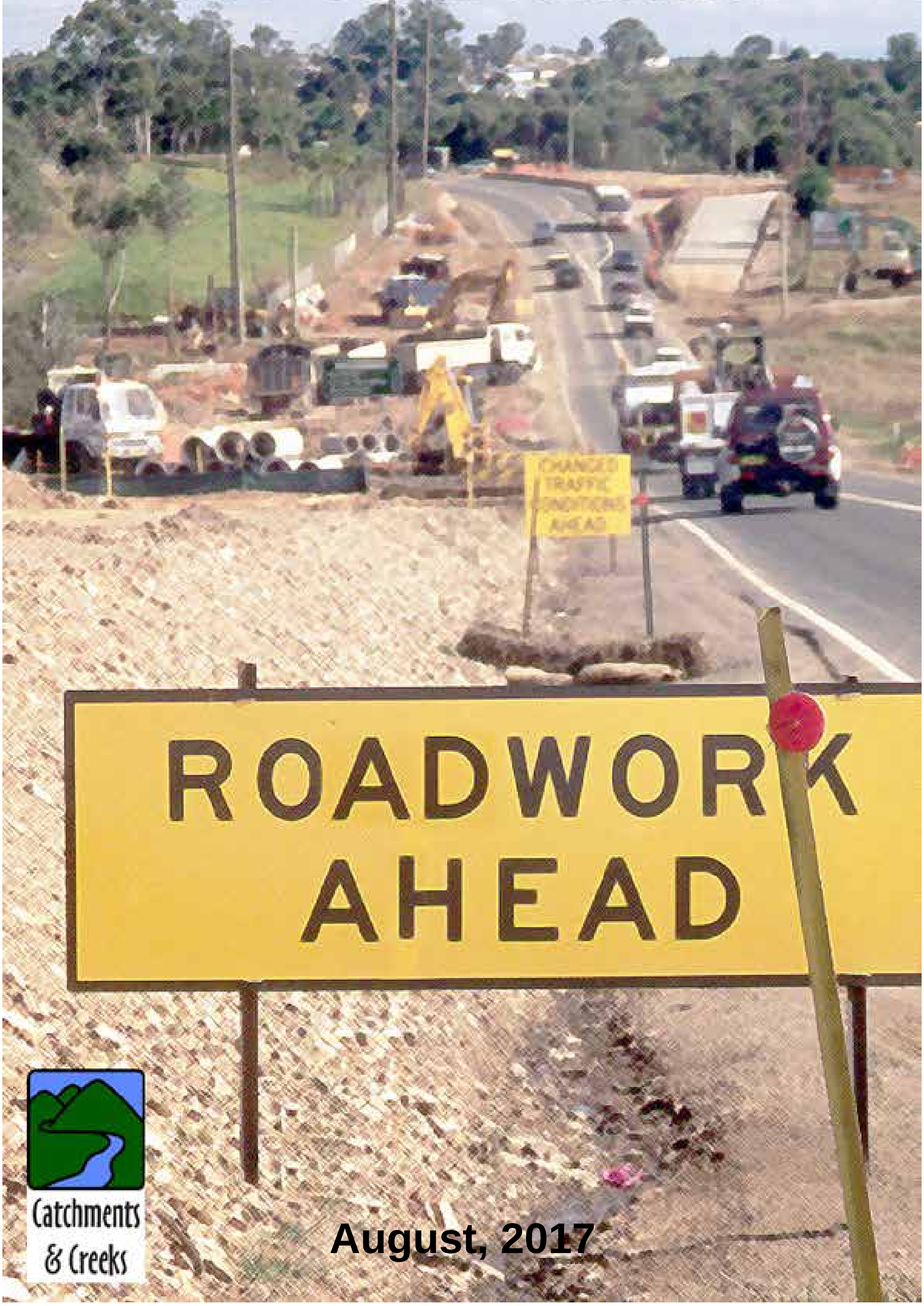
Erosion & Sediment Control for Road Construction

Part 1 - General Construction



Catchments & Creeks

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Erosion & Sediment Control Field Guide for Road Construction – Part 1

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Significant effort has been taken to ensure that this document is representative of current (2017) best practice erosion and sediment control practice; however, the author cannot and does not claim that the document is without error, or that the recommendations presented within this document will not be subject to future amendment as techniques and knowledge improve.

To be effective, erosion and sediment control measures must be investigated, planned, and designed in a manner appropriate for the given work activity and site conditions. No warranty or guarantee, express, implied, or statutory is made as to the accuracy, reliability, suitability, or results of the methods or recommendations.

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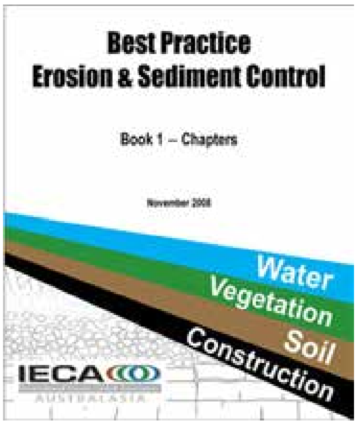
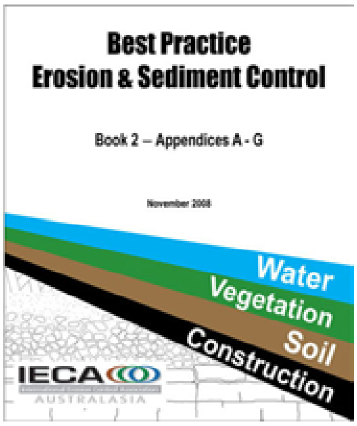
Principal reference documents:



IECA (2008) – Book 1



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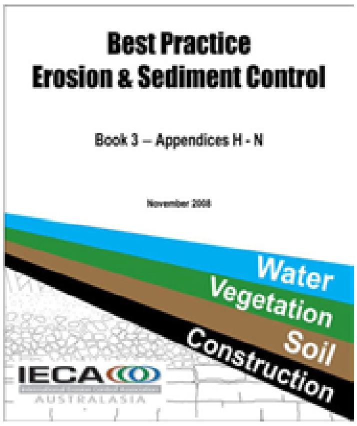

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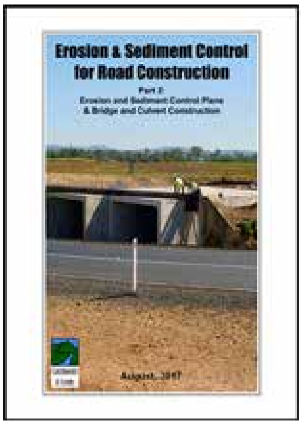

Field Guide for Road Construction, Part-2

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

1. Introduction
2. Principles of erosion and sediment control
3. Site planning
4. Design standards and technique selection
5. Preparation of plans
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G. Model code of practice

Books 1 to 3 may be purchased through:

www.austieca.com.au

Book 3: Appendices

H. Building sites
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J. Road and rail construction
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Erosion & Sediment Control Field Guide for Road Construction – Part 2, 2017

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Purpose of field guide

Part 1 of this field guide has been prepared specifically to provide:

- the road construction industry with general information on the management of their work sites with respect to soil erosion and the control of sediment runoff
- construction personnel working within the road construction field with an additional training tool on Erosion and Sediment Control.

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

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

It is noted that approximately 73% of the photos presented within this field guide have originated from road construction projects.

About the author

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

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

Introduction

The three cornerstones of the erosion and sediment control (ESC) industry are *drainage control*, *erosion control*, and *sediment control*. The primary functions of construction phase drainage, erosion, and sediment controls are outlined below:

- **drainage control measures** aim to prevent or reduce soil erosion caused by concentrated flows (including the management of rill and gully erosion) and to appropriately manage the movement of 'clean' and 'dirty' water across the site
- **erosion control measures** aim to prevent or reduce soil erosion caused by raindrop impact and sheet flow (i.e. the control of splash and sheet erosion)
- **sediment control measures** aim to trap and retain sediment displaced by up-slope erosion processes.

It is noted that on most construction sites, best practice sediment control measures cannot, on their own, provide adequate protection of downstream environments. Therefore, appropriate drainage and erosion control measures must also be applied, at all times, especially on clayey soils. Desirable environmental protection is only achieved when all three ESC measures are working in a coordinated manner during each phase of the construction process.

One of the most notable features of the erosion and sediment control profession is that there is almost always an exception to every rule and guideline. The fact that a control measure is observed to work well on one site does not mean that it will work well on all sites. Similarly, the fact that a control measure has repeatedly failed within one region does not mean that the technique will not be useful within another climatic or topographic region.

Even though erosion and sediment control practices sit at the cutting edge of common sense, their application to a given site must represent an appropriate balance between theory, past experience, and common sense. Also, no rule or recommendation should be allowed to overrule the application of unique, site-specific solutions, where such solutions can be demonstrated to satisfy the stated environmental objectives, and/or the specified performance standards.

Introduction

Major arterial roadway

Major arterial roadways

- This field guide does not attempt to address all of the erosion and sediment (ESC) control issues faced by all of the different types of road construction projects.
- The focus of this document is on those ESC issues associated with major arterial roads constructed within a rural landscape.

Sealed urban road

Urban roads

- Only parts of this document will be applicable to the construction of urban roads due to the space restrictions that often exist on such projects.
- Road construction within new urban developments can often make use of Type 1 sediment traps (i.e. sediment basins) built within the subdivision.
- Space limitations often limit general urban road construction to the use of Type 3 sediment traps, with Type 2 sediment traps used at creek crossings.

Unsealed road

Unsealed (dirt/gravel) roads

- The need for erosion and sediment does not diminish simply because the road is unsealed or the landscape is rural.
- Temporary drainage control often becomes the primary concern.
- Major sediment controls are focused on waterway crossings.
- Appropriate soil management (especially the management of dispersive soils) is essential on road batters to minimise the need for ongoing road maintenance.

Unsealed construction access road

Construction access roads/tracks

- It is unfortunate that the location of temporary construction access roads are so often not marked on the project's Erosion and Sediment Control Plans.
- Instructions on the appropriate management of temporary access roads often exist only within the general construction specifications.
- ESC issues are just as important on construction access roads as they are on the main road works.

An exception to every rule

Road construction

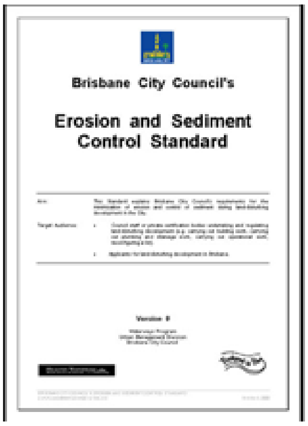
The first rule of ESC

- The first rule of *Erosion and Sediment Control* is that there is almost always an exception to every rule and guideline.
- The fact that a control measure is observed to work well in one location does not mean that it will work well in another location.
- Similarly, the fact that a control measure fails in one climatic region of does not mean that the technique will not be useful within another region.

Semi-arid environment

The importance of 'local significance'

- The information contained within the field guide is 'generic' in content, and must be appropriately assessed in relation to the local context.
- The application of ESC measures on road construction projects varies significantly from urban to rural to arid landscapes.
- Not everything is warranted in every situation, and not everything is practical, or even possible, in every situation.


Brisbane City Council's

Erosion and Sediment Control Standard

Local laws

Local laws and policies

- The recommendations presented within the field guide represent only the views of the author.
- Ultimately it is up to governments and regulators to nominate the design standards for road construction projects in their area.
- This field guide should not be treated as 'policy', but solely as a training tool, a source of ideas, and a general guideline.

Common sense gone missing!

Application of 'common sense'

- Erosion and sediment control practices **must** represent an appropriate balance between the application of the ideal design philosophy and the application of *common sense*.
- No rule or recommendation should be allowed to overrule the application of a unique, site specific solution where such a solution can be demonstrated to satisfy the principle objective and the specified performance standard.

Sediment as a form of pollution

Components of soil

On-site deposition of coarse sediment

Various suspended solids concentrations

Deposition of cement wash-off on a road

Components of soil and sediment

- 'Sediment' should not be viewed as a single pollutant.
- Sediment runoff from construction sites can consist of the following pollutants:
  - clay-sized particles
  - silt-sized particles
  - sand-sized particles
  - cement wash-off
  - metals and other colloidal particles often attached to clay particles
  - organic matter, including weed seed.

Fine and coarse sediment

- The components of sediment runoff are often grouped into 'fine' and 'coarse' sediments.
- Fine sediments consist of clay-sized particles and the finer silts.
- Coarse sediments consist of the coarser silts, and sand-sized particles.
- The finer sediment fraction usually travels as suspended sediment, much of which constitutes water 'turbidity' (the brown colouration of stormwater runoff).

Impact of coarse and fine sediment

- In general, the runoff of coarse sediment primarily causes human-related problems, such as traffic safety issues, and drainage and flooding problems.
- The runoff of the finer sediment particles generally causes most of the ecological harm, such as damage to aquatic ecosystems.
- Erosion control measures aim to minimise the release of fine sediments, while sediment control practices primarily aim to minimise the release of coarse sediments.

Cement wash-off

- Cement wash-off can be generated from various construction activities.
- The environmental harm caused by cement wash-off is primarily linked to the pH (alkalinity) of the liquid waste, **not** the actual sediment.
- The deposition of cement and concrete waste within urban drainage systems can cause blockages and increase the effective 'roughness' of these drainage surfaces, which reduces their hydraulic capacity.

Impacts of soil erosion and sediment runoff

Construction site dust

Dust generation

- Dust generated on road construction projects can cause significant annoyance to neighbouring properties.
- Excessive dust can cause problems for workers' health, and in extreme cases, safety problems associated with reduced visibility.

Sedimentation of drainage pipe

Blockage of stormwater pipes and drains

- Sediment deposition within stormwater drainage pipes and roadside drains can:
  - increase flooding and safety risks on roadways
  - increase maintenance costs for asset owners such as local governments
  - increase the likelihood of mosquito breeding.

Sedimentation of a wetland

Sedimentation within wetlands

- The deposition of coarse sediment into wetlands can:
  - cause the introduction of weeds and dry-land plant species into the wetland
  - cause a loss of essential aquatic habitats
  - cause significant environmental damage to the wetland and its associated wildlife as a result of de-silting operations
  - increase maintenance costs for the asset owner.

Discolouration of farm dam

Turbidity within farm dams

- The release of fine sediments and turbid water into farm dams can:
  - adversely affect the water quality of these water storages
  - increase the concentration of nutrients and metals within these waters
  - increase the cost of maintaining associated domestic water treatment systems.

Impacts of storm runoff and sediment on waterways

Gully erosion along a drainage line

Erosion and sediment impacts on dry gullies

- Concentrated stormwater runoff from rural road construction projects can cause both erosion and sedimentation problems within shallow drainage lines and gullies.
- Rural lands are often very fragile, and minor increases in stormwater runoff, or the redirection of this runoff, can initiate or aggravate gully erosion within the land down-slope of the road works.

Deposition of coarse sediment in a creek

Sediment impacts on minor waterways

- The deposition of coarse sediment in minor waterways, such as creeks, can:
  - increase the risk of property flooding
  - cause bank erosion and channel instabilities
  - cause the loss of essential aquatic habitats
  - increase weed infestation of creeks
  - increase maintenance costs for the asset owner, such as the landowner or council.

Sediment transportation along a river

Sediment impacts on rivers and estuaries

- The release of sediment and turbid water into rivers and estuaries can:
  - adversely affect the health and bio-diversity of aquatic life
  - increase the concentration of nutrients and metals
  - increase the deposition of bed sediments
  - reduce light penetration into the water
  - reduce navigation capabilities along the waterway.

Flood-induced sediment release

Sediment impacts on oceans and bays

- The release of fine sediment and turbid water into oceans can:
  - adversely affect the health and bio-diversity of aquatic life
  - increase the concentration of nutrients
  - smother coral and aquatic habitats
  - cause a significant loss of seagrasses.
- The purpose of the above discussion is to identify the wider impacts of fine sediments on the environment—it does not imply that all such impacts originate solely from road construction projects.

<u>On-site</u> impacts of soil erosion

Truck bogged in wet soil

Excess generation of on-site mud

- Effective on-site drainage control practices provide the benefit of reduced site wetness and mud generation.
- Poorly managed sites can be difficult to traffic during wet weather, resulting in costly delays to both the project and contractors.

Storm damage to road works

Damage to the road works

- Inadequate temporary erosion and drainage control measures can result in severe damage to unsealed road surfaces.
- Recently backfilled stormwater trenches are especially vulnerable to erosion because of the relative low shear strength of the backfill.
- The risk of these problems occurring increases if the soils are dispersive.

Storm damage to road batter

Damage to road batters

- Failure to control storm runoff during the construction phase can lead to the rilling of road batters and damage to revegetation measures.
- Fill batters are typically in their most vulnerable condition immediately after construction and during the early revegetation phase—during this period it is important to manage potential 'run-on' water that could spill down the batters.

Damage to construction access road

Damage to access roads

- Inadequate drainage controls on construction access roads can lead to rilling of the road surface.
- Vehicle access tracks formed in dispersive subsoils are highly susceptible to severe erosion and unstable surface conditions.

Types of soil erosion

Evidence of raindrop impact erosion

Raindrop impact erosion

- Raindrops can exert significant force upon the ground.
- The resulting soil erosion is often difficult to detect and thus is often ignored.
- Raindrop impact erosion is a major cause of the release of fine clay-sized particles resulting in highly turbid (brown) runoff.
- Uncontrolled raindrop impact erosion can easily cause the release of 1 to 2 cm of soil, even during a short construction phase.

