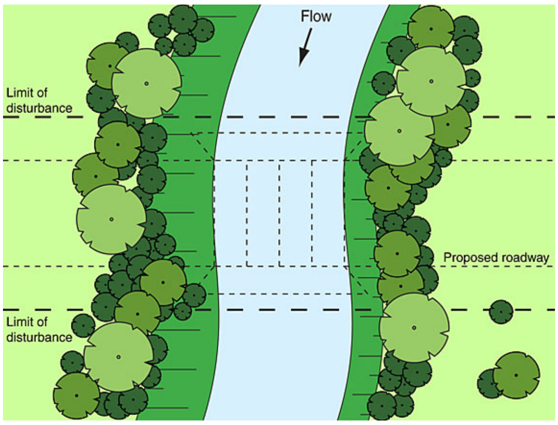
Stage 4



Stage 5

Temporary bypass road

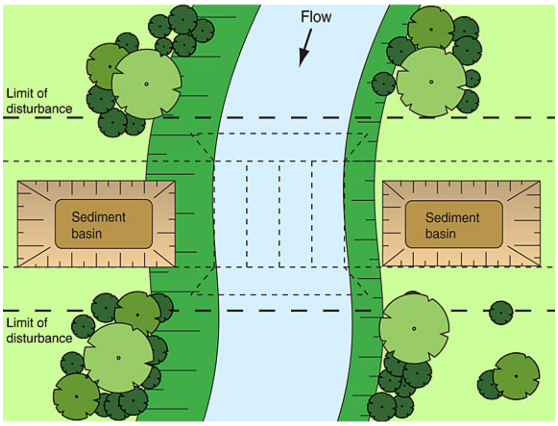
Case Study 6 – Sediment basins located within the road corridor



Pre-construction waterway

Case Study 6

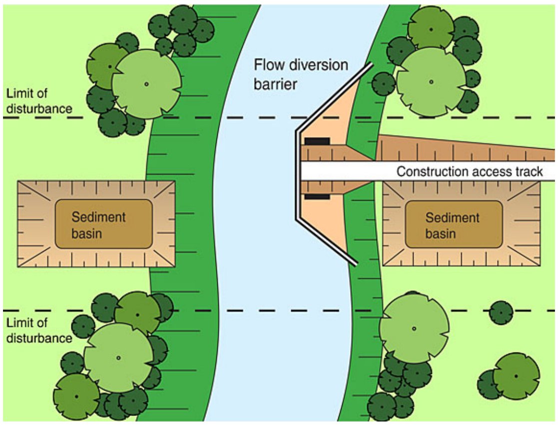
- This construction procedure represents one of the most complex construction scenarios.
- Construction difficulties include:
  - providing a watertight seal on the isolation barriers
  - directing all sediment-laden water to the sediment basins
  - ensuring the existence of the sediment basins does not adversely affect the long-term stability of the pavement foundations.



Stage 1

Locating sediment basins

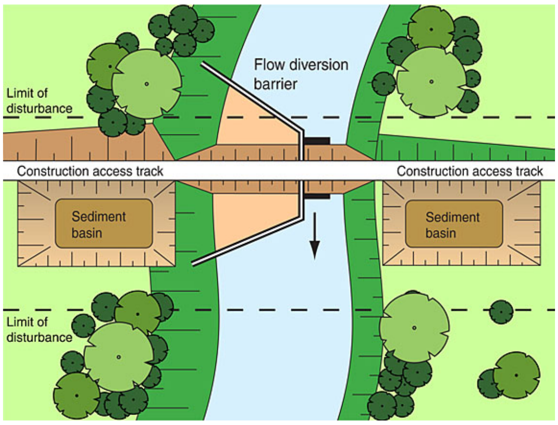
- Ideally, the width of the road corridor should be expanded at waterway crossings to allow sediment basins to be constructed to the side of the embankment.
- Alternatively, negotiations can occur with the adjacent land owners to allow the temporary use of their land for the construction of temporary sediment basins—possibly resulting in the delivery of a permanent farm dam.



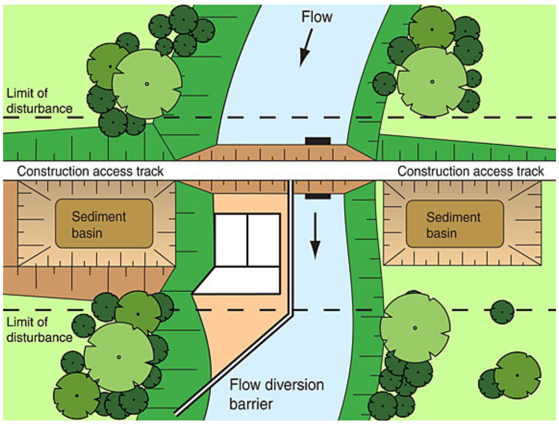
Stage 2

Locating sediment basins within the road corridor

- Locating sediment basins within the envelop of a proposed road embankment can introduce several construction difficulties, including:
  - possible additional expenditure of revised geotechnical specifications
  - possible rejection of the construction practice by the geotechnical consultant
  - strict supervision of the de-silting of the basins prior to forming the road embankment.

