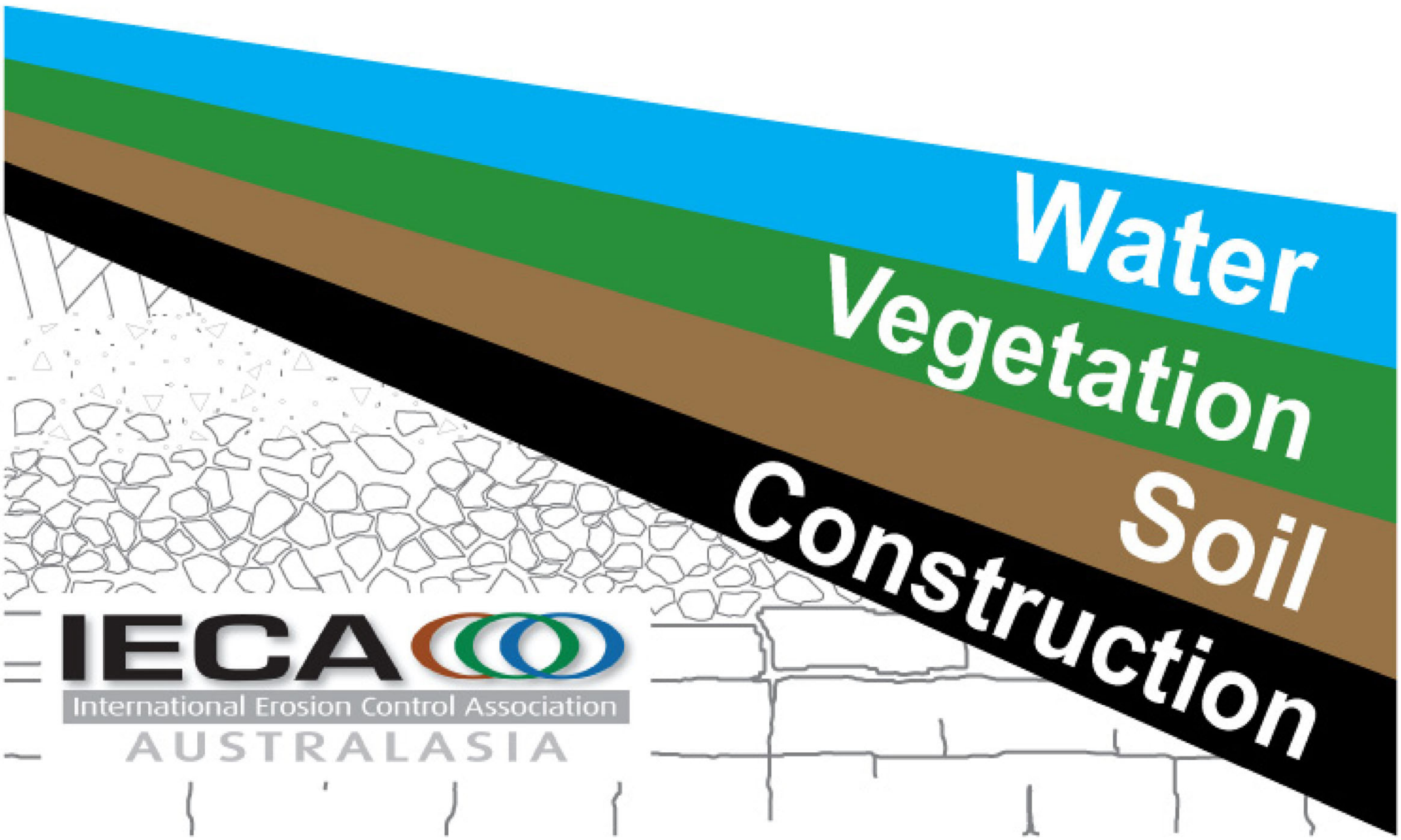
Best Practice Erosion & Sediment Control

Book 3 – Appendices H - N

November 2008



Best Practice Erosion & Sediment Control

– for building and construction sites

Book 3 – Appendices H-N

November 2008

International Erosion Control Association (Australasia)

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Appendix H

Building sites

This appendix provides guidelines on the development of Erosion and Sediment Control Plans for detached-dwelling building sites. The primary function of this appendix is to provide government bodies and the building industry with a model Code of Practice for the building industry. Government bodies are encouraged to explore the development of a regional-based Code of Practice using the model code as a template.

H1 Introduction

Residential and small commercial building sites represent a unique set of site conditions within the erosion and sediment control industry. These sites are usually too small to incorporate high standard sediment control measures such as *Sediment Basins*, and it is also often impractical to incorporate erosion control measures until the building activities are near completion. It is for these reasons that the focus of erosion and sediment control on building sites changes slightly from the traditional focus adopted for larger construction sites.

In reality the principles of on-site erosion and sediment control do not change whether the soil disturbance is a small building or large construction site, or if the site is located in the tropics or temperate zone. However, the priority given to each of the principles must change based on the anticipated site conditions.

What is considered reasonable and practicable on a construction site may not be considered reasonable and practicable on a typical building site, and vice versa. However, some building sites can be significant in size, such as many medium density townhouse developments, in which case the building site needs to treated in the same manner as a construction site of equivalent size.

H2 Building design

The following principles need to be incorporated into the building design and site layout where appropriate.

- Investigate site constraints and appropriately integrate the building into the site in a manner that minimises both short- and long-term environmental harm.
- Consider the use of elevated pole homes on steep blocks.
- Allow enough accessible room on the site to store all building materials, especially stockpiles of erodible material.
- Allow enough space to install all necessary sediment control measures, especially along the lower property boundary.
- Do not specify exposed aggregate concrete surfaces in areas where the cement wash-off cannot be fully contained within the site or an associated slurry collection pit.

H3 Principles of building site erosion and sediment control

The following key principles apply, wherever reasonable and practicable, to the management of building sites.

(i) Prepare and implement an Erosion and Sediment Control Plan (ESCP) for the site.

(ii) Allow for the early stabilisation of any disturbed areas located outside the immediate work area. As an example, after the completion of earthworks, it is often possible to stabilise (i.e. turf) the backyard before works commence on the building.

(iii) Minimise the number of site entry points, preferably to one stabilised rock pad.

(iv) Expose the smallest possible area of land for the shortest possible time.

(v) Save and promptly replace the topsoil.

(vi) Divert up-slope stormwater runoff around soil disturbances.

(vii) Connect roof water downpipes to the permanent drainage system immediately the roof and guttering are installed.

(viii) Actively control wind- and rain-induced soil erosion.

(ix) Firmly compact and stabilise all backfilled service trenches.

(x) Minimise sediment released from the property.

(xi) Place all long-term stockpiles of erodible material within the sediment control zone.

(xii) Fully contain all wash-water from concreting, ceramic cutting, and cleaning operations within an on-site area of grass or open soil.

(xiii) Promptly revegetate or otherwise stabilise disturbed areas.

(xiv) Maintain all control measures in proper working order at all times.

H4 Development of Erosion and Sediment Control Plans

The following section has been developed to provide a procedure for the preparation of Erosion and Sediment Control Plans (ESCPs) for single-dwelling building sites. This procedure has been supplied as a guide only.

The following recommendations are not intended to replace the need for site-specific evaluation and design. It is of course important for Erosion and Sediment Control Plans to comply with all relevant local, State and Federal legislation and codes of practice.

The design steps incorporated into this procedure are summarised below:

Step 1. Evaluate site limitations.

Step 2. Stabilise site entry/exit points.

Step 3. Locate material stockpile areas.

Step 4. Control up-slope stormwater.

Step 5. Control sediment runoff.

Step 6. Control erosion on disturbed areas.

Step 7. Control roof water drainage.

Step 8. Define the installation sequence.

Step 9 Prepare technical notes for the ESCP.

Step 1. Evaluate site limitations.

Assess the site constrains and any site-specific concerns, including:

- protected vegetation that may need to be identified and/or fenced;
- highly erodible soils that may require increased erosion control measures;
- up-slope drainage catchments that may need to be diverted around the site;
- work space limitations that may require site-specific sediment control measures and/or the extensive use of mini-skips for material storage and waste removal.

Step 2. Stabilise site entry/exit points.

Where reasonable and practicable, restrict site access to one entry/exit point. A stabilised entry/exit point normally consists of a rock pad.

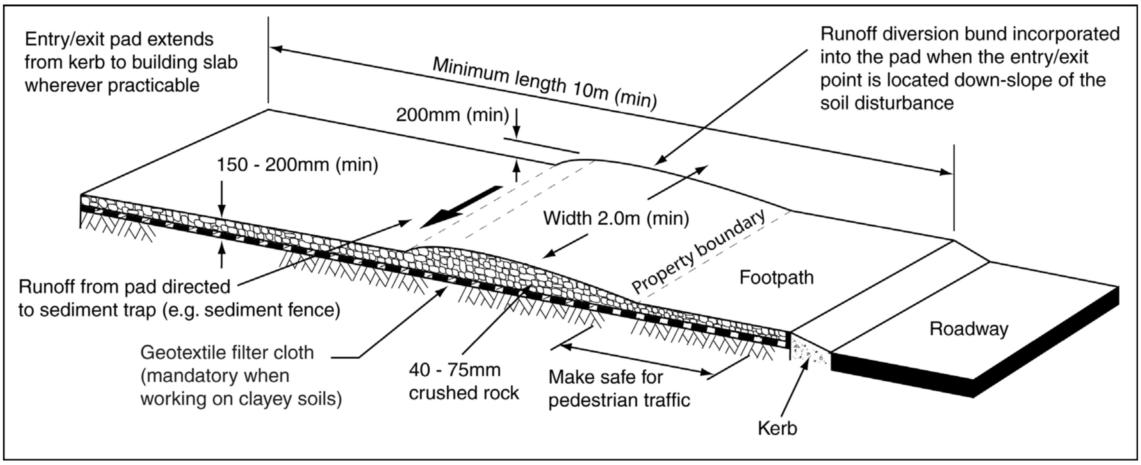


Figure H1 – Entry/exit rock pad for building sites

If the building site is elevated above the road, then it is likely that stormwater runoff will wash sediment from the entry/exit pad onto the roadway. To avoid this, it is usually necessary to construct a raised flow diversion bund across the rock pad (Figures H1 and H2) to direct stormwater runoff into an adjacent *Sediment Fence*.

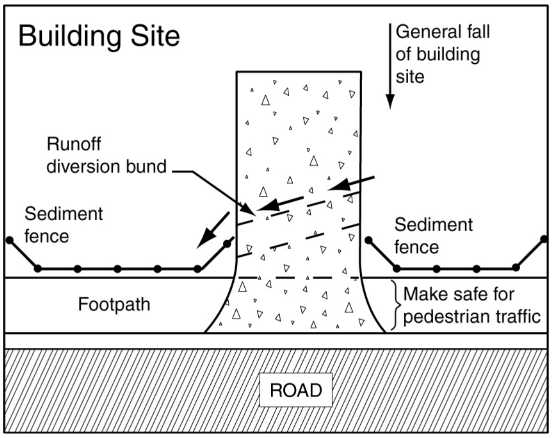


Figure H2 – Stormwater runoff being directed off an entry/exit pad

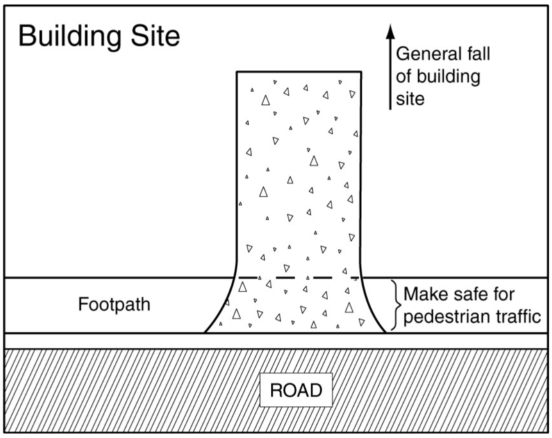


Figure H3 – Example of an entry/exit pad that drains back into a site

The entry/exit pad is usually displayed on the ESCP using either of the following standard symbols.

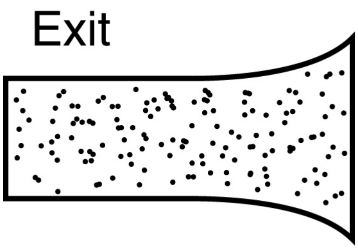


Figure H4 –

Entry/exit pad without drainage control

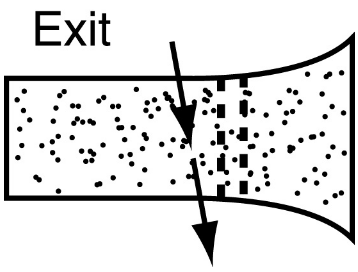


Figure H5 –

Entry/exit pad with drainage control

Step 3. Locate material stockpile areas.

Locate suitable areas up-slope of the main sediment barrier to store materials. The building layout should allow sufficient room on the site to locate all building materials. On steep sites or sites with limited available space, erodible materials may need to be stored in commercial sized bins or mini-skips.

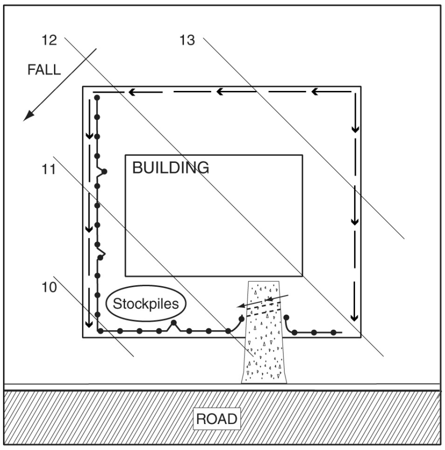


Figure H6 – Placement of stockpile area

Step 4. Control up-slope stormwater.

During those months when the rainfall is expected to exceed 45mm, up-slope catchment area that exceed 1500 m^2 should be diverted around stockpiles, soil disturbances and the building activities wherever reasonable and practicable. However, stormwater must not be diverted if such a flow diversion would inconvenience neighbouring properties, or result in the stormwater being unlawfully diverted into a neighbouring property.

Up-slope stormwater may be collected and moved across the site by constructing either a *Catch Drain* or *Flow Diversion Bank* (Table H1). If the site is steep, then a temporary flow diversion *Chute* may need to be constructed (Table H2).

If flow velocities within these drains are expected to cause erosion, then the options are to either line the surface of the drain with turf, filter cloth, or *Erosion Control Mats*; or to place *Check Dams* in the channel to reduce the flow velocity. *Check Dams* (Table H3) are most effective when used in channels with a gradient less than 10% (1 in 10).

Table H1 – Low gradient flow diversion techniques

Technique	Symbol	Typical Usage
Catch Drains	→ CD →	• Shallow spoon drain cut into soil up-slope of earthworks. • Used for the diversion of sheet flow and minor concentrated flows.
Flow Diversion Banks – earth	→ DB →	• Small embankment of soil placed up-slope of earthworks. • Used for the diversion of minor flow when soils are dispersive or otherwise highly erodible.

Table H2 – Steep gradient flow diversion techniques

Technique	Symbol	Typical Usage
Chutes	→ CH →	• Transfer concentrated water down steep slopes.
Level Spreaders	LS ↓↓↓↓↓↓	• Used to convert minor concentrated flows back to "sheet" flow before releasing it down a stable grassed slope.

Table H3 – Types of *Check Dams*

Technique	Symbol [1]	Typical Usage
Sandbag Check Dams	→ SBC →	• Used in shallow channels typically less than 500mm deep because they are usually small in height and are less likely to divert water out of the channel.
Rock Check Dams	→ RCD →	• Used in deep channels typically greater than 500 mm deep.

Note: [1] The standard symbol for a *Check Dam* is not usually used on ESCPs. Instead their use is specified as a technical note on the plan.

Step 5. Control sediment runoff.

On building sites, the control of sediment runoff is normally limited to Type 3 sediment traps such as a *Sediment Fence*. Wherever reasonable and practicable the *Sediment Fence* is supplemented through the placement of *Grass Filter Strips*.

Wherever reasonable and practicable, *Sediment Fences* should be installed along a line of constant elevation to allow stormwater to pass evenly through the fence. On most building sites, however, it is usually only practical to install the *Sediment Fence* along the lower property boundary, thus the fence is often installed down a slight gradient. In such cases, regular returns (i.e. fence turned at least 1 m up the slope) at a maximum 10 m spacing (Figure H8) are required to avoid the Sediment Fence directing all the runoff to the lowest corner of the property.

Figure H7 – Standard symbol for a *Sediment Fence*

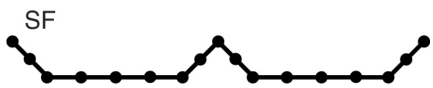


Figure H8 – Symbol for a *Sediment Fence* with intermediate fence return

Step 6. Control erosion on disturbed areas.

Appropriate erosion control measures should be employed to limit soil erosion as soon as reasonable and practicable. Erosion control measures are best identified through the use of technical notes on the plans—refer to Step 9.

The application of erosion control measures greatly depends on the likelihood and intensity of expected rainfall. If building activities occur during the dry months when the monthly rainfall is expected to be less than 45 mm, then erosion control requirements are likely to be significantly less than if building works were to occur during the wetter months.

In addition to a down-slope *Sediment Fence*, long-term stockpiles of “clayey” material may require an impervious cover to minimise the release of turbid runoff. Stockpiles of clean sand that are located behind a *Sediment Fence*, will only need a protective cover if the stockpiles are likely to be exposed to strong winds.

Newly formed earth batters should be covered with topsoil and mulched, vegetated or otherwise stabilised as soon as reasonable and practicable. If the earth batters are not going to be grassed, and the application of loose mulch is unlikely to stabilise the slope, then commercially available *Erosion Control Blankets* may need to be used to stabilise the batter.

Where practicable, the site should be turfed as soon as building activities are completed and a heavy mulch layer should be placed on exposed garden beds to control soil erosion. Builders are encouraged to include such items within the building contract. It must be acknowledged that the use of turf is not appropriate in all climatic regions.

Step 7. Control roof water drainage.

To reduce soil erosion and site wetness, roof water should be discharged away from the active work area and any disturbed soil surface. During periods when there is a reasonable likelihood of rainfall, permanent or temporary downpipes need to be installed to suitably manage roof water as soon as the roof and guttering is laid.

Roof water drainage controls are best identified through the use of technical notes on the plans—refer to Step 9. The use of such controls can significantly reduce down-time and clean-up costs following extended periods of wet weather.

Step 8. Define the installation sequence.

Whether temporary or permanent, there are usually critical drainage, erosion, and sediment control measures that should be the first items installed before building works commence.

An ESC installation or construction sequence should be developed for all specified drainage, erosion, and sediment control measures. A typical construction sequence is presented below. Also refer to Table H6 in Section H7.

1. Obtain all necessary permits, licences and approvals before site establishment.
2. Establish a single, stabilised entry/exit point (e.g. rock pad).
3. Install sediment fence(s) down-slope of the site.
4. Divert up-slope water around the work site and stabilise any drainage channels.

5. Clear only those areas necessary for building works to occur.
6. Strip and stockpile the topsoil before commencing earthworks or excavations.
7. Stockpile erodible materials within the sediment control zone.
8. Stabilise exposed earth banks (e.g. mulch, turf, erosion control blankets).
9. Install on-site waste receptors (e.g. mini-skips, bins, wind-proof litter receptors).
10. Commence building activities.
11. Establish the site's underground drainage system (if any).
12. Connect roof water downpipes to the permanent underground drainage system as soon as the roof and guttering is laid.
13. Regularly inspect all drainage, erosion and sediment control measures and maintain all measures in proper working order at all times.
14. Progressively revegetate/stabilise the site.
15. Remove any remaining temporary drainage, erosion and sediment control measures upon complete stabilisation of the site.

Step 9 Prepare technical notes for the ESCP.

Technical notes should be attached to the Erosion and Sediment Control Plan to highlight site-specific issues and to detail maintenance requirements of the ESC measures. An example of possible technical notes is provided below. Only those notes relevant to a given site should be adopted.

Example technical notes:

- All sediment fences to be installed prior to commencement of earthworks if rain is possible while earthworks are occurring.
- Prior to commencing excavations, topsoil must be stripped from the designated area and stockpiled on site for later use.
- Immediately following the completion of bulk earthworks, all disturbed areas outside the footprint of the base slab (if used, otherwise all disturbed areas) to be mulched (minimum 50 mm) or otherwise stabilised against erosion.
- Designated earth batters to be stabilised, as directed on the plans, immediately after bulk earthworks have been completed on the site.
- Appropriate building waste receptors must be located on the site and suitably maintained during the building phase.
- All ground cover vegetation outside the immediate building area to be preserved during the building phase.
- Damage to the road reserve (i.e. footpath) vegetation to be minimised and repaired as soon as reasonable and practicable at the builder's expense.
- No materials to be stockpiled outside the property boundaries beyond the end of a working day.
- Soil and sand stockpiles to be covered if strong winds are forecast that could displace the material from the site.
- Stockpiles of earth are to be covered with an impervious cover if rain is forecast.
- The site's underground stormwater drainage system to be installed and operational prior to roof installation.

- Roof water downpipes (temporary or permanent) to be connected to the stormwater drainage system immediately after the roof and guttering is laid.
- All temporary drainage and sediment control measures to remain functional during the building phase.
- All erosion and sediment control structures to be inspected each working day and maintained in proper working order at all times.
- Sediment to be removed from up-slope of each sediment fence immediately after rainfall if the depth of sediment exceeds 200 mm.
- Excessive sediment deposition on the rock entry/exit pad to be removed.
- Additional rock to be applied to the rock entry/exit pad as necessary to maintain its function.
- All sediment deposited off the site as a result of work-related activities is to be collected and disposed of in a manner that will prevent any safety or erosion hazard.

H5 Example building site ESCPs

- The *Sediment Fence* may require occasional returns (zigzags) installed to prevent stormwater simply flowing down the fence to the lowest corner of the property. Fence returns are normally installed at a maximum spacing of 10 m. These returns should extend at least 1 m up the slope.
- *Catch Drains* or *Flow Diversion Banks* placed along the up-slope edges of the property are generally required only if there is more than 1500 m^2 of catchment area up-slope of the building and the monthly rainfall is expected to exceed 45 mm.
- A flow diversion bund may or may not be required on the entry/exit pad of building sites depending on the expected quantity of sediment and surface runoff discharging down the rock pad.

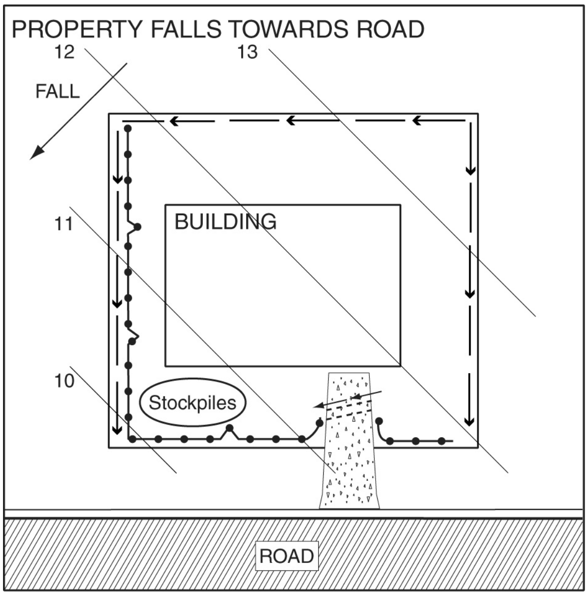


Figure H9 – Example site plan

- In Figure H10 the entry/exit pad does not require a raised flow diversion bund because sediment-laden runoff from the rock pad will not be flowing onto the road.
- Placing a *Sediment Fence* or safety fence along the front of the property can help to restrict traffic movement to the entry/exit pad.
- The *Sediment Fence* may be fixed to the back fence (if available), but must still be suitably buried (anchored).
- Stormwater runoff from stockpiles must drain to the *Sediment Fence* or other suitable sediment trap.

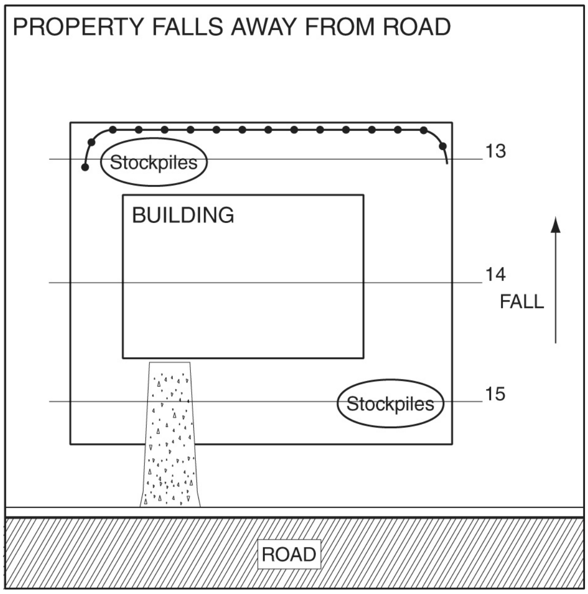


Figure H10 – Example site plan

- If property fencing already exists, then the *Sediment Fence* (suitably anchored) may be fixed to this fence for support.
- Extending the *Sediment Fence* along the front of the property can help to control traffic movement onto the site.
- Intermediate returns are not required on a *Sediment Fence* if it is installed along level ground.
- The entry/exit pad may or may not require a raised flow diversion bund to prevent sediment-laden water flowing off the rock pad onto the road.
- *Catch Drains* or *Flow Diversion Banks* placed along the up-slope edges of the property are generally required only if there is more than 1500 m^2 of catchment area up-slope of the building and the monthly rainfall is expected to exceed 45 mm.

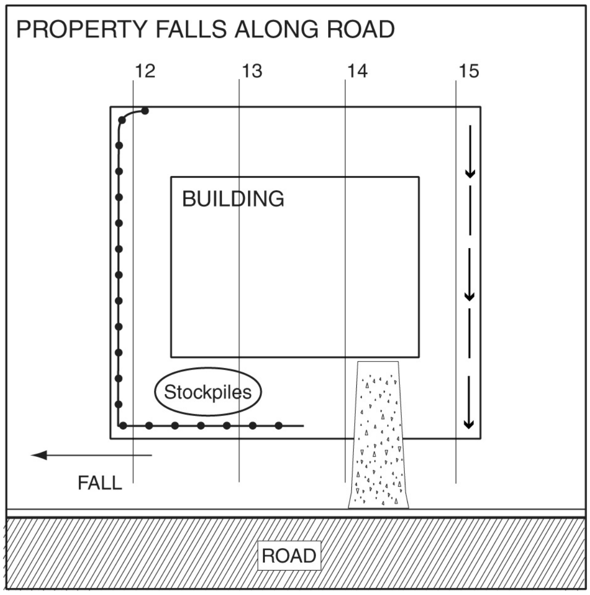


Figure H11 – Example site plan

- Initially a *Sediment Fence* should be located along the full length of the lower property boundaries. Sections of this *Sediment Fence* may be removed to allow foundations and building works to be completed, but it must remain in place and in proper working order for as long a practical.
- *Catch Drains* or *Flow Diversion Banks* placed along the up-slope edges of the property are generally required only if there is more than 1500 m^2 of catchment area up-slope of the building and the monthly rainfall is expected to exceed 45 mm.
- A flow diversion bund may or may not be required on the entry/exit pad of building sites depending on the expected quantity of sediment and surface runoff discharging down the rock pad.

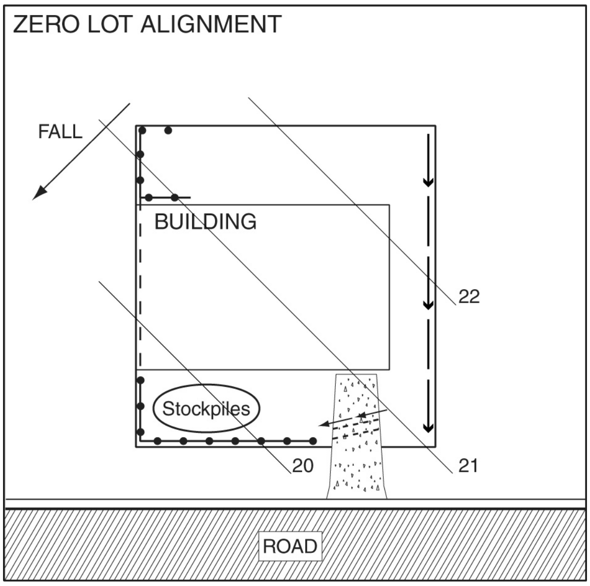


Figure H12 – Example site plan

- *Catch Drains* or *Flow Diversion Banks* placed along the up-slope edges of the property are generally required only if there is more than 1500 m^2 of catchment area up-slope of the building and the monthly rainfall is expected to exceed 45 mm.
- *Catch Drains* located along the side of the property are only required if it is necessary to either permanently direct stormwater away from adjacent properties, or to temporarily direct sediment-laden water to the *Sediment Fences*.
- If the *Catch Drains* carry only "clean" stormwater runoff, then they should be directed **around** the *Sediment Fence* as shown on the right-hand-side of the diagram.
- A flow diversion bund may or may not be required on the entry/exit pad of building sites depending on the expected quantity of sediment and surface runoff discharging down the rock pad.

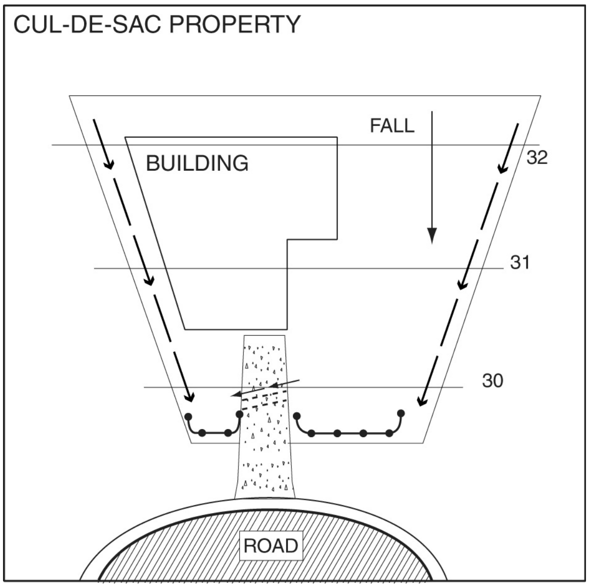


Figure H13 – Example site plan

- In most cases drainage and sediment controls on narrow lots should be as per larger building sites.
- The *Sediment Fence* may need to be located across the full width of the lower property boundary. In such cases, the fence may be lowered during working works to allow access, but must be raised at the end of each working day and while rain is occurring.
- A flow diversion bund may or may not be required on the entry/exit pad of building sites depending on the expected quantity of sediment and surface runoff discharging down the rock pad.

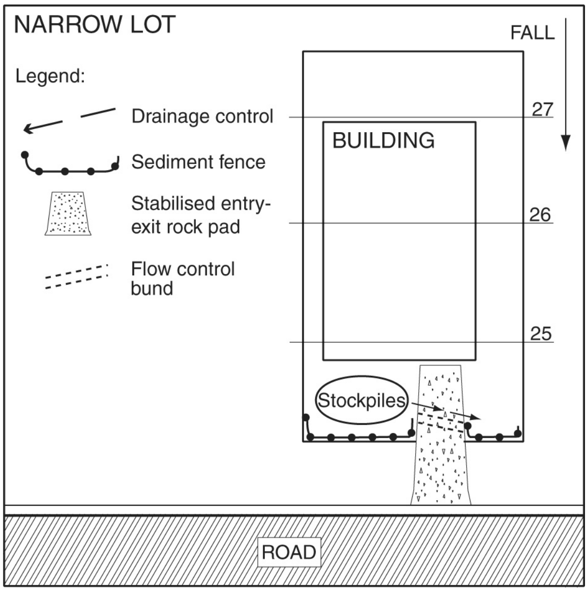


Figure H14 – Example site plan

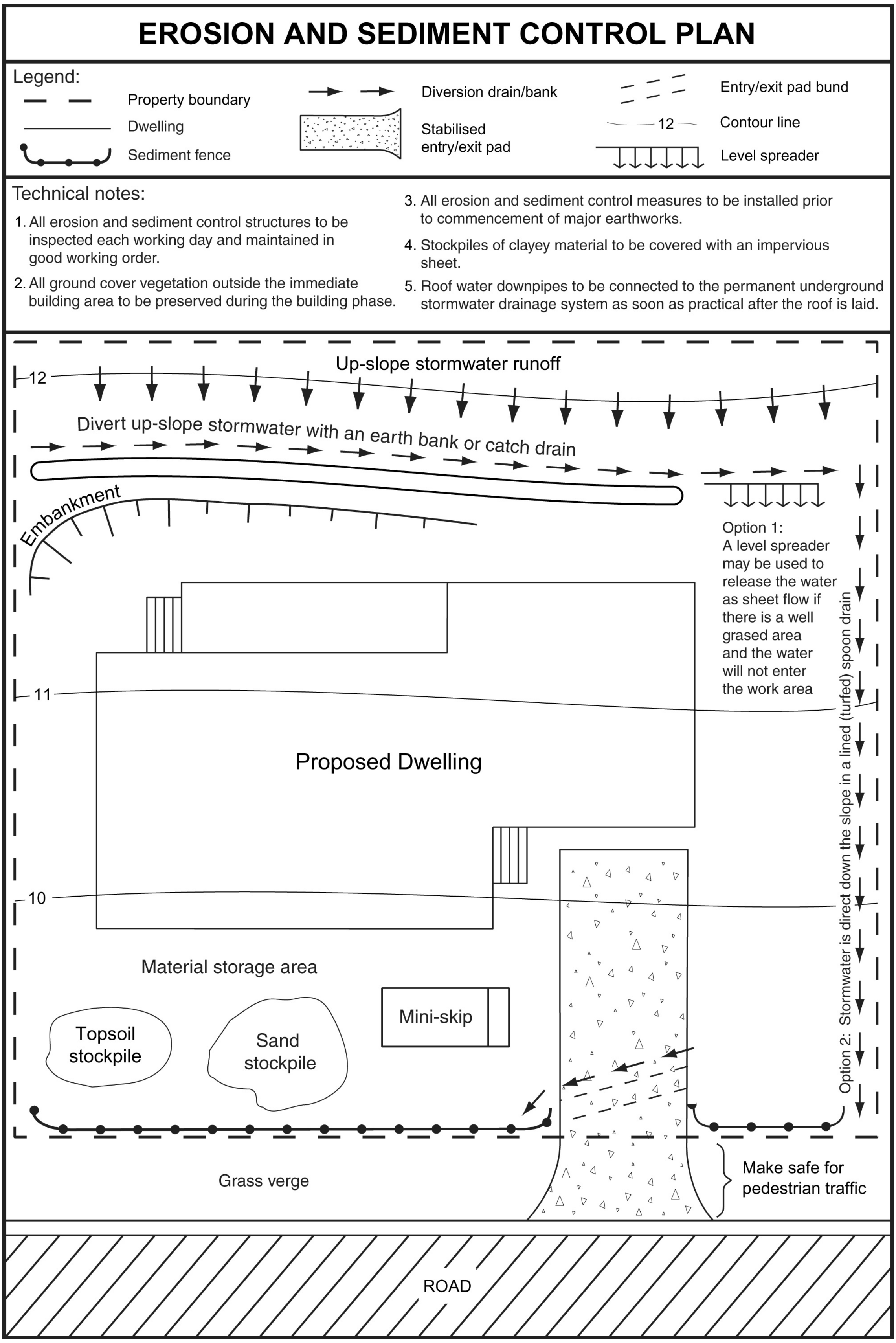


Figure H15 – Example Erosion and Sediment Control Plan

H6 Model Code of Practice for building sites

This model Code of Practice has been provided as an example of a local government building code for the management of erosion and sediment control on detached-dwelling building sites.

Compliance with a given Performance Criterion can only be achieved by:

(i) complying with the all items listed as the Acceptable Solution; or

(ii) formulating an alternative solution which complies with the Performance Criterion, or is shown to be at least equivalent to the acceptable solutions; or

(iii) a combination of (i) and (ii).

The Explanatory Notes (Section H7) form part of this model Code of Practice. The Explanatory Notes provide essential information that is otherwise not contained within the Code.

DRAINAGE CONTROL			
Performance Criteria		**Acceptable Solution**	
P1	Up-slope stormwater runoff is managed to minimise soil erosion and site wetness.	**A1**	(a) If the area of land up-slope of the soil disturbance exceeds 1500 m^2, then all reasonable and practicable measures are taken to divert this stormwater around the soil disturbance in a manner that does not increase soil erosion or result in the contamination of the diverted water. (b) Wherever reasonable and practicable, sandbags, *Catch Drains*, *Flow Diversion Banks* or other appropriate drainage systems are used to divert stormwater around excavations and service trenches. (c) Wherever reasonable and practicable, flow diversion systems are used to direct up-slope stormwater away from unprotected earth batters steeper than 4:1 (H:V).
P2	Stormwater runoff does not cause unacceptable levels of soil erosion.	**A2**	(a) Appropriate measures are used to control soil erosion within all temporary and permanent drainage systems (e.g. through the use of channel linings, turfing, or the placement of velocity control *Check Dams*). (b) All stormwater discharges onto a stable surface.
P3	Stormwater runoff does not cause a nuisance or damage to adjoining properties.	**A3**	(a) Stormwater is discharged in a non-erosive manner at a legal point of discharge. (b) Temporary drainage systems immediately up-slope of existing residential properties are designed to a standard commensurate with the risk of nuisance flooding and/or sediment deposition.
P4	Roof water from within the site does not unreasonably increase soil wetness within the work area.	**A4**	(a) A temporary or permanent roof water drainage system is installed before the roof covering is laid. (b) Roof water is discharged through a temporary or permanent roof drainage system to a location that minimises soil erosion and site wetness.

EROSION CONTROL			
Performance Criteria		**Acceptable Solution**	
P5	Site activities are carried out in a manner that minimises the duration that disturbed soils are exposed to the erosive forces of wind, rain and flowing water.	**A5**	(a) Soil disturbance is not carried out until the principal on-site activities are ready to commence. (b) All reasonable and practicable measures are taken to minimise the removal of, or disturbance to, vegetation and ground covers (organic or inorganic) on the site prior to and during land-disturbing activities. (c) All reasonable efforts are taken to coordinate: (i) the activities of subcontractors to minimise the duration of soil disturbance; and (ii) common trenching of utilities.
P6	Soil erosion resulting from rainfall is minimised.	**A6**	(a) Existing ground covers (grass, mulch, and so on) are protected from damage and retained as long as practicable. (b) All reasonable and practicable measures are taken to cover, stabilise or otherwise protect non-vegetated soil surfaces from the erosive effects of rainfall as soon as reasonable and practicable after works on these surfaces have been completed. (c) Service trenches are: (i) backfilled, compacted and capped with a layer of topsoil to a level at least 75 mm above the adjoining ground level; or (ii) backfilled, compacted and rehabilitated in a manner that best prevents undesirable water flow and soil erosion along the trench.
P7	Soil erosion resulting from strong winds is minimised.	**A7**	Stockpiles of erodible material are covered during periods of strong wind or when strong winds are expected.
P8	Stormwater is not contaminated by unacceptable levels of sediment resulting from material stockpiles.	**A8**	(a) Stockpiles of erodible material are not located within drainage depressions. Otherwise up-slope stormwater runoff is diverted around these stockpiles in a non-erosive manner. (b) Stockpiles of erodible material are covered with a synthetic cover, mulch, or temporary vegetation if not fully used within four (4) weeks. (c) Short-term stockpiles of erodible material located outside of the sediment control zone are covered if it is raining; or rain is imminent; or at the end of the working day.
P9	Exposed soil surfaces are rehabilitated as soon as practicable to prevent or minimise soil erosion.	**A9**	All reasonable and practicable steps are taken to: (i) incorporate all necessary site rehabilitation measures into the building contract such that these works will be completed before the end of the contracted works; and/or (ii) coordinate, facilitate and expedite the prompt rehabilitation of finished earthworks with the land owner and/or external contractors.

SEDIMENT CONTROL			
Performance Criteria		**Acceptable Solution**	
P10	Adequate precautions are taken to minimise sediment leaving the work area due to site traffic.	**A10**	(a) Vehicle access to the site is limited to stabilised entry/exit points. (b) The number of entry/exit points for the site is minimised. (c) If vehicular access into, or out of, a site is likely to track sediment onto an external sealed roadway, then a stabilised, sediment control entry/exit system (e.g. *Rock Pad, Vibration Grid*) is placed adjacent the external roadway.
P11	Site activities do not allow unacceptable levels of sediment to leave the work area.	**A11**	(a) Soil disturbances are not conducted until the associated Erosion and Sediment Control Plan has been approved. (b) No clearing or soil disturbance is undertaken unless preceded or accompanied by installation of adequate drainage and sediment control measures. (c) A suitable sediment barrier is placed down-slope of any on-site soil disturbance. (d) An appropriate sediment barrier is placed around any on-site stormwater inlet that would otherwise be subject to sediment-laden inflow. (e) Sufficient space is provided for the on-site storage of all erodible materials up-slope of a suitable sediment barrier. (f) Appropriate additional or alternative ESC measures are undertaken if it is determined that unacceptable off-site sedimentation is occurring. (g) Material removed from sediment control devices is disposed of in a manner that does not cause ongoing soil erosion or environmental harm.
P12	Sediment control measures are located within the property boundary.	**A12**	All sediment control measures are located within the property boundary, unless: (i) it is that portion of the entry/exit pad located between the property boundary and the sealed road; or (ii) the sediment control measure is required to collect sediment wash-off from building works located along the property boundary; and (iii) approval has been obtained from the relevant regulatory authority and the relevant landowner or asset manager.
P13	Extent and duration of damage and/or disturbance to vegetation contained within the road reserve must be minimised.	**A13**	Damage to vegetation contained within the road reserve that is the direct result of the building works, including that resulting from the parking of vehicles or equipment, or the storage of materials, must be: (i) minimised in both extent and duration, to that required to carry out necessary building works; and (ii) stabilised, repaired, or revegetated as soon as reasonable and practicable.

SITE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P14	Off-site material spills and accumulated sediment deposits are managed in a way that minimises environmental harm, safety issues, and damage to public and private property.	**A14**	(a) Sediment and other material that has originated from the work area, or as a result of the transportation of materials to or from the work area, that collects on sealed roads or within gutters or drains outside the immediate work area, is removed: (i) immediately if rain is occurring or imminent; or (ii) immediately if considered a safety hazard; or (iii) if items (i) or (ii) do not apply, before completion of the day's work. (b) Sediment, including clay, silt, sand, gravel, soil, mud, cement and ceramic waste, deposited off the site as a direct result of an on-site activity, is collected and the area appropriately cleaned in accordance with (a) above, and in a manner that gives appropriate consideration to the safety and environmental risks associated with the deposited material. (c) Washing/flushing of sealed roadways only occurs in circumstances where sweeping has failed to remove sufficient deposited material and the remaining material represents a safety risk. In such circumstances, all reasonable and practicable sediment control measures must be used to prevent, or at least minimise, the release of sediment into receiving waters. Any material collected is disposed of in a lawful manner that does not cause ongoing soil erosion or environmental harm.
P15	All reasonable and practicable measures are taken to prevent concrete waste from entering gutters, drains and waterways.	**A15**	(a) Solid and liquid waste from concrete trucks and equipment is fully contained on the site. (b) Cement residue from work activities is: (i) washed onto a pervious surface (e.g. a grassed or open soil area, or excavated trench); or (ii) filtered through a fine-grained, porous embankment lined with an appropriate filter cloth; or (iii) collected and disposed of in a manner that does not cause ongoing environmental harm.
P16	All reasonable and practicable measures must be taken to prevent contaminated water resulting from cutting and cleaning activities entering gutters, drains and waterways.	**A16**	(a) Washing of tools and painting equipment is carried out within the property and over a porous grassed surface or open soil wherever reasonable and practicable. (b) The cutting of concrete, or other fine-grained or sediment-producing material, is carried out in a manner that: (i) fully contains any contaminated water for later treatment or disposal; or (ii) appropriately filters any resulting contaminated water through soil or heavy-duty filter cloth prior to its release from the work area.

P17	Drainage, erosion, and sediment control measures are maintained in proper working order at all times.	**A17**	(a) All temporary ESC measures are maintained in proper working order for: (i) the duration of the soil disturbance; or (ii) the duration of occupation of the site. (b) All ESC measures are inspected after rainfall to assess maintenance requirements and their effectiveness.
P18	Operational safety issues are given due consideration.	**A18**	ESC measures are installed and/or operated in a manner that does not cause a safety risk to the public or site personnel.

PLAN PREPARATION			
Performance Criteria		**Acceptable Solution**	
P19	For high-risk sites, an Erosion and Sediment Control Plan (ESCP) is prepared prior to site disturbance that provides sufficient information on proposed measures to control stormwater drainage, soil erosion, and sediment runoff, in sufficient detail and clarity, to achieve the required environmental protection, soil management, and timely installation of proposed measures.	**A19**	An ESCP is prepared including plan(s) no larger than 1:1000 that can be readily understood and applied on-site. The ESCP contains the following information where applicable: (a) North point and plan scale. (b) Site and easement boundaries. (c) Proposed building works and limits of disturbance. (d) Site access points. (e) Location of stockpiles. (f) Retained vegetation including protected trees. (g) Existing and final site contours. (h) Location of all drainage, erosion and sediment control measures. (i) Site revegetation requirements (if part of building contract). (j) Technical notes on ESC measures, installation sequence and maintenance requirements. (k) Any other information about the ESCP or the site that is considered necessary in order for the satisfactory application of the Plan.
P20	The ESCP is appropriate for the site conditions.	**A20**	(a) The standard of the control measures are commensurate with the degree of environmental risk associated with the proposed works, and the type, cost, and scope of the proposed works. (b) The level of detail supplied in the ESCP is commensurate with the complexity of the proposal.

H7 Explanatory notes for Model Code of Practice

Performance Criterion P1

One of the best ways of controlling sediment runoff is to prevent, or at least minimise, soil erosion in the first place. One of the best ways of minimising soil erosion is to appropriately control the flow of stormwater across a building site.

The intent of this Performance Criterion is to minimise the risk of stormwater runoff (either originating from the site or from up-slope properties) causing the following problems:

(i) soil erosion caused by "sheet" or "concentrated" stormwater runoff;
(ii) soil erosion caused by stormwater spilling down unstable earth batters;
(iii) increased site wetness (i.e. the generation of saturated soil and/or mud);
(iv) excessive quantities of stormwater runoff either overloading, or causing structural damage to, down-slope sediment barriers such as a *Sediment Fence*.

Acceptable Solution A1(a)

The diversion of stormwater runoff around a soil disturbance is always beneficial, unless of course, rainfall is unlikely to occur during the building works.

For the purpose of this Code it has been assessed that a catchment area of 1500 m^2 is likely to produce sufficient quantities of stormwater runoff to warrant the use of a flow diversion system. Local authorities may vary this catchment area based on local hydrological conditions.

Some local authorities may consider that flow diversion is usually only justified during periods of actual rainfall, or during those months when the average monthly rainfall is medium or higher (i.e. greater than 45 mm). In such a case the Solution may be stated as:

If the area of land up-slope of the soil disturbance exceeds 1500 m^2, then during those months when the rainfall is expected to exceed 45 mm, all reasonable and practicable measures are taken to divert this stormwater around the soil disturbance in a manner that does not increase soil erosion or result in the contamination of the diverted water.

Acceptable Solution A1(b)

Minimising the quantity of water entering excavations and trenches will reduce site wetness and the quantity of sediment-laden water that needs to be pumped/drained from these trenches to allow works to continue.

Acceptable Solution A1(c)

Unprotected earth batters can be highly susceptible to soil erosion, including "rilling", if exposed to excessive stormwater flows. Earth batters that expose dispersive soil can also be susceptible to gully erosion and/or structural failure.

Earth batters may be protected with the use of: vegetation, mulch (small batters), *Erosion Control Blankets*, rock or structural retaining walls. Earth batters that expose dispersive soil should always be protected with a layer (minimum 100 mm) of non-dispersive soil before placement of the final batter stabilisation.

Performance Criterion P2

Unacceptable levels of soil erosion include, but are not restricted to, the following examples:

(i) soil erosion caused by "sheet" flow that results in the loss of the equivalent of more than 10mm of soil from an area greater than 1m^2;
(ii) soil erosion that results in clearly visible "rilling" or channelling within the soil, or rill erosion to a depth greater than 100 mm;
(iii) the displacement of more than 10% of the erosion-control mulch placed over previously disturbed soil.

Acceptable Solution A2(a)
Stormwater runoff across the property must be managed in a non-erosive manner. This will require one or more of the following:

(i) stormwater runoff is diverted around disturbed soil;
(ii) flow velocities are controlled to avoid soil erosion;
(iii) drainage surfaces are lined with a material (i.e. turf, erosion control mats, filter cloth, or sediment fence fabric) that prevents erosion of the underlying soil;
(iv) water is transported within suitably sized drainage pipes.

In some cases, flow velocities in open channels can be controlled by installing a series of small *Check Dams* (Figure H16). These *Check Dams* are usually constructed from sand or gravel-filled bags. In deep channels (>500 mm deep), *Rock Check Dams* can be used. It is important to ensure these *Check Dams* do not cause flow to be diverted from the channel.

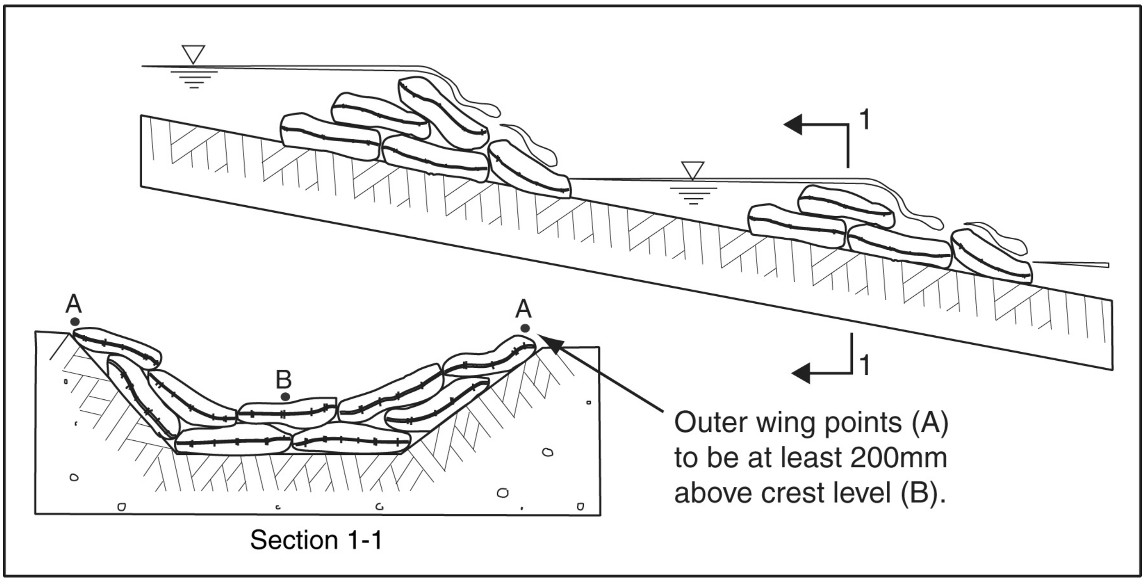


Figure H16 – Sandbag *Check Dams*

Acceptable Solution A2(b)
Diverted stormwater must not be allowed to cause unacceptable soil erosion upon its release from a drainage channel, *Chute* or stormwater pipe. In these circumstances, "unacceptable soil erosion" would mean any obvious form of soil erosion.

Performance Criterion P3
Diverted water must not be directed onto an adjacent property or be allowed to cause a nuisance within an adjoining, or any other downstream property. Some local authorities may accept water being temporarily diverted onto an adjoining property if that property is owned by, and in the control of, the same landowner or builder of the property from where the water was diverted.

Acceptable Solution A3(a)
If the water already flows into the adjoining property and this is considered to be its natural direction of flow, then before it reaches the property boundary, any diverted water must be returned to its original flow conditions in terms of velocity, quantity and direction.

If the adjoining property is owned and controlled by the same builder/owner, then a proposal to divert water into the adjoining property must be addressed in consultation with the appropriate authority. Stormwater must only discharge at a legal point of discharge.

Acceptable Solution A3(b)
The size and stability of a flow diversion system must take appropriate consideration of the expected flow rate, the risk of nuisance flooding to the downstream property, and the likely nuisance that sediment deposition would have on the downstream property.

The design storm standard would likely be between the 1 in 1 year to 1 in 10 year ARI design storm in accordance with the requirements of the regulatory authority. Where appropriate, reference may be made to the recommendation presented in Table 4.3.1, Chapter 4 – *Design standards and technique selection*.

Performance Criterion P4

Stormwater runoff from roofs and other impervious surfaces can unnecessarily disturb the work site and increase the potential for the site to cause environmental harm. Failing to adequately manage roof water can cause the following problems:

(i) decrease the efficiency of on-site sediment control devices by increasing the volume of water required to be treated by these devices;

(ii) increase the likelihood that sediment control devices will fail during periods of high rainfall;

(iii) increase soil erosion, especially near the outlets of downpipes;

(iv) increase the generation of mud through increased site wetness, thus increasing the transportation of clay-sized particles from the site;

(v) increase building delays and decrease site safety through increased frequency and duration of soil saturation within the work area;

(vi) increase soil erosion within or along service trenches.

Acceptable Solution A4(a)

Due to the relative size of the roof to the average urban property, the immediate connection of roof water downpipes to the permanent, underground, stormwater drainage system is arguably the most financially beneficial soil erosion and sediment control measure on building sites.

In some regions of Australia there may be no requirements for the construction of a sub-surface, roof water drainage system. In such cases, all reasonable efforts should be taken to install a temporary above ground drainage pipe that will direct roof water away from disturbed soil and the work area, at least during those months that have an average monthly rainfall greater 45 mm.

If the permanent drainage system incorporates sub-surface drainage pipes from the building to the road reserve, or other legal point of discharge, then this drainage system should be installed prior to the roofing system being laid.

Acceptable Solution A4(b)

During those months when the average monthly rainfall exceeds 45 mm, the roof water drainage system should be connected to either a surface or sub-surface, erosion-resistant drainage system (i.e. pipe) immediately after the roof and guttering is laid. This connection may either be through the use of temporary pipes (Figure H17) or permanent downpipes.

The use of temporary downpipe connections allows for the removal of these pipes during working hours to minimise disruption to building activities. However, these temporary downpipes must be reconnected if rain is occurring, or at the end of the day's work if rain is imminent or likely to occur after work hours.

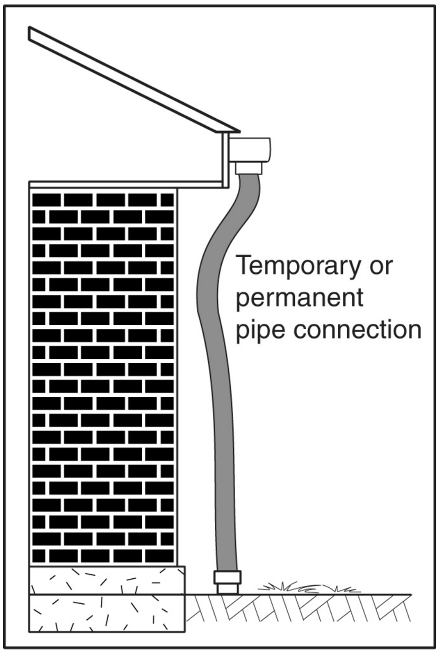


Figure H17 – Temporary downpipe

Performance Criterion P5

It is important to recognise that *Erosion Control* and *Sediment Control* are two very different activities. Erosion control measures aim to prevent soil erosion, whereas sediment control measures aim to trap sediment released by some up-slope erosion process.

There are virtually no sediment control measures that can trap all forms of sediment during all storm events. Specifically, there are very few sediment control measures that successfully trap clay-sized particles (grain size <0.002 mm).

Due to the inadequacy of sediment control measures to prevent the discharge of clay-sized particles from a building site, it is important to minimise the initial erosion of clayey soils. One of the most effective forms of erosion control is the principle of *minimising soil disturbance*.

The most important principle of *minimising soil disturbance* is to minimise the **duration** that soils are exposed to the erosive forces of wind, rain and flowing water.

Acceptable Solution A5(a)

All reasonable and practicable measures must be taken to minimise the time between the initial disturbance of soil on the site, and the commencement of building works.

Acceptable Solution A5(b)

Even if the entire site will eventually be disturbed at some stage, all reasonable efforts should be taken to minimise disturbance to any ground cover whether it is grass, mulch, leaf litter, or gravel, and to delay any required disturbance as long as practicable.

Acceptable Solution A5(c)

Soil disturbance resulting from the excavation of service trenches can result in significant sediment runoff. Minimising the number of service trenches and the duration these trenches are exposed can help reduce soil erosion and sediment runoff.

Performance Criterion P6

Almost any form of rainfall-induced soil erosion will release fine-grained, clayey particles that can readily pass through most sediment traps/barriers. Therefore, all reasonable and practicable measures must be taken to minimise unnecessary soil erosion.

Unnecessary soil erosion means erosion resulting from:

- unnecessary site disturbance; or
- unnecessary delays in site stabilisation or rehabilitation; or
- unnecessary exposure of dispersive soils; or
- concentrated stormwater flowing over unprotected soils.

Acceptable Solution A6(a)

The disturbance to any forms of existing ground cover (including, grasses, gravel, and mulch) should be minimised in order to minimise the exposure of soils to rainfall. In addition, any necessary disturbance to these existing ground covers should be delayed as long as practicable.

Acceptable Solution A6(b)

Appropriate erosion protection may be influenced by the following factors:

- slope of land;
- length of slope;
- expected weather conditions;
- erodible nature of the exposed soil;
- depth of soil to bedrock;
- type and availability of local vegetation;
- area of exposed soil;
- cost effectiveness and financial limitations.

On building sites located upstream of critical waterway habitats, all disturbed areas outside the footprint of the base slab (if used, otherwise all disturbed areas) should be mulched (minimum 50 mm) or otherwise stabilised against erosion immediately following the completion of bulk earthworks.

An example of possible erosion protection on slopes steeper than 10:1 (H:V) for various expected rainfall conditions is provided in Table H4.

Table H4 – Possible erosion protection measures

Expected rainfall conditions [1]	Possible erosion control measures
Extreme rainfall (e.g. months with an average rainfall greater than 225 mm)	• Well-anchored (e.g. pegged) turf. • Erosion control blankets placed over seeded topsoil and/or planted with trees and shrubs on small areas of land. • High strength (e.g. reinforced) *Erosion Control Blankets* placed over seeded topsoil and/or planted with trees and/or shrubs on large areas.
High rainfall (e.g. months with an average rainfall of 100 to 225 mm)	• Appropriately anchored (e.g. pegged) turf. • *Erosion Control Blankets* placed over seeded topsoil and/or planted with trees and/or shrubs.
Low to moderate rainfall (e.g. months with an average rainfall less than 100 mm)	• Heavy mulching planted with trees and/or shrubs. • Light mulching placed over grass-seeded topsoil. • Any option listed for the above categories.

Note [1]: Rainfall conditions do not necessarily correspond to definitions provided in Appendix N – *Glossary of terms*, instead, rainfall conditions are linked to the erosion risk rating presented in Section 4.4, Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A6(c)(i)
If a backfilled trench is not compacted to a firm condition, then soil settlement can occur over time or after significant rainfall. This lack of compaction can lead to the formation of a drainage depression along the trench resulting in the concentration of stormwater runoff and possible soil erosion.

Backfilling the trench to a level at least 75 mm above the adjoining ground level will usually address any future soil settlement (even if appropriate initial compaction is achieved). Variations of this requirement exist in different regions, thus always seek advice from the regulatory authority.

Acceptable Solution A6(c)(ii)
An alternative to A6(c)(i) would be to rehabilitate service trenches in a manner that has proven in the past to prevent unacceptable soil erosion or sediment runoff.

Performance Criterion P7
Wind erosion is typically a problem in coastal regions that have sandy soils. Strong winds are winds of sufficient velocity to erode the exposed soil or stockpiled material.

Acceptable Solution A7
Stockpiles most likely to be affected by strong winds are stockpiles of sandy soils located in coastal regions. Areas likely to be affected by strong winds may be identified by the regulatory authority.

Erosion from these stockpiles can be reduced by covering the stockpile with plastic sheeting, *Erosion Control Blankets*, mulch (light or heavy mulching), or temporary vegetation.

Performance Criterion P8
Stockpiles of erodible material such as soil, sand and mulch can be a major source of pollution. Proposed stockpile management techniques must address the following factors:

- type of material;
- expected duration of storage prior to its use;
- alternative storage arrangements and/or locations;
- the movement of concentrated stormwater runoff through the building site;
- practicability of covering the stockpile (to protect material from raindrop impact);
- likelihood and intensity of rainfall;
- expected environmental harm likely to be caused by the displacement of material.

Acceptable Solution A8(a)
Stockpiles of erodible material should not be placed in a location where up-slope stormwater runoff will likely cause the material to be washed away.

The sediment control zone is defined as that portion of a building site that drains to a sediment control device, excluding the entry/exit pad.

Acceptable Solution A8(b)
Protective cover may include plastic sheeting, filter cloth or *Erosion Control Blankets*. Organic covers such as mulch may be appropriate during periods of low wind. Temporary vegetation is only appropriate for very long-term stockpiles. Clayey material should ideally be covered with an impervious cover to reduce rainwater infiltration into the material.

Synthetic stockpile covers, such as plastic sheeting, may not be practical if regular loss/theft of these covers from the building site places an unreasonable financial burden on the builder.

Acceptable Solution A8(c)
In some circumstances it is not practical to temporarily store some materials in an area protected by a sediment barrier. A short-term stockpile means a stockpile that is located on-site or off-site for less than 24 hours.

Building materials that could reasonably be expected to be removed from the property or storage site by wind, rainfall, or other water may be temporarily stored on hard surfaces in the following circumstances:

(i) where it is necessary to place erodible material on a hard surface (e.g. a road or driveway) to undertake work and no other reasonable options are available (e.g. placing the material on a nearby grassed area or in a mini-skip); and/or

(ii) the material is stockpiled for less than 24 hours.

In such cases, the material must be:

- removed immediately if rainfall or strong winds are imminent or occurring; otherwise
- removed by the end of the day's work even if rainfall or strong winds are neither imminent nor occurring.