Land slope subject to sheet erosion

Sheet erosion

- Sheet erosion is the removal of a thin layer of surface soil through the actions of raindrop impact and sheet runoff.
- Sheet erosion is likely to occur if storm runoff flows over open soil at a speed greater than approximately walking pace.
- It is noted that the erosion of a 1 cm layer of soil represents the loss of 100 cubic metres of soil per hectare.
- After a distance of around 10 m, sheet erosion is likely to change into rill erosion.

Rill erosion on a cut batter

Rill erosion

- A 'rill' is an shallow eroded channel less than 300 mm deep.
- Rill erosion is typically caused by high-velocity concentrated flows (typically water flowing at a brisk walking pace or faster).
- Rilling can also result from the erosion of a soil dispersion (see below).
- Along with flow velocity, soil compaction and soil chemistry can also influence the degree of rilling.

A form of rilling known as 'fluting'

Chemically induced erosion

- Soil chemistry can have a significant influence on the severity and extent of soil erosion.
- If a soil is **dispersive**, then it is likely to be highly unstable when wet, resulting in severe, deep rilling (or 'fluting' as shown left), tunnel erosion and/or gully erosion.
- As a general guide, if an individual 'rill' is significantly deeper than its width, then soil chemistry is likely (not always) to be a significant contributing factor to the soil erosion.

Types of soil erosion

Tunnel erosion

Tunnel erosion

- Tunnel erosion is most commonly formed when groundwater begins to weep through a series of connected cracks within the soil.
- If the soil is dispersive, then the ongoing removal of soil from these minor sub-surface flow paths can eventually form well-defined tunnels.
- Tunnel erosion is typically an indicator of dispersive or sodic soils, especially if these soils are used as backfill within a pipe/service trench.

Gully erosion

Gully erosion

- Gullies are open cuts in the soil that are greater than 300 mm deep.
- Gullies are the inevitable outcome of expanded rill erosion.
- Gully erosion can occur within almost any soil type, but is most commonly found within dispersive and slaking soils.

Bank slumping on a cut batter

Mass movement

- Mass movement failures are most commonly associated with land slips and landslides where significant volumes of earth are displaced down a slope through the actions of gravity.
- Mass movement failures also include some forms of bank erosion observed within waterways, including ‘bank slumping’ and ‘bank undercutting’.

Wind erosion

Wind erosion

- Wind erosion is the displacement of surface soil through the actions of wind.
- It is because of the potential for wind erosion that it would be incorrect for construction personnel to assume that soil erosion was not a concern during dry weather.
- Dust problems can be a common complaint received from those properties that adjoin construction sites.

Soil types

Sandy soil

Sandy soils

- Sandy soils commonly occur along coastal regions, but can also occur on existing and ancient floodplains.
- Heavy storms can cause significant quantities of sediment (sand) to be washed from a construction site if appropriate erosion control measures are not employed.
- The efficiency of on-site sediment control measures usually increases with the increasing sand content of the soil.

Highly 'plastic' clayey soil

Clayey soils

- Clayey soils can be either highly erodible or highly erosion resistant.
- As a general guide, the higher the sodium content, or the lower the organic content and soil compaction of the soil, the **greater** the soil's erosion potential.
- When working in clayey soils, priority should be given to minimising soil erosion wherever practical—don't just rely on the application of sediment control practices.

Dispersive soil

Dispersive (sodic) soils

- Soil chemistry typically affects soil erosion through a process known as *dispersion*, which most commonly results from high levels of sodium within the soil.
- Dispersive soils are often recognised by the occurrence of deep, narrow rilling; often with the rills spaced only a few centimetres apart (known as 'fluting').
- The underside of dispersive soils often has as rounded but textured surface, which results from raindrop splash that has bouncing off an adjacent surface.

Slaking soil

Slaking soils

- Slaking soils are commonly associated with granite country, but can occur elsewhere too.
- These soils often display similar visual signs to dispersive soils, but the lack of dispersive clay particles within the soil means stormwater runoff is generally **not** highly turbid.
- These soils can be difficult to stabilise, and can release significant quantities of clean sand into waterways when they erode.

Identifying problematic soils

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

Soil analysis

Soil testing

- With the exception of small, low-risk pipeline installations, appropriate soil testing should be performed prior to initiating any construction works.
- Construction site managers should be aware of those areas along a road corridor that are likely to contain problematic soils, such as highly erodible soils, dispersive or slaking soils, or acid sulfate soils.

'Fluting' erosion within a dispersive soil

Dispersive and slaking soils

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

Culvert damaged by acidic water

Acid sulfate soils

- Prior to the disturbance of soils below an elevation of 5 m AHD, the soil should be tested for its acid sulfate potential.
- These soils can already be acidic, or have the potential to become acidic if disturbed.
- Actual and potential acid sulfate soils must be managed in accordance with the local state-approved guidelines.

Saline soil

Saline soils

- Saline soils can introduce complex revegetation problems, as well as long-term structural problems for some engineered structures.
- Saline soils can be identified through appropriate soil testing, such as:
  - electrical conductivity (EC) of either a 1:5 extract > 1.5 dS/m, or a saturated extract > 4 dS/m.
- The management of saline soils requires local expert advice.

Aggregate Immersion Test

Slightly dispersive soil

Aggregate Immersion Test

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

Non dispersive, non slaking soil

Non-dispersive soil

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

Dispersive soil

Dispersive soils

- If the water discolours both horizontally and vertically around the soil clumps, then the soil could be dispersive.
- Highly dispersive clumps of soil will collapse in less than 10 minutes.
- Caution; using tap, tank or groundwater can sometimes mask the dispersive reaction due to minerals and/or chemicals in the water.

Slaking soil

Slaking soils

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

Visually identifying dispersive soils

Fluting erosion

Fluting

- In dispersive or sodic soils, the rills passing down steep banks and batters are normally deep, narrow and regularly spaced—a form of erosion known as 'fluting'.

Deep rilling and tunnel erosion

Tunnel erosion

- Tunnel erosion is typically an indicator of dispersive or sodic soils.
- Tunnel erosion can initially appear as just examples of bank rilling, until further investigations discover that this rilling is directly connected to an up-slope tunnel with the tunnel inlet some metres from the crest of the embankment.

Rilling limited to a given soil horizon

Rilling/fluting only within a band of soil

- If the rilling only occurs in a specific region of the earth batter, then this could mean:
  - dispersive soils are only present within this specific band of soil, or
  - the upper soil may be dispersive, but has been well sealed and stabilised, or
  - the soil is <u>not</u> dispersive, but instead the rilling is the result of excessive flow velocity—in such cases the rills are normally spaced further apart then the dispersive fluting shown left.

Rilling that extends to top of bank

Rilling/fluting that extends to top of bank

- If the rilling extends to the top of the batter, then this **may** indicate that the erosion is influenced by run-on water spilling over the bank.
- In such cases, investigate the drainage conditions up-slope of the earth batter.
- If the soils are also dispersive (sodic) then they will need to be ameliorated with such chemicals as gypsum.

Visually identifying slaking soils

Deep rilling within a sandy soil

Deep rilling with near-vertical sides

- When slaking soils and non-cohesive (sandy) soils first erode, the erosion is often (but not always) deeper than it is wide, and the sides of the rill are often near-vertical.
- This form of erosion can exist if the soil has one or more of the following attributes:
  - slaking
  - non-cohesive (sandy)
  - poorly compacted
  - very low in organic content.

Inlet to tunnel erosion in pipe trench

Tunnel erosion

- Both dispersive and slaking soils are susceptible to tunnel erosion if used as backfill within a pipe or service trench.

Erosion of backfilled service trench

Erosion of compacted backfill

- Slaking soils can still be highly erodible even if firmly compacted, especially if the soil lacks sufficient organic matter, such as a very sandy soil.

Bank not exposed to direct rainfall

Textured surface

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

Table 1 – Management of problematic soils

Soil type	Drainage/erosion control	Sediment Control
Dispersive (sodic) soils	· Avoid 'cutting' drainage channels into dispersive soils; instead, divert and channel water using flow diversion banks or topsoil windrows. · Dispersive soils **must** be treated with gypsum/lime or buried under a minimum 100–300 mm layer of non-dispersive soil before placing any revegetation or erosion control measures. · Avoid the use of *Check Dams* in drains containing exposed dispersive soils.	· Dispersive soils usually require the addition of gypsum or similar to improve settlement properties. · Sediment control usually relies on the use of Type A, B or D *Sediment Basins*. · Priority should be given to the application of effective erosion control measures along the RoW, rather than trying to control sediment runoff and turbidity. · Look for opportunities to release turbid waters as sheet flow over adjacent grassed land.
Non-cohesive sandy soils	· It is essential to control water movement and flow velocity. · Erosion control may be achieved through *Erosion Control Blankets, Soil Binders* or *Mulch* anchored with a suitable tackifier or mesh. · Long-term erosion control is best achieved with groundcover vegetation such as grass.	· Sediment control measures are most effective in sandy soil areas. · Grassed *Buffer Zones* (adjacent to the pipeline) are only effective if sheet flow can be maintained. · It is important to maximise the 'surface area' of sediment control ponds.
Highly erodible clayey soils	· Control flow velocities in diversion drains through the use of *Check Dams.* · Short-term erosion control may be achieved with *Erosion Control Blankets* or *Mulching*. · Long-term erosion control is likely to rely on the establishment of a good vegetative cover.	· Give preference to the use of Type-1 & 2 sediment controls over Type-3 sediment controls. · Sediment control usually relies on the use of Type A, B or D *Sediment Basins*. · Priority should be given to the application of erosion control measures. · Important to maximise the volume of sediment control ponds.
Low fertility soils	· These soils are usually more erodible than fertile soils. · These soils may be protected with the use of *Rock Mulching*, unless the soils are modified to allow successful revegetation.	· No special (unique) sediment control requirements exist for these soils.
Potential acid sulfate soils	· Minimise disturbance of the soil. · Where disturbance is necessary, minimise the duration of exposure, especially for sandy soils. · Treat exposed soils in accordance with state policies/guidelines. · Backfill trenches within 24-hours. · Follow local guidelines for site rehabilitation and revegetation.	· Acidic water may wash from sediment control devices, and this water may need further treatment to adjust the pH.

Management of dispersive soils

Erosion of a dispersive soil

Failure of a check dam on a dispersive soil

Tunnel erosion under concrete

Erosion of recently seeded surface

Stabilisation of earth batters

- Dispersive soils **must** be:
  - treated with gypsum or other appropriate calcium-based material, or
  - buried under a minimum 100–300 mm layer of non-dispersive soil before placing any vegetation or erosion control measures.
- The minimum thickness of capping depends on the bank slope and the likelihood of future soil disturbance by stock, vehicles or creek erosion.

Stabilisation of open drains

- Avoid cutting drainage channels into dispersive soils.
- Avoid the use of *Check Dams* within any drain that cuts into a dispersive soil.
- The use of *Check Dams* only extends the duration of water ponding, and thus the risk of erosion.
- Instead, line the drain with a non-dispersive soil and revegetate.
- If very high soil compaction is achieved, then revegetation may not occur.

Prevention of tunnel erosion

- Dispersive soils are highly susceptible to tunnel erosion.
- Sealing batter chutes (formed in dispersive soils) with concrete can result in tunnel erosion forming under the concrete.
- Similarly, tunnel erosion can also form under dispersive soil batter chutes lined with rock or rock mattresses.

Treatment of soil prior to seeding

- Do not directly seed an untreated dispersive soil.
- A well-established vegetative root system cannot prevent the release (dispersion) of clay particles from the soil, which ultimately will undermine the vegetation.
- Instead, treat the soil with gypsum (or the like) and/or cover the dispersive soil with a minimum 100 to 300 mm layer of non-dispersive soil.
- The required depth of cover depends on the likely degree of future soil disturbance.

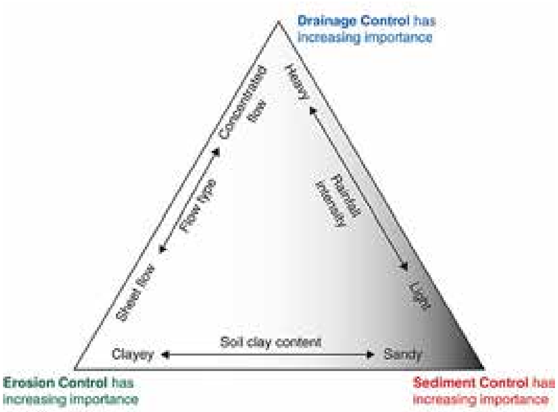
Principles of erosion and sediment control

Sheet and rill erosion

Sediment deposition

Erosion Process	Primary Control Measure
Splash erosion	Erosion control
Sheet erosion	
Rill erosion	Drainage control
Gully erosion	Permanent stormwater management
Tunnel erosion	Soil management
Mass movement	Vegetation and land management
Watercourse erosion	Permanent stormwater management
Coastal erosion	Land use management
Wind erosion	Erosion control

Techniques used to control soil erosion



Setting priorities base on site conditions

Factors affecting soil erosion

- The factors affecting water-induced soil erosion include:
  - **Rainfall erosivity**; the ability of rainfall to dislodge soil particles
  - **Soil erodibility**; the ability of the soil to resist being eroded
  - **Slope length**; the length over which water flows uninterrupted
  - **Slope grade**; the steepness of a slope
  - **Surface cover**; ability of the surface cover to protect soils from erosion
  - **Land management practices**

Factors affecting sediment runoff

- The factors affecting the degree of sediment runoff from a site include:
  - **Degree of soil erosion**; linked to drainage and erosion controls
  - **Type of sediment controls adopted on the site** – types 1, 2 or 3 controls
  - **Design flow rate of the treatment train**; e.g. 0.5Q1, Q1, Q2, where Q1 = 1 in 1 year design storm
  - **Percentage of the site's runoff directed to sediment traps**.

Management of soil erosion

- Each form of soil erosion is generally controlled by a different land management practice.
- Drainage control and erosion control measures focus on different activities.
- *Drainage Control* measures focus on the control of soil scour and rill erosion.
- *Erosion Control* measures focus on the control of splash and sheet erosion.

Principles of erosion and sediment control

The key principles of erosion and sediment control are centred around the following tasks:

1. Minimise disturbance
2. Control site drainage
3. Control soil erosion
4. Promptly revegetate
5. Control sediment runoff
6. Develop effective and flexible ESC Plans
7. Implement ESC Plans and monitor the site

Construction contracts

Road construction

Basins retained for stormwater treatment

Batter without appropriate erosion control

Progressive batter revegetation

Good construction contracts

- In general, an appropriately worded construction contract has a **greater** potential to produce favourable environmental outcomes than a well-prepared ESC Plan.
- The best ESCP is easily 'crippled' if the wording of the construction contract either:
  - prevents the main contractor or their sub-contractors from implementing the plan, or
  - provides the contractor with loopholes to avoid their environmental duty.

Allowing space of major sediment traps

- The available road reserve width, or the contracted use of neighbouring land, **must** allow the contractor sufficient space to construct and operate appropriately sized sediment basins at key locations.
- The allocation of sufficient space for sediment basins is more likely to occur if these basins are incorporated into the road's permanent stormwater treatment infrastructure.
- Space limitations often prevent the use of sediment basins in urban settings.

Batter stabilisation vs batter revegetation

- It is **NOT** appropriate to leave finished road batters exposed to the weather simply because the contractor feels that:
  - batter stabilisation measures consist solely of batter revegetation, or that
  - batter revegetation has been sub-contracted to another organisation that currently does not have access to the site.
- If road batters are not to be immediately vegetated, then the contract **must** specify temporary erosion control measures.

Maintenance and revegetation provisions

- The construction contract must include adequate provisions for:
  - ongoing maintenance of ESC measures
  - progressive site stabilisation and revegetation.
- 'Inspection and Test Plans' should be incorporated into the site revegetation specifications wherever practical.
- 'Witness Points' or 'Hold Points' can be used to ensure that road batters are stabilised at maximum 3 m lifts.

Key issues on road construction projects

Road construction

Sediment basin

Flow diversion drains

Type 2 sediment trap

Introduction

- The preparation of ESCPs for road construction projects is primarily based on managing the following key issues:
  - locating major sediment traps
  - diversion of run-on water
  - treating dirty water runoff from the road
  - managing soil stockpiles
  - control of soil erosion on road batters
  - management of waterway crossings
  - preparing the site for imminent storms
  - site revegetation.

Locating major sediment traps

- One of the most effective ways of controlling sediment runoff from construction activities is through the use of sediment basins.
- Ideally, the need for, and location of, sediment basins should be resolved during the planning phase of new roads.
- Sediment basins are most commonly located adjacent waterway and drainage line crossings.

Diversion of run-on water

- During the construction phase there are two forms of drainage, *temporary drainage*, which is active only during the construction phase, and *permanent drainage*, which is operational during the life of the road.
- Drainage control measures are used to divert 'clean' run-on water away from road works and newly formed road batters.

Treating dirty water runoff

- Sediment traps can be classified as: Type 1, Type 2, Type 3, & supplementary.
- Type 1 sediment traps, which include most sediment basins, are designed to capture a full range of sediment particles from sands to clays.
- Type 2 sediment traps are designed to focus on the capture of sands and silts.
- Type 3 sediment traps are primarily designed to trap coarse-grained particles (sand) larger than 0.14 mm.