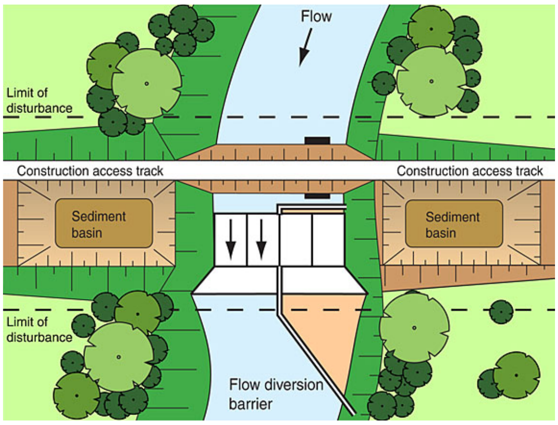


Stage 3

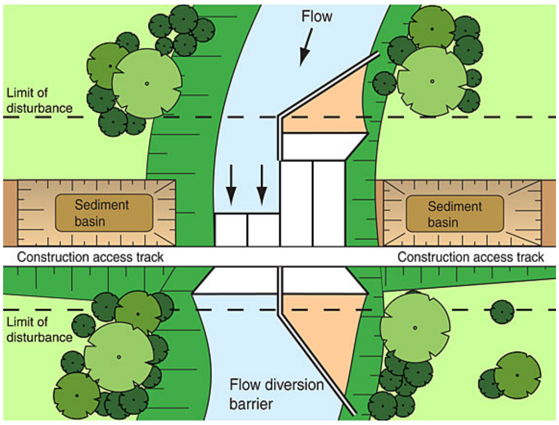


Stage 4

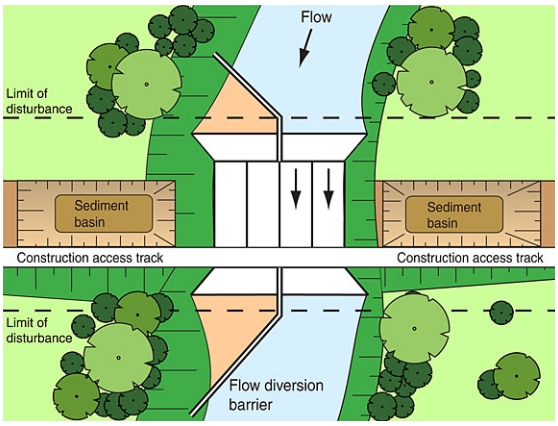
Case Study 6 – Sediment basins located within the road corridor (cont.)



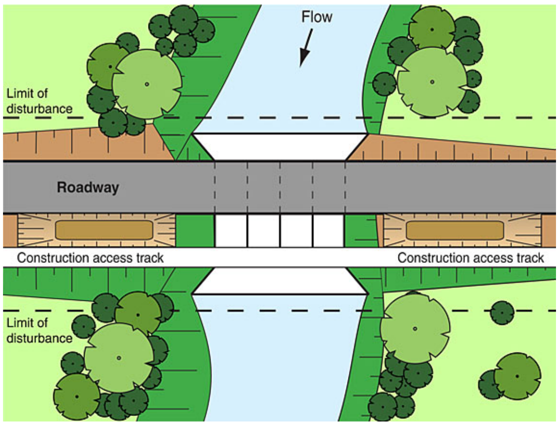
Stage 5



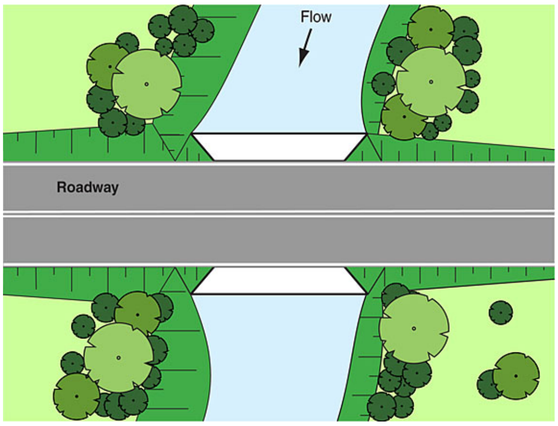
Stage 6



Stage 7



Stage 8



Finished roadway

Avoid complex construction practices

- Complex construction practices, such as those described above, 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 possible benefits of using a pipe culvert instead of a box culvert.

Bridge

Arch bridge

Temporary Vehicle Crossings of Waterways and Gullies

Temporary watercourse crossings

Barge crossing of tidal inlet

Barge crossings

- A barge can be used as a mobile transportation system to cross estuaries and protected waterways.
- Barges can be used as a fixed bridge structure (left) to cross narrow estuary inlets.

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 bridge deck across narrow streams.
- It is important to control stormwater drainage on the access tracks leading to watercourse crossings in a way that will minimise the risk of sediment-laden water from these tracks being discharged, untreated, into the watercourse.

Temporary pipe culvert

Temporary culvert crossings

- Temporary culvert crossings are typically used on wide stream crossings.
- 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 alluvial stream

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.
- *Cellular Confinement Systems* can be used to stabilise dry sandy-bed crossings.

Temporary vehicular crossings of waterways

Mud generated by vehicular traffic

Clay-based waterway crossings

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

Sand-based ford crossing

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 sediment release or damage to the waterway, even if the bed is wet.
- These bed-level crossings can also be temporarily reinforced with a cellular confinement system, but this synthetic material **must** eventually be removed.

Gravel-based ford crossing

Gravel-based waterway crossings

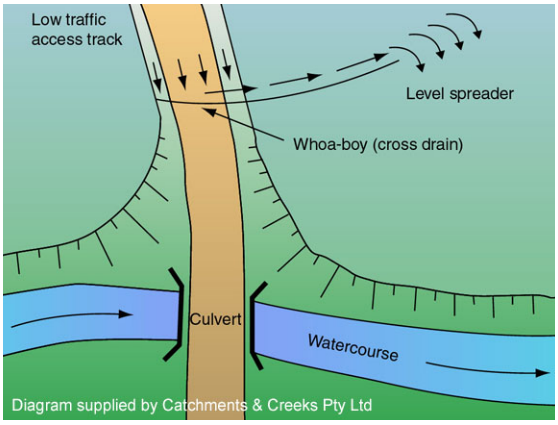
- Gravel-based waterways usually contain a series of pools and riffles along the channel bed.
- The channel bed is typically flat, and bed-level crossings (fords) are normally located at riffles where flows are shallow.
- It is **important** to avoid sand and fine sediments entering the riffle, so drainage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

Rock-based ford crossing

Rock-based waterway crossings

- The waterway bed is normally very stable on rock-based waterways, 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 substrate.

Design of approach roads



Diversion of road runoff

Drainage control

- Critical to the management of temporary vehicle crossings of waterways is the appropriate management of road runoff adjacent to the waterway.
- Road runoff must be diverted off the approach roads such that sediment-laden water does not discharge, untreated, into the waterway.
- Typically, cross drainage berms (cross banks) are used to divert runoff into a sediment trap or the adjacent bushland 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 the approach road into the channel bank can provide both positive and negative outcomes for the waterway.
- 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 channel features.

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 weight and number of vehicles
  - the likelihood of wet weather.
- Ideally, hard engineering structures should be avoided within the waterway and riparian zone, especially if the waterway is unstable or mobile (i.e. subject to natural lateral movement).