Such materials must not be stored on a road reserve without obtaining permission from the road authority, usually the regulatory authority. Material placed on the road reserve must not block traffic, or cause safety or environmental problems.

If erodible materials are to be temporarily stored within a road reserve, then a suitable waterproof cover must be available on the site for use in the event of rain. Upon removal of the stockpiled material from the road reserve, the area must be appropriately cleaned (swept), stabilised, and rehabilitated.

Performance Criterion P9
Rehabilitation, in particular revegetation, of a site is one of the most effective ways of minimising long-term soil erosion and environmental harm. Vegetation can significantly reduce raindrop impact erosion, thus reducing runoff turbidity. Note, however, some forms of revegetation (e.g.

grass seeding) do not provide effective erosion control during the plant establishment phase unless incorporated with appropriate *Mulching* or *Erosion Control Blankets*. To be effective, at least 70% of the soil surface must be protected from raindrop impact.

Turfing is one of the most effective means of providing instant erosion control to a finished soil surface.

Acceptable Solution A9
The appropriate rehabilitation of a site depends on the many factors, including:

- local soil and weather conditions;
- condition and type of vegetation usually expected within the local area;
- expected long-term use of the land;
- financial considerations.

During periods of actual or expected heavy rainfall (i.e. expected monthly rainfall is greater than 100 mm), it can be highly beneficial for proposed grassed areas to be turfed rather than grass seeded. Future garden beds can be mulched (e.g. heavy mulching, i.e. greater than 50 mm depth).

During periods of extreme rainfall (i.e. actual or expected monthly rainfall is greater than 225 mm), *Erosion Control Blankets* may need to be used on steep sites and in areas of concentrated stormwater runoff.

The higher the expected rainfall intensity, the greater the need to expedite the rehabilitation processes.

Straw mulch (light mulching) can be spread over grass-seeded areas to control soil erosion while the grass is being established. This mulch can also benefit rehabilitation by reducing watering requirements and increasing seed germination.

In those location where turfing is an appropriate means of site rehabilitation, it should be actively promoted, especially during periods of high to extreme rainfall (i.e. expected monthly rainfall is greater than 100 mm).

Performance Criterion P10
Sediment deposited on public roads can create a traffic safety hazard as well as being washed into downstream water bodies. Thus all reasonable and practicable measures need to be taken to minimise the quantity of sediment leaving the site at entry/exit points.

It is noted that a stabilised entry/exit rock pad would have questionable value if access to the building site is via an unsealed (i.e. erodible) public road. Therefore, this Performance Criterion may not need to be satisfied if site access is via an unsealed public road—refer to the relevant regulatory authority for advice.

Acceptable Solution A10(a)
All reasonable efforts should be taken to promote site access only via a stabilised access point that satisfies A10(c). In most cases, the placement of a *Sediment Fence* along the front of the property will promote site access via the stabilised entry/exit point.

Where practicable, heavy machinery such as bobcats, backhoes, and concrete trucks should always access the site via an entry/exit pad.

Acceptable Solution A10(b)
Minimising the number of entry/exit points will reduce the potential for environmental harm.

Acceptable Solution A10(c)
The type of stabilised entry/exit system depends on the site's soil properties and the drainage conditions of the site (i.e. whether stormwater runoff from the entry/exit pad flows into or away from the property).

Stabilised rock entry/exit pads for small, single-dwelling building sites typically consist of a 150 to 200 mm deep, 2 m wide pad containing 40 mm (minimum) to 75 mm crushed rock (Figure H18). Where practicable, the stabilised rock pad should extend from the road to the building, but for a distance of at least 10 m. Where necessary, 20 mm aggregate should be placed over the crushed rock between the property boundary and the sealed road to make the rock pad safe for pedestrian traffic.

Stabilised crushed rock entry/exit pads can be used on both sandy and clay-based soils.

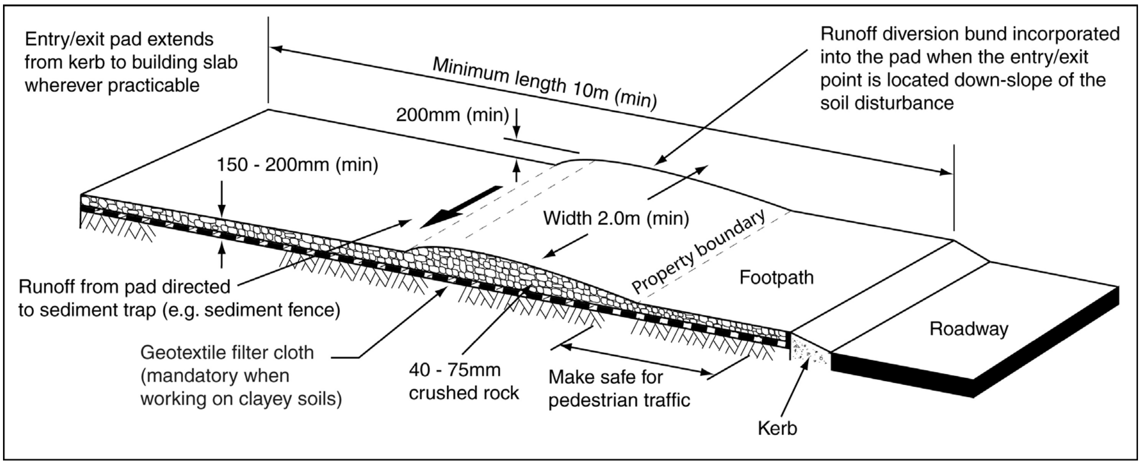


Figure H18 – Stabilised rock entry/exit pad for building sites (not construction sites)

On sites containing sandy soils, a prefabricated *Vibration Grid* (i.e. cattle grid) can be used to shake sand from vehicles. However, a gravel or aggregate pad must exist between the *Vibration Grid* and the road. The length of the *Vibration Grid* should be sufficient to remove loose sediment from vehicles. A minimum length of 3.5 m is recommended. A *Vibration Grid* must not be located within the road reserve.

The environmental benefits of a stabilised entry/exit pad can be greatly diminished if sediment trapped on the pad is allowed to wash from the site during storm events. This problem typically occurs on building sites that are above road level.

Placing a minimum 200 mm high flow diversion bund diagonally across the top of the entry/exit pad can deflect stormwater across the pad and into a suitable sediment trap. This sediment trap may consist of the main *Sediment Fence*, or a separate, *U-shaped Sediment Trap*.

Performance Criterion P11

There are two forms of sediment that can cause harm to the environment, fine sediment and coarse sediment. Fine, clay-sized particles may be controlled using good site drainage and erosion control techniques and by promptly rehabilitating all disturbances. Coarse sediment is usually controlled through the use of sediment control measures.

All reasonable and practicable measures must be taken to minimise the total volume of sediment leaving the work site.

Unacceptable levels of soil and sediment runoff means:

(i) Any quantity of soil or sediment that may cause harm to the environment taking into consideration the cumulative effects of other building and construction activities within the drainage catchment.

(ii) Any quantity of soil or sediment runoff from the site that results in the accumulation of more than 500 g of soil or sediment within any 1 m^2 area outside the property. This quantity of loose, coarse sediment represents approximately two, 70 mm diameter balls of dry sediment, within any 1 m^2.

Acceptable Solution A11(a)
Where an Erosion and Sediment Control Plan is required by a regulatory authority for the building works, then this plan must be approved by the regulatory authority prior to any site disturbance.

Acceptable Solution A11(b)
In most circumstances all necessary up-slope drainage controls and down-slope sediment controls should be installed prior to commencing any soil disturbance including land clearing. The exceptions are:

(i) land clearing and soil disturbance required to allow access to, and installation of, the various drainage and sediment control measures;

(ii) works conducted during an initial period when rainfall is highly unlikely and thus there is no measurable risk of contributing to environmental harm.

Sediment barriers may be removed or lowered to allow site access and building operations, but the barrier must be ready for immediate reinstallation in the case of rain, and the barrier must also be fully operational at the end of each day's work.

Acceptable Solution A11(c)
Sediment barriers are usually placed along the property boundary immediately down-slope of the soil disturbance. Where conditions allow, the barrier should be placed along a line of constant elevation to avoid the barrier concentrating or diverting stormwater runoff.

On most building sites, the most appropriate sediment barrier is a *Sediment Fence* formed from purpose-made fabric (Figure H19). Filter cloth or shade cloth must **not** be used.

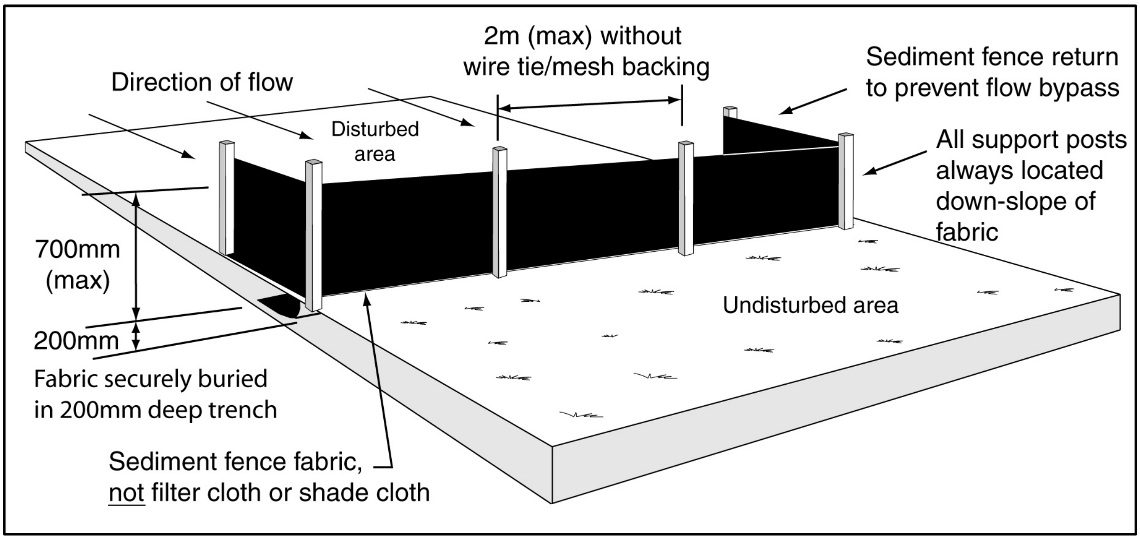


Figure H19 – Installation of a *Sediment Fence*

Sediment fence fabric should be manufactured from a woven UV-stabilised geotextile or non-woven geotextile reinforced with a UV-stabilised polypropylene mesh. The geotextile fabrics are to be either polyester or polypropylene manufactured to the requirements specified in Table H5.

Table H5 - *Sediment Fence* material property requirements

Property	Test Method	Units	Typical Value
Flow rate	AS 3706.9	L/s/m^2 (under 100 mm head)	145
Wide strip tensile strength	AS 3706.2	kN/m	17 both directions
Pore size (EOS) (O_{95})	AS 3706.7	µm	110
Mass per unit area	AS 3706.1	gsm	225

Stakes should consist of 1250 mm^2 (cross section) hardwood, or 1.5 kg/m (minimum) steel star pickets suitable for attaching fabric.

Acceptable Solution A11(d)
An appropriate sediment barrier should be installed around any on-site stormwater inlet to minimise the release of sediment from the property.

Appropriate sediment barriers include heavy-duty filter cloth or *Sediment Fence* fabric wrapped around the grate, or a vertical *Sediment Fence* constructed around the inlet.

Acceptable Solution A11(e)
Building works should not be approved unless it can be demonstrated that there is sufficient room within the property, and within the sediment control zone, to locate all necessary long-term stockpiles of erodible material.

Where necessary, stockpile areas should be clearly identified to prevent materials being delivered to the wrong location.

The sediment control zone is defined as that portion of a building site that drains to a sediment control device, excluding the entry/exit pad.

Acceptable Solution A11(f)
If the adopted erosion and sediment control measures fail to prevent unacceptable levels of off-site sedimentation, then additional measures will be required unless such measures would be considered unreasonable or impracticable.

Acceptable Solution A11(g)
Sediment removed from a sediment control barrier should either be integrated with on-site soils, or removed from the site. In either case, the sediment should not be placed in a position, or in a manner, that would likely result in the sediment being washed or blown from the site, or washed into an external gutter, drain, or water body.

Performance Criterion P12
Wherever reasonable and practicable, all ESC measures should be fully located within the property; however, it must be acknowledged that part of a stabilised entry/exit pad must extend outside the property boundary.

Acceptable Solution A12
No sediment control measure should be located outside the property boundary, unless:

(i) that control measure includes that portion of the entry/exit pad located between the property boundary and the sealed road; or

(ii) the sediment control measure is required to collect sediment wash-off from building works located along the property boundary (such as the construction of a front retaining wall); and

(iii) regulatory authority permission has been obtained for the location of the sediment control measure outside the property.

Performance Criterion P13
One of the best ways of controlling sediment runoff is to prevent, or at least minimise, soil erosion in the first place. One of the best ways of minimising soil erosion is to minimise the disturbance to existing ground covers, including the grassed pedestrian area (verge) located within the road reserve.

Acceptable Solution A13
The road reserve is considered a public asset and as such damage to this public asset, including any vegetation, should only occur if there are no other reasonable options available to carry out the necessary building works.

If vegetation damage does occur within the road reserve, and if this damage could result in soil erosion, then all reasonable and practicable measures should be taken to minimise the extent and duration of this erosion hazard, including prompt stabilisation, repair or revegetation of the area.

Performance Criterion P14
Material spills and sediment deposits located outside the sediment control zone have a higher risk of causing a safety hazard or being washed into a gutter, drain or water body. Such material spills and sediment deposits must be cleared from the area within a reasonable time frame and in an appropriate manner, based on the assessed safety and environmental risks.

Acceptable Solution A14
Some material spills located outside the property boundaries may be beyond the reasonable control of the builder or property owner; however, if these deposits are directly associated with the building activities (e.g. resulting from the delivery of materials), then all reasonable and practicable measures must be taken to minimise both the safety risk and potential environmental harm.

Reasonable and practicable measures may include:

(i) providing appropriate delivery instructions;
(ii) providing adequate and appropriate space for the delivery of materials;
(iii) providing a stabilised access pathway for the delivery of materials;
(iv) actively investigating alternative delivery methods or material suppliers if regular pollution problems occur;
(v) assisting in the prompt removal of sediment deposits and material spills.

To clean materials from hard surfaces, the bulk of the material should first be shovelled, then swept onto an area enclosed by a suitable sediment barrier (i.e. up-slope of a *Sediment Fence*). An acceptable procedure for cleaning the remainder of the material from the surface is detailed below in order of priority.

1. Use a vacuum unit (e.g. hired street sweeper), where the cost can be justified.
2. Manually sweep the material onto an adjacent grassed or open soil surface where sediment controls are in place (e.g. up-slope of a *Sediment Fence*).
3. If a safety hazard may result from the remaining material being left on the hard surface, then, and only then, hose the remaining material onto a grassed surface or into a temporary filter dam constructed in the gutter. After allowing the excess water to drain from the dam, the retained material must be collected and disposed of in a location where it would not be expected to wash off into a gutter, drain or water body.

The above recommendations are based on the principle that less environmental harm will be caused if small amounts of sediment are removed from a sealed road by stormwater runoff rather than by manually washing the road during dry weather.

Performance Criterion P15
Cement and concrete residue can increase water turbidity, alter water pH, and adversely affect the hydraulic capacity of drainage pipes. Typically, state authorities will have legislative requirements regarding the acceptable pH range for site discharges (e.g. 6.5 to 8.5).

Acceptable Solution A15(a)
Cement and concrete residue from concrete trucks or on-site mixers must not be allowed to enter drains or waterways. Excess concrete should be stockpiled on-site for later disposal.

Acceptable Solution A15(b)
Approval should not be given to a proposed concrete surfacing technique if the proponents fail to demonstrate how the proposed surfacing technique will be prepared without causing undue environmental harm.

Where appropriate, the options provided in Acceptable Solution A16 may be used to minimise the potential environmental harm caused by cement/concrete residue.

Any construction technique that would not cause environmental harm, or the release of cement, concrete or contaminated water into a stormwater pipe or water body, would satisfy this Performance Criterion.

Performance Criterion P16

Waste water generated by water-cooled cutting activities and the cleaning of equipment usually contains large quantities of fine-grained sediments that can readily pass through most sediment control devices. Therefore, a sediment control barrier cannot be relied upon to minimise the potential environmental harm caused by these building activities.

On some building sites it may not be practicable to prevent all forms of pollution generated by such activities from leaving the site; however, all reasonable and practicable measures must still be taken to minimise any potential harm.

Acceptable Solution A16(a)

The first priority should always be to conduct all cutting and cleaning activities within the property and specifically within the sediment control zone.

When porous grassed or open soil areas are available, then all mobile, pollution-generating activities should be conducted within these areas to minimise the release of pollutants from the site. If the soil becomes saturated, thus significantly limiting further infiltration of water, then the activity should be relocated, or an alternative pollution control technique should be used.

In some cases it may be beneficial to place filter cloth over the soil before commencing the cutting or cleaning activity.

Acceptable Solution A16(b)(i)

The waste water may be fully contained in an excavated pit and allowed to infiltrate the soil, or pumped from the pit to a mini-skip, or to a *Filter Bag* for treatment.

Acceptable Solution A16(b)(ii)

Some heavy clay soils allow little or no infiltration of water. In such cases, all reasonable and practicable steps should be taken to filter the polluted water through a temporary, porous bank formed from fine-grained material, such as fine sand. The bank must have sufficient width/depth to significantly reduce the turbidity of the polluted water.

The efficiency of the filter bank can be improved by placing heavy-duty filter cloth over the upstream face of the bank and/or placing filter cloth under the pollution-generating activity.

Performance Criterion P17

Proper working order means the control devices are operating in an *efficient manner* that is consistent with intended function of the device, and in a manner that prevents or minimises potential or actual environment harm.

Efficient manner means the control device is functioning in a manner that will:

(i) intercept the maximum quantity of polluted water (within the structural capabilities of the device); and

(ii) trap the maximum quantity of pollutants; and

(iii) contain trapped pollutants for sufficient time to allow for their appropriate removal.

Acceptable Solution A17(a)

Maintaining ESC measures in “proper working order” means taking all reasonable and practicable measures to sustain all ESC measures in such a condition that:

- will best achieve the site’s required environmental protection, including any specified water quality objectives for all discharged water (principle objective); and
- is in accordance with the specified operational standard for each ESC measure; and
- prevents or minimises safety risks.

A soil disturbance may be considered to exist up until a minimum 70% coverage (vegetative, organic or inorganic) is achieved over **all** soils disturbed (directly or indirectly) as a result of the building activities.

A minimum 70% coverage does **not** mean that a minimum of 70% of the site is protected from erosion. Rather it means that all areas of erodible soil on the site have at least 70% coverage of vegetation, mulch or other suitable material to prevent raindrop impact on the soil and erosion by flowing water. As such, 70% coverage is measured by looking vertically down on the soil, and applies to any and all disturbed areas of the building site.

Acceptable Solution A17(b)
All reasonable and practicable measures must be taken to minimise regular structural failures and to facilitate the immediate repair of necessary control measures. Measures may include:

(i) storing on-site, or within the immediate area, sufficient *Sediment Fence* fabric to facilitate necessary repairs;
(ii) modifying damaged control measures to reduce the potential for ongoing failure;
(iii) modify on-site drainage patterns to reduce the risk of ongoing damage to ESC measures;
(iv) install additional and/or alternative ESC measures to minimise the risk of ongoing failure.

Repairs should be sufficient to re-establish the required efficiency of the ESC measure.

Performance Criterion P18
The safety of the public and all site personnel is a high priority.

Acceptable Solution A18
Appropriate consideration should be given to potential safety risks associated with a proposed erosion and sediment control measure. Any ESC measure should not be installed if it represents an unacceptable safety risk. In such cases, suitable alternative ESC measures must be employed.

Performance Criterion P19
High-risk sites may be identified through the use of an appropriate Erosion Hazard Assessment of the site. Land disturbance on sites steeper than 20% may not always be classified as high-risk sites; however, due to the difficulties of working on such sites, it is recommended that they be included within this Performance Criterion. A regulatory authority may exempt a site from the need to submit an Erosion and Sediment Control Plan (ESCP).

It is noted that one or more plans may be required to adequately describe the proposed erosion and sediment control measures, or to describe the various building stages or drainage conditions that will exist on the work site during the building phase.

Building works assessed as low-risk sites are still required to take all reasonable and practicable measures to minimise environmental harm caused by on-site soil erosion and sediment runoff. On low-risk sites, an ESCP may still need to be prepared to convey to site personnel the proposed erosion and sediment control measures, but this plan does not need to be approved unless specifically requested by the regulatory authority.

Low-risk sites will still need to satisfy Performance Criteria P1 to P18.

Acceptable Solution A19
A plan scale of preferably 1:200, 1:250 or 1:500 is recommended, but not larger than 1:1000.

Identifying existing and final contours allows regulators to appreciate the extent of earthworks involved in the building proposal. If major earthworks are to be staged, and if these earthworks affect stormwater drainage patterns, then more than one ESCP may be required to adequately describe the proposed soil erosion and sediment control measures (i.e. one ESCP prepared for each stage of earthworks).

Identifying the proposed building works assists regulators to assess the minimum required limits of disturbance.

Identifying the limits of site clearing allows regulators to determine the extent and likely duration of soil exposure.

In rural areas, often the only sediment control measure required around a building site is the extensive grassed areas that surround the building site. If such areas are to be used as a sediment barrier, then the ESCP should indicate that these areas will remain largely undisturbed.

A stabilised site entry/exit point should form part of the site's sediment control measures, and therefore should be shown on the ESCP. If separate site entry and exit points are required, then this should also be indicated on the plan.

Stockpile locations need to be shown to demonstrate:

(i) adequate room exists for the proposed building activities to occur without causing unnecessary harm to the environment;
(ii) stockpiles will not be located within an overland flow path;
(iii) stockpiles will be located within a sediment control zone.

It is not sufficient to simply list which ESC control measures are proposed for use on a building site. The location of the proposed ESC measures must be shown on the ESCP.

Technical notes on ESC measures should be used to describe those ESC measures that are required in the event of unexpected circumstances, or to provide necessary information on the installation, operation, or maintenance of ESC measures.

The installation sequence is presented to demonstrate that the control measures will be in place at appropriate times relative to the proposed earthworks and building activities. A table may be used to indicate the installation and removal times relative to certain building activities, as demonstrated in Table H6 below.

Table H6 – Example construction sequence table

Item	Plan [1] Number	Installation	Removal
Construct entry/exit pad	1	Before site clearing.	After building works are completed, or sealed driveway is installed.
Install sediment fences SF-1 and SF-2	1	Before earthworks.	After mulching and 70% grass coverage is achieved.
Install catch drain CD-1	1	Before earthworks.	After mulching and 70% grass coverage is achieved.
Strip and stockpile topsoil	2	Immediately before earthworks.	Spread as soon as possible.
Revegetate backyard	1	ASAP, but before building works commence.	
Land shaping and earthworks	2	Immediately prior to commencing building.	
Install on-site waste receptacles	1	Following completion of earthworks.	Upon completion of building works.
Stockpile materials	1	As required.	Before removing sediment fence.
Commence building works	3	Immediately after earthworks.	
Install underground drainage	3	Before installing roof.	
Install temporary downpipes	3	Immediately after laying roof and guttering.	When ready to install permanent downpipes.
Spread topsoil	1	Upon completion of building works.	
Turf and mulch	1	Immediately after spreading topsoil.	

Note [1] Plan number is only required if there are several plans used in the building submission.

Performance Criterion P20

It is important for the ESCP to show control measures that are reasonable and practicable for the site condition, the assessed erosion risk, and the risk of causing or contributing to environmental harm.

Acceptable Solution A20

Small building sites generally require fewer ESC measures than the larger more complicated sites. Similarly, building sites with a low erosion risk generally require fewer ESC measures than high-risk sites.

Regulatory authorities should not unnecessarily burden builders with the development of extensive ESCPs if there is negligible assessed risk of causing or contributing to environmental harm.

Building Site

Erosion Hazard Assessment Form

Project Name: . . . .

Site Address: . . . . **Date:** . . . .

Controlling Factors	Points	Score
Item 1 – Average slope of the whole site prior to building works: [1]		
• Slope < 3%	0	
• 3% </= Slope < 5%	1	
• 5% </= Slope < 10%	2	
• 10% </= Slope < 15%	4	
• Slope >/= 15%	5	
Item 2 – Soil type (of soil to be disturbed): [2]		
• Sandy soil/gravel	0	
• Sandy loam	1	
• Clay loam	2	
• Clay soil	2	
Item 3 – Total extent of site disturbance: [3]		
• Soil disturbance < $10m^2$	0	
• Soil disturbance of 10–$100m^2$	1	
• Soil disturbance > $100m^2$	2	
Item 4 – Anticipated duration of soil disturbance: [4]		
• Duration < 2 weeks	0	
• 2 weeks </= Duration < 3 months	2	
• 3 months </= Duration < 6 months	4	
• Duration > 6 months	5	
Item 5 – Anticipated rainfall risk during soil disturbance: [5]		
• Low rainfall (average rainfall for any given month < 45mm)	0	
• Moderate rainfall (average rainfall for any given month: 46–100mm)	1	
• High rainfall (average rainfall for any given month: 101–225mm)	2	
• Very high rainfall (average rainfall for any given month: 226–1500mm)	3	
• Extreme rainfall (average rainfall for any given month > 1500mm)	4	
Item 6 – Runoff entering the site:		
• Score 1 point if stormwater runoff entering the site is not diverted around the soil disturbance.	1	
Total score [6]		

Erosion Hazard Assessment Form Notes

[1] Building sites steeper than 20% are generally considered high-risk sites independent of the total score.

[2] Where there is more than one type of soil within the proposed disturbance area, select the category with the highest point value.

[3] Total area of disturbance excludes the area occupied by the stabilised entry/exit pad provided the entry/exit pad is placed immediately upon initiation of site disturbance.

[4] The time from when the building site will first become vulnerable to erosion (i.e. initial soil disturbance) to the time the disturbed soil will be fully stabilised (e.g. grassing, mulched or covered with erosion control blankets).

[5] Based on average rainfall depths for various months of the year as supplied by the Bureau of Meteorology for the regulatory authority. Points scored shall be based on the anticipated worst month in which soil disturbance is expected to occur. Note that if there is no grass, vegetation, or mulch cover on more than 10% of the site's soil surface before building works are programmed to commence, then the time period shall start from the time this form is completed.

[6] Low-risk sites have a total score less than the "critical hazard value".

High-risk sites have a total score equal to, or greater than the "critical hazard value".

The recommended "critical hazard value" = 11 points. Local authorities may choose to adopt an alternative "critical hazard value" for any or all districts within their jurisdiction.

Daily Site Inspection

LOCATION . . . .

SITE SUPERVISOR . . . . **DATE** . . . .

SIGNATURE . . . .

Legend: OK Not OK N/A Not applicable

Item	Consideration	Assessment
1	All tradespeople working on the site have been informed of the erosion and sediment control requirements of the site.	. . . .
2	All required builder identification, safety notices, and pollution (e.g. litter and sediment control) management signs are visible.	. . . .
3	The work site and all erosion and sediment control measures do not represent a safety risk to tradespeople or the public.	. . . .
4	Public roadways are clear of sediment.	. . . .
5	Turfing on the footpath area is clear of sediment, sand and mud.	. . . .
6	Entry/exit pads are clear of excessive sediment deposition.	. . . .
7	Entry/exit pads have adequate available void spacing to trap sediment.	. . . .
8	The construction site is clear of litter and unconfined rubbish.	. . . .
9	Long-term (> 24 hours) soil/sand stockpiles are protected from wind, rain, and stormwater flow.	. . . .
10	At end of day, all short-term soil/sand stockpiles located outside the sediment control zone have been removed and cleaned.	. . . .
11	No dust problems exist on the site.	. . . .
12	Up-slope "clean" water is being appropriately diverted through the site in a non-erosive manner.	. . . .
13	Drainage lines are free of soil scour and sediment deposition.	. . . .
14	Stormwater flow down exposed earth batters does not cause erosion.	
15	Appropriate erosion controls of all finished soil disturbances have been discussed with the client.	. . . .
16	Sediment fences have been correctly installed (e.g. fabric buried and standing up-slope of stakes) and are free of damage.	. . . .

17	Sediment fences have been installed in a manner that will allow sediment-laden stormwater to temporarily pond and settle behind the fence rather than flow around the fence.	....
18	Appropriate sediment controls have been placed adjacent to, or around, stormwater inlets—as appropriate for the type of inlet.	....
19	All sediment traps are free of excessive sediment deposition.	....
20	Finished service trenches have been appropriately backfilled, compacted and stabilised.	....
21	All reasonable and practicable measures are being taken to control sediment runoff from the site.	....
22	The site is adequately prepared for potential storms.	....
23	Adequate stockpiles exist of ESC materials, such as extra sediment fence fabric.	....
24	Temporary downpipes have been correctly connected to any installed roof gutters.	....

Appendix I

Instream works

This appendix demonstrates how the principles of erosion and sediment control are applied to construction and maintenance activities occurring within a drainage channel or watercourse. Specifically, the appendix addresses the management of activities such as vegetation removal and the de-silting of channels, the construction or rehabilitation of drainage channels, and the construction of waterway structures such as stormwater outlets and waterway crossings.

This appendix also provides a model Code of Practice for conducting instream works. Government bodies are encouraged to explore the development of a regional-based Code of Practice using the model code as a template.

The function of this appendix is both educational and prescriptive. Those personnel involved in the management of instream construction or maintenance projects, or those wishing to apply this information to a specific site, should first ensure they are familiar with the general principles of erosion and sediment control outlined in Chapter 2 – Principles of erosion and sediment control.

This appendix does not specifically address the management of construction projects within coastal areas where significant wave action is likely to occur. However, most of the concepts developed within this appendix will be appropriate to all instream construction activities, including those works occurring within coastal waters.

I1. Introduction

Unless adequately managed, instream construction and maintenance activities can represent a significant environmental hazard. These activities have the potential to cause widespread bed and bank disturbances, generating significant quantities of bed load sediment and potentially harmful concentrations of suspended sediment.

Understanding and managing the geological and ecological processes that occur within natural waterways can be very complicated, often requiring specialist training and years of experience. Sometimes the seemingly simple task of stabilising an eroded stream bank can initiate other environmental problems including downstream erosion, increased weed infestation of the stream, or significant alteration to wildlife habitat values. Therefore, no construction or maintenance activities should be performed within a watercourse, natural or constructed, without an appropriate assessment of the potential environmental impacts.

In most states, instream works will require approval by the state government, usually a department of Natural Resources or similar. If the works are within tidal waters, then approval may also be required by a fisheries authority (often a section of the Department of Primary Industries) and/or a department of environmental protection (e.g. EPA).

The potential impact of both temporary instream structures (e.g. flow diversion structures and instream sediment control measures) and permanent structures (e.g. weirs and culverts) on fauna passage, including fish migration, must be considered in consultation with the relevant State and local government bodies.

I2. Terminology

The following terminology will apply specifically to this appendix.

Instream	Any area between the banks of a constructed drainage channel, watercourse, or waterway.
Instream works	Any human-induced mechanical disturbance of the bed or banks of a constructed drainage channel, watercourse, or waterway.
Channel	Any natural or constructed flow path with well defined bed and banks.
Stream	A watercourse.
Watercourse	Any natural or constructed channel with well-defined bed and banks, including constructed drainage channels of a natural appearance, creeks and rivers, but not grass-lined or hard-surface constructed drainage channels void of ecological values.
Waterway	Any natural or constructed channel, watercourse or water body, including creeks, rivers, lakes, wetlands, estuaries, and bays.
Waterway channel	Whichever is the greater of the area of land between the overbank riparian zones, and the area of land located below the top of the lower banks (i.e. not including the floodplain).
Riparian zone	A strip of land usually located along each side of a waterway channel within which vegetation grows that has either a habitat or lifecycle link to the waterway, or directly affects water quality.
River	A major watercourse (relative to others within the region) normally with a significant sediment load transported by flood events. Bed vegetation is normally sparse and usually does not play a significant role in long-term channel stability.
Creek	A minor or intermediate watercourse with either a fixed or mobile bed that is dry (ephemeral) or has a minor constant (perennial) discharge during dry weather. In fixed-bed systems the bed material and bed shape generally do not move or alter during most stream flows. In mobile-bed systems the loose bed material migrates down the channel during floods. Natural creeks with mobile beds include gravel-based and sand-based systems, whereas fixed bed creeks are typically clay-based systems.
Gravel-based creek	Typically a high gradient (steep) fast-flowing watercourse with bed material dominated by loose gravel, rocks, and/or boulders. Bed conditions normally consist of pools and riffles.
Sand-based creek	Typically a medium gradient watercourse with loose, fine-grained (sandy) bed material. If a low-flow channel exists, it can be highly mobile with a constantly changing bed/plan form.
Clay-based creek	A minor watercourse formed into clayey soils. In open canopy creeks, ground cover vegetation is dominant on both the bed and banks. In closed canopy creeks, sparse vegetation cover usually still exists, but generally the bare clayey soils are visible.

I3. Potential impacts of instream works

Sediment released from a work site into a waterway or water body can cause an increase in both turbidity and bed load sediment. Turbidity consists of the clay and fine silt particles that generally do not settle until they reach quiescent or saline waters. Bed load sediment consists of the coarser silts, sands, and gravels that move along, or close to, the bed of a watercourse.

Unnaturally high turbidity levels can cause adverse effects on aquatic life, such as:

- damage to fish gill membranes;
- reduced ability for aquatic life to feed by sighting food;
- general altering of aquatic habitat and behaviour;
- increased susceptibility to disease caused by stress;
- health problems associated with the transportation of pollutants attached to clay particles such as nutrients, metals and pesticides.

Bed load sediment can fill the voids between the stones within riffle systems and natural gravel beds, a process called “matrix infiltration”. A consequence of this sedimentation process can be a permanent change to the ecological processes occurring within the stream. In extreme cases the natural gravel bed can be totally smothered by weeds and sediment.

The potential impacts of elevated bed load concentrations depends on the structure of the watercourse, and more importantly, on the natural bed conditions within the watercourse. There are basically four types of streams: clay-based, sand-based, gravel-based, and spilling or steep rocky systems.

Some of the potential impacts likely to result from unnaturally high bed-load sediment concentrations are listed below for the various stream types.

Clay-based creeks

- Smothering of bed vegetation resulting in increased bed erosion. Such erosion can also initiate or aggravate erosion of adjacent channel banks.
- Reduction or total loss of aquatic habitat areas along the bed of the watercourse.
- Filling of natural pools (these pools often act as important habitat areas).

Sand-based creeks

- The potential impacts can be significantly less than in clay or gravel-based streams, especially if the introduced bed load material has a similar grain size distribution to the natural bed material. However, if the introduced sediment contains clay or organic material, then environmental harm can occur, including weed infestation.

Gravel-based creeks

- Fine sediment can fill the voids between natural bed gravels causing the following adverse effects:
  - (i) loss of essential aquatic habitat areas (both within the pools and riffles);
  - (ii) a reduction in the total submerged surface area (by infilling bed and riffle voids and other surface irregularities) thus reducing the potential food supply;
  - (iii) an increase in the stability of riffle rock, thus reducing the “natural” movement and sorting of the bed material.

- A constant supply of introduced bed sediment can eventually turn a gravel-based stream into either a sand or clay-based system.

Rocky spilling creeks

- Filling of pools with coarse sediment.
- Reduction or total loss of aquatic habitat values along the bed of the watercourse.

Tidal waterways

- Fine sediments that enter such waterways can be constantly resuspended into the water column by tidal movement resulting in increased turbidity levels.
- High water column turbidity can reduce habitat diversity.
- Settled bed load sediment can increase local flooding problems and reduce the navigational limits of the waterway.

Coastal regions

- Coarse sediment can smother aquatic vegetation and bed habitats.
- Fine sediments can settle as a fine dusting over the seabed, causing loss of seagrass through reduced photosynthesis, and damage to coral habitats.

All stream types

In all streams, the deposition of sediment (fine or coarse) can damage aquatic habitats by:

- reducing the diversity and abundance of bottom dwelling (benthic) organisms, thus affecting a food supply for other aquatic life;
- destroying spawning areas;
- reducing the survival of fish eggs through the direct deposition of sediment;
- destroying aquatic vegetation.

In addition, unnaturally high levels of coarse sediment can:

- increase weed infestation of creek and wetland systems;
- damage drinking water supplies;
- increase the need for maintenance dredging;
- infill dams, lakes and wetlands;
- decrease recreational and commercial fishing;
- damage the aesthetic, ecological, and recreational values of waterways.

When assessing the potential impacts of proposed instream works on the environment, it is important to recognise and understand the relevance of the following points.

(a) Usually a very complex relationship exists between the quantity of pollution and the resulting environmental harm. Site managers should **not** assume that a 50% reduction in the quantity of sediment released from the site will necessarily achieve a 50% reduction in the resulting environmental harm. Sometimes it is just a small percentage of the sediment (e.g. the clay fraction) that causes most of the environmental harm—this of course will depend on the type of receiving water.

(b) Even though it is always a good idea to minimise the quantity of sediment released from a work site, the focus should always be on minimising the overall environmental harm. For example, the process of installing and removing some instream sediment traps can cause significant disturbance (harm) to the bed and banks of a waterway. Therefore, unless the benefits gained by their use exceed the potential harm caused by the installation and removal process, then their value must be questioned. In which case an alternative sediment trap or construction process must be considered.

(c) In many creeks, natural or modified, it is common for water quality to decrease with increasing flow rate. Thus water clarity is usually highest during those periods of low flow between storm events. Therefore, to minimise the harm caused to small waterways such as creeks, the aim should be to achieve the highest quality water standards during these periods of low flow. Thus, those instream sediment traps that allow the "filtration" of sediment-laden waters during periods of low flow usually provide the greatest environmental benefit.

One of the keys to minimising environmental harm is to program instream works to occur at the least vulnerable times of the year. Ecological activity within a stream, both terrestrial and aquatic, is usually highly variable throughout the year; therefore, the potential impacts of instream disturbances also vary throughout the year. Good environmental management of instream works requires an understanding of ***when*** wildlife moves, breeds and feeds within the waterway.

I4. Design of works in and around waterways

Numerous Federal, State and local guidelines currently exist on the management of waterways and on the design of works in and around waterways. Where appropriate, these guidelines should be referred to when designing waterway channels and instream structures.

The following recommendations summarise some of the key design principles:

(i) Identify and protect essential terrestrial and aquatic habitats and movement corridors. Witheridge (2002) provides guidelines on the design of fish-friendly watercourse crossings.

(ii) Avoid placement of structures within the identified riparian zone, even if such riparian vegetation does not currently exist. If riparian widths or minimum riparian widths have not been identified/mapped for the waterway, then take appropriate steps to identify minimum riparian widths based on geomorphological, hydraulic, and environmental considerations.

(iii) Minimise disturbance to the riparian zones and waterway channel to the minimum necessary to achieve the required project outcomes.

(iv) Minimise the number of waterway crossings (e.g. roadways, footpaths, services).

(v) Minimise the placement of services (e.g. power, water, sewerage) within the waterway channel and riparian zone.

(vi) Avoid the placement of fixed structures:

- adjacent to the outside of sharp, erodible channel bends;
- adjacent to unstable channel banks;
- within 15m of the top of bank, or within a distance of three times the bank height from the toe of the bank (whichever is greater).

(vii) When locating access tracks, utilise the riparian vegetation as an operational buffer zone to separate the track from the stream. Ideally, the minimum width of the riparian zone between the track and the edge of the stream should be at least the width of the stream (measured at the top of the bank) or 30 m whichever is the lesser. Note, the riparian zone must be protected from damage by sediment runoff during construction of the track.

(viii) Avoid causing permanent changes to the natural pool–riffle sequence (size and spacing) within the low-flow channel.

(ix) Give priority to those forms of erosion control and bank stabilisation that allow the successful integration of vegetation, especially adjacent any permanent or near permanent waters.

(x) Maximise the integration of natural vegetation into any erosion control and bank stabilisation works.

(xi) Ensure that if ongoing maintenance activities (e.g. de-silting) will be required on the instream structure, then appropriate allowances, including site access, are made such that these activities can occur in a manner that will minimise potential environmental harm. Discussion on the design of culverts to reduce the need for de-silting operations is provided in Section I7.1.

I5. Instream sediment control vs off-stream sediment control

The well-established principles of off-stream sediment control, as presented in Chapter 2, are primarily based on the gravitational *settlement* of sediment from captured water. In most cases, the captured water results from either local storm runoff, or process water such as de-watering activities, equipment cleaning and material cutting operations.

Instream sediment control measures, however, primarily rely on the *filtration* of sediment from dry weather stream flows. The reasons for focusing on filtration as the preferred treatment process are presented below.

(a) Most off-stream sediment control practices focus on the capture of the coarser sediment fraction—*Sediment Basins* being the one major exception to this rule. On the other hand, instream sediment control practices need to focus on both coarse sediment and turbidity levels.

(b) Most instream maintenance and construction activities are conducted during dry weather, or at least when only low flows are expected within the watercourse.

(c) Thus, environmental protection normally focuses on the appropriate management and treatment of dry weather flows. This is different from traditional off-stream sediment control practices, which primarily focus on the management of wet weather events.

(d) Thus, instream sediment control techniques are normally required to treat much lower flow rates and volumes compared to the design flow rates for off-stream sediment control measures.

(e) Due to the lower flow rates experienced by instream sediment measures, sediment blockages are more easily detected and necessary maintenance can usually be carried out immediately. This is different from traditional off-stream sediment controls where sediment blockages normally occur during storm events when maintenance of the device is usually impracticable.

(f) Also, instream construction and maintenance activities are normally conducted over much shorter time periods compared to off-stream works, therefore, the high maintenance requirements and sediment blockage problems associated with filtration systems are less likely to seen as a significant problem to site managers.

(g) It is also noted that most streams flow much cleaner during periods of dry weather, thus higher treatment standards (i.e. filtration) are usually required during these periods of dry weather flow in order to minimise environmental harm.

I6. Key management principles

The key management principles for instream erosion and sediment control are:

1. Appropriately plan and organise the work activities.
2. Minimise channel disturbance.
3. Control the movement of water.
4. Minimise soil erosion.
5. Minimise the release of sediment and sediment-laden water.
6. Promptly rehabilitate disturbed areas.

The above key principles may be expanded into the following specific management principles.

I6.1 Appropriately plan and organise the work activities

All reasonable and practicable measures must be taken to:

(i) Carry out only those channel maintenance activities (e.g. mechanical weeding, snag removal and channel de-silting) that are considered necessary.

(ii) Program instream works for those times of the year that minimise overall environmental harm, giving appropriate consideration to:
- expected weather conditions and stream flow rates;
- periods of fish migration;
- periods of aquatic bird nesting and/or migration;
- other relevant environmental factors.

(iii) Plan and conduct instream maintenance activities in a manner that will help reduce the potential environmental harm likely to occur if and when similar activities are required some time in the future.

(iv) Give appropriate consideration to the potential harm caused by the installation and removal of proposed instream flow control and sediment control devises in comparison to the environmental protection gained by their use.

I6.2 Minimise channel disturbance

All reasonable and practicable measures must be taken to:

(i) Limit instream disturbances to the minimum area and reach length necessary.

(ii) Limit the disturbance to overbank vegetation (i.e. riparian vegetation) to the minimum necessary, and wherever reasonable and practicable, access the channel through a minimum number of narrow access corridors.

(iii) Where practicable, limit disturbance and channel access to one side of the channel at any given time.

I6.3 Control the movement of water

All reasonable and practicable measures must be taken to:

(i) Divert the lateral (overbank) inflow of stormwater runoff away from the work area. On bridge and culvert construction, this may require the temporary diversion of table drains away from the construction zone.

(ii) Ensure any overbank flow diversions allow water to enter the channel in a non-erosive manner.

(iii) Divert instream flows around the work area by isolating (e.g. bunding or flow diversion barriers) the disturbance area and/or piping or channelling stream flows around the disturbance. Appropriate consideration must be given to fish passage requirements during these periods of flow diversion. As a minimum, consideration needs to be given to the duration of flow diversion, the likelihood and extent of fish movement during this period, and the cost/benefit of alternative construction procedures.

(iv) Avoid the contamination of any water flowing around or through a work site.

(v) Minimise the flow of water, including rainwater, into excavations.

I6.4 Minimise soil erosion

All reasonable and practicable measures must be taken to:

(i) Avoid unnecessary disturbance to bed, bank and overbank vegetation.

(ii) Restrict the area of disturbance to as small an area as possible during those periods when rainfall is possible.

(iii) Use of appropriate erosion control techniques to stabilise disturbed areas and unstable banks as soon as practicable.

I6.5 Minimise the release of sediment and sediment-laden water

All reasonable and practicable measures must be taken to:

(i) Give priority to those work procedures and practices that minimise the contamination of water.

(ii) Give priority to those sediment control techniques that not only achieve the required treatment standard during the *design flow*, but can produce even higher quality discharge during lesser flows. Such sediment control techniques often incorporate *filtration* practices that assist in the treatment of low flows.

(iii) Appropriately treat all water contaminated by the work activities.

(iv) Appropriately treat all contaminated water pumped from excavations and other areas of the work site.

(v) Appropriately treat sediment runoff from the de-watering of material stockpiles.

(vi) Establish work practices that minimise accidental spills and sediment releases.

(vii) Promptly clean up any sediment spills/releases that occur outside the sediment control zone.

I6.6 Promptly rehabilitate disturbed areas

All reasonable and practicable measures must be taken to:

(i) Promptly rehabilitate (e.g. revegetate) disturbed areas.

(ii) Actively stabilise and/or rehabilitate stressed and unstable stream banks rather than waiting for natural regeneration.

(iii) Revegetate areas with appropriate native plants wherever possible. It is noted that in some cases it may be beneficial to establish an initial, temporary, ground cover (e.g. grass) prior to planting the proposed long-term vegetative cover.

(iv) Avoid the use of “plastic” reinforced *Erosion Control Blankets* in bushland areas.

(v) Leave soils in an appropriate firm (i.e. not excessively compacted) condition that will assist in the quick establishment of vegetation.

I7. Investigation procedure

The following investigation and design procedure has been developed for the management of instream maintenance and construction works.

Step 1 Assess the need for and extent of works

Step 2 Initial site assessment

Step 3 Determine the appropriate timing of works

Step 4 Determine an appropriate work procedure

Step 5 Control water movement in and around the work site

Step 6 Select erosion control measures

Step 7 Select sediment control measures

Step 8 Select material handling, transport and disposal methods

Step 9 Assess water quality monitoring requirements

Step 10 Determine site clean up and rehabilitation procedures

Step 11 Prepare an Erosion and Sediment Control Plan (ESCP)

Step 1 Assess the need and extent of works

Instream works may be divided into two categories: construction projects and maintenance activities. The “need” and “extent” of proposed instream disturbances should have been thoroughly investigated and reviewed prior to the detail design, consequently no further discussion will be provided in this section on such projects.

Instream maintenance activities may include vegetation removal for flood management, channel de-silting or dredging, snag removal, tree removal (e.g. removal of weed species), and channel stabilisation or rehabilitation measures.

In flood-prone urban areas, open canopy channels often need routine maintenance to remove excessive sediment and weed growth to maintain the channel’s flood carrying capacity. Much of the bed vegetation, such as reeds, is a direct result of un-natural sediment deposition. **Therefore, one of the most effective ways of reducing the need for regular channel maintenance is to improve erosion and sediment control practices throughout the catchment as part of responsible catchment management.**

Extensive hydraulic modelling is usually required to determine the true benefits of proposed channel de-silting and vegetation control programs. In some circumstances these works can be proposed solely for political reasons to manage a *perceived* flood control problem. However, what at first may appear to the public as an obvious connection between local flooding and the accumulation of weed growth and sediment may actually turn out to be a more complicated hydraulic problem with a variety of previously unconsidered solutions.

Intelligent design, prudent waterway management procedures, and appropriate channel revegetation can often be used to significantly reduce the need and extent of channel maintenance requirements.

De-silting and vegetation control programs should not be done to remove or solve a perceived problem, but should only be done to address actual hydraulic or environmental problems for which there are no other, more appropriate solutions.

When determining the "need" and "extent" for proposed instream maintenance activities, waterway and drainage managers should give the following guidelines and recommendations appropriate consideration.

(a) Stormwater outlets

De-silting and vegetation control is often required at stormwater outlets for the following reasons:

- To allow proper drainage of the pipe—thus avoiding ponding, mosquito breeding and sedimentation in and around the pipe.
- To improve the hydraulic efficiency of the outlet—thus increasing the hydraulic capacity of the stormwater pipe and reducing the likelihood of local flooding problems.
- To remove accumulated sediment and other pollutants from the end of the outlet before they are allowed to migrate into the main channel or into a downstream water body.

Stormwater outlets that discharge into tidal waterways and drains are particularly susceptible to sedimentation problems.

As a general rule, the smaller the diameter of the stormwater pipe, the greater the need to maintain the immediate downstream channel free of sediment, debris, and tall bed vegetation. Larger stormwater outlets, say 1200 mm or greater, have a greater depth of flow and thus a greater ability for the water to flatten bed vegetation during periods of high flow.

The de-silting of stormwater outlets is likely to be warranted in the following situations:

- The hydraulic and/or environmental benefits have been clearly demonstrated by past de-silting operations.
- The sediment has been accumulating for some time and vegetation is beginning to stabilise the sediment causing the outlet channel to be blocked, or flow to be diverted into the adjacent channel banks.
- The outlet is submerged or tidal.

Selective vegetation removal is likely to be warranted in the following situations:

- The pipe size is less than 1200 mm in diameter.
- There is an established history of the bed vegetation (e.g. reeds) not being flattened by typical storm discharges from the pipe.
- The vegetation is causing outflows to be directed into the channel banks, resulting in bank erosion.
- The vegetation is considered noxious or damaging to the ecological integrity of the watercourse.

(b) Drains, channels and waterways

De-silting and vegetation control within drains, channel and waterways is usually required for the following reasons:

- To improve the hydraulic capacity of the channel, thus reducing local flooding or drainage problems.

- To control bank erosion caused by sediment and/or bed vegetation deflecting channel flows into the channel banks.
- To remove accumulated sediment from purpose-built instream sediment traps or ponds.
- To remove undesirable and/or noxious weeds from a watercourse.
- To remove pollutants, including contaminated sediment, from the channel.

As a general guide, vegetation control within drainage channels is unlikely to be warranted if the vegetation consists only of grasses or other flexible plants, and the height of the vegetation is less than the bank height of the stream.

The de-silting of a drain, channel and waterway is likely to be warranted in the following situations:

- The hydraulic and/or environmental benefits have been clearly demonstrated by past de-silting operations.
- The sediment has been accumulating for some time and is significantly restricting the hydraulic capacity of the channel.

If sediment inflow to a drainage channel or watercourse cannot be controlled through the establishment of appropriate catchment management practices, then consideration should be given to the establishment of permanent sediment extraction points at key locations along the channel, such as immediately upstream of road culverts. These permanent instream sediment traps usually require the construction of permanent, low-impact, low-intrusion, maintenance access ramps.

Selective vegetation control within drains, channels and waterways is likely to be warranted in the following situations:

- History has shown that the vegetation is not flattened by normal storm flows.
- The vegetation consists of woody weeds that are likely to aggravate local flooding problems.
- The vegetation is causing flows to be directed into the channel banks resulting in bank erosion.
- The vegetation is considered noxious or damaging to the ecological integrity of the downstream watercourse.

(c) Culverts and bridges

In most circumstances, de-silting and vegetation management occurs upstream and downstream of culverts and bridges to improve the hydraulic efficiency of the structure, thus reducing upstream flood levels.

De-silting of culverts is usually more common in multi-cell culverts. Hydraulically, a multi-cell culvert behaves in a manner similar to an over-excavated (i.e. unnaturally wide) or dredged channel. The sedimentation that occurs within the outer cells of a culvert is the same natural response that would be expected in an unnaturally wide waterway. Eventually low flows begin to concentrate into just one or two of the cells. Over time, sediment in the outer cells can compact and become erosion-resistant, thus reducing the probability of the material being washed from the culvert during high flows.

To reduce the likelihood of sedimentation within existing multi-cell culverts, and therefore to reduce the “need” for regular de-silting activities, a low-flow sediment training wall (Figures I1 and I2) can be constructed in front of the culvert to direct low flows to just one cell, thus allowing the bulk of the sediment to collect within the channel immediately upstream of these walls.

Sediment training walls are specialist hydraulic structures that need to be designed by experienced hydraulic engineers.

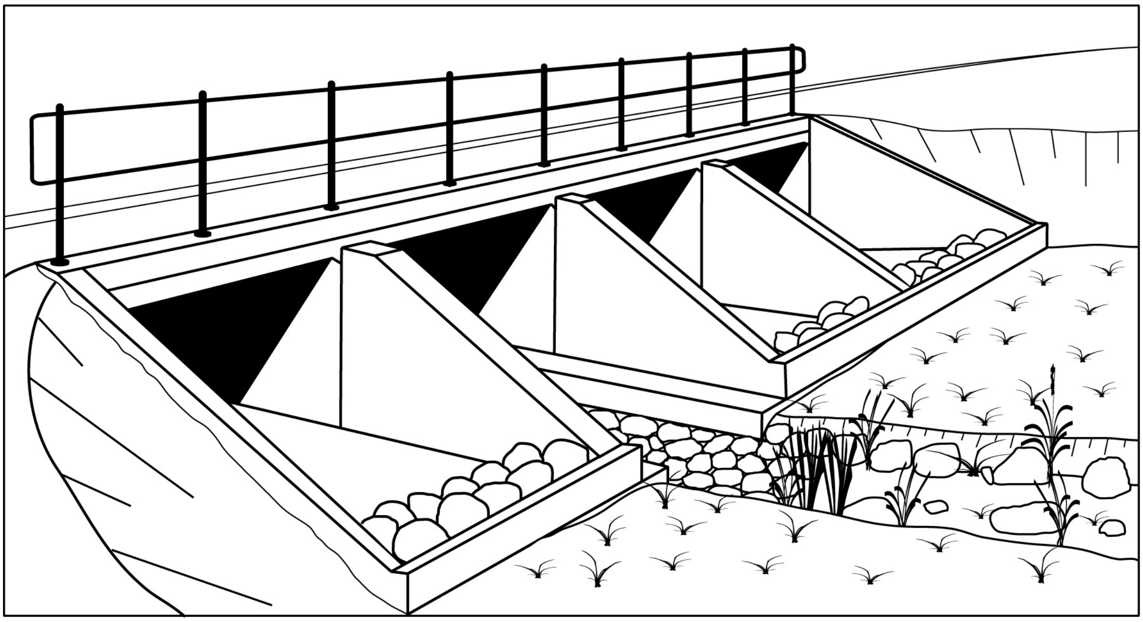


Figure I1 – Sediment training wall incorporated with debris deflection walls

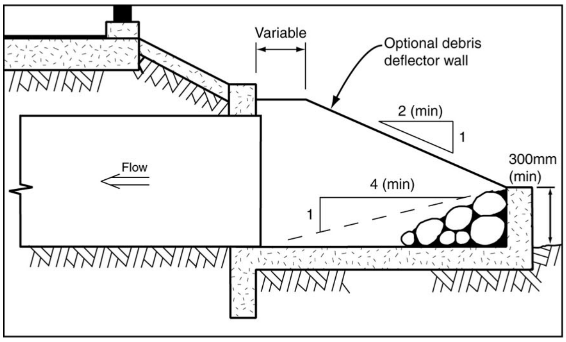


Figure I2(a) – Sediment training wall with debris deflection wall

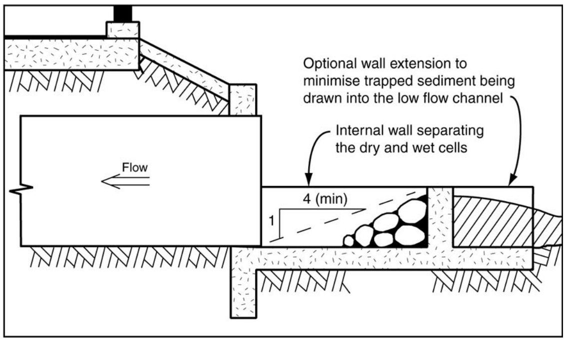


Figure I2(b) – Sediment training wall without debris deflection wall

If de-silting and/or vegetation clearing is proposed immediately upstream of a culvert or bridge to improve its hydraulic capacity, then these works should normally extend upstream a distance no greater than the total width of the culvert or bridge opening (Figure I3). Beyond this point the hydraulic benefits may be questionable.

When removing vegetation downstream of a culvert or bridge, it is important to recognise the following hydraulic requirements.

- The most hydraulically efficient way to expand flood flows exiting from a bridge or culvert is to allow the water to expand gradually, rather than abruptly.
- There are some circumstances where vegetation placed in specific locations adjacent to the abutments of a bridge or culvert can actually improve the hydraulics of the structure by allowing the gradual expansion of the outlet jet. Expert hydraulic advice should always be obtained before designing such vegetation schemes.

- Floodplain vegetation located outside approximately a 45° angle from the inlet or outlet of a bridge or culvert is unlikely to interfere with the hydraulics of the structure.
- If a floodplain exists on one or both sides of the channel, then riparian vegetation along the banks of the channel must allow flood flows from the culvert or bridge to leave the channel and gradually enter the floodplain (Figure I3).

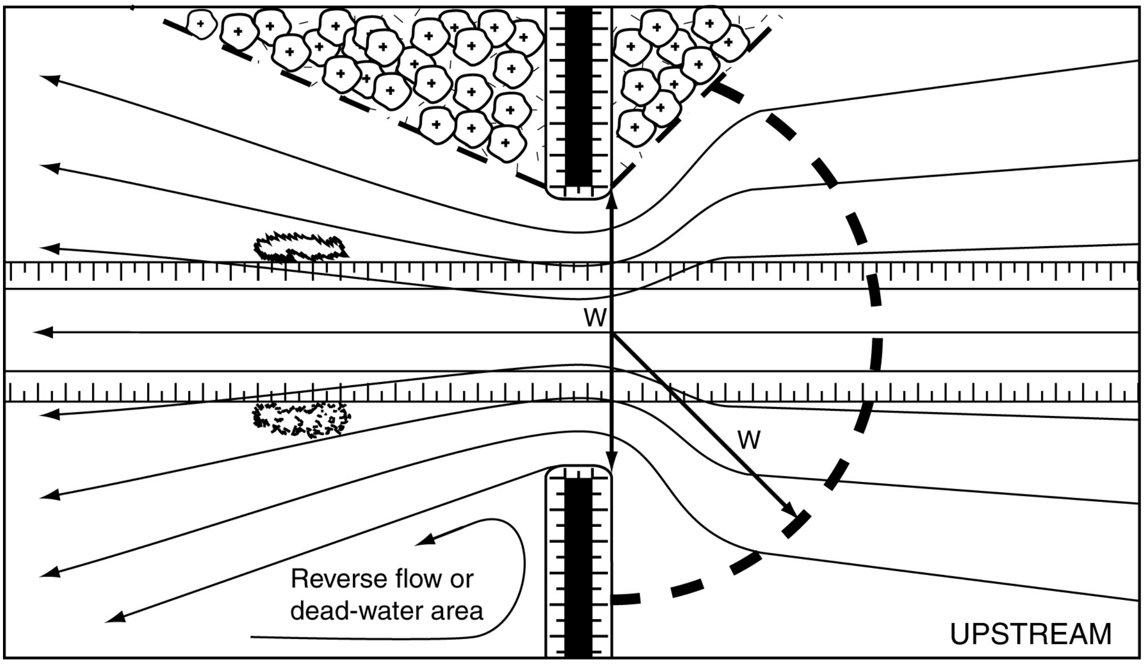


Figure I3 – Critical inflow control zone

De-silting works are likely to be warranted upstream, within, or downstream of a bridge or culvert in the following situations:

- The hydraulic and/or environmental benefits have been clearly demonstrated by past de-silting operations.
- The sediment has been accumulating for some time and has not been removed by past flood events.
- The sediment accumulated downstream of a culvert is causing water to pond within the culvert resulting in water quality, public safety, or public health problems (e.g. mosquito breeding).

Selective vegetation clearing is likely to be warranted upstream or downstream of a bridge or culvert in the following situations:

- The hydraulic and/or environmental benefits have been clearly demonstrated by past clearing operations.
- Woody vegetation is restricting flood flows from leaving the upstream floodplain and entering the bridge or culvert.
- Woody vegetation is restricting the flow of floodwaters exiting the bridge or culvert from entering into the downstream floodplain.
- Woody or inflexible vegetation is growing within an area defined by one culvert/bridge width upstream of the bridge or culvert (Figure I3).
- The vegetation is considered noxious or damaging to the ecological integrity of the downstream watercourse.

Step 2 Initial site assessment

An initial site assessment will usually be required in order to collect site data and assess the erosion and sediment control requirements of the site. During the site visit the following key issues need to be considered.

1. Will the site require flow diversion, and if so, how?
2. Will the site require the implementation of instream sediment control practices, and if so, what systems are likely to be most appropriate?
3. Will the site require the de-watering of excavations or the excavated material?
4. Will it be necessary to maintain fish passage while works are in progress?
5. Will it be necessary to maintain public access along the waterway?

Among other things, the initial site inspection may require determination of the following information to assist in the selection of instream sediment/flow control measures:

- Type of watercourse (e.g. drain, creek, river, tidal, non-tidal)
- Site access conditions (e.g. access for heavy machinery)
- Stockpile and de-watering areas (i.e. suitable areas to allow material de-watering)
- Existing water quality (i.e. is the base flow clear or turbid, and TSS or NTU reading)
- Typical flow depth (i.e. less than or greater than 0.8m)
- Typical flow velocity (e.g. estimate by timing the velocity of surface debris)
- Typical flow rate (determine by estimating the flow area and average velocity)
- Bed material (e.g. clay, sand, gravel, or rock)
- Bed shape (e.g. irregular or flat bed)
- Expected duration of works (e.g. 1–2 days, 3–5 days, > 5 days)

Step 3 Determining the appropriate timing of works

Instream works should be programmed to avoid:

- periods of fish migration;
- known nesting or breeding periods for aquatic birds;
- the wet season, periods of extended wet weather, or periods of above-average stream flow.

Extreme care should be taken when determining the appropriate timing of those works that are to be conducted in streams that exhibit one or more of the following characteristics:

- streams with clear-water, dry weather flows;
- streams with reaches located in the upper parts of a large drainage catchment;
- streams containing aquatic life;
- pristine streams unaffected by urbanisation.