Key issues on road construction projects

Topsoil stockpile

Managing soil stockpiles

- Road construction often involves the long-term stockpiling of both topsoil and embankment fill.
- Critical issues include:
  - investigating if the plant seed within the topsoil should be preserved
  - locating stockpiles away from road works and overland flow paths
  - controlling soil moisture levels in proposed fill material
  - sediment control measures.

Batter stabilisation

Control of soil erosion on road batters

- Batter stabilisation can be integrated with site revegetation, or treated as a separate process.
- '**Batter stabilisation**' is a part of the earth works phase that must occur immediately after a new batter is formed.
- '**Batter revegetation**' can be implemented by a separate contractor after earthworks are completed, but in such cases, the batter must be stabilised with temporary erosion control measures as apart of the earthworks contract.

Approaching storm

Preparing the site for imminent storms

- Construction sites need to be prepared for both likely and unlikely, but possible, weather conditions.
- Critical issues include:
  - conducting a pre-storm site inspection
  - establish temporary flow diversions around newly constructed works
  - stabilising drainage pathways
  - securing erosion control blankets
  - establishing spill-through weirs or flow bypass around sediment controls.

Batter revegetation

Site revegetation

- Final site rehabilitation measures should be treated as a separate construction item to temporary erosion control measures.
- Revegetation plans should provide details or contract conditions on:
  - temporary revegetation measures in the event of an unplanned site shut-down
  - timing of site revegetation relative to the time of year or assessed erosion risk
  - method of plant establishment.

Site Establishment and Operational Issues

Site establishment

Site meeting

Site entry and office

Storage of various construction fabrics

Concrete truck wash-out point

Pre-construction meetings

- Erosion and sediment control outcomes on road construction projects can benefit greatly from appropriate site planning.
- Critical discussion topics include the location of major sediment traps, the staging of land clearing, and the division of responsibilities for batter stabilisation and batter revegetation (if performed by different contractors).
- Pre-construction meetings can help to ensure all parties are aware of the critical issues associated with any new works.

Set-up of site office

- Site entry points should be limited to the minimum number of locations.
- Stabilise all site entry and exit points as appropriate for the type of vehicle movement and soil conditions.
- Wherever practical, ensure stormwater runoff from buildings and sheds will not cause unnecessary soil erosion or the generation of mud, especially around heavy traffic areas.

On-site storage of emergency materials

- Stockpile all necessary materials to establish and maintain the site's erosion and sediment control (ESC) measures.
- Maintain adequate supplies of emergency ESC materials such as: straw bales, wire, stakes, sediment fence fabric, filter cloth, wire mesh, and clean aggregate.
- The materials shown in the photo (left) are jute blanket (top), shade cloth (not used for erosion or sediment control), and filter cloth (bottom).

Concrete wash-out points

- If significant concreting is to occur on the site, then establish a concrete disposal area lined with plastic sheeting, permeable earth filter-banks, or other appropriate filter materials.
- Ensure these areas are clearly visible or well signed so that contractors and delivery drivers will be able to identify their location.

Site management

On-site training

Staff training

- Site induction courses need to incorporate information on environmental management and incident reporting.
- Ensure employees receive adequate training on:
  - environmental management
  - best practice erosion and sediment control practices
  - incident reporting procedures
  - site inspection and maintenance procedures (selected staff only).

Damaged fence tagged for repair

Site inspections

- Nominate the officer(s) responsible for the inspection of on-site erosion and sediment control measures.
- Establish an appropriate site inspection routine, as well as maintenance and reporting procedures.
- Identification tags, such as strips of filter cloth stapled to sediment fence fabric (shown left), can be used to identify those ESC measures requiring maintenance.

Examples of suspended solids content

Water quality testing

- Identify the target water quality objectives (WQOs) for the site.
- WQOs are normally assigned by the state or local government.
- Typical water quality objectives are:
  - 50 mg/L of total suspended solids
  - a turbidity level no greater than 10% above that of the receiving water
  - water pH in the range 6.5 to 8.5
- Only appropriately trained people should collect and test water samples.

Sediment deposition in a wetland

Reporting of environmental harm

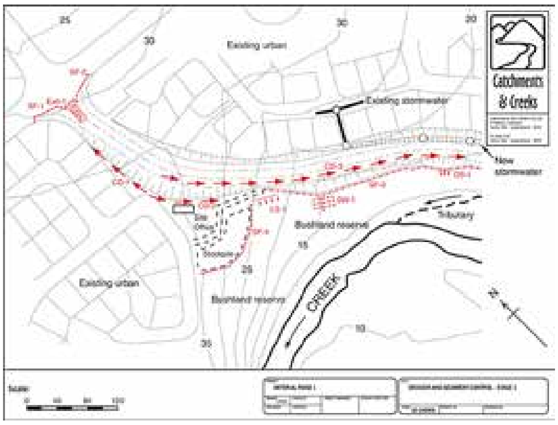
- Best practice site management requires establishment of appropriate incident reporting procedures, including:
  - identifying the chain of responsibility
  - procedures for recording areas of non-compliance
  - monthly reporting procedures (if required)
  - procedures for recording corrective actions
  - internal recording and filing procedures.

Site inspection and monitoring

Storm undermines a sediment fence

Upstream & downstream water samples

Deposition of sediment in a storm drain



Erosion and Sediment Control Plan

Regular site inspections

- All erosion and sediment control measures should be inspected:
  - at least daily when rain is occurring (when it is safe to do so)
  - at least weekly (even if work is not occurring on-site)
  - within 24 hours prior to expected rainfall
  - within 18 hours of a rainfall event of sufficient intensity to cause runoff.
- A formal *Site Checklist* should be completed weekly or monthly.

Collection of water samples

- Site inspections need to be conducted during both dry and wet weather.
- On large pipeline installations, regular third-party site inspections should occur.
- On large or high-risk sites, monitoring is likely to include specific water quality sampling and detailed logbook entries of the site's monitoring and maintenance activities.

Investigate the source of sediment runoff

- When a site inspection detects a notable failure in the adopted ESC measures, the source of this failure must be investigated, and appropriate amendments made to the site and the ESC plans.
- If the site inspection identifies that a revised ESCP is required, then while this plan is being prepared, site personnel should take appropriate steps to minimise the risk of environmental harm—waiting for the revised plan to arrive is not a reason for delaying reasonable actions.

Responding to poor test results

- Erosion and Sediment Control Plans (ESCPs) are living documents that can and should be modified if:
  - site conditions change, or
  - the adopted measures fail to achieve the required treatment standard (e.g. the water quality objectives).
- Site monitoring and inspections can form the key difference between the initial 'Primary ESCP' and the subsequent 'Progressive ESCPs'.

Site entry and exit points

Divided site entry and exit lanes

Stabilised site entry/exit points

- Stabilised site entry/exit conditions are required if the entry/exit point abuts a sealed roadway.
- If the site abuts an unsealed roadway, then the general requirement that sediment-laden water should not be allowed to freely discharge from the site still applies.
- Divided entry and exit points only work if driver movement can be properly controlled.

Rock pad

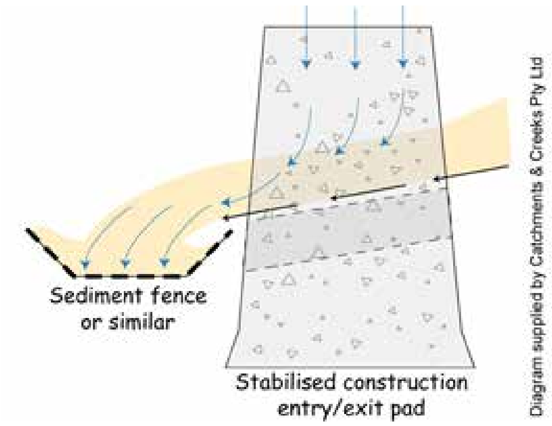
Rock pads

- Rock entry/exit pads are suitable for all soil types.
- The critical design parameter is the total void spacing volume between the rocks.
- Minimum 15 m length.
- The width of the rock pad is usually not critical.
- Requires a geotextile underlay.
- Rock pads generally perform better than *Vibration Grids* during wet weather.

Site signage

Rock selection

- A uniform rock size is required to maximise the void spacing.
- Rock sizes of:
  - 40 to 75 mm, or
  - 100 to 150 mm.
- Rock sizes of 75 to 100 mm are generally avoided because they can become wedged between dual tyres and transported off the site.



Sediment-laden flow directed off rock pad

Drainage controls on rock pads

- Runoff from the rock pad must be directed away from public roads.
- Drainage controls (e.g. cross banks, speed control berms) may need to be incorporated into the rock pad to direct sediment-laden runoff to an appropriate sediment trap.
- A drainage pipe (culvert) can be installed below the cross bank to carry 'clean' run-on water under the rock pad (not shown left).

Site entry and exit points – Vibration grids

Vibration grid

Vibration grids

- Vibration grids are best suited to sandy soils.
- They can also be used in clayey soil regions to control sediment movement from heavy construction traffic during periods of dry weather.

Vibration grid

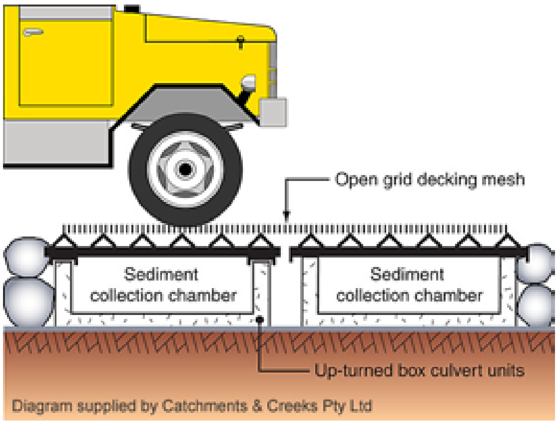
Incorporation of gravel pad

- A gravel pad must extend from the grid to the sealed roadway to prevent the re-contamination of the vehicle tyres.
- Appropriate measures (fencing, flagging, etc) may need to be employed to ensure vehicles don't bypass the vibration grid.

Vibration grid

Modified vibration grid design

- Welding reinforcing mesh over a standard vibration grid can reduce potential damage to construction vehicles caused by passing over traditional vibration grids.



Sediment storage below vibration grid

Clean-out pits

- It is **essential** for vibration grids to be raised well above the ground to allow the collection of sediment below the grid.
- Up-turned box culverts can be used as sediment collection and clean-out troughs.

Site entry and exit points – Wash bays

Wash bay

Wash bays

- Wash bays are preferred when:
  - working near fragile environments
  - when turbidity control is critical, or
  - when working with highly cohesive (sticky) clays.
- Manual or automatically operated water jets can be incorporated into the wash bay.

Drained wash bay (vibration grid)

Operation of wash bay during dry weather

- Wash bays generally need to operate as 'dry' vibration grids during periods of dry weather, otherwise the wash bay can lead to mud generation on the access track, which can then be tracked off the site.

Vehicle wash-down area

Wash-down areas

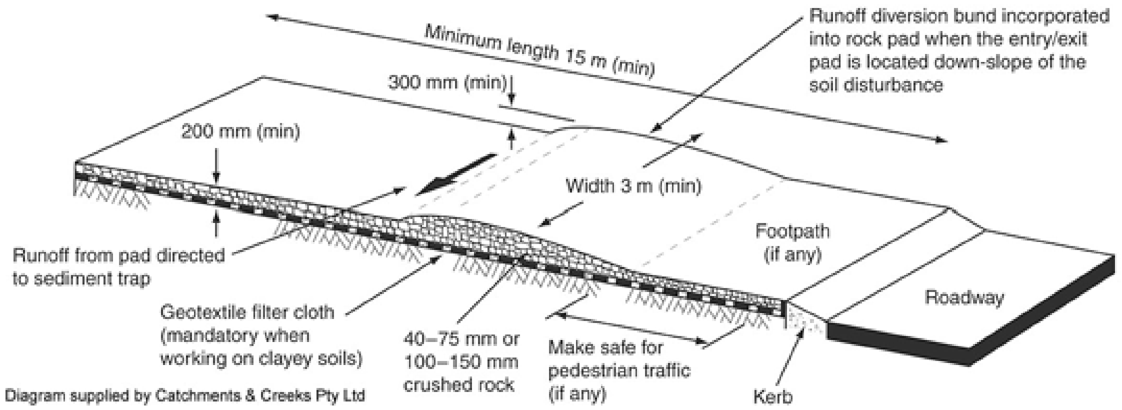
- In rural areas, wash-down areas can incorporate the two important functions of weed control and sediment control.
- Wash bays at property boundaries (e.g. for weed seed removal) must be suitably stabilised (e.g. *Rock Pads*) in order to maintain suitable traffic conditions.

Vehicle wash-down area

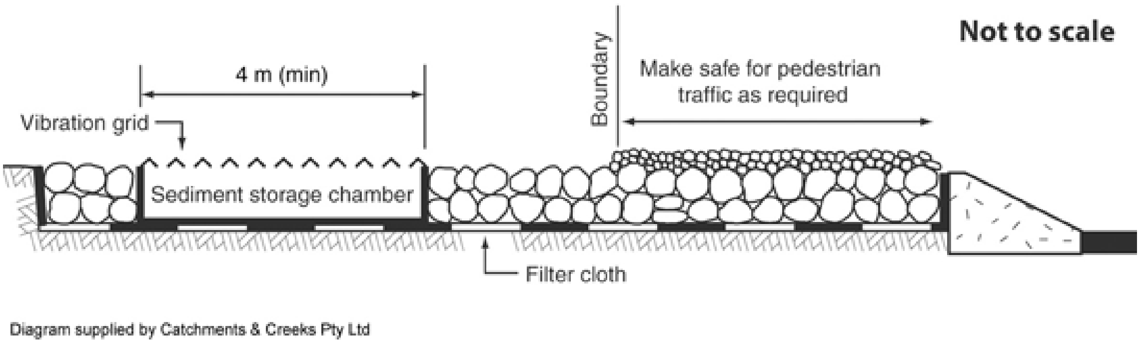
Wash-down areas

- Appropriate safety gear must be worn while washing-down vehicles.

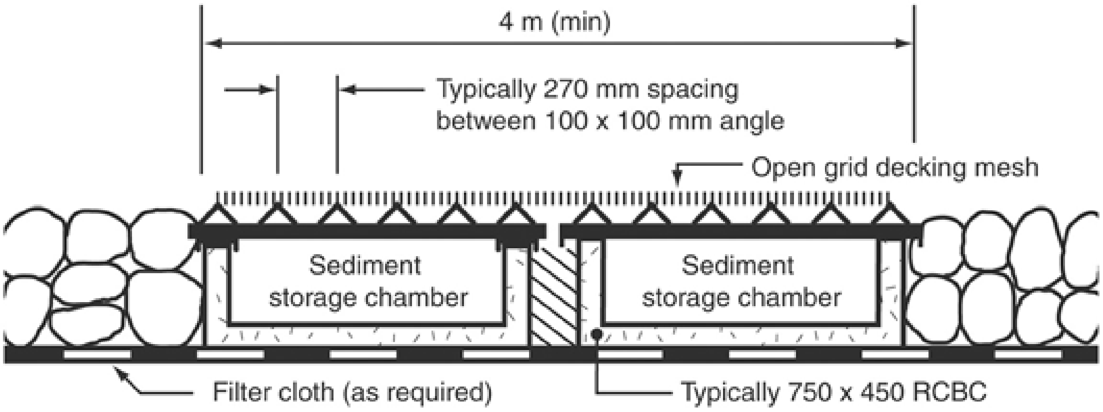
Site entry and exit points – typical layouts



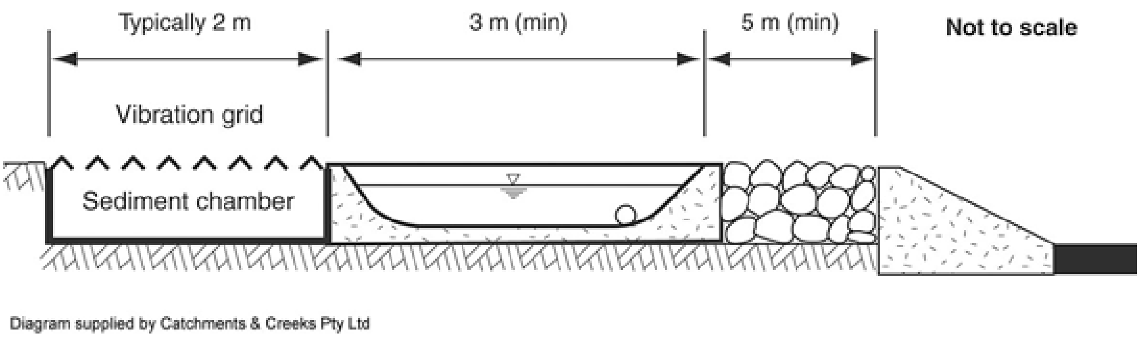
Typical rock pad for construction sites



Typical layout of a 'traditional' vibration grid



Alternative layout of a vibration grid



Typical layout of a low-speed wash bay (high-speed wash bays are longer)

Minimising the extent and duration of disturbance

Land clearing

Land clearing

- The timing of soil disturbances along the road corridor is critical.
- Land clearing should proceed just ahead of construction works so as to minimise the duration of soil exposure to rainfall.
- The extent of active land clearing should be inversely proportional to the expected monthly rainfall.
- Land clearing should not occur unless immediately preceded by the installation of all necessary drainage and sediment control measures.