Vehicular crossings of dispersive soil gullies

Dispersive soil gully

Dispersive soil gullies

- Rural road projects often encounter deep gullies that have cut through highly-erodible dispersive soils.
- In most cases, these gullies will represent recent geological features (i.e. less than 50 years old) that have resulted from past land management practices rather than natural forces.
- Temporary vehicular crossings of these gullies can be **very** unstable if not appropriately designed and constructed.

Lateral bank erosion

Controlling lateral bank erosion

- Lateral bank erosion is the formation of new gully lines that cut laterally into the banks of the main gully.
- Lateral bank erosion is normally caused by overland flows spilling into the gully.
- Drainage systems associated with a roadway crossing often initiate such bank erosion, which in turn can damage the approach roads for the crossing.
- Ideally, road drainage should enter the gully well away from the road crossing.

Unstable gully banks (fluting erosion)

Stabilising the banks and inflow drains

- The key to managing dispersive soils is to over-excavate all surfaces by at least 500 mm and then to cap the exposed dispersive soil with a 500 mm thick layer of non-dispersive soil.
- Exposed dispersive soils typically only need to be capped with a minimum 200 to 300 mm layer of non-dispersive soil; however, when working in a gully or watercourse, an allowance must be made for additional soil disturbance by animals and natural stream erosion.

Tunnel erosion

Managing tunnel erosion

- Drainage systems associated with roadway crossings of dispersive soil gullies can easily be damaged by tunnel erosion.
- Tunnel erosion <u>cannot</u> be repaired by simply filling the tunnel with treated soil; instead, consider the following options:
  - excavate the full length of the gully and fill with compacted, treated soil, or
  - excavate a trench 'across' the tunnel and backfill the trench with treated clayey-soil of low permeability.

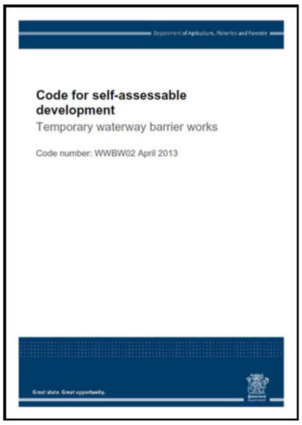
Instream Construction Practices

Introduction

Bridge construction

Cofferdam construction

Inappropriate instream sediment control



Code for self-assessable development
Temporary waterway barrier works
Code number: WWBW02 April 2013

Fisheries construction code

Instream work practices

- Temporary drainage, erosion and sediment control measures can be applied to certain instream work practices.
- The use of <u>instream</u> sediment systems can be controversial, and preference should be given to the use of *isolation barriers* wherever practical.
- Instream sediment control measures can only treat <u>minor</u> dry weather flows.
- These sediment control techniques cannot treat elevated stream flows.

Typical uses of instream sediment control techniques

- Typical uses of instream sediment control include:
  - temporary sediment controls during the installation, relocation, or removal of isolation barriers
  - temporary sediment control during the formation or removal of cofferdams
  - sediment control during the maintenance (de-silting) of waterway culverts.

Inappropriate uses of instream sediment control measures

- Examples of instream work practices that should not utilise instream sediment control measures include:
  - construction of works within streams that have base flows exceeding the capacity of a small bypass pump
  - works within waterways containing migrating fish.
- Woven fabrics, such as 'sediment fences' should NOT be used in waterways.

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 used, including the construction of cofferdams.

Critical management issues

Long-reach excavator

Basic principles instream work practices

- Ensure all necessary government approvals are obtained **prior** to any disturbance to a watercourse.
- To the maximum degree practical, minimise disturbance to riparian vegetation each side of the watercourse.
- Take all reasonable and practical measures to avoid the operation of construction equipment within the main channel of the waterway.

Isolation barrier

Isolation of disturbances from stream flow

- Wherever practical, priority should be given to the use of instream flow diversion systems that successfully isolate all soil disturbances from the stream flow.
- Isolation barriers can be formed from sediment fence fabric (flow depth < 0.8 m), floating silt curtains (depth > 0.8 m), large water-filled rubber dams, and sheet piling.
- Photo (left) shows a sediment fence (adjacent to the bank) forming a coarse sediment trap, with a second fence (adjacent the stream) forming a quiescent settling pond to settle fine sediments.

Instream sediment control system

Instream sediment control measures

- The use of instream sediment control measures should only be used as a last resort, and only when it is not practical to divert dry weather flows around all disturbances.
- Instream sediment control measures usually require the incorporation of ‘filtration’ systems, such as *Filter Tubes* (left).
- Instream sediment control measures must not be used during periods of fish migration—seek expert advice.

Bank rehabilitation

In-bank erosion control measures

- All disturbed surfaces, bed, banks and overbank areas, must be appropriately rehabilitated as soon as practical.
- Temporary erosion control measures include the use of rock (along the toe of the bank), biodegradable erosion control mesh, and native vegetation.
- *Jute or Coir Logs* may be incorporated into the toe of the bank to protect newly stabilised banks from minor flows as an alternative to rock stabilisation of the bank toe.

Instream sediment control techniques

Instream rock filter dam

Rock filter dams

- Rock filter dams are in-effect, large rock check dams used to slow and filter waters passing through the dam.
- Instream rock filter dams are normally wrapped in filter cloth, which is used as the primary filter.
- Aggregate-based filters are generally not employed on instream rock filter dams.
- Fine aggregate, however, can be used to control the rate of flow passing through the rock filter dam.

Instream sediment weir

Sediment weirs

- A sediment weir is similar in structure to a gabion wall.
- Sediment weirs are formed from two or more parallel wire mesh fences (staked perpendicular to the flow) in between which aggregate (preferred) or straw bales are placed to control the rate of through-flow.
- Fine aggregate and/or filter cloth is then placed on the upstream face to act as the primary filter (which can be removed and replaced after elevated flows occur).