Step 4 Determine an appropriate work procedure

There is almost always more than one way of conducting the proposed construction or maintenance activities. Selection of the preferred work procedure will depend, in part, on the answers obtained to the questions raised in Step 3.

Some of the most common site management procedures are discussed below.

If it is necessary to cause soil disturbance across the full width of the channel without staging the disturbance, then a full-width instream sediment trap may be required.

Such devices are only suitable in “dry” channels or streams with very low flow rates, and only during periods when storm or flood flows are not expected to occur. In all other cases a stream flow diversion system will be required.

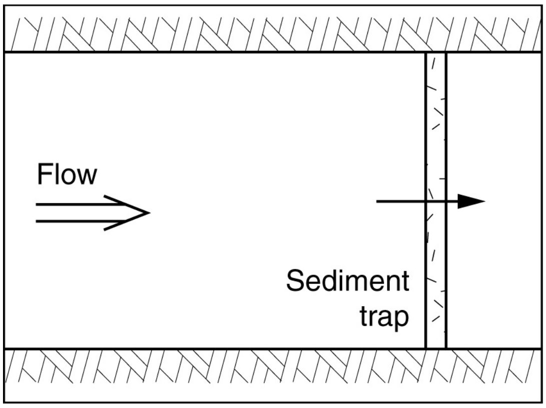


Figure I4 – Full-width sediment trap

If it is necessary to establish a “dry” work area, then cofferdams or *Isolation Barriers* will be needed to isolate the work area from stream flow.

In such cases, it is usually desirable to allow the stream’s base flows to pass through the site within a gravity flow bypass pipe rather an establishing a pumped bypass.

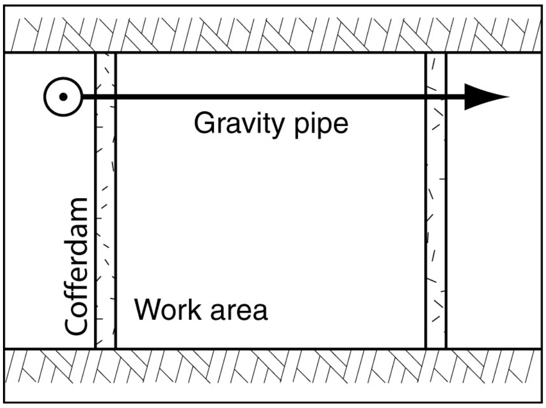


Figure I5 – Gravity flow bypass

If a pumped bypass is required, then special arrangements may need to be made to maintain the pump over weekends, and to manage possible debris blockage and vandalism problems.

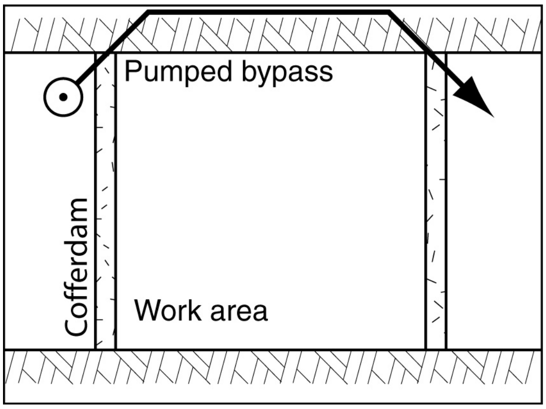


Figure I6 – Pumped flow bypass

If the works can be staged to allow stream flows to be diverted around the soil disturbance, then determine how many construction stages will be required, and what type of *Isolation Barrier* will be needed.

In most circumstances this is the preferred construction method. This procedure requires works, such as the construction of a culvert base-slab, to be divided into at least two stages. This may require changes to the structural design (i.e. steel reinforcing) of the base-slab.

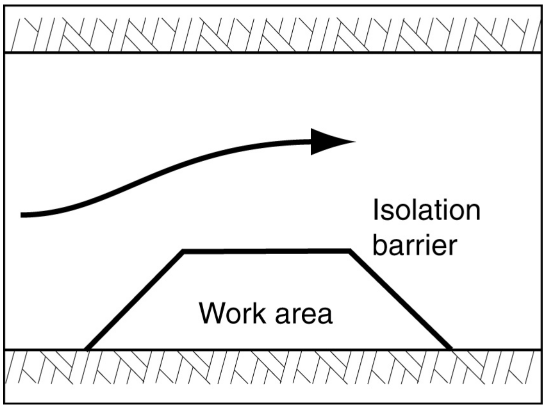


Figure I7 – Isolation barrier

If the work area is likely to be “wet”, then the enclosed water will usually need to be treated before it is allowed to re-enter the stream.

The preferred method is usually to pump the water to an off-stream sediment control system (located on the floodplain), then allow the treated water to filter (as “sheet” flow) through bank vegetation before re-entering the channel.

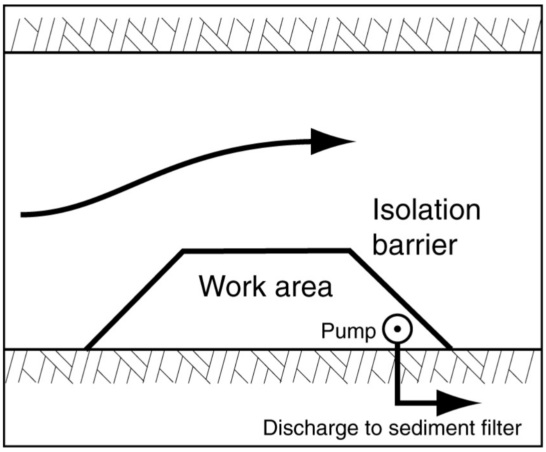


Figure I8 – Isolation barrier

If the material excavated from the channel needs to be de-watered before being transported from the site, then an area needs to be made available for stockpiling the material, and a suitable de-watering procedure needs to be established.

Usually the best method is to stockpile the material as far from the stream as possible, and to ensure any sediment-laden water draining from the stockpile is appropriately filtered through **non-woven**, heavy-duty filter cloth (i.e. *Filter Fence*), **not** woven sediment fence fabric.

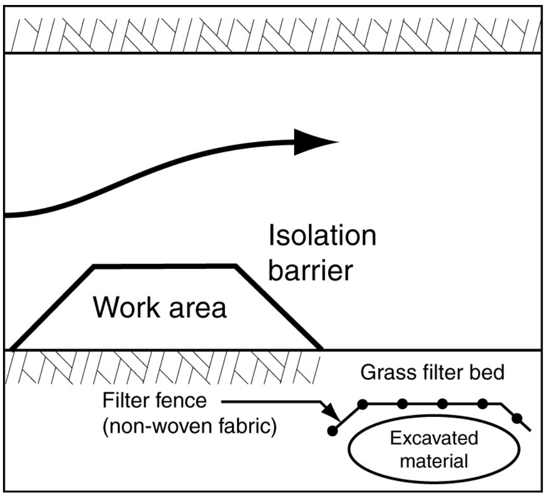


Figure I9 – Isolation barrier

Step 5 Control water movement in and around the work site

There are usually two sources of water flow that need to be managed while conducting instream works: firstly stream flows passing through the work area, and secondly lateral inflows, usually consisting of local stormwater runoff flowing towards the channel.

All reasonable and practicable measures need to be taken to convey the lateral inflow of stormwater runoff around or through the work area in a non-erosive manner. Wherever reasonable and practicable, this inflow of "clean" water should not mix with any "dirty" water generated within the work area.

The diversion of lateral inflow is recommended in the following cases:

(i) when rainfall is expected or likely; and

(ii) material stockpiles on the side of the channel contains clayey, silty or otherwise harmful material, and any materials washed from these stockpiles are likely to wash into the drain or waterway; or

(iii) lateral inflows are likely to flow over exposed soil or cause bank erosion within the work area.

Catch Drains or *Flow Diversion Banks* (earth or straw bales) can be used to divert up-slope stormwater runoff around stockpiles and other soil disturbances. The diverted water can either be directed as sheet flow towards an undisturbed channel bank, or discharged to a temporary geotextile *Chute* constructed down the channel bank.

The most critical flow diversion activities are those used to divert in-bank stream flows around the work site. As discussed in the previous section, there are basically three ways of diverting stream flows, those being:

- use of cofferdams with a gravity bypass pipe;
- use of cofferdams with a pumped bypass;
- use of an *Isolation Barrier*.

The advantages and disadvantages of the three systems are summarised in Table I1.

The greater the flow rate and the cleaner the stream flow, the greater the need and value of instream flow diversion. Therefore, the first option should always be to delay instream soil disturbances until channel flow and the risk of flood flows is at a minimum.

Wherever reasonable and practicable, flow diversion works and temporary bank stabilisation works should be designed to be structurally stable during at least the 1 in 2 year stream flow.

Once an instream work area has been isolated from the stream flow, it is important to take all reasonable and practicable measures to extract wildlife from the enclosure prior to commencing construction or maintenance activities. It should be noted that in most states the capture and release of aquatic wildlife is strictly regulated by State authority, and may only be done by registered wildlife handlers. It is also highly likely that the use of a cofferdam or *Isolation Barrier* will require approval by one or more State authorities.

Recommendations for flow diversion are presented in Table I2.

Table I1 – Advantages and disadvantages of various flow bypass options

Bypass option	Advantages	Disadvantages
Cofferdam with gravity bypass pipe	• No power cost.	• Bypass pipeline may interfere with work activities. • Flood flows still pass through the work site. • Disruption to fish passage.
Cofferdam with pumped bypass	• Bypass pipeline does not interfere with work activities.	• Added power and maintenance costs. • Flood flows still pass through the work site. • Disruption to fish passage.
Isolation barrier	• Minimal disturbance to normal channel flow. • Minimal disruption to fish passage. • Better able to isolate the work area from flood flows.	• Some *Isolation Barriers*, such as *Silt Curtains*, are not watertight. • Requires work across the channel bed to be staged.

Table I2 – Flow diversion recommendations

Condition	Recommendations
Default conditions	• Program works in accordance with Step 3. • Flow diversion shall only occur if it is financially feasible and the environmental benefit gained by its use exceeds the potential harm caused by the installation and removal of the *Isolation Barrier* or cofferdams.
No base flow	• If there is no base flow (i.e. no obvious running water, but permanent pools may be present) and stream flow is **not** expected during the construction or maintenance activity, then refer to the default conditions.
	• If there is no base flow (i.e. no obvious running water, but permanent pools may be present) but stream flow is possible, then appropriate consideration must be given to the installation of an *Isolation Barrier*.
Base flow exists in the stream	• If there is base flow and increased stream flows are **not** expected, then appropriate consideration must be given to the installation of cofferdams with a low-flow bypass system.
	• If there is base flow and increased stream flows (i.e. in response to a storm) are possible, but not likely, then the choice between the use of an *Isolation Barrier* or cofferdams will depend on the likelihood of stream flows overtopping the cofferdams.
	• If there is base flow and increased stream flows are expected (i.e. in response to a storm), then the first option should be to delay the proposed works until stream flows are a minimum. In any event, priority should be given to the install an *Isolation Barrier*.
Fish passage required to be maintained	• First preference: an *Isolation Barrier* that isolates no more than 30% of the stream width at any given time. • Second preference: an *Isolation Barrier* that isolates no more than 50%, of the stream width at any given time if the first preference is either unreasonable or impracticable.

Step 6 Select erosion control measures

Appropriate erosion control measures need to be employed to limit soil erosion especially along the bed and banks of the stream. In particular, clayey or unstable soils need to be stabilised or covered with *Erosion Control Blankets*, *Mats*, or *Mesh* to minimise soil erosion as soon as reasonable and practicable.

Technical Note I1: Blankets, mats and mesh

The term "blanket" generally refers to erosion control fabric used on soils subjected to sheet flow conditions such as the high bank areas of a channel well above normal stream flows.

The term "mat" generally refers to erosion control fabric used on soils subjected to concentrated flow, such as those within a drainage channel.

The term "mesh" refers to erosion control fabric consisting of an open weave (like a net) usually formed from jute or coir. These products are most appropriate within natural waterways when it is important to avoid the use of potentially damaging synthetic (plastic) mesh or mat reinforcing.

A "hydraulically-applied" blanket refers to the liquid spray-on products that dry to form a solid, continuous blanket with a thickness approximating that of an *Erosion Control Blanket*. Hydraulically-applied blankets, also known as *Bonded Fibre Matrix* (BFM), are commonly used in the revegetation of drainage channels due to their higher flow resistance compared to hydromulching.

If dispersive soils are exposed, then these soils should either be treated to stabilise their dispersive nature, or buried under a layer of non-dispersive soil (refer to Step 10). Discussion on dispersive soils and their treatment is supplied within Appendix G – *Soils and revegetation*.

The extent and type of erosion control measures greatly depends on the likelihood and intensity of expected rainfall and/or stream flow. If construction occurs during the dry season when rainfall and stream flow are unlikely, then the degree of erosion protection is likely to be significantly less than if construction occurs during the wet season.

The recommended design flow velocities for various erosion control products are provided in Chapter 4 (Section 4.7, Step 13). Erosion control mesh, whether jute or coir, has proven to be most valuable as a temporary surface stabilisation measure within drainage channels and some low velocity waterways.

Technical notes placed on the Erosion and Sediment Control Plan (ESCP) and/or within the supporting documentation need to clearly specify the degree of erosion control required for different periods of the year, or for different levels of anticipated rainfall and/or stream flow.

One of the best ways of minimising soil erosion is to minimise site disturbance and the disturbance of high-risk areas. This can be achieved by:

- avoiding unnecessary disturbance of bed or bank vegetation;
- avoiding disturbance on the outside bank of a channel bend;
- minimising the soil disturbance needed to provide access to the site;
- not accessing the site via the outside of a channel bend, or via an unstable bank;
- using long-reach excavation equipment that allows all work to be done from the top of bank rather than allowing machinery to access the channel bed.

Step 7 Select sediment control measures

There are potentially three main sources of sediment runoff:

- sediment-laden water released from instream disturbances;
- sediment-laden water released during the de-watering of the work site;
- sediment-laden runoff from the de-watering of material stockpiles.

All three sources of sediment need to be appropriately managed, with each source usually requiring a different sediment control technique.

(a) Instream sediment control techniques

Instream sediment controls are installed to treat only the dry-weather base flow passing down the channel. It is rarely practical to design instream sediment controls to treat stream flows resulting from storms or floods.

The choice of instream sediment control technique depends on a number of variables including channel shape, flow rate, water depth, undisturbed water quality, and the duration of the works. Tables I5 to I7 provide guidelines on appropriate instream sediment control techniques. Wherever reasonable and practicable, preference must be given to Type 1 sediment control systems (Table I3), followed by Type 2, then Type 3 systems as required by Table I4.

Sediment runoff generated outside the waterway channel must be treated prior to its discharge into the watercourse. When constructing waterway crossings, four sediment traps or basins are usually required, one each side of the road, on each side of the waterway (Figure I10).

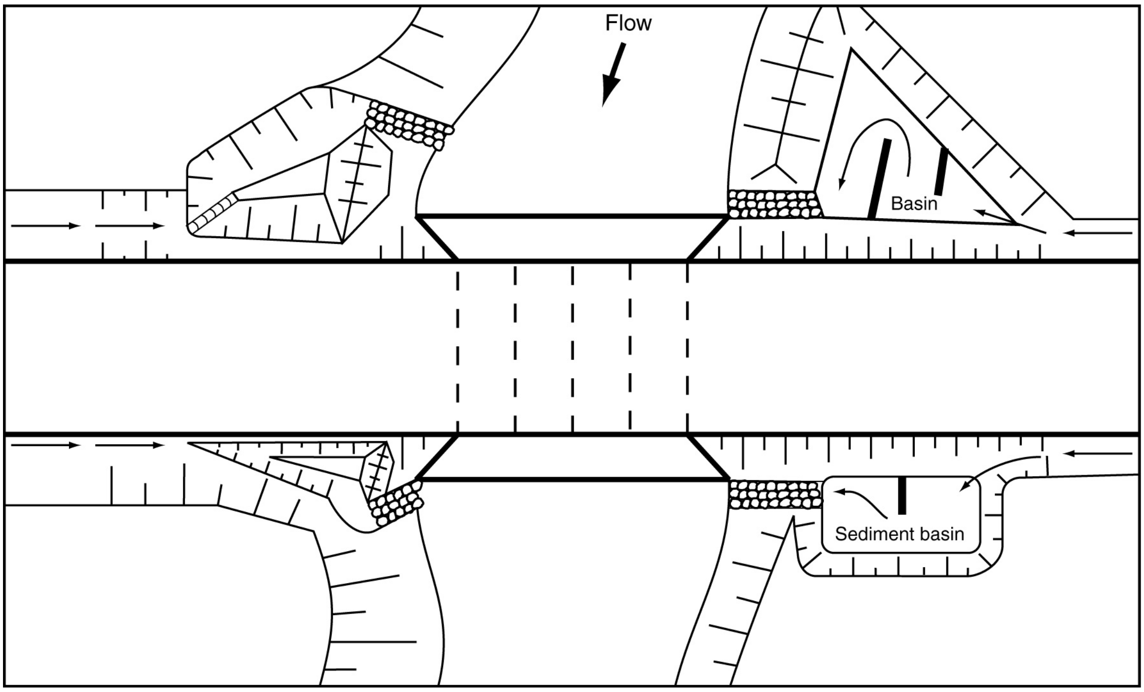


Figure I10 – Sediment basins adjacent to culvert construction

Table I3 – Sediment trap classification system

Classification	Critical entrapment particle size
Type 1	< 0.045mm
Type 2	0.045 to 0.14mm
Type 3	> 0.14mm

Table I4 – Classification of instream sediment control techniques [1]

Type 1	Type 2	Type 3
• Pump sediment-laden water to an off-stream Type F or Type D Sediment Basin or high filtration system	• Filter Tube Barrier • Rock Filter Dam • Sediment Weir	• Modular Sediment Barrier • Sediment Filter Cage • Sediment Fence • Straw Bale Barrier

Note [1] Classification may vary depending on design details

Table I5 – Recommended site conditions of use for various sediment controls

Instream sediment trap	Typical site conditions
Filter Tube Barrier	• Channels with “clear” base flow. • Channels with poor settling (i.e. clayey) sediment. • Suitable for medium and long-term works.
Floating Silt Curtain	• Water depths greater than 0.8m. • Tidal waters. • Very low velocity flow. • Typically only used as an *Isolation Barrier* and thus **not** normally placed across the full channel width.
Modular Sediment Barrier [1]	• Concrete-lined channels and overland flow paths. • Areas with poor access for heavy machinery. • Short-term works where the units can be reused.
Rock Filter Dam [1]	• Long-term works (i.e. more than 5 days). • Dry weather conditions when over-topping flows are not expected. • Constructed or heavily modified channels only. • Channels with turbid or slightly turbid low-flow.
Sediment Filter Cage [1]	• Short-term works (i.e. 1 to 2 days). • Channels with turbid or slightly turbid low-flow. • Channel containing good settling sediments. • Narrow channels.
Sediment Weir [1]	• Medium to long-term works (i.e. more than 2 days). • Channels with turbid or slightly turbid base flows. • Sites with poor machinery access. • Channels with an irregular bed shape. • Wide channels.
Sediment Fence	• Dry channels/drains when channel flow is highly unlikely. • Only suitable for trapping sediment displaced by bed/bank works.
Straw Bale Barrier	• Can be used as a temporary sediment trap while installing the primary instream sediment control device.

Note: [1] Techniques that can be supplemented with the use of one or more Filter Tubes.

Table I6 – Selection of preferred instream sediment control technique [1]

Site Condition	Technique [2]	Comments
Short-term works (1 to 2 days)	Various	Preferred choice of sediment control device depends on site conditions and knowledge gained from past practices.
Default device for medium to long-term works (> 2 days)	Filter Tubes	The *Filter Tubes* may be used in association with an earth embankment, *Rock Filter Dam, Sediment Weir,* or *Modular Sediment Barrier* in accordance with the expected base flow rate and the environmental sensitivity of the watercourse.
Deep water drain or waterway	Floating Silt Curtain	Typically used in water depths greater than 0.8m and near-zero flow velocity.
	Isolation Barrier	If significant channel flows exist, then preference should be given to the use of an *Isolation Barrier*.
No machinery access	Filter Tube Barrier	Used on medium to long-term works. Needs suitable site conditions so the *Filter Tubes* (when full) can be winched or otherwise removed from the channel. The *Filter Tubes* need to be incorporated into an in-situ *Modular Sediment Barrier, Sediment Weir* or other portable frame.
	Modular Sediment Barrier	Most components, except filter cloth, are reusable. Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
	Sediment Weir	Possible use of straw bales as the filter media within the *Sediment Weir*, or the use of lightweight modular units.
	Sediment Fence	Only suitable if channel flows are highly unlikely. Suitable for trapping minor sediment displaced by works on the bed and banks of a dry channel.
Small, constructed drain	Filter Tube Barrier	The *Filter Tubes* need to be incorporated into an in-situ *Modular Sediment Barrier, Sediment Weir* or other portable frame.
	Rock Filter Dam	Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
	Modular Sediment Barrier	Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
Low-flow concrete drain or rocky channel	Off-stream de-watering techniques	Consider the feasibility of pumping contaminated water to a *Filter Bag* or other off-stream de-watering sediment control system.
	Modular Sediment Barrier	Modular units must be wrapped in filter cloth and anchored to the channel bed. Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
	Filter Tube Barrier	*Filter Tubes* incorporated into modular filter units or an impermeable weir securely anchored to the channel bed.

Notes: [1] Instream sediment traps should only be used when delaying the works and/or the use of an *Isolation Barrier* is not practical.

[2] Techniques listed in general order of preference.

Table I7 – Selection of preferred instream sediment control technique [1]

Site Condition	Technique [2]	Comments
Significant sediment flows (in volume) are expected such as in a sandy bed channel	Sediment Cage	Used in narrow, flat-bed channels or during low flow.
	Sediment Weir	A *Sediment Weir* is a possible option if a *Sediment Cage* could not be suitably installed.
	Filter Tubes	The preferred option if high turbidity levels are expected.
	Rock Filter Dam	Not suitable if there is a high risk of failure caused by high stream flows. Generally only suitable for constructed or modified channels where heavy machinery access exists.
Channels with existing turbid low-flows	Sediment Cage	Used in narrow, flat-bed channels or during low flow.
	Sediment Weir	Possible option if no heavy machinery access exists.
	Rock Filter Dam	Suitable for constructed or modified channels where heavy machinery access exists. May not be suitable if significant stream flows are likely.
Coarse gravel bed channels	Filter Tube Barrier	The preferred option if the *Filter Tubes* can be installed without causing irreversible or unacceptable bed damage.
	Rock Filter Dam	May require the use of a thick filter cloth to separate the gravel bed and *Rock Filter Dam*. May not be suitable if significant stream flows are likely.
Natural dry-bed waterway where stream flows are most unlikely	No instream controls	Site conditions may allow instream works to occur without the need for instream sediment controls if the risk of stream flow is sufficiently low.
	Modular Barrier	Most components can be reusable from site to site.
	Sediment Weir	Use of straw bales as the filter media may allow the bales to be reused if flow does not occur.
Natural dry-bed waterway where stream flows are possible	Isolation Barrier	Stage disturbance across the channel to allow the free, uncontaminated bypass of likely stream flows or lateral inflows resulting from local storms.
	Sediment Weir	Use of straw bales as the filter media may allow the bales to be reused if flow does not occur. Otherwise consider the use of a *Modular Sediment Barrier*.
Natural waterway with minor base flow	Delay works	1st option: Delay works until a suitable low-flow period.
	Isolation Barrier	Stage disturbance across the channel to allow the free, uncontaminated bypass of stream flows with minimal impact on aquatic passage.
	Filter Tube Barrier	The *Filter Tubes* need to be incorporated into an in-situ *Modular Sediment Barrier,* or *Sediment Weir*.
Narrow channels with significant base flow	Delay works	1st option: Delay works until a suitable low flow period.
	Isolation Barrier	Stage channel disturbance wherever practical.
	Cofferdam	Cofferdam with gravity base-flow bypass pipe.
Wide channels with significant base flow	Delay works	1st option: Delay works until a suitable low flow period.
	Isolation Barrier	Stage disturbance across the channel and isolated from the main channel flow.

Notes: [1] Instream sediment traps should only be used when delaying the works and/or the use of an *Isolation Barrier* is not practical.

[2] Techniques listed in general order of preference.

(b) Sediment controls for the de-watering of the work site

The best way to minimise environmental harm is to minimise the volume of external water that is allowed to enter an excavation or trench. This is normally achieved by diverting any surface water away the work area.

All sediment-laden water pumped from the channel or an excavation must be suitably treated before being discharged back into the channel. Wherever reasonable and practicable, preference must be given to Type 1 sediment control systems, followed by Type 2, then Type 3 systems as described in Table 4.5.3 of Chapter 4 – *Design standards and technique selection*.

The preferred technique for treating contaminated water also depends on the volume of water and the frequency of such discharges. Table 4.5.15 of Chapter 4 – *Design standards and technique selection* outlines the attributes of various sediment control techniques used during de-watering operations.

When de-watering instream work sites it is important to instigate appropriate measures to minimise the risk of aquatic wildlife being sucked into the intake pipe. Such measures may include:

- removing trapped animals from enclosures prior to de-watering; and/or
- forming a wire mesh cage or similar fine mesh frame around the intake pipe; and/or
- wrapping the intake pipe in shade cloth (**not** sediment fence fabric); and/or
- placing the intake pipe inside a perforated (fine-hole size) PVC pipe; and/or
- use of a gravel-filled *Sump Pit* to house the intake pipe.

(c) Sediment controls for the de-watering of material stockpiles

The de-watering of material removed from excavations, or dredged from the channel, is normally performed by temporarily stockpiling the material within a designated sediment control area. The process may also be done after the material is loaded into a truck, in which case the truck is required to remain within the sediment control area until sufficient water has drained from the truck.

If the material is loaded directly into a truck, then where practicable, filter cloth should be placed over the ground to capture sediment spills. This also helps in the final clean-up/rehabilitation of the site.

Table 4.5.14 of Chapter 4 – *Design standards and technique selection* outlines best practice sediment control measures for the de-watering of excavated material and other stockpiles.

The recommended water quality standard for de-watering operations is presented in Tables 4.5.13 and 4.5.14 of Chapter 4 – *Design standards and technique selection*.

Table I8 provides general comments on the de-watering of various materials.

Table I8 – De-watering of excavated instream material

Material	Recommendations and comments
Black organic "muck"	**Comments:** • Avoid de-watering such material on-site if the runoff is expected to re-enter the stream, especially if the stream's flow rate is low or non-existing. • Strong odour problems often occur when stockpiling such material. • Runoff can be high in nutrients and very low in dissolved oxygen. • Few sediment controls can adequately treat such runoff unless the volume of water is so small that close to 100% infiltration occurs. • The best form of treatment involves infiltration or filtration through sand or soil. **Recommended control techniques:** • Soil infiltration or *Grass Filter Beds* for very minor quantities of material. • Otherwise, for medium to large quantities of material, establish a runoff collection sump down-slope of the stockpile area, and pump all runoff to a suitable sediment trap as per Step 7(b).
Clayey material	**Comments:** • Significant environmental problems can result if the highly turbid water is allowed to enter a water body. • Runoff is likely to contain high levels of nutrients and other pollutants. • On-site de-watering is generally not practical during extended wet weather. **Recommended control techniques:** • Soil infiltration or *Grass Filter Beds* for very minor quantities of material. • *Filter Fence* formed from well-braced filter cloth. • Otherwise, establish a runoff collection sump down-slope of the stockpile area, and pump all runoff to a suitable sediment trap as per Step 7(b).
Non-clayey material	**Comments:** • On-site de-watering is most effective for these materials. **Recommended control techniques:** • *Grass Filter Beds* for small quantities of material. • *U-shaped (non-woven) Sediment Trap* placed down-slope of stockpile. • *Filter Fence* formed from well-braced filter cloth. • Otherwise, establish a runoff collection sump down-slope of the stockpile area, and pump all runoff to a suitable sediment trap as per Step 7(b).

Step 8 Select material handling, transport, and disposal methods

Discussion is provided in Step 4 on the benefits of various work procedures. It will also be necessary for site managers to determine the preferred means of transporting materials from the site.

In most cases it will be necessary to de-water excavated material before it leaves the site. This is because it is generally unacceptable practice to transport saturated material that may discharge polluted waters along public roadways. Discussion on the de-watering of excavated material is provided in Step 7(c).

Step 9 Assess water quality monitoring requirements

Monitoring the effectiveness of the adopted work procedures and the Erosion and Sediment Control Plan (ESCP) is part of responsible site management.

ESCPs should be looked upon as living documents that can and should be modified as site conditions change. When a monitoring program detects a notable failure in the adopted ESC measures, the source of this failure should be investigated and appropriate amendments made to the plans.

Monitoring the water quality before, during and after construction will, in part, enable the effectiveness of adopted control measures to be assessed. Such monitoring should be done simultaneously upstream and downstream of the channel disturbance.

Monitoring requirements are normally specified as part of the state government licensing requirements of the instream works. Otherwise, contact the relevant State Government department for both monitoring requirements and sampling procedures.

Step 10 Determine site clean-up, stabilisation and rehabilitation

Exposed soil surfaces must be rehabilitated as soon as practicable to prevent or at least minimise the risk of environmental harm caused by long-term soil erosion. Channel banks should be actively revegetated rather than just waiting for natural regeneration (refer to Appendix N for definitions of rehabilitation, revegetation and stabilisation).

Revegetation is one of the most successful long-term stabilisation techniques for both natural and urban waterways. In-stream ecology is greatly enhanced by the re-establishment of riparian vegetation, especially bank vegetation. Riparian vegetation introduces shading for water temperature control; the establishment of habitat diversity; the creation of snags; and the linking of aquatic and riparian habitats.

Wherever reasonable and practicable, revegetate to the water's edge to increase the value and linkage of the aquatic and riparian habitats. Rock protection of the bank toe is usually required to provide stabilisation during plant establishment. Figure I11 to I16 provide examples of partial and full-face rock protection on good soils (Figures I11 to I14) and dispersive soils (Figures I15 and I16) for both open face rock and vegetated rock cases.

During plant establishment it may be necessary to protect the soil from short-term erosion with the aid of an *Erosion Control Blanket, Mat* or *Mesh*. *Erosion Control Blankets* or *Mats* reinforced with synthetic mesh are **not** recommended for use along waterways containing ground-dwelling wildlife (refer to discussion in Step 6).

The short-term maintenance of site rehabilitation can include: watering, weed control, replacement of dead or damaged plants, re-firming plants loosened by wind-rock, pruning plants of dead or diseased parts, and maintenance of protective fencing.

In the absence of a locally adopted risk assessment procedure, Table I9 is presented as the default erosion risk rating system for major drainage channels and watercourses. Table I10 presents an alternative rating system for application to minor drains and waterways where channel flow is directly related to local rainfall. Best practice requirements for the clearing and progressive stabilisation of drainage channels and watercourses are provided in Table I11.

Table I9 – Erosion risk rating based on expected channel flow conditions

Erosion risk rating	Expected flow conditions [1]
Very Low	No rainfall or channel flow expected during plant establishment.
Low	Light local rainfall is expected which is likely to result in only a minor increase in channel flow above the normal dry-weather flow rate.
Moderate	Heavy local rainfall is expected which is likely to cause stormwater inflows into the channel and a minor increase in channel flow above the normal dry-weather flow rate.
High	Medium to high-velocity in-bank flows are expected during the plant establishment period that are likely to inundate unstable, disturbed or recently revegetated channel surfaces.
Extreme	Medium to high-velocity overbank or near bankfull channel flows are expected during the plant establishment period that are likely to inundate unstable, disturbed or recently revegetated channel surfaces.

Note: [1] Erosion risk rating based on worst-case of the expected flow conditions.

Table I10 – Alternative erosion risk rating based on expected daily and average monthly rainfall

Erosion risk rating [1]	Expected 24-hour rainfall	Average monthly rainfall
Very Low	0 to 2 mm	0 to 30 mm
Low	2+ to 10 mm	30+ to 45 mm
Moderate	10+ to 25 mm	45+ to 100 mm
High	25+ to 100 mm	100+ to 225 mm
Extreme	> 100 mm	> 225 mm

Note [1] Erosion risk rating based on worst case of expected rainfall within any 24 hour period or average monthly rainfall.

Table I11 – Best practice channel clearing and stabilisation requirements

Risk [1]	Best practice requirements
All cases	• All reasonable and practicable steps taken to apply best practice erosion control measures to completed channel works, or otherwise stabilise such works, prior to an anticipated increase in stream flow.
Very low	• Channel clearing limited to maximum 8 weeks of programmed work. • Disturbed soil surfaces stabilised with minimum 70% cover [2] within 30 days of completion of works within any constructed drainage channel or waterway. • Non-completed works stabilised if exposed, or expected to be exposed, for a period exceeding 30 days.
Low	• Channel clearing limited to maximum 6 weeks of programmed work. • Disturbed soil surfaces stabilised with minimum 70% cover [2] within 30 days of completion of works within any constructed drainage channel or waterway. • Non-completed channel works stabilised if exposed, or expected to be exposed, for a period exceeding 30 days.
Moderate	• Channel clearing limited to maximum 4 weeks of programmed work. • Disturbed soil surfaces stabilised with minimum 80% cover [2] within 10 days of completion of works within any constructed drainage channel or waterway. • Appropriate consideration given to the use of rock protection, biodegradable *Erosion Control Mesh* or the equivalent, on all erodible stream banks subject to high velocity flows. • Non-completed channel works stabilised if exposed, or expected to be exposed, for a period exceeding 20 days.
High	• Channel clearing limited to maximum 2 weeks of programmed work. • Disturbed soil surfaces stabilised with minimum 90% cover [2] within 5 days of completion of works within any constructed drainage channel or waterway. • Appropriate consideration given to the use of rock protection, biodegradable *Erosion Control Mesh* or the equivalent, on all erodible stream banks subject to high velocity flows. • Non-completed channel works stabilised if exposed, or expected to be exposed, for a period exceeding 10 days.
Extreme	• Channel clearing limited to maximum 1 week of programmed work. • Disturbed soil surfaces stabilised with minimum 90% cover [2] within 5 days of completion of works within any area of a work site. • Appropriate consideration given to the use of rock protection, biodegradable *Erosion Control Mesh* or the equivalent, on all erodible stream banks subject to high velocity flows. • Non-completed channel works stabilised if exposed, or expected to be exposed, for a period exceeding 5 days.

Notes: [1] Erosion risk based on channel flow conditions (Table I9), or daily/monthly rainfall depth (Table I10) as directed by the relevant regulatory authority.

[2] Minimum cover requirement may be reduced if the natural cover of the immediate land is less than the nominated value, for example in arid and semi-arid areas.

Table I12 outlines the attributes of various short- and long-term channel bank stabilisation methods applicable during channel revegetation.

Table I12 – Bank stabilisation methods during channel revegetation

Bank stabilisation method	Uses and attributes
Short-term measures	
Hydraulically applied blankets	• Includes *Bonded Fibre Matrix* and *Compost Blankets*. • Low to medium shear strength, thus only suitable for low velocity channels. • Suitable for application on irregular surfaces and steep bank slopes. • *Compost Blankets* can provide a nutrient source.
Jute or coir blankets/matting	• Low shear strength, thus only suitable for low velocity channels. • Require good soil preparation and removal of surface irregularities from the bank.
Jute or coir mesh	• Medium shear strength. • Generally suitable for the short-term protection of drainage channels and minor stream and creeks. • Typical design life in dry environments of 12 to 24 months. • Do not represent a threat to wildlife.
Synthetic reinforced blankets/matting	• Medium shear strength • Plastic mesh can represent a threat to wildlife. • Generally **not** suitable for the stabilisation of watercourses where wildlife such as lizards, snakes and birds may be present.
Geo Logs	• Diversion of minor high-velocity flows away from seedlings planted close to the water's edge. • Protection of plants along the water's edge from wave action, particularly in lakes. • Must be used with extreme care if placed parallel to the stream flow, otherwise erosion may occur behind the logs.
Long-term measures	
UV-stabilised Turf Reinforcement Matting (TRM)	• High shear strength. • May be damaged by grass fires. • Generally **not** suitable for the stabilisation of watercourses where ground-dwelling wildlife such as platypus and bank-nesting birds may be present.
Rock stabilisation of the water's edge or toe of bank	• Used in areas where channel velocities are high, but near-bankfull flow velocities are low. • Commonly used to minimise the risk of bank erosion caused by minor flows during the revegetation phase.
Rock stabilisation (rock beaching) of full bank	• Stabilisation of very steep channel banks, with or without vegetation. • Commonly used on the outside face of high velocity or sharp channel bends, or to minimise the risk of bank erosion caused by near-bankfull flows during the revegetation phase.

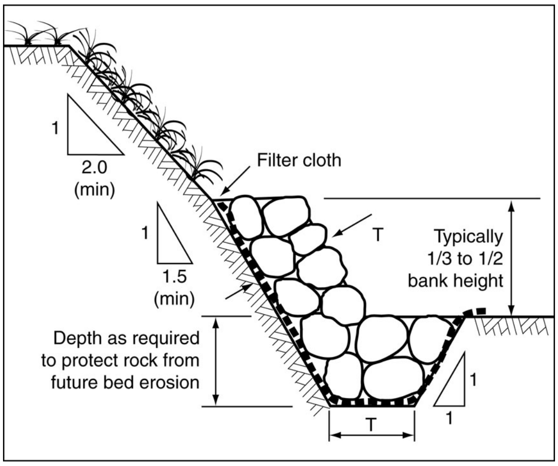


Figure I11 – Open rock, toe protection

Advantages:

Reduced quantity of rock.

Disadvantages:

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

Reduced aquatic habitat values in absence of vegetation.

Use:

Partial bank protection is used in areas where channel velocities are high, but upper-bank and overbank velocities are low.

Inside face of fully shaded, high velocity channel bends.

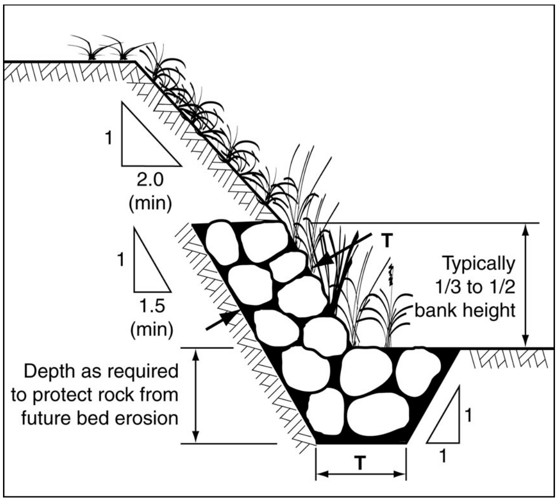


Figure I12 – Vegetated rock, toe protection

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 of upper bank soil into the rock protection.

Use:

Partial bank protection is used in areas where channel velocities are high, but upper-bank and overbank velocities are low.

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

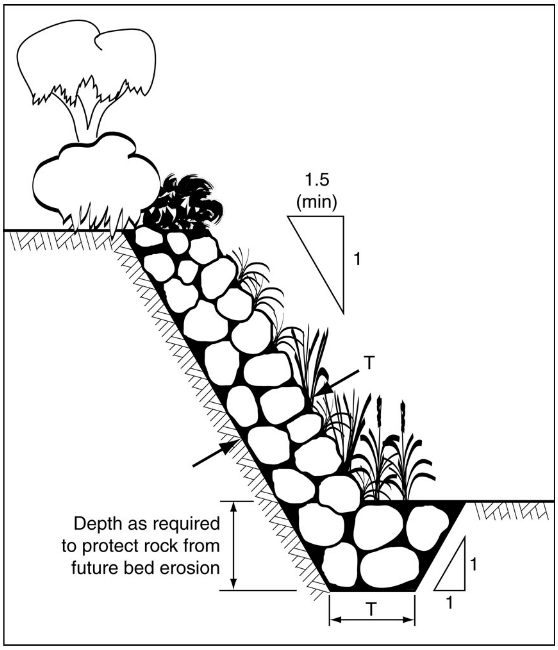


Figure I13 – Full face, vegetated rock

Advantages:

Retention of aquatic habitat values.

Very high scour protection once vegetation is established.

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.

Areas where both the channel velocity and overbank flow velocities are likely to be erosive.

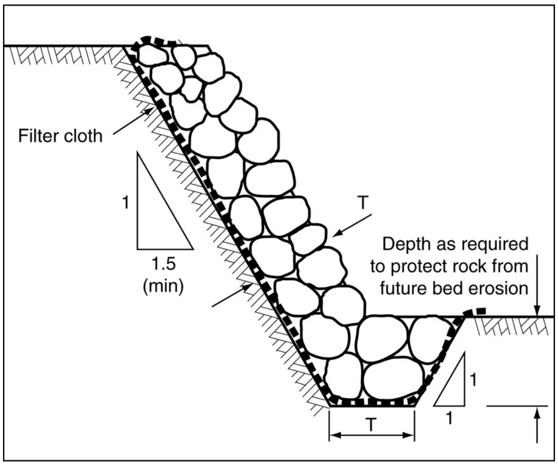


Figure I14 – Full face, open rock

Advantages:

Cheaper installation cost compared to vegetated rock protection.

Generally steeper bank grades can be formed compared to partially protected banks (Figure I11).

Disadvantages:

Poor aesthetics.

High risk of weed invasion unless fully shaded.

Use:

Fully shaded, high velocity areas.

Outside face of fully shaded channel bends.

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

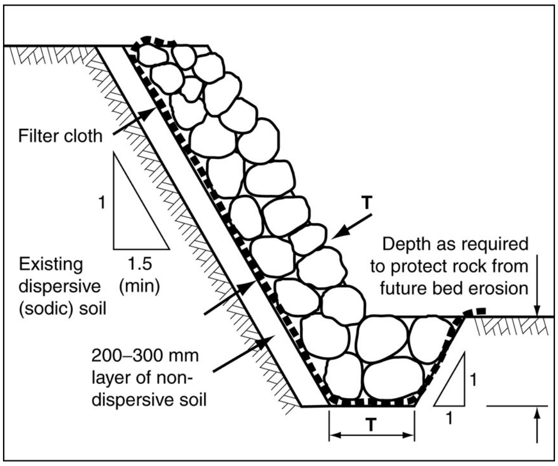


Figure I15 – Full face, open rock on dispersive soil

Advantages:

Long-term protection of highly erodible soils.

Disadvantages:

Poor aesthetics.

High risk of weed invasion unless fully shaded.

Very poor aquatic habitat values.

Use:

Rock protection in fully shaded areas containing dispersive soils.

Outside face of fully shaded channel bends.

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

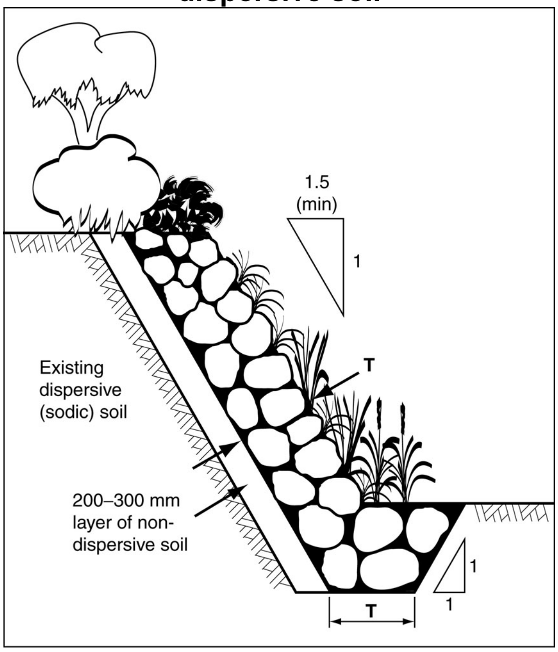


Figure I16 – Full face, vegetated rock on dispersive soil

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 overbank flow velocities are likely to be erosive.

(a) Plant selection:

Selecting the most suitable plant establishment techniques, plant species, seeding rates, planting densities, fertilisers, watering rates, and maintenance techniques, requires the guidance of experts such as local bushland groups, specialist waterway landscape and revegetation consultants, and government bodies.

The type of vegetation most critical to the stabilisation of a waterway depends on a number of factors including:

- channel flow velocity at bankfull flow;
- depth below bankfull elevation;
- frequency of bankfull flows;
- frequency of natural channel erosion (i.e. meandering);
- type and frequency of sediment movement along the channel bed;
- location of the plant within the channel cross section;
- location of the plant relative to the most immediate upstream channel bend.

An emphasis should be placed on the planting of indigenous species, preferably those grown from locally collected seed. However, this may not be the case in regions where expansion of the watercourse—caused by changes in catchment hydrology—have irreversibly converted a closed-canopy watercourse into an open-canopy watercourse. In these areas the preferred species may need to come from a downstream reach of the watercourse where a similar open-canopy occurs naturally.

The type of root system is an important erosion control characteristic of bank vegetation. Ideally, bank vegetation in dynamic creeks should have a root system with the characteristics described in Table I13.

Table I13 – Desirable plant root characteristics

Plant type	Desirable root system characteristics
Ground covers	• Vast, fibrous root ball, including near surface roots
Trees and shrubs	• A vast surface root system. • Ability to withstand long-term exposure to sun and water without drying out or fracturing as a result of debris impact during flood events. • A root system that extends below the bed level of the channel to prevent undermining.

Table I14 provides a general discussion on various vegetation types and their benefit to scour protection.

Table I15 outlines the types of vegetation most likely to be effective in the control of the various forms of channel erosion.

Table I14 – Vegetation types and erosion control characteristics

Type	Scour control	Bank stability	Hydraulic issues
Aquatic plants	Provide good stability to the low-flow channel and waters edge.	Can assist bank stability by protecting the toe of the bank. Some plants (e.g. reeds) can become inflexible as plant density increases. This can cause channel flow to be deflected into the channel bank causing bank erosion.	Minor flow resistance if the water depth is greater than the plant height, i.e. plant height is less than the bank height. Thick stands of reeds can effectively block a channel aggravating upstream flood levels.
Ground covers	The most effective form of soil erosion control. Ground covers (including grasses) generally control only soil scour (i.e. erosion of the surface layer), not the mass movement of soil resulting from bank failures. To be effective, these plants should be flexible and continuous. Isolated, clumped plants may aggravate soil erosion. Plants with a matted or fibrous (hairy) root system are the best in sandy soils.	Usually ineffective in the prevention of mass movement erosion. These plants usually have a shallow root system and thus provide only scour control. They can be very effective in the stabilisation of channel banks during the early stages of revegetation.	Generally have little effect on flood levels. Some plants, such as *Lomandra*, can grow to a height of around 1 m, and thus may choke small channels. These plants are best placed near the toe of the bank where they are fully submerged during regular flood events.
Shrubs	May provide effective scour control if the branches prevent high velocity water from coming into contact with the soil. Localised soil erosion can occur around the edge of isolated plants.	Shrubs can significantly increase bank strength depending on the height of the bank and the depth of the root system. Unlikely to prevent undermining of the bank unless the shrubs are located close to the toe of the bank.	Shrubs have the greatest potential to affect the hydraulics of the waterway and thus increase upstream flood levels. Avoid the planting of shrubs in areas where flood control is important.
Trees	Usually provide little protection against soil scour. Some plants have root systems that can survive when exposed to air. Such plants can control toe erosion.	Trees provide the main form of bank reinforcement to control mass movement. Trees are most effective in the control of bank slumping erosion and bank undercutting (but only if the roots penetrate below bed level).	Grouped trees can significantly affect flood levels if their spacing is less than say, 5 times the trunk diameter. Well-spaced trees with branches above flood level provide little hydraulic interference.

Table I15 – Plant selection for the control of watercourse erosion

Erosion form	Active force	Primary vegetation	Comments
Head-cut (bed) [1] and lateral bank erosion	Velocity		• Controls normally involve hard engineering such as rock chutes, pool–riffle systems, and grade control structures. • In gullies, stiff grasses such as vetiver grass, can be used to slowly stabilise and raise the bed gully.
Scour (bed) [2]	Velocity	Reeds (wet beds) and grasses (dry beds)	• Vegetation can be critical in shallow water channels, otherwise stabilise the bed with rock. • Grasses and other flexible, non-clumping ground covers may be used on ephemeral streambeds. • In gullies, the erosion may expose poor quality soils that require adjustment prior to revegetation.
Scour (bank) [2]	Velocity	Ground covers, vetiver grass, and/or shrubs	• Flexible ground covers in lower bank and along waters edge. • Low-branch woody species (e.g. shrubs) on mid and upper bank, especially on the outer bank of channel bends. • Generally the banks need to be “hydraulically” rougher than the channel bed.
Slumping [3]	Gravity	Trees, shrubs and vetiver grass	• Shrubs on mid and upper bank, especially on the outer bank of channel bends. • Trees on the upper bank and over-bank areas, especially on steep and high banks.
Undercutting [4]	Velocity and gravity	Ground covers, vetiver grass, shrubs and trees	• Stabilisation of the lower bank with rock and ground covers, including tall, flexible, reeds and grasses. • Shrubs on mid and upper bank, especially on the outer bank of channel bends. • Trees on the upper bank and over-bank areas, especially on steep and high banks. • Lower bank often requires mechanical support (e.g. rock and/or groynes) during the plant establishment phase.
Fretting [5]	Wave action	Reeds and mangroves	• Can be stabilised through the formation of a “beach” in front of, or as a replacement for the eroded bank. • Vegetation is often integrated with rock.

Notes:

[1] The rapid deepening of the channel bed usually resulting in the formation of a waterfall or head cut that migrates up the channel.

[2] The direct removal of material from the bed or banks resulting from water flow.

[3] The mass movement (slipping) of bank material due to either, deepening of the channel, surcharging of the bank, or the rapid lowering of flood waters.

[4] The removal of material from the base of the bank by direct water scour resulting in the creation of an overhanging bank which may or may not fail later.

[5] The direct removal of erosion-prone material from the bank by wave action. This erosion usually results in the undercutting and eventual failure of the bank.

I8. Model Code of Practice (Instream works)

Compliance with a given Performance Criterion can only be achieved by:

(i) complying with the Acceptable Solution; or

(ii) formulating an alternative solution which complies with the Performance Criterion, or is shown to be at least equivalent to the acceptable solutions; or

(iii) a combination of (i) and (ii).

Unless otherwise indicated, all outcomes listed within the Acceptable Solution must be satisfied in order to comply with the Acceptable Solution.

Attachment A forms part of this Code. The Attachment provides essential information and requirements not otherwise provided within the Code.

If the scheduled works incorporate off-stream construction activities, then the model code of practice provided in Appendix G – *Model code of practice* shall apply.

In the event of a conflict over the desired outcome of a *Performance Criterion* or an *Acceptable Solution*, then the outcome shall be that which best achieves the *objective* of the Code, that being:

> *To protect the environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.*

To achieve this objective a person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm.

In assessing all reasonable and practicable measures, appropriate consideration must be given to:

(i) the nature of the potential harm; and

(ii) the sensitivity of the receiving environment; and

(iii) the current state of technical knowledge for the activity; and

(iv) the likelihood of successful application of the various measures that might be undertaken; and

(v) the financial implications of the various measures relative to the type of activity.

The various recommendations presented in this guideline are an indication of what may be considered *reasonable and practicable* for the construction industry.

This model code of practice does not provide all the information necessary to adequately control soil erosion and sediment runoff in all situations. Users of the Code should always make their own site-specific evaluation, testing and design, and refer to their own advisers and consultants as appropriate.

Specifically, the adoption of this model code of practice will not necessarily guarantee:

(i) compliance with any statutory obligations or licence conditions;

(ii) avoidance of all environmental harm or nuisance.

SITE PLANNING AND DESIGN			
Performance Criteria		**Acceptable Solution**	
P1	Adequate data is obtained to allow appropriate site planning and design.	**A1**	(a) The extent and complexity of data collection is commensurate with the potential environmental risk, and the extent and complexity of the instream disturbance. (b) Adequate soil data is obtained for the site to: (i) identify dispersive soils; (ii) identify potential acid sulfate soils; (iii) assess site revegetation/stabilisation works; (iv) select and design ESC measures.
P2	The design and layout of instream works minimise the risk of environmental harm occurring during the construction phase.	**A2**	(a) Potential high-risk instream activities are identified during site planning. (b) Environmental risk, cost and safety are appropriately considered when determining the construction/maintenance process. (c) The design and layout of the instream works do not cause unnecessary soil disturbance if an alternative design or layout (which reduces the potential environmental harm) is available that achieves the same or equivalent project outcomes at a reasonable cost. (d) Site planning minimises the duration that any and all areas of soil will be exposed to the erosive effects of wind, rain and flowing water, in part through the progressive and prompt stabilisation of disturbed areas. (e) Instream sediment control measures are not employed if there is an appropriate off-stream sediment control process. (f) Development of the Erosion and Sediment Control Plan is an integral part of site planning. (g) Essential ESC control measures are appropriately integrated into the project's design and costing. (h) Adequate space is provided for the installation and maintenance of essential ESC measures. (i) The number of temporary watercourse crossings is minimised.
P3	The programming of instream works minimises the risk of environmental harm occurring during the construction phase.	**A3**	(a) Instream disturbances are programmed to occur during the least erosive and environmentally damaging period of the year. (b) Instream works that require the construction of a weir or cofferdam, or an alteration in stream flow conditions, including flow velocity, bed roughness or flow rate, are not programmed for those periods when essential fish migration is expected to occur.
P4	The design and layout of instream works minimise the risk of post-construction environmental harm.	**A4**	(a) Flow velocities at the inlet and outlet of permanent drainage systems (e.g. stormwater pipes) are controlled to minimise ongoing erosion. (b) To the maximum degree reasonable and practicable, instream works are designed to minimise potential environmental harm during operational works and ongoing maintenance.

EROSION AND SEDIMENT CONTROL PLAN (ESCP)			
Performance Criteria		**Acceptable Solution**	
P5	An Erosion and Sediment Control Plan (ESCP) is prepared prior to site disturbance that provides sufficient information to achieve the required environmental protection.	**A5**	(a) The design standard of drainage, erosion and sediment controls (whether instream or off-stream) comply with the requirements of the relevant regulatory authority, or where such a standard does not exist, are designed in accordance with current best practice. (b) As a minimum, the standard of drainage, erosion and sediment controls are commensurate with the site conditions, (e.g. soil type, flow rate and erosion hazard), type of watercourse, local environmental values, and the type, cost and scope of the works. (c) The level of information and detail supplied in the ESCP is commensurate with the potential environmental risk, and the complexity of the proposed works; and is of sufficient clarity to allow on-site personnel to appropriately implement the plan.
P6	The ESCP is prepared by, or under the supervision of, suitably qualified and experienced personnel.	**A6**	(a) The qualifications and experience of the personnel preparing and/or supervising the preparation of the ESCP is commensurate with the potential environmental risk, and the extent and complexity of the soil disturbance. (b) On sites with a soil disturbance greater than $50m^2$, the ESCP is signed-off by a suitably qualified and experienced professional. (c) On sites with a flow diversion barrier extending over one-third of the channel width, or a temporary structure extending over the full channel width (e.g. watercourse crossing or instream sediment trap) the ESCP is signed-off by an engineer experienced in waterway hydraulics.
P7	The ESCP remains relevant, at all times, to the current site conditions.	**A7**	(a) The ESCP remains both effective and flexible, and is based on anticipated soil, weather, stream flow, and construction conditions (as may vary from time to time). (b) The ESCP is appropriately amended if the implemented works fail to achieve the *objective* of the ESCP, the required performance standard, or the State's environmental protection requirements, or otherwise if there is the risk of serious or material environmental harm.

SITE ESTABLISHMENT			
Performance Criteria		**Acceptable Solution**	
P8	Site personnel are provided with all necessary information prior to site establishment.	**A8**	The Development Approval Conditions, Waterways Permit/Licence, Erosion and Sediment Control Plan, Monitoring and Maintenance Program, Site Rehabilitation Plan, and any other document required for the management of soil erosion and sediment control, are provided to the principal contractor prior to the commencement of land disturbing activities.

P9	Appropriate personnel are engaged to monitor the site prior to commencement of site disturbance.	**A9**	(a) Prior to the commencement of any instream disturbance, appropriately trained and experienced personnel are engaged to undertake regular ESC audits of the site. (b) Prior to commencement of site works, a "chain of command" in relation to the implementation, modification, and maintenance of ESC measures is established.
P10	Site establishment does not cause unnecessary soil disturbance or environmental harm.	**A10**	(a) No land-disturbing activities occur on the site until all appropriate ESC measures have been constructed in accordance with the ESCP and best practice erosion and sediment control. (b) All site office facilities and operational activities are located such that all effluent, including wash-down water, can be totally contained and treated within the site.
P11	Site access is appropriately managed to minimise the risk of environmental harm.	**A11**	(a) All reasonable and practicable measures are taken to ensure stormwater runoff from site access tracks and stabilised entry/exit systems, drains to an appropriate sediment control device. (b) Wherever reasonable and practicable, access tracks, whether temporary or permanent, are located a distance from the top of bank of at least 30 m, or the width of the stream (measured at the top of the bank), whichever is the lesser.

SITE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P12	The work site is managed such that environmental harm is minimised.	**A12**	(a) No land-disturbing activities (instream or off-stream) are undertaken prior to appropriate consideration being given to erosion and sediment control issues. (b) All works subject to an Erosion and Sediment Control Plan (ESCP) are carried out in accordance with the ESCP (as amended from time to time) unless circumstances arise where compliance with the ESCP would increase the potential for environmental harm as assessed by a recognised authority. (c) All ESC measures are installed, operated and maintained in accordance with current best management practice. (d) Land-disturbing activities are undertaken in such a manner that allows all reasonable and practicable measures to be undertaken to: (i) allow stormwater and stream flow to pass through the site in a controlled manner and at non-erosive flow velocities; and (ii) minimise soil erosion resulting from wind, rain and flowing water; and (iii) minimise the duration that disturbed soils are exposed to the erosive forces of wind, rain and flowing water; and (iv) prevent, or at least minimise, environmental harm (including public nuisance and safety issues) resulting from work-related soil

			erosion and sediment runoff. (e) Site spoil is lawfully disposed of in a manner that does not result in ongoing soil erosion or environmental harm.
P13	Those responsible for erosion and sediment control are appropriately trained and equipped.	**A13**	Site managers and/or the nominated responsible ESC personnel achieve and maintain a good working knowledge of the correct installation and operational procedures of all ESC measures used on the site.
P14	Disturbance to ESC measures by on-site personnel is minimised.	**A14**	(a) On-site personnel are appropriately instructed and educated as to the purpose and operation of adopted drainage, erosion and sediment control (ESC) measures, and the need to maintain such measures in proper working order at all times. (b) Unnecessary disturbance to ESC measures by on-site personnel, sub-contractors and construction traffic (including site management and material delivery vehicles) is minimised.
P15	The adopted ESC measures remain relevant at all times to the current site conditions.	**A15**	(a) Performance of the site's ESC measures is monitored in accordance with the site's Monitoring and Maintenance Program. (b) The adopted erosion and sediment control measures are appropriately amended if site conditions significantly change, or are expected to significantly change, from those conditions assumed during development of the ESCP. (c) The adopted erosion and sediment control measures are appropriately amended if the implemented works fail to achieve the "objective" of the ESCP, or the required performance standard, or the State's environmental protection requirements, or unacceptable environmental harm is occurring or is likely to occur.
P16	The work site is appropriately prepared for imminent construction activities and weather conditions.	**A16**	(a) Adequate supplies of drainage, erosion and sediment control, and relevant pollution clean-up materials, are retained on-site during the construction period. (b) Appropriate short-term drainage control measures (e.g. flow diversion around soil disturbances and recently opened trenches) are installed and operational prior to impending storms or increased stream flows.
P17	Land disturbing activities do not cause unnecessary soil disturbance.	**A17**	(a) Land disturbing activities do not cause unnecessary soil disturbance if an alternative construction process (that reduces potential environmental harm) is available that achieves the same or equivalent project outcomes at a reasonable cost. (b) The extent of unnecessary soil disturbance, including disturbances outside the designated work area, is minimised.
P18	Damage to retained or protected vegetation is minimised.	**A18**	(a) Prior to the commencement of land disturbing activities within any given area, all protected vegetation and significant areas of retained vegetation within that area, are appropriately identified to minimise the risk of disturbance to such areas.

			(b) No damage is allowed to occur to roots, trunk or branches of retained vegetation, unless under the direction of an appropriate Vegetation Management Plan.
P19	Adopted work practices minimise the release of pollutants into receiving waters.	**A19**	(a) Emergency and pollution control procedures are commensurate with the site conditions, local environmental values, and the type, cost, scope and complexity of the works. (b) All liquid chemicals, including petroleum products, that could potentially be washed or discharged from the site in association with sediment, are stored and handled on-site in accordance with relevant standards such as AS1940. (c) Adequate supplies of erosion control, sediment control, and pollution clean-up materials are retained on-site during the construction period. (d) Cement-laden runoff, concrete waste, and chemical products (including petroleum and oil-based products), are managed on-site in accordance with current best management practice. (e) All equipment is washed down (cleaned) well away from the water's edge, and in a manner that prevents sediment-laden water entering the waters. (f) All non water-soluble pollutants washed or blown onto waters are collected and secured as soon as practicable. (g) All waste receptors are sealed and/or covered outside working hours to prevent the entry of water and vermin, or wind disturbance of the contained material.
P20	Adopted work practices minimise the release of pollutants into tidal waters.	**A20**	(a) No erodible material is stockpiled within 40m from the high tide mark. (b) Sediment deposition within the voids between natural and introduced rock located within the tidal zone is minimised. (c) All materials being transported by boats or barges are adequately secured during transportation. (d) Drip pans are placed under all vehicles and motorised equipment placed on docks, barges, or other structures that extend over water bodies, if the vehicle or equipment is expected to be idle for more than 1 hour. (e) All barges are fitted with watertight curbs or toe boards to contain spills and prevent materials, tools, and debris from leaving the barge. (f) All appropriate measures are deployed to provide secondary containment for any spills while materials and/or equipment are being transferred on and off barges to (e.g. floating sediment curtains).