Land clearing adjacent a waterway

Staging of land clearing

- Land clearing should be staged to minimise the extent and duration of soil exposure.
- Land clearing on steep slopes and waterway banks must be delayed for as long as possible.
- In rural areas, progressive land clearing improves the 'natural' relocation of wildlife.

Land clearing without soil disturbance

Delayed removal of tree roots

- If vegetation clearing must be carried out well in advance of earthworks, then this clearing should be limited to the removal of aboveground woody material only.
- Wherever possible, the grubbing and the removal of any ground cover (mulch or vegetation) should not commence until immediately prior to pipeline trenching.

Full vegetation clearing

Full vegetation clearing and the use of temporary grass seeding

- If land clearing is carried out by a separate contractor, then the options are:
  - clearing of woody matter only as described above, with final grubbing (root removal) carried out in phase with the main earthworks
  - full clearing and grubbing with a temporary grass cover applied to the cleared road reserve (shown left).

Management of cleared vegetation

Brushwood barrier sediment trap

Tub grinder

Mulch berm

Woody debris placed along a fill batter

Stockpiling tree debris

- Cleared vegetation can either be:
  - stockpiled for later use during site revegetation (rural areas)
  - mulched for use as 'clean' water flow diversion banks
  - mulched for use as 'dirty' water flow diversion banks
  - mulched and used as berms to control the velocity of runoff on steep slopes
  - mulched for use as mulch berm sediment traps.

Tub grinding vs chipping

- Vegetation can be mulched using either:
  - mulch chipper
  - tub grinder
- Chipping the vegetation produces a mulch that can be easily spread with a 'blower', but can also be easily washed away by stormwater runoff.
- Tub grinding produces a more hydraulically-stable mulch that can be used to form *Mulch Berms* and this process typically produces less tannins than chipping.

Beneficial use of mulch on site

- Mulch berms can be used to divert either clean run-on water, or site-generated dirty water.
- The mulch should <u>not</u> be totally 'clean', but should contain a small proportion of topsoil (generated from the mulching of tree roots) to help stabilise the mulch.
- If high flow velocities are expected adjacent to the mulch berm, then *Check Dams* can be formed adjacent to the berm to slow these flow velocities.

Use of tree debris on rural fill batters

- In rural areas, tree debris can also be placed on fill batters to:
  - help provide a seed source for native regeneration
  - act as a drainage control system on steep batters to help slow stormwater runoff
  - help stabilise (anchor) an underlying erosion control blankets.
- Placing such woody debris on cut batters could be judged 'unsightly', and could be washed onto the road in severe storms.

Construction access roads

Permanent maintenance access road

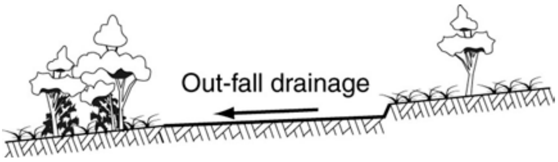
Drainage and erosion controls

- Temporary access roads are often used during road construction to access stockpiles and borrow pits, while also providing bypass roads for the public.
- Appropriate drainage controls will be required on all unsealed roads, even if the road is temporary.
- Gravelling of **long-term** unsealed roadways can significantly reduce the release of fine sediments and turbid runoff from the roadway.

Gravel road with out-fall drainage

Out-fall drainage

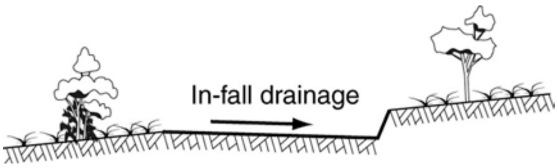
- Out-fall drainage is only used when road runoff can sheet evenly off the road.
- Out-fall drainage can cause erosion problems if:
  - the outer embankment is unstable, or
  - an earth windrow is likely to form along the outer edge of the roadway.



Dirt road with in-fall drainage

In-fall drainage

- In-fall drainage is generally the preferred road drainage system, especially when:
  - the outer road embankment consists of poor or unstable soils, or
  - an earth windrow is likely to form along the outer edge of the road, e.g. during road grading operations.



Cross bank drainage

Cross drainage structures

- Cross banks can be used to direct stormwater runoff across the road to a stable outlet.
- The typical spacing of cross banks on unsealed roads is:
  - 120 m for road grades less than 2%
  - 60 m for road grades of 2 to 4%
  - 30 m for road grades of 4 to 8%
  - 15 m for road grades greater than 8%
- The occurrence of erosion on the road, or within the table drain, is a likely indicator of insufficient drainage control.

Gravelling

Gravelled depot and storage area

Gravelling

- The term ‘gravel’ has several meanings in engineering; however, in this case the term refers to crushed rock with sizes varying from dust up to the nominated rock size (but less than 75 mm).
- The term ‘aggregate’ refers to crushed rock or river stones of near uniform size.
- A surface layer of gravel or aggregate can be used to control raindrop impact across areas such as the site office, depot, storage areas, temporary car parks, and access roads.

Placement of gravel over geotextile

Geotextile underlay

- Gravel is typically placed directly on the soil surface; however, this can result in the eventual loss of the gravel into the soil profile.
- Gravel can also be placed over a geotextile underlay to increase the durability of the gravelled surface, but the use of underlays is questionable on surfaces that require regular grading.
- Woven fabric underlays (left) can be more durable than non-woven filter cloth.

Gravelled access road

Gravel roads and access track

- The gravelling of active construction access roads and tracks can provide questionable benefits because, under heavy construction traffic, the gravel can quickly integrate into the underlying soil.
- Gravelling normally provides greatest benefits for the stabilisation of long-term maintenance access roads after the construction phase is finished.
- The cost/benefit should be assessed on a site-by-site basis.

Natural surface gravels

Arid and semi-arid areas

- In arid and semi-arid areas, natural surface gravels and sands can be an important aspect of the soil’s natural erosion control.
- These gravels should be stripped and stockpiled separately from the topsoil; and should be returned to the surface of access tracks during site rehabilitation.

Dust suppression measures

Straw mulching of road shoulder

Mulching

- Well-anchored (e.g. crimped or tackified) mulch can be used for dust control on large, open-soil areas.
- Mulching is primarily used in association with temporary grass seeding.
- Mulch can also be used as an alternative to temporary grass seeding during times of water restrictions or severe drought, or as a longer-term ground cover in sparse woodland areas where the natural ground cover consists primarily of natural mulch.

Application of soil binders

Soil binders

- Soil binders are typically used for dust control on unsealed roads and mining operations.
- Selection of the best product depends on the potential environmental impacts, and required trafficability and longevity.
- The application and success of soil binders varies from region to region.
- It is usually best to trial various measures and learn from experience.

Seeding road batter

Temporary seeding

- Temporary grass seeding can be used in association with mulching for medium to long-term dust control.
- At least 70% ground cover (combined plant and mulch) is considered necessary to provide a satisfactory level of erosion control.
- Temporary grass seeding is most commonly used to stabilise road corridors that have been stripped of woody vegetation well ahead of construction works.

Water truck used for dust control

Water trucks

- Water trucks can be used for dust control on unsealed roads and access tracks.
- Dust levels can also be controlled by minimising the movement of site traffic outside designated traffic areas.
- The addition of wetting agents and polymer binders to the water can decrease both the water usage and the required application frequency.

Preparing a site for the expected weather conditions

Approaching storm

Being prepared for storms

- Construction sites need to be appropriately prepared for both likely and unlikely (but possible) weather conditions.
- Only in those regions where extended periods of dry weather can be anticipated with high certainty can erosion and sediment control measures be reduced to a minimum.

Table 2 – Overview of critical ESC measures for various weather conditions

Expected weather conditions	Likely critical aspects of erosion and sediment control
No rainfall or strong winds expected	· If favourable dry-weather conditions are likely to exist with a reasonable degree of certainty, then avoid unnecessary expenditure on excessive ESC measures (seek expert advice); however, always ensure the site is appropriately prepared for possible, unseasonable weather conditions. · It should be noted that effective sediment controls at site entry/exit points are generally always required, even during dry-weather conditions.
Light rainfall	· In general, the lighter the rainfall, the better the desired quality (mg/L & turbidity-NTU) of the water discharged from the site. · Wherever practical, sediment control measures should be designed to maximise the 'filtration' of sediment-laden water during periods of light rainfall, rather than gravity-induced sedimentation. · It should be noted that if a site discharges to a minor watercourse, then the release of sediment-laden water during periods of light rainfall can potentially cause more environmental harm than if the same quantity of sediment were released during periods of moderate to heavy rainfall.
Moderate to heavy rainfall	· It is critical to ensure effective drainage control measures exist on the site to prevent the formation of rill and gully erosion. · It is critical to ensure that sediment traps have an effective flow bypass system to prevent structural failure of the sediment trap. · Wherever practical, sediment control measures should be designed to maximise the gravity-induced 'settlement' of sediment-laden waters during periods of moderate to heavy rainfall. · It is noted that sediment control measures that rely on 'filtration' processes (i.e. filtration through geotextile filter cloth) often experience excessive blockage during heavy storms.
Strong winds	· Ensure erosion control measures are appropriately anchored. · Maintain soil surfaces in a roughened condition to reduce dust generation. · Assess the benefits of chemical-based soil stabilises (i.e. soil binders) instead of just using water trucks.

Preparing a site for an imminent storm

Temporary flow diversion berm

Establish temporary flow diversions

- Form temporary berms up-slope of open newly formed road batters to:
  - direct road runoff to slope drains or batter chutes
  - prevent mulch and seed being washed off batters
  - minimise the risk of bank slumping.
- Temporary flow diversion berms can be formed from sandbags, topsoil, straw bales, geo logs or tub-ground mulch.

Filter cloth anchored with timber stakes

Stabilise all drainage pathways

- If not already stabilised, line any steep or unstable drainage lines, including batter chutes, with well-secured geotextile cloth.
- Ensure that channel linings are anchored in accordance with the soil conditions, e.g. wire staples for stiff clay soils, barbed pins for loose soil, and timber stakes for loose or sandy soils.
- In general, do **not** rely on metal staples for immediate anchorage because 'rusting' will not have occurred in a manner that helps anchor the staple/pin.

Blankets displaced by wind

Secure erosion control blankets

- If strong winds are expected, then additional anchorage may be required on erosion control blankets if the following site conditions exist:
  - erosion control blankets have been anchored with metal staples
  - insufficient rain has occurred to cause the staples/pins to rust
  - the soil is loose to firm, but not hard.
- Additional anchorage can be provided by tree debris, sandbags, rocks or timber stakes.

Sediment fence with spill-through weir

Stabilise spill-through or bypass points

- Some storms can exceed the design conditions of the ESC Plan; however, this does not mean that sediment controls should be allowed to fail.
- Spill-through weirs should be incorporated into sediment traps if such measures are required to prevent structural damage to the sediment trap or undesirable flow bypassing.
- There are many examples of poorly built spill-through weirs, so inspectors should pay special attention to their use.

Maintenance of sediment traps

Sediment fence in need of maintenance

The need for maintenance

- All ESC measures must be maintained in **proper working order** at all times until their function is no longer required.
- To assist in achieving this requirement, technical notes and/or construction specifications attached to the *Erosion and Sediment Control Plan* must specify the maintenance requirements of all sediment traps.

Maintenance of control measures

Proper working order

- The term 'proper working order' means:
  - a condition that achieves the site's required environmental protection, including specified water quality objectives
  - in accordance with the specified operational standard for each ESC measure, and
  - prevents or minimises safety risks.

Poor maintenance practice

Proper disposal of sediment

- All water (clean or dirty), debris and sediment removed from ESC measures must be disposed of in a manner that will not create an erosion or pollution hazard.
- It is **not** sufficient to throw shovelfuls of sediment into the adjacent bushland, or to hose the sediment into a roadside stormwater drain.

Sediment fence not removed after use

Decommissioning control measures

- Upon decommissioning any ESC measures, all materials used to form the control measure must be disposed of in a manner that will not create an erosion or pollution hazard.
- The area upon which the ESC measure was located must be properly stabilised and rehabilitated.
- Sediment fences must not be left in-situ to simply collapse from wear and tear!

Locating Major Sediment Traps

Types of sediment traps

Road construction

Sediment basin

Rock filter dam

Sediment fence

Allocating space for sediment basins

- One of the most effective ways of controlling sediment runoff from construction activities is through the use of sediment basins.
- However, sediment basins can only be built when sufficient space has been provided within the overall construction footprint.
- Ideally, the need for, and location of, sediment basins should be resolved during the planning phase of new roads.

Type 1 sediment traps (sediment basins)

- Type 1 sediment traps, which include most sediment basins, are the most effective type of sediment trap.
- Sediment basins have the capacity to capture both coarse and fine sediments.
- Type 1 sediment traps are also the only means of reducing turbidity levels (i.e. colour) within stormwater runoff.
- There are currently four types of sediment basins, Type A, Type B, Type C and Type D basins (see IECA, Appendix B update).

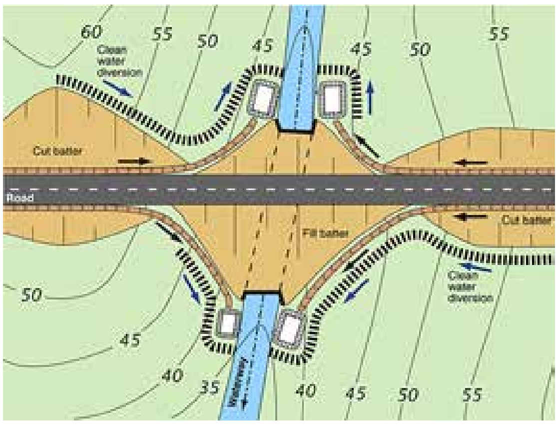
Type 2 sediment traps

- Type 2 sediment traps include:
  - rock filter dams
  - sediment weirs
  - sediment trenches
  - filter tube dams
  - large compost/mulch berms
- Type 2 sediment traps are used within small sub-catchments, and when space is not available for the construction of a sediment basin.

Type 3 sediment traps

- Type 3 sediment traps include:
  - sediment fences
  - sediment sumps
  - small compost/mulch berms
  - check dam sediment traps
  - U-shaped sediment traps
- Type 3 sediment traps are most commonly used along the outer boundaries of the road reserve to treat stormwater runoff that cannot be directed to a Type 1 or Type 2 sediment trap.

Locating major sediment traps



Culvert construction

Locating major sediment traps

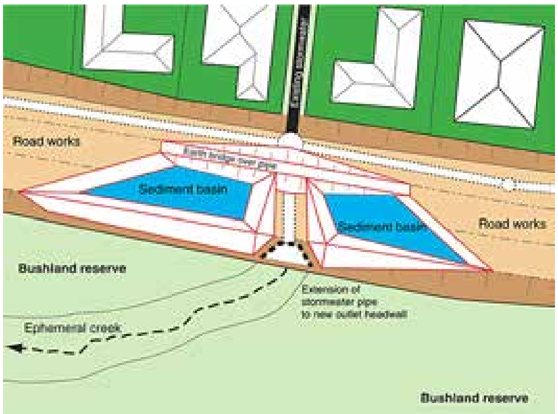
- On road construction projects, major sediment traps are most commonly positioned in the following locations:
  - within those isolated areas of land formed by motorway access ramps
  - each side of the roadway, and each side of a watercourse crossing.
- Further discussion on the use and placement of sediment traps is provided in Part 2 of this two-part field guide.

Bridge construction

Bridge construction

Sediment basins on road construction

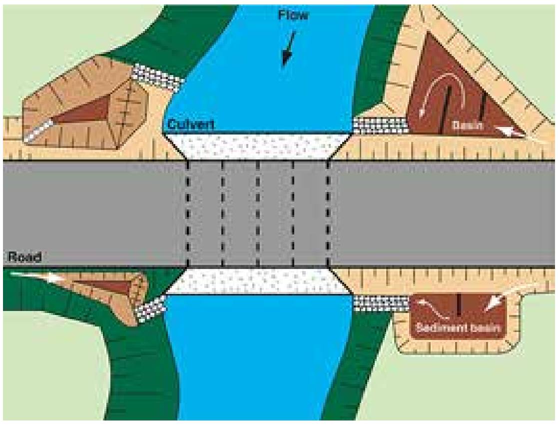
Basin located within a land-locked area



Road works over a pipe extension

Actual site conditions for diagram (left)

Assessing the need for a sediment basin



Culvert construction

Sediment laden runoff

Sediment retained in a basin

Assessing the need for a sediment basin

- The need for a Type 1 sediment trap should be based on the connected catchment area and the assessed erosion risk, which is normally based on:
    - a sub-catchment soil disturbance area exceeding 0.25 ha (see next page) <u>and</u>
    - an assessed (USLE) soil loss rate during the construction phase exceeding 150 t/ha/yr.
- However, space limitations may prevent the use sediment basins in some urban road construction projects.

USLE

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

$$A = R \, . \, K \, . \, LS \, . \, C \, . \, P$$

USLE/RUSLE

The terms used in the USLE equation are:

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

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

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

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

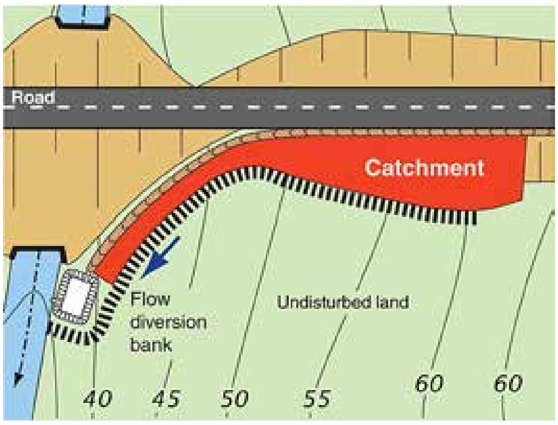
- divided by the soil density (t/m^3).