Rock filter dam with filter tubes

Filter tube dams

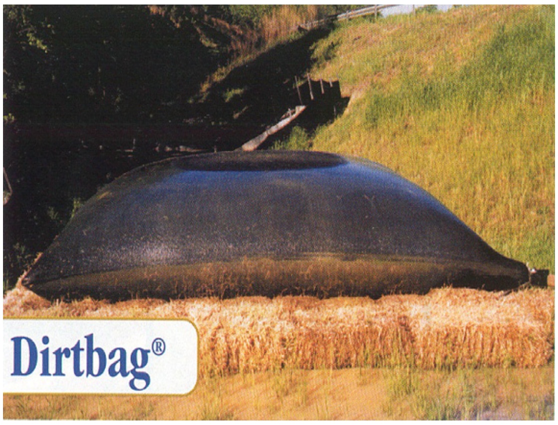
- A filter tube dam is a rock filter dam, into which ribbed drainage pipes are set, onto which non-woven, geotextile filter tubes (below) are attached.
- Instream sediment traps are only suitable for use within constructed drainage channels, natural drainage lines and ephemeral waterways, and are designed **only** to treat dry-weather base flows.
- Elevated stream flows should be allowed to pass over the sediment trap without causing damage to the trap.

Elevated stream flows at work site

Filter tube connected to ribbed pipe

Sediment Control During Site De-watering

De-watering sediment controls



Filter bag

Filter bags

- Commercial filter bags are suitable for the treatment of low flow rates.
- The bags collect only coarse-grained sediments (they provide minimal control of turbidity levels).
- It is important to ensure that there are suitable means of collecting and removing the bags once they are full of sediment.
- Placing the filter bags within a mini skip (drainage plug removed) can reduce the complications of removing the used bags.

Compost-filled filter sock/berm

Filter fence

- Suitable for the coarse and fine-grained soils, but **not** for turbidity control.
- Non-woven fabrics must be used.

Compost berms

- Can provide good filtration and limited turbidity control.
- Compost-filled socks (*Filter Socks*) can also be used.
- Performance of both systems can be improved if incorporated with a substantial grass filter bed (e.g. a wide floodplain).

Filter pond

Filter ponds

- Used on flat or near-flat ground.
- Most effective for the treatment of water containing coarse-grained sediment.
- Limited control over turbidity.
- Diameter of the pond and the composition of the filter wall depends on the soil type and design flow rate.
- Performance can be improved if located adjacent a substantial grass filter bed (e.g. a wide floodplain).

Filter tube

Filter tubes

- Commercial filter tubes are suitable for the treatment of low to medium flow rates.
- Filter tubes collect only coarse-grained sediments, with minimal control of turbidity.
- It is important to ensure that there are suitable means of collecting and removing the filter tubes once full of sediment.
- Placing the filter tube up-slope of a substantial grass filter bed can improve the collection of fine sediments and turbidity control.

De-watering sediment controls

Grass filter bed

Lamella settling tank

Settling pond

Sump pit acting as a pipe intake filter

Grass filter beds

- The most common de-watering sediment control technique is to pump sediment-laden water onto a grassed surface to allow the water to infiltrate and 'filter' through the underlying soil.
- It is important to understand that a grassed area only provides effective filtration while the underlying soil remain unsaturated.
- Consequently, the pumped outflow **must** be spread over as large an area as is possible.

Portable settling tanks

- Wide variety of different systems can be employed.
- *Lamella* settling tanks utilise laminar flow conditions to optimise the settlement of non-dispersive soils, but allowable flow rates are low.
- Some systems have good control over turbidity, while other systems have little or no control over turbidity.
- Units can be hired, and operation costs are low.

Settling ponds

- Settling ponds contain a free draining outlet system, usually consisting of a *Rock Filter Dam,* or a series of *Filter Tubes*.
- Only suitable for waters containing fast settling (coarse) sediments.

Stilling ponds

- Stilling ponds do not incorporate a free draining outlet system.
- These ponds are operated similar to 'wet' sediment basins.
- Turbidity control can be achieved.

Sump pits

- Sump pits can be used as a pre-treatment system in association with an outlet-type treatment system (i.e. any of the above treatment systems).
- Filtration occurs at the pump inlet rather than at the outlet of the pipe.
- Commonly used as a pre-treatment system when de-watering instream works.

Rehabilitation of Waterways

Introduction

Bridge construction

Flood damage to bridge pier

Rock stabilisation of bed and banks

Fish passage along a creek bed

Waterway rehabilitation

- Both bridge and culvert construction can cause significant disturbance to the bed and banks of waterways, which will require rehabilitation at the end of the construction process.
- Revegetation needs under a bridge deck can be complex, and the revegetation outcomes are often required to satisfy the sometimes conflicting needs of:
  - scour protection, and
  - fish passage.

Scour protection measures under bridges

- The existence of a bridge almost certainly will increase flow velocities during flood events due to the reduced flow area.
- Scour protection measures will usually be required to prevent:
  - damage to bridge abutments
  - the undermining of abutments
  - scour around the base of bridge piers
  - scour damage to the channel's bed and banks.

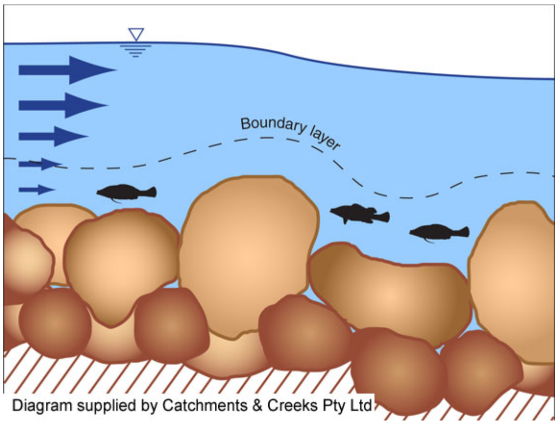
Scour protection of waterway bed and banks adjacent bridges and culverts

- Both bridges and culverts experience accelerated flow velocities immediately upstream and downstream of the crossing.
- Scour protection is normally achieved through the use of rock stabilisation of the channel banks, and possibly (?) rock stabilisation of the channel bed.
- Bed stabilisation measures are questionable if the waterway experiences the natural movement of bed material (e.g. sand and gravel-based waterways)

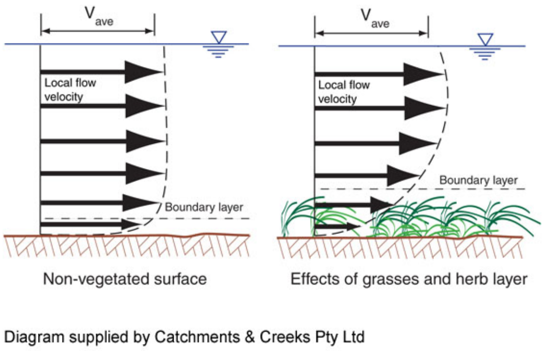
Fish passage considerations

- The adopted scour protection measures need to be compatible with the needs of fish passing under the bridge, or through the culvert as the case may be.
- Understanding how to make scour protection measures 'fish friendly' requires expert advice, and a common understanding by the engineers and scientists of the critical issues.