P21	Environmental harm, safety issues, and nuisance or damage to public and private property resulting from off-site sediment deposits, material spills, and/or the adopted ESC measures is minimised.	**A21**	(a) Sediment and other material originating from the work area, or as a result of the transportation of materials to or from the work area, that collect on sealed roads, or within gutters, drains or drainage channels outside the immediate work area, is removed: (i) immediately if rain is occurring or imminent; or (ii) immediately if considered a safety hazard; or (iii) if items (i) or (ii) do not apply, as soon as practicable, but before completion of the day's work. (b) The adopted ESC measures do not adversely affect drainage or flooding conditions within neighbouring properties.
P22	Potential safety risks to site workers and the public as a result of ESC measures are minimised.	**A22**	All stream flow diversion and ESC measures are installed and operated in a manner that does not cause a safety risk to the public or site personnel.
P23	Potential harm to wildlife as a result of ESC measures is minimised.	**A23**	(a) Disturbance to wildlife habitats is limited to the minimum necessary to complete the approved works. (b) Synthetic (plastic) reinforced fabrics are not placed within, or adjacent to, bushland areas, riparian zones and watercourses if such materials are likely to cause harm to wildlife or wildlife habitats. (c) The design of temporary instream structures does not adversely impact on terrestrial and aquatic passage along the waterway. (d) To the maximum degree reasonable and practicable, instream disturbances are programmed to occur during periods of least impact to fish migration. (e) Sediment traps, flow diversion systems and isolation barriers allow appropriate egress of wildlife where such wildlife could enter such areas. (f) Site rehabilitation procedures and outcomes are compatible with site conditions and local environmental values (including local wildlife).

SITE DISTURBANCE			
Performance Criteria		**Acceptable Solution**	
P24	Potential environmental harm resulting from land clearing is minimised.	**A24**	(a) All land clearing is conducted in accordance with State and local government Vegetation Protection and/or Preservation requirements and/or policies. (b) No instream disturbances are undertaken prior to development of a Vegetation Management Plan. (c) No instream soil disturbance occurs until the principal instream works are ready to commence. (d) Controls placed on the extent and duration of soil disturbance are commensurate with the potential erosion risk and/or erosion hazard.

			(e) To the maximum degree reasonable and practicable, disturbance to deep-rooted vegetation on slopes susceptible to mass movement is minimised, if not totally avoided. (f) Compliance with Performance Criterion P18.
P25	Disturbance to natural watercourses is minimised.	**A25**	(a) Disturbance to natural watercourses (including bed and bank vegetation) and their associated riparian zones is limited to the minimum necessary to complete the approved works. (b) The number, location, type and size of temporary watercourse crossing are such that the overall adverse impact on the environment is minimised. (c) All temporary watercourse crossings, including their approach roads, employ appropriate drainage, erosion and sediment controls to minimise sediment inflow into the watercourse.
P26	Disturbance to tidal and intertidal areas including any associated riparian zones is minimised.	**A26**	(a) Disturbance to aquatic vegetation, particularly seagrasses and mangroves, is minimised. (b) Vehicle/boat damage to seawalls (e.g. due to wave and wash conditions) is minimised.

SOIL AND STOCKPILE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P27	Maximum benefit is obtained from existing topsoil.	**A27**	(a) The topsoil is managed (i.e. stripped, treated, stockpiled and reused) in accordance with the recommendations of an approved Vegetation Management Plan or similar. OR (b) Topsoil is stripped, stockpiled, placed, and where necessary treated, in accordance with current best practice.
P28	Environmental harm caused by the temporary stockpiling of erodible material is minimised.	**A28**	Stockpiles of erodible material are: (i) appropriately protected from wind, rain and surface flows in accordance with current best practice; and (ii) located at least 2 m from hazardous areas, retained vegetation; and (iii) located up-slope of an appropriate sediment control system.
P29	Exposed dispersive soils are managed such that the risk of ongoing soil erosion is minimised.	**A29**	Construction details for drainage systems and bank stabilisation works within dispersive soil areas clearly demonstrate how these soils will be managed to prevent future erosion problems.
P30	Exposed potential acid sulfate soils are appropriately managed.	**A30**	(a) If acid sulfate soils conditions exist on site, then appropriate warnings are placed on the ESCP. (b) All exposed actual or potential acid sulfate soils are managed in accordance with current best practice. (c) On-site personnel involved in the disturbance of actual or potential acid sulfate soils are appropriately trained and/or supervised.

MANAGEMENT OF STREAM FLOW			
Performance Criteria		**Acceptable Solution**	
P31	Temporary drainage control measures are designed, constructed and maintained to an appropriate standard.	**A31**	(a) The standard of stream flow control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, flow controls are designed in accordance with current best practice. (b) The adopted stream flow control measures remain relevant, at all times, to the current and imminent site conditions. (c) Instream flow diversion structures are structurally sound during a 1 in 2 year ARI channel flow. (d) Wherever reasonable and practicable, isolation barriers do not isolate more than 30% of the channel width at any given time, otherwise not more than 50%, while channel flows are occurring.

DRAINAGE CONTROL			
Performance Criteria		**Acceptable Solution**	
P32	Temporary drainage control measures are designed, constructed and maintained to an appropriate standard.	**A32**	(a) The standard of drainage control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, drainage controls are designed in accordance with current best practice. (b) The adopted drainage control measures remain relevant, at all times, to the current and imminent site conditions.
P33	Stormwater movement through the site is appropriately managed to minimise soil erosion.	**A33**	(a) If the overbank drainage area up-slope of a soil disturbance exceeds 1500 m^2, and the average monthly rainfall exceeds 45 mm, all stormwater discharged from this area (up to the design storm) is diverted around or through the soil disturbance in a manner that minimises soil erosion. (b) Appropriate drainage controls are installed above an exposed stream bank to minimise soil erosion on the bank. (c) Flow velocities within flow diversion channels and at the entrance and exit of all drainage structures (including *Chutes*, and *Slope Drains*) are controlled in such a manner that prevents soil erosion during all discharges up to the relevant design discharge.
P34	Stormwater movement through the site is appropriately managed to minimise environmental harm.	**A34**	(a) Overbank stormwater runoff passing around or through the work site does not cause erosion to the banks of water bodies. (b) All reasonable and practicable measures are taken to ensure stormwater runoff entering an area of soil disturbance is diverted around or through that area in a manner that minimises soil erosion and contamination of that water for all discharges up to the specified design discharge.

			(c) Adequate drainage controls (e.g. cross drainage systems and/or longitudinal drainage) are applied to access tracks to minimise erosion on, and sediment runoff from, such areas.

EROSION CONTROL			
Performance Criteria		**Acceptable Solution**	
P35	Erosion control measures are designed, installed and maintained to an appropriate standard.	**A35**	(a) The standard of erosion control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, erosion controls are designed in accordance with current best practice. (b) As a minimum, the type and degree of erosion control are commensurate with the expected site conditions, soil type, stream flow, potential environmental risk, and the type, cost and scope of the works. (c) The adopted erosion control measures remain relevant, at all times, to the current and imminent site conditions.
P36	The control of soil erosion is given appropriate priority.	**A36**	(a) Wherever reasonable and practicable, priority is given to the prevention, or at least minimisation, of soil erosion, rather than allowing soil erosion to occur and trying to trap the resulting sediment. (b) The existence of best practice sediment control measures within a given sub-catchment does not diminish the need for the application of current best-practice erosion control measures.
P37	Soil erosion is minimised.	**A37**	(a) Existing ground covers are protected from damage and retained as long as practicable. (b) Site activities are carried out in a manner that minimises the duration that any and all disturbed soil surfaces are exposed to the erosive forces of wind, rain and flowing water. (c) All temporary erosion control measures are appropriately anchored to the soil as appropriate for the expected flow conditions. (d) Mechanical equipment does not enter the channel if alternative equipment or construction procedures are available that would allow the works to be conducted from an overbank location.
P38	Soil erosion resulting from stream flow is minimised.	**A38**	(a) All reasonable and practicable steps are taken to apply best practice erosion control measures to completed channel works, or otherwise stabilise such works, prior to an anticipated increase in stream flow. (b) Bed and bank stabilisation and revegetation methods are appropriate for the expected stream flow conditions such that ongoing soil erosion is minimised. (c) Dispersive soils are either treated, or covered with a layer of non-dispersible soil (200 mm minimum) before being covered with vegetation, rock, mulch, or erosion control blankets.

SEDIMENT CONTROL			
Performance Criteria		**Acceptable Solution**	
P39	Sediment control measures are designed, installed, operated and maintained to an appropriate standard.	**A39**	(a) The standard of sediment control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, sediment controls are designed in accordance with current best practice. (b) As a minimum, the type and degree of sediment controls are commensurate with the expected site conditions, soil type, stream flow, potential environmental risk, and the type, cost and scope of the works. (c) Instream sediment control measures are designed for the expected base flow (i.e. stream flow not affected by flood flows or storm runoff). (d) The adopted sediment control measures remain relevant at all times to the current and imminent site conditions.
P40	Sediment contamination of instream waters is minimised.	**A40**	(a) All reasonable and practicable measures are taken to prevent, or at least minimise, the release of sediment from overbank areas into waters. (b) Wherever reasonable and practicable, instream disturbances are managed in accordance with the following hierarchy: (i) minimise, if not totally avoid, direct contamination of stream flows (e.g. through the use of flow diversion systems and the appropriate timing of instream works); (ii) treatment of sediment-laden water within off-stream sediment traps; (iii) treatment of sediment-laden water within instream sediment traps. (c) A suitable off-stream sediment trap is placed down-slope of any off-stream soil disturbance prior to the disturbance occurring. (d) Appropriate stream flow and/or sediment controls are installed and made operational before any instream soil disturbance occurs.
P41	Sediment displaced off site by vehicular traffic is minimised.	**A41**	(a) Number of site entry/exit points is limited to the minimum practical number. (b) Site entry/exit points are appropriately designed and stabilised to minimise sediment being washed off the site or into adjacent waters. (c) Sediment-laden stormwater runoff from access tracks and stabilised entry/exit systems drains to an appropriate sediment control device.
P42	Sediment-related environmental harm resulting from de-watering activities is minimised.	**A42**	(a) Flow diversion barriers, or other appropriate systems, are used to minimise the quantity of watering entering excavations and trenches. (b) As a minimum, sediment control measures implemented for the control of sediment-laden discharge from de-watering activities are designed to satisfy current best practice.

SITE STABILISATION AND REHABILITATION			
Performance Criteria		**Acceptable Solution**	
P43	Site rehabilitation, including site revegetation, is designed, installed and maintained to an appropriate standard.	**A43**	(a) A Site Stabilisation Plan or similar is prepared and approved by the relevant regulatory authority prior to site establishment. (b) The standard of site rehabilitation complies with the requirements of the relevant regulatory authority or, where such a standard does not exist, complies with current best practice. (c) As a minimum, the type and degree of site rehabilitation is commensurate with the expected site conditions, soil type, stream flow, potential environmental risk, and the type, cost and scope of the works.
P44	Site rehabilitation methods and procedures minimise the risk of environmental harm.	**A44**	(a) Site revegetation (excluding temporary revegetation conducted for purposes of erosion control) is conducted in accordance with a Site Stabilisation Plan or similar, where such a plan exists. (b) Disturbed soil surfaces are appropriately stabilised to minimise the risk of short-term soil erosion. (c) All temporary ESC measures are removed and the land rehabilitated as soon as practicable after their use is no longer needed.
P45	Site rehabilitation methods, procedures and outcomes are compatible with site conditions and local environmental values.	**A45**	(a) The qualifications and experience of the personnel preparing and/or supervising the preparation of any Site Stabilisation Plan, Vegetation Management Plan, or similar, is commensurate with the potential environmental risk, and the extent and complexity of the works. (b) Plant selection and landscape design are compatible with identified environmental values.

SITE INSPECTION AND MONITORING			
Performance Criteria		**Acceptable Solution**	
P46	A Monitoring Program is prepared by, or under the supervision of, suitably qualified and experienced personnel.	**A46**	(a) A Water Quality Monitoring Program is prepared and approved by the relevant regulatory authority prior to site establishment. (b) The qualifications and experience of the personnel preparing and/or supervising the preparation of the Monitoring and Maintenance Program is commensurate with the potential environmental risk, and the extent and complexity of the works.
P47	The performance of the site's drainage, erosion and sediment control measures is regularly monitored.	**A47**	(a) The extent and complexity of site monitoring (including water quality monitoring) is commensurate with the potential environmental risk, and the extent and complexity of the works. (b) A record is maintained of the site's compliance and non-compliance with erosion and sediment control approval requirements. (c) All site monitoring data including environmental incidents, rainfall records, dates of water quality testing, testing results, and records of controlled water releases for the site, are kept in a register.
P48	The site's stream flow, drainage, erosion and sediment control measures remain relevant at all times to the current site conditions.	**A48**	All stream flow and ESC measures are inspected by site personnel: (i) at least daily (when work is occurring on-site); (ii) at least weekly (when work is not occurring on-site); (iii) within 24 hours of expected rainfall; and (iv) within 18 hours of a rainfall event of sufficient intensity and duration to cause runoff on the site.

SITE MAINTENANCE			
Performance Criteria		**Acceptable Solution**	
P49	All ESC measures are maintained in proper working order at all times during their required operational life.	**A49**	(a) All ESC measures are maintained in proper working order for the duration of the period in which their operation is required in order to satisfy the required treatment standard, and/or the objective of the ESCP. (b) All sediment control measures are maintained in accordance with the requirements of the relevant regulatory authority, or where such a standard does not exist, in accordance with current best practice. (c) As a minimum, the maintenance of all ESC measures is commensurate with the expected site conditions, and potential environmental risk.
P50	The maintenance of ESC measures does not cause environmental harm.	**A50**	All materials removed from ESC devices during maintenance or decommissioning, whether solid or liquid, is lawfully disposed of in a manner that does not cause ongoing soil erosion or environmental harm.

Attachment A (Instream works code of practice)

SITE PLANNING AND DESIGN

The *intent* of the Site Planning and Design section is to:

- Enable erosion and sediment control issues to appropriately influence the planning and design of instream works for the purpose of minimising their overall adverse environmental impact.
- Enable planners and designers to recognise that along with consideration of the operational phase of a development, appropriate consideration must be given to how something is to be constructed and maintained, and the potential adverse impacts of the construction and maintenance phases.
- Take all reasonable and practicable measures to actively avoid foreseeable soil erosion problems and associated environmental hazards during the construction phase.

The term "maintenance phase" refers to such activities as the de-silting of instream structures such culverts, stormwater pipes, and permanent instream sediment traps.

Acceptable Solution A1(a)
Data collection may include: soil testing, identification of potential site constraints, and development of a Conceptual Erosion and Sediment Control Plan (where such data and/or plans are considered reasonably necessary to enable appropriate site planning and design). Appropriate site planning and design refers to the aim of minimising the potential environmental harm (both during the construction and operational phases) of the instream works. The extent and complexity of data collection is discussed further in Chapter 3 – *Site planning*.

The "potential environmental risk" relates to the potential of a land-disturbing activity to cause harm, whether material, serious, reversible or irreversible, to an environmental value, including nuisance to a neighbouring property or person. The potential environmental risk is related, in part, to the assessed Erosion Hazard (refer to Appendix F – *Erosion hazard assessment*).

Acceptable Solution A1(b)
Data collection necessary to assist the design of site revegetation is outlined in Sections C3 and C9 of Appendix C – *Soils and revegetation*.

Acceptable Solution A2(a)
Construction activities that are deemed to represent a high to extreme erosion hazard include:

- Any disturbance of high to extreme hazard areas, or a problematic soil that could result in unmanageable soil erosion and/or environmental harm.
- Any construction or building activity, or procedure, that could potentially cause "serious" environmental harm.
- Any soil disturbance that could cause the transformation of significant quantities of potential acid sulfate soils (PASS) into actual acid sulfate soils (AASS), such as to cause "material" or "serious" environmental harm.

Acceptable Solution A2(f)
Ideally, Erosion and Sediment Control Plans (ESCPs) should be developed in close association with construction planning because the needs and limitations of the construction process represent an important component of the ESCP. In theory, a construction process cannot be finalised without reference to an ESCP, and an ESCP cannot be finalised without knowledge of the construction process.

Acceptable Solution A2(g)
Essential ESC control measures includes any instream sediment control and flow diversion systems, and bank and overbank drainage, erosion or sediment control measures.

Acceptable Solution A2(h)
The most critical issue is ensuring sufficient space is available to construct and maintain all *Sediment Basins* and flow diversion systems.

Acceptable Solution A2(i)
"Temporary" watercourse crossings refer to those crossings constructed for use only during the construction phase.

Acceptable Solution A3(a)
Minimising the potential environmental harm can be achieved, in part, by scheduling major land disturbances, and disturbances to high and extreme erosion risk areas, for the least erosive periods of the year.

The least erosive period of the year is usually the period of lowest stream flow. The least environmentally damaging period of the year usually relates to periods of no, or minimum, fish migration. Refer to State fisheries authorities for advice.

Acceptable Solution A4(a)
Ongoing erosion problems can result from any of the following:
- changes to the volume, duration, frequency or rate of stormwater runoff;
- excessive (i.e. erosive) flow velocities;
- inappropriate distribution of flow velocities throughout the depth and width of flow discharged from a stormwater drain into a receiving water;
- inappropriate direction of flow discharged from a stormwater drain into a receiving water.

Acceptable Solution A4(b)
"Ongoing maintenance" refers to such activities as the de-silting of instream structures such culverts, stormwater pipes, and permanent instream sediment traps.

EROSION AND SEDIMENT CONTROL PLAN (ESCP)

The *intent* of this section is to ensure Erosion and Sediment Control Plans (ESCPs):
- are appropriate for the site conditions, which may vary from time to time;
- are prepared by, or under the supervision of, suitable personnel;
- are able to achieve the required design standard and environmental protection.

Acceptable Solution A5(a)
Such a clause shall not reduce the responsibility of applying and maintaining, at all times, all necessary sediment control measures in accordance with the sediment control standard.

Acceptable Solution A5(b)
Refer to A1(a) for discussion on "environmental risk".
It is recognised that the degree of erosion and sediment control is related to the type, cost and scope of works in addition to the environmental risk. This association is acknowledged within the terms of current best practice erosion and sediment control as defined within this document (2008 conditions).

Acceptable Solution A5(c)
On very minor works, such as regular council maintenance activities, or the installation of minor services, the ESCP may be represented by standard drawings prepared by the principle company/organisation as part of an in-house Code of Practice. The key *intent* is to ensure that appropriate consideration is given to erosion and sediment control requirements **before** works commence.

For instream works with a soil disturbance greater than 50 m^2, the Erosion and Sediment Control Plan (including supporting documentation and construction specifications) must include:
(i) North point and plan scale.
(ii) Site and easement boundaries and adjoining roadways.
(iii) Construction access points.
(iv) Site office, car park and location of stockpiles.
(v) Proposed construction activities and limits of disturbance.
(vi) Retained vegetation including protected trees.
(vii) General soil information and location of problem soils.
(viii) Location of critical environmental values (where appropriate).
(ix) Existing site contours (unless the provision of these contours adversely impacts the clarity of the ESCP).

(x) Final site contours including locations of cut and fill.
(xi) General layout and staging of proposed works.
(xii) Location of all drainage, erosion and sediment control measures.
(xiii) Full design and construction details (e.g. cross-sections, minimum channel grades, channel linings,) for all drainage and sediment control devices, including *Flow Diversion Barriers* and instream sediment traps.
(xiv) Construction specifications for adopted ESC measures (as appropriate).
(xv) Site revegetation requirements (if not contained within separate plans).
(xvi) Site Monitoring and Maintenance Program, including the location of proposed water quality monitoring stations.
(xvii) Technical notes relating to:
- site preparation and land clearing;
- extent, timing and application of erosion control measures;
- temporary ESC measures installed at end of working day;
- temporary ESC measure in case of impending storms or elevated stream flows, or emergency situations;
- installation sequence for ESC measures;
- application rates (or at least the minimum application rates) for mulching and revegetation measures;
- legend of standard symbols used within the plans.

(xviii) Calculation sheets for the sizing of ESC measures.
(xix) A completed Erosion and Sediment Control Plan checklist such as presented in *(insert publication).*
(xx) Any other relevant information the regulatory authority may require to properly assess the ESCP.

The ESCP must clearly state that no land-disturbing activities shall occur on the site until all associated perimeter ESC measures, including flow diversion barriers, sediment traps and temporary drainage controls, have been constructed in accordance with the ESCP and current best practice erosion and sediment control procedures.

Acceptable Solution A6(a) & (b)
A suitably qualified and experienced professional is defined as a person with:
(i) training and/or qualifications in erosion and sediment control that are recognised by the regulatory authority; and
(ii) professional affiliations with an engineering, environmental engineering, soil science, and/or scientific organisation (e.g. the International Erosion Control Association; Engineers Australia; Environment Institute of Australia and New Zealand; or the Australian Society of Soil Science Inc.) and
(iii) at least 2 years experience in the management of erosion and sediment control that can be verified by an independent third party.

ESCPs for high-risk sites should be reviewed by a suitably qualified and experienced third party reviewer prior to its implementation.

The assessment and categorisation of high-risk sites may be defined by the relevant regulatory authority; otherwise, refer to the discussion in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

Acceptable Solution A6(c)
The *intent* is to ensure the adoption of appropriate design procedures for temporary instream structures, and to minimise the risk of avoidable harm to the waterway.

Acceptable Solution A7(a)
The timing and degree of ESC specified in the Erosion and Sediment Control Plan(s) needs to be appropriate for the given soil properties, expected weather conditions, and susceptibility of the receiving waters to environmental harm resulting from sediment-laden runoff. Current (2008) best practice design standard of the drainage, erosion and sediment control measures are outlined in Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A7(b)
Additional and/or alternative erosion and sediment control measures must be implemented, and a revised Erosion and Sediment Control Plan (ESCP) must be prepared and submitted to relevant regulatory authority for approval (where required) in the event that:

(i) site conditions significantly change from those previously anticipated; or
(ii) there is a high probability that serious or material environmental harm might occur as a result of sediment leaving the site; or
(iii) the implemented works fail to achieve the adopted ESC standard, or the State's environmental protection requirements; or
(iv) site inspections indicate that the implemented works are failing to achieve the "objective" of this ESCP.

SITE ESTABLISHMENT

The *intent* of this section is to ensure that during site establishment:

- on-site personnel are provided with all necessary information to fully comply with all legal requirements, minimise environmental harm, and achieve the objective of the ESCP; and
- land disturbing activities proceed in a manner consistent with the objective of the ESCP.

Acceptable Solution A8
Supply of such material is relevant only to that material that exists, or is required to exist.

Acceptable Solution A9(a)
On low-risk site, ESC audits (including site inspections and water quality monitoring) may be performed by site personnel; however, as the risk of environmental harm increases, the need for third-party site inspections and water quality monitoring increases.

In reference to instream works, "low-risk sites" would include works conducted within dry-bed channels during periods when stream flow is highly unlikely.

Personnel undertaking ESC audits of a site must, collectively, have the following capabilities:

(i) an understanding of the local environmental values that could potentially be affected by the proposed works; and
(ii) a good working knowledge of the site's Erosion and Sediment Control (ESC) issues, and potential environmental impacts, that is commensurate with the complexity of the site and the degree of environmental risk; and
(iii) a good working knowledge of current best practice ESC measures for the given site conditions and type of works; and
(iv) ability to appropriately monitor, interpret, and report on the site's ESC performance, including the ability to recognise poor performance and potential ESC problems; and
(v) ability to provide advice and guidance on appropriate measures and procedures to maintain the site at all times in a condition representative of current best practice, and that is reasonably likely to achieve the required ESC standard; and
(vi) a good working knowledge of the correct installation, operational and maintenance procedures for the full range of ESC measures used on the site.

Acceptable Solution A9(b)
The construction industry's method of dealing with workplace safety issues is a good model for the development of an appropriate "chain of command" for the protection of environmental values. The aim is to produce a fair, reasonable and practicable approach based on environmental risk.

As in workplace safety, the responsibility of environmental protection, and therefore erosion and sediment control, rests with **all** site personnel, whether or not the work site is the normal place of work of any and all personnel. Establishing a "chain of command" does **not** diminish the responsibility of each and every person to take all reasonable and practicable measures to minimise environmental harm resulting from their actions as per their "environmental duty of care".

Acceptable Solution A10(a)
The exception to this clause is land disturbance necessary to provide access and allow the installation the initial ESC measures.

In general, initial land-disturbing activities should be limited to the establishment of the site compound, site entry/exit points, temporary drainage controls (including drain stabilisation measures), haul road(s), perimeter sediment controls, installation of flow diversion barriers, and any sediment basins/traps required for the first stage of works.

Acceptable Solution A10(b)
"Operational activities" include such things as material stockpiles, storage areas, or concrete waste receptors.

Acceptable Solution A11(a)
It is recognised that it may not be practicable for **all** stormwater runoff from **all** areas of site entry/exit paths to be directed to a sediment trap; however, such areas must be limited to the minimum practicable.

SITE MANAGEMENT

Acceptable Solution A12(a)
Where appropriate, an Erosion and Sediment Control Plan is prepared (in accordance with Section G3.3), and where necessary approved by a relevant regulatory authority, prior to commencing any land-disturbing activities.

Acceptable Solution A12(b)
The potential for environmental harm must be assessed by a recognised expert or authority.

Acceptable Solution A12(c)
Refer to A1(a) for a discussion on "potential environmental risk".

Acceptable Solution A12(d)
Applies to all land-disturbing activities, whether planned or unplanned, and especially to any works that are required to be conducted without an associated Erosion and Sediment Control Plan.

Acceptable Solution A12(d)(iv)
Includes ensuring that the value and use of land/properties adjacent to the development (including roads) are not diminished as a result of work-related soil erosion and sediment runoff.

Acceptable Solution A13
"Responsible ESC personnel" are those persons employed or contracted by the landowner and/or developer as the principal officer(s) responsible for ensuring appropriate application of the planned ESC measures and for the provision of advice in response to unplanned ESC issues.

Acceptable Solution A14(a)
Recommended training requirements are discussed in Section 6.19 of Chapter 6 – *Site management*.

Acceptable Solution A14(b)
Necessary disturbance to ESC measures would include the short-term removal of an ESC measure to allow the installation of services under the ESC measure, or to allow vehicular or material access.

Performance Criterion P15
Performance Criteria P15 and P16 require work sites to be appropriately prepared for both current and imminent site conditions. Compliance with these criteria requires ESCPs to be living documents that remain both effective and flexible, and thus are able to appropriately adapt to changing site conditions.

Acceptable Solution A15(b)

A significant change in site conditions includes:

- unseasonable weather conditions;
- unseasonable stream flow;
- exposure of problematic soil conditions not previously anticipated;
- significant change in construction methodology, staging or programming of earthworks and/or site stabilisation activities;
- significant change in the development design or layout;
- an unprogrammed site shutdown.

Performance Criterion P16

Performance Criteria P15 and P16 require work sites to be appropriately prepared for both current and imminent site conditions. Compliance with these criteria requires ESCPs to be living documents that remain both effective and flexible, and thus are able to appropriately adapt to changing site conditions.

Acceptable Solution A18(a)

Appropriate identification depends on the level of risk of damage to protected or retained vegetation. Appropriate identification does not necessarily mean markers, signs or fencing; however, such measures may be appropriate in some areas.

Acceptable Solution A19(b)

AS1940 *The storage and handling of flammable and combustible liquids* (as amended from time to time).

In addition to the above:

- Impervious bunds must be constructed around all storage areas containing more than 1m^3 of petroleum and oil-based products such that the enclosed volume is large enough to contain 110% of the volume held in the largest, individual storage tank.
- On-site personnel involved in the handling and storage of flammable and combustible liquids, including all liquid chemicals, must be appropriately trained and/or supervised, as required in order to allow such personnel to appropriately preform such activities.

Acceptable Solution A19(d)

Current (2008) best practice requires that all reasonable and practicable measures are taken to:

(i) prevent the release of cement-laden runoff, concrete waste, and chemical products (including petroleum and oil-based products), into an internal or external water body, completed internal drainage systems, or any external drainage system, excluding those on-site drains and water bodies specifically designed to contain and/or treat such material;

(ii) ensure all solid and liquid waste from concrete production, concreting equipment (including delivery and placement vehicles), is fully contained within the property;

(iii) ensure cement residue from work activities is:
- retained on a pervious surface (e.g. a grassed or open soil area, or excavated trench); or
- filtered through a fine-grained, porous, earth embankment; or
- collected and disposed of in a manner that minimise ongoing environmental harm.

Acceptable Solution A19(e)

Current (2008) best practice requires that wherever practicable, the washing of tools and painting equipment is carried out in a manner that:

(i) complies with current State guidelines, policies and legislation; and

(ii) fully contains any contaminated waste water for later treatment and/or lawful disposal; or

(iii) appropriately filters (e.g. through a fine-grained, porous earth embankment) any contaminated liquid prior to its release from the immediate work area; or

(iv) appropriately infiltrates all contaminated liquid matter into an area of porous grass or open soil.

Acceptable Solution A21(a)

“Sediment and other material” includes clay, silt, sand, gravel, soil, mud, cement and fine-ceramic waste.

Acceptable Solution A21(b)
Sealed surfaces include sealed roads and car parks.

In circumstances where the washing/flushing of sealed surfaces is required, all reasonable and practicable sediment control measures must be employed to prevent, or at least minimise, the release of sediment into receiving waters. Only those measures that will not cause safety issues or adverse property flooding to third parties shall be employed.

Acceptable Solution A22
"Appropriate consideration" includes taking all reasonable and practicable measures to minimise safety risks. As a general rule, safety issues take a higher priority than ESC issues; however, this does **not** mean that the existence of potential safety issues diminishes the ESC standard required of a work site.

Public safety risks include potential damage to public vehicles resulting from the use of inappropriate kerb-inlet sediment traps on public roads. The potential safety risk of a proposed sediment trap to site workers and the public must be given appropriate consideration **before** its installation, especially those sediment traps located within publicly accessible areas.

Sediment and sediment-laden runoff must not settle or collect on public roadways where such material could result in a traffic or safety hazard.

Performance Criterion P23
The protection of wildlife does not diminish the required ESC standard, or the need to take all reasonable and practicable measures to minimise environmental harm resulting from soil erosion and displaced sediment.

Acceptable Solution A23(c)
Refer to Witheridge (2002) for guidelines on the design of fish-friendly watercourse crossings.

Acceptable Solution A23(b)
Synthetic reinforced fabrics include "plastic" reinforced *Erosion Control Blankets*, *Mats* and *Meshes*.

SITE DISTURBANCE

Acceptable Solution A24(d)
Operational restrictions on the extent and duration of land disturbance, including land clearing only apply when such land disturbance is at risk, or potentially at risk, of erosion by wind, rain or flowing water.

The potential erosion risk is related (in part) to the potential rainfall erosivity as defined in Section 4.4 of Chapter 4 – *Design standards and technique selection*. The potential erosion hazard may be identified through the application of an appropriate Erosion Hazard Assessment scheme such as those discussed in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

Acceptable Solution A24(e)
The full impact of the removal of deep-rooted vegetation from steep slopes may not be evident for 5 to 10 years, or until such time as the plant root system begins to fail (assuming that the root system remains within the soil profile after removal of the upper portion of the plant). Planners and designers must appreciate that plants provide many essential roles besides the provision of "scenery".

Periods of high and extreme erosion potential refers to the variation in the erosion hazard throughout a calender year based on variations in the rainfall erosivity as described in Appendix E – *Soil loss estimation*. Periods of high to extreme erosion potential include:

- periods of high to extreme erosion risk as defined in Section 4.4 of Chapter 4 – *Design standards and technique selection*; and
- periods of strong winds sufficient to cause significant dust problems.

Acceptable Solution A25(a)
The extent of unnecessary soil disturbance, including disturbances outside the designated work area, must be minimised at all times.

Wherever reasonable and practicable, land clearing must be limited to the current stage of works. Current (2008) best practice recommends that land clearing not extend beyond the parameters indicated in Table I11.

Table I11 does not imply that land clearing should occur to the full extent of these limits, rather than all reasonable and practicable measures are taken to limit land clearing to no more than these limits. In all cases, land clearing must be limited to the minimum necessary to complete the approved works.

SOIL AND STOCKPILE MANAGEMENT

Performance Criterion A27
Applies to all areas of proposed soil disturbance, including footprint of proposed stockpiles prior to placement of soil within such areas. Does not include any material best described as subsoil.

Acceptable Solution A27(b)
Current (2008) best practice recommendations for the management of topsoil are presented in Table 6.2 in Chapter 6 – *Site management*.

Acceptable Solution A28(ii)
The diversion of overbank, stormwater is recommended during those periods when rainfall is possible and the overbank catchment area exceeds.

Current (2008) best practice recommendations for the protection of sand and soil stockpiles from the erosive effects of wind and rainfall are presented in Table 4.6.1 in Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A28(iv)
Current (2008) best practice recommendations for the selection of an appropriate sediment control system is presented in Table 4.6.2 in Chapter 4 – *Design standards and technique selection*.

Short-term stockpiles of erodible material located outside of an appropriate sediment control zone must be covered if it is raining, or if rain is imminent or possible.

Acceptable Solution A29
Dispersive soils normally need to be stabilised (i.e. treated with gypsum or lime depending on desired pH adjustment) and/or buried under a layer of non-dispersive soil prior to placement of channel lining (whether rock, gabion, synthetic material, or concrete), or initiation of revegetation.

Refer to Section 6.12 in Chapter 6 – *Site management*, or Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of dispersive soils.

Acceptable Solution A30
Refer to Section 6.12 in Chapter 6 – *Site management*, or Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of acid sulfate soils.

Within Queensland, guidelines on the management of acid sulfate soils is provided in State Planning Policy 2/02 *Guideline: Planning and Managing Development involving Acid Sulfate Soils*, and Dear, et al. 2002, *Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines.* Department of Natural Resources and Mines, Indooroopilly, Queensland.

DRAINAGE CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure of soil to the erosive forces of flowing water. It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining drainage control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A32(a)
Current (2008) best practice construction phase drainage standards are presented in Table 4.3.1 of Chapter 4 – *Design standards and technique selection*. Drainage systems must be designed to have a minimum non-erosive hydraulic capacity (excluding 150 mm freeboard) in accordance with this table.

Acceptable Solution A32(b)
Construction Drainage Plans are normally prepared for sites with a soil disturbance exceeding 50 m^2. Further discussion on the requirements of *Construction Drainage Plans* is presented in Acceptable Solution A11(d).

Acceptable Solution A33(b)
Sandbag flow diversion banks, catch drains, and flow diversion banks are examples of appropriate drainage systems that can be used to divert stormwater around excavations and other soil disturbances.

EROSION CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure of soil, sand, silt, mud or cement to the erosive forces of wind, rain and flowing water. It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining erosion control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A35(a)
Current (2008) best practice (construction phase) land clearing and site rehabilitation standards are presented in Table I11. Unless otherwise stated by the relevant regulatory authority, the potential erosion risk is based on the rating outlined in Tables I9 and I10.

In addition, all temporary earth banks, flow diversion systems, and off-stream *Sediment Basin* embankments should be machine-compacted, seeded and mulched within ten (10) days of formation for the purpose of establishing a vegetative cover, unless otherwise stated within an approved Site Stabilisation Plan, Revegetation Plan, or Vegetation Management Plan.

Acceptable Solution A35(b)
Erosion control measures primarily focus on the control of fine sediments such as clay and silt-sized particles. Thus, with respect to the value of "erosion control measures", potential environmental harm is strongly related to the susceptibility of the receiving waters to environmental harm resulting from turbid runoff (i.e. suspended fine sediments).

Erosion control measures need to be appropriate for the land slope and the expected wind, rain and hydraulic conditions. Application of effective drainage control measures should help to control hydraulic conditions such that damage to adopted erosion control measures during regular rainfall events is minimised.

Acceptable Solution A35(c)
This clause requires compliance with Performance Criteria P15 and P16.

Acceptable Solution A36(a)
Such a clause shall not reduce the responsibility to apply and maintain, at all times, all necessary sediment control measures.

The minimisation of soil erosion requires the application of effective drainage and erosion control throughout each and all sub-catchments.

Acceptable Solution A37(b)
Compliance with this clause requires:
- soil disturbance within any sub-catchment to be delayed as long as possible, and ideally, not until the principal on-site activities within that area are ready to commence;
- soil disturbance at any given time to be limited to the minimum necessary to perform the required works;
- the extent of unnecessary soil disturbance, including disturbances outside the designated work area, to be minimised.

The stabilisation of non-completed earthworks that are likely to be exposed to rainfall is discussed in Table I11.

Compliance with the requirements outlined within Table I11 does not diminish the need to apply all reasonable erosion control measures as soon as practicable.

Acceptable Solution A38(c)
Dispersive soils normally need to be stabilised (i.e. treated with gypsum or lime depending on desired pH adjustment) and/or buried under a layer of non-dispersive soil prior to placement of channel lining (whether rock, gabion, synthetic material, or concrete), or initiation of revegetation.

Refer to Figures I15 and I16 (Appendix I), Section 6.12 in Chapter 6 – *Site management*, and Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of dispersive soils.

SEDIMENT CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure, placement, or displacement of sediment (including soil, sand, silt, mud and cement). It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining sediment control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A39(a)
Current (2008) best practice (construction phase) sediment control standards are presented in Table 4.5.1 of Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A39(b)
Relevant site conditions include the soil type, design flow rate, flow condition (i.e. sheet flow or concentrated flow) and erosion hazard.

Unless otherwise noted within this document, or specified by the regulatory authority, the design storm for off-stream sediment traps (excluding de-watering and instream sediment control measures) must be taken as 0.5 times the 1 in 1 year ARI peak discharge.

The “potential environmental risk” is discussed in Acceptable Solution A1(a), and is summarised in Table 5.1 of Chapter 5 – *Preparation of plans*.

Acceptable Solution A42(a)
The *intent* of this clause is to minimise the quantity of water that needs to be de-watered from excavations and trenches. Thus, if water does not need to be de-watered from such areas, then the clause does not apply.

Acceptable Solution A42(b)
Current (2008) best practice sediment control standards for de-watering activities are outlined in Table 4.5.13 of Chapter 4 – *Design standards and technique selection*.

Alternatively, Table 4.5.14 of Chapter 4 presents a water quality standard for de-watering operations based on Nephelometric Turbidity Units (NTU).

Appropriate sediment controls placed down-slope of material stockpiles during the de-watering of such stockpiles are summarised in Table 4.5.14 of Chapter 4 – *Design standards and technique selection*.

SITE STABILISATION AND REHABILITATION

Acceptable Solution A43(a)
Site Stabilisation Plans, Landscape Plans, and/or Vegetation Management Plans must show progressive stabilisation of exposed soil for the purposes of erosion control, including but not limited to, all of the following:

- (i) schedule for stabilisation of exposed soil areas; and
- (ii) specifications for subsoil and topsoil preparation and application; and
- (iii) specification of stabilisation by mulching or other appropriate surface treatment (note, grass seeding without adequate mulching is generally not considered best practice); and
- (iv) details on the type and application rate of any tackifiers to be used in the application of mulches (including *hydromulch*, *Bonded Fibre Matrix*, and *Compost Blankets*).

Water Quality Monitoring Programs must document proposed water quality monitoring, and include:

- (i) location of all instream water quality monitoring stations;
- (ii) water quality monitoring, sampling, and analysis procedures and standards.

Acceptable Solution A43(b)
Current (2008) best practice site rehabilitation standards are presented in Table I11. Unless otherwise stated by the relevant regulatory authority, the potential erosion risk is based on the rating outlined in Tables I9 and I10.

Acceptable Solution A44(a)
Temporary revegetation conducted for the purpose of erosion control must be conducted in accordance with a Site Stabilisation Plan, Landscape Plan, Revegetation Plan, or Vegetation Management Plan, where such a plan specifically refers to such activities.

Acceptable Solution A44(b)
The type of permanent vegetation applied to completed earthworks must be compatible with the anticipated long-term land use, current and ongoing erosion risk, environmental requirements (including weed control), and associated components of the site rehabilitation.

Performance Criterion P45
Local environment includes local wildlife.

SITE INSPECTION AND MONITORING

Acceptable Solution A46(b)
Personnel preparing and/or supervising the preparation of the Monitoring and Maintenance Program must, collectively, have the following capabilities:

- (i) an understanding of the local environmental values that could potentially be affected by the proposed works; and
- (ii) a good working knowledge of the site's Erosion and Sediment Control (ESC) issues, and potential environmental impacts, that is commensurate with the complexity of the site and the degree of environmental risk; and
- (iii) a good working knowledge of current best practice Erosion and Sediment Control measures appropriate for the given site conditions and type of works; and
- (iv) a good working knowledge of the correct installation, operational and maintenance procedures for the full range of ESC measures used on the site.

Refer to A1(a) for discussion on "potential environmental risk ".

Acceptable Solution A47(a)
Discussion on scheduling and conducting site inspections by internal and external parties is provided in Chapter 7 – *Site inspection*.

In those instances where specific site monitoring stations are identified within the Monitoring and Maintenance Program, then:
- during periods of water discharge from the site, water quality samples are collected at each monitoring station at least once on each calendar day until such discharge stops; and
- a minimum of 3 water samples are taken and analysed, and the average result used to determine quality.

Current (2008) best-practice procedures for "high-risk" sites, requires regular ESC audits to be:
(i) undertaken by a person suitably qualified and experienced in erosion and sediment control that can be verified by an independent third-party (this person must not be an employee or agent of the principal contractor); and
(ii) conducted on the next business day following a rainfall event in which greater than 10 mm of rainfall has been recorded by the Bureau of Meteorology rain gauge nearest to the site; and
(iii) conducted at intervals of not more than one (1) calendar month commencing from the day of site disturbance until all disturbed areas have been adequately stabilised against erosion to the acceptance of the relevant regulatory authority; and
(iv) conducted using an appropriate Site Inspection Checklist.

"High-risk sites" are work sites that:
- satisfy the requirements of a high-risk site as defined by either the State or local government; or
- satisfy the requirements of those risk categories greater than high-risk (such as extreme-risk) where such categories have been defined (i.e. score a hazard rating equal to or greater than the "critical hazard value").

Discussion on the assessment of *erosion hazard* and *site risk assessment* is presented in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

ESC audits must include, as a minimum:
- copies of all original Site Inspection Checklists; and
- non-conformance and corrective action reports;
- sediment basin water quality and site discharge water quality monitoring results;
- a plan showing the areas of completed soil stabilisation; and
- rainfall records including date and rainfall depth.

Acceptable Solution A48
Discussion on scheduling and conducting of site inspections is provided in Chapter 7 – *Site inspection*.

SITE MAINTENANCE

Performance Criterion P49
Proper working order includes maintaining the required hydraulic capacity and operational effectiveness.

Acceptable Solution A49(b)
Current (2008) best practice requirements for the maintenance of sediment control devices requires these devices to be maintained and made fully operational as soon as reasonable and practicable in accordance with Table 6.1 of Chapter 6 – *Site management*.

I9. Example ESCP for a bridge construction

The site is covered with native vegetation with a 20m wide riparian zone on the northern bank and a depleted riparian zone along the southern bank. The site is well drained and slopes towards the river from both the north and south. At present there exists minimal erosion on the site or within the waterway.

The river has a constant flow and the water depth exceeds 1m close to the southern bank even during extended dry weather. Downstream of the site the river flows into a tidal estuary that eventually discharges into the ocean. The river has high environmental values and fish passage must be maintained during construction.

The overpass (Figure I17) consists of a 4-lane highway that falls towards the south. The proposed underpass is a minor 2-lane rural road with grass swale drainage falling slightly towards the west.

As a result of the bridge works, rock protection of the river banks will be required within the region of the bridge. This work will require partial clearing of the bank and overbank vegetation.

Geotechnical investigations of the site reveal that the topsoil consists of a highly fertile, non-dispersive, dark sandy loam with depths varying from 100 to 200 mm.

Subsoils comprise a reddish, non-dispersible clayey loam. Rock outcrops are not expected; however, high groundwater levels are anticipated.

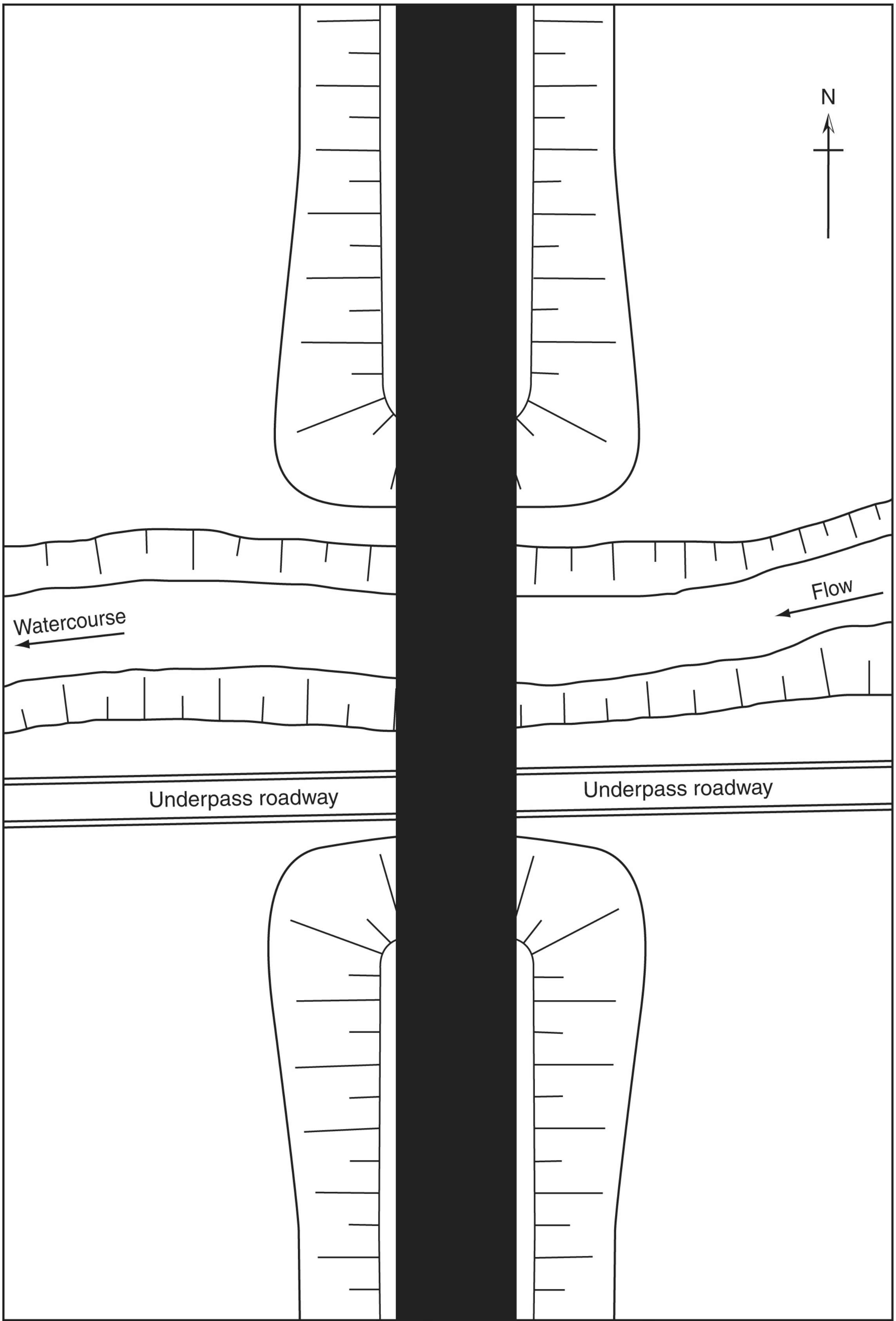
ESCP Explanatory Notes:

1. Note, the site's entry/exit point, site office and stockpile areas are not defined in this example.
2. The work site effectively acts as two separate work areas (north and south of river) during most of the construction phase and thus two separate ESCPs could be developed; however, in this example the two sites are combined.
3. The Isolation Barrier (IB-1) consists of a floating silt curtain anchored in the stream using a combination of land and marine posts and anchors.
4. Isolation Barrier (IB-2) consists of a floating silt curtain. This barrier is used because the water depth adjacent to the southern bank is greater than 0.8 m and there is a need to recess the bank stabilisation rock at least 1m below the existing toe of the bank.
5. Isolation Barrier (IB-3) consists of a *Sediment Fence Isolation Barrier*. The first staked sediment fence is located at the toe of the rock stabilisation, with the second fence located 2 m instream (south) of the first fence at a location where the river flow depth is less than 0.8 m. This type of barrier can be used because of the relatively shallow water depth adjacent to the north bank.
6. All Sediment Fences should consist of high quality non-woven composite fabric.
7. This example ESCP demonstrates the use of various types of sediment basins with four types of outlet systems and spillways. *Sediment Basin* (SB-1) is a Type C basin with a riser pipe outlet. The riser pipe outlet is trenched through to the river bank. During storm events the basin discharges down the riverbank via a rock mattress *Chute* (CH-1).

8. *Sediment Basin* (SB-2) is a Type F basin which is de-watered using a portable pump. During storm events, the basin discharges down the river bank via a high strength geotextile *Chute* (CH-4).
9. *Sediment Basin* (SB-3) is a Type C basin with a *Rock Filter Dam* outlet. During storm events the basin discharges down the river bank via a rock *Chute* (CH-2). The *Rock Filter Dam* outlet makes this a Type 2 sediment trap.
10. *Sediment Basin* (SB-4) is a "wet" Type C basin with pumped outlet. During storm events the basin discharges down the river bank via a gabion *Chute* (CH-3).
11. Inflow into each *Sediment Basin* will be controlled with the use of a geotextile *Chute*.
12. As the road embankments are formed, the temporary drainage *Chutes* (CH-5, 6, 7 & 8) are extended by successive placement of filter cloth, which forms the chutes.
13. *Catch Drains* (CD-9, 10, 11 & 12) are formed at the end of each day's filling to allow adequate drainage to the temporary embankment chutes.
14. Construction "Hold Points" exist at each 3 m lift within the embankments. The embankments will be stabilised with a *Bonded Fibre Matrix* (BMF) after each 3m lift is obtained.

Installation sequence:

Item	Plan No.	Installed	Removed
Mark out initial limits of disturbance	D-002	Prior to site disturbance	
IB-2	D-002	Prior to vegetation clearing	After pocket planting the river bank rock protection.
IB-3	D-002	Prior to vegetation clearing	Partial removal prior to installation of IB-1.
CH-1	D-002	After IB-2	After decommissioning SB-1
CH-2	D-002	After IB-3	After decommissioning SB-3
CH-3	D-002	After IB-3	After decommissioning SB-4
CH-4	D-002	After IB-2	After decommissioning SB-2
IB-1	D-003	After rock placement	After pier installation
Construction of central bridge pier within waterway			
SF-1	D-003	Prior to overbank land clearing	After site revegetation
SF-2	D-003	Prior to overbank land clearing	After site revegetation
SF-3	D-003	Prior to overbank land clearing	After site revegetation
SF-4	D-003	Prior to overbank land clearing	After site revegetation
Commencement of land clearing			
SB-1	D-003	After land clearing	After site stabilisation
SB-2	D-003	After land clearing	After site stabilisation
SB-3	D-003	After land clearing	After site stabilisation
SB-4	D-003	After land clearing	After site stabilisation
CD-2, -3, -6, -7	D-003	After land clearing	After site stabilisation
CD-1, -4, -5, -8	D-003	After land clearing	After site stabilisation
Commence embankment and underpass construction			
CD-9, -10, -11, -12	D-003	At end of each day's earth works on the embankments	Prior to sealing roadway
CH-5, -6, -7, -8	D-003	At end of each day's earth works on the embankments	After decommissioning CD-9, CD-10, CD-11 & CD-12



Drawing No. D-001 Bridge construction Final layout	Date: November, 2003	Scale: 0 10 20 30

Figure I17 – Proposed bridge layout

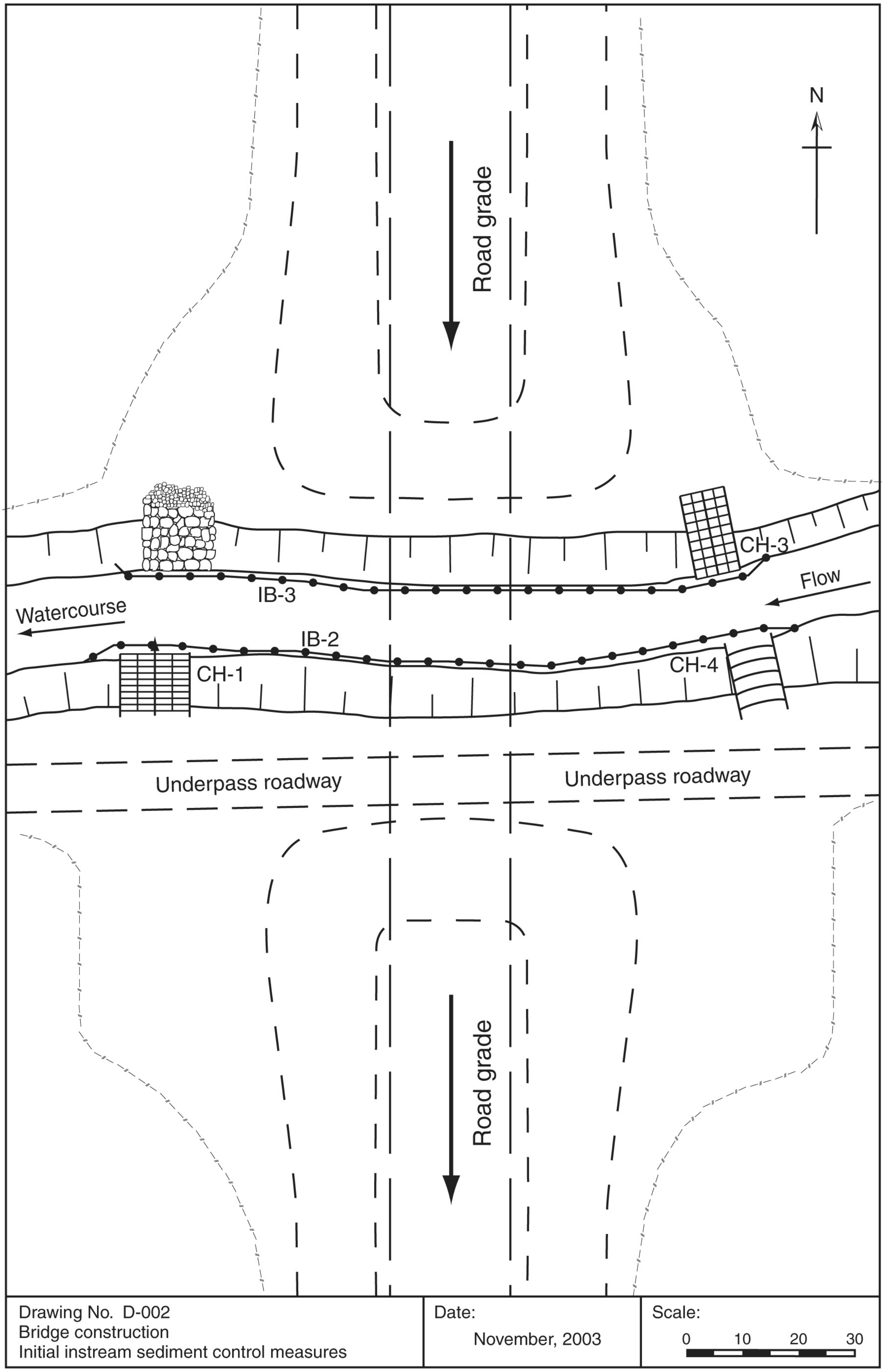
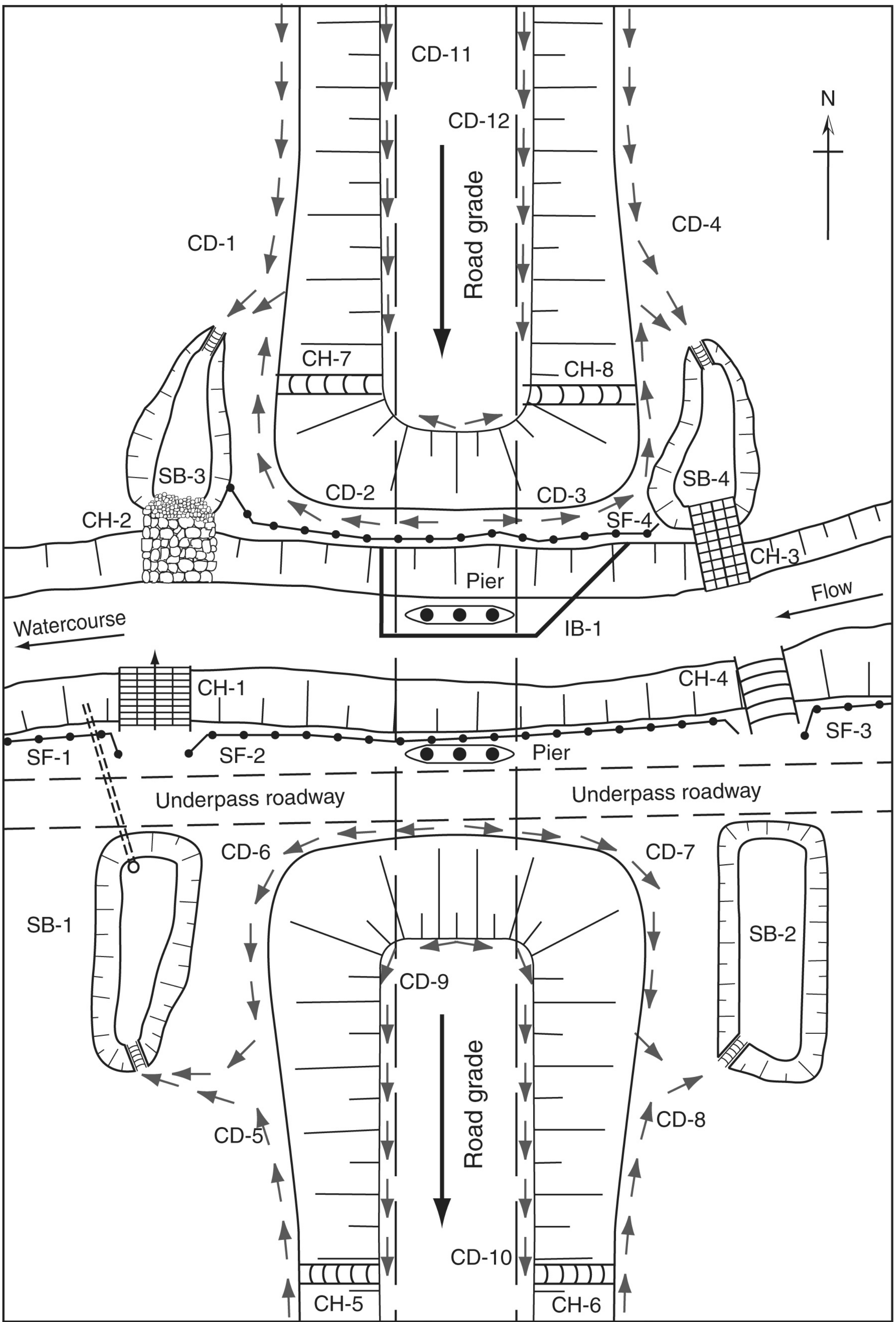


Figure I18 – Initial land clearing



Drawing No. D-003 Bridge construction Embankment construction	Date: November, 2003	Scale: 0 10 20 30

Figure I19 – Construction phase

I10. Culvert construction and the installation of buried pipeline crossings

There are usually a number of variables that must be considered before finalising the construction procedure for a culvert. These variables may include the following.

(i) risk of flood flows during the construction period;
(ii) risk of adjacent property flooding during the construction period;
(iii) fish passage requirements;
(iv) construction issues relating to the type of culvert;
(v) degree and clarity of base flow within stream;
(vi) requirements for construction access across the stream;
(vii) requirements for public traffic during construction;
(viii) erosion and sediment control requirements during the construction period.

The following information and examples are provided **not** as a code of practice, but as a guide to assist in the development of creative solutions.

I10.1 Risk of flood flows during the construction period

Condition	Comments
High flows unlikely (dry season)	• Cofferdams and temporary watercourse crossings are unlikely to wash away.
High flows possible (dry/wet season)	• Temporary crossing to be structurally sound during 1 in 1 year to 1 in 10 year flood risk depending on economic practicality. • Desired flood immunity of a temporary crossing also depends on desired trafficability during the construction phase. • Consider the use of *Isolation Barriers* to separate construction works from stream flows. • *Isolation Barriers* should ideally not block more than 1/3 to 1/2 of the channel's bed width depending on flood risk.
High flows likely (wet season)	• Temporary crossing designed to be structurally sound during minimum 1 in 10 year flood event. • Desired flood immunity of a temporary crossing also depends on desired trafficability during the construction phase. • Consider the use of *Isolation Barriers* to separate construction works from stream flows. • *Isolation Barriers* should ideally not block more than 1/3 to 1/2 the channel bed width depending on flood risk.

I10.2 Risk of adjacent property flooding during the construction period

Condition	Comments
Flooding would not inundate floor levels	• No extra considerations.
Flooding could inundate floor level of adjacent properties	• Construction should avoid periods of high flood risk. • Hydraulic analysis must be performed on each stage of construction to assess flood risk. • When diverting low-flows away from some or all of the culvert cells, avoid partially blocking the entrance to the culvert. Wherever practicable, flow diversion barriers should be located well upstream of the culvert inlet.

I10.3 Fish passage requirements

Condition	Comments
No fish passage requirements exist	• Instream sediment control measures can be constructed without risk to fish passage. • Minor flow bypassing can be achieved with cofferdams using either pumped or gravity bypass lines. • A temporary sidetrack crossing may be used as a cofferdam.
Short-term interruption acceptable to fish passage	• Temporary instream sediment controls may be employed while installing long-term sediment controls, or constructing minor instream works. • Temporary watercourse crossings and temporary sidetrack culverts might or might not need to be fish friendly. Obtain expert Fisheries advice/approval.
No fish passage interruptions allowable	• Consider the use of *Isolation Barriers* to separate construction activities from stream flows. • Temporary watercourse crossing and sidetrack culverts must be fish friendly. Obtain expert Fisheries advice/approval. • Minimum hydraulic capacity of a temporary watercourse crossing should be equal to the stream's base flow rate.

I10.4 Construction issues relating to the type of culvert

Condition	Comments
Single pipe culvert	• Two-stage fish-friendly construction may be impractical on a single pipe culvert.
Single box culvert	• Two-stage fish-friendly construction may be impractical on a single box culvert. • The need to form a base slab makes it difficult to construct a single cell box culvert in streams with a high base-flow, especially when fish passage must not be interrupted.
Multi-cell pipe culvert	• Allow for two-stage construction and the use of *Isolation Barriers* to separate construction works from stream flows.
Multi-cell box culvert	• Allow for two-stage construction and the use of *Isolation Barriers* to separate construction works from stream flows • Base slab must be structurally designed and detailed to allow two-stage construction.