The erosion hazard is linked to the tonnage of soil loss, rather than the rate (t/ha/yr). Thus, the sediment standard is best linked to <u>both</u> the soil loss rate and area of disturbance, as below.

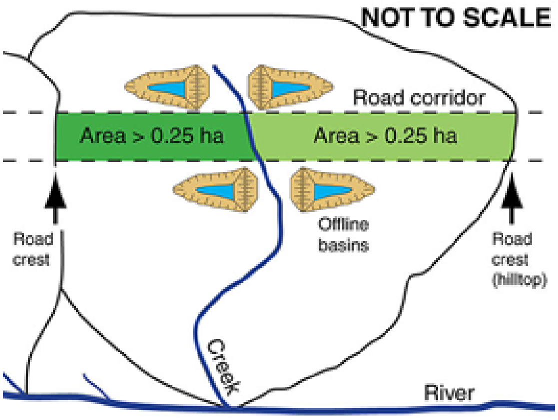
Table 3 – Example sediment control standard (IECA, 2008)

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

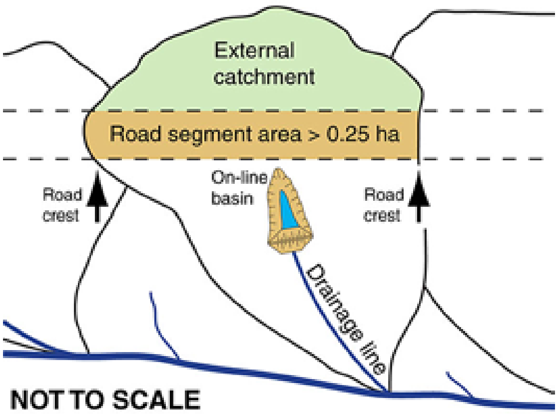
Assessing the need for a sediment basin



Clean water diversion around a basin



Offline sediment basins



On-line sediment basin

Terminology

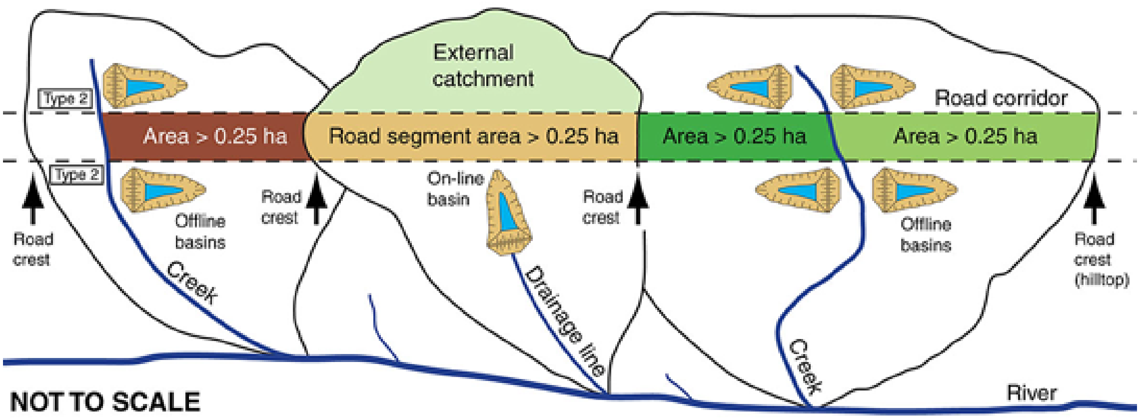
- The full '**catchment**' is the total drainage area up-slope of a given location.
- Catchments can be divided into '**sub-catchments**' through the use of flow diversion banks and catch drains.
- The size of a sediment basin is based on the size of the drainage area that directly feeds into the basin; therefore the size of a basin can be minimised by:
  - diverting 'clean' water around the basin
  - locating basins 'offline', i.e. not on drainage lines or waterways.

Locations where up-slope run-on water can be diverted around the main sediment trap

- If the sediment trap **can** be located offline, (i.e. up-slope 'clean' water is diverted around the sediment trap) then:
  - a sediment basin is usually required if the sub-catchment area (hilltop to valley floor) connected to the sediment trap exceeds 0.25 hectares
  - a Type 2 or Type 3 control is usually sufficient if the sub-catchment area is less than 0.25 hectares.

Locations where up-slope run-on water cannot be diverted around the main sediment trap

- If the main sediment trap **cannot** be located offline (i.e. both up-slope 'clean' water and construction site 'dirty' water runoff flow into the sediment trap) then:
  - a sediment basin (Type 1) is usually required if the road segment area (hilltop to hilltop) exceeds 0.25 hectares
  - however, the sediment basin must be designed to treat the full catchment area, including the external catchment.



Road construction crossing several drainage catchments

Conversion of basins to permanent stormwater treatment ponds

Stormwater treatment pond

Permanent stormwater treatment ponds

- Following completion of the construction phase, sediment basins can either be backfilled and the land rehabilitated, or they can be converted into:
  - permanent road runoff treatment ponds or wetlands
  - pollution containment traps (for the collection of pollution spills resulting from traffic accidents)
  - farm dams (i.e. basins located outside the road reserve).

Stormwater treatment pond (2009)

Same pond (left) in 2017

Type 2 sediment trap (1994)

Same sediment trap (left) in 1997

Post-construction farm dam

Stormwater treatment pond

Diversion of Run-on Water

(Drainage Control)

Drainage control practices

Temporary and permanent road drainage

Catch drain and table drain

Geo log flow diversion

Temporary batter chute

Temporary drainage control measures

- During the construction phase there are two forms of drainage, *temporary drainage*, which is active only during the construction phase, and *permanent drainage*, which is operational during the life of the road.
- This section of the field guide deals with those temporary drainage measures that are used to:
  - direct 'clean' water around traps
  - direct 'dirty' water to sediment traps
  - carry stormwater down road batters.

Use of catch drains

- In road construction, temporary catch drains are typically used in the same locations where permanent drainage channels are likely to be constructed.
- Catch drains are typically used to:
  - collect and divert clean run-on water along the top of cut batters
  - collect and transport dirty water runoff along the base of road batters
  - transport stormwater along future table drains.

Use of flow diversion banks and berms

- The most common means of temporarily diverting stormwater runoff along the edge of a road surface is through the use of flow diversion banks or berms.
- Flow diversion and banks and berms can be formed from:
  - stripped topsoil
  - tub-ground mulch (mulch berms)
  - geo logs
  - sandbags
  - straw bales (short-term use only).

Temporary slope drains and batter chutes

- Temporary batter chutes and slope drains are used to carry stormwater down newly formed road batters while the permanent batter drainage system is being constructed.
- The use of re-useable drainage pipes, also known as 'slope drains', is generally limited to regions of relatively low rainfall intensity.
- In Australia, temporary batter drainage is most commonly achieve through the use of geotextile-lined batter chutes.

Clean water flow diversions

Clean water flow diversion

Definition of 'clean' water

- Clean water is water that either:
  - enters the road reserve from an external source and is unpolluted by site activities, or
  - water that has originated from the work site, but is of such quality that it does not need treatment to meet the project's water quality objectives.
- Wherever practical, clean water should be carried across the road reserve without becoming contaminated.

Flow diversion channel

Diversion channels

- Diversion channels are effectively large 'catch drains' that have been individually sized for a specific catchment area.
- Temporary diversion channels can be formed by pushing the excavated soil down the slope to form an adjoining flow diversion bank.
- Ideally, diversion channels are designed with a channel gradient that avoids the need for an expensive channel lining.

Catch drain

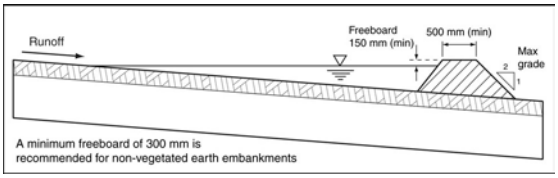
Catch drains

- Catch drains differ from 'diversion channels' in that they are normally a standard size, which means there is a maximum catchment area that can be connected to an individual catch drain.
- Catch drains should only be used if the soils are non-dispersive.
- It is not advisable to cut a drain into a dispersive soil because it can initiate severe rill erosion along the invert of the drain.

Mulch berm

Flow diversion banks

- Flow diversion banks can be formed from stripped topsoil or suitably mulched vegetation (mulch or compost berms).
- The main benefit of using flow diversion banks is that they can be placed on dispersive soils without cutting into the soil.



Use of mulch berms for flow diversion

Mulch berm

Beneficial use of mulch on site

- Mulch berms can be used to divert either clean run-on water or site-generated dirty water.
- Mulch berms are most commonly used when road works cut through existing bushland that can be mulched without contributing to the spread of weed seed.
- Mulch berms can also be used to filter sediment-laden sheet flow.

Tub-grinded mulch

Make-up of hydraulically-stable mulch

- Tub-grinded mulch produces a more hydraulically-stable mulch that can be used to form flow diversion berms.
- The mulch should **not** be totally 'clean', but should contain a small quantity of topsoil (generated from the mulching of tree roots) to help stabilise the mulch against high-velocity flows.

Velocity control check dams

Velocity control adjacent to mulch berms

- If high flow velocities are expected adjacent to a mulch berm, then *Check Dams* can be formed adjacent to the berm to slow these flows.

Flow release points

Outlet structures

- Eventually the collected flow will need to be discharged from the mulch berm.
- 'Clean' water can simply be released from the berm at regular intervals.
- 'Dirty' water should be released only after passing through an appropriate sediment trap.
- Filter cloth can be staked over the mulch berm at selected overflow points.

Use of catch drains

Permanent catch drain

Permanent catch drains

- Permanent catch drains are typically used to collect and divert clean run-on water along the top of cut batters.

Catch drain used to divert run-on water

Clean water diversion drains

- If a permanent catch drain does not exist, then a temporary catch drains can be used to divert 'clean' run-on water away from road works and newly cut batters.

Benched cut batter

Benching tall cut and fill batters

- Catch drains can also be used to collect stormwater runoff from benches cut into tall road batters.
- As a general guide, the benching of road batters is normally required when the batter exceeds a height of 10 metres.

Bench cut into a dispersive soil

Caution the benching of road batters that cut into dispersive soils

- Severe rill erosion can occur along benches that have been cut into dispersive subsoils.
- To avoid such erosion problems, the soil around the drainage line will need to be suitably lined or treated with gypsum.
- Do <u>not</u> attempt to control such erosion with the use of 'check dams', because these structures will simply pool water on these dispersive soils increasing the erosion risk.

Permanent channel linings

Concrete-lined catch drain

Concrete

- Permanent catch drains are most commonly lined with concrete if the drains are likely to transport high-velocity flows.

Pre-grown reinforced grass

Turf and reinforced grass

- Turf can be used for the lining of low-velocity batter chutes, catch drains and diversion channels.
- Pre-grown reinforced grass can be used for the lining of high-velocity permanent catch drains and batter chutes.
- Particular attention (i.e. placement and anchorage) must be given to the crest, toe and sides of the grass to avoid the potential for erosion along the edges of the turf.

Rock-lined catch drain

Rock lining

- Rock can be used for the lining of high-velocity permanent drains, batter chutes and sediment basin spillways.
- An underlying geotextile filter is generally required unless all voids are filled with soil and pocket planted—the latter option is preferred when near waterways.
- It should be noted that rounded river rock can be significantly less stable than angular (fractured) quarry rock, especially when placed on steep slopes.

Mattress-lined sediment basin spillway

Rock mattresses

- Rock-filled mattresses can be used to line batter chutes and sediment basin spillways (expensive option).
- In most cases, permanent rock mattress-lined batter chutes should be vegetated (grassed) unless located in arid or semi-arid areas.
- The wire mattress should be laid with the diaphragm (internal dividing wall) at right-angles to the dominant direction of flow.

Temporary Road and Batter Drainage

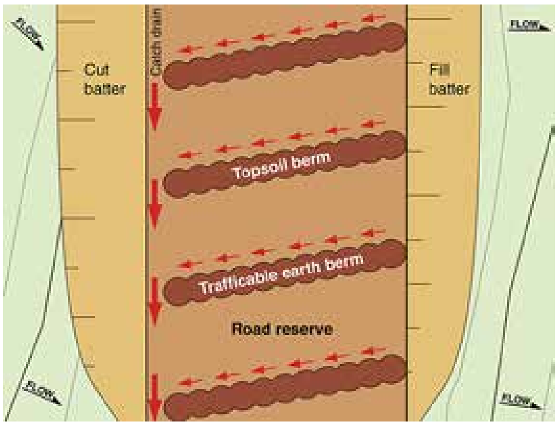
(Drainage Control)

Temporary road and batter drainage

Saturated roadway

The need for drainage control

- Heavy rainfall can cause lengthy construction delays on road projects.
- Soils can become boggy and sediment runoff can increase significantly.



Trafficable flow control berms

Separation of construction traffic and drainage paths

- A key to managing wet weather problems is to separate water movement from traffic movement.
- If possible, trafficable flow control berms (cross banks) should be used to restrict stormwater runoff to the sides of the roadway, with construction traffic utilising just the centre of the carriageway.
- This also means sediment control devices only need to located along the edges of roadways.

Storm damage to pavement road base

Controlling storm damage to pavement foundations

- Most urban roads are designed as overland flow paths, which means the surrounding land is contoured to direct stormwater runoff towards the roadway.
- This concentration of stormwater runoff can lead to severe erosion of the road base.
- Various drainage control measures can be implemented to minimise such storm damage.

Rill erosion on newly formed fill batter

Preventing uncontrolled discharges down unstable fill batters

- Newly formed road batters are vulnerable to sheet erosion and rilling during the revegetation phase.
- Temporary drainage controls need to be employed to prevent uncontrolled storm flows passing down road batters.
- Temporary 'batter chutes' and 'slope drains' can be used to carry stormwater runoff down newly formed road batters.

Controlling storm damage to pavement foundations

Storm damage to pavement road base

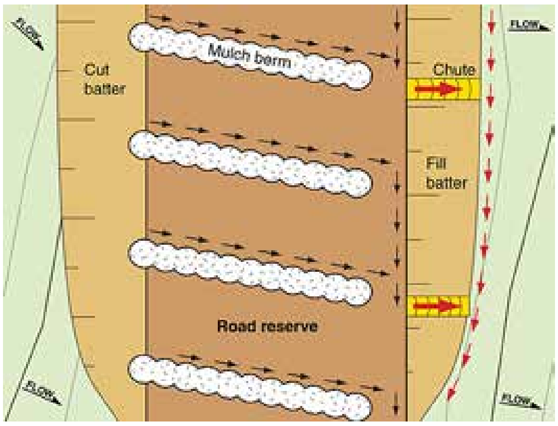
Controlling storm damage to road foundations

- It is usually impractical to direct all stormwater runoff away from urban roadways.
- It is also impractical in most cases to schedule road works to only occur during the dry weather months of a year.
- Fibre rolls (below) can be used to control the velocity of stormwater runoff, and thus reduce storm damage to pavement foundations.

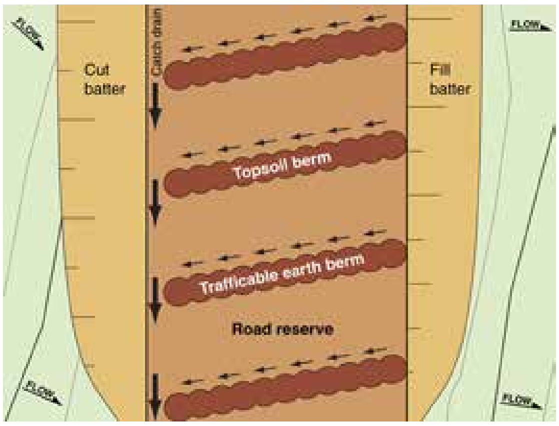
Fibre rolls

Separation of drainage flow and construction traffic

- Trafficable berms (below) can be used to move stormwater runoff to one side of the roadway, thus allowing construction traffic to move along road surfaces that are more stable and less damaged by erosion.
- Berms should be spaced with a maximum horizontal spacing or 80 m and vertical fall of 2 m between each berm.
- Sandbag berms can be used to direct road runoff away from newly formed kerb and channel.



Mulch berms



Trafficable earth berms

Storm damage to road works

Storm damage to road works

Controlling runoff on elevated road embankments

Filter sock flow diversion berm

Filter sock flow diversion berms

- Sand-filled geotextile socks can be used to divert stormwater away from unstable road batters, and to direct such water to temporary batter chutes.

Sandbags used to divert road runoff

Sandbag flow diversion berms

- Sandbags can also be used to divert road runoff away from steep batter slopes.
- The photo presented (left) shows sandbags being used to divert road runoff away from a section of steep batter adjacent a newly constructed waterway culvert.

Topsoil flow diversion bank

Earth and topsoil flow diversion banks

- Stripped topsoil can be used to form flow diversion banks (perimeter banks) along the edge of road embankments that direct stormwater runoff to temporary slope drains.
- The difficulty of using earth berms comes from the 'width' of these berms, which can require the initial over-filling of road batters in order to provide sufficient space for the placement of the berms while road works continue.