Fish passage considerations



Variation in velocity with depth



Effects of channel roughness

Adverse under-deck planting conditions

Poor light conditions under a bridge

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.

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 thick, fish-friendly, boundary layers.
- Ground covers, such as soft grasses, fold flat in high velocity flows resulting in thin, non fish-friendly boundary layers.

The importance of establishing vegetation under bridge decks

- Fish passage not only occurs within the main waterway channel, but can also occur along the upper banks and across overbank areas during flood events.
- Appropriate vegetation can aid fish passage in the following locations:
  - channel bed (ephemeral streams)
  - channel banks (moderated flows)
  - overbank areas (minor floods)
  - bridge abutments (major floods)

Difficulties in establishing vegetation under bridge decks

- The bank and overbank areas under a bridge deck can be hostile areas for vegetation growth.
- The problems experienced include:
  - shading from sunlight
  - lack of natural rainfall resulting in dry ground conditions even through the area can be close to a flowing stream
  - high flow velocities during flood events.

Fish-friendly scour protection measures

Gravel-based waterway

Replacement of natural bed material

- Natural bed material (substrate) should be returned to the channel bed wherever possible.
- The replacement of the natural substrate is important for:
  - fish passage
  - maintaining the natural boundary layer flow conditions along the bed
  - maintaining the natural migration of bed material down the waterway during floods (alluvial waterways only).

Natural bank vegetation

Stiff grasses

- Wherever possible, the bank vegetation should mimic the natural bank vegetation, which usually requires integrating vegetation with introduced hard engineering measures such as rock.
- Critical to fish passage needs is the reinstatement of edge plants along the bank and the water's edge.
- Stiff grasses, such as Lomandra, can be very important along the lower bank region of waterways.

Vegetated rock stabilisation

Vegetated rock stabilisation

- Vegetated rock surfaces are always more stable than non-vegetated rock.
- Wherever practical, rock stabilisation measures should be actively vegetated to ensure appropriate plants are established rather than weed species.
- The voids between the rocks should be filled with soil and pocket-planted.

Vegetated rock mattresses

Vegetated rock mattresses and gabions

- Non-vegetated gabion and rock mattress surfaces are 'hydraulically' smooth, and consequently produce boundary layers that are too thin for most fish.
- To aid fish passage, these surfaces should be suitably vegetated to ensure appropriate plants and surface roughness conditions are established.
- When placed near waterways, all wire basket products **must** be vegetated due to the limited working life of the wire baskets.

Potentially unfavourable scour protection measures

Non-vegetated rock stabilisation

Non-vegetated rock stabilisation

- In some circumstances, plain, non-vegetated, rock-lined surfaces can also represent a barrier to fish passage.
- Such surfaces may not be able to produce desirable boundary layer flow conditions, or desirable shading of the water's edge.
- In permanent streams, open voids below the water line can provide ideal fish habitat; however, above the water line it is generally preferable for vegetation to be established over the rock protection.

Non-vegetated rock mattresses

Non-vegetated rock mattresses

- When placed in an aquatic (waterway) environment, the wire baskets used to form gabions and rock mattresses can be damaged by the natural movement of bed sediments (sand) and woody debris.
- The wire only has a limited life span prior to rusting, even if the wire is galvanised and plastic-coated.
- Appropriate vegetation cover is **essential** for the long-term durability of gabion structures in aquatic environments.

Concrete abutments

Concrete and grouted stone pitching

- Concrete, shotcrete, and grouted stone pitching are commonly used as a surface material on bridge abutments.
- These 'hydraulically' smooth surfaces do not provide the suitable boundary layer conditions required for fish passage during flood events.
- Grouted stone pitching is also not very durable and the inevitable cracking of the grout will ultimately result in the failure of the scour protection (see below).

Grouted stone pitched abutment

Failed stone pitching (same bridge)

Temporary erosion control measures

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 uncommon in waterway rehabilitation because of the risk of elevated stream flows lifting and washing away the blankets along with several of the plants.
- If jute blankets are used, then these blankets are more likely to be the thicker blankets to help suppress the re-establishment of weed species.

Jute mesh with additional rock anchors

Jute and coir mesh

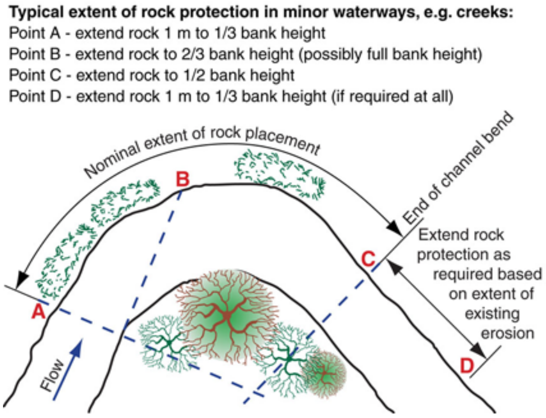
- Jute or coir mesh is the most commonly used and recommended erosion control mat for waterway environments.
- These meshes are less likely to be disturbed by elevated stream flows, and are easier to plant into.
- The mesh is commonly anchored with traditional metal or plastic pins, plus additional rock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

Synthetic reinforced erosion control mat

Caution the use of synthetic reinforced erosion control mats

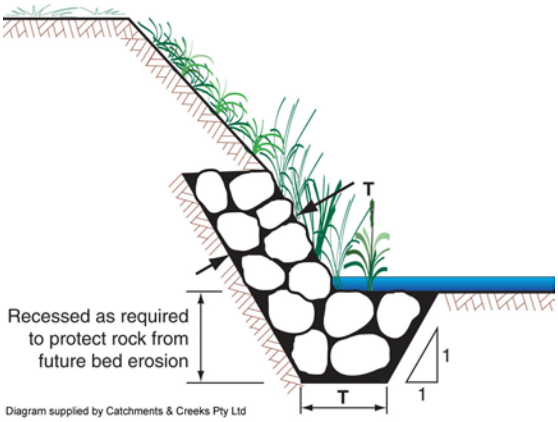
- Some temporary erosion control mats contain an organic mulch reinforced with a synthetic mesh that will eventually breakdown under sunlight.
- These synthetic reinforced mats should <u>not</u> be used in bushland and waterway environments because ground dwelling animals, such as lizards, snakes, and seed-eating birds, can become entangled in the netting.