I10.5 Degree of base flow within stream

Condition	Comments
No flow (dry creek)	• Minor flow bypassing can be achieved using cofferdam with either pumped or gravity bypass line. • A temporary sidetrack crossing may be used as a cofferdam.
No flow but permanent pools	• Fish passage requirements may exist that may prevent the use of cofferdams and flow bypassing.
Minor base flow (wet creek)	• Fish passage requirements are likely to exist that may prevent the use of cofferdams and flow bypassing. • Minimum hydraulic capacity of a temporary watercourse crossing equal to the stream's base flow rate. • Choice between piped flow bypass or *Isolation Barriers* is likely to depend on flow rate and fish passage requirements.
Significant base flow	• Use an *Isolation Barrier* to construct the culvert in isolation from the stream flow.

(a) Examples of stream flow bypass and diversion systems

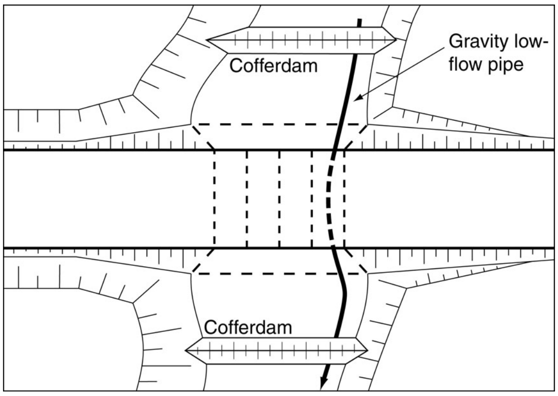


Figure I20 – Cofferdam with gravity bypass pipe

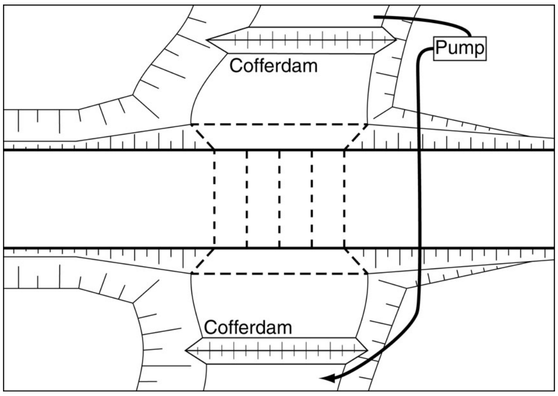


Figure I21 – Cofferdam with pumped bypass flow

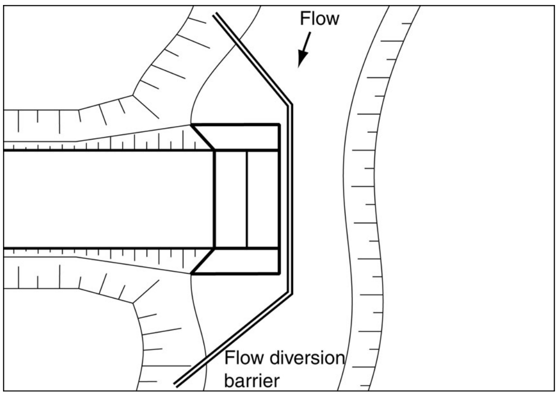


Figure I22 – Stage 1: Use of flow diversion barrier

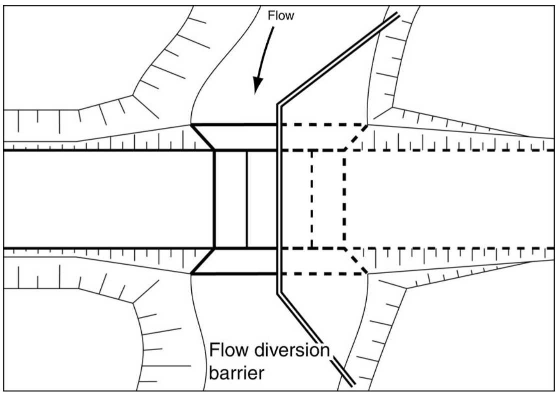


Figure I23 – Stage 2: Use of flow diversion barrier

I10.6 Requirements for construction access across the stream

Condition	Comments
No need for temporary watercourse crossing	• No additional requirements.
Temporary construction access required across stream	• Possible fish passage requirements for the temporary crossing. Minimum hydraulic capacity of a temporary watercourse crossing equal to the stream's base flow rate. • Temporary bed level crossings (fords) can introduce high sediment flows into the stream unless the creek is dry or base flows are bypassed around the crossing. Sandy channel beds may need to be reinforced with a synthetic *Cellular Confinement System*. Bed level (ford) crossings are not normally recommended in clay-based streams. • Temporary culvert crossings can cause significant bed disturbance during installation and removal. • Temporary bridge crossing (possibly using precast box culvert bridging slabs) are least likely to adversely affect fish passage.

Examples of temporary waterway crossings:

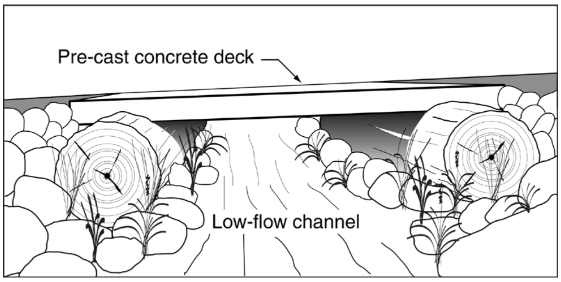


Figure I24 – Bridge formed from logs and a box culvert bridging slab

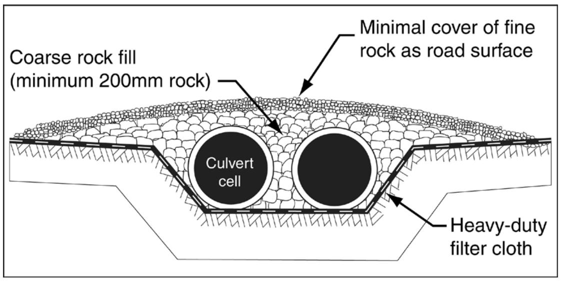


Figure I25 – Temporary pipe culvert

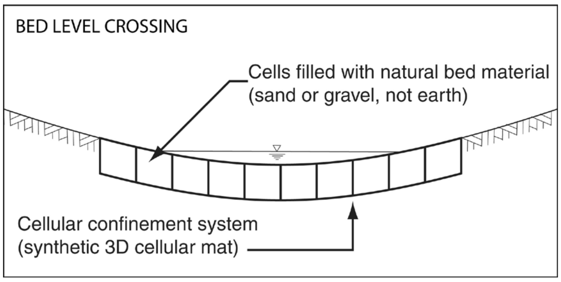


Figure I26 – Ford crossing stabilised with a cellular confinement system (CCS) mat

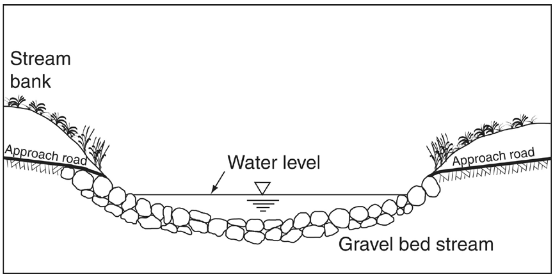


Figure I27 – Natural ford crossing of a gravel-based stream bed

Witheridge (2002) provides guidelines on the design of fish-friendly watercourse crossings.

I10.7 Requirements for vehicular traffic during construction

Condition	Comments
No traffic	• No additional requirements.
Traffic via temporary side road	• Possible fish passage requirements may apply to the side road crossing.
Traffic via adjacent roadway	• Possible use of the land between the two roads as a sediment trap/basin.
Traffic needs to be maintained on the road being built	• Construction of culvert must be staged.

Case Study A – Expansion of an existing culvert

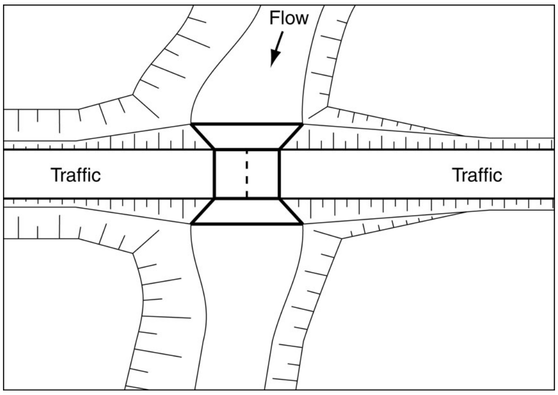


Figure I28 – Existing culvert

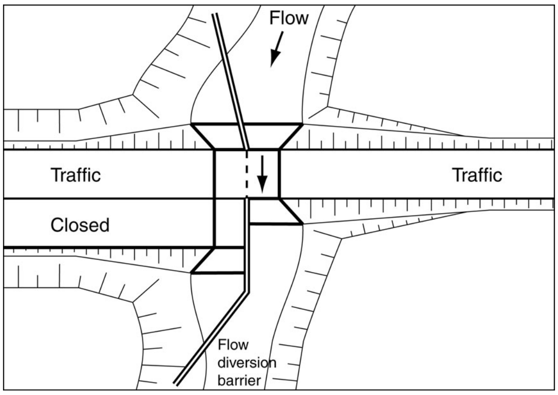


Figure I29 – Stage 1: Partial construction of culvert

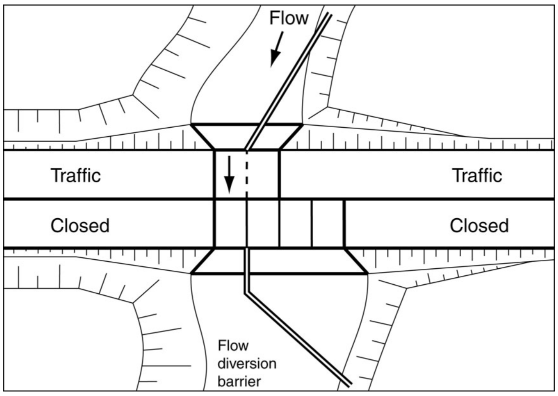


Figure I30 – Stage 2: Partial construction of culvert

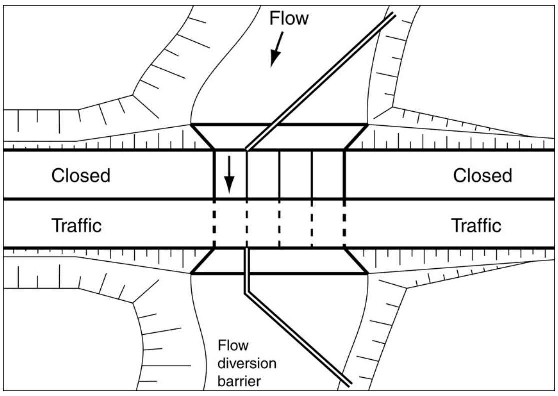


Figure I31 – Stage 3: Relocate traffic and final culvert construction

Case Study B – Construction of a new culvert

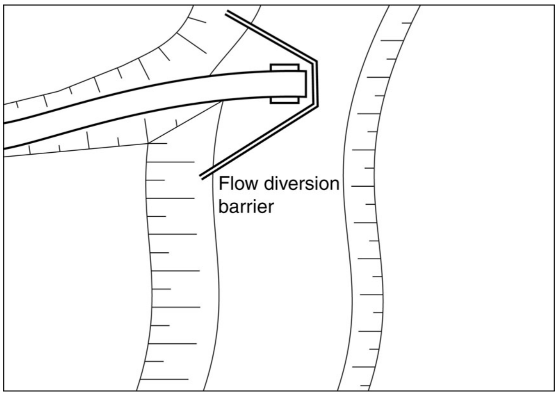


Figure I32 – Stage 1: Construct half of access track

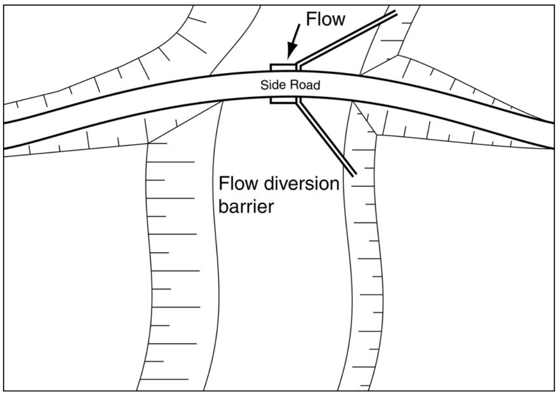


Figure I33 – Stage 2: Construct rest of access track

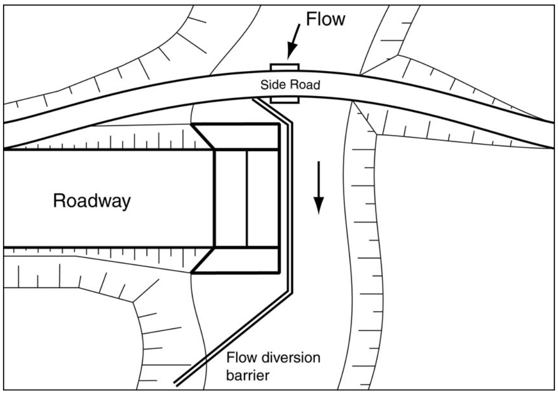


Figure I34 – Stage 3: Construction of half culvert

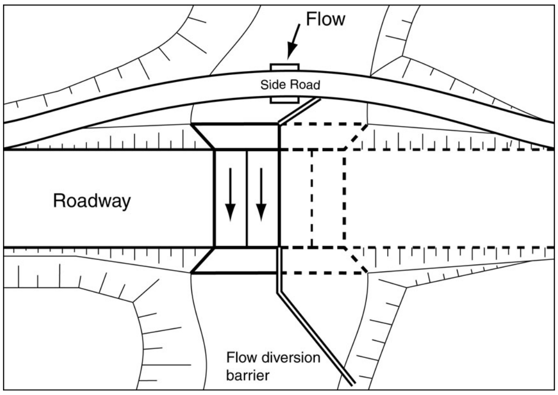


Figure I35 – Stage 4: Finish culvert

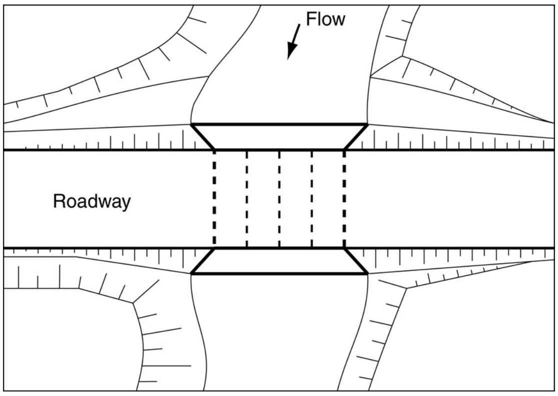


Figure I36 – Stage 5: Construct roadway

I10.8 Erosion and sediment control requirements during the construction period

Condition	Comments
Space is available for off-road *Sediment Basins*	• Sediment traps/basins formed each side of road, each side of the stream. • Sediment traps operational during all stages of construction and revegetation. • Possible retention of sediment traps as permanent stormwater treatment system.
No room available for off-road *Sediment Basins*	• Consideration given to the formation of sediment traps/basins within the road reserve each side of the culvert. These *Sediment Basins* will be slowly backfilled as earthworks are completed.

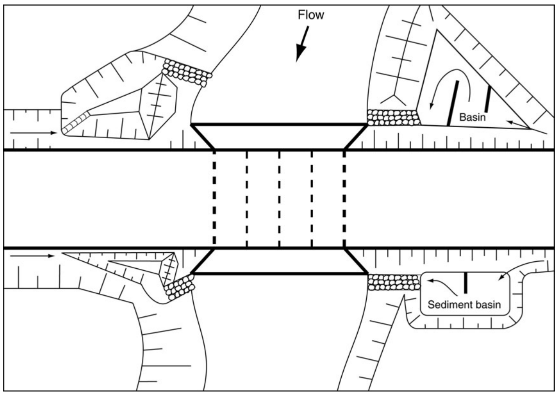


Figure I37 – Incorporation of four off-stream *Sediment Basins*/traps

Off-stream sediment traps:

Sediment Basins used to treat runoff from adjacent road works and to treat water pumped from the culvert excavations.

Preference should always be given to the use of off-stream sediment traps.

Sediment traps may be retained after the construction phase as permanent stormwater treatment ponds.

Case Study C – Construction of a major cross drainage stormwater pipe on a new road

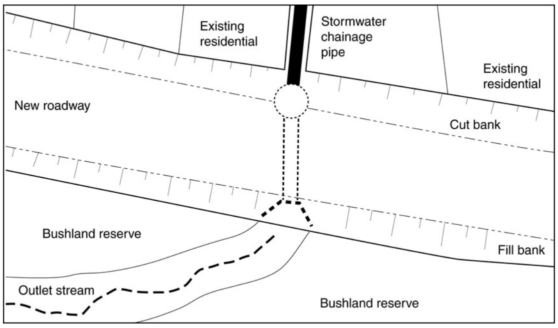


Figure I38 – Stage 1: Major stormwater pipe extended across proposed roadway

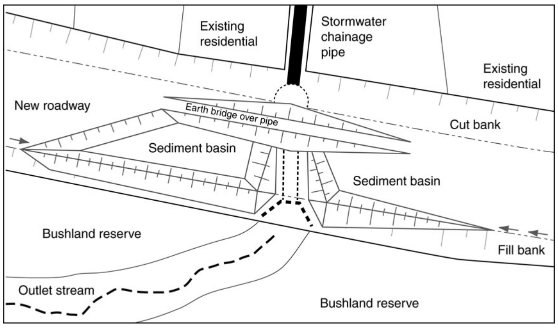


Figure I39 – Stage 2: Earth bridge built over pipe to allow construction access and *Sediment Basins* formed within the road reserve to minimise damage to the adjacent stream and bushland reserve

Case Study D – Construction of culvert within restricted road width

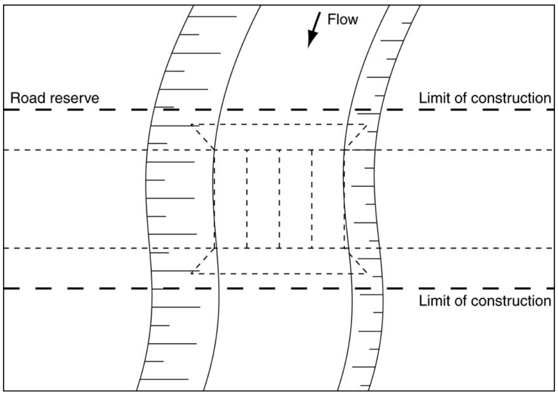


Figure I40 – Example of new culvert constructed within a narrow road reserve

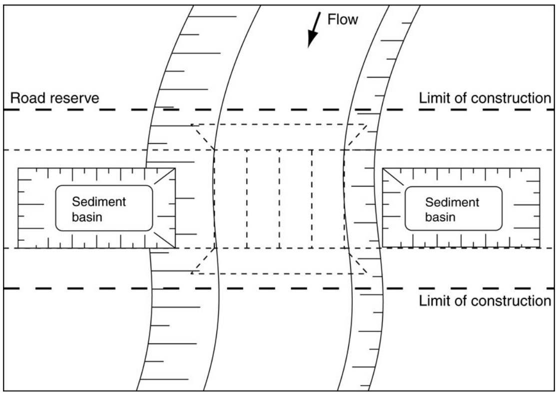


Figure I41 – Stage 1: Construct off-stream *Sediment Basins*

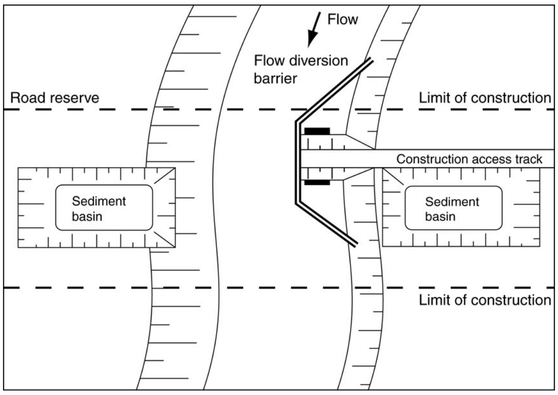


Figure I42 – Stage 2: Partial construction of access track across stream

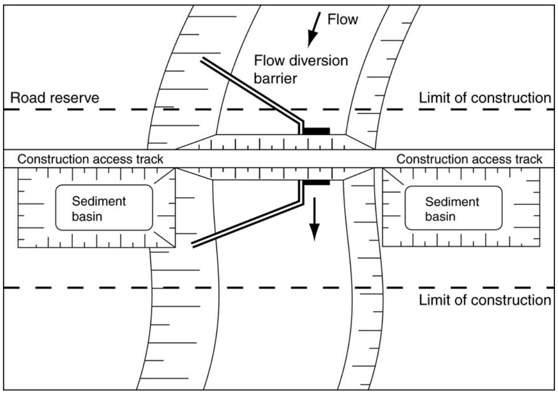


Figure I43 – Stage 3: Construct remainder of the access track

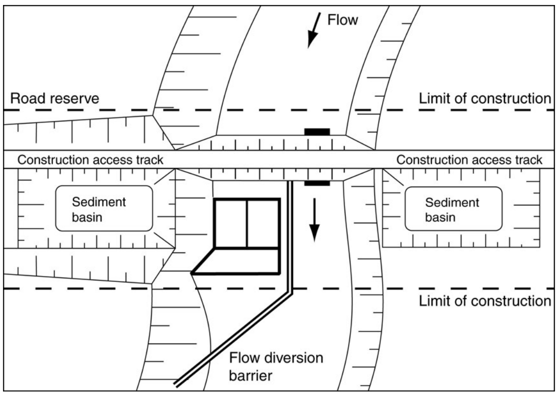


Figure I44 – Stage 4: Construct first phase of culvert

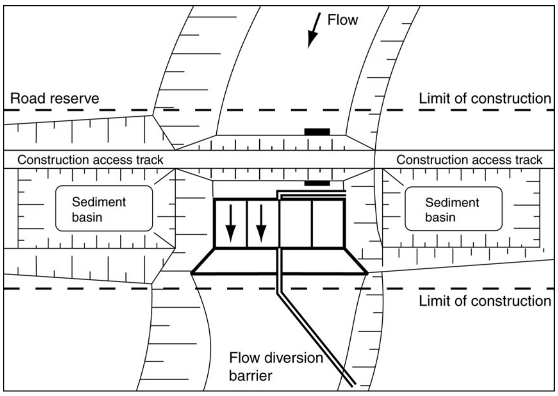


Figure I45 – Stage 5: Construct second phase of culvert

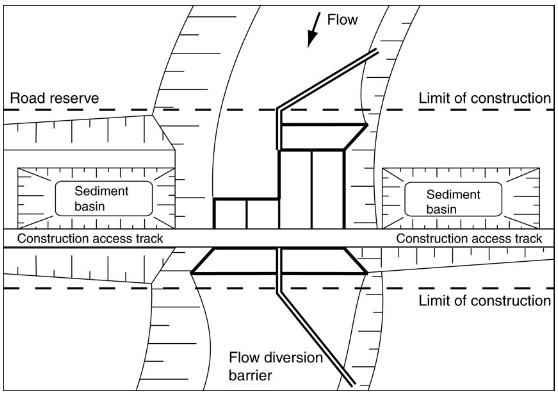


Figure I46 – Stage 6: Relocate access track by partially backfilling the *Sediment Basins*, then construct third phase of the culvert

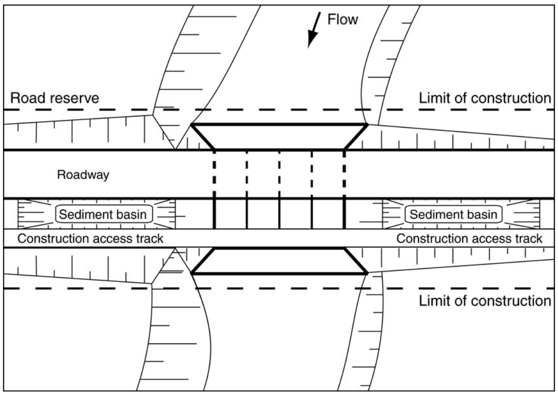


Figure I47 – Stage 7: Finish culvert and construct half of the roadway slowly backfilling the *Sediment Basins*

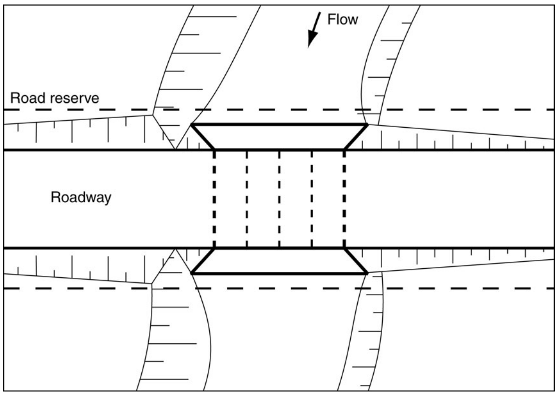


Figure I48 – Stage 8: Finish construction of roadway

The above Case Study represents a worst case scenario with the following conditions applying to the construction phase:

- Fish passage must be maintained.
- Wet stream with significant base flow requiring use of flow diversion barriers.
- Continuous construction access required across the stream.
- No construction allowed outside the road reserve limits, thus requiring all sediment traps to be located within the roadway.

I11. Construction of buried pipeline crossings

The variables to be considered when preparing installation procedures for major pipeline crossings are very similar to those variables presented in Section I11 for culvert construction. The main difference is that in pipeline construction there is often the potential to significantly reduce disturbances to the bed and banks of the watercourse. The degree of channel disturbance depends on:

- the width of the watercourse;
- base flow conditions within the watercourse;
- whether or not it is necessary for heavy machinery to enter the channel;
- if heavy machinery must enter or cross the channel, whether or not it will be necessary to construct an elevated access track across the bed.

In most cases the least intrusive installation procedure involves directional drilling. The following Case Studies provide examples of various open trench installation procedures in cases where directional drilling is not practicable.

Case Study E – Pipeline installation across a narrow watercourse with all construction equipment operating from the channel banks

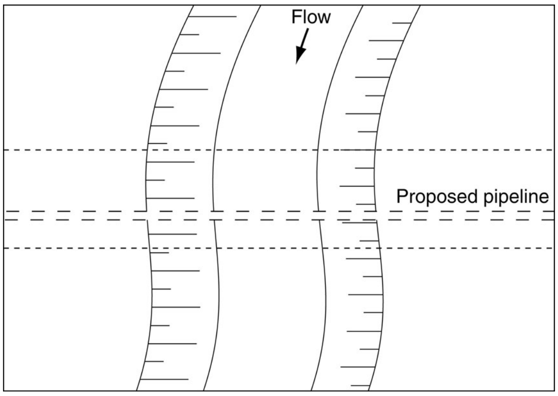


Figure I49 – Proposed pipeline across flowing watercourse

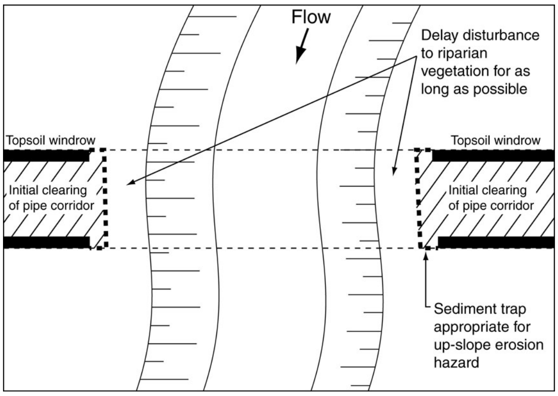


Figure I50 – Initial clearing prior to pipe installation

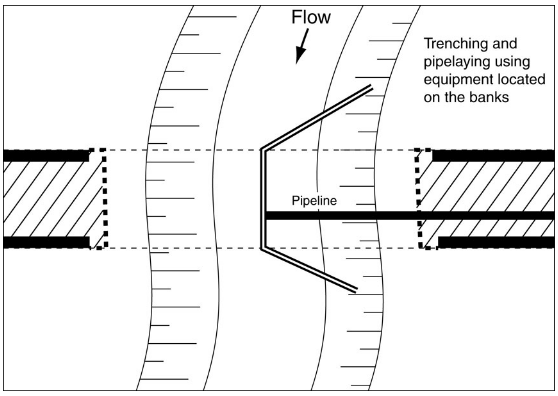


Figure I51 – Stage 1: Pipeline installation

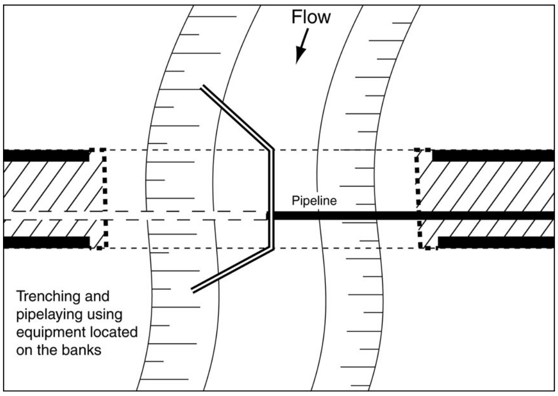


Figure I52 – Stage 2: Pipeline installation

Case Study F – Pipeline installation across a wide, dry-bed watercourse where minor channel flows are possible

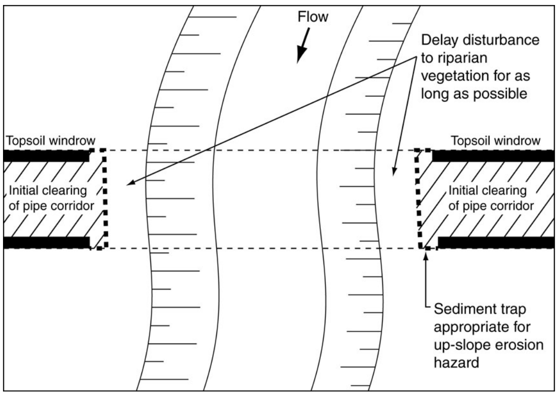


Figure I53 – Initial clearing of the easement prior to the pipe being ready for installation

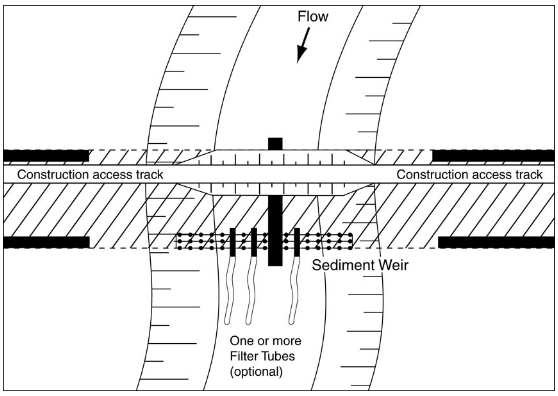


Figure I54 – Construction of instream sediment trap and construction access with bypass pipe in case of minor stream flows

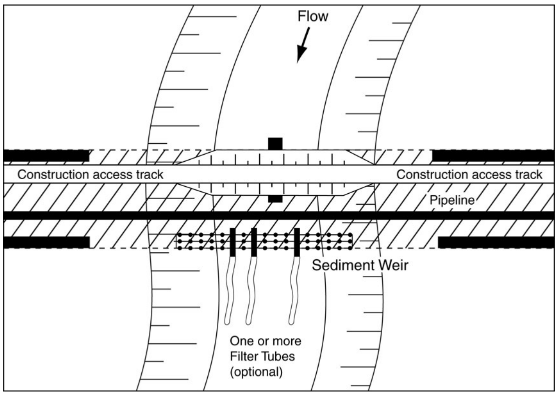


Figure I55 – Installation of pipeline. Note part of the bypass pipe may need to be removed to allow pipe installation

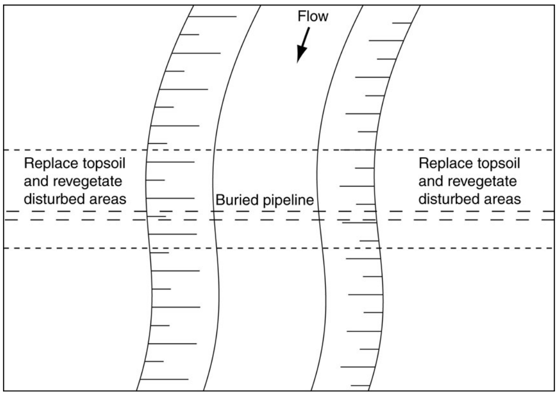


Figure I56 – Removal of access track and instream sediment trap followed by site rehabilitation

Case Study G – Pipeline installation across a wide watercourse with constant low flow and where increased channel flows are possible

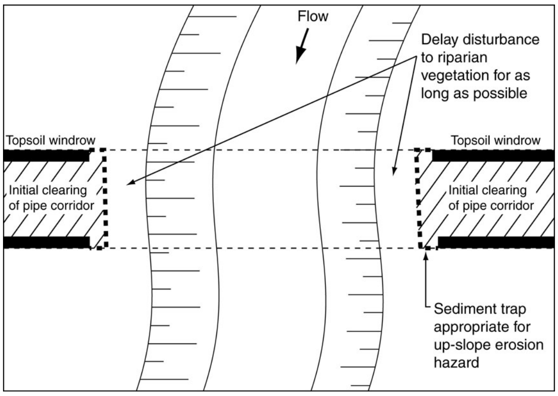


Figure I57 – Initial clearing of the easement prior to the pipe being ready for installation

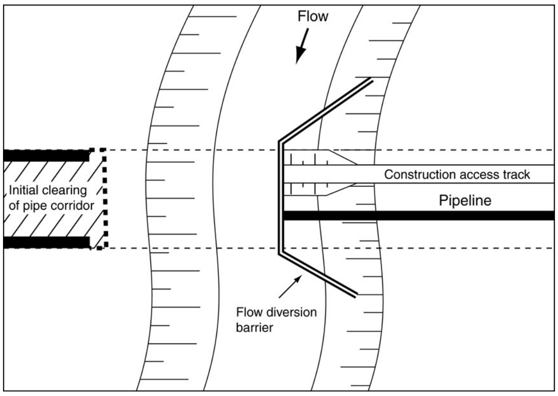


Figure I58 – Stage 1 of pipe installation using an isolation barrier

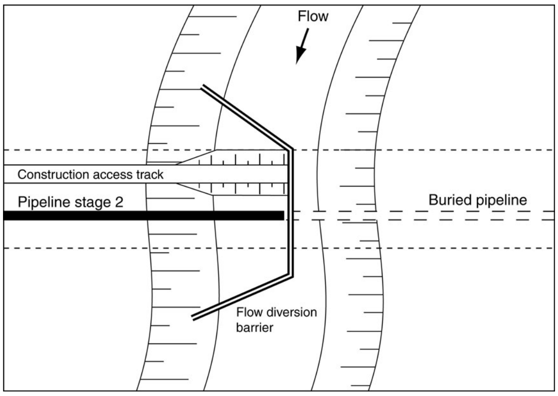


Figure I59 – Stage 2 of pipe installation using an isolation barrier

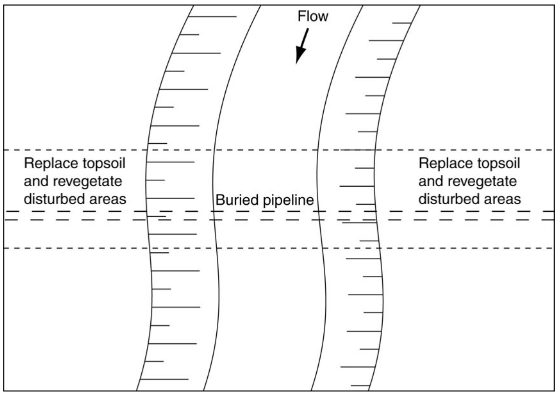


Figure I60 – Removal of access track and instream sediment trap followed by site rehabilitation

Case Study H – Alternative pipeline installation across a wide, watercourse with constant low flow and where increased channel flows are possible

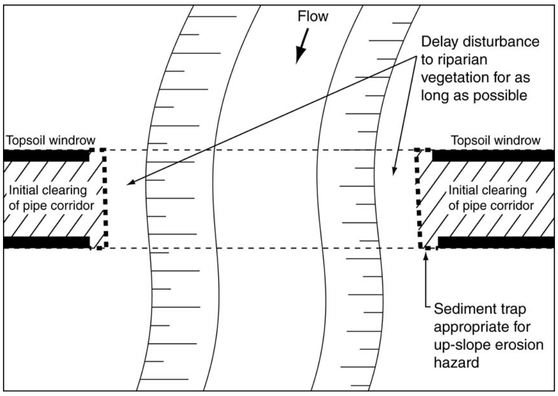


Figure I61 – Initial clearing of the easement prior to the pipe being ready for installation

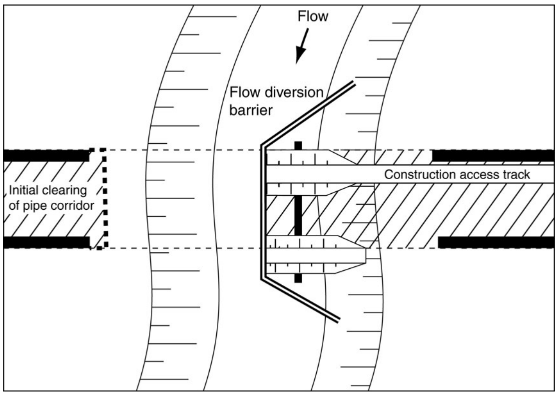


Figure I62 – Partial channel clearing and partial installation of cofferdam and construction access

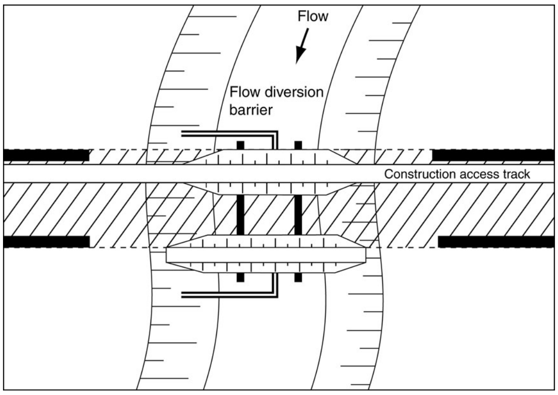


Figure I63 – Final channel clearing and final installation of cofferdam and construction access with full channel flow bypass

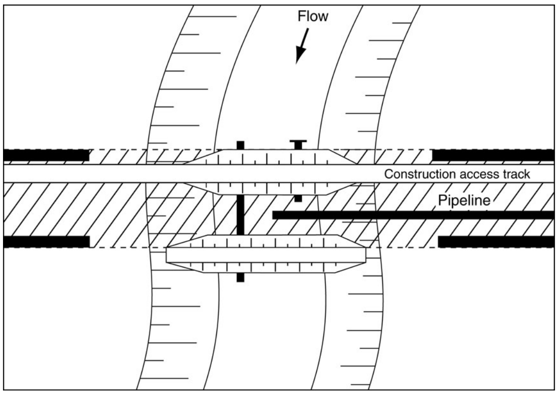


Figure I64 – Stage 1 of pipeline installation with one of the bypass pipes taken off-line to allow better access for pipe installation

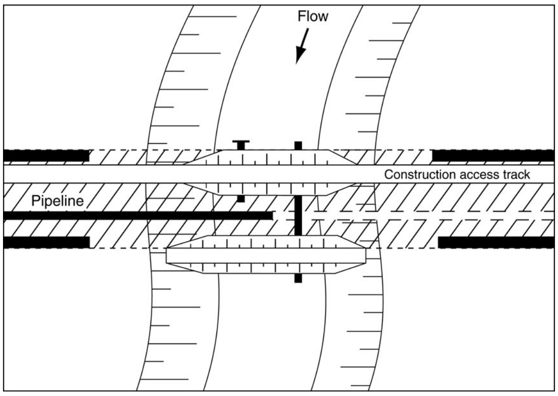


Figure I65 – Stage 2 of pipeline installation with the other bypass pipe taken off-line to allow better access for pipe installation

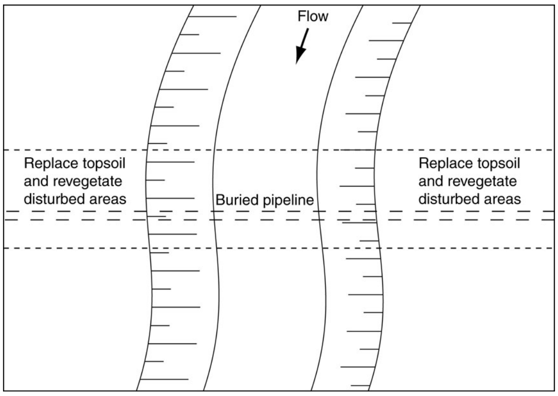


Figure I66 – Removal of access track and instream sediment trap followed by site rehabilitation

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Appendix J

Road and rail construction

This appendix provides specific guidelines on how the principles of erosion and sediment control are adapted to road and rail construction projects. Its function within this document is primarily educational. Those people involved within the road and rail construction industry, or wishing to apply erosion and sediment control measures to a specific site, should first ensure that they familiar with the general principles outlined in Chapter 2 – Principles of erosion and sediment control.

J1. Introduction

Road construction can be one of the most difficult environments for controlling sediment runoff. What is considered reasonable and practicable on an open (broad acre) construction site is often significantly different from what is considered reasonable and practicable in road construction.

Road construction activities can vary from minor road works associated with subdivisions and local government activities, to major highways. Similarly rail works can vary from the construction of car parks and track duplications to the formation of new branch lines. Independent of the size of the works, all road and rail construction projects are likely to experience some common ESC issues.

(i) The works usually involve "strip" construction within a well defined and often narrow transportation reserve. In urban areas it is often impractical to locate any form of temporary sediment control outside the designated reserve. However, there is usually inadequate space inside the reserve to construct a desirable *Sediment Basin*.

(ii) Road and rail works can cross several drainage catchments, thus requiring several major sediment traps instead of just one.

(iii) While under construction, the road/rail reserve effectively becomes a major drainage channel collecting up-slope water and feeding it through the length of the construction site. This problem is often amplified by the fact that the unfinished road surface is below the lip of the constructed kerb drainage system.

(iv) Road works often incorporate several site entry/exit points that may move from week to week as works progress. This means considerable care needs to be taken to reduce the tracking of sediment onto an adjacent sealed roadway, especially if the roadway is open to public use.

(v) Pedestrian and vehicular passage through the site may need to continue while the works are in progress, thus public safety issues can significantly influence the selection and design of the ESC measures.

(vi) Some aspects of sediment control on road construction projects can be closely linked to those activities associated with controlling the undesirable transport of weed seed by construction equipment, for example, cleaning mud and dirt from equipment.

Though focused on road construction, the majority of the following discussion applies equally to rail construction activities.

J2. Road planning

It is essential for erosion and sediment control issues to be incorporated into the planning phase of road design and road construction, especially on major projects. If land is being acquired to build a road, then consideration must also be given to the resumption or short-term leasing of any additional land required for the construction of major sediment traps such as *Sediment Basins*.

In the planning of traffic routes, *Erosion Risk Mapping*, as discussed in Chapter 3, can be used to assess the erosion hazard rating of each road layout. The assessed erosion hazard can then be weighed against other engineering, social, economic, and environmental considerations when appraising alternative proposals.

It must be clearly recognised that the *Erosion Hazard* is just one of the factors requiring consideration in the planning and design of roads. The relative weighting of this factor will vary from project to project, and possibly from location to location within a given project.

Factors that should be considered when preparing Erosion Risk Maps for road works include soil erodibility, rainfall erosivity, topography, vegetation cover, land use, and the proximity to water bodies, high-risk habitats and valued ecosystems.

When planning the road alignment, wherever reasonable and practicable, the existing topography should be utilised to eliminate the need for extreme landform modifications. The degree of cut and fill should be minimised by judicious selection of the vertical alignment.

Technical Note J1 – Retention of remnant vegetation

Rural road reserves often contain the only remaining examples of mature, native trees and other remnant vegetation such as grasses shrubs and herbs. Tree-lined roadsides can act as essential corridors for wildlife movement and as a gene pool for indigenous flora. Unfortunately, the need to retain existing roadside vegetation is often in conflict with the desire to construct roadside drainage channels (instead of kerb and channel), and cut and fill batters that are flat enough to control long-term soil erosion and allow effective revegetation.

J3. Batter design

The design of a road is rarely controlled by the short-term requirements of erosion and sediment control; however, road design, and in particular drainage and batter design, can significantly affect the long-term erosion potential of a roadway. The benching of long batter slopes can help reduce ongoing erosion problems by allowing better control of runoff-producing erosion, in particular, the control of rilling.

Batters should be designed to a stable gradient based on consideration of topography, soil type, vegetation, and the presence of rock formations. Typical **maximum** batter slopes are presented in Table J1 (Hunt, 1992).

Table J1 – Typical maximum batter slopes

Erosion hazard of soil	Maximum desirable batter slope
Low	2:1 (H:V)
High	3:1 (H:V)
Extreme	4:1 (H:V)

Technical Note J2 – Erosion hazard and soil erodibility

The erosion hazard rating of an earth embankment depends on a number of variables including soil erodibility, and the type and extent of vegetative cover.

Soil erodibility is the susceptibility of a soil to erosion. It is independent of such factors as topography, land use, rainfall intensity and plant cover, but may be changed by land management practices.

A minimum organic content of 3% is required for good soil structure (i.e. low erodibility) and nutrient supply in the surface horizon, while 5% is considered desirable. Structural problems become significant if the organic matter fall below 1.5% (Bridge and Probert, 1993).

Table J2 – Soil erodibility classes for water erosion (Charman & Murphy, 2007)

Erodibility	Topsoil	Subsoil
Low	High organic matter (>3%) (soils have a dark colour and feel greasy when textured). High coarse sand.	Cemented layers including silcrete, ortstein and laterite iron, manganese, and silica pans. High coarse sand.
	Well-structured, non-dispersible clay loams and clays having aggregates that do not slake in water to particles less than 2mm (Emerson Aggregate Classes 4, 6, 7 and 8), such as Red Ferrosols, some Vertosols, some structured loams, and Chromosols with friable surface soils.	
Moderate	Moderate organic matter (1.5 to 3%). Moderate fine sand and silt, such as some surface soils of Red Chromosols and Red Kandosols. Well-structured clay loams and clays that slake in water to particles less than 2mm (Emerson Aggregate Classes 3 to 6), such as strongly self-mulching Vertosols.	Stable, non-dispersible loams and clay loams, such as Red and Yellow Kandosols. Non-dispersible or slightly dispersible clays with particles that slake to finer than 2mm (Emerson Aggregate Classes 3 to 6), such as some Chromosols.
High	Low (0.9 to 1.5%) to very low (<0.9%) organic matter, such as soils with bleached A2 horizons. High to very high silt and fine sand (>65%).	Dispersible clays (Emerson Aggregate Classes 1 and 2), such as Sodosols. Unstable, dispersible clayey sands and sandy clays, such as Yellow and Grey Kandosols formed on sandstone and some granites. Unstable materials high in silt and fine sand, such as unconsolidated sediments and alluvial materials.

Soil erodibility may also be linked to the soil erodibility K-factor used within the Universal Soil Loss Equation (USLE) and RUSLE analysis as presented in Table J3.

Table J3 – Soil erodibility based on USLE K-factor

RUSLE K-factor	Rating	Typical soil groups	
0.0–0.01	Very low	(SP)*	S
0.01–0.02	Low	GW, GP (GM, GC, SW, SP)*	CLS, SC, LMC, MC, HC
0.02–0.04	Moderate	SM, SC, OL (GM, GC, SW, SP)*	LS, SL, FSL, SCL, CL, FSCL, SiC, LC
0.04–0.06	High	ML, CL, (MH, CH)*	L, Lfsy, SCL, SiCL
>0.06	Extreme	(MH)*	Dispersive soils

* Classification is highly variable for this soil group (Unified Soil Class System)

Geotechnical advice on the design of batter slopes is always recommended; however, geotechnical advice that is excessively conservative often results in soil compaction specifications for earth batters that are inconsistent with desirable revegetation requirements. It is noted that even though well-compacted, non-vegetated earth batters may appear to exhibit good short-term stability, they often experience long-term "sheet" erosion problems resulting in ongoing environmental harm.

It is usually preferable to concentrate on the provision of suitable revegetation conditions on the road batter, than to focus on high surface compaction and short-term erosion control. To achieve suitable revegetation conditions, the bulk density of the soil should not exceed the values presented in Table J4 throughout the depth of the proposed root zone. Desirable soil bulk densities for revegetation may be obtained from Table J5.

Table J4 – Critical bulk density for restricted plant growth [1]

Texture	Critical bulk density (g/cm^3)
Sandy loam	1.8
Fine sandy loam	1.7
Loam and clay loam	1.6
Clay	1.4

[1] After Hazelton and Murphy (1992)

Table J5 – Desirable soil bulk density conditions for revegetation

Bulk Density (g/mL)	Sands	Loams	Clays
< 1.0	N/A	good conditions	satisfactory
1.0–1.2	N/A	satisfactory	satisfactory
1.2–1.4	very open	satisfactory	some too compact
1.4–1.6	satisfactory	some too compact	too compact
1.6–1.8	most too compact	too compact	extremely compact
> 1.8	too compact	extremely compact	N/A

In general, the following design guidelines should be considered.

- Earth batters that are likely to be vegetated should be as flat as possible—with due regard to economics, loss of existing mature trees, and so on.
- Earth batters that are **not** likely to be vegetated (i.e. within arid and semi-arid zones) should be as steep as possible—with due regard to soil stability, safety issues, and so on.

In areas of low rainfall it is often rare in nature for a healthy continuous vegetation cover to exist close to the edge of a sharp change in grade, such as is often found at the top of cut batters. Infiltrated rainwater quickly moves away from these extreme edges and thus plants can be starved of water. To avoid this problem, the very top of a batter may need to be rolled back (i.e. rounded-off) to form a more natural land formation as demonstrated in Figure J1.

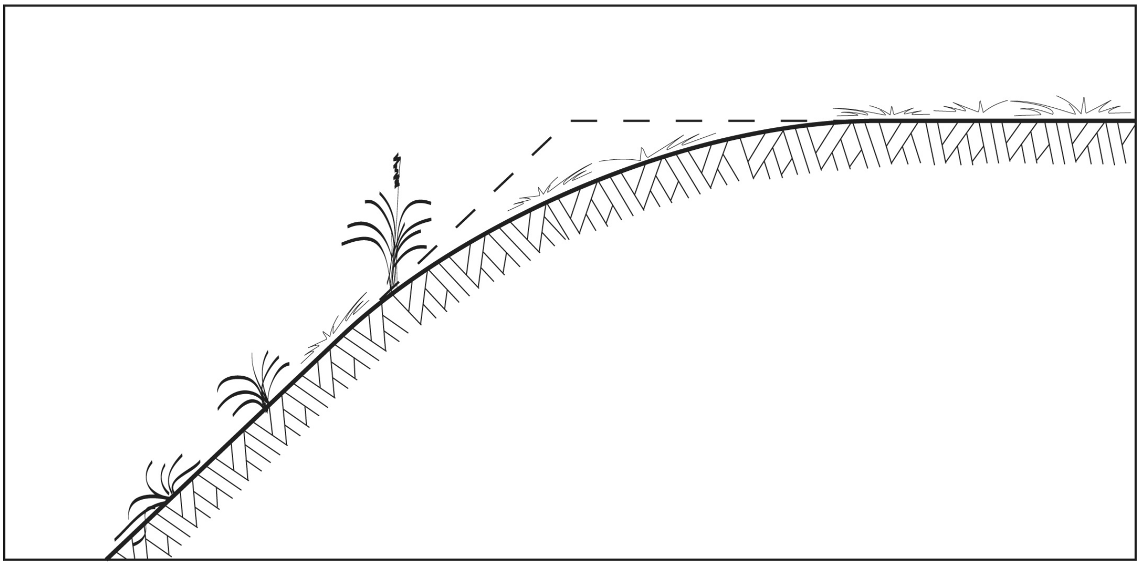

Figure J1 – Rounding-off the batter crest

Berms or benches are recommended on batters with a vertical height greater than 5m. The bench should be at least 1m wide, but a greater width may be necessary to allow for the movement of equipment used to establish and maintain vegetation on the batter.

Benches should have a positive slope in towards the hill and have a minimum longitudinal grade of 1% if vegetated, or 0.5% if paved. The maximum grades should be restricted to a level consistent with the maximum permissible velocity for the type of surface lining used. A maximum lateral bench slope of 10% (10:1) towards the toe of the upper batter should apply.

The appropriate spacing of benches down a slope should always be based on site-specific investigation and design. Numerous factors can change the bench spacing including soil condition, local hydrology, the potential hazards associated with bank failure, and of course the type and extent of vegetation cover. The typical spacing of benches down long grassed slopes is provided in Table J6.

Table J6 – Recommended maximum bench spacing on vegetated slopes

Batter slope			Horizontal spacing (m)	Vertical spacing (m)
Percentage	Degrees	(H):(V)		
< 10%	5.71	10:1	Site specific	Site specific
12%	6.84	8.33:1	100	12
15%	8.53	6.67:1	80	12
20%	11.3	5:1	55	11
25%	14.0	4:1	40	10
30%	16.7	3.33:1	30	9
> 36%	> 19.8	> 2.78:1	Site specific	Site specific

J4. Construction activities

J4.1 Environmental considerations

On major road projects, formal *Environmental Site Induction* procedures should be established for all site personnel, including subcontractors. These documented procedures should include the creation of a site register of induction and job training activities. Environmental Site Induction would include such items as:

- objectives of the *Environmental Management Plan, Stormwater Management Plan,* and/or *Erosion and Sediment Control Plan* as appropriate for the site;
- statement of *duty of care;*
- identification of site specific *Environmental Values;*
- specific conditions of any *Environmental Licence, Permit* and *Approvals;*
- use of the site's *Environmental Emergency Plan;*
- incident reporting procedures;
- specific equipment operational and maintenance procedures.

J4.2 Erosion and sediment control

The principles and guidelines of *Erosion and Sediment Control* presented throughout this document for general civil construction projects are equally applicable to road and rail construction projects.

Due to the nature of most major road projects, erosion and sediment control planning is often best subdivided into clearly defined ESC zones or sectors, usually based on catchment boundaries. In addition to the road easement boundaries, ESC zones should be established around:

- compound areas, including site office and concrete batching plant;
- access and haulage roads;
- borrow pits;
- stockpile and material storage areas.

Soil disturbances should not be conducted within these ESC zones until an appropriate Erosion and Sediment Control Plan (ESCP) has been approved for this area. Subdividing the ESCP into well-defined ESC zones can also assist in the preparation and approval of amended ESCPs.

The submission of an ESCP for a specific ESC zone should be recognised as a ***Milestone***, and the subsequent approval/acceptance of the ESCP by the Superintendent should be recognised as a ***Hold Point*** within the construction contract and/or Environmental Management Plan.

Common sediment-related construction activities, such as those listed below, should be detailed within Environmental Management Plan, or an overall site ESCP:

- equipment cleaning;
- site and material de-watering procedures;
- treatment of acid sulfate soils;
- treatment of dispersive soils;
- rock pad sediment traps at site entry/exit points;

J4.3 Batter construction

Embankments should be constructed so that adequate drainage of the embankment is maintained throughout the construction period.

The following principles of batter construction and stabilisation (Hunt, 1992) should be reviewed when preparing design and construction specifications.

(i) Provision must be made to prevent surface runoff damaging cut and fill batters. *Catch Drains* and *Flow Diversion Banks* above and below batters, and benches within batter slopes, can be used to intercept surface runoff and transport it to safe disposal points.

(ii) With cut batters, a *Catch Drain* or *Flow Diversion Bank* should be constructed above the top of the cut before excavation commences. Temporary toe drainage should be maintained as the work progresses, with permanent toe drainage installed when the final landform is achieved.

(iii) As the batter is excavated, serrated cuts may be placed in the batter to help hold topsoil and to assist with the establishment of vegetation.

(iv) For fill batters, permanent toe drainage should be installed at an early stage and should discharge to a suitable outlet. At the completion of each day's work, or at the onset of rain, a windrow of suitably compacted soil material should be constructed along the recently completed fill slope. Permanent top drainage measures should be installed on completion of the filling operation.

(v) *Chutes* or *Slope Drains* may be required at points along a *Catch Drain* or channel to allow safe disposal of runoff down the face of the batter.

Batters should be topsoiled, seeded and mulched (where appropriate) as work progresses. Revegetation should be programmed in stages at approximately equal increments with a maximum desirable unprotected batter fall height of around 3m. Ideally, the staged placement of erosion control measures (e.g. seeding and mulching) on earth batters in 3m lifts should become ***Hold Points*** within the construction contract.

Recommendations for surface roughening techniques applicable to earth batters is provided below (North Carolina SCC & DEHNR, 1993).

(a) Non-mowable cut slopes:

(i) For cut slopes steeper than 3:1 (H:V) that are not to be mown, stair-step or groove the slopes.

(ii) Use stair-step grading on any erodible material soft enough to be ripped with a bulldozer. Slopes consisting of soft rock with some subsoil are particularly suited to stair-step grading.

(iii) Make the vertical cut distance less than the horizontal distance, and slightly slope the horizontal portion of the step in towards the vertical wall.

(iv) Do not make individual vertical cuts more than 600mm in soft materials or more than 900mm in rocky materials.

(v) Grooves consisting of a series of ridges and depressions that run across the slope (i.e. along the contour) should be created by any appropriate implement that can be safely operated on the slope. These grooves should be not less than 75mm deep and spaced no more than 375mm apart.

(b) Non-mowable fill slopes:

(i) Place fill slopes with a gradient not steeper than 3:1(H:V) in lifts not to exceed 225m, and make sure each lift is properly compacted. Ensure that the face of the slope consists of loose, uncompacted fill 100–150mm deep. Use grooving to roughen the face of the slopes, if necessary.

(ii) Do not blade or scrape the final slope face.

(c) Mowable cuts, fills and graded areas:

(i) Make mowed slopes no steeper than 4:1(H:V).

(ii) Roughen these areas to shallow grooves by normal tilling, discing, harrowing, or other suitable means. Make the final pass of any such tillage implement on the contour.

(iii) Such grooves should be spaced no less than 250mm and not less than 25mm deep. Excessive grooving is undesirable where mowing is planned. Areas should generally be mulched.

(iv) Limit roughening by tracked machinery to sandy soils to avoid undue compaction of the soil surface.

(v) Operate tracked machinery up and down the slope to leave horizontal depressions in the soil. Do not back-blade during the final grading operation.

J4.4 Bridge and culvert construction

There are a number of variables that must be considered before finalising the construction procedure for a bridge or culvert. These variables may include the following:

- risk of flood flows during the construction period;
- risk of adjacent property flooding during the construction period;
- fish passage requirements;
- construction issues relating to the type of bridge or culvert;
- degree of base flow within stream;
- requirements for construction access across the stream;
- requirements for vehicular traffic across the existing bridge during construction;
- erosion and sediment control requirements during the construction period.

Detailed discussion on instream sediment control practices for bridge and culvert construction is provided in Appendix I – *Instream works*.

J4.5 Revegetation of road batters

Early stabilisation of exposed batters is essential. They should be adequately protected from erosion by vegetation, or other means. *Grass Filter Strips* can be used to maintain sheet flow down the embankment. Typically these turf strips (minimum 300mm wide) are placed in continuous rows along the contour, and at a spacing of 1 to 2m (Figure J2). These turf strips also assist as a Type 3 sediment trap.

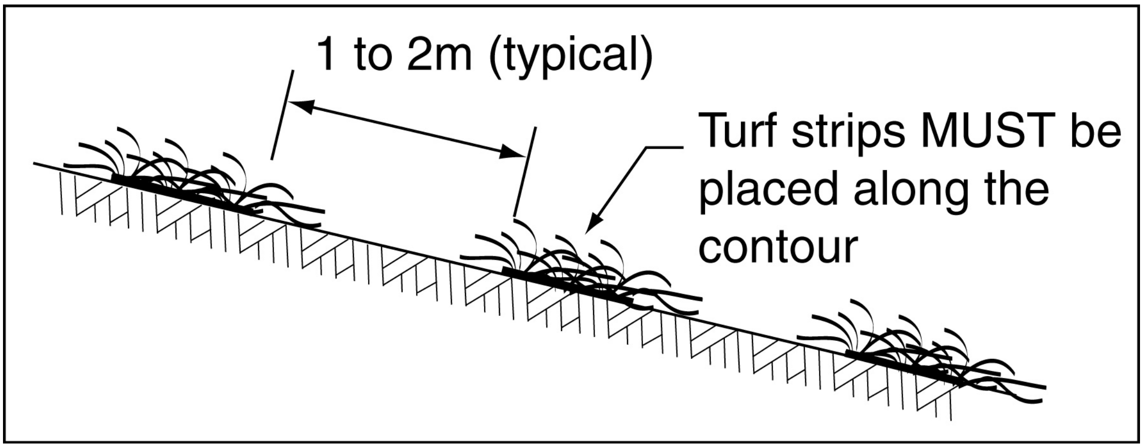

Figure J2 – Use of turf to maintain sheet flow down earth batters during the revegetation phase

J5. Rural roads

In rural areas, landholders can often make good use of stormwater runoff from roads. Long-term cooperation with landholders can reduce road and property drainage design problems with the potential of providing long-term financial savings. The real difficulty is maintaining this successful long-term partnership within an ever-changing political and social environment.

If roads are managed in conjunction with the surrounding land, both erosion and siltation problems can be reduced by coordinating erosion control structures, such as contour banks on the properties, and diversion channels within the road reserve. Where land under cultivation adjoining the road reserve is not contour banked, it is not advisable for diversion banks or drains to direct concentrated runoff onto it, because this may result in massive erosion of the unprotected topsoil.

Adjoining landholders can greatly increase the catchment areas of their dams by constructing diversion banks across pasture or cultivation to discharge water from roadside table drains into these dams. Construction of such diversion banks or channels requires permission from the local road authority and adjacent landowners. Before constructing drainage works, the road authority and landholder will need to negotiate an agreement for responsibility for maintenance of the channels and banks.

These roadside drainage structures can be more easily maintained if provision is made for opening of fences where they enter adjoining properties. Care must also be taken to control cattle movement along adjoining fence lines and to prevent the formation of deep cattle tracks along these fences.

In locations where landholders are keen to preserve trees within the road reserve, they should offer cleared land inside their boundary fence lines to the road authority for use as a temporary side track while new roads are being constructed or upgraded.