Mulch berm

Mulch and compost berms

- Mulch berms can be used to divert either clean run-on water, or site-generated dirty water.
- However, on road construction projects, mulch berms are most commonly used for managing road runoff.
- In rural projects, mulch berms can also be used as sediment filters, but only when sufficient space is available along the edge of the road reserve.

Use of temporary slope drains

Slope drains

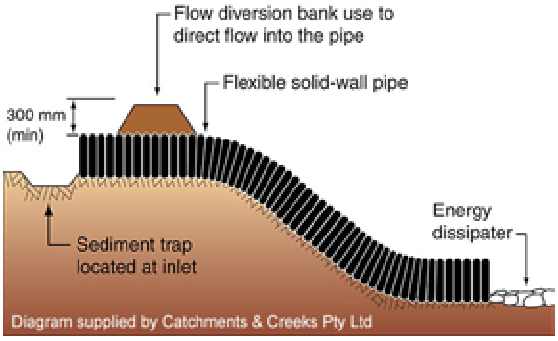
Flexible, reusable, solid-wall slope drains

- Slope drains are most commonly used in locations where stormwater runoff discharge is expected to be low (i.e. not exceed the inlet capacity of the pipe).
- Slope drains can also be uses to direct concentrated flows through bushland with minimal disturbance occurring to the bushland.

Flow control berm at pipe inlet

Flow control at pipe entry

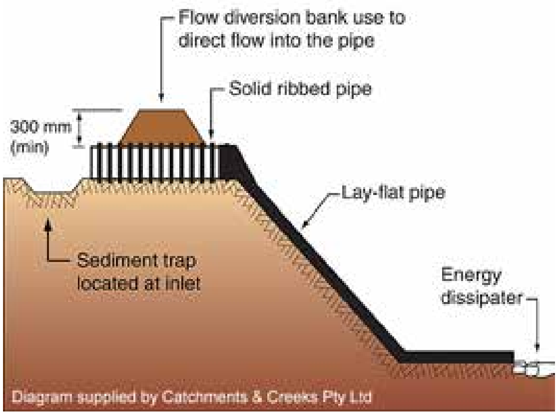
- A flow diversion bank is required at the inlet of the slope drain to direct water into the pipe.



Flexible, solid-wall slope drain

Sediment traps and energy dissipation

- Sediment traps can be incorporated into the inlet and/or outlet of these pipes.
- ALL slope drains require:
  - suitable *Flow Diversion Banks* at the pipe inlet to control flow entry
  - a means of preventing sediment blockage of the pipe's inlet
  - a stable outlet (*Outlet Structure*) at the end of the slope drain to control erosion.



Lay-flat pipe slope drain

Flay-flat pipes

- Lay-flat pipes can be uses as an alternative to solid-wall PVC pipes.

Use of temporary batter chutes

Filter cloth lined batter chute

Filter cloth linings

- Geotextile cloth can be used to provide temporary scour protection in temporary, low to medium velocity diversion drains.
- Heavy-duty filter cloth can also be used to form temporary batter chutes.
- Filter cloth should **not** be used as a channel lining if the surface soils are dispersive—this is because severe rilling or tunnel erosion can occur under the fabric.

Temporary plastic sheet batter chute

Impervious plastic sheeting

- Impervious sheeting can be used to form short, temporary drainage chutes down earth batters, but they must be used with caution—water flow must be prevented from passing under the plastic.
- Plastic sheeting can be use on dispersive soils, but with extreme care.

Temporary half-pipe batter chute

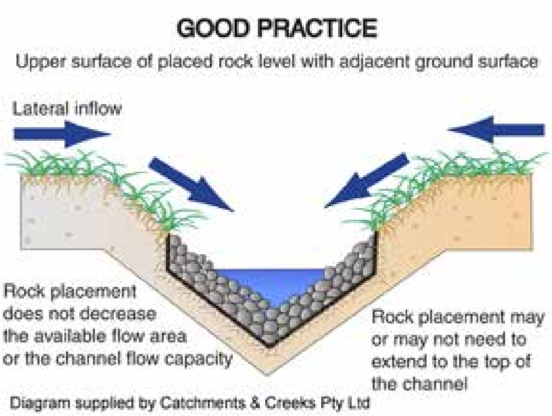
Half-pipe slope drains

- Solid half-pipes can be used on unstable or dispersive soils.
- ALL chutes require:
  - berms to direct flow into the chute
  - a good water seal at the chute's inlet (note images below)
  - a well-defined cross-section to fully contain the flow down the chute
  - a stable outlet and energy dissipation system at the base of the chute.

Corrugated iron batter chute

Concrete water seal at chute inlet

Placement of rock within drainage channels



Rock recessed into channel earth

Placement of rock

- In general, the rocks should be recessed into the ground rather than just sitting on the natural ground surface.
- It is important to ensure that the top of the rock surface is level with, or slightly below, the adjacent land surface to allow the free entry of water (including lateral inflows if required).

Filter cloth

Placement of rock over filter cloth

- Filter cloth is typically placed under the rocks in the following structures:
  - batter chutes
  - drainage channels
  - non-vegetated bank stabilisation
  - energy dissipaters & outlet structures.
- The filter cloth must have sufficient strength (minimum ‘bidim A24’ or equivalent) and must be suitably overlapped to withstand potential lateral movement during the placement of the rocks.

Vegetated rock-lined batter chute

Vegetating rock-lined drains and chutes

- Vegetating rock-lined drains and chutes can significantly increase the stability of the rocks; however, it can also reduce the drain’s hydraulic capacity.
- Issues to be considered include:
  - impact on the channel’s flow capacity
  - practicality of controlling weed growth and conducting mowing (if required)
  - the likelihood of fully-established plants forcing flows to spill out of the drain.

Rock-lined drainage channel

Use of rounded river stone

- The aesthetics of non-vegetated drainage channels can be improved through the use of rounded river stone.
- However, minimal aesthetic value is achieved if the rocks will eventually be covered by weeds and grasses.
- As previously discussed, it is noted that rounded rock can be significantly less stable (reduced by 30%) than angular (fractured) rock, especially when placed on steep slopes.

Common rock-lined batter chute construction problems

Newly established rock chute

Flow spills around rocks

- A rock-lined drainage chute should **not** be formed by simply filling an eroded gully with rocks such that the upper surface of the rocks sits above the adjacent ground level.
- In this case (left) soil erosion would be expected along each side of the recently placed rocks.
- Also, weeds will likely grow among the rocks, and these weeds will be difficult to manage.

Rocks sitting above the soil profile

Flow spills around rocks

- In the example shown left, the rocks have not been recessed into the bank, but instead sit above the adjacent land surface.
- Inflows are likely to move to the edge of the rocks causing rilling down the side of the batter chute.

Rocks slipping down batter chute

Rocks slip down smooth filter cloth

- These rocks have been placed as a single layer, on a steep slope, over filter cloth.
- The filter cloth effectively acts as a low-friction 'slide' and the rocks are now slowly slipping down the slope.
- If rocks need to be placed on steep slopes, then the rocks should be 'keyed' into the bank/soil.
- Keying can be done by 'stair-stepping' the bank prior to placing the filter cloth.

Batter chute placed on a dispersive soil

Rock placed on dispersive or slaking soils

- Rocks should **not** be placed directly onto an untreated dispersive, sodic or slaking soil.
- If the subsoils are dispersive or slaking, then the batter chute should be over-excavated, then topped with a minimum 200 mm layer of non-dispersive (or treated) soil, then covered with filter cloth prior to placement of the amour rock.

Temporary stabilisation of table drains

Sandbag check dams

Jute erosion control mat

Temporary erosion control mat

Jute mesh channel lining

Use of velocity control check dams

- Check dams are most effective when used in channels with a gradient less than 10% (1 in 10), i.e. <u>not</u> batter chutes.
- There are basically three types of check dams: sandbags, rock, and jute/coir logs.
- Sandbags are generally used in shallow drains less than 500 mm deep.
- Rock check dams should only be used in deep drains (i.e. > 500 mm deep).
- Jute & coir logs should only be used in drains where flows will overtop (not pass around) the logs.

Use of erosion control mats

There are basically four types of erosion control mats, including:

- Temporary, non-woven filter cloth.
- Temporary biodegradable mats—usually made from plant-based products such as jute (hemp) or coir (coconut fibre).
- Temporary (light-sensitive) synthetic reinforced mats.
- Permanent, UV-stabilised, turf reinforcement mats (TRMs).

Synthetic erosion control mats

- Some temporary erosion control mats contain an organic mulch reinforced with a synthetic mesh that will eventually breakdown under sunlight.
- They can be used to provide temporary scour protection in low to medium velocity drains.
- Caution should be taken when using any synthetic reinforced mats in bushland areas as ground dwelling animals, such as lizards, snakes, and seed-eating birds, can become tangled in the netting.

Jute and coir mesh

- Jute/coir mesh is a form of *erosion control mat* used to provide temporary scour control in low to medium velocity drains.
- These products are generally preferred in bushland and waterway areas.
- Overall erosion control and channel revegetation can be improved by:
  - pinning the mesh over a layer of mulch
  - spraying the mesh with a light coating of an anionic bitumen emulsion or a soil binder.

Anchorage systems for erosion control mats

Timber stakes

Timber pegs and stakes

- Short timber pegs can be used in a wide variety of soils.
- Typically used to anchor turf placed in areas likely to experience high-velocity flows soon after turf placement (instead of using metal staples).
- Stakes can be used to anchor erosion control blankets, especially if storms or strong winds are imminent.
- Caution; if used along drainage lines, flood debris can wrap around stakes.

Metal staples

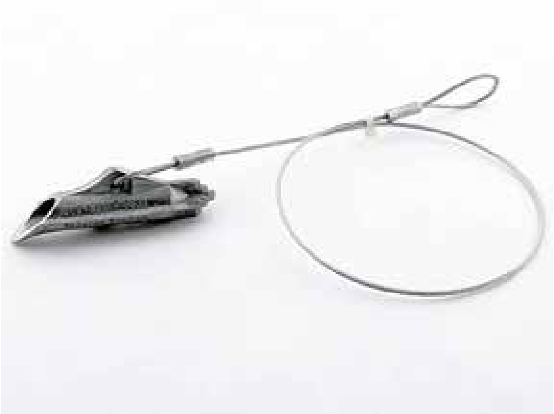
Metal pins or staples

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

Barbed plastic pins

Barbed plastic pins

- Barbed plastic pins are best used in soft to firm clayey soils.
- Only limited anchorage may be achieved in very sandy soils.
- They can be difficult to use if the soil is heavily compacted (i.e. undisturbed soil).
- Care must be taken when they are used to anchor an erosion control 'mesh' to ensure the pin adequately captures or twists around the mesh.



Duck-billed soil anchor

Duck-billed soil anchor

- Duck-billed soils anchors are best used in soft sandy or silty soils, or any soil that has insufficient strength to hold other types of anchors.
- These anchors can be used to anchor logs and fallen trees, which in-turn can be used to anchor erosion control mats on the banks of **some** waterways.

Controlling flow velocity in table drains

Fibre rolls

Fibre rolls

- Fibre rolls consist of small-diameter (150–200 mm)biodegradable straw-filled logs.
- They can be used as check dams in wide, shallow drains so long as the logs can be anchored to prevent movement.
- Best used in locations where it is desirable to allow the fibre rolls to integrate into the permanent vegetation, such as in vegetated channels; however, some products contain a plastic mesh that may represent a wildlife/environmental risk.

Geo-log check dam

Geo-log check dams

- Geo logs have a larger diameter (approx 300 mm) compared to fibre rolls.
- Geo logs made from coir (coconut fibres) can be very durable and last for a year or more (depending on the frequency of wetting and drying).
- It is very important to ensure that:
  - flows do not undermine the logs, and
  - flows spill **over** the logs, **not** around the ends of the logs.

Sandbag check dam

Sandbag check dams

- Sandbag check dams are typically used in drains less than 500 mm deep, with a gradient less than 10% (1 in 10).
- These check dams are small (in height) and therefore are less likely to divert water out of the drain in comparison to rock check dams.
- The biodegradable sandbags are usually left in-place and allowed to integrate into the final drain vegetation.

Rock check dam

Rock check dams

- Rock check dams should **only** be used in drains at least 500 mm deep, with a gradient less than 10%.
- Also, they should only be used in locations where it is known that they will be removed once a suitable grass cover has been established within the drain.
- It is important to ensure that flows spill **over** the crest and do not flow around the rocks—this means the crest of the check dam needs to be curved, not flat.

Common problems associated with the use of check dams

Rock check dam placed on dispersive soil

Check dams placed on dispersive soil

- Dispersive soils become unstable if water is allowed to pool on the soil.
- Therefore, check dams should **not** be used to control flow velocity if the exposed soils are dispersive.

Check dams placed on a batter chute

Check dams placed on steep slopes

- Velocity control check dams provide questionable benefit when placed on steep slopes.

Flows forced to pass around check dams

Check dams staked in a manner that allows flow bypassing

- Check dams must be installed in a manner that allows water to pool up-slope of the check dam and then spill **over**, not around, the check dams.

Geo log not adequately staked

Failure to adequately anchor geo logs

- Common problems experienced with geo-log check dams is the failure to:
  - adequately anchor the logs onto the soil, or
  - prevent water passing under the logs.

Treating Dirty Water Runoff

(Sediment Control)

Types of sediment traps

Sediment basin (Type 1)

Rock filter dam (Type 2)

Sediment fence (Type 3)

Kerb inlet protection (supplementary)

Type 1 sediment traps

- This field guide classifies sediment traps as: Type 1, Type 2, Type 3, and supplementary systems.
- Type 1 sediment traps are designed to collect a wide range of sediment particles down to less than 0.045 mm.
- In general terms these sediment traps target particle sizes from clays to sands.
- Type 1 sediment traps include *Sediment Basins* and some of the advanced filtration systems used in de-watering operations.

Type 2 sediment traps

- Type 2 sediment traps are designed to capture sediments down to a particle size of between 0.045 and 0.14 mm.
- In general terms these sediment traps target particle sizes from sands down to coarse silts.
- Type 2 sediment traps generally do **not** reduce turbidity levels (i.e. water colour).
- Type 2 sediment traps include *Mulch Berms, Rock Filter Dams, Sediment Weirs* and *Filter Ponds.*

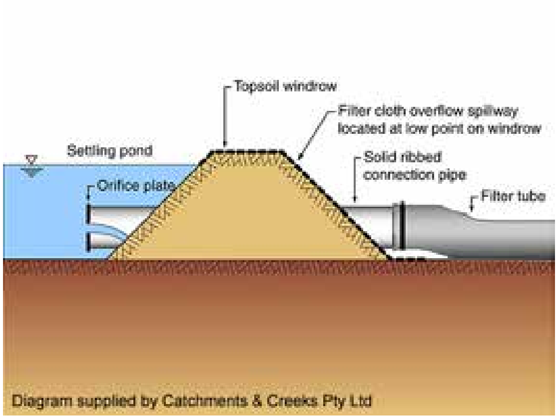
Type 3 sediment traps

- Type 3 sediment traps are primarily designed to trap coarse-grained particles larger than 0.14 mm.
- These systems include *Sediment Fences, Buffer Zones* and some stormwater inlet protection systems.
- There is no doubt that these traps can capture small quantities of fine sediments; however, there should be **no** expectation of a change in water colour (turbidity) as flows pass through the sediment trap.

Supplementary sediment traps

- Some sediment traps, such as *Grass Filter Strips* and most kerb inlet sediment traps, have such limited treatment efficiency, or are so easily damaged, that they can only be used to *supplement* a type 1, 2 or 3 sediment trap.
- Even though these sediment traps have a relatively low efficiency, their use on small domestic road construction projects is still considered to be a component of best practice sediment control.

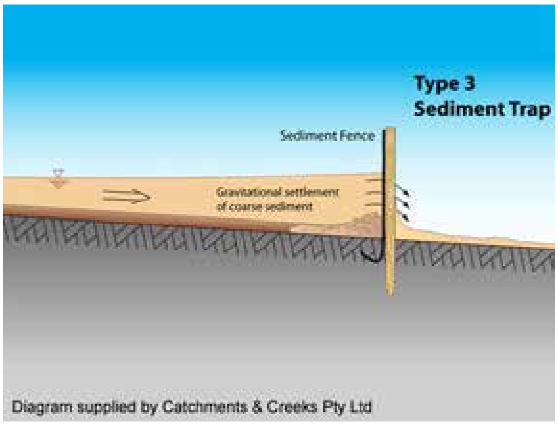
Types of sediment traps



Windrow sediment trap with filter tube

Mechanics of sediment traps

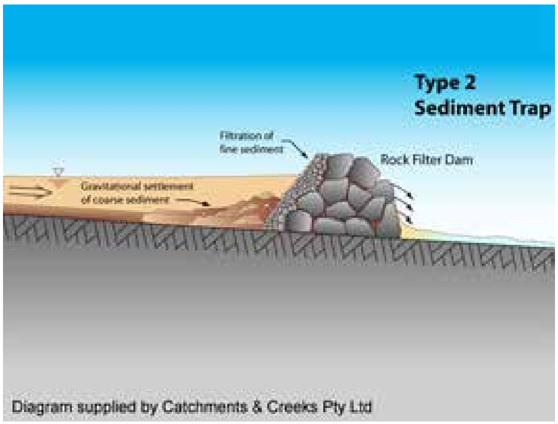
- The mechanics of sediment trapping can generally be categorised into the following groups:
  - ponding traps that utilise gravity-induced particle settlement
  - ponding traps that utilise a filtration system for the treatment of low-flows
  - extended detention settling basins
  - geotextile filters
  - sand and aggregate filters
  - compost filters.