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 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 extent 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

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 then 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.

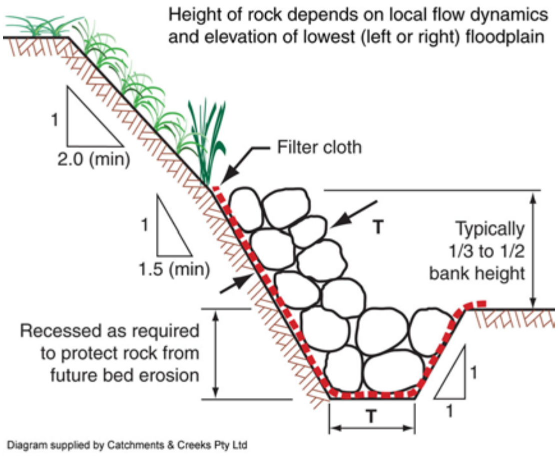
Maximum bank slope

- 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 hydraulic capacity of waterway crossing if woody species are establish within critical hydraulic areas.

Rock placement on waterway banks



Rock placement with open voids

Advantages:

Reduced quantity of rock.

Disadvantages:

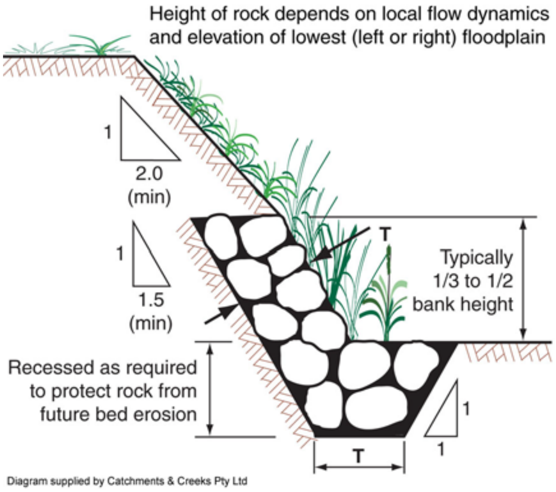
Problems can occur with lateral inflows (i.e. local stormwater runoff) entering into, or passing under, the rock.

Can result in reduced aquatic habitat values in the absence of vegetation.

Use:

Ideally, the use of this rock placement method should be limited.

Used on the inside face of fully shaded, high-velocity channel bends.



Rock placement with soil-filled voids

Advantages:

Improved aquatic habitat values.

Retention of riparian values.

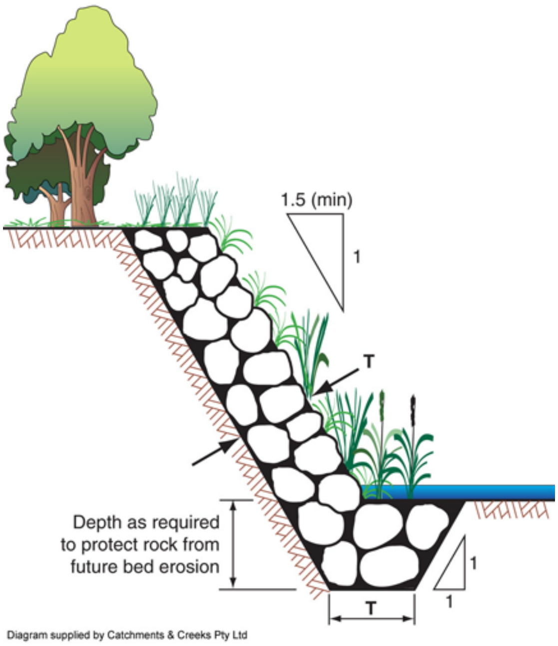
Disadvantages:

Care must be taken to ensure all voids are filled with soil to prevent loss (seepage) of the upper bank soil into the rock layer.

Use:

Toe protection of channel banks in regions of high flow velocity, or areas where the channel bed may experience scour.

Generally the preferred method of rock placement within waterways.



Full-height rock placement

Advantages:

Can provide very high scour protection once vegetation is established.

Retention of aquatic habitat values.

Retention of riparian values.

Banks can be steeper than vegetated banks that do not contain rock protection.

Disadvantages:

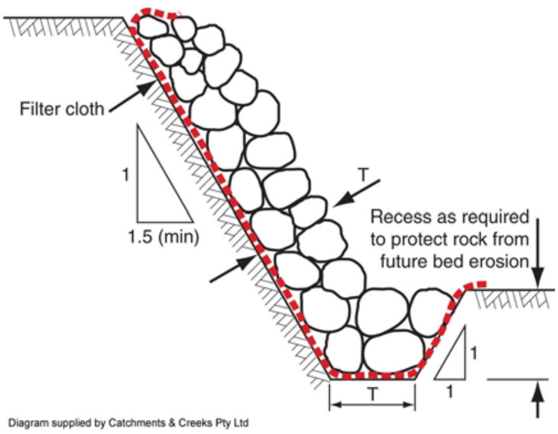
High installation cost.

Use:

Outside face of high velocity or sharp channel bends.

Also, used in areas where both the channel velocity and over-bank flow velocities are likely to be very high and thus erosive.

Rock placement on waterway banks



Full-height with open voids

Advantages:

Cheaper installation cost compared to vegetated rock protection.

Disadvantages:

Poor aesthetics.

Poor aquatic habitat and fish passage.