Discussion on the revegetation of rural road works is provided in Section C15 of Appendix C – *Soils and revegetation*.

J5.1 Table drains

The depth and width of table drains varies largely with soil type and vegetation cover. Extreme care is required on very erodible soils, or drains with highly dispersive subsoils, as exposure of such soils can have disastrous consequences. In such cases the proper management of the topsoil and the choice of drain depth are extremely important.

In areas known to have dispersive subsoils, soil chemistry should be analysed to determine whether the soil properties can be economically improved to aid soil stability and revegetation.

To avoid exposing the subsoil, it is preferable to design wide shallow table drains. However, where possible, table drains should be at least 300mm below the bottom of a pavement to prevent water entering the pavement material.

To reduce water velocity, table drains should be flat-bottomed with a slight slope away from the road at all times. To allow maintenance by earthmoving equipment, the flat-bed width should be a minimum of 2.5m.

J5.2 Diversion drains

Diversion drains are the constructed drainage channels that collect water from the table drain and direct it to a suitable disposal area. Ideally these drains should be flat-bottomed and not V-shaped. The drains should have an excavated cross-sectional area at least equal to that of the upstream table drain.

The initial grade ("kick out" grade) in the diversion drain should approximate the grade of the table drain to avoid energy loss, and hence siltation and bank failure. As the drain increases in length, the grade in the channel should progressively decrease. Ideally, diversion drains should have a surveyed grade of 0.2% for the final 30m (i.e. 6 cm fall in 30m).

Herbert and Evans (1992) provides the recommended spacing for diversion drain outlets along table drains (always seek local guidelines):

- 120m for slopes up to 2%
- 60m for slopes from 2% to 4%
- 30m for slopes from 4% to 8%
- 15m for slopes greater than 8%

If the diversion drain is built through a fence, it is preferable that landholders ensure that a floodgate is constructed so the fence can be easily reopened for maintenance.

Discharge from a diversion drain may also be spread over a pasture to ensure grass growth. This can be achieved with the use of a *Level Spreader*.

In areas with known dispersive subsoils, the use of *Flow Diversion Banks* rather than excavated diversion drains may be preferred.

J6. Road maintenance

In some cases, poorly maintained drainage works can be more detrimental to roads and adjoining properties than no drainage at all.

During maintenance, the area of exposed soil should be minimised. Ways to do this include those listed below:

- Use slashers or controlled herbicides rather than graders to maintain roadside vegetation. Where possible, slashed vegetation and debris should be removed from the drain to avoid blockages downstream.
- Ensure that adequate provision is made for drainage during road construction and maintenance. It is important to avoid sudden changes in direction and/or height.
- Suitably line drainage inverts in scour-prone country.

J6.1 Maintenance of unsealed roads

Grader operators play a major role in any attempt to control erosion. It is important that they receive adequate training in erosion control and maintenance techniques. Such techniques include the following.

- Grading diversion channels from the outlet end towards the road. If this is possible, it will aid in topdressing the drain and rebuilding the table drain block (the earth mound constructed in the table drain to divert water into the diversion channel).
- Where practicable, table and diversion drains should be converted from V-drains to flat-bottom drains.
- When de-silting table drains or when road construction operations are carried out with a grader, silt should **not** be left in a windrow along the side of the table drain. These windrows can cause concentration of surface runoff and possible erosion.
- When removing the windrow, the overseer or engineer should investigate the suitability of using the material for road construction. However, windrow material has often lost its fines and is not acceptable as paving material.
- Maintaining road height and form. During regular maintenance, grading should start from both edges, with material being moved towards the centre of the road. Then, to achieve crossfall and height, the material should be spread away from the centre line to the edge ensuring that any excess is suitably spread. If this operation is not carried out, the continual grading of the road results in the carriageway eventually being lower than the surrounding land.
- Adequate crowning needs to be provided for all roads. The cross-fall on unsealed roads should be between 4% and 5% to prevent longitudinal scour along wheel path ruts.

Where fines have been lost from unsealed road surfaces, investigate the possibility of importing and mixing clay or loam binder, or crushing oversize rock. This is considered preferable to wasting material on the side of the road reserve.

Correct crowning, road surfacing, and road cross-drainage should alleviate the need for banks across unsealed roads (whoa-boys). Whoa-boys present an obstacle to motorists, and can be dangerous to traffic even when newly constructed and adequately maintained. Whoa-boys should only be considered as a temporary measure to limit the extent of erosion while waiting for maintenance works to restore suitable drainage controls.

J6.2 Maintenance of table drains and earth batters

The grader maintenance of table drains adjacent to rural arterial roads has resulted in a common erosion problem occurring at a number of locations. For reasons of traffic safety, graders are forced to pass on the embankment side of guideposts often forcing the grader to ride up the toe of the embankment (Figure J3).

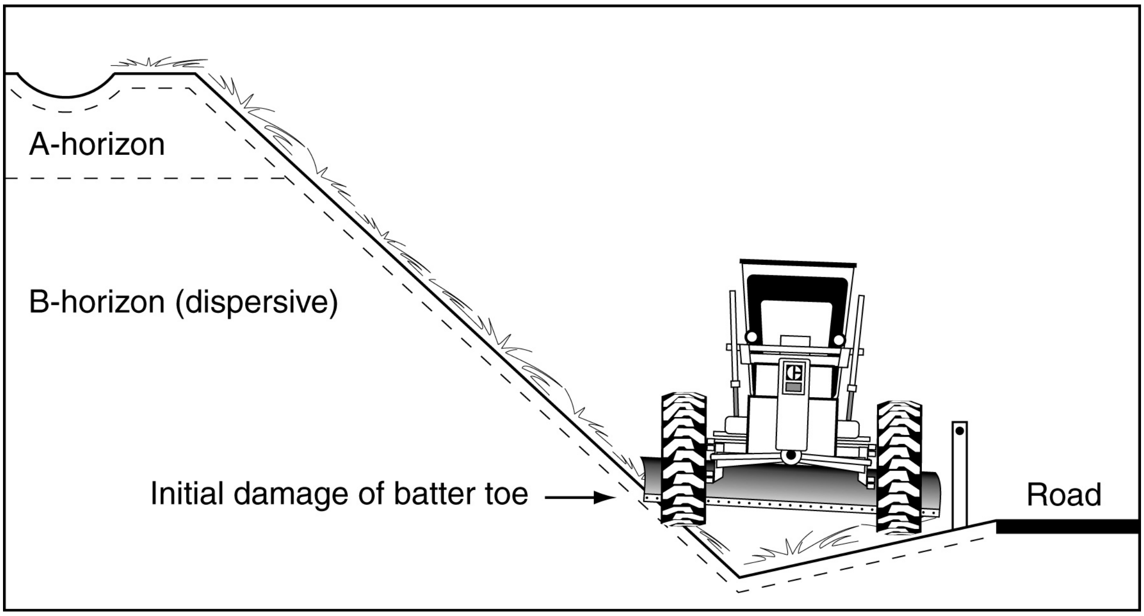

Figure J3 – Grader maintenance of table drains

If the embankment subsoils are dispersive (a common situation) then these dispersive soils can become exposed to erosion at the toe of the road batter (Figure J4). This erosion eventually migrates up the slope until all the topsoil and grass cover is removed and the road batter is left as a concave, poorly vegetated, eroding slope (Figure J5).

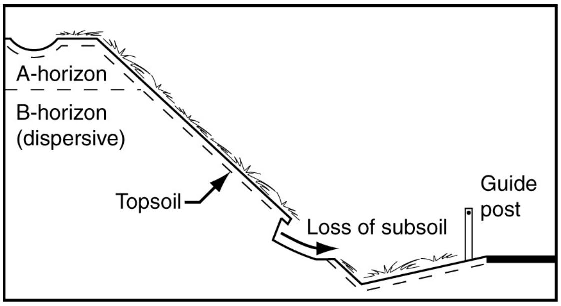

Figure J4 – Initial toe damage

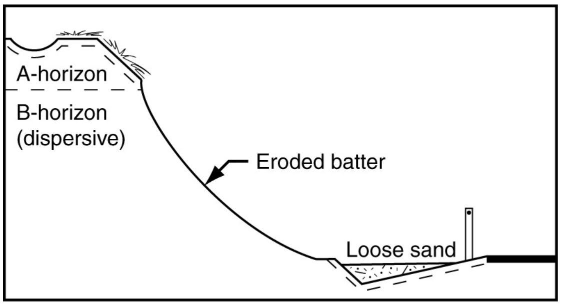

Figure J5 – Final outcome

The most desirable preventative measure is to ensure that there is sufficient room between the guideposts and the toe of the batter to allow typical maintenance machinery such as slashers and graders to pass.

Technical Note J3 – Dispersive soils

Dispersive soil road batters are often identified by the following common indicators:

- "clean" , lightly coloured sand deposited along the toe of the batter;
- closely spaced, deep rilling down all or part of the batter (known as *fluting*, with the depth of each rill usually significantly greater than its top width);
- appearance of erosion (rilling) can change significantly from one layer of soil to another (indicating soils of different degrees of dispersibility).

J7. References

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Appendix K

Access Tracks and Trails

This appendix provides specific guidelines on how the principles of erosion and sediment control are applied to the construction and maintenance of unsealed access tracks and trails. Its function within this document is primarily educational. Those people wishing to apply erosion and sediment control measures to the construction or management of access tracks and trails should first ensure that they familiar with the general principles outlined in Chapter 2 – Principles of erosion and sediment control.

K1. Introduction

Access tracks are used in engineering to provide temporary access on construction sites, or permanent low-traffic access for ongoing maintenance activities. Trails are typically walking tracks that may be used by small, all-terrain vehicles for fire fighting or maintenance access. Aspects of the following discussion also apply to long, unsealed driveways in rural residential areas. Discussion on the design and maintenance of low to medium use unsealed roadways is provided in Appendix J – *Road and rail construction*.

The degree of planning and design that goes into the engineering of tracks and trails should **not** be related to the volume of expected traffic, but to the potential environment risk exposed through the construction and operation of these pathways.

K2. Planning considerations

The planning of tracks and trails should consider the following factors (Soil Conservation Service, 1984):

- purpose and service life of the track;
- type and volume of authorised and possible unauthorised traffic;
- restrictions introduced to limit unauthorised traffic and public usage;
- soil properties and identified erosion hazard areas;
- topographic restrictions (steep slopes, rocky outcrops, areas subject to mass movement, swampy areas, etc.);
- location of natural drainage lines;
- location of protected, rare, or otherwise highly valued vegetation;
- location of alterative access routes.

A track or trail should be located to minimise both short and long-term soil and vegetation disturbance, while giving appropriate consideration to the intended purpose of the pathway. When planning the location of a track or trail, the following points should be given appropriate consideration.

(i) Tracks should generally follow the land contour with a gentle gradient of between 1 and 4%.

(ii) Avoid long, sustained grades where stormwater cannot be regularly removed from the track or its associated side drain.

(iii) Avoid locating tracks or trails down the centre of a valley or along the centre of an overland flow path. Unsealed tracks and trails should only act as drainage paths in exceptional circumstances.

(iv) Avoid steep grades, areas of dense timber, or locations where it may be difficult to control drainage. In particular, avoid circumstances where the track may collect and transport stormwater runoff.

(v) Allow the track to regularly rise and fall in elevation so that stormwater is forced to leave the track at regular intervals.

(vi) Aim to minimise the number of gully and stream crossings, and place any crossings at locations that have stable bed and banks.

(vii) Wherever reasonable and practicable, locate permanent tracks above the 1 in 2 year flood level, and temporary tracks above the 1 in 1 year flood level, and at least above the low bank of streams.

(viii) Avoid any unnecessary disturbance to the riparian zone of streams, and where possible, utilise this vegetation as a buffer zone to separate the track from the stream. Ideally, the minimum width of the riparian zone between the track and the edge of the stream should be at least the width of the stream (measured at the top of the bank) or 30m whichever is the lesser.

(ix) Avoid potential mass movement areas and highly erodible soils, such as:

(a) grey and yellow soils derived from granite, sedimentary and meta-sedimentary (slightly metamorphosed sedimentary rock), especially coarse grained types;

(b) unconsolidated sediment;

(c) slopes with steps, clay beds, hummocky topography (i.e. an elevated track rising above the general level of a marshy region);

(d) dispersive soils.

(x) Avoid crossing long, steep, unstable slopes, especially where the bedrock is highly weathered.

(xi) Avoid opening up moisture-laden foot-slopes.

(xii) Ensure the maximum gradient of tracks used as fire trails is 16% (NSW Department of Housing – Fire Trail Details, Dwg. RM26)

(xiii) Ensure that if the track is used as a fire trail and the track has insufficient width to allow passing, then passing bays are provided at intervals of between 200 to 400m (NSW Department of Housing – Fire Trail Details, Dwg. RM26).

(xiv) If a track follows a fence line on a long, steep slope, deviate the track every 60 to 80m to help divert runoff from the track at regular intervals (Figure K1).

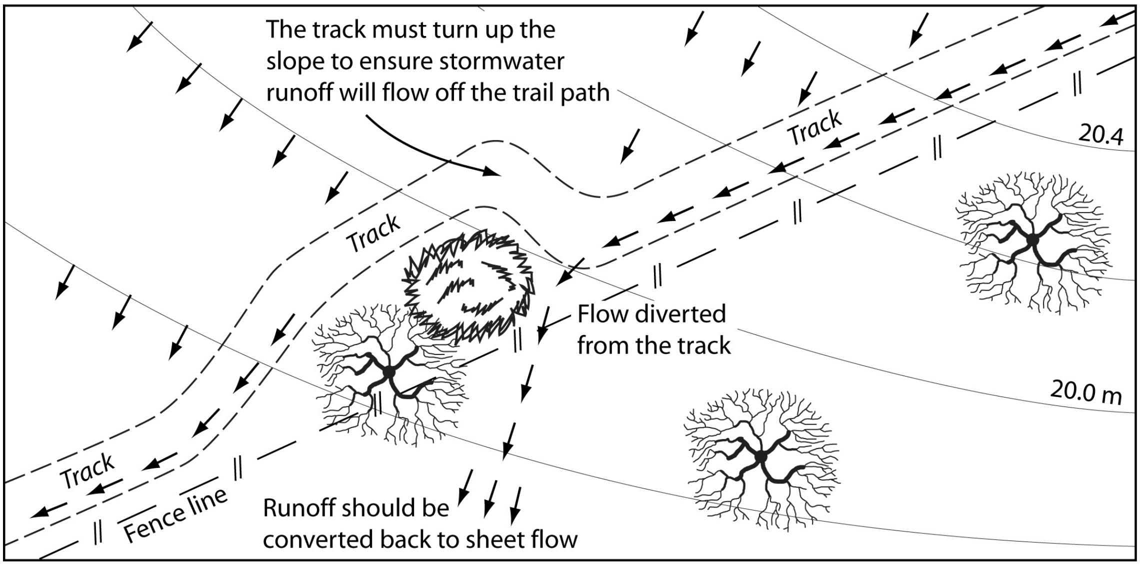


Figure K1 – Control of drainage along fence-line tracks

Where access is required across a slope, the track should be sited as close as possible to the contour of the land. This allows up-slope stormwater runoff to pass evenly across the track, thus avoiding flow concentration. If the track surface is allowed to erode forming a drainage channel, or if a windrow is allowed to form along the down-slope edge of the track, then drainage problems are likely to exist, even if the track is located along the contour. In such cases, regular maintenance of the track should aim to appropriately control the movement and ponding of surface water.

In situations where a track diagonally traverses a slope, the track will likely collect and concentrate up-slope stormwater runoff. Where practicable, these tracks should be zigzagged to allow the regular discharge of stormwater from the track, otherwise appropriate drainage controls need to be constructed to allow runoff to be regularly removed from the track.

Ridges often provide an excellent location for tracks because runoff can discharge each side of the track. If no suitable ridge is available, and slope gradients are not too steep, an alternative is to run the track alignment directly up the slope, provided that this does not initiate excessive erosion on the track.

K3. Design aspects

There are basically three types of track cross sections: sub-surface, ground level, and formed roads (Figure K2). Sub-surface tracks are generally not recommended. They collect large quantities of up-slope runoff effectively turning the track into a drainage channel.

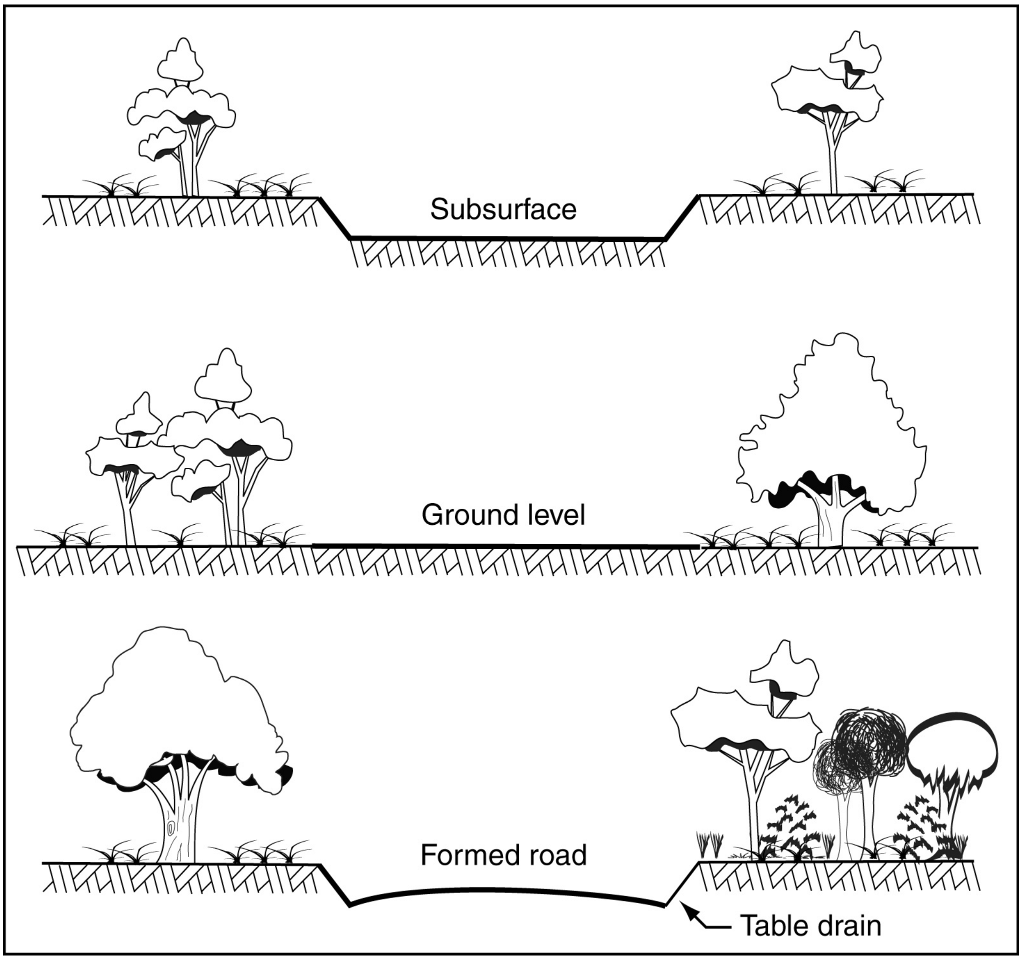


Figure K2 – Typical track cross sections (after Carey, 1992)

Ground level tracks are formed by slashing or blading the surface vegetation. Low cost, low traffic temporary tracks are best constructed at ground level. Unfortunately, many ground level tracks eventually become sub-surface tracks through excessive soil compaction, traffic erosion, stormwater erosion, or through the application of inappropriate maintenance procedures.

Formed roads should be used where a track is likely to be permanent and when it is likely to carry significant volumes of traffic. Formed roads have a raised formation with table drains on each side of the road. Further discussion on unsealed, formed roadways is provided in Appendix J – *Road and rail construction*.

In locations where sediment runoff from the track may cause environmental problems, the track can be covered with gravel to reduce runoff turbidity caused by raindrop impact erosion. Low-traffic tracks can also be formed using “structural soils”.

Technical Note K1 – Vegetated structural soils

Structural soil tracks are formed by boxing out the track to a depth of around 100mm, then filling it with a mixture of uniformly-graded aggregate and a small quantity of sandy soil (sufficient only to fill the voids). The track is then seeded with appropriate grass species.

The benefit of this construction technique is that the weight of vehicular traffic is transferred directly through aggregate to aggregate contact, thus reducing soil compaction and damage to the root system of the grass cover. The disadvantages with this form of track construction include the long establishment time (i.e. grass growth from seed during which traffic must be avoided on the track), and the potential for these grassed tracks to become a fire hazard.

The trafficable track width is generally 3 to 4m, with a maximum desirable clearing width of 5m for minor tracks (though not always practical). Haul roads may require much wider widths to allow passing and to provide safe slight lines. Track clearing should be reduced to the minimum practicable if located within 30m of any watercourse.

Tracks should have at least a slight longitudinal grade to allow free surface drainage and to avoid excessive ponding within wheel tracks. Generally the grade of a track should be less than 10° (1 in 5.7 or 17.5%). Short lengths of steeper grades may be needed to negotiate difficult sections, or to take advantage of favourable terrain. Such sections may need to be sealed with bitumen or concrete, or otherwise stabilised (timber sleepers, soil-cement treatment, gravel, and so on).

If it is necessary to design track sections with grades exceeding 10°, then it should be noted that trafficable drainage cross banks are generally limited to a maximum track grade of approximately 12° (1 in 4.7 or 21%). Tracks steeper than 12° will normally require special drainage works.

The sealing of earth tracks can greatly reduce soil erosion resulting from vehicular traffic, stormwater runoff, raindrop impact erosion and wind erosion. Table K1 provides suggested surface treatments that may assist in the reduction of sediment-laden runoff from low to medium traffic tracks. These recommendations are only a general guide—appropriate consideration should always be given to experience gained from past practices within different regions.

In addition to the surfacing treatments presented in Table K1, there is also a variety of *Surface Stabilisers* (soil binders) which are discussed in more detail in Book 4.

Of course, many of the options listed in Table K1 would result in the track becoming a sealed roadway. Wherever reasonable and practicable, sealed tracks should be profiled to allow sheet flow off the track.

Table K1 – General guide to the surface treatment of low to medium traffic areas

Road Grade	Option	Road Finish
< 5%	1st option	Compacted crushed rock.
	2nd option	Resin-impregnated for added wear.
	3rd option	Bitumen.
5 to 10%	1st option	Hot-rolled bituminous surface over compacted sub-base.
	2nd option	Resin-impregnated soil.
	3rd option	Bitumen.
10 to 20%	1st option	Asphaltic AC10 concrete over compacted sub-base.
	2nd option	Resin-impregnated soil.
	3rd option	Bitumen.
> 20%	1st option	Mesh-reinforced concrete (40MPa) over compacted sub-base.

K4. Track drainage

There are three forms of track crossfall: outfall, infall and crowned (i.e. formed road). Tracks constructed on a ridge or gentler slope should be crowned; however, minor tracks may not have sufficient width to make a crowed profile practicable. Crowning can ease drainage problems by allowing water to be shed from both sides of the track.

Outfall drainage (i.e. drainage directed away from the hillside) allows stormwater to discharge from the track as "sheet" flow. If outfall drainage is installed, then any "windrows" that develop along the down-slope side of the track during the construction, operational or maintenance phase need to be removed. Outfall drainage should **not** be used when any of the following conditions exist, in which case infall drainage is usually preferred:

- down-slope fill batters are unconsolidated and likely to erode;
- down-slope fill batters exceed 1.5m in height;
- sediment-laden runoff needs to be directed to a sediment trap;
- the track is subject to rutting causing stormwater to be redirected down the track rather than across the track;
- maintenance procedures are likely to result in the formation of an earth "windrow" along the outside edge of the track. Such windrows can cause stormwater to pond on the track and to eventually discharge as concentrated flow at breach points.

When using infall drainage, the formed table drains should represent the primary drainage path within road reserves. Stormwater should be removed from the trafficable road surface as soon as practicable. The crossfall required to achieve effective drainage is generally 4% (1 in 25). For safety reasons, the maximum crossfall should not exceed 10%.

To ensure stormwater sheets off the track into the table drain it may be necessary to construct either infall or outfall cross banks (also known as "whoa-boys") at selected locations.

Outfall cross banks (Figure K3) or outfall drains (e.g. culverts) are used to remove water from the table drain at appropriate outfall locations. *Infall cross banks* (Figure K4) are used at locations where a cross bank is required to direct water off the road surface (as per the recommended drainage spacing presented in Table K2), but it is inappropriate to direct this water off the side of the road.

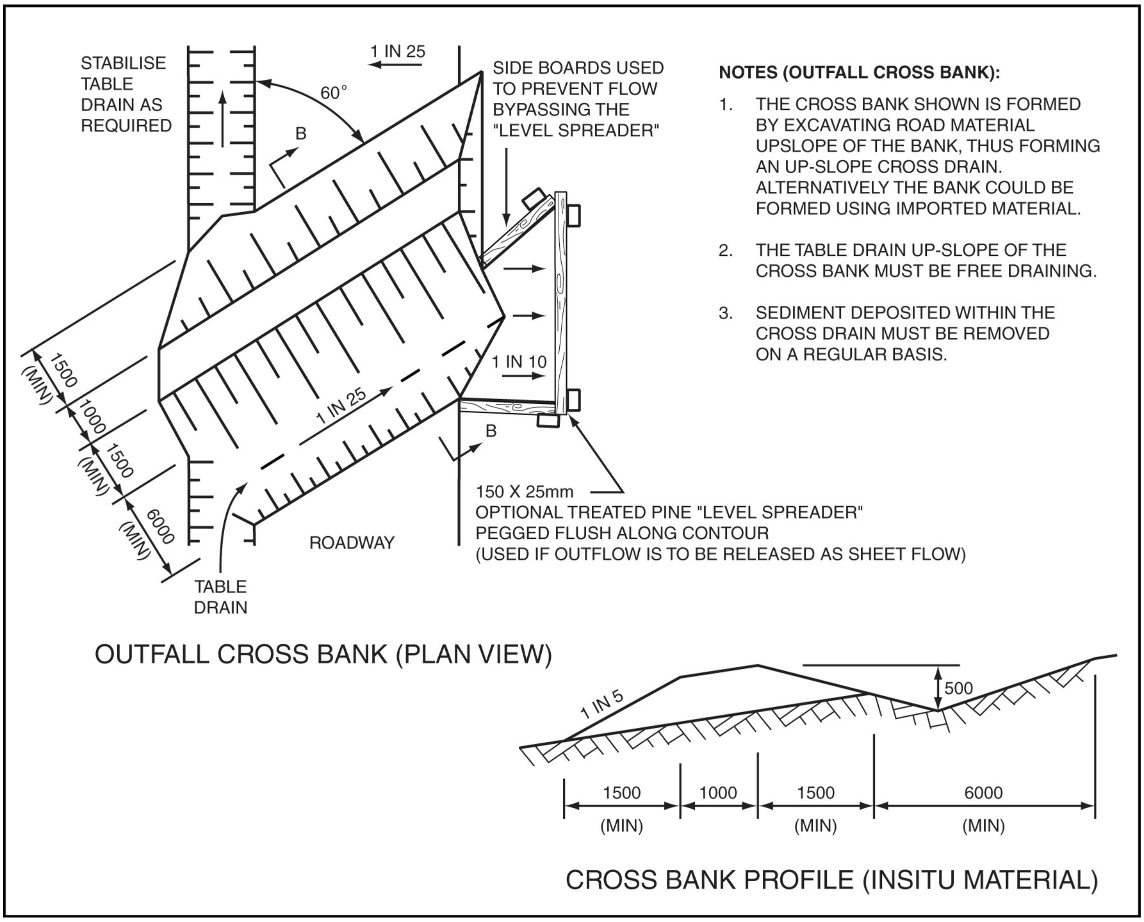


Figure K3 – Outfall cross bank for low speed tracks

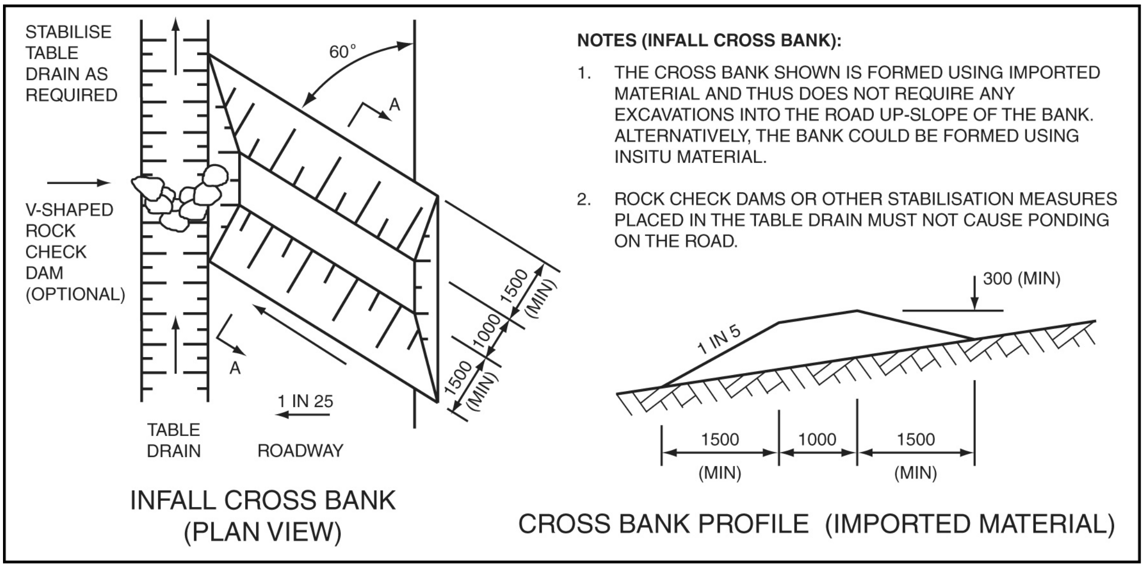


Figure K4 – Infall cross bank for low speed tracks

Cross banks consist of a trafficable earth mound (speed bump) constructed across a track to collect and divert runoff. Cross banks are used in low speed areas and can be used as speed control devices (hence the term "whoa-boys"). In medium or high-speed areas, sub-surface cross drainage (i.e. culverts) should be used.

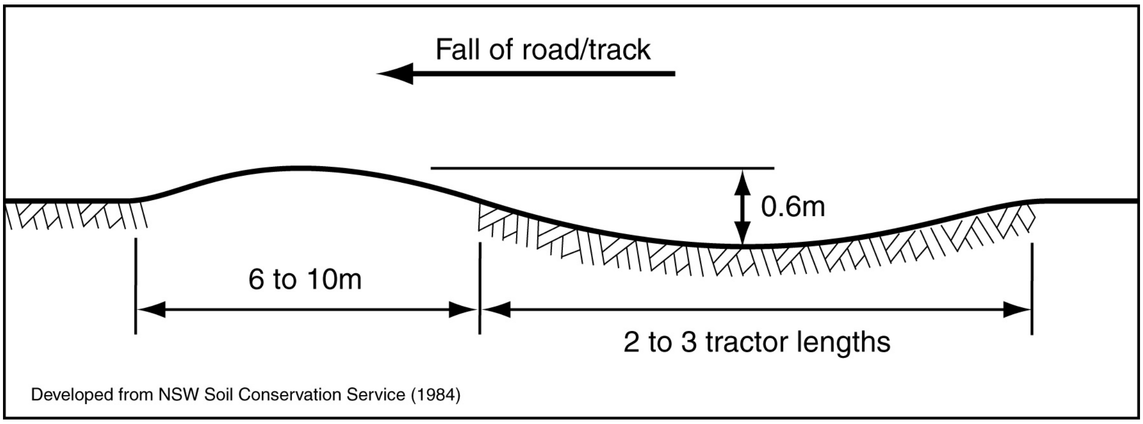


Figure K5 – Typical cross bank profile for low to medium speed traffic areas

The profile of the cross bank should be of sufficient length to ensure comfortable vehicle passage. The height of the cross bank should be sufficient to allow adequate drainage taking into account slope and soil type. The preferred dimensions of a cross bank will depend on the type, speed and frequency of vehicular traffic.

The dimensions provided in Figures K3 to K5 may need to be adjusted based on local conditions. The drainage outlet of the cross bank should allow water to escape rapidly from the track. Ideally this water should be converted back to sheet flow using a suitable *Level Spreader. Level Spreaders* are only used when it is desirable to release the water as "sheet" flow. *Level Spreaders* can be formed from earth or from treated timber (as shown in Figure K3).

If the track runs parallel to a watercourse, then every effort should be made to sheet water off the track, discharging it as "sheet" flow through the adjoining riparian zone. Maximum use should be made of this riparian zone to filter sediment from stormwater runoff before it enters the watercourse.

If the track runs along a ridge, then ideally, stormwater runoff should be discharged evenly off each side of the ridge. Examples of possible drainage for ridge tracks are provided in Figure K6. For the unformed road example provided in Figure K6, if a ground level road profile is used, then the cross banks may alternate to discharge water each side of the ridge.

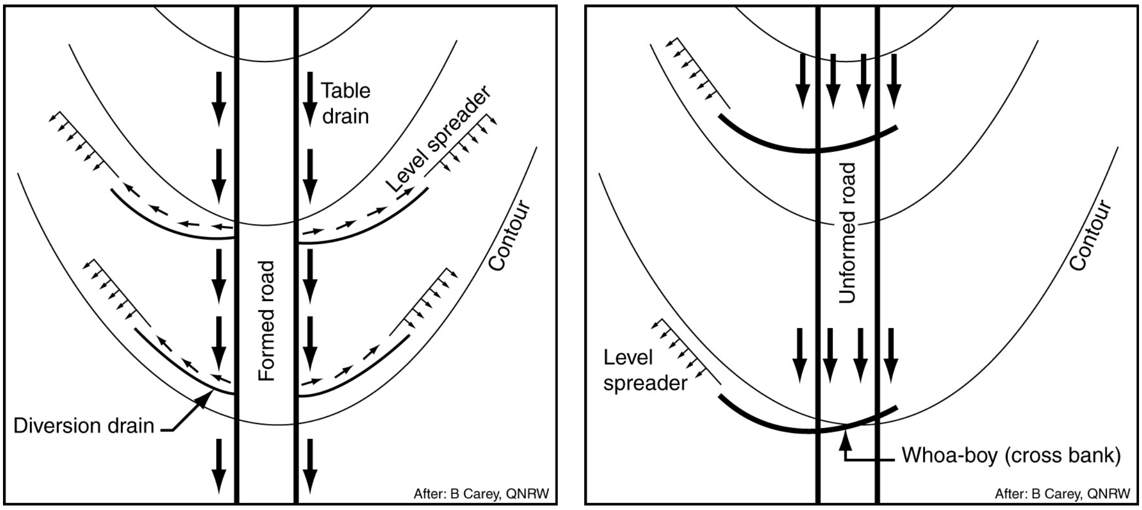


Figure K6 – Drainage of formed and unformed roads on a ridge (Carey, 1992)

In the absence of locally accepted guidelines, cross banks should be constructed at the spacing presented in Table K2.

Table K2 – Maximum spacing of cross drains [1]

Grade of track	Maximum spacing of cross drains (m)			
	Low hazard [2]		Moderate and high hazard [2]	
	North of Rockhampton [3]	Other areas	North of Rockhampton [3]	Other areas
< 9% (5°)	60	80	30	40
9–27% (5-15°)	40	50	20	30
27–47% (15-25°)	20	30	10	20
> 47% (25°) [4]	10	20	10 [4]	10 [4]

Notes:

[1] Sourced from Department of Primary Industries, Queensland – Forest Service, 1988.

[2] Soil erodibility may be recognised by the soil descriptions provided in Table K3.

[3] Only applicable in areas north and/or east of the 1000mm isohyet.

[4] Cover crop establishment of all drains is recommended on slopes exceeding 47%. Gradients of this magnitude are only recommended for short distances on these soil types.

Table K3 – Soil erodibility classification [1]

Erosion hazard rating	Soil type		Parent material [2]
	Surface texture and subsoil colour	Soil groups	
High	Shallow gravelly soils. Sands or sandy loams with yellow, pale grey or black subsoils (or derived from granitic material). Loams or clay loams with pale grey or black subsoils.	Lithosols Alluvials, podzols, siliceous sands Soloths, solodized solonetz, grey podzolics	Coarse textured igneous rocks, (granites, granodiorite, diorite, gabbro). Deeply weathered sandstones.
Moderate	Sands or sandy loams with red subsoils (except on granitic material, then erosion hazard rating is high). Loams or clay loams with red or yellow subsoils. Clays with yellow, grey or black colours.	Red earths, red podzolics Red or yellow podzolics Black earths, grey or brown clays, prairie soils	Sedimentary rocks (shales, mudstones, conglomerates, lightly weathered sandstones). Moderately hard metamorphics.
Low	Clay with yellow subsoils. Clay with red subsoils.	Xanthozem, euchrozem Krasnozem	Fine textured igneous rocks (basalt, andesite, rhyolite, trachyte). Hard metamorphics.

Notes:

[1] Sourced from Department of Primary Industries, Queensland – Forest Service, 1988.

[2] Refers to the erosion hazard of exposed weathered material other than true soil. It is not implied that the above soils are derived directly from the rocks in the adjoining column.

Notwithstanding the above guidelines, observations of actual track performance will eventually dictate the location and spacing of cross banks.

The following points should be considered when locating cross bank drainage:

- any spacing recommendations contained in regional guidelines, with appropriate adjustments made based on past experience and existing track conditions;
- location of concentrated stormwater inflow and preferred points of discharge;
- location of short sections of flatter track grade within a length of steep track that would facilitate the construction of a cross bank.

Whoa-boys cannot be used on slopes steeper than 20% because the back batter becomes too steep to be negotiated by a vehicle.

The consolidated bank should be shaped with batters no steeper than 5:1(H:V) in relation to the track grade. The bank can be shaped with the tractor blade, and the entire length of the bank should be track or wheel rolled to obtain maximum compaction and a smooth even bank.

If it is necessary to fill an eroded table drain in order to form the cross bank, then the bank should be compacted at this point with extra earth to allow for slumping and to cope with concentrated runoff within the drain.

Following construction, a small, temporary *U-Shaped Sediment Trap* may need to be constructed at the drainage outlet to collect sediment. These traps should only be constructed if they do not promote down-slope erosion or ponding on the track.

If the soil up-slope of the bank is likely to be saturated on a regular basis, and if past experience has shown that this soil will eventually turn into a "bog", then it may be necessary to embed a sheet of synthetic earth reinforcing mesh into the soil (Figure K7). This reinforcing mesh will reduce the risk of track damage by pedestrian and vehicular traffic.

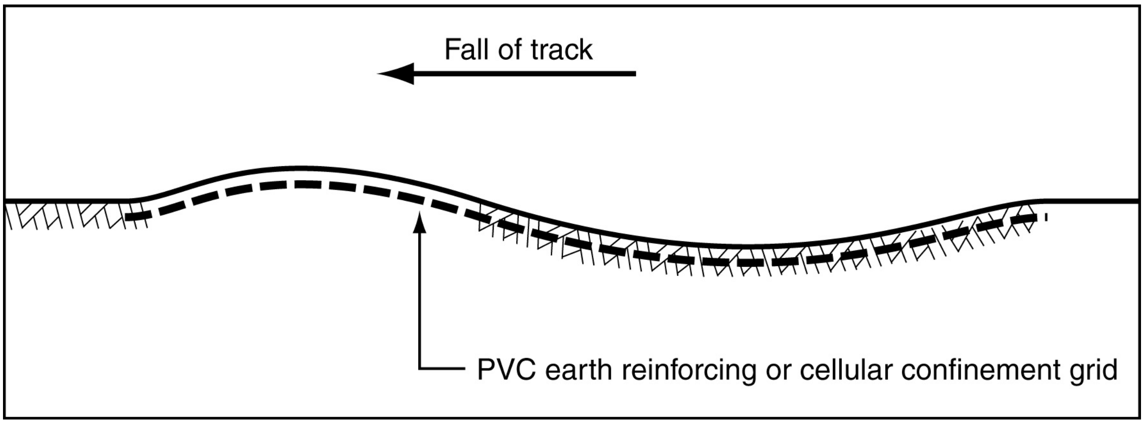


Figure K7 – Cross bank reinforced with sheet of synthetic earth reinforcing mesh

Avoid the formation of deep V-shape table drains. Wherever practicable, form wide U-shape drains to minimise potential invert erosion.

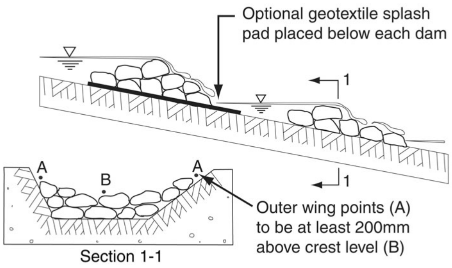
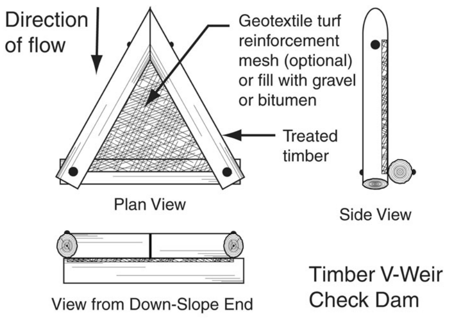
Table drain lining options are presented in Table K4. Table drains should not be sealed with an inflexible material such as concrete until the adjacent roadway is sealed or otherwise stabilised to prevent erosion.

Table K4 – Advantages and disadvantages of table drain sealing options

Option	Advantages	Disadvantages
Concrete	• Suitable in high flow velocity areas.	• Can only be used adjacent to sealed roads. • Failures may occur at driveway junctions unless care is taken in the design of the road and driveway.
Bitumen	• In most cases grass will eventually invade and replace the bitumen.	• Can only be used adjacent to sealed roads. • Grass growth can cause the bitumen to eventually fail.
Rock	• Easy to place. • Can be very stable if vegetation is allowed to interlock the rocks. • For a 300mm deep V-drain use: (i) 100mm (min) rock for slopes 5 to 12%. (ii) 150mm (min) rock for slopes 12 to 20%. (iii) 200mm (min) rock for slopes steeper than 20%.	• Difficult to clear of sediment without displacing the rocks. • Grass can eventually grow too thick and block the drains. • May require regular spraying of the grass or "wicking" to control grass growth. • High risk of failure, especially if gully erosion progresses up the drain.
Reinforced grass	• Easy placement. • Can be progressively installed.	• Difficult to clear of sediment without damaging the mats. • Grass can eventually grow too thick and block the drains. • May require regular spraying of the grass to control growth. • Introduces "plastic" to the environment. • Maintenance of the drain can be difficult. • Turf reinforcing may be damaged by grass fires.
Grass	• For a 300mm deep V-drain, grass lining is suitable for slopes of 0 to 5%.	• Requires regular cutting to prevent hydraulic blockages.

Table drain velocity-control *Check Dam* options are presented in Table K5.

Table K5 – Typical semi-permanent velocity control *Check Dams* options for unsealed table drains

Option	Advantages	Disadvantages
 **Rock Check Dam**	• Easy to place. • Rock size is 200mm to 300mm and thus can be placed by hand.	• May interfere with grass mowing. • Can lose their value when placed in drains steeper than 10% (1 in 10 fall).
 **Log V-Weir**	• Treated timber units can be assembled prior to installation. • Light to carry and thus easy to transport to remote locations.	• More expensive. • Typically can only be used in the flatter drains compared to *Rock Check Dams*. • Long-term release of wood treatment chemicals into the soils and drainage system.

"Sag" points on tracks are often subject to damage either by excessive stormwater flow across the track, or by traffic damaging the saturated track surface. In such cases it may be desirable to construct a concrete dish crossing as shown in Figure K8.

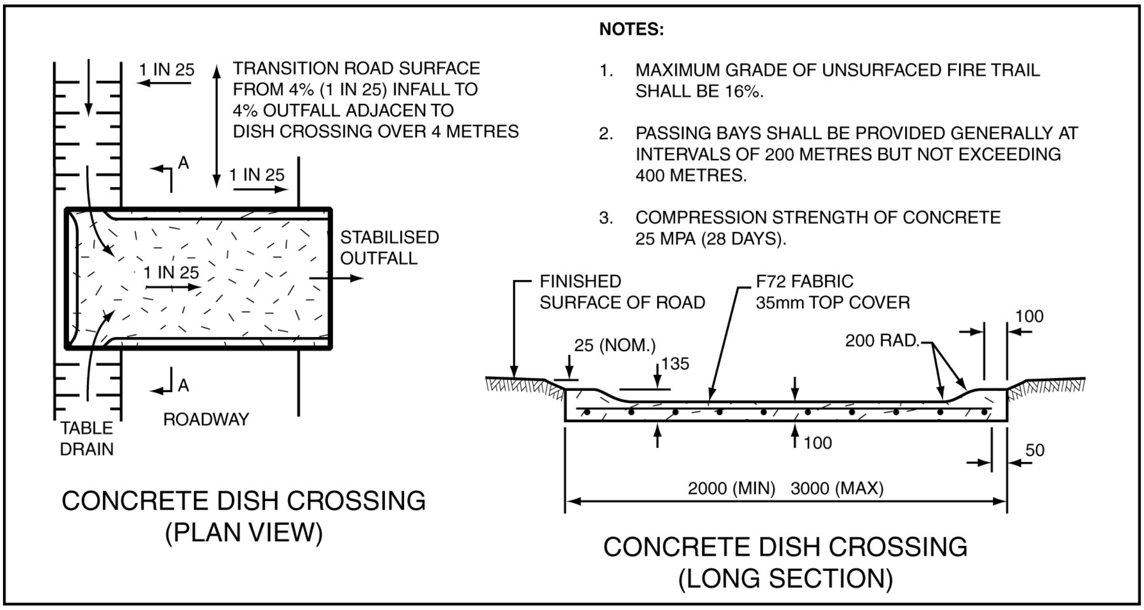


Figure K8 – Details of concrete dish crossing
(NSW Department of Housing – Fire Trail Details)

K5. Watercourse crossings

Where possible, crossings of streams should be constructed at right angles to the stream and in locations where the stream channel is straight and has well-defined banks.

When suitable materials are available, approaches to crossings should be covered with non-erodible materials such as rock or gravel. Otherwise, track layout and drainage measures should be designed to prevent sediment-laden water from running down the approaches directly into the stream as shown in Figure K9.

Access to a gully or watercourse should be protected with a cross bank immediately above the access cut (Figure K9). If the access is longer than 15m it may be necessary to construct additional flow diversions down the cutting.

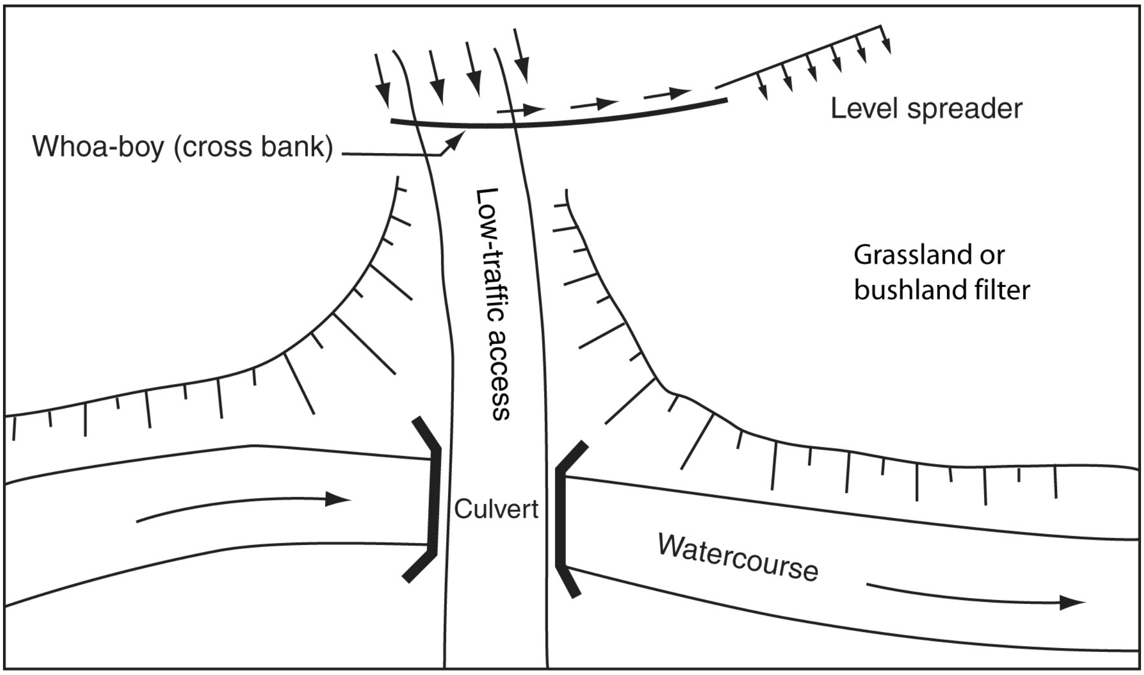


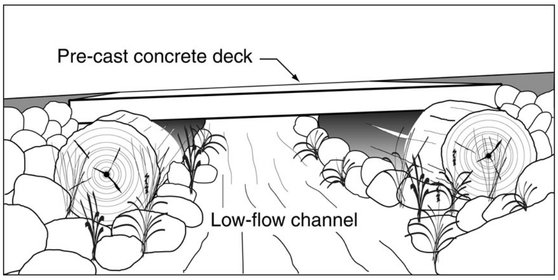
Figure K9 – Track drainage control adjacent stream crossings

Cleared vegetation and other debris should be removed from the floodplain if there is the potential for this material to cause damage to downstream structures if carried away by floodwaters.

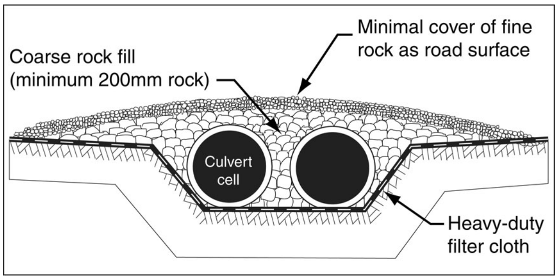
Watercourse crossings may consist of fords, culverts or bridges (Figure K10). Log dam crossings are generally not recommended because they can obstruct flood flows and create excessive turbulence and erosion.

In all cases, requirements for fish passage must be considered. In critical fish passage areas, the order of preference for waterway crossings is:

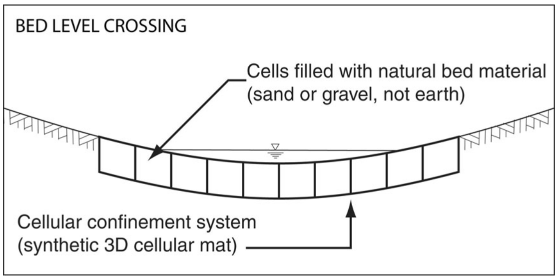
1. Bridge (preferred option)
2. Precast arch structure
3. Ford (natural bed material, or stabilised where required)
4. Buried box culvert with earth/rock bed
5. Box culvert
6. Pipe culvert
7. Causeway (least preferred)



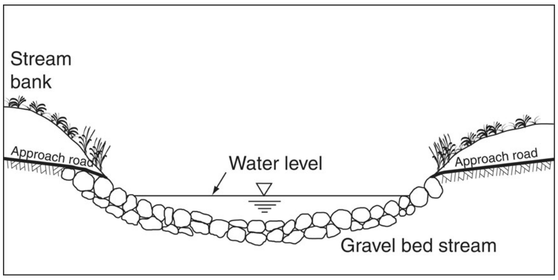
(a) Bridge formed from logs and a box culvert bridging slab



(b) Temporary pipe culvert



(c) Ford crossing stabilised with a Cellular Confinement System



(d) Natural ford crossing of a gravel-based stream bed

Figure K10 – Temporary stream crossings

Temporary bridge crossings may be formed from felled timber, or a culvert bridging slab (SLBC) suspended between well-anchored logs (as shown in Figure K10a).

Culvert designs should always consider the effects of debris blockages and potential erosive forces caused by overtopping flows. The assumed risk of debris blockage should reflect both the degree of upstream vegetation and the frequency of maintenance inspections.

The culvert diameter should be 450mm or larger, and the culvert should not discharge onto, or over, fill material. Ideally, culverts should have a flow capacity at least equal to the normal channel capacity of the watercourse when the water level is just below the crest of the culvert deck.

Embankments on a major crossing should be protected with suitable abutments, e.g. concrete, timber abutments, logs or rocks.

Appropriate consideration should be given to the following guidelines when designing culverts:

- culvert cells aligned with the downstream channel;
- culvert cells recessed 10% of their height/diameter into the bed (if fish passage is an issue);
- culvert cells should extend well beyond the fill embankment;
- riprap placed on the upstream embankment face to prevent fill material being swept into the culvert during high flows;
- armour rock placed on the downstream embankment face to control erosion caused by overtopping flows;
- where circumstances allow, the overtopping spillway may be formed adjacent the culvert to improve scour protection of the embankment.

When fish passage is critical, the low-flow conditions through culverts should be designed to simulate the existing low-flow geometry and flow velocities. Typical conditions include:

- maximum low-flow velocity over short reaches (e.g. at riffles) of 1m/s;
- maximum low-flow velocity over long reaches of 0.3m/s;
- minimum flow depth during periods of fish passage of 0.2 to 0.5m.

Witheridge (2002) provides guidelines on the design of fish-friendly watercourse crossing.

Fords should not be used where the stream has a deep channel cross-section that would require considerable bank excavation to form the approach roads, or when medium to high traffic volumes are expected. Ford crossings are generally only suitable on alluvial streams (i.e. sand-based or gravel-based streams). If the ford crossing is stabilised with a concrete pad, then fish passage problems can occur over time if the downstream bed lowers in elevation relative to the concrete pad.

Appropriate consideration should be given to the following guidelines when designing ford crossings:

- crossings at right angles to stream;
- ideally, no more than 10m road width;
- use of straight approaches that make the location of the crossing obvious even when flooded;
- use of non-erodible road surfacing material on the surface of the crossing, and for at least 15m each side of the crossing;
- bed stabilisation, if used, must be recessed to align with normal bed level;
- preferred use of flexible surfacing materials on the surface of the ford (such as rock or granular material contained within a *Cellular Confinement System* – Figure K10c) rather than concrete.

Temporary watercourse crossings should be located on sites with stable streambed material and where bank restoration will be possible. Construction activities should be timed to coincide with dry weather, and wherever practicable, removed before the commencement of the wet season. Upon removal of the crossing, the stream's bed and banks should be restored as near as possible to their original condition.

K6. Track construction

Track construction should incorporate the following practices wherever reasonable and practicable.

(i) Access tracks should be constructed with the general aim of minimising total disturbance to both soil and vegetation.

(ii) Construct the track by slashing or "blading" the surface vegetation. Avoid blading the soil except where it is necessary to build a track bench on side-slopes, to form drainage line approaches, or to make rough surfaces trafficable.

(iii) Tree clearing should be limited to 0.5m either side of the track. Where extra clearing widths are needed to allow for sun drying of the track or adequate safe-sight distance, or similar, then clear by felling rather than dozing to limit the amount of soil disturbance.

(iv) Track clearing should be reduced to the minimum practical within 30m of any watercourse.

(v) Where drainage conditions and soil properties allow, batters less than 1.5m in height should be cut vertically or to the maximum sustainable gradient for the given soil conditions.

(vi) If the soil exposed in batter construction is dispersive, then the batter should be cut back at a sufficient gradient to allow the placement of a minimum 200mm layer of non-dispersive soil on the batter.

(vii) Cut batters that are higher than 1.5m may require special stabilisation measures including laying back, revegetation and installation of suitable drainage.

(viii) Excessive or concentrated stormwater runoff up-slope of a batter should be suitably controlled and discharged either along or down the batter with the use of *Catch Drains,* or *Chutes*.

(ix) Fill batters should be no steeper than 2:1(H:V) and flatter where possible to encourage natural revegetation. Vegetation debris should not be allowed to contaminate fill because this will result in poor compaction with hollows and slumping occurring as the vegetation rots.

(x) When work is necessary next to a watercourse, precautions should be taken to contain sediment and stabilise the work area during construction to minimise erosion. The area should be stabilised within 1 week, unless stream flows are considered extremely unlikely during the proposed revegetation period.

(xi) Push-outs should be suitably cleared prior to any earthworks such that displaced earth will not cause trees to fall onto surrounding vegetation.

(xii) Where necessary, swampy or unstable ground should be reinforced with synthetic earth reinforcement mesh (e.g. geogrid) to allow construction of the track to progress and to reduce the risk of bogging heavy equipment.

(xiii) Grubbing in fine-grained soil should be avoided during wet weather.

(xiv) Exposed springs should be managed with appropriate sub-surface drainage (e.g. subsoil drainage or aggregate drain).

(xv) Appropriately bench the virgin soil before placement of fill to prevent slippage along the interface.

(xvi) If the track is temporary, then culverts and fill deposited within floodplain areas should be removed when no longer required.

K7. Maintenance

Frequent maintenance is essential to ensure effective erosion control and track stability, especially in the early years after construction. It is essential that a sound cover of vegetation and/or forest litter develops on the surface of the track, on constructed batters, and on approaches to watercourse crossings.

A maintenance program should consider the following points (Soil Conservation Services of NSW, 1990).

(i) Inspect all tracks at least annually and following heavy traffic usage or exceptionally heavy rainfall, especially if culvert crossings are used.

(ii) Restrict destruction of vegetation to the removal of excess regrowth preferably by slashing or spraying.

(iii) Do not remove any more vegetation than is necessary to maintain safety on the track. Fell timber rather than bulldozing. Where possible, stumps should be left intact, especially above cut batters and adjacent to drainage lines.

(iv) Avoid unnecessary grading or blading during maintenance. This usually requires the appropriate training of maintenance personnel.

(v) Leave material slumping from cut batters untouched if it does not unduly restrict the operating width of the track. If it is necessary to remove material, take care to avoid undercutting the toe of the batter.

(vi) Encourage effective outfall drainage by removing any windrows along the outside edge of the trail.

(vii) The location, spacing and size of cross banks should be reviewed when developing a maintenance program. An appropriate cross bank spacing will be indicated by the distance water runs on a track or within the table drain before rilling commences.

(viii) All table drains should be stable. If scouring occurs, they should be reformed to a broad dish shape, seeded, fertilised and protected with jute mesh and bitumen, or other similar surface protection or flow control structures.

(ix) Do not dispose of timber, scrub, soil or debris along drainage lines or within flood prone areas.

(x) Fencing should be installed and maintained, as required, to control unauthorised traffic or material dumping, especially if public safety problems can occur as a result of such unauthorised activities.

(xi) During grading operations, loose material should be moved towards the centre of the roadway to avoid the loss of essential fines from the surface mix and to avoid the creation of windrows.

K8. Track sediment yield

Expected track sediment yield may be estimated from the work of Melbourne Water (1991).

(i) The rate of coarse sediment production from a typical Melbourne Water unsealed road is in the order of 30t/ha/yr. By comparison, an undisturbed forested catchment may produce approximately 0.3t/ha/yr in total sediment.

(ii) The case of a high use and low maintenance regime produces approximately 35t/ha/yr of coarse sediment; however, under high maintenance this drops to 27t/ha/yr. This compares with the low use, low maintenance test road that, in the long-term, produced approximately 18t/ha/yr of coarse sediment. The low use, low maintenance test road produced 30t/ha/yr lying between the two high use maintenance regimes.

(iii) As would have been intuitively expected, a properly gravelled road produces less sediment than an unsealed road. However, if a road is to be gravelled using the local high clay, unsorted, unwashed "gravelly" material, the gravelling thickness must be adequate, because a "thinly" gravelled road produced the most sediment and deteriorated quickly. Data from the gravelling phases show 38t/ha/yr of coarse sediment and 41g/L of suspended sediment from the thinly gravelled road was produced, compared with 20t/ha/yr and 35g/L for the thicker gravelling treatment.

(iv) Under a low use regime, the level of road maintenance was not a factor in sediment production. However, under a high use regime, the level of maintenance had a significant impact on erosion rates.

(v) Suspended sediment production was of the order of 23g/L under low use, low maintenance, ranging up to 35 to 40g/L under high use, low maintenance. Under high use, high maintenance conditions the suspended sediment rate dropped to 23g/L. However, these figures should be treated with caution due to expected sampling problems.

Melbourne Water (1991) made the following recommendations and conclusions.

- Unsealed earth roads of about 10% grade built in a stable clay subsoil can produce an average 45–60t/ha/yr of sediment.
- About one-third of the above load is coarse sediment and two-thirds is suspended sediment.
- Where such a road is subject to a low level of use only, a low level of surface maintenance is required between periodic gradings. Where the road is subject to a high level of use, a high level of surface maintenance is required to reduce sediment production.
- Roads are most susceptible to disturbance and have their sediment production increased during periods of wet weather (longitudinal wheel rutting occurs, concentrating surface runoff and erosion). Minimising use during these periods will reduce sediment production.
- The surface of thinly gravelled roads rapidly deteriorates compared to the surface of thickly gravelled roads.
- Gravelled roads can produce high volumes of sediment immediately after gravelling. This may present a significant management problem.
- To protect water quality, maintenance, good road design, drainage and appropriate management (i.e. access) policies are essential.

K9. References

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Appendix L

Installation of services

This appendix provides a model code of practice for the installation of minor underground services such as stormwater, water supply, wastewater, gas and telecommunications. The function of this appendix is both educational and prescriptive. Those people wishing to apply erosion and sediment control measures to the installation of services should first ensure that they familiar with the general principles outlined in Chapter 2 – Principles of erosion and sediment control.

Service providers are encouraged to adopt the following code of practice or develop their own in-house code using the model code as a guide. Such a code should include default erosion and sediment control procedures and plans for typical site activities.

L1. Introduction

The principles of Erosion and Sediment Control (ESC) as used by service providers and those contracted to install services are the same as those used by the general building and construction industry. Differences exist only in which principles attract a greater degree of attention.

Broad acre residential construction normally focuses on the management of water movement and soil erosion across wide areas, with sediment control occurring at key stormwater collection points. On the other hand, service providers often operate within an existing building envelope, and the primary focus of their sediment control is usually on the appropriate management of stockpiles and trench de-watering activities.

As for all aspects of the construction industry, service providers must take all reasonable and practicable measures to:

- minimise the adverse environmental impacts resulting from their products, processes and activities;
- actively promote employee awareness of the potential environmental risks associated with their work activities, and the means of managing these risks;
- monitor and review environmental outcomes, making appropriate modifications to work practices and operational guidelines;
- appropriately address areas of non-conformance;
- report the provider's environmental performance both internally and externally.