Type 3 treatment system

Type 3 sediment traps

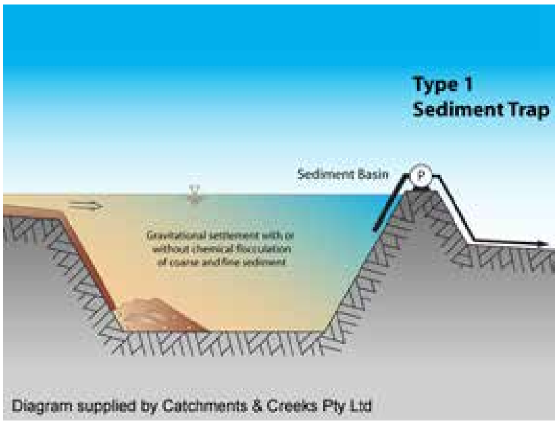
- Most Type 3 sediment traps are designed to slow the passage of water to such a degree that pooling occurs up-slope of the trap.
- It is this pooling of water that allows gravity-induced settlement of the coarser grained particles (i.e. sands).
- A sediment fence is **not** a 'filter'.
- A sediment fence is just a porous dam that encourages sediment-laden water to pool up-slope of the fence.



Type 2 treatment system

Type 2 sediment traps

- The key components of a Type 2 sediment trap are a 'settling pond' followed by a 'coarse-particle filter'.
- Just like a sediment fence, a Type 2 sediment trap is designed to encourage the pooling of water up-slope of the trap.
- Gravity-induced settlement is then supplemented by either a geotextile, aggregate or compost sediment filter.
- A compost filter is simply a compost berm through which water can percolate.



Type 1 treatment system

Type 1 sediment traps

- Type 1 sediment traps utilise either:
  - extended detention to encourage the settlement of clay-sized particles; or
  - super-fine, high-pressure filters.
- Sediment basins operate as either:
  - continuous-flow systems; or
  - plug-flow system.
- High-pressure filters are normally only used during specialist de-watering operations in urban areas (not common in road construction).

Critical features of sediment traps

Rock filter dam with aggregate filter

Roadside sediment basin

Sediment fence fails to capture sediment

Stormwater traps placed on site access

Critical features of a sediment trap

- Most sediment traps incorporate the following features:
  - the ability to pool water
  - adequate retention time to allow the settlement of suspended particles
  - the capacity to collect and retain a specific volume of settled sediment
  - adequate hydraulic capacity prior to the commencement of flow bypassing
  - limits on the maximum depth of pooling in areas where public safety is a concern.

Critical features of the settling pond

- The presence of a settling pond means the focus is on gravity-induced settlement.
- In a continuous-flow system, the critical design parameter is the **surface area** of the pond (as in the design of a Type-A, B & C sediment basin).
- In a plug-flow system, the critical design parameter is the **volume** of the settling pond (as in the design of a Type D sediment basin).
- Surface area and volume are critical for Type A basins.

Ability to capture and hold sediment

- A sediment trap should not just divert sediment-laden water from one location to another.
- When constructing a sediment trap, ask yourself:
  - Will the device cause a safety problem?
  - Where is the water going to flow?
  - Where is the sediment going to settle?
  - How will the trapped sediment be collected and removed?

Caution regarding the placement of sediment trap on steep slopes

- On steep slopes, say steeper than 10% (1 in 10), the focus should firstly be on controlling soil erosion, and secondly on controlling the flow of water down the slope.
- Wherever practical, the trapping of sediment should occur at the base of the slope, or at a location well away from the slope where it is safe and convenient to temporarily pond water.

Types of sediment filters

Sand-filled filter sock

Types of filters

- Many sediment traps incorporate some type of filtration system.
- The filter media may consist of straw, sand, aggregate, geotextile or compost.
- Straw-based filters are very inefficient and their primary purpose is usually to encourage the pooling of water rather than the filtration of sediments.
- Most sand-based filters are also very inefficient due to their low through-flow discharge.

Rock filter dam with aggregate filter

Aggregate filters

- The most important thing to know about aggregate filters is that they rely on the effects of partial sediment blockage to activate (start) the filtration process.
- A filter formed from clean aggregate does not provide much 'filtration'; at best it simply helps to slow water flow to encourage up-slope ponding.
- Aggregate filters are best used in sandy or silty soils (i.e. soils with a clay content less than, say 20%).

Filter tube attached to an embankment

Geotextile filters

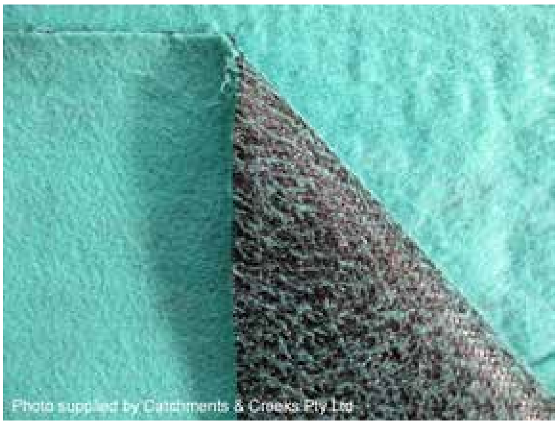
- Geotextile filters are made from non-woven fabrics (woven fabrics should **not** be used).
- Most geotextile filters initially have a high flow rate, but sediment blockage can eventually reduce this to zero.
- The use of geotextile filters is preferred if the capture of fine-grained sediments is required.
- Geotextile filters rarely reduce turbidity levels, thus the water remains 'brown'.

Compost-filled filter sock

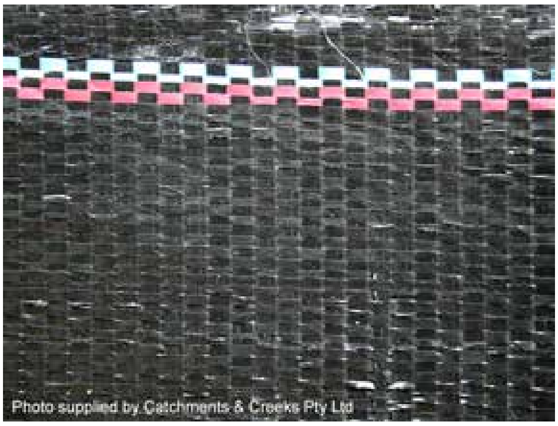
Compost filters

- Compost filters use both *filtration* and *adsorption* processes to clean the through-flow.
- Thus compost filters can adsorb minor amounts of dissolved and fine particulate matter such as metals.
- These filters are considered to perform better than most sand, aggregate or geotextile filters, provided the filter remains undamaged and outflows are not allowed to bypass the filter.

Use of geotextiles in sediment control



Composite sediment fence fabric



Woven sediment fence fabric

Non-woven filter cloth

Filter sock

Use of geotextiles in sediment control

- Geotextiles can be used for a number of purposes, including:
  - slowing water flow to encourage pooling and sedimentation
  - the filtration of flows
  - geotechnical engineering.
- Composite fabrics are sometimes used when it is desirable to perform more than one of the above tasks.
- Composite ESC fabrics are not always commercially available.

Woven fabrics

- The primary purpose of a woven fabric is to **slow** the passage of water—these fabrics are **not** used for filtration.
- In most cases, the fabric is made from thin strips of impervious material; thus water can only weep through the small gaps where the fabric strips overlap.
- These fabrics are normally carbon stabilised (often producing the black colour) to reduce UV damage and to extent their working life.

Non-woven fabrics

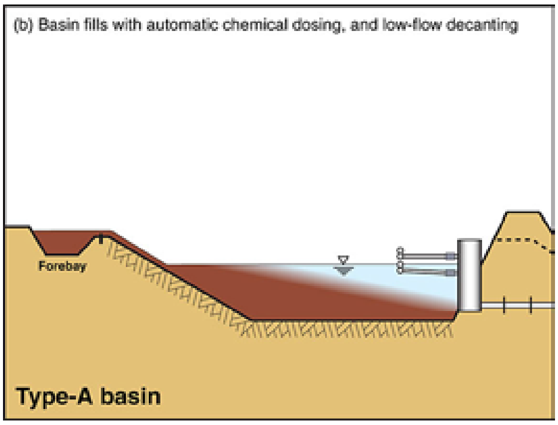
- Non-woven fabrics are primarily used for filtration and geotechnical engineering.
- Most non-woven fabrics are not UV stabilised, thus they have a limited working life if exposed to direct sunlight.
- *Filter cloth* is the most common non-woven fabric found on construction sites.
- In Australia, filter cloth is commonly graded using the 'bidim' grading of A12 (thin) to A64 (thickest).

Hessian fabric

- Hessian fabrics fall outside the normal rules because they are woven fabrics, but unlike most woven fabrics, they encourage filtration.
- Hessian fabrics can be used to form erosion control blankets as well as hessian sandbags.
- Hessian sandbags can be filled with sand or aggregate to form a filter berm.

Sediment Control Techniques
Type 1 controls

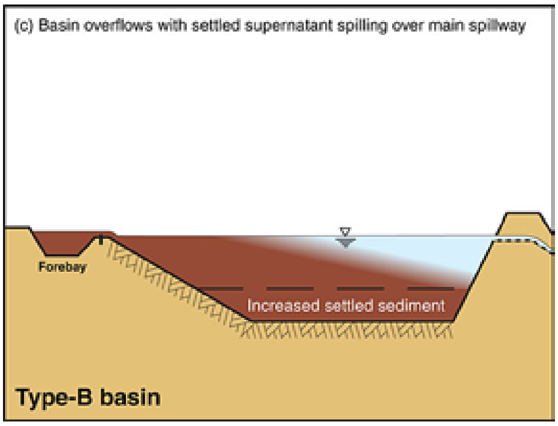
Sediment basins (Type 1)



Low-flow decanting of a Type A basin

Type A sediment basins

- A Type 1 sediment trap.
- Used on drainage catchments greater than 2500 m^2.
- It is recommended that individual basins are limited to catchment areas less than 5 hectares.
- Used when the duration of the soil disturbance, within a given drainage catchment, exceeds 12 months.



Overflow of a Type B basin

Type B sediment basins

- A Type 1 sediment trap.
- Used on drainage catchments greater than 2500 m^2.
- Maximum recommended catchment area is 5 hectares.
- Used when the duration of the soil disturbance within a given drainage catchment does not exceed 12 months.
- Water can be retained in these basins for use on-site for revegetation watering and dust control.

Type C sediment basin

Type C sediment basins

- Type C basins are used to treat the runoff from coarse-grained soils.
- These basins are free draining, which does not normally allow sufficient time for chemical flocculation, thus the sediment must have good settling properties.
- These are typically the smallest basins because of the fast settling properties of coarse-grained soils.
- Internal baffles may be needed to help control water flow through the basin.

Type D sediment basin

Use of Type D sediment basins

- Type D (dispersive soils) basins are best suited to fine-grained and/or dispersive soils.
- These basins retain inflows without free-draining, which allows time for flocculation and particle settlement.
- These basins can be up to twice the size of Type C basins, but are significantly more effective at controlling turbidity.
- The development of Type A basins has effectively depleted the need and use of Type D basins.

Sediment basins

US example of a major Type 2 sediment trap with rock filter dam outlet system (1995)

Type C sediment basin with riser pipe outlet (1995)

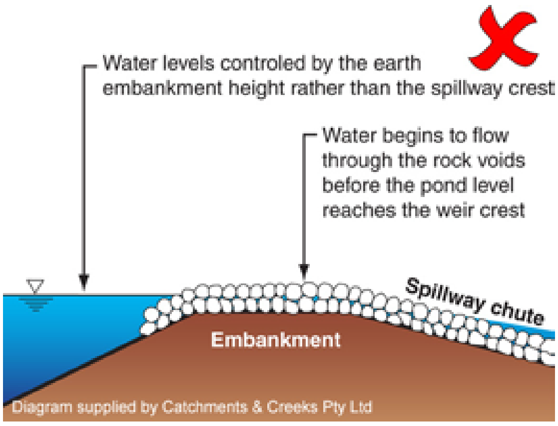
Type C sediment basins with siphon pipe decant system (2017)

Type D sediment basin which is retained for permanent stormwater treatment (1999)

Sediment basin spillways

Spillway with well-defined weir profile

Spillway formed within virgin soil



Flows can pass through the rock voids

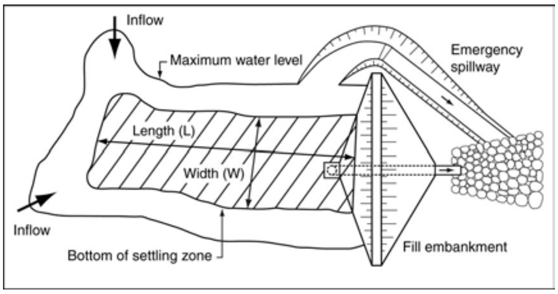
Inappropriate spillway crest profile

Function of a basin spillway

- All sediment basins that are not fully recessed below natural ground level will require the construction of a formally designed spillway.
- The spillway must have a well-defined weir profile (cross-section) that fully contains the nominated peak discharge.
- A suitable energy dissipater will be required at the base of the spillway.
- Spillways are critical engineering structures that need to be designed by suitably qualified engineers.

Preferred location of spillways

- Ideally, the emergency spillway should be constructed in virgin soil (i.e. adjacent to the fill embankment).



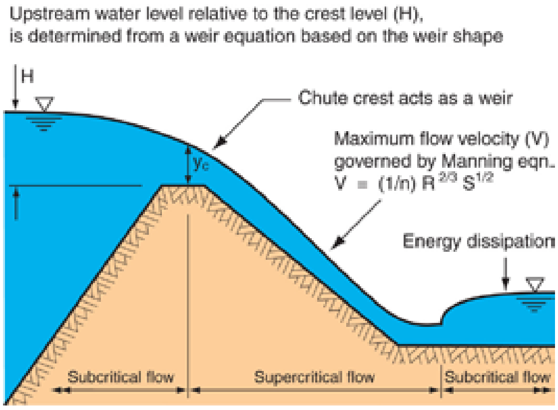
Controlling leakage at spillway crest

- For rock and rock mattress lined spillways, it is important to control seepage flows through those rocks located near the crest of the spillway.
- Seepage control is required so that the settling pond can achieve its required maximum water level prior to flows discharging over the spillway.
- Concrete capping of the spillway crest may be required in order to prevent these seepage flows.

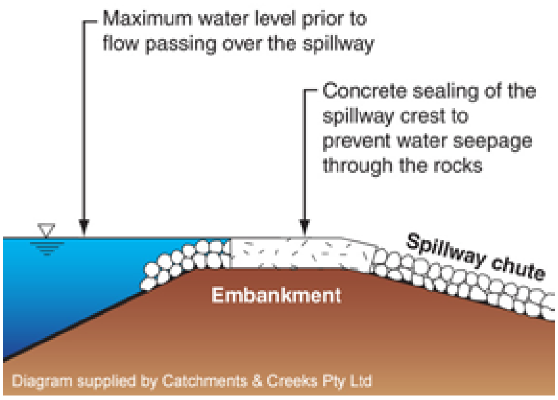
Preferred crest profile

- It is important to ensure that the spillway crest has sufficient depth and width to fully contain the nominated design storm discharge.
- The spillway crest normally requires a greater depth, but equal width, to that of the downstream spillway chute.
- Photo (left) shows a spillway crest that has inadequate depth or flow profile, in fact the rock-lined crest sits ‘above’ the adjacent earth embankment crest!

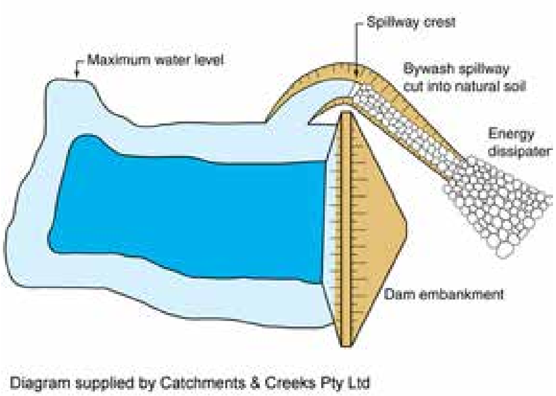
Sediment basin spillways



Dam spillway hydraulics



Sealing of spillway crest



Dam spillway cut into virgin soil

Energy dissipation pond

Hydraulic design

- Basin spillways are hydraulic structures that need to be designed for a specified design storm.
- The hydraulic design of spillways can be broken down into three components:
  - design of the spillway inlet using an appropriate weir equation
  - sizing rock for the face of the chute based on Manning's equation velocity
  - sizing rock for the energy dissipater.

Design of spillway crest

- Flow conditions at the spillway crest may be determined using an appropriate weir equation.
- It is important to ensure that the required maximum potential water level within the basin can be fully contained by the basin's embankments.
- The sealing of the spillway crest is often necessary to maximise basin storage and prevent leakage through the rock voids.