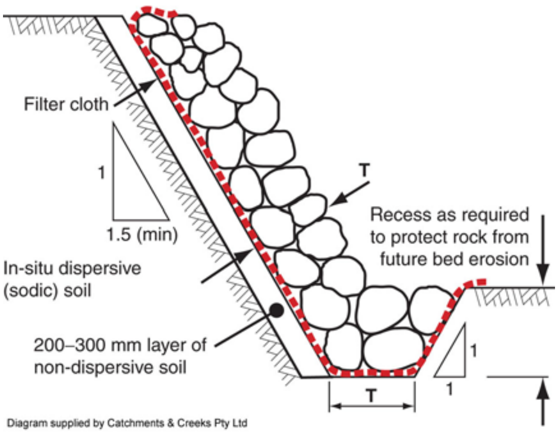
High risk of weed invasion unless fully shaded.

Use:

Heavily shaded, high velocity areas.

Outside face of fully shaded channel bends.

Very high velocity regions where vegetation is not expected to survive.



Rock placement over dispersive soils

Advantages:

Long-term protection of highly erodible soils.

Disadvantages:

Poor aesthetics.

Poor aquatic habitat and fish passage.

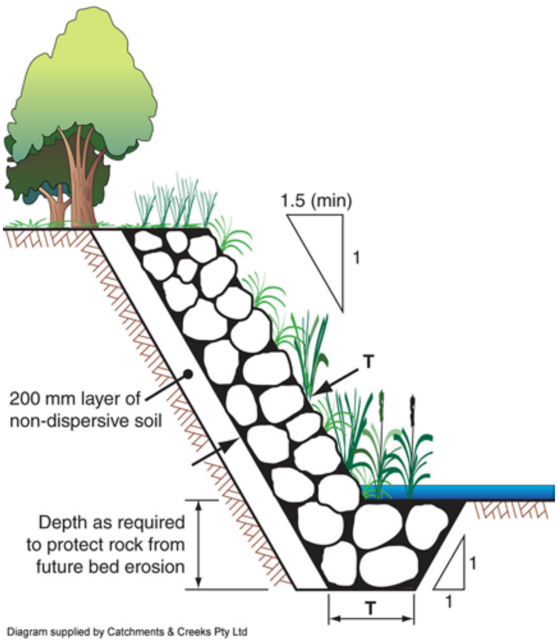
High risk of weed invasion unless fully shaded.

Use:

Heavily shaded areas containing dispersive soils.

Outside face of fully shaded channel bends.

Very high velocity regions where vegetation is not expected to survive.



Vegetated rock placement over poor soils

Advantages:

Retention of aquatic habitat values.

Long-term protection of highly erodible soils.

Reduced maintenance costs.

Disadvantages:

Higher installation cost compared to non-vegetated rock protection.

Use:

Outside face of high velocity or sharp channel bends in dispersive soil regions.

Dispersive soil areas where both the channel velocity and over-bank flow velocities are likely to be very high and therefore erosive.

Generally the preferred method of rock placement within dispersive-soil gullies and waterways.

Vegetated rock stabilisation

Planted rock-stabilised creek bank

Introduction

- Wherever practical, rock protected areas should be lightly covered with soil (to fill all voids) and pocket planted to encourage the preferred plant growth across the bank and along the water's edge.
- In areas where dense revegetation is not desirable (e.g. critical hydraulic area adjacent the bridge or culvert entry and exit) then the establishment of soft grasses over the rocks can (in some cases) reduce the likelihood of woody species being established.

Voids filled with soil ready for planting

Infill soil

- Experience has shown that minimal soil is lost from the rock voids during flood events.
- The image presented left shows a recently planted bank that experienced a bankful flow just weeks after planting—all plants were lost from the bank, but most of the soil remained.
- **Important:** In order to allow proper plant growth, the infill soil needs to be placed progressively as the layers of rock are added to the bank.

Planting along the water's edge

Planting along the water's edge

- Wherever practical, vegetation should extend to the water's edge to increase the value and linkage of aquatic and terrestrial habitats.
- Plants that branch over the water's edge can provide essential shading of the water to provide pockets of cool water for aquatic life.
- Edge plants also assist aquatic life to shelter from predators.

Planted rock covered with jute mesh

Use of erosion control mats

- During plant establishment it may be necessary to mulch around newly placed plants to control soil moisture loss.
- Covering such areas with a jute or coir mesh can help to reduce the loss of mulch by wind and minor flows.
- However, it is noted that the compete loss of the matting during high flows can cause damage to, or the total loss of, recently established plants.

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 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 toe of the rock 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 placed on a dispersive (e.g. sodic) 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.

Glossary of terms

Acid sulfate soil	A soil type containing significant amounts of iron sulfide (usually pyrite, FeS_2) which generates sulfuric acid when exposed to oxygen; typically associated with coastal lowlands (< 5 m AHD) and estuarine floodplains.
Aggregate immersion test	A simple soil test performed in the field that is similar to the *Field Emerson Aggregate Test*, except undisturbed samples of the soil are tested rather than a formed 'bolus'.
Alluvial waterway	A natural waterway formed primarily from flood-laid deposits of sand, silt and gravel, or a constructed channel primarily lined with alluvial material extracted from a waterway or floodplain. Typically represented by sand-based and gravel-based waterways.
Bankful elevation	A water surface elevation estimated by various procedures that describe the channel flow condition preceding significant overbank flow. If benches are well established within the channel, then significant overbank flows might occur prior to the inundation of the floodplain. To avoid erroneous and/or highly variable results, bankful elevation should not be determined by the shape of a single cross-section, but with observations made along a length of the channel.
Bankful width	The width of a watercourse when it completely fills its channel and the elevation of the water reaches the upper margins of the bank.
Causeway	A raised road or path constructed across low, wet ground or across tidal water.
Clay-based waterway	In these waterways, clayey soils dominate the make-up of the stream bed. Channel stability is most commonly governed by the strength of the bed and bank vegetation. Often referred to as 'fixed-bed' waterways—the relative stability of the bed allows for increased longevity of bed vegetation. In their natural condition, minor clay-based waterways often have little if any measurable sediment flow. There is usually a gradual change in plant species from the bed to the lower bank, to the upper bank, to the over-bank areas.
Clayey soil	A soil that contains at least 20% clay. These are fine-grained soils that readily form a clod when compressed in the hand, feel very smooth and sticky when wet, and are very difficult to shovel or break-up when compacted.
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 either does not need to be treated in order to achieve the required water quality standard, or would not be further improved if it was to pass through the type of sediment trap specified for the sub-catchment.
Coarse sediment	That part of sediment consisting of sands and the coarser fraction of silts.
Cross bank	A longitudinal earth mound with low vertical curvature placed diagonally across an unsealed road or track to collect and divert stormwater runoff across the road or track to a table drain or suitable discharge point.
Cross drain	A drain of various forms (e.g. cross bank or sub-surface pipe) that collects the flow of water on a road, trail or other access way and diverts it across the road surface. Typically required where runoff cannot be controlled by crossfall drainage.