The application of erosion and sediment control on the small soil disturbances commonly associated with the installation of services can generally be achieved through consideration of the following rules:

1. **Safety first**—don't install or operate an ESC device in a manner that may cause a safety hazard.
2. **Look up the slope**—judge where stormwater runoff may come from, then if practicable, and if rain is likely, divert this runoff around any soil disturbance.
3. **Look at the site**—judge the best way to access the site, stockpile materials, perform the necessary works, and de-water trenches, while taking all reasonable and practicable measures to minimise the extent and duration of soil disturbance.

4. **Look down the slope**—judge where sediment runoff will flow, then place appropriate sediment traps to filter or settle-out sediment.

5. **Look at the sediment controls**—immediately following the installation of any sediment trap, confirm that water will temporarily pond up-slope of the trap, and will **not** simply be diverted around the trap.

6. **Leave the site in a stable condition**—it is important to minimise the duration disturbed soils will be exposed to rainfall and ongoing soil erosion problems.

L2. Model Code of Practice

This model Code of Practice has been provided as a practical example of an operational guideline for erosion and sediment control during the installation of minor services.

Compliance with a given Performance Criterion can only be achieved by:

(i) complying with the Acceptable Solution; or

(ii) formulating an alternative solution which complies with the Performance Criterion, or is shown to be at least equivalent to the acceptable solutions; or

(iii) a combination of (i) and (ii).

Attachment A forms part of this Code. The Attachment provides essential information and requirements not otherwise provided within the Code.

In the event of a conflict over the desired outcome of a *Performance Criterion* or an *Acceptable Solution*, then the outcome must be that which best achieves the *"objective"* of the Code, that being:

> *To protect the environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.*

If the scheduled works incorporate the following construction activities, then the relevant operational Code of Practice should be consulted:

(i) construction of a building—refer to Appendix H (*Building sites*) for management practices;

(ii) major service installation, construction or earthmoving activity—refer to Appendix G (*Model code of practice*) for management practices.

This model Code of Practice does not provide all the information necessary to adequately control soil erosion and sediment runoff in all situations. Users of the Code should always make their own site-specific evaluation, testing and design and rely on their own advisers and consultants.

Specifically, the adoption of this model code of practice will not guarantee:

(i) compliance with any statutory obligations;

(ii) avoidance of environmental harm or nuisance.

SITE PLANNING			
Performance Criteria		**Acceptable Solution**	
P1	Adequate site data is obtained to allow appropriate site planning.	**A1**	The extent and complexity of site data, including soil mapping, is commensurate with the potential environmental risk, and the extent and complexity of the soil disturbance.
P2	Site planning aims to minimise the risk of environmental harm.	**A2**	(a) Development of the Erosion and Sediment Control Plan (ESCP) is an integral part of site planning. (b) High-risk construction activities are identified during site planning. (c) High-risk construction activities and disturbances of high to extreme erosion hazard areas are minimised, if no totally avoided, especially during periods of high to extreme erosion potential. (d) All reasonable and practicable measures are taken to design/plan the site layout, programming, staging and methodology to minimise environmental risks associated with high-risk work activities. (e) Site planning aims to minimise the duration that any and all areas of soil will be exposed to the erosive effects of wind, rain and flowing water, in part through the progressive and prompt stabilisation of disturbed areas.

EROSION AND SEDIMENT CONTROL PLAN (ESCP)			
Performance Criteria		**Acceptable Solution**	
P3	An Erosion and Sediment Control Plan (ESCP) is prepared prior to site disturbance that provides sufficient information to achieve the required environmental protection.	**A3**	(a) The design standard of drainage, erosion and sediment controls comply with the requirements of the relevant regulatory authority, or where such a standard does not exist, are designed in accordance with current best practice. (b) As a minimum, the ESC design standard applied to a site at any given instant is commensurate with the degree of environmental risk, and the type, cost, and scope of the proposed works. (c) The level of information and detail supplied in the ESCP is commensurate with the potential environmental risk and the complexity of the proposed works; and of sufficient clarity to allow on-site personnel to appropriately implement the plan. (d) The ESCP is appropriate for the site conditions and the potential environmental risk. (e) The ESCP remains both effective and flexible, and is based on anticipated soil, weather, and construction conditions (as may vary from time to time). (f) The ESCP is appropriately amended if the implemented works fail to achieve the "objective" of the ESCP, the required performance standard, or the State's environmental protection requirements.

P4	The ESCP is prepared by, or under the supervision of, suitably qualified and experienced personnel.	**A4**	(a) The qualifications and experience of the personnel preparing and/or supervising the preparation of the ESCP is commensurate with the potential environmental risk, and the extent and complexity of the soil disturbance. (b) On sites with a soil disturbance greater than 2500m^2, the degree of review of the ESCP is consistent with best-practice requirements for general construction projects.

SITE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P5	The work site is managed such that environmental harm is minimised.	**A5**	(a) No land-disturbing activities are undertaken prior to appropriate consideration being given to erosion and sediment control issues. (b) All works subject to an Erosion and Sediment Control Plan (ESCP) are carried out in accordance with the ESCP (as amended from time to time) unless circumstances arise where compliance with the ESCP would increase the potential for environmental harm as assessed by a recognised authority. (c) All ESC measures are installed, operated and maintained in accordance with current best management practice. (d) Land-disturbing activities are undertaken in such a manner that allows all reasonable and practicable measures to be undertaken to: (i) allow stormwater to pass through the site in a controlled manner and at non-erosive flow velocities; and (ii) minimise soil erosion resulting from wind, rain and flowing water; and (iii) minimise the duration that disturbed soils are exposed to the erosive forces of wind, rain and flowing water; and (iv) prevent, or at least minimise, environmental harm (including public nuisance and safety issues) resulting from work-related soil erosion and sediment runoff. (e) Land-disturbing activities do not cause unnecessary soil disturbance. (f) Site spoil is lawfully disposed of in a manner that does not result in ongoing soil erosion or environmental harm.
P6	Disturbance to ESC measures by on-site personnel is minimised.	**A6**	(a) On-site personnel are appropriately instructed and educated as to the purpose and operation of adopted drainage, erosion and sediment control (ESC) measures, and the need to maintain such measures in proper working order at all times. (b) Unnecessary disturbance to ESC measures by on-site personnel, sub-contractors and construction traffic (including site management and material delivery vehicles) is minimised.

P7	The adopted ESC measures remain relevant at all times to the current site conditions.	**A7**	(a) The adopted erosion and sediment control measures are appropriately amended if site conditions significantly change, or are expected to significantly change, from those conditions assumed during development of the ESCP. (b) The adopted erosion and sediment control measures are appropriately amended if the implemented works fail to achieve the “objective” of the ESCP, or the required performance standard, or the State’s environmental protection requirements, or unacceptable environmental harm is occurring or is likely to occur.
P8	The work site is appropriately prepared for imminent construction activities and weather conditions.	**A8**	(a) Adequate supplies of drainage, erosion and sediment control, and relevant pollution clean-up materials, are retained on-site during the construction period. (b) Appropriate short-term drainage control measures (e.g. flow diversion around recently opened trenches and excavations) are installed and operational prior to impending storms.
P9	Damage to retained or protected vegetation is minimised.	**A9**	(a) Prior to the commencement of land disturbing activities within any given area, all protected vegetation and significant areas of retained vegetation within that area, are appropriately identified to minimise the risk of disturbance to such areas. (b) No damage is allowed to occur to roots, trunk or branches of “retained” vegetation, unless under the direction of an appropriate Vegetation Management Plan.
P10	Adopted work practices minimise the release of pollutants into receiving waters.	**A10**	(a) Emergency and pollution control procedures are commensurate with the site conditions, local environmental values, and the type, cost, scope and complexity of the works. (b) Cement-laden runoff, concrete waste, and chemical products (including petroleum and oil-based products), are managed on-site in accordance with current best management practice. (c) Brick-, tile- and masonry-cutting activities are carried out in accordance with current best management practice. (d) Washing of tools and painting equipment is carried out in accordance with current best management practice.
P11	Environmental harm, safety issues, and nuisance or damage to public and private property resulting from off-site sediment deposits, material spills, and/or the adopted ESC measures is minimised.	**A11**	(a) Sediment and other material originating from the work area, or as a result of the transportation of materials to or from the work area, that collects on sealed roads, or within gutters, drains or waterways outside the immediate work area, is removed: (i) immediately if rain is occurring or imminent; or (ii) immediately if considered a safety hazard; or (iii) if items (i) or (ii) do not apply, as soon as practicable, but before completion of the day’s work. (b) Washing/flushing of sealed surfaces only occurs where sweeping has failed to remove sufficient

			sediment, and there is a compelling need to remove the remaining sediment (e.g. for safety reasons). (c) Sediment deposits that cause nuisance to, or adversely affect the use or value of, neighbouring properties are removed and the area rehabilitated as soon as practicable. (d) The adopted ESC measures do not adversely affect drainage or flooding conditions within neighbouring properties.
P12	Potential safety risks to site workers and the public as a result of ESC measures are minimised.	**A12**	Operational safety issues (public and site personnel) are given appropriate consideration during the installation, operation, maintenance and removal of ESC measures.
P13	Potential harm to wildlife as a result of ESC measures is minimised.	**A13**	Synthetic (plastic) reinforced fabrics are not placed within, or adjacent to, bushland areas, riparian zones and watercourses if such materials are likely to cause harm to wildlife or wildlife habitats.
P14	Disturbance to natural watercourses is minimised.	**A14**	(a) Instream works are conducted in accordance with an approved Code of Practice for instream works. (b) No instream land-disturbing activities are undertaken prior to development of a Vegetation Management Plan. (c) Disturbance to natural watercourses (including bed and bank vegetation) and their associated riparian zones is limited to the minimum necessary to complete the approved works.

LAND CLEARING			
Performance Criteria		**Acceptable Solution**	
P15	Potential environmental harm is minimised as a result of land clearing.	**A15**	(a) All land clearing is conducted in accordance with State and local government Vegetation Protection and/or Preservation requirements and/or policies. (b) On sites with a soil disturbance greater than one (1) hectare, no land clearing is undertaken prior to approval of a Vegetation Management Plan. (c) Limits on the extent and duration of soil disturbance are commensurate with the potential erosion risk and/or erosion hazard.
P16	Land clearing is limited to the minimum necessary.	**A16**	(a) Land clearing does not cause unnecessary soil disturbance if an alternative process (which reduces the potential environmental harm) is available that achieves the same or equivalent project outcomes at a reasonable cost. (b) Land clearing at any given time during periods of potential soil erosion is restricted to only those areas required for the current stage of works.
P17	Soil erosion during and following land clearing is minimised.	**A17**	(a) Land clearing within any sub-area is delayed as long as reasonable and practicable. (b) Land clearing and site rehabilitation are staged to minimise the extent and duration that any and all areas of soil are exposed to the erosive effects of wind, rain and flowing water.

			(c) If tree clearing is required well in advance of future earthworks, then tree clearing methods that will minimise potential soil erosion are employed, especially in areas of high to extreme erosion risk.

SOIL AND STOCKPILE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P18	Maximum benefit is obtained from existing topsoil.	**A18**	(a) The topsoil is managed (i.e. stripped, treated, stockpiled and reused) in accordance with the recommendations of an approved Vegetation Management Plan or similar. OR (b) Topsoil is stripped, stockpiled, placed, and where necessary treated, in accordance with current best practice. AND (c) Topsoil originating from the site is respread as the topsoil to maximise erosion control and revegetation, except where it has been assessed that such soil will not improve erosion control and/or revegetation on the site.
P19	Environmental harm caused by the temporary stockpiling of erodible material is minimised.	**A19**	Stockpiles of erodible material are: (i) located fully within the relevant property; (ii) appropriately protected from wind, rain and excessive surface flows in accordance with current best practice; and (iii) located at least 2m from hazardous areas, retained vegetation, and overland flow paths; and (iv) located up-slope of an appropriate sediment control system.
P20	Exposed dispersive soils are managed such that the risk of ongoing soil erosion is minimised.	**A20**	Construction details for drainage systems and bank stabilisation works within dispersive soil areas clearly demonstrate how these soils will be managed to prevent future erosion problems.
P21	Exposed potential acid sulfate soils are appropriately managed.	**A21**	(a) If acid sulfate soils conditions exist on site, then appropriate warnings are placed on the ESCP. (b) All exposed actual or potential acid sulfate soils are managed in accordance with current best practice. (c) On-site personnel involved in the disturbance of actual or potential acid sulfate soils are appropriately trained and/or supervised.

DRAINAGE CONTROL			
Performance Criteria		**Acceptable Solution**	
P22	Temporary drainage control measures are designed, constructed and maintained to an appropriate standard.	**A22**	The standard of drainage control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, drainage controls are designed in accordance with current best practice.
P23	Stormwater movement through the site is appropriately managed to minimise soil erosion.	**A23**	(a) If the drainage area up-slope of a soil disturbance exceeds 1500m^2, and the average monthly rainfall exceeds 45mm, all stormwater discharged from this area (up to the design storm) is diverted around or through the soil disturbance in a manner that minimises soil erosion. (b) Flow velocities within drainage channels and at the entrance and exit of all drainage structures (including chutes, slope drains and spillways) are controlled in such a manner that prevents soil erosion during all discharges up to the relevant design discharge.
P24	Stormwater movement through the site is appropriately managed to minimise environmental harm.	**A24**	(a) All temporary and permanent drainage systems are installed as soon a practicable. (b) "Clean" water is diverted around sediment traps in a manner that maximises the sediment trapping efficiency of the sediment trap. (c) All reasonable and practicable measures are taken to ensure stormwater runoff entering an area of soil disturbance is diverted around or through that area in a manner that minimises soil erosion and contamination of that water for all discharges up to the specified design discharge. (d) Adequate drainage controls (e.g. cross drainage systems and/or longitudinal drainage) are applied to all unsealed roads and tracks to minimise erosion on, and sediment runoff from, such surfaces. (e) All reasonable and practicable measures are taken to ensure sediment-laden runoff from access roads and stabilised entry/exit systems drains to an appropriate sediment control device. (f) All reasonable and practicable measures are taken to divert stormwater around excavations and trenches.
P25	Stormwater entering into, or discharged from, the site is appropriately managed to minimise flooding, damage and nuisance to neighbouring properties.	**A25**	(a) All waters discharged during the construction phase are discharged onto stable land, in a non-erosive manner, and at a legal point of discharge. (b) All drainage channels up-slope of neighbouring properties are constructed and maintained with sufficient size, gradient and surface conditions to maintain the required hydraulic capacity. (c) Stormwater is not unlawfully diverted into neighbouring properties.

EROSION CONTROL			
Performance Criteria		**Acceptable Solution**	
P26	Erosion control measures are designed, installed and maintained to an appropriate standard.	**A26**	(a) The standard of erosion control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, erosion controls are designed in accordance with current best practice. (b) As a minimum, the type and degree of erosion control are commensurate with the expected site conditions, soil type, potential environmental risk, and the type, cost and scope of the works.
P27	The control of soil erosion is given appropriate priority.	**A27**	(a) Wherever reasonable and practicable, priority is given to the prevention, or at least minimisation, of soil erosion, rather than allowing soil erosion to occur and trying to trap the resulting sediment. (b) The existence of best practice sediment control measures within a given sub-catchment does not diminish the need for the application of best-practice erosion control measures.
P28	Soil erosion is minimised.	**A28**	(a) Site activities are carried out in a manner that minimises the duration that any and all disturbed soil surfaces are exposed to the erosive forces of wind, rain and surface water. (b) Erosion control measures are applied to exposed soils as soon as practicable after earthworks have been completed within each sub-area. (c) Unfinished earthworks that are not expected to be disturbed for an extended period of time (relative to the erosion risk) are appropriately stabilised in accordance with current best practice.
P29	Soil erosion resulting from surface water flow is minimised.	**A29**	Service trenches are: (i) backfilled, compacted, capped with a layer of topsoil to a level at least 75mm above the adjoining ground level, and rehabilitated; or (ii) backfilled, compacted and rehabilitated in a manner that best prevents undesirable water flow and soil erosion along the trench.
P30	Soil erosion resulting from wind erosion is minimised.	**A30**	(a) Erosion control measures used to control wind erosion are commensurate with soil exposure and the expected wind conditions in terms of speed and direction. (b) Stockpiles of erodible material are covered during periods of strong wind or when strong winds are imminent.

SEDIMENT CONTROL			
Performance Criteria		**Acceptable Solution**	
P31	Sediment control measures are designed, installed, operated and maintained to an appropriate standard.	**A31**	(a) The standard of sediment control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, sediment controls are designed in accordance with current best practice. (b) As a minimum, the type and degree of sediment controls are commensurate with the site conditions, soil type, potential environmental risk, and the type, cost and scope of the works.
P32	The on-site retention of sediment is maximised.	**A32**	(a) All reasonable and practicable measures are taken to prevent, or at least minimise, the release of sediment from the site, or into water where it is likely to cause environmental harm. (b) Appropriate sediment controls are installed and made operational before any up-slope soil disturbance occurs. (c) All sediment-laden runoff from the site is directed to an appropriate sediment control device in accordance with the required treatment standard. (d) Sediment traps are designed, constructed, and maintained to collect and **retain** sediment.
P33	Sediment displaced off-site by vehicular traffic is minimised.	**A33**	(a) Number of site entry/exit points is limited to the minimum practical number. (b) Site entry/exit points are appropriately designed and stabilised to minimise sediment being washed off the site by stormwater and/or being transported off the site by vehicles. (c) All reasonable and practicable measures are taken to ensure sediment-laden stormwater runoff from access roads and stabilised entry/exit systems drains to an appropriate sediment control device.
P34	Sediment-related environmental harm resulting from de-watering activities is minimised.	**A34**	(a) Flow diversion barriers, or other appropriate systems, are used to minimise the quantity of watering entering excavations and trenches. (b) All sediment control measures implemented for the control of sediment-laden discharge from de-watering activities are designed to satisfy, as a minimum, current best practice discharge standards. (c) As a minimum, the type and degree of sediment controls utilised during de-watering operations are commensurate with the site conditions, soil type, potential environmental risk, and the type, cost and scope of the works.
P35	The quantity of sediment released within process water resulting from work activities is minimised.	**A35**	Waste water from work activities such as “directional drilling” is: (i) suitably treated on-site to minimised turbidity levels and suspended sediment; or (ii) collected and transported from the site in a manner that does not cause ongoing environmental harm.

SITE STABILISATION AND REHABILITATION			
Performance Criteria		**Acceptable Solution**	
P36	Site rehabilitation, including site revegetation, is designed, installed and maintained to an appropriate standard.	**A36**	(a) The standard of site rehabilitation complies with the requirements of the relevant regulatory authority or, where such a standard does not exist, complies with current best practice. (b) As a minimum, the type and degree of site rehabilitation is commensurate with the expected site conditions, soil type, potential environmental risk, and the type, cost and scope of the works.
P37	Site rehabilitation methods and procedures minimise the risk of environmental harm.	**A37**	(a) Disturbed soil surfaces are appropriately stabilised to minimise the risk of short-term soil erosion. (b) Site stabilisation and/or revegetation are commenced as soon as practicable after earthworks are completed within any given manageable drainage area. (c) All temporary ESC measures are removed and the land rehabilitated as soon as practicable after they are no longer needed.
P38	Site rehabilitation methods, procedures, and outcomes are compatible with site conditions and local environmental values.	**A38**	The qualifications and experience of the personnel preparing and/or supervising the preparation of any Site Stabilisation Plan, Vegetation Management Plan, or similar, are commensurate with the potential environmental risk, and the extent and complexity of the works.

SITE INSPECTION AND MONITORING			
Performance Criteria		**Acceptable Solution**	
P39	Appropriate personnel are engaged to implement and monitor all necessary ESC measures.	**A39**	(a) Prior to the commencement of any construction activities or soil disturbance, appropriately trained and experienced personnel are engaged to undertake regular ESC audits of the site. (b) Prior to commencement of site works, a “Chain of Command” in relation to the implementation, modification, and maintenance of Site Erosion and Sediment Control measures is established. (c) Site managers and/or the nominated responsible ESC personnel achieve and maintain a good working knowledge of the correct installation and operational procedures of all ESC measures used on the site.
P40	A Monitoring and Maintenance Program is prepared by, or under the supervision of, suitably qualified and experienced personnel.	**A40**	The qualifications and experience of the personnel preparing and/or supervising the preparation of the Monitoring and Maintenance Program is commensurate with the potential environmental risk, and the extent and complexity of the works.
P41	The performance of the site’s drainage, erosion and sediment control measures is regularly monitored.	**A41**	(a) The extent and complexity of site monitoring (including water quality monitoring) is commensurate with the potential environmental risk, and the extent and complexity of the works. (b) A record is maintained of the site’s compliance and non-compliance with erosion and sediment

			control approval requirements. (c) All site monitoring data including environmental incidents, rainfall records, dates of water quality testing, testing results, and records of controlled water releases for the site, are kept in an on-site register.
P42	The site's drainage, erosion and sediment control measures remain relevant at all times to the current site conditions.	**A42**	(a) The adopted ESC measures remain relevant at all times to the current and imminent site conditions. (b) All ESC measures are inspected by site personnel: (i) at least daily (when work is occurring on-site); (ii) at least weekly (when work is not occurring on-site); (iii) within 24 hours of expected rainfall; and (iv) within 18 hours of a rainfall event of sufficient intensity and duration to cause runoff on the site.

SITE MAINTENANCE			
Performance Criteria		**Acceptable Solution**	
P43	All ESC measures are maintained in proper working order at all times during their required operational life.	**A43**	(a) All ESC measures are maintained in proper working order for the duration of the period in which their operation is required in order to satisfy the required treatment standard, and/or the objective of the ESCP. (b) All sediment control measures are maintained in accordance with the requirements of the relevant regulatory authority, or where such a standard does not exist, in accordance with current best practice.
P44	The maintenance of ESC measures does not cause environmental harm.	**A44**	All materials removed from ESC devices during maintenance or decommissioning, whether solid or liquid, is lawfully disposed of in a manner that does not cause ongoing soil erosion or environmental harm.

Attachment A (Services code of practice)

SITE PLANNING

The *intent* of the Site Planning section is to:

- take all reasonable and practicable measures to actively avoid foreseeable soil erosion problems and associated environmental hazards during the construction/installation phase; and
- ensure that those involved in construction planning do **not** assume that the environmental impact of such hazards can be totally resolved (irrespective of the site's layout, methodology, staging, and programming) through applying best practice erosion and sediment control.

"Site planning" refers to planning the layout, methodology, staging, and programming (timing and scheduling) of the construction/installation phase.

Acceptable Solution A1
Data collection may include soil testing, identification of potential site constraints, and development of a Conceptual Erosion and Sediment Control Plan (where such data and/or plans are considered reasonably necessary to enable appropriate site planning and design). Appropriate site planning and design refers to the aim of minimising the potential environmental harm (both during the construction and operational phases) of the development. The extent and complexity of data collection is discussed further in Chapter 3 – *Site planning*.

Sufficient soil data must be obtained on the site to:
(i) reasonable identify the location of dispersive soils;
(ii) reasonable identify the location of potential acid sulfate soils;
(iii) allow the appropriate selection, design and specification of ESC measures;
(iv) maximise the erosion control benefits of the proposed site revegetation and stabilisation works.

The "potential environmental risk" relates to the potential of a land disturbing activity to cause harm, whether material, serious, reversible or irreversible, to an environmental value, including nuisance to a neighbouring property or person. The potential environmental risk is related, in part, to the assessed Erosion Hazard (refer to Appendix F – *Erosion hazard assessment*).

Acceptable Solution A2(a)
Ideally, Erosion and Sediment Control Plans (ESCPs) should be developed in close association with construction planning because the needs and limitations of the construction process represent an important component of the ESCP. In theory, a construction process cannot be finalised without reference to an ESCP, and an ESCP cannot be finalised without knowledge of the construction process.

Acceptable Solution A2(b) & (c)
Construction activities that are deemed to represent a high to extreme erosion hazard include:

- Any disturbance of high to extreme hazard areas, or a problematic soil that could result in unmanageable soil erosion and/or environmental harm.
- Any installation, construction or building activity, or procedure, that could potentially cause "serious" environmental harm.
- Any soil disturbance that could cause the transformation of significant quantities of potential acid sulfate soils (PASS) into actual acid sulfate soils (AASS), such as to cause "material" or "serious" environmental harm.

Periods of high and extreme erosion potential refers to the variation in the erosion hazard throughout a calendar year based on variations in the rainfall erosivity as described in Appendix E – *Soil loss estimation*. Periods of high to extreme erosion potential include:

- periods of high to extreme erosion risk as defined in Section 4.4 of Chapter 4 – *Design standards and technique selection*; and
- periods of strong winds sufficient to cause significant dust problems.

EROSION AND SEDIMENT CONTROL PLAN (ESCP)

The *intent* of this section is to ensure Erosion and Sediment Control Plans (ESCPs):
- are appropriate for the site conditions, which may vary from time to time;
- are prepared by, or under the supervision of, suitable personnel;
- are able to achieve the required design standard and environmental protection.

Acceptable Solution A3(a)
Such a clause shall not reduce the responsibility of applying and maintaining, at all times, all necessary sediment control measures in accordance with the sediment control standard.

Acceptable Solution A3(b)
It is recognised that the degree of erosion and sediment control is related to the type, cost and scope of works in addition to the environmental risk. This association is acknowledged within the terms of current best practice erosion and sediment control as defined within this document (2008 conditions).

Acceptable Solution A3(c)
On very minor works, such as regular council maintenance activities, or the installation of minor services, the ESCP may be represented by standard drawings prepared by the principle company/organisation as part of an adopted Code of Practice. The key *intent* is to ensure that appropriate consideration is given to erosion and sediment control requirements **before** works commence.

Site-specific ESCPs must address all aspects of proposed site disturbance, temporary drainage works, erosion and sediment control measures, installation sequence, and site rehabilitation for the duration of the construction phase, including (where appropriate) the nominated maintenance period.

Acceptable Solution A3(e)
The timing and degree of ESC specified in the Erosion and Sediment Control Plan(s) needs to be appropriate for the given soil properties, expected weather conditions, and susceptibility of the receiving waters to environmental harm resulting from sediment-laden runoff. Current (2008) best practice design standard of the drainage, erosion and sediment control measures are outlined in Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A3(f)
Additional and/or alternative erosion and sediment control measures must be implemented, and a revised Erosion and Sediment Control Plan (ESCP) must be prepared and submitted to relevant regulatory authority for approval (where required) in the event that:
(i) site conditions significantly change from those previously anticipated; or
(ii) there is a high probability that serious or material environmental harm might occur as a result of sediment leaving the site; or
(iii) the implemented works fail to achieve the adopted ESC standard, or the State's environmental protection requirements; or
(iv) site inspections indicate that the implemented works are failing to achieve the objective of this ESCP.

SITE MANAGEMENT

Acceptable Solution A5(a)
Where appropriate, an Erosion and Sediment Control Plan is prepared (in accordance with Section G3.3), and where necessary approved by a relevant regulatory authority, prior to commencing any land-disturbing activities.

Acceptable Solution A5(b)
The potential for environmental harm must be assessed by a recognised expert or authority.

Acceptable Solution A5(c)
Refer to A1(a) for discussion on "potential environmental risk".

Acceptable Solution A5(d)
Applies to all land-disturbing activities, whether planned or unplanned, and especially to any works that are required to be conducted without an associated Erosion and Sediment Control Plan.

Acceptable Solution A5(d)(iv)
Includes ensuring that the value and use of land/properties adjacent to the development (including roads) are not diminished as a result of work-related soil erosion and sediment runoff.

Acceptable Solution A6(a)
Recommended training requirements are discussed in Section 6.19 of Chapter 6 – *Site management*.

Acceptable Solution A6(b)
Necessary disturbance to ESC measures would include the short-term removal of an ESC measure to allow the installation of services under the ESC measure, or to allow vehicular or material access.

Performance Criterion P7
Performance Criteria P7 and P8 require work sites to be appropriately prepared for both current and imminent site conditions. Compliance with these criteria requires ESCPs to be living documents that remain both effective and flexible, and thus are able to appropriately adapt to changing site conditions.

Acceptable Solution A7(a)
A significant change in site conditions includes:
- unseasonable weather conditions;
- exposure of problematic soil conditions not previously anticipated;
- significant change in construction methodology, staging or programming of earthworks and/or site stabilisation activities;
- significant change in the development design or layout;
- an unprogrammed site shutdown.

Performance Criterion P8
Performance Criteria P7 and P8 require work sites to be appropriately prepared for both current and imminent site conditions. Compliance with these criteria requires ESCPs to be living documents that remain both effective and flexible, and thus are able to appropriately adapt to changing site conditions.

Acceptable Solution A9(a)
Appropriate identification depends on the level of risk of damage to protected or retained vegetation. Appropriate identification does not necessarily mean markers, signs or fencing; however, such measures may be appropriate in some areas.

Acceptable Solution A10(b)
Current (2008) best practice requires that all reasonable and practicable measures are taken to:

(i) prevent the release of cement-laden runoff, concrete waste, and chemical products (including petroleum and oil-based products) into an internal or external water body, completed internal drainage systems, or any external drainage system, excluding those on-site drains and water bodies specifically designed to contain and/or treat such material;

(ii) ensure all solid and liquid waste from concrete production, and concreting equipment (including delivery and placement vehicles), is fully contained within the property;

(iii) ensure cement residue from work activities is:
  - retained on a pervious surface (e.g. a grassed or open soil area, or excavated trench); or
  - filtered through a fine-grained, porous earth embankment; or
  - collected and disposed of in a manner that minimises ongoing environmental harm.

Acceptable Solution A10(c)
Current (2008) best practice requires that wherever practicable, the cutting of bricks, concrete, ceramics, and other slurry-producing materials must be carried out in a manner that:
(i) complies with current State guidelines, policies and legislation; and
(ii) fully contains any contaminated waste water for later treatment and/or lawful disposal; or
(iii) appropriately filters (e.g. through a fine-grained, porous, earth embankment) any contaminated slurry/water prior to its release from the immediate work area.

Acceptable Solution A10(d)
Current (2008) best practice requires that wherever practicable, the washing of tools and painting equipment is carried out in a manner that:
(i) complies with current State guidelines, policies and legislation; and
(ii) fully contains any contaminated waste water for later treatment and/or lawful disposal; or
(iii) appropriately filters (e.g. through a fine-grained, porous earth embankment) any contaminated liquid prior to its release from the immediate work area; or
(iv) appropriately infiltrates all contaminated liquid matter into an area of porous grass or open soil.

Acceptable Solution A11(a)
"Sediment and other material" includes clay, silt, sand, gravel, soil, mud, cement and fine-ceramic waste.

Acceptable Solution A11(b)
Sealed surfaces include sealed roads and car parks.

In circumstances where the washing/flushing of sealed surfaces is required, all reasonable and practicable sediment control measures must be employed to prevent, or at least minimise, the release of sediment into receiving waters. Only those measures that will not cause safety issues or adverse property flooding to third parties shall be employed.

Acceptable Solution A12
"Appropriate consideration" includes taking all reasonable and practicable measures to minimise safety risks. As a general rule, safety issues take a higher priority than ESC issues; however, this does **not** mean that the existence of potential safety issues diminishes the ESC standard required of a work site.

Public safety risks include potential damage to public vehicles resulting from the use of inappropriate kerb-inlet sediment traps on public roads. The potential safety risk of a proposed sediment trap to site workers and the public must be given appropriate consideration **before** its installation, especially those sediment traps located within publicly accessible areas.

Performance Criterion P13
The protection of wildlife does not diminish the required ESC standard, or the need to take all reasonable and practicable measures to minimise environmental harm resulting from soil erosion and displaced sediment.

Performance Criterion P14
Further discussion on the protection of waterways and the conducting of instream works is provided in Appendix I – *Instream works*.

LAND CLEARING

Acceptable Solution A15(c)
Operational restrictions on the extent and duration of land disturbance, including land clearing (as presented by Performance Criterion P15), only apply when such land disturbance is at risk, or potentially at risk, of erosion by wind, rain or flowing water.

The potential erosion risk is related (in part) to the potential rainfall erosivity as defined in Section 4.4 of Chapter 4 – *Design standards and technique selection*. The potential erosion hazard may be identified through the application of an appropriate Erosion Hazard Assessment scheme such as those discussed in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

Acceptable Solution A16(b)
The extent of unnecessary soil disturbance, including disturbances outside the designated work area, must be minimised at all times.

Wherever reasonable and practicable, land clearing must be limited to the current stage of works. Current (2008) best practice recommends that land clearing not extend beyond the parameters indicated in Table 4.4.7 of Chapter 4 – *Design standards and technique selection;* that being the minimum necessary to provide:

(i) up to eight (8) weeks of site activity during those months when the expected rainfall erosivity is less than 100, six (6) if between 100 and 285, four (4) weeks if between 285 and 1500, and two (2) weeks if greater than 1500; or

(ii) up to eight (8) weeks of site activity during those months when the actual or average rainfall is less than 45mm, six (6) if between 45 and 100mm, four (4) weeks if between 100 and 225mm, and two (2) weeks if greater than 225mm.

Condition (ii) generally only applies if directed by the relevant regulatory authority.

Acceptable Solution A17(c)
During such tree clearing, all reasonable and practicable measures must be taken to minimise unnecessary removal of, or disturbance to, any existing ground cover (organic or inorganic) until just prior to final grubbing and topsoil removal.

In some cases is might be advantageous to perform bulk removal of trees and shrubs at the beginning of each stage of works, followed by the establishment of a temporary grass, mulch or other ground cover. Final grubbing of roots and topsoil removal should then be delayed until just prior to commencement of bulk earthworks.

SOIL AND STOCKPILE MANAGEMENT

Performance Criterion A18
Applies to all areas of proposed soil disturbance, including footprint of proposed stockpiles prior to placement of soil within such areas. Does not include any material best described as subsoil.

Acceptable Solution A18(b)
Current (2008) best practice recommendations for the management of topsoil are presented in Table 6.2 in Chapter 6 – *Site management*.

Acceptable Solution A19(ii)
The diversion of up-slope stormwater is recommended during those periods when rainfall is possible and the up-slope catchment area exceeds 1500m^2.

Current (2008) best practice recommendations for the protection of sand and soil stockpiles from the erosive effects of wind and rainfall are presented in Table 4.6.1 in Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A19(iv)
Current (2008) best practice recommendations for the selection of an appropriate sediment control system is presented in Table 4.6.2 in Chapter 4 – *Design standards and technique selection*.

Short-term stockpiles of erodible material located outside of an appropriate sediment control zone must be covered if it is raining, or if rain is imminent or possible.

Acceptable Solution A20
Dispersive soils normally need to be stabilised (i.e. treated with gypsum or lime depending on desired pH adjustment) and/or buried under a layer of non-dispersive soil prior to placement of channel lining (whether rock, gabion, synthetic material, or concrete), or initiation of revegetation.

Refer to Section 6.12 in Chapter 6 – *Site management*, or Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of dispersive soils.

Acceptable Solution A21
Refer to Section 6.12 in Chapter 6 – *Site management*, or Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of acid sulfate soils.

Within Queensland, guidelines on the management of acid sulfate soils is provided in State Planning Policy 2/02 *"Guideline: Planning and Managing Development involving Acid Sulfate Soils"*, and Dear, et al. 2002, *Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines.* Department of Natural Resources and Mines, Indooroopilly, Queensland.

DRAINAGE CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure of soil to the erosive forces of flowing water. It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining drainage control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A22
Current (2008) best practice construction phase drainage standards are presented in Table 4.3.1 of Chapter 4 – *Design standards and technique selection*. Drainage systems must be designed to have a minimum non-erosive hydraulic capacity (excluding 150mm freeboard) in accordance with this table.

Acceptable Solution A23(b)
Sandbag flow diversion banks, catch drains, and flow diversion banks are examples of appropriate drainage systems that can be used to divert stormwater around excavations and other soil disturbances.

Acceptable Solution A23(b)
The relevant design discharge is related to Acceptable Solution A22. The "design flow" or "design discharge" is the design hydraulic capacity of that component of the drainage system.

All temporary and permanent drainage systems must be able to accept the design flow within 10 days of construction. This may require the application of an appropriate permanent or temporary channel liner, or the use of velocity control *Check Dams*.

Acceptable Solution A24(a)
"Temporary" drainage systems are only utilised during the construction phase, and only until the permanent drainage systems are constructed and made operational.

The *intent* of installing the permanent drainage system as soon as practicable is to maximise the effective passage of "clean" water through the site without the risk of contamination by on-site sediment.

Acceptable Solution A24(b)
"Clean" water is defined as water that either enters the property from an external source and has not been further contaminated by sediment within the property; 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 site.

Acceptable Solution A24(f)
Does not refer to excavations and trenches that form or act as sediment traps.

EROSION CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure of soil, sand, silt, mud or cement to the erosive forces of wind, rain and flowing water. It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining erosion control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A26(a)
Current (2008) best practice (construction phase) land clearing and site rehabilitation standards are presented in Table 4.4.7 of Chapter 4 – *Design standards and technique selection*. Unless otherwise stated by the relevant regulatory authority, the potential erosion risk is based on the rating outlined in Table 4.4.1 of Chapter 4 – *Design standards and technique selection*.

In addition, all temporary earth banks, flow diversion systems, and sediment basin embankments should be machine-compacted, seeded and mulched within ten (10) days of formation for the purpose of establishing a vegetative cover, unless otherwise stated within an approved Site Stabilisation Plan, Revegetation Plan, or Vegetation Management Plan.

Acceptable Solution A26(b)
Erosion control measures primarily focus on the control of fine sediments such as clay and silt-sized particles. Thus, with respect to the value of "erosion control measures", potential environmental harm is strongly related to the susceptibility of the receiving waters to environmental harm resulting from turbid runoff (i.e. suspended fine sediments).

Erosion control measures need to be appropriate for the land slope and the expected wind, rain and hydraulic conditions. Application of effective drainage control measures should help to control hydraulic conditions such that damage to adopted erosion control measures during regular rainfall events is minimised.

Acceptable Solution A27(a)
Such a clause shall not reduce the responsibility to apply and maintain, at all times, all necessary sediment control measures.

The minimisation of soil erosion requires the application of effective drainage and erosion control throughout each and all sub-catchments.

Acceptable Solution A28(a)
Compliance with this clause requires:

- soil disturbance within any sub-catchment to be delayed as long as possible, and ideally, not until the principal on-site activities within that area are ready to commence;
- soil disturbance at any given time to be limited to the minimum necessary to perform the required works;
- the extent of unnecessary soil disturbance, including disturbances outside the designated work area, to be minimised.

Acceptable Solution A28(b)
Compliance with the requirements outlined within Table 4.4.7 of Chapter 4 – *Design standards and technique selection* does not diminish the need to apply all reasonable erosion control measures as soon as practicable.

A "sub-area" being an area within a given sub-catchment fully contained within a set of drainage control structures designed to minimise the risk of rill erosion within that area.

Acceptable Solution A28(c)
Disturbed soils associated with non-completed earthworks that are likely to be exposed to rainfall are protected from soil erosion:

(i) if further soil disturbances are likely to be delayed for more than 30 days during those months when the expected rainfall erosivity is less than 100, or 20 days if between 100 and 285, or 10 days if between 285 and 1500, or 5 days if greater than 1500; or
(ii) where directed by the regulatory authority, further soil disturbances are likely to be delayed for more than 30 days during those months when the expected rainfall is less than 45mm, or 20 days if between 45 and 100mm, or 10 days if between 100 and 225mm, or 5 days if greater than 225mm.

Condition (ii) generally only applies if directed by the relevant regulatory authority.

Acceptable Solution A29(i) & (ii)
All stormwater, sewer line and other service trenches not in streets are mulched and seeded, or otherwise appropriately stabilised, within 7 days after backfill, or otherwise rehabilitated in accordance with an approved Site Stabilisation Plan, Landscape Plan, Revegetation Plan, or Vegetation Management Plan.

Acceptable Solution A29(i)
If a backfilled trench is not compacted to a firm condition, then soil settlement can occur over time or after significant rainfall. This lack of compaction can lead to the formation of a drainage depression along the trench resulting in the concentration of stormwater runoff and possible soil erosion.

Backfilling the trench to a level at least 75mm above the adjoining ground level will usually address any future soil settlement (even if appropriate initial compaction is achieved). Variations of this requirement exist in different regions, thus always seek advice from the local government and/or appropriate regulatory authority.

Acceptable Solution A29(ii)
An alternative to A29(i) would be to rehabilitate service trenches in a manner that has proven in the past to prevent unacceptable soil erosion or sediment runoff.

Acceptable Solution A30(b)
This clause requires compliance with Performance Criterion P19.

SEDIMENT CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure, placement, or displacement of sediment (including soil, sand, silt, mud and cement). It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining sediment control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A31(a)
Current (2008) best practice (construction phase) sediment control standards are presented in Table 4.5.1 of Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A31(b)
Relevant site conditions include the soil type, design flow rate, flow condition (i.e. sheet flow or concentrated flow) and erosion hazard. The erosion hazard may be related to the expected soil loss rate (as presented in Table 4.5.1 of Chapter 4, and Appendix E – *Soil loss estimation*), or other factors such as discussed in Appendix F – *Erosion hazard assessment*.

Unless otherwise noted within this document, or specified by the regulatory authority, the design storm for sediment traps (excluding de-watering and instream sediment control measures) must be taken as 0.5 times the 1 in 1 year ARI peak discharge.

The "potential environmental risk" is summarised in Table 5.1 of Chapter 5 – *Preparation of plans*.

Acceptable Solution A32(a)
Compliance with this clause means that no sediment control system is utilised if another more appropriate system (of equivalent treatment standard, i.e. Type 1, 2 or 3) is available. This means that straw bale sediment traps (appropriately wrapped in filter cloth) must not be used unless site conditions prevent the use of any other more appropriate sediment control systems.

Acceptable Solution A32(b)
This means that the catchment area of a *Sediment Basin* is not grubbed of vegetation, or stripped of topsoil, until the sediment basin is fully constructed and operational.

Acceptable Solution A32(d)
This clause means that sediment traps are **not** designed to simply divert sediment and sediment-laden waters away from stormwater inlets.

Compliance with this clause includes the following actions:
(i) Wherever practical, *Sediment Fences* are located along the contour to maintain "sheet" flow conditions down-slope of each fence. Where this is not practical, regular returns are utilised to allow water to pond at regular intervals along the length of the fence.
(ii) Adopted roadside kerb inlet sediment traps are appropriate for the type of inlet (i.e. sag or on-grade), for further discussion refer to Principle 8.14 in Chapter 2 – *Principles of erosion and sediment control*.

Acceptable Solution A34(a)
The *intent* of this clause is to minimise the quantity of water that needs to be de-watered from excavations and trenches. Thus, if water does not need to be de-watered from such areas, then the clause does not apply.

Acceptable Solution A34(b)
Current (2008) best practice sediment control standards for de-watering activities are outlined in Table 4.5.13 of Chapter 4 – *Design standards and technique selection*.

Alternatively, Table 4.5.14 of Chapter 4 presents a water quality standard for de-watering operations based on Nephelometric Turbidity Units (NTU).

Appropriate sediment controls placed down-slope of material stockpiles during the de-watering of such stockpiles are summarised in Table 4.5.14 of Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A34(c)
The "potential environmental risk" is summarised in Table 5.1 of Chapter 5 – *Preparation of plans*.

Acceptable Solution A35(i)
Current (2008) best practice requires treatment of sediment-laden process water in a manner that:
(i) complies with current State guidelines, policies and legislation; and
(ii) fully contains any contaminated waste water for later treatment and/or lawful disposal; or
(iii) appropriately filters (e.g. through a fine-grained, porous earth embankment) any contaminated liquid prior to its release from the immediate work area; or
(iv) appropriately infiltrates all contaminated liquid matter into an area of porous grass or open soil.

SITE STABILISATION AND REHABILITATION

Acceptable Solution A36(a)
Current (2008) best-practice site rehabilitation standards are presented in Table 4.4.7 of Chapter 4 – *Design standards and technique selection*. Unless otherwise stated by the relevant regulatory authority, the potential erosion risk shall be based on the rating outlined in Table 4.4.1 of Chapter 4.

Acceptable Solution A37(a)
The type of permanent vegetation applied to completed earthworks must be compatible with the anticipated long-term land use, current and ongoing erosion risk, environmental requirements (including weed control), and associated components of the site rehabilitation.

Acceptable Solution A37(b)
A "manageable drainage area" refers to an area of open soil that can be managed (at any given time) within the limits of the specified ESC treatment standard without the need for the placement of erosion control measures (e.g. mulching) on any part of the soil.

On a well-managed site, it is typical for a "manageable drainage area" to consist of a series of "sub-areas" interconnected by temporary or permanent drainage channels. A "sub-area" being an area within a given sub-catchment fully contained within a set of drainage control structures designed to minimise the risk of rill erosion within that area.

Performance Criterion P38
Local environment includes local wildlife.

SITE INSPECTION AND MONITORING

Acceptable Solution A39(a)
On low-risk sites, ESC audits (including site inspections and water quality monitoring) may be performed by site personnel; however, as the risk of environmental harm increases, the need for third-party site inspections and water quality monitoring increases.

Personnel undertaking ESC audits of a site must, collectively, have the following capabilities:

(i) an understanding of the local environmental values that could potentially be affected by the proposed works; and
(ii) a good working knowledge of the site's Erosion and Sediment Control (ESC) issues, and potential environmental impacts, that is commensurate with the complexity of the site and the degree of environmental risk; and
(iii) a good working knowledge of current best practice Erosion and Sediment Control measures for the given site conditions and type of works; and
(iv) ability to appropriately monitor, interpret, and report on the site's ESC performance, including the ability to recognise poor performance and potential ESC problems; and
(v) ability to provide advice and guidance on appropriate measures and procedures to maintain the site at all times in a condition representative of current best practice, and that is reasonably likely to achieve the required ESC standard; and
(vi) a good working knowledge of the correct installation, operational and maintenance procedures for the full range of ESC measures used on the site.

Acceptable Solution A39(b)
The construction industry's dealing of workplace safety issues provides a good model for the development of an appropriate "Chain of Command" for the protection of environmental values. The aim is to produce a fair, reasonable and practicable approach based on environmental risk.

As in workplace safety, the responsibility of environmental protection, and therefore erosion and sediment control, rests with **all** site personnel, whether or not the work site is the normal place of work of any and all personnel. Establishing a "chain of command" does **not** diminish the responsibility of each and every person to take all reasonable and practicable measures to minimise environmental harm resulting from their actions as per their "environmental duty of care".

Acceptable Solution A39(c)
"Responsible ESC personnel" are those people employed or contracted by the land owner and/or developer as the principal officer(s) responsible for ensuring appropriate application of the planned ESC measures and for the provision of advice in response to unplanned ESC issues.

Acceptable Solution A40
Personnel preparing and/or supervising the preparation of the Monitoring and Maintenance Program must, collectively, have the following capabilities:

(i) an understanding of the local environmental values that could potentially be affected by the proposed works; and
(ii) a good working knowledge of the site's Erosion and Sediment Control (ESC) issues, and potential environmental impacts, that is commensurate with the complexity of the site and the degree of environmental risk; and
(iii) a good working knowledge of current best practice Erosion and Sediment Control measures appropriate for the given site conditions and type of works; and
(iv) a good working knowledge of the correct installation, operational and maintenance procedures for the full range of ESC measures used on the site.

Acceptable Solution A41(a)
Discussion on scheduling and conducting site inspections by internal and external parties is provided in Chapter 7 – *Site inspection*.

In those instances where specific site monitoring stations are identified within the Monitoring and Maintenance Program, then:

- during periods of water discharge from the site, water quality samples are collected at each monitoring station at least once on each calendar day until such discharge stops; and
- a minimum of 3 water samples are taken and analysed, and the average result used to determine quality.

Sediment basin water quality samples are taken at a depth no greater than 200mm above the top surface of the settled sediment within the basin.

Current (2008) best-practice procedures for "high-risk" sites, requires regular ESC audits to be:

(i) undertaken by a person suitably qualified and experienced in erosion and sediment control that can be verified by an independent third-party (this person must not be an employee or agent of the principal contractor); and
(ii) conducted on the next business day following a rainfall event in which greater than 10mm of rainfall has been recorded by the Bureau of Meteorology rain gauge nearest to the site; and
(iii) conducted at intervals of not more than one (1) calendar month commencing from the day of site disturbance until all disturbed areas have been adequately stabilised against erosion to the acceptance of the relevant regulatory authority; and
(iv) conducted using an appropriate Site Inspection Checklist.

"High-risk sites" are work sites that:

- satisfy the requirements of a high-risk site as defined by either the State or local government; or
- satisfy the requirements of those risk categories greater than high-risk (such as extreme-risk) where such categories have been defined (i.e. score a hazard rating equal to or greater than the "critical hazard value").

Discussion on the assessment of *erosion hazard* and *site risk assessment* is presented in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

ESC audits must include, as a minimum:

- copies of all original Site Inspection Checklists;
- non-conformance and corrective action reports;
- sediment basin water quality and site discharge water quality monitoring results;
- a plan showing the areas of completed soil stabilisation; and
- rainfall records including date and rainfall depth.

Acceptable Solution A42(b)
Discussion on scheduling and conducting of site inspections is provided in Chapter 7 – *Site inspection*.

SITE MAINTENANCE

Performance Criterion P43
Proper working order includes maintaining the required hydraulic capacity and operational effectiveness.

Acceptable Solution A43(b)
Current (2008) best practice requirements for the maintenance of sediment control devices requires these devices to be maintained and made fully operational as soon as reasonable and practicable in accordance with Table 6.1 of Chapter 6 – *Site management*.

The top of a *Sediment Basin's* sediment storage volume must be clearly identified by the horizontal member of a marker post (cross).

Appendix M

Erosion processes

This appendix provides information on the processes of soil erosion. Its function within this document is primarily educational.

M1. Introduction

Soil erosion is the process through which the effects of wind, water, or physical action, displace soil particles, causing them to be transported. It is important to note that the force causing the transportation of soil may be different from the force that originated the erosion.

Soil erosion falls into one of two groups: natural geological erosion and accelerated human-induced erosion. In geological erosion the erosion processes are caused by naturally occurring agents. In a balanced system soil loss by natural geological erosion is equal to the formation rate of soil from natural weathering of surface and sub-surface materials. Such an erosion rate would be around 0.01 to 0.1mm/yr of the soil depth.

In accelerated erosion, the deterioration and eventual loss of soil is usually strongly influenced by human activities. Accelerated erosion rates are generally much greater than the soil formation rate.

M2. Water erosion

M2.1 Forms of water erosion

The most common forms of water erosion are:

- Splash erosion (raindrop impact)
- Sheet erosion (includes splash erosion)
- Rill erosion
- Gully erosion
- Tunnel erosion
- Watercourse erosion
- Coastal erosion

Splash erosion (raindrop impact):
Splash erosion (Figure M1) is the spattering of soil particles caused by the impact of raindrops on soil. Displaced soil particles are typically moved distances up to 1m when initially dislodged. Splash erosion is usually a major contributor to runoff turbidity.

Disturbed soil particles may or may not be subsequently removed by surface runoff. Soil particles dislodged by raindrop impact can also reduce infiltration rates by sealing the soil pores, resulting in increased surface runoff and possibly increased down-slope rill erosion.

Splash erosion is significantly reduced when water depths covering the soil surface exceed 2mm.

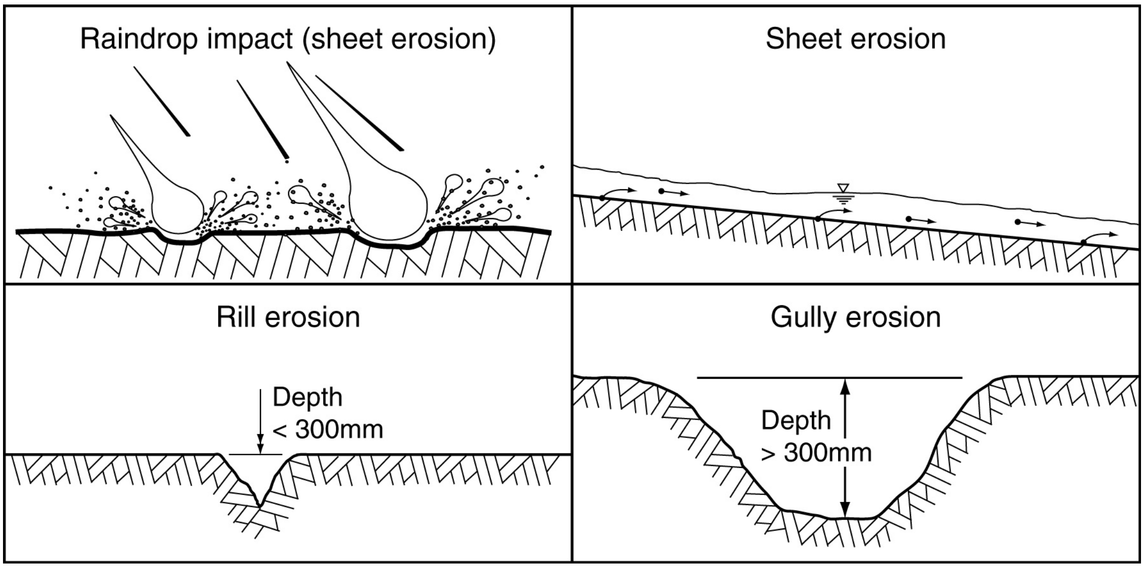

Figure M1 – Forms of water erosion

In general, soil detachability increases with increasing particle size, while soil transportability decreases with increasing particle size. That is, clay particles are generally more difficult to detach than sand particles if they are totally cohesive, but clay particles is more easily transported once detached. The exceptions are (a) dispersive clays which readily "disperse" when wet, and (b) aggregated soils, particularly those that self-mulch.

Factors affecting the rate of detachment are slope, wind, surface condition and impediments to splash such as vegetative cover, both living and dead.

Sheet erosion

Sheet erosion or inter-rill erosion as it is also known, is the uniform removal of soil in thin layers from sloping land (Figure M1). Although important, sheet erosion often remains unnoticed because it occurs gradually and evenly across a slope, and thus is often not obvious to the untrained observer.

The detachment of soil particles by raindrop impact, combined with shallow surface flow leads to sheet erosion. From an energy standpoint, splash erosion is by far the most important for detachment because raindrops have velocities of about 6 to 9m/s, whereas overland flow velocities are about 0.3 to 0.6m/s.

Rill erosion

Rill erosion (Figure M1) is the removal of soil by water concentrated in small but well-defined channels. There is no sharp line of demarcation between sheet erosion and rill erosion. Rills (generally up to 300mm deep) are small enough to be easily removed by normal agricultural equipment.

Although rill erosion is more apparent than sheet erosion, it likewise is often overlooked. On poorly managed sites, rill erosion can contribute around 50% of the eroded sediment leaving a site. Therefore, avoiding, or at least minimising rill erosion on an active construction site can significantly reduce the quantity of displaced soil.

Rill erosion is most serious where intense storms occur on soils that are exposed, loose and shallow. This situation often occurs on development sites.

Gully erosion

Gully erosion (Figure M1) produces channels deeper and larger than rills (generally greater than 300mm deep). These channels carry water during and immediately after rainfall. Gullies are generally too large to be simply ploughed over by normal agricultural equipment.

Gully erosion is not just an advanced stage of rill erosion. Most gully erosion is caused by changes to the hydrology or hydraulics of a valley or sub-catchment, or the up-slope movement of a “head-cut”. Once formed, the head of the gully usually migrates, or “cuts” its way up the slope.

The rate of gully erosion depends primarily on the runoff-producing features of the catchment: the drainage area; surface soil characteristics; subsoil characteristics; the alignment, size and shape of the gully; and the slope in the channel.

Tunnel erosion

Tunnel erosion is the removal of subsoils along a sub-surface tunnel. This form of erosion is usually associated with dispersive soils and normally occurs near gullies, creek lines and constructed embankments.

Tunnel erosion can form through a variety of mechanics. Water can pass through the ground along paths of soils that are dispersible and hence break down into individual particles. The dispersion process allows these individual soil particles to be displaced (flow) from the soil profile, forming minor tunnels that usually grow with time, possibly collapsing to form gullies. Water can also pass through non-dispersible soil and find weak drainage paths, or open cracks in an underlying dispersible soil causing a tunnel to form.

Tunnel erosion can also occur when water moves down through a permeable soil layer and then encounters a less permeable layer (e.g. duplex soil). Lateral movement tends to take place to an outlet lower down the slope or in the side of a gully. With relatively rapid flow, very fine material is then transported towards the outlet and a tunnel is formed.

The slow decay of old tree roots passing through dispersible soil can also initiate tunnel erosion. As the tree root decays it forms a small, open drainage path through the soil that can quickly erode to form a tunnel. In order for the tunnel to form, however, this sub-surface drainage path must eventually discharge to the surface or to an existing tunnel. Thus, this form of tunnel erosion is most commonly associated with trees placed on embankments, or along the bank of a waterway or drainage channel.

Watercourse erosion

Nature protects stream banks often through a delicate interaction between the stream flow, channel capacity, the soil/rock exposure, and the bed and bank vegetation. The removal or modification of any of these components will normally result in the initiation and/or propagation of bed and/or bank erosion.

Factors that influence the stability of stream bank material include:

- the slope and height of the bank;
- the size of the particles that make up the stream banks;
- the amount of vegetative ground cover binding the bank material;
- the relative hydraulic roughness of the bed and banks;
- the dispersibility and erodibility of the bank material;
- the frequency, duration and velocity of near-bankfull flows.

Appropriate treatment of watercourse erosion is assisted through the development of Waterway Management Plans, revegetation programs, control of human and stock access to banks, and by minimising changes to the volume, frequency, duration and velocity of stream flows. Structural treatments are expensive and thus the implementation of catchment management options that reduce the likelihood of watercourse erosion are generally preferred.

Developments adjacent to stream banks should avoid causing disturbance to the riparian zone and should incorporate adequate buffer zones to compensate for likely future erosion and stream migration.

Watercourse erosion occurs when fluvial energy exceeds the resistance of the bed and bank material. Watercourse erosion may result from the following actions:

- changes to the frequency, duration and velocity of near-bankfull flows;
- changes to the ratio of stream curvature to stream width;
- straightening of the channel resulting in an increase in channel slope;
- dredging the stream channel, thus increasing flow velocities;
- artificial constrictions placed within the channel that increase local turbulence;
- obstacles, whether natural (e.g. fallen tree) or artificial, that divert channel flows towards an unprotected or lightly vegetated stream bank.

Coastal erosion
The coastlines are where tides, winds and waves can attack the land, and where the land responds to these forces through a variety of “give and take” measures that effectively dissipate the sea’s energy. The areas most directly affected by the forces of the sea are the beaches and the near-shore zone regions that experience the full impact of the sea’s energy.

Coastal erosion includes wave-induced erosion to the banks of large enclosed water bodies such as lakes. Areas of land located adjacent to large water bodies (lakes, rivers and oceans) are often subjected to the effects of wind-generated waves. This can result in shoreline and bank erosion, the undermining of structures, and localised flooding.

Coastal dunes are constantly under threat from the erosive forces of wind and wave energy. To overcome this threat, appropriate vegetation cover and urban development controls are required to prevent the winds removing sands and to allow wave energy to dissipate “naturally”. When vegetation is removed, vast volumes of sand usually become mobile.

M2.2 Factors affecting water erosion

In general terms, soils that exhibit any of the following features are likely to be prone to water induced erosion:

- soil with low surface cover;
- shallow surface soils overlying low permeable subsoils or rock;
- surface soils with a high percentage of fine sands or silts;
- surface soils that are hardsetting or have a surface crust;
- soils with low levels of organic matter;
- soils with dispersible properties.

The main factors affecting soil erosion are related to the local climate, topography, soil type and surface cover. Climate and topographic factors, excluding slope length, usually cannot be controlled, whereas vegetation cover—and to some extent the soil characteristics—may be varied.

Surface cover

The most important surface condition relating to erosion is cover. Increasing the effective surface cover has a direct influence on potential soil erosion. The retention of a well vegetated cover is recognised as the best long-term mechanism for maintaining infiltration rates and soil hydraulic properties, reducing runoff amounts and rates, limiting sediment detachment and transport, and thus preventing erosion. If raindrops fall on vegetation, not only is the energy absorbed, but fewer drops make direct contact with the soil surface.

A good surface cover does not have to be vegetative to be effective. Rock mulching has similar soil conservation properties. In arid areas, soils tend to be protected by either a layer of sand or rocks. Hence deserts are normally either sandy or rocky (with the exception of floodplains), the clay having long ago being washed or blown from the surface.

The main benefits of vegetation, roots and organic matter in the reduction of soil erosion are listed below:

- the interception of rainfall and absorption of the energy of the raindrops;
- reduced surface flow velocities resulting from increased surface roughness;
- the physical anchoring of bulk soils to prevent mass movement;
- improvement of aggregation and porosity of the soil thus increasing infiltration and reducing runoff;
- increased biological activity within the soil, thus improving soil structure;
- transpiration of soil moisture resulting in a drier soil, thus increasing annual infiltration rates.

Climate

Climatic factors affecting erosion are precipitation, temperature, wind, humidity and solar radiation. Of these, precipitation (rainfall erosivity) gains increasing importance within tropical regions. Temperature and wind affect evaporation and transpiration. Wind, however, also affects the angle of impact and velocity of raindrops. Humidity and solar radiation affect temperature and are less directly involved.

The amount and intensity of rainfall both affect soil loss. Rainfall “intensity” is usually more important than the “volume” of rainfall. In many instances, one or two high-intensity storms can cause as much soil loss as all other storms during a given season.

Rainfall erosivity

Rainfall intensity is one of the most potent factors that influence soil erosion. Rainfall erosivity represents the ability of rain to cause erosion. In most regions this erosivity varies with the seasons, because raindrop size and rainfall intensity are generally greater during summer months—even if the actual rainfall volume is less than in the winter months.

Topography

Topographic features that influence erosion are the degree of slope; length of slope; and size and shape of the catchment. Specifically:

- the steeper the slope the greater the runoff velocity;
- longer slopes permit more of the runoff to concentrate; and

- convex slopes spread surface runoff more evenly resulting in less runoff concentration.

Sheet and rill erosion will increase with both the slope steepness and the length of the slope, the former being more influential. The length of the slope is important because it provides a greater opportunity for runoff to concentrate and increase its velocity.

Soil erodibility

The physical properties of soil affect the soil's infiltration capacity, and the extent to which soil particles can be detached and transported. Properties that influence soil erosion include: soil structure, texture, organic matter, moisture content and density (compaction), as well as the chemical and biological characteristics of soil.