Design of spillway chute

- Determination of rock size on the spillway is based on either the maximum unit flow rate (q, $m^3/s/m$) or the maximum flow velocity (V, m/s) down the spillway.
- The upstream portion of the spillway's inflow channel can be curved (i.e. that section upstream of the spillway crest).
- Once the spillway begins to descend down the embankment (i.e. where the flow is supercritical) the spillway chute **must** be straight.

Design of energy dissipater

- A suitable energy dissipater or outlet structure is required at the base of the spillway.
- The design of the energy dissipater **must** be assessed on a case-by-case basis.
- Energy dissipation ponds often need to be recessed below the downstream discharge channel in order to achieve ideal energy dissipation—this may mean that water is retained within these ponds for some time after an overtopping event.

Common spillway design and construction problems

Poorly defined spillway crest

Inadequate spillway crest profile

- A poorly defined spillway crest profile (e.g. insufficient cross-sectional width or depth) can result in flows bypassing the spillway.
- In such cases (left) damage to the earth embankment is likely to occur.

Insufficient scour protection at outlet

Insufficient scour control at base of spillway

- Rock protection should extend beyond the embankment toe to form a suitable energy dissipater (outlet structure).

Rocks sit above the embankment height

Spillway crest not recessed below the embankment crest

- It is essential to ensure that the crest of the rock-lined spillway is set well below the crest of the adjacent earth embankment.
- In such cases (left) damage to the earth embankment is likely to occur.

Inadequate rock size

Inadequate rock size

- Selection of appropriate rock (size, density and shape) is critical.
- If sufficient quantities of the specified rock size cannot be obtained, then an alternative spillway design will be required.

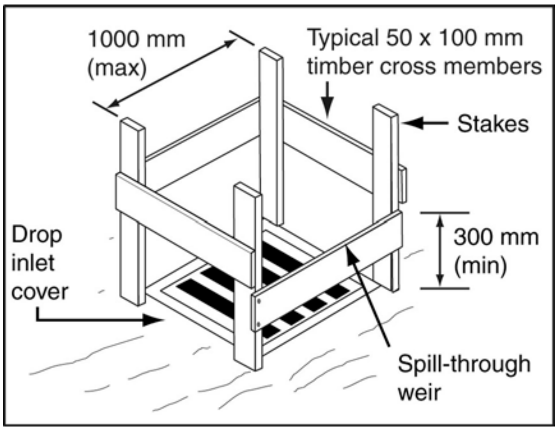
Sediment Control Techniques
Type 2 controls

Field (drop) inlet sediment traps (Type 2 & 3)

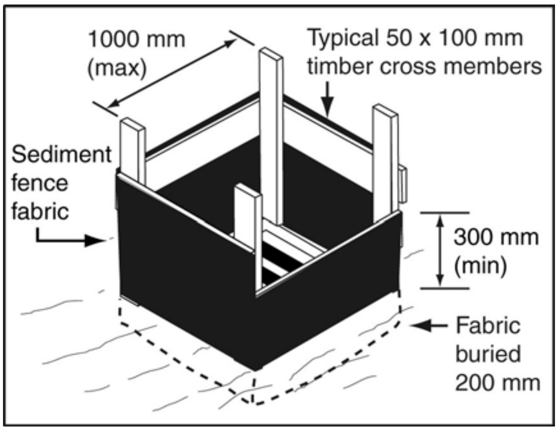
Fabric drop inlet protection

Fabric drop inlet protection (Type 3)

- A Type 3 sediment trap.
- Fabric drop inlet protection is best used on sandy soils.
- Suitable for relatively small catchment areas.
- Maximum spacing of support posts is 1 m (photo left is a poor example).
- A spill-through weir normally needs to be incorporated into one side of the sediment trap to control the depth of ponding.



Installation of support frame

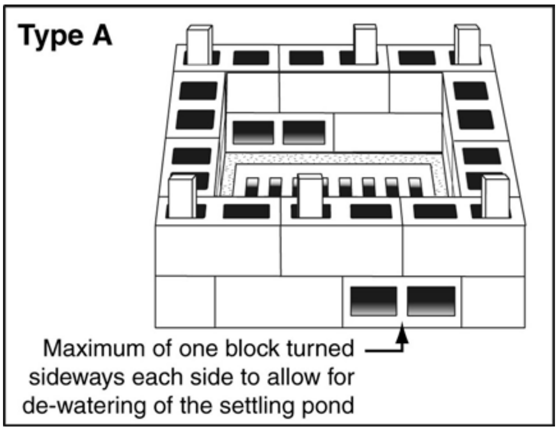


Placement of fabric

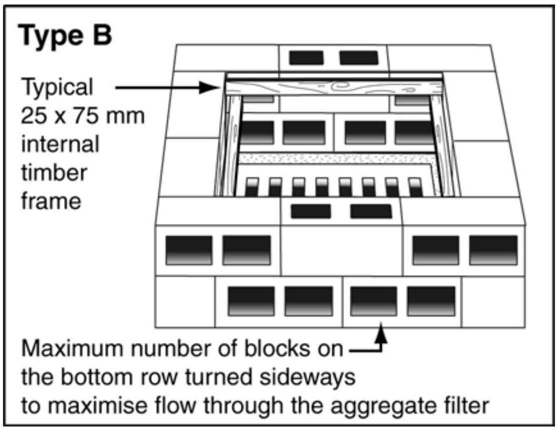
Block & aggregate drop inlet protection

Block & aggregate inlet protection (Type 2)

- Block & aggregate drop inlet protection is suitable for small to medium catchments.
- In clayey soils, filter cloth is placed between the aggregate and blocks to improve the removal of fine sediments.
- The depth of ponding upstream of the stormwater inlet is governed by the height of the blocks.
- The diagrams below show two types of block arrangements (prior to placement of the aggregate).



Block details for low flow rate system



Block details for high flow rate system

Field (drop) inlet sediment traps (Type 2)

Mesh & aggregate drop inlet protection

Mesh & aggregate inlet protection

- A Type 2 sediment trap.
- Mesh & aggregate drop inlet protection is suitable for small to medium catchments.
- The depth of ponding upstream of the field inlet is governed by the height of the aggregate filter placed around the wire mesh.
- In clayey soils, filter cloth may be placed over the aggregate to improve the removal of fine sediments (as per *Rock Filter Dams*).

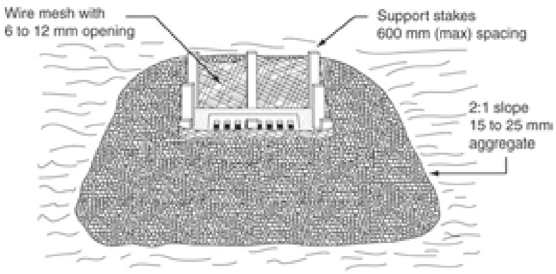


Diagram supplied by Catchments & Creeks Pty Ltd

Mesh & aggregate drop inlet protection

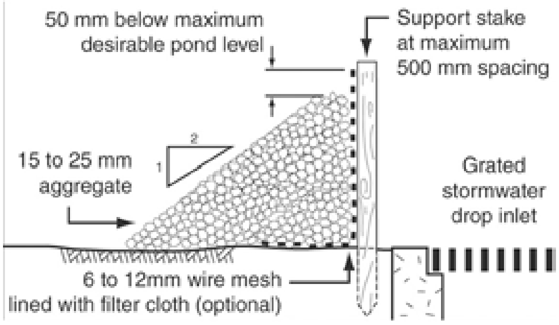


Diagram supplied by Catchments & Creeks Pty Ltd

Construction detail

Rock & aggregate drop inlet protection

Rock & aggregate inlet protection

- A Type 2 sediment trap.
- Rock & aggregate drop inlet protection is best used in sandy soil areas.
- Most commonly used in the construction of duel-carriageways where the drop inlet is located within the median strip.
- The critical design parameter is the surface area of the settling pond that forms around the protected drop inlet.
- *Flow Diversion Banks* (below) may need to be incorporated into any of the above inlet protection systems to control the depth and extent of ponding.
- Pooled water should not be allowed to spill onto trafficable lanes.

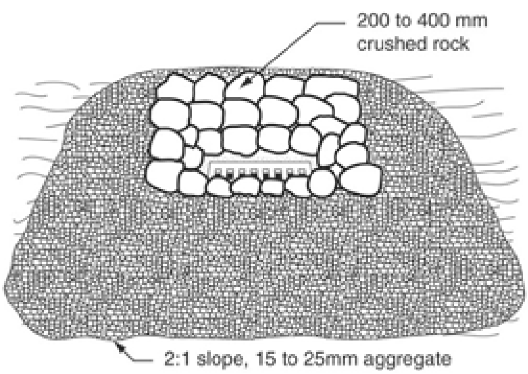
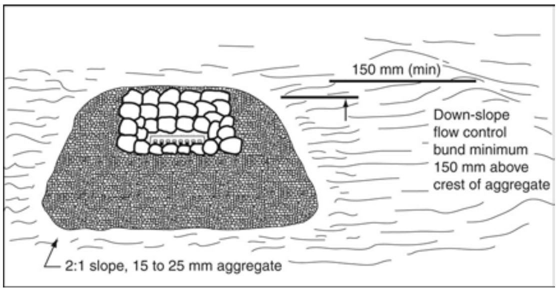


Diagram supplied by Catchments & Creeks Pty Ltd

Rock & aggregate drop inlet protection



Flow diversion bank adjacent drop inlet

Mulch berm sediment traps (Type 2)

Mulch berm

Mulch berms

- A Type 2 sediment trap.
- Mulch and compost berms can act as both drainage control systems and sediment control systems.
- In general, mulch berms perform better than a traditional sediment fence (being only a Type 3 system) but only if the berm remains undamaged by construction traffic and excessive stormwater runoff.

Tub-grinded mulch

Make-up of hydraulically-stable mulch

- The mulch should **not** be totally 'clean', but should contain a small quantity of topsoil (generated from the mulching of tree roots) to help stabilise the mulch.
- The mulch must be produced through the use of tub grinders or the like, but **not** by chipping.
- The mulch needs to be very fibrous such that woody splinters achieve good interlocking and help the mulch to resistance movement.

Velocity control check dams

Velocity control adjacent to mulch berms

- During minor storms, flow will generally filter through the mulch; however, during major storms it is likely that flows will be diverted along the edge of the berm.
- If flow velocities adjacent the mulch berm are expected to be high during major storms, then *Check Dams* can be used to control these velocities.
- Rock check dams can also be used to increase the percentage of flow filtering though the berm.

Flow release points

Outlet structures

- Eventually the collected flow will need to be discharged from the mulch berm.
- 'Clean' water can simply be released from the berm at regular intervals.
- 'Dirty' water should be released only after passing through an appropriate sediment trap.
- Filter cloth can be staked over the mulch berm at selected overflow points.

Rock filter dams (Type 2)

Rock filter dam - aggregate filer

Use of rock filter dams

- A Type 2 sediment trap.
- Rock filter dams can be used as sediment traps connected to the outlets of mulch berms and topsoil windrows.
- Rock filter dams wrapped in filter cloth can also be used as 'instream' sediment traps when working in ephemeral channels (refer to part 2 of this field guide).

Rock filter dam - geotextile filter

Rock filter dam with geotextile filter

- Rock filter dams can be used in locations where it is impractical to construct a formal *Sediment Basin*.
- The critical design parameter is the surface area of the settling pond, which must be maximised.
- The use of filter cloth as the primary 'filter' is the preferred construction technique if the capture of fine-grained sediment is considered critical.

Rock filter dam - aggregate filer

Rock filter dam with aggregate filer

- Aggregate-based filtration systems are best used in sandy soil areas.
- Aggregate filters generally rely on the effects of partial sediment blockage to achieve their optimum filtration performance.
- Rock filter dams with aggregate filters are generally not suitable for use on pipeline projects because their working life is usually too short to allow the aggregate filter to develop its optimum filtration properties.

Excavated sediment trap

Sediment collection pits

- **Caution;** placing an excavated pit immediately up-slope of an 'aggregate filter' may reduce the filtration performance of a rock filter dam.
- Aggregate filters rely upon the partial blockage of the aggregate with coarse and fine sediments in order to commence the 'filtration' process—an excavated sediment collection pit therefore reduces the essential partial sediment-blockage of the aggregate filter.

Sediment weirs (Type 2)

Sediment weir (field inlet protection)

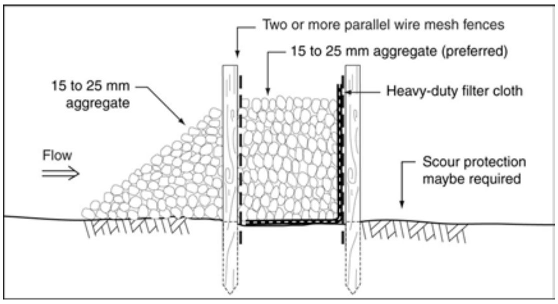
Sediment weir

Use of sediment weirs

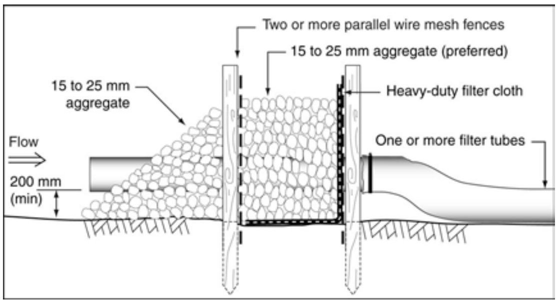
- A Type 2 sediment trap.
- Sediment weirs are used where space is limited (i.e. when space is not available for the construction of a *Rock Filter Dam*).
- Sediment weirs can be very durable in conditions of high flow rates where the sediment trap may be subjected to regular over-topping flows.
- They can also be used as a primary outlet structure on a Type 2 *Sediment Basin* (as is the case shown left).

Use as in-channel sediment traps

- Sediment weirs can also be used as temporary instream sediment traps when working in ephemeral channels (refer to Part-2 of the field guide).
- *Filter Tubes* can be incorporated into the sediment weir to increase the treatable flow rate.
- The critical design parameter is the 'surface area' of the settling pond, which must be maximised.



Sediment weir with aggregate filter



Sediment weir with filter tube incorporated into the weir

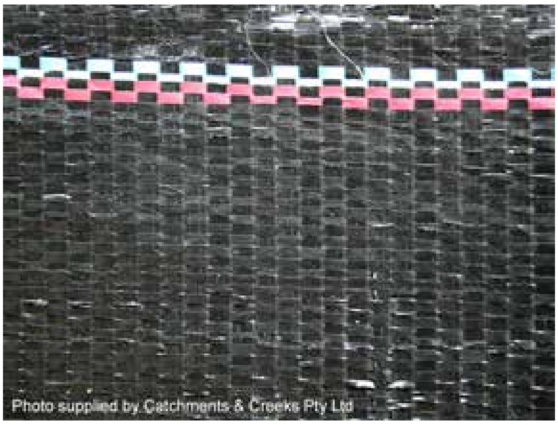
Construction of a sediment weir

Construction difficulties

- Sediment weirs are less likely to be damaged by shifting earth, heavy sediment flows, or severe storms.
- However, sediment weirs require significantly more time and effort to construct compared to rock filter dams and mulch berms.

Sediment Control Techniques
Type 3 controls & supplementary sediment traps

Sediment fence – suitable for ‘sheet’ flow conditions (Type 3)



Woven sediment fence fabric

Woven sediment fence

- A Type 3 sediment trap.
- Suitable for sheet flow conditions only.
- Woven fabrics (left) are generally suitable for all soil types, but sediment capture is limited to the coarser sediment fraction.
- The traditional woven fabrics are generally preferred on long-term construction sites that are likely to experience several storm events.

Sediment fence with top wire

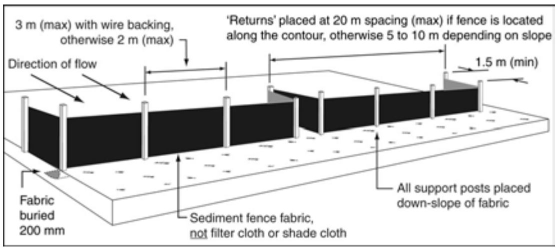
Sediment fence support system

- Support post must be placed at a maximum 2 m spacing unless the fence has:
  - a top wire (anchored at 1 m spacing), or
  - a wire mesh backing, in which case a 3 m spacing of support post is allowed.
- Ideally, a sediment should be installed along the land contour; however, in road construction these opportunities rarely exists; instead, regular ‘returns’ (below) are used to maximise the total surface area of pooling upstream of each fence.

Placement of regular ‘returns’

Use of ‘returns’

- Sediment fences must incorporate regular ‘returns’, generally at a maximum 20 m spacing, but can be less as the slope along the fence increases.



Double sediment fence

Double sediment fence

- Use of a ‘double sediment fence’ may be desirable in the following circumstances:
  - if shifting soil or rock during land filling is likely to place pressure on a single fence causing it to be damaged (such as when forming a ‘fill batter’)
  - when work space is limited and it is desirable to use the gap between a double fence to divert ‘clean’ water past a construction zone, while also using the up-slope fence as a sediment control barrier.

Common sediment fence installation problems

Inappropriate use of shade cloth

Inappropriate fabrics

- Do NOT construct sediment fences from 'shade cloth' or open weave fabrics.
- Sediment fences should also not be constructed from filter cloth—the only exception being the formation of a *Filter Fence* down-slope of a stockpile or as used in association with material de-watering.

Fence not returned up-slope at end

Inappropriate installation techniques