Deposit	Means any discharging, spraying, releasing, spilling, leaking, seeping, pouring, emitting, emptying, throwing, dumping or placing.
Dirty water	Water not classified as clean water.
Dispersive soil (dispersible soil)	A structurally unstable soil that readily disperses into its constituent particles (clay, silt and sand) when placed in water. Moderately to highly dispersive soils are normally highly erodible and are likely to be susceptible to tunnel erosion. Most sodic soils are dispersive, but not all dispersive soils may be classified as sodic. Some dispersive soils are resistant to erosion until mechanically disturbed.
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.
Dry gully	Gully erosion that does not contain permanent water.
Emerson aggregate class	A classification of soil aggregates based on their coherence in water. Soil aggregates are classified into 8 types according the conditions in which they slake, swell and disperse, in which Class 1 is the most stable through to Class 8 which is least stable. Classes 2 and 3 may be further subdivided according to the degree of dispersion.
Ephemeral waterway	A watercourse that flows during and for short periods after storms.
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.
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	Means 'erosion and sediment control'
ESCP	Means 'Erosion and Sediment Control Plan'
Fine sediment	That part of sediment consisting of clay-sized particles and the finer fraction of silts.
Fish	Includes: parts of fish; shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals; and, the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.
Fish barrier	Means any weir, dam, non-natural vegetation condition or other obstruction impeding the free passage of fish.
Fish habitat	Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.
Fluting	A series of vertically elongated grooves (flutes) down gully sides caused by rill erosion. Most commonly experienced in dispersive soils. In severe cases the rills may become isolated from the gully walls to form narrow tapered pinnacles.
Ford	A shallow place where a river or other body of water may be crossed by wading or otherwise passing through the water.

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. Bank stability is governed by the strength of the bank vegetation. The bed material can be highly mobile during severe floods, but generally stable during minor floods. Bed vegetation may consist of mature woody and non-woody species, but significant loss of vegetation can occur during severe floods. Bank vegetation can be similar to clay-based waterways.
Grubbing	A construction activity that involves removing vegetation, tree roots and stumps and surface soil from the pipeline right-of-way or other areas that will be under development.
Gully erosion	A complex of processes in which soil removal is characterised by large incised channels, usually deeper than 30 cm. The severity of gully erosion may be recorded as minor, moderate, severe or very severe.
Inland waterway	A waterway located well away from a coastline, such as waterways that ultimately discharges to a trapped water body, or most of the tributaries of the Murray–Darling rivers catchment.
Mitigation	Actions taken during the planning, design, construction and operation of works and undertakings to alleviate potential adverse effects on the productive capacity of fish habitats.
Raindrop impact erosion	The splattering of soil particles caused by the impact of raindrops on the soil surface. The loosened particles may or may not be subsequently removed by runoff. Raindrop impact erosion is a component of sheet erosion.
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.
Riprap	Loose, medium to large rock or stone used to protect earth surfaces against erosion by flowing water or wave action, as in a revetment.
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. The waterway bed is normally very stable; however, significant sediment flows can still occur during floods. Within vegetated sections of the bed, plant species are usually governed by the type of bed material (clay, sand or gravel).
Sand-based waterway	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. There is normally a clearly defined change in plant species from the bed to the channel bank. Upper bank vegetation can be similar to clay-based waterways.

Sandy soil	A soil that contains at least 50% sand. These are coarse-grained soils that are easy to shovel and break-up when compacted. It is very difficult to form a clod when sandy soils are compressed in the hand.
Sediment	Any clay, silt, sand, gravel, soil, mud, cement, fine-ceramic waste, or combination thereof, transported from its area of origin.
Sheet flow	Flow that passes evenly over the ground as a thin sheet of water as opposed to concentrated flow. Normally occurs on plan surfaces (ground not heavily concaved), and on uniformly grassed areas when the depth of flow is not significantly greater than the blade length of the grass.
Slaking	The process of natural collapse of a soil aggregate in water where its mechanical strength is insufficient to withstand the swelling of clay and the expulsion of air from pore spaces. It does not include the effects of soil dispersion. Slaking aggregates readily break down when immersed in water, but do not disperse. Clouding of the water, if any, is limited to just around individual aggregates. Slaking soils are highly erosive and structurally unstable, but readily settle in water.
Sodic soil	A soil containing sufficient exchangeable sodium to adversely affect soil stability, plant growth and/or land use. Such soils are dispersive and typically contain a horizon in which the exchangeable sodium percentage (ESP), expressed as a percentage of cation exchange capacity, is 6 per cent or more. Strongly sodic soils are considered to be those with an ESP of 15 per cent or more.
Substrate	The material, whether organic and inorganic, found on the bed of the watercourse.
Tunnel erosion	An erosion process involving the removal of sub-surface soil by water while the surface soil remains relatively intact. Water seeps through soil causing the dispersion and/or slaking of soil particles. The dispersed soil is then removed by seepage until the seepage path takes the form of a tunnel.
Turbidity	A measure of the clarity of water. Commonly measured in terms of Nephelometric Turbidity Units (NTU).
Type 1, 2 & 3 sediment traps	A classification system used to rank sediment control measures based on their ability to trap a specified grain size.
Watercourse	A channel with defined bed and banks, including any gullies and culverts associated with the channel, down which surface water flows on a permanent or semi-permanent basis or at least, under natural conditions, for a substantial time following periods of heavy rainfall within its catchment.
Waterway	A term commonly interchangeable with the term ‘watercourse’. The legal definition may vary from state to state, and region to region.