When exposed to the same rainfall erosivity, different soils will display different rates of erosion. The vulnerability or susceptibility of the soil to erosion is known as its *erodibility*. The erodibility of a soil depends on the tendency for its aggregates to breakdown, and also on way the soil is managed.

Soils with large, water-stable aggregates separated by large pore spaces, absorb water rapidly and are resistant to erosion. These soils generally have a high clay content; however, some clays are dispersive and break down when wet making them highly erodible.

Soils with fine aggregates or no aggregates, or aggregates that break down when wet (unstable aggregates) are usually highly erodible.

Sandy soils are generally less erodible on gently sloping land, but the reverse is true on steep slopes. Duplex soils that have characteristically high clay content subsoils beneath a loose surface, favour erosion. The installation of underground services down a mild, vegetated slope can result in gully erosion in such fragile soils.

Dispersible soils are structurally unstable in water, breaking down into their constituent particles (sand, silt and clay) and consequently allowing the dispersive clay fraction to disperse and cloud the water. Further discussion on dispersive soils is provided within Appendix C – *Soils and revegetation*.

Surface condition

Loose, uncompacted soil will always be more readily detached and transported by flowing water; however, the critical issue is determining the ideal degree of compaction—not too loose to control rill erosion, but also not too hard to aid in complete and rapid revegetation. As a general guide, exposed soil on flat land should be rough and loose prior to revegetation; whereas exposed soil on sloping ground should be rough, but firm, and only "hard" (i.e. well compacted) when revegetation is undesirable.

The roughness of an exposed soil surface modifies the process of raindrop impact. A roughened soil surface acts as a barrier that absorbs energy released during raindrop impact. This reduction in energy results in fewer soil particles becoming detached and thus reduced erosion rates.

It is often mistakenly thought that by leaving a soil surface smooth and compacted, erosion will be reduced. Even though soil compaction will generally reduce the risk of rill erosion, it will also increase the runoff potential of the surface and may even increase soil detachment by raindrop impact. High soil compaction is also likely to reduce and/or delay revegetation, which in turn will prolong soil erosion. A roughened soil surface can also counteract the effects of slope by reducing the potential for surface runoff to concentrate.

M3. Wind erosion

M3.1 Introduction

Wind erosion is usually significant in regions where severe winds occur during the drier periods of the year. It can be widespread in the semi-arid and arid areas, and along coastal areas where dunal sands are exposed. The problem is usually associated with non-vegetated, dry, non-cohesive, granular soils that predominantly consist of fine sands and silts.

Movement of soil by wind involves three processes:

- surface creep
- saltation
- suspension

Surface creep
Surface creep is the rolling and sliding of large particles generally in excess of 1mm that are too heavy to be lifted into the air. The horizontal component of wind rolls these particles across the soil surface, bumping soil particles against each other and dislodging other surface particles in the process.

Saltation
Saltation refers to the action of wind on soil particles with diameters generally between 0.1 and 0.5mm causing them to hop and bounce across the surface of the soil. This type of movement dislodges other particles on impact and breaks up soil crumbs, thus exposing them to further wind or water induced erosion.

Suspension
Suspension refers to the movement of small dust particles less than 0.1mm in diameter into the air through the vertical component of wind. These particles are lifted higher into the air and are sometimes carried into high altitude air streams, thus forming storm clouds. In the past, severe dust storms in Victoria have carried Australian soils as far as New Zealand.

M3.2 Mechanics of wind erosion

Wind erosion takes place in three distinct phases:

- initial detachment;
- transportation;
- deposition.

Detachment
Soil movement initiates as a result of wind velocity and turbulence. The fluid threshold velocity is the minimum velocity required to produce soil movement by direct action of the wind, whereas the impact threshold velocity is the velocity required to initiate movement from the impact of soil particles carried in saltation.

Except near the surface and at very low velocities (less than about 3kph), the surface wind is always turbulent. Saltation begins at about 12kph.

Transportation
The quantity of soil moved is influenced by particle size, the gradation of particle sizes, wind velocity and distance across the eroding area (fetch length).

The rate of soil movement increases with distance from the windward edge of the field or eroded area. Fine particles drift and accumulate on the leeward side of the area or pile up in dunes. The rate of erosion varies for different soils, some being as much as 10 times more erodible than others.

The atmosphere has a tremendous capacity for transporting soil, particularly those soil fractions less than 0.1mm in diameter. It is estimated that the potential carrying capacity of 1km^3 of the atmosphere is up to 31,000 tonnes of soil, depending on wind velocity.

Deposition
Deposition occurs when either the wind velocity drops or turbulence drops. The heavier soil particles are deposited first. A solid obstacle to the wind path can cause a drop in velocity and sediment (sand) deposition, but the same obstacle may also increase turbulence thus increasing the pick up of fine particles (silts and clays). A semi-permeable obstacle decreases both velocity and turbulence.

M3.3 Factors affecting wind erosion

The major factors affecting erosion by wind are land use, exposure, climate, soil, and vegetation. Topography appears to be relatively unimportant in the wind erosion process, but the length of the eroding surface greatly influences soil movement.

Land use and exposure
Any permanent land use or temporary construction activity that leaves the soil surface bare during dry, windy periods will increase the soil's susceptibility to wind erosion.

Climate
The principal characteristics of wind that affects erosion are velocity, direction, duration and turbulence. The rate of soil movement is proportional to the cube of the wind velocity.

Wind erosion is greater in the dry season when soils are more likely to be vulnerable. A hot wind rapidly dries the soil surface and reduces the effectiveness of ground cover vegetation.

Soil characteristics
The soil factors affecting wind erosion are texture, structure, particle density, density of soil mass, organic matter, moisture content, and surface roughness. The moisture content is especially significant because only a relatively dry soil is subject to wind erosion.

Surface roughness generally decreases wind erosion. Surface crusts have a retarding influence on soil movement, even though they have a tendency to decrease the effective surface roughness.

Sandy soils with a low clay content lack cohesion and are therefore prone to wind erosion.

Vegetation
The vegetation factors affecting wind erosion are the height and density of cover, type of vegetation and seasonal distribution. Living plant roots and tops are more effective in retarding erosion than surface litter, but the latter often provide a practical solution. Windbreaks can be important in decreasing wind velocities.

M4. Mass movement

M4.1 Introduction

Mass movement is the general term used to describe the movement of large volumes of soil and/or rock down steep slopes, or the movement of deep subsoils on slopes of various gradients. The most common triggering agent is heavy rainfall, which infiltrates the soil profile, reduces shear strength and increases slope load on susceptible soil surfaces.

M4.2 Contributing factors

Charman and Murphy (1991) identified the following factors that can lead to an increase in slope mass loading.

(a) removal of lateral or underlying support:

- undercutting by water (for example, rivers and waves);
- weathering of weaker rock strata at the toe of the slope;
- washing out of granular material by seepage;
- cuts and fills, excavations, draining of lakes or reservoirs.

(b) increased disturbing forces:

- natural accumulation of water, snow, talus;
- artificially increased pressures (such as stockpiles or ore, tip-heaps, rubbish dumps or buildings);
- build-up of pore-water pressure (such as in joints and cracks, especially in the tension crack zone at the rear of the slide).

(c) transitory earth stresses:

- earthquakes;
- continual passing of heavy traffic.

Charman and Murphy (1991) also identified the following factors that can lead to a reduction in the shear strength of the soil material.

(a) weakness in materials:

- for example, some bed materials decrease in shear strength if water content increases e.g. clays, shale, mica, schist, talc, serpentine (the watertable may be artificially increased in height by reservoir construction, or as a result of stress release, vertical and/or horizontal, following slope modification);
- low internal cohesion (such as consolidated clays, sands, porous organic matter);
- in bedrock for example faults, bedding planes, joints, foliation in schists, cleavage, brachiated zones and pre-existing shears;
- higher groundwater table as a result of increased precipitation or because of human interference (for example, dam construction).

(b) weathering or other changes:

- weathering reduces effective cohesion and, to a lesser extent, the angle of shearing resistance;
- absorption of water leading to changes in the fabric of clays (such as loss of bonds between particles, or the formation of fissures).

M4.3 Soil testing

To define the physical behaviour of a soil in relation to mass movement the following laboratory tests are used:

- Particle size distribution to define soil texture
- Attenberg limits and plastic and liquid limits, plasticity index
- Linear shrinkage
- Dispersiveness – determined by Emerson Aggregate Test
- Shear strength including California Bearing Rates
- Proctor compaction for bulk density and optimum moisture content
- Cone penetrometer
- Field moisture content
- Cation exchange capacity
- Mineral identification with X-ray techniques

Not all of these analyses are required all the time. The severity of the problem on the development site will usually determine the extent of analysis.

M4.4 Planning and design considerations

Charman and Murphy (1991) recommend a number of techniques be adopted to reduce mass movement hazards on sites where the hazard is assessed as marginal and the cost of control measures is warranted. These techniques are listed below:

(a) Cut and fill operations should be restricted to a minimum, and deep cuts and excessive fill should be avoided to reduce slope loading and avoid reducing shear strength. Location of roads up and down rather than across the slope, and construction of houses raised above ground level, can assist this aim (for example, pole houses).

(b) Where batters are formed, low angles of cut or fill are desirable. High batters should, if possible be benched and provided with adequate drainage. A structural facing such as gabions or a crib wall can be used to strengthen batters against failure, subject to engineering design.

(c) Removal of subsoil moisture assists stabilisation of areas prone to mass movement by reducing the amount of soil water available to trigger failures.

(d) Efficient surface drainage up-slope of slip-prone areas will also reduce the hazard of failure, removing surface runoff before it can enter the rock and soil of the unstable zone. Diversion channels may be installed immediately up-slope of batters for this purpose.

(e) Sealed diversion drains formed at intervals down the face of high batters, or on berms if these have been formed on the batter face, will prevent the accumulation of local runoff.

(f) An impervious surface course is desirable on pavements to limit infiltration and water movement into the subsoil.

(g) Surface drainage of road pavements should not direct runoff onto fill batters.

(h) All household and road drainage should be carried in pipes or sealed drains away from unstable areas. The use of vegetated waterways and runoff-retarding measures is not generally applicable to such areas, because the primary aim must be to remove surplus water as quickly as possible.

(i) Apart from drainage and structural techniques, the stability of slip-prone areas can be improved, though not so rapidly, by extensive planting of native trees and shrubs. Their strong and extensive root systems bind the soil, and the trees significantly reduce soil moisture. They will regenerate if their roots are broken by soil movement. However, the roots can be a hazard to sewers and drainage pipes.

(j) Further engineering techniques such as grouting, electro-osmotic draining and chemical treatment of highly plastic clays are also sometimes used to stabilise slip-prone areas where development must take place on them.

While all these measures may reduce slip hazard, they will not always eliminate it. As a general rule, when a development is proposed on suspect areas, prior geotechnical survey should be carried out. If this survey confirms a hazard of mass movement, advice should be obtained from professionals experienced in the field of slope stabilisation for the design and installation of all cuts, fills, foundations and drainage.

M5 References

Charman, P.E.V. and Murphy, B.W. 1991, *Soils – Their Properties and Management*. A Soil Conservation Handbook for New South Wales, Sydney University Press and NSW Soil Conservation Service, Sydney, NSW, ISBN 042 400183 7.

The Institution of Engineers, Australia 1996, *Soil Erosion and Sediment Control – Engineering Guidelines for Queensland Construction Sites.* The Institution of Engineers, Australia, Queensland Branch, Brisbane.

Appendix N

Glossary of terms

Accelerated erosion	Any increase over the rate of natural erosion from wind or water as a result of human activities.
Acceptable solution	An action or solution that satisfy the relevant Performance Criteria, but which does not preclude other solutions.
Aggregate	Commercially processed rock of near-uniform size. Similar to commercial "gravel" but without the finer rock sizes. This is different from the common soil science description.
AHD	Australian Height Datum. A common datum used in land survey.
Ameliorant	A substance used to improve the chemical or physical qualities of a soil.
Annual exceedance probability (AEP)	The probability of exceedance of a given discharge within a period of one year. AEP is generally expressed as 1 in Y (years). The terminology of AEP is generally used where the data and procedures are based on an annual series analysis.
Annual plant	A plant which completes its life cycle and dies within one year or less. The life cycle includes production of roots, stems, leaves, flowers and finally seed for further regeneration.
Anticipated weather conditions	Likely weather conditions given reliable weather forecasting or normal seasonal weather patterns, whichever represents the worst case.
ARI	Average Recurrence Interval.
Assessing authority	Any regulatory authority, whether Federal, state, local government or other, involved in the approval and/or setting of conditions of approval for a land development, building or other soil disturbance.
Average Recurrence Interval (ARI)	The average or expected value of the period between exceedances of a given discharge. ARI is generally expressed as Y years. The terminology of ARI is generally used where the data and procedures are based on a partial series analysis.
Base flow	Underlying stream flow rate that cannot be directly attributed to storm events, and is present during part or all of dry periods.
Bench	A constructed ledge formed at one or more levels between the top and bottom of a batter. Its purpose to intercept runoff and reduce slope instability.
Benching	The incorporation of benches within an earth batter.
Best practice	Any program, technology, process, siting criteria, operating method, or device recognised as best practice when assessed against those processes currently used nationally and internationally.
Blading	Trimming or shaving the soil surface with the blade of a grader.
Buffer zone	1. A significant area of vegetation primarily containing an even cover of long grass (>50mm strand length) located down-slope of a soil disturbance and used as a sediment trap. To be effective as a sediment trap, the buffer zone must not contain any drainage depressions, swales or spoon drains that may concentrate flow. The height of the grass must be at least as high

as the maximum depth of sheet flow expected to pass through the buffer. The buffer should contain at least 70% ground cover.

2. A formal land buffer, often permanent, established between to areas of potentially conflicting land usage such as a buffer separating urban development from a waterway, protected bushland, or sensitive environmental habitat.

Building A habitable room; retail or commercial space; factory or warehouse; basement providing car parking space, building services or equipment; or enclosed car park or enclosed garage.

Building envelope 1. The enclosed area or areas on a lot defining the limits of building works, including all soil disturbance, outbuildings, landscaping and driveways.

2. The representation of such areas on a diagram or plan.

Building phase 1. The duration of a building work on a given lot. The building phase would extend beyond the duration of the building contract if the contracted works do not result in the final stabilisation (i.e. adequate control of soil erosion) of the building site.

2. That phase of land development following the construction phase on any stage of works during which building work occurs within that stage (zone) of the site. On large, multi-stage sites, the site may experience periods when the construction, maintenance and building phases are occurring concurrently within different stages (zones) of the land development.

Building site A site where the fabrication or erection of a building or structure is the primary activity.

Building work Those works associated with:

- the erection or construction of a building; or
- the renovation, alteration, extension, improvement, or repair of a building; or
- removal or resiting of a building; or
- works directly associated with the erection or construction of a building including the installation of services, landscaping and paving.

Bypass flow That portion of the flow redirected out of a system, or around a device (such as a sediment trap or stormwater treatment system) such that the bypassed flow does not pass through, or is treated by, the device.

Causeway A raised carriageway across a watercourse or across tidal water, specially constructed to resist the effects of submergence.

Cement residue Cement and cement-laden water washed from concrete surfaces or from the cleaning of equipment.

Channel freeboard Vertical distance between the design water surface elevation in an open channel and the level of the top of the channel bank.

Clay Soil particles less than 0.002mm in equivalent diameter. When used as a soil texture group such soil contains at least 35% clay and no more than 40% silt.

Clay mineral groups include:

- *Kandite group* (e.g. kaolinite and halloysite) extremely stable clay minerals, very low swell and shrink, low CEC (about 5 cmol(+)/kg clay), used for pottery and chinaware;
- *Mica group* (e.g. illite) stable under wetting and drying, potassium ions act as a “glue” sticking the unit cells together, medium CEC (about 30 cmol(+)/kg clay);

- *Smectite group* (e.g. montmorillonite and bentonite) high shrink-swell capacity due to high surface area per unit weight, usually very unstable under wetting and drying, high CEC (about 100 cmol(+)/kg clay), these clays have been used to seal minor cracks in earth dams.

Clay-based creek A minor watercourse formed in clayey soils. In open canopy creeks, groundcover vegetation is dominant on both the bed and banks. In closed canopy creeks, sparse vegetation cover usually still exists, but generally the bare clay soils are clearly visible. Typically watercourse stability in such streams is dominated by bed and bank vegetation and in their natural state there is usually very little sediment flow along the creek during most storm events.

Clay-based soil A soil that contains at least 10% clay.

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.

Clay loam A soil texture group representing a well-graded soil composed of approximately equal parts by weight of clay, silt and sand [when dispersed].

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.

Clod A large compact and coherent soil aggregate produced artificially.

Coefficient of discharge A dimensionless coefficient, used in the Rational Method for the calculation of the peak rate of storm runoff.

Coefficient of runoff Alternative name for “coefficient of discharge”.

Conceptual ESCP A conceptual Erosion and Sediment Control Plan used to assist in the appropriate integration of ESC and construction issues into the planning of developments and other land disturbances. These plans are generally not as detailed as the final ESCPs because their very purpose requires them to be prepared before key site layout and design information are finalised.

Concrete waste Wet or dry concrete or cement residue removed from a concrete surface or from the cleaning of equipment, or excess concrete wasted from a delivery truck or manufacture process. Also see “cement residue”.

Construction planning Planning and design of the site layout, methodology, staging, and programming (timing and scheduling) of the construction phase.

Construction phase That period of civil works extending from initial site access (excluding preliminary site survey and data collection) to the commencement of the contracted/specified maintenance period. On staged works, the construction phase extends to the commencement of the maintenance period of the final stage of completed works.

A regulatory authority may specify on a site-by-site basis that the construction phase includes the maintenance period.

Construction site A site where major earthworks, civil construction (e.g. construction of public works and infrastructure) and/or non-domestic building works are conducted.

Contaminant	Toxic substances within the environment that represent a health hazard to biota.
Contour	An imaginary line connecting a series of points on the surface of the ground that are all the same elevation. It is also the line representing this on a map or plan.
Controllable erosion	Accelerated (unnatural) soil erosion that can be controlled or prevented through reasonable and practicable measures while allowing necessary development and land-disturbing activities to continue.
Cover crop	A cover crop is a temporary, fast growing, vegetative cover grown to provide protection for the soil during the establishment phase of slower growing plants. The latter may be introduced by under-sowing and in due course provide permanent vegetative cover to stabilise the area concerned. The term can include an "intermediate crop" that can be removed with selective herbicides.
Creek	A minor or intermediate watercourse with either a fixed or mobile bed that is either dry (ephemeral) or has a minor constant (perennial) discharge during dry weather. In fixed bed systems the bed material and bed shape generally do not move or alter during most flood events. In mobile bed systems the loose bed material migrates down the channel during flood events. Creeks with mobile beds include gravel-based and sand-based systems while fixed bed creeks are typically clay-based systems.
Critical depth	The depth occurring in an open channel or part full conduit at a condition of flow between subcritical and supercritical flow, such that the specific energy is a minimum for the given flow per unit width.
Critical flow	The condition of flow in a section of an open channel or part full conduit when the flow is at critical depth and the specific energy is a minimum for the given flow per unit width.
Critical hazard value	The erosion hazard value nominated by the regulatory authority that distinguishes "high-risk" and "low-risk" sites.
Critical velocity	The average velocity of flow in a section of an open channel or part full conduit when the flow is at critical depth the specific energy is a minimum for the given flow per unit width.
Cross bank	A raised embankment, in a form similar to a traffic "speed bump", with low vertical curvature placed diagonally across an unsealed road or track to collect and divert stormwater runoff off the track to a table drain or suitable discharge point.
Cross drain	A drain of various forms that collect the flow of water down a track and divert it across the track surface. The capacity of the drain is defined by its cross section. Cross drains are designed to handle smaller flows than cross banks, but larger flows than can be controlled by crossfall drainage.
Dead water zone	That part of a sediment basin or settling basin that does not form part of the effective flow path and thus does not significantly contribute to the design efficiency (i.e. sediment trapping efficiency) of the basin.
Detached dwelling	A separate house on an individual lot, including a community title lot.
Development site	A building or construction site.
Dirty water	Water not classified as clean water.
Dispersible soil	A structurally unstable soil that readily disperses into its constituent particles (clay, silt and sand) when placed in water. Moderately to

highly dispersible soils are normally highly erodible and are likely to be susceptible to tunnel erosion.

Most sodic soils are dispersible, but not all dispersible soils may be classified as sodic.

Some dispersible soils are resistant to erosion unless mechanically disturbed.

Dispersive soil Terminology commonly used in engineering. See "dispersible soil".

Dispersion percentage A measure of soil dispersibility representing the proportion of clay plus fine silt (< 0.005mm approx) in a soil that is dispersible, expressed as a percentage. It is a measure of the amount of soil material that is easily dispersible in water, as opposed to the ease of such dispersion.

Dispersion potential The likelihood that soils will release a cloud of fine clay particles when brought into contact with water.

Domestic building site A site where domestic building work is the primary activity, or where the land is being prepared for domestic building works to commence.

Domestic building work Those works associated with:

- the erection or construction of a detached dwelling; or
- the renovation, alteration, extension, improvement, or repair of a domestic dwelling; or
- removal or resiting of a detached dwelling; or
- works directly associated with the erection or construction of a detached dwelling including the installation of services, landscaping, paving, or the erection or construction of a building or fixture associated with the detached dwelling such as a garage or carport.

Drainage control measure Any system, procedure or material employed to:

- prevent or minimise soil erosion caused by "concentrated" overland flow (including the management of rill and gully erosion);
- divert flow around or through a work site or soil disturbance; or divert "clean" water away from a sediment trap;
- to appropriately manage the movement of "clean" and "dirty" water through a work site.

Drop inlet An inlet to a sub-surface drainage system located within an open area where the water falls vertically into the connecting chamber. Known also as a "field inlet".

Dry basin A sediment basin that is free draining, and thus begins to de-water soon after water enters the basin.

Dyke A ridge or bank of earth formed to control the movement of overland flow. Usually formed using imported material, or in-situ material during the excavation of a trench. Usually larger than a "berm". (USA: Dike)

Ecological harm Any adverse effect, or potential adverse effect (whether temporary or permanent) on an environmental value directly associated with an ecological feature.

Entry/exit pad A well-defined, rock-lined surface (pad) placed immediately adjacent a sealed roadway over which vehicles access to into or from a work site. The entry/exit pad is used to extract and retain sediment from the tyres of vehicles entering and leaving a work site.

Known also as *Rock Pads*, *Rumble Pads* and *Construction Exits*.

Environmental harm	Any adverse effect, or potential adverse effect (whether temporary or permanent) on an environmental value.
Environmental risk	The potential of an activity to cause harm, whether material, serious, reversible or irreversible, to an environmental value. It includes potential nuisance caused to a property or person.
Environmental value	A particular attribute or use of the environment that is conducive to public welfare, safety, health or benefit (whether social, economic cultural or environmental). Several environmental values may be designated for a specific environment or component of the environment.
Erosion	Detachment and movement of granular material (including soil, earth, sand, silt, mud, sediment, or cement) by water, wind, ice or gravity. Includes accelerated, geological, gully, natural, rill, sheet, splash, gully or wind erosion.
Erosion and sediment control (ESC)	The application of structural and non structural measures to control stormwater drainage, soil erosion and sediment runoff during the construction and building phases of land development. Some measures often being retained as part of the permanent site rehabilitation and stormwater management practices.
Erosion and Sediment Control Plan (ESCP)	A site plan, or set of plans, including diagrams and explanatory notes, that demonstrate proposed measures to control stormwater drainage, soil erosion, and sediment runoff during the conduction/building, site stabilisation, and maintenance phases of a construction, building or other soil disturbance activity.
Erosion and Sediment Control Program (ESC Program)	Referring to a collection of ESC plans, specifications and supporting documentation relating to a specific site. The term may be interchangeable with ESCP.
Erosion and Sediment Control standard	Specific design criteria or specifications used in the design of erosion and sediment control measures (including temporary drainage measures) that comply with a given policy or water quality standard.
Erosion and sediment control techniques, measures and work practices	Those techniques, measures and work practices used to control stormwater drainage, soil erosion and sediment runoff during the construction and building phases of land development (including site stabilisation, and construction maintenance phases). It includes those techniques, measures and work practices referred to as *Drainage Control, Erosion Control* and *Sediment Control.*
Erosion control blanket	A blanket of synthetic and/or natural material, used to protect soil against erosion caused by wind, rain and minor overland flows. The term “blanket” generally refers to products best used in areas of sheet flow (e.g. on earth banks) rather than in drainage channels where “erosion control mats” are generally preferred. Known also as a rolled erosion control product (RECP) which is primarily used in areas of sheet flow.
Erosion control mat	A mat of synthetic and/or natural material, used to protect soil against erosion caused by wind, rain and concentrated surface flows. Known also as a rolled erosion control product (RECP) that is primarily used in areas of concentrated flow, such as a drainage channel.
Erosion control measure	A system, procedure or material used to prevent or reduce the effects of erosion on soil and other granular material. Within this document, *erosion control measures* primarily refer to those measures that can aid in the control of raindrop impact and

	sheet erosion.
Erosion control mesh	An open weave blanket formed from synthetic or natural twine such as hessian rope, which is used to protect soil against erosion caused by concentrated surface flows. Usually formed from jute, coir or synthetic twine.
Erosion control technique	A term interchangeable with the term "erosion control measure".
Erosion Hazard Assessment Form	A standard site assessment procedure (presented on a standard form) used to access a work site's potential to cause environmental harm as a consequence of on-site soil erosion and the resulting off-site deposition of sediment.
Erosion risk	An evaluation of the "risk" of soil erosion when consideration is given to both the degree of erosion and the likelihood of the erosion occurring.
Erosion Risk Mapping	The identification and mapping of areas of varying erosion risk. Usually performed by land developers as part of initial site planning, or as part of the conceptual planning of construction procedures. Only those site constraints that directly relate to soil erosion are mapped (i.e. does not assess overall environmental risk). In effect, it is a mapping exercise based on a suitable soil erosion model such as the Revised Universal Soil Loss Equation (RUSLE).
Erosivity (rainfall)	The erosive potential of rainfall expressed as the product of total storm energy and the maximum 30 minute intensity of each storm.
ESC	Erosion and sediment control.
ESC measure	Any erosion and sediment control technique or work practice.
ESC Plan	Erosion and Sediment Control Plan.
ESC Program	Erosion and Sediment Control Program. Referring to a collection of ESC plans, specifications and supporting documentation relating to a specific site. The term may be interchangeable with ESCP.
ESC standard	Refer to *Performance standard* or *Treatment standard.*
ESCP	Erosion and Sediment Control Plan.
Exposed aggregate concrete surface	A concrete surface that has had the upper layer of cement removed (washed-off prior to final setting) to expose a layer of aggregate.
Extreme erosion risk (or potential)	A extreme likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).
Extreme rainfall	Rainfall with an intensity greater than 50mm/hr, and a total rainfall depth greater than the equivalent of the 1hr duration, 1 in 10 year ARI design storm rainfall depth over a 24 hour period. For example, if the 1hr duration, 1 in 10 year ARI average rainfall intensity at a given location is 70mm/hr, then extreme rainfall would be a rainfall depth greater than 70mm within any 24 hour period, or a rainfall intensity exceeding 50mm/hr at any given time.
Fetch length	The distance the wind blows over a water surface in generating waves.
Field inlet	An inlet to a sub-surface drainage system located within an open area where the water falls vertically into the connecting chamber. Known also as a "drop inlet".

Filter cloth	Industrial grade, non-woven synthetic fabric traditionally used to separate soils and rock of different textures or grain size, but also used as a short-term filter for the removal of medium to coarse sediment from a liquid (usually water).
Filter dam	A small porous embankment formed from fine-grained material such as loam or fine sand, and covered or wrapped with a heavy-duty, non-woven filter cloth. Alternatively, a heavy-duty, non-woven filter cloth placed over a pollution containment dam formed from sand or gravel-filled bags. The purpose being the removal of medium to coarse sediment from water passing through the sediment trap.
Flocculation	The process by which colloidal or very fine clay particles, that repel one another when suspended in water, come together into larger masses or loose "flocs" which eventually settle out of suspension.
Flood	The temporary inundation of land by expanses of water that overtop the natural or artificial banks of a watercourse, including a drainage channel, stream, creek, river, estuary, lake or dam, and any associated water holding structures.
Floodplain	The extent of land inundated by the *Probable Maximum Flood*.
Fluting	A process of rilling or gully erosion whereby a series of vertically elongated grooves, called flutes, is created down the surface of the soil. The rilling, or fluting, is caused by runoff passing vertically down the slope dissolving the dispersive soil. Typically these rills are deeper than they are wide.
Ford	A shallow place in a stream where the bed may be crossed by traffic.
Freeboard	The vertical distance between a design water level and the top of a channel or embankment used as a factor of safety.
Frequency factor	A factor that is multiplied by the coefficient of runoff for the 10 year ARI to determine the coefficient of runoff for the design ARI, for the location being considered.
Geotechnical specialist	A person suitably trained and competent to practice geotechnical engineering or science.
Gravel	A mixture of coarse mineral particles larger than 2mm but less than 75mm in equivalent diameter.
Gravel-based watercourse	A watercourse that contains a layer of loose gravel and rocks (including boulders) along the bed. A slow, progressive movement of the bed material down the watercourse is normally expected during periods of flood. Minor watercourses are normally shaded by riparian vegetation and as such may not contain significant quantities of stabilising bed vegetation.
Ground cover	A vegetative layer of grasses, low-growing plants or plant residues providing protection to the soil against erosive agents. A good ground cover is an essential part of the majority of soil conservation programs.
Grubbing	The clearing of roots. Normally refers to the removal of tree roots following land clearing.
Hazard	A source of potential harm.
Hazard rating	The erosion hazard number (score) assigned to a work site following site assessment using an Erosion Hazard Assessment Form.

Heavy rainfall
Rainfall with:

(i) an intensity equal to, or greater than, 10mm/hr but less than 50mm/hr; or

(ii) a total rainfall depth equal to, or greater than, the equivalent of the 1hr duration, 1 in 2 year ARI design storm rainfall depth over a 24 hour period, but less than the equivalent of the 1hr duration, 1 in 10 year ARI design storm rainfall depth over a 24 hour period.

For example, if the 1hr duration, 1 in 2yr and 1 in 10yr ARI average rainfall intensity at a given location is 47mm/hr and 70mm/hr respectively, then heavy rainfall would be a rainfall depth of 47 to 70mm within any 24 hour period, or a rainfall intensity between 10 and 50mm/hr at any given time.

High level basin outlet
The outlet of a sediment basin provided for discharging flows in excess of the capacity of the low-level outlet.

High erosion risk (or potential)
A high likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).

High-risk site
A building or construction site that satisfies the requirements of:

(i) a high-risk site as defined by either the State or local government; or

(ii) those risk categories greater than high-risk (such as extreme-risk) where such categories have been defined (i.e. score a hazard rating equal to or greater than the specified "critical hazard value").

Highly erodible material
Material that can readily wash from a stockpile or work site, or can readily discolour stormwater during regular rainfall events.

Hold point
A stage in the construction program beyond which work must not proceed unless either a stated activity has been completed, or the works have been authorised by an appropriate officer (e.g. Site Superintendent, or representative from the regulatory authority).

Hydraulic design
The component of drainage design that involves the determination of velocities, pressure heads and water levels as storm runoff passes through the drainage system.

Hydraulic efficiency correction factor
A factor used in the formula for sizing Type C sediment basins. Its value depends on flow conditions entering the basin and the shape of the settling pond.

Hydraulic radius
The ratio A/P, where A is the cross-sectional area and P the wetted perimeter—that being the length of the line of contact (on the cross section) between the water and the channel boundary.

Hydraulically-applied blanket
Erosion control products applied as a liquid spray (spray-on products) that dry to form a solid, continuous blanket with a thickness approximating that of a rolled *Erosion Control Blanket*. It does not include *Soil Binders*.

In-bank areas
That part of a channel, including bed and banks, below the channel bank elevation above which the water would spill out of the channel or begin to enter the floodplain.

Independent third party
Any person, organisation or authority considered independent of a given person, organisation or authority.

Infiltration bed
An excavated basin designed to capture and temporarily retain stormwater runoff specifically for the purpose of allowing the stormwater to infiltrate into the underlying soil profile. Commonly used as part of the permanent stormwater treatment system.

If the underlying bed consists of a constructed filter media, then the

	system is referred to as a "filter bed" or "filtration bed".
Instream	Any area between the banks of a constructed drainage channel, watercourse or waterway.
Instream works	Any construction, building or land-disturbing activities conducted between the banks of a constructed drainage channel, watercourse or waterway.
Intent	A statement of the desired and/or required outcomes to be achieved in the completed development, building or work activity (including those activities relating to the planning, design and maintenance of soil disturbing activity), relating to a particular design element or activity.
Invert	The lowest portion of the internal surface of a drain.
Invert erosion	Erosion along the invert of a channel or drain usually as a result of water scour.
Land-disturbing activity	Any carrying out of construction or building work, plumbing or drainage work, or reconfiguring of a lot (i.e. subdivision) where there is potential for accelerated erosion from wind or water and/or the discharge of sediment to drains or waterways.
Lawful point of discharge	A point of discharge which is either under the control of a local government or statutory authority, or at which discharge rights have been granted by registered easement in favour of the local government or statutory authority, and at which discharge from a development will not create a worse situation for downstream property owners than that which existed prior to the development.
Legal point of discharge	A point of discharge which is either under the control of a local government or statutory authority, or at which discharge rights have been granted by registered easement in favour of the local government or statutory authority.
Light rainfall	Rainfall with an intensity less than 2mm/hr, and a total rainfall depth less than the equivalent of the 1hr duration, 1 in 1 year ARI design storm rainfall depth over a 24 hour period. For example, if the 1hr duration, 1 in 1 year ARI average rainfall intensity at a given location is 36mm/hr, then light rainfall would be a rainfall depth less than 36mm within any 24 hour period with an intensity not exceeding 2mm/hr at any given time.
Likelihood	Probability or frequency of an event.
Loam	A medium-textured soil of approximate composition 10 to 25% clay, 25 to 50% silt, and less than 50% sand when dispersed. Such a soil is typically well-graded.
Local authority	Any local or regional external authority—whether government or non-government, including local governments and the State Government—that has a legal interest in the regulation or management of a given activity, or the land on which the activity is occurring, or is proposed to occur. Reference to "the local authority" shall also imply the plural.
Local government	The local city or shire council with jurisdiction over the land in which the activity in question is occurring, or is proposed to occur.
Long-term stockpile	On a building site it is a stockpile that is located on-site or off-site for more than 24 hours. On a construction site it is a stockpile that is located on-site or off-site for more than 30 days.
Low gradient flow diversion technique	A flow diversion drain, channel or bank with a gradient sufficiently low to maintain subcritical flow along its length.

Low level basin outlet The outlet of a free-drainage sediment basin from which discharge will first occur (usually via a pipe).

Low erosion risk (or potential) A low likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).

Low-risk site A building or construction site that scores a hazard rating (within a given Erosion Hazard assessment procedure) less than the "critical hazard value".

Maintenance phase That period of civil works extending from completion the construction phase on any given stage (zone) of works to that instance when ongoing maintenance of works is handed over to the asset manager (i.e. commencement of off-maintenance period).

Known also as the on-maintenance period.

Regulatory authorities may specify on a site-by-site basis that the maintenance period is part of the construction period.

Major sediment trap Any sediment control measure or device that constitutes part of the most critical components of a site's sediment control measures. Any device with a sediment control ranking (e.g. Type 1, 2 or 3) equivalent to the highest ranked sediment control device on a given site.

Within this document a Type 1 sediment trap ranks higher than Type 2, which ranks higher than Type 3.

Manageable drainage area An area of open soil that can be managed (at any given time) within the limits of the specified ESC treatment standard without the need for the placement of erosion control measures (e.g. mulching) on any part of the soil.

On a well-managed site, it is typical for a "manageable drainage area" to consist of a series of "sub-areas" interconnected by temporary or permanent drainage channels.

Manning's roughness coefficient A measure of the surface roughness of a conduit or channel to be applied in the Manning's equation.

Media (filter) The material that constitutes a filter or filter medium.

Medium (filter) An intervening substance, layer of material, or composite material, that acts as a filter such that liquid (typically water) is allowed to pass, but adjacent particulate matter, or particulate matter contained within the liquid, is restricted in its movement.

Moderate erosion risk (or potential) A moderate likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).

Moderate rainfall Rainfall with:

(iii) an intensity equal to, or greater than, 2mm/hr but less than 10mm/hr; or

(iv) a total rainfall depth equal to, or greater than, the equivalent of the 1hr duration, 1 in 1 year ARI design storm rainfall depth over a 24 hour period, but less than the equivalent of the 1hr duration, 1 in 2 year ARI design storm rainfall depth over a 24 hour period.

For example, if the 1hr duration, 1 in 1yr and 1 in 2yr ARI average rainfall intensity at a given location is 36mm/hr and 47mm/hr respectively, then heavy rainfall would be a rainfall depth of 36 to 47mm within any 24 hour period, <u>or</u> an intensity between 2 and 10mm/hr at any given time.

Monitoring A term that is generally interchangeable (within this document) with the term “site inspection”.

The term “monitoring” more commonly refers to the observation, inspection, and/or testing of the performance of a work site (as an entity), or a given erosion and sediment control measure. The term may refer specifically to “water quality monitoring” which involves the sampling, testing, interpretation and reporting of water quality at specific locations. Such monitoring may be performed before, during or after rainfall, especially if the monitoring locations include a watercourse that passes through, or adjacent to, the work site.

NATA National Association of Testing Authorities.

Natural erosion Erosion that occurs at a rate that would be expected if the ground surface had not experienced disturbance due to development.

Nature strip Refer to “verge”.

NTU Nephelometric Turbidity Units.

A measure of water turbidity or the optical clarity of a liquid.

On-grade kerb inlet Stormwater inlet formed into the kerb of a roadway where the roadway has a positive longitudinal grade (i.e. water approaches the inlet from only one direction).

Operational phase 1. For civil works, that period immediately following the construction phase on any given stage (zone) of works. It includes the maintenance phase (unless specified as part of the construction phase) and the building phase (if any).

2. For building works, that period immediately following the contracted building works. It includes the period of final site stabilisation/revegetation if not completed prior to termination of the contracted building works.

Overbank Any region located outside that region between the top of the banks of a channel.

Overbank flow That portion of a flood flow which flows outside the main river channel, flowing at relatively small depths over part of, or the full width of the floodplain, and flowing in a direction essentially parallel with the direction of the main channel.

Overland flow path The travel path of:

- storm flows in excess of the capacity of the underground drainage system (where a piped drainage system exists); or
- surface runoff from the higher parts of the catchment to a watercourse, channel or gully.

It does not include a watercourse, channel or gully with well-defined bed and banks.

Perennial plant A plant whose lifecycle extends for more than two years and continues to live from year to year.

Performance Criteria The criteria to be used in the preparation, submission and assessment of building and development proposals for measuring performance of the proposal against the “objective” or “intent”.

Performance standard The minimum performance or outcome required for a specific ESC measure, process, sub-catchment, or work site as a whole. Performance may be measured in relation to water quality objectives, or the ability of an ESC measure to perform its required function during a given flow rate or weather condition.

Person Includes a body of persons, whether incorporated or unincorporated.

Planners Any person who contributes to the initial planning of a building or other land development, the design of the spatial layout of such a building or development, or the conceptual planning of the building/construction procedures including the conceptual design of erosion and sediment control practices.

Pollutant Any constituent present in sufficient quantity to impair the beneficial uses of a receiving water body.

Pollution containment system Typically a non-free-draining pond designed to capture and hold pollution spills, such as that resulting from traffic accidents. The trapped pollution usually being collected and treated and/or disposed of off-site.

Practical completion The completion of works except for minor defects and omissions that do not prevent the works from being used for their intended purpose.

Preliminary Erosion and Sediment Control Plan A conceptual Erosion and Sediment Control Plan prepared, usually during the planning phase, prior to preparation of the final, development approval, Erosion and Sediment Control Plan.

Known also as a "conceptual Erosion and Sediment Control Plan".

Probable Maximum Flood (PMF) The largest flood that could conceivably occur at a particular location, resulting from the probable maximum precipitation (PMP) and, where applicable, snowmelt, coupled with the worst flood-producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.

The PMF defines the extent of flood-prone land (floodplain).

Problematic soil Any soil type of condition that potentially could result in significant short-term or ongoing environmental harm if disturbed, even if current best practice construction and ESC procedures are adopted during the disturbance. Such soil conditions are likely to include highly dispersive soils (ESP >15%) and actual or potential acid sulfate soils.

It should be noted that "soils" are not in themselves a "problem" or "problematic". The problem only arises through disturbance or management of the soil.

Project manager Principal officer or entity in charge of the management of a development site, whether or not such management activities are performed on-site or off-site.

Proper working order Means taking all reasonable and practicable measures to sustain all ESC measures in a condition that:

- will best achieve the site's required environmental protection, including specified water quality objectives for all discharged water (principal objective);
- is in accordance with the specified operational standard for each ESC measure, where such a standard is consistent with the site's required environmental protection including specified water quality objectives for all discharged water, or where such a standard is not specified, is consistent with current best practice for each individual ESC measure; and
- prevents or minimises safety risks.

Raindrop impact erosion The spattering of soil particles caused by the impact of raindrops on the soil. The loosened particles may or may not be subsequently removed by runoff.

Rainfall Rainwater that falls directly onto a surface of the earth. Periods of low, medium, high, very high and extreme rainfall are defined below:

Low rainfall means those months when the long-term average

	rainfall over the month is not greater than 50mm. Medium rainfall means those months when the long-term average rainfall over the month is greater than 50mm but not greater than 100mm. High rainfall means those months when the long-term average rainfall over the month is greater than 100mm but not greater than 150mm. Very high rainfall means those months when the long-term average rainfall over the month is greater than 150mm but not greater than 200mm. Extreme rainfall means those months when the long-term average rainfall over the month is greater than 200mm.
Rainfall erosivity	The erosive potential of rainfall expressed as the product of total storm energy and the maximum 30-minute intensity of each storm.
Ramsar wetland	A wetland identified as internationally important for the protection of migrating birds by the Ramsar Convention on Wetlands of 1971 held in the Iranian town of Ramsar which resulted in a United Nations treaty enacted in 1975.
Regular storm event	A storm or rainfall event of a given rainfall intensity that is expected to be equalled or exceeded at least twice within a given 28 day period.
Regulatory authority	Any local or regional external authority—whether government or non-government, including local governments and the State Government—that has a legal interest in the regulation or management of either the activity in question, or the land on which the activity is occurring, or is proposed to occur.
Rehabilitate	To restore land to a condition appropriate for the desired ongoing land use, and sufficiently stable to achieve the desired discharge water quality objectives.
Rehabilitation (watercourse)	Improving the geomorphological and ecological conditions of a watercourse to those more closely resembling natural conditions. This includes channel enhancement to minimise erosion and siltation, stream bank protection and revegetation of the watercourse channel and corridor.
Resin-impregnated earth	The method of soil stabilisation using pine resin. Stabilisation may be done on either the subgrade or the pavement itself.
Responsible ESC officer	That person, or team of people of which there is a principal officer, employed or contracted by the land owner and/or developer as the principal officer/entity responsible for ensuring appropriate application of the planned ESC measures and for the provision of advice in response to unplanned ESC issues. Terminology will vary from site to site and region to region. May also be referred to as the *ESC Officer*, *Erosion & Sediment Control Officer*, *Sediment Control Officer*, *Environmental Officer*.
Restoration (watercourse)	To restore original (natural) values and structure, such as returning a watercourse ecosystem back to a pre-impact condition.
Return (sediment fence)	That part of a sediment fence that is turned up a slope to either prevent water flowing along the fence, or flowing around the end of the fence.
Revegetate	The re-establishment of plants on an area of ground depleted or devoid of vegetation in order to provide protection against erosive agents and to improve the nutrient and sediment interception and filtration capacity as well as to provide improved fauna habitat.

Rilling — The removal of soil by runoff from the land surface as sheet flow begins to concentrate in one or more small channels, generally up to 300mm deep.

Riparian zone — That part of the landscape adjacent to streams that exert a direct influence on streams or lake margins and on the water and aquatic ecosystems contained within them.

Riparian zones includes both the stream banks and a variable sized belt of land alongside the banks. Riparian zones have been defined in a legal context in some States as a fixed width along designated rivers and streams.

Risk — The chance of something happening that will have an impact on objectives. It is measured in terms of a combination of the consequences of an event and their likelihood.

River — A major watercourse relative to other streams within a given region, ordinarily with a high natural sediment flow, a near constant base flow and with sufficient bed width to result in an open canopy. Bed vegetation is normally sparse and usually does not play a significant role in channel stability due to the disturbing influence of the high sediment load.

It is noted that a watercourse that is recognised as a river in a region of low rainfall may be smaller than some watercourses referred to as creeks in regions of high rainfall.

Rivers in arid and semi-arid areas can run dry.

Road reserve — The land between property boundaries and that has been so classified. Within the road reserve there is the central carriageway with or without kerb or “kerb and gutter”, and flanked on either side by the road verge.

Rolled erosion control products (RECPs) — Erosion control mats and blankets that are delivered to a site in large rolls and are installed by rolling the synthetic material over the ground surface.

Roof drainage system — A system complying with AS3500.3.2, which discharges at a point approved by the local government.

Runoff — 1. That part of rainfall which is not lost to infiltration, evaporation, transpiration or depression storage.

2. That part of the water precipitated on to a catchment area which flows from the catchment area past a specified point, or the surface flow of “waste” water originating from on-site activities such as equipment cleaning or cutting operations.

RUSLE — The Revised Universal Soil Loss Equation (RUSLE) is commonly used to predict long-time “average” soil loss rates resulting from sheet and rill flow (not wind or gully erosion).

Sag kerb inlet — Stormwater inlet formed into the kerb of a roadway where the roadway has a zero longitudinal grade (i.e. stormwater approached the inlet from both directions).

Sand — A soil separate consisting of particles between 0.02 and 2.0mm in equivalent diameter when dispersed. Fine sand is defined as particles between 0.02 and 0.2mm, and coarse sand as those between 0.2 and 2.0mm.

Sand-based stream — A watercourse that contains a layer of loose sand along the channel bed. The progressive movement of this material down the watercourse is normally expected during flood events.

The channel bed may contain significant quantities of vegetation, but the vegetation is usually smothered by sediment during flood events and thus usually does not play a significant role in the long-term stability of the channel. If a low-flow channel exists, it can be highly mobile with a constantly changing bed/plan form.

Sand filter bed — A bed of sand or other media through which surface runoff passes. The filtered water is then collected by a subsurface drainage system and discharged.

Sand filters are normally operated in association with an upstream pre-treatment system to remove coarse sediment and to ensure an even inflow distribution across the filter.

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.

Scarifier — A tillage implement used for both primary and secondary tillage at depths up to 150mm. Medium duty tines are fitted at an overall tyne spacing ranging from 150 to 250mm.

Sediment — Any clay, silt, sand, gravel, soil, mud, cement, fine-ceramic waste, or combination thereof, transported from its area of origin.

Sediment barrier — Any sediment control device that prevents the passage of coarse sediment either by filtration, or physical blockage of a potential flow path, such as the sealing of a stormwater inlet to prevent the inflow of all water and sediment.

The definition of a sediment barrier varies from region to region. Some authorities use the term to refer to the less effective sediment traps such as Type 3 sediment traps and supplementary sediment traps.

Sediment basin — A dam and associated basin used to capture and retain sediment-laden runoff from a land disturbance primarily through the actions of sedimentation.

A key design component is the promotion of low-velocity, low-turbulent water flow to facilitate the settling process. Chemical flocculation or coagulation maybe used to assist in the settlement of dispersive or slow-settling particles.

Sediment basins commonly consist of an excavated or natural basin, stabilised flow entry points, de-watering system and high-flow emergency spillway.

Temporary sediment basins used during the construction phase of civil projects are normally designed to different standards to those incorporated into permanent stormwater management systems, such as those ordinarily located immediately upstream of wetlands, lakes and stormwater treatment ponds.

Sediment control measure — Any system, procedure or material used to filter, trap or settle sediment from sediment-laden waters.

Sediment control technique — A term interchangeable with the term “sediment control measure”.

Sediment control zone — That portion of a work site that drains to a sediment control device, excluding the entry/exit pad.

Sediment deposit — Any gravel, sand, silt, clay, soil, mud, cement, or combination thereof, deposited in an area from where it did not originate.

Sediment fence — A purpose-made, woven or composite (non-woven with woven backing), geotextile fabric sediment trap constructed as a vertical fence in continuous (buried) contact with the ground and supported by posts.

Sediment runoff Sediment transported by the movement of water.

Sediment trap Any sediment control device that collects and retains sediment from a fluid either by filtration or gravity-induced settlement.

The definition of a sediment trap varies from region to region. Generally the term applies to settling ponds smaller than traditional sediment basins (i.e. Type 2 sediment traps). Throughout this document the term generally applies to any device that traps sediment.

Sedimentation basin A permanent sediment collection basin as opposed to a temporary construction site "sediment basin". A tank or basin designed for low-velocity, low-turbulent flows suitable for settling coarse sediment particles from stormwater runoff.

When attached to a wetland the basin may also be referred to as an *inlet pond*. When attached to a bioretention/biofiltration system it may be referred to as a *coarse sediment forebay*. In each case the design procedures and target sediment size are different.

Settling pond 1. That portion of a sediment basin in which sediment-laden water ponds and sedimentation occurs.

2. A sediment trap typically used in de-watering operations to settle sediment from sediment-laden water. A settling pond differs from a *Stilling Pond* in that it incorporates an outlet structure that allows the pond to freely drain.

Sheet flow Water flowing at a thin, near-uniform depth that is significantly less than the width of flow.

Short-term stockpile On a building site it is a stockpile that is located on-site or off-site for less than 24 hours. On a construction site it is a stockpile that is located on-site or off-site for less than 30 days.

Shutdown period Any period during which construction, building and other land-disturbing activities are suspended for an extended period of time (usually greater than three days) prior to the works being continued or completed.

Typically during such periods the site is required to be operating in a condition of low erosion risk in accordance with a specified development approval condition or self imposed operating condition.

Significant rainfall Unless otherwise defined, rainfall that is sufficient to cause runoff given a specific soil type and soil moisture condition.

Silt Silt is a soil separate consisting of particles between 0.002 and 0.02mm in equivalent diameter i.e., intermediate between clay and fine sand sized particles.

Site The lot or lots of land on which building, construction, or other soil disturbing activities are occurring or proposed to occur.

Site inspection A term that is generally interchangeable (within this document) with the term "site monitoring".

The term more commonly refers to the observation (at close range) and reporting of the physical condition of a work site (as an entity) and its associated erosion and sediment control measures. Site inspections may be performed before, during or after rainfall, especially if runoff-producing rain occurs, stormwater runoff discharges from the site, or significant volumes of water enter any sediment basin.

Site manager Principal officer in charge of the day to day activities on a work site.

Site monitoring The monitoring of a site.

Slaking	The partial breakdown of soil aggregates in water due to the swelling of clay and the rapid expulsion of air from pore spaces. It does not include the effects of soil dispersion.
Sodic soil	A soil containing sufficient exchangeable sodium for the clay in the soil to readily disperse when placed in water.
Soil erosion	The process whereby wind, water and physical action detach soil particles (including soil, earth, sand, silt, mud, sediment, or cement) and cause them to be transported.
Soil map	A map or plan defining the location and extent of specific soil groups. Such a map may also contain relevant soil information.
Spill-through weir	A level weir installed in a sediment fence, U-shaped sediment trap, or other sediment trap to control the maximum water levels within the trap specifically to reduce the risk of undesirable flooding and/or to reduce the risk of hydraulic failure of the device.
Sprig	Section of plant stem material (rhizome, shoot, or stolon) used in vegetative planting.
Stabilisation (watercourse)	To make the channel surface, form and location stable relative to its natural (undisturbed) conditions, including the application of short-term stabilisation measures to the channel surface for the purpose of controlling soil erosion during the revegetation phase.
Stabilise	To make stable or to achieve a stabilised surface.
Stabilised surface	Any surface, or region of a drainage catchment, which has sufficient resistance to erosion to limit the displacement of granular materials, including clay, silt, sand and gravel, and other specified matter to an acceptable rate. The acceptable rate is based on a specified water quality objective. In cases where an acceptable rate has not been defined, a stabilised surface may be defined as a surface which erodes or otherwise allows the displacement of pollutants from its surface at a rate no greater than a similar surface in its natural (i.e. undisturbed) condition.
Steep gradient flow diversion technique	A flow diversion drain, channel or chute with a gradient sufficiently steep to cause supercritical flow within its length.
Steep site	A site where the predominant ground slope is greater than 10% (i.e. 10:1 [H:V]) when measured perpendicular to the contour.
Stilling pond	A sediment trap typically used in de-watering operations to settle sediment from sediment-laden water. A stilling pond differs from a “settling pond” in that it does not incorporate a low-flow outlet structure. Thus, following settlement of the suspended sediment, the pond is normally de-watered using a pump.
Stolon	Modified plant stem that grows horizontally on the soil surface.
Stormwater	1. Surface water runoff following a rain event (including piped flows). 2. Rainwater that runs off pervious and impervious surfaces such as soil, vegetation, rock, roofs, roads and car parks.
Stormwater inlet	Any inlet to a stormwater pipe, including “field inlets” (also known as drop inlets) and “kerb inlets”.
Stream	A small watercourse such as a creek or brook with a sustained base flow that may or may not be permanent. When used in the terms streambed, stream bank and stream flow, it may refer to any type of watercourse, whether or not there is a sustained base flow.

Structural soil A soil profile artificially reinforced with interconnecting aggregate or synthetic products to improve the trafficability, wear characteristics or strength of the soil.

Sub-area An area within a given sub-catchment fully contained within a set of drainage control structures designed to minimise the risk of rill erosion within that area.

Known also as a "manageable drainage area".

Sub-catchment That part of a drainage catchment draining to a specific sediment trap.

Subcritical flow Flow in a channel or conduit that has a depth greater than the critical depth and a velocity less than the critical velocity.

Subsoil Sub-surface soil material comprising the B-horizons of soils with distinct profiles.

Supercritical flow Flow in a channel or conduit that has a depth less than the critical depth and a velocity greater than the critical velocity.

Supplementary sediment trap A minor sediment trap, such as *Grass Filter Strips* and most kerb inlet sediment traps, that is not effective enough to be classified as a Type 3 sediment trap. Even though these sediment traps are relatively ineffective, their incorporation into most Erosion and Sediment Control Plans is considered a relevant part of the best practice sediment control.

Table drain The side drain of a road adjacent to the shoulders, and comprising part of the formation.

Toe drain A drain located along the toe of a slope or batter specifically for draining runoff discharged from the slope.

Topsoil Topsoil is that part of the soil profile, typically the A1 horizon, containing material which is usually more fertile and better structured than underlying layers.

Total area-time-exposure The sum of the product of the area (ha) of each sub-area of disturbance times the duration (days) of exposure of that sub-area.

Treatment standard The specified minimum performance of a drainage, erosion or sediment control technique, or the specified water quality objective.

It includes the drainage control standard, erosion control standard and sediment control standard.

The treatment standard for sediment control measures may also be specified in accordance with the treatment classification (i.e. Type 1, Type 2 or Type 3).

Treatment train A series of water quality treatment systems through which contaminated water flows and is treated where the treatment systems vary in both the type of treatment (i.e. settlement, filtration, infiltration, adsorption) and the standard of treatment (i.e. Type 1, Type 2 and Type 3 sediment retention standard).

Tree protection zone A temporary (construction phase) exclusion zone established around protected and/or retained vegetation.

TSS Total suspended solids, usually reported in units of mg/L.

Turbid water Discoloured water usually resulting from the suspension of fine sediment particles.

Turbidity A measure of the clarity of water. Commonly measured in terms of Nephelometric Turbidity Units (NTU).

Type 1, Type 2, Type 3 sediment traps A classification system used to rank sediment control measures based on their ability to trap a specified grain size.

Type 1 sediment traps are designed to collect sediment particles less than 0.045mm in size. These sediment traps include sediment basins and some of the more sophisticated filtration systems used in de-watering operations.

Type 2 sediment containment systems are designed to capture sediments down to a particle size of between 0.045 and 0.14mm. Type 2 sediment traps include rock filter dams, sediment weirs and filter ponds.

Type 3 sediment containment systems are primarily designed to trap sediment particles larger than 0.14mm. These systems include sediment fences, grass buffer zones, and certain stormwater inlet protection systems.

Type C sediment basin These basins are mostly suitable for coarse grained, good settling soils (defined as Type C soils). Type C basins may be operated as either "dry" or "wet" basins depending on the requirement for stormwater reuse on the site.

Type C soil A soil that contains a significant proportion of coarse-grained particles (less than 33% finer than 0.02mm) and will settle relatively quickly without the need for flocculation.

Type D sediment basin These basins are required for the treatment of dispersive soils that do not readily settle without the use of flocculating agents (defined as Type D soils). Type D basins can only be operated as wet basins.

Type D soil A soil that contains a significant proportion (>10%) of fine (<0.005mm) "dispersible" materials that will never settle unless flocculated or coagulated. That is, where the percentage of clay plus half the percentage of silt (roughly the fraction <0.005mm) multiplied by the dispersion percentage is equal to or greater than 10.

Type F sediment basin These basins are generally suitable for fine-grained soils that can readily settle without the need for flocculating agents (defined as Type F soils). Type F basins can only be operated as wet basins.

Type F soil A soil that contains a significant proportion of fine-grained particles (33% or more finer than 0.02mm) and require extended settlement periods to achieve efficient settlement that may or may not benefit from chemical flocculation.

Typical seasonal storm A storm event that is likely to occur at least twice during a specified "season" of a year taking into consideration anticipated variations in weather from year to year.

Uncontaminated runoff Stormwater runoff that has not been contaminated by sediment from the work site, or has not been directly or indirectly contaminated as a result of actions associated with the work site.

Unified soil classification system A widely used soil classification system that groups soils according to particle size, grading, liquid limit and plasticity index.

Unit catchment area A term used to define the product of the catchment area (A) and the coefficient of discharge (C). It is equivalent to the maximum allowable catchment area for a coefficient of discharge equal to unity (C = 1.0).

Universal Soil Loss Equation (USLE) A soil loss estimation equation developed to predict the long-term, average annual soil loss resulting from sheet and rill erosion acting on a given soil area. The equation does not account for soil erosion occurring within drainage channels or resulting from gully erosion.

The equation's soil loss output (A) has units of tonnes per hectare per year, and incorporates variables accounting for rainfall erosivity

	(R), soil erodibility (K), slope length and grade (SL), erosion control practices (P) and ground cover and management (C). USLE equation: A = R.K.LS.P.C [t/ha/yr]
Up-slope	Any location or activity that exists within the higher part of a slope relative to a reference point on the slope. Ordinarily used in reference to overland flow paths or other areas primarily subjected to sheet flow. When referring to drainage lines, channels and watercourses, the term "upstream" is normally used.
Upstream	Any location or activity that exists within, or moves towards, the higher part of a channel or watercourse relative to a reference point within the channel or watercourse. Ordinarily used in reference to drainage lines, channels and watercourses. When referring to overland flow paths or other areas primarily subjected to sheet flow, the term "up-slope" is normally used.
USCS	Unified Soil Classification System.
USLE	Universal Soil Loss Equation.
Values	That property of a thing by which it is esteemed, desirable, or useful, or the degree of worth (monetary or intangible) this property possesses. Refer also to "environmental values".
Vegetation Management Plan (VMP)	A plan and/or document outlining how site vegetation will be managed, including site clearing, tree protection and preservation, and the management of earthworks adjacent to retained vegetation.
Verge	That part of the street or road reserve between the carriageway and the boundary of adjacent lots (or other limit to street reserve).
Vertical metre	A distance of 1 metre measured in a vertical direction. Typically used to define a section of a slope that has the equivalent vertical fall as the specified vertical metre distance.
Very low erosion risk (or potential)	A very low likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).
Violent rainfall	Refer to "Extreme rainfall".
VMP	Vegetation Management Plan.
Volumetric runoff coefficient	The ratio of the volume of stormwater runoff to the volume of rainfall that produced the runoff. Different coefficients will be obtained when analysing single storm events compared to the assessment of the average annual runoff.
Waste water	Water runoff, including any contaminants, discharged from cutting equipment (e.g. cooling water), the washing of tools, surfaces or equipment, or any waters containing cement residue. A term different from "wastewater" which refers to water discharged from residential, commercial and industrial properties (during the normal operational phase) through a formal sewer system.
Water bar	A raised embankment, cut drain, timber step or other device placed diagonally across an unsealed road or track to collect and divert stormwater runoff.
Watercourse	Any natural or constructed drainage channel with well-defined bed and banks, including constructed drainage channels of a natural

appearance, creeks and rivers.

Waters Any significant body of water whether natural or constructed, or natural drainage system, including creeks, rivers, ponds, lakes and wetlands.

Waterway Any natural or constructed drainage line, watercourse with well-defined bed and banks, including creeks and rivers, and any water body including lakes, wetlands, estuaries, bays and oceans.

Waterway channel Whichever is the greater of, the area of land between the riparian zones, or the area of land located below the top of the lower bank (i.e. excluding the floodplain).

Wet basin A sediment basin that is not free-draining, and thus needs to be de-watered after a storm.

Whoa-boy A raised embankment, in a form similar to speed bump, with low vertical curvature placed diagonally across an unsealed road or track to collect and divert stormwater runoff across the track to a table drain or suitable discharge point. Also see “cross bank”.

Wicking A procedure for selectively applying herbicide to tall grasses within small drains. A length of stiff wire is shaped to the approximate cross-section of the drain, then wrapped in cloth soaked with herbicide. The “wick” is then passed down the drain such that the herbicide only comes in contact with the taller grasses.

Windbreak Any device used to reduce the velocity of wind passing over exposed soil.

Windrow A ridge of soil that may build up along the edge of a track during its construction or maintenance. Windrows can be used to direct road/track runoff to a stable outlet, in which case it is called a “windrow drain”.

Witness point A construction activity that is to be observed by a nominated “witness” such as the Site Superintendent.

Work area The area that will be disturbed by building or construction works, including the area that fully encloses any soil disturbances, the building activities, materials stockpiles and vehicle pathways.

Work site The area of potential disturbance by building or construction works, or any other soil disturbance that could potentially cause environmental harm, including: any area enclosed by temporary exclusion fencing, the area of ground disturbance and material stockpiles, and the footprint of all new structures and vehicle pathways.

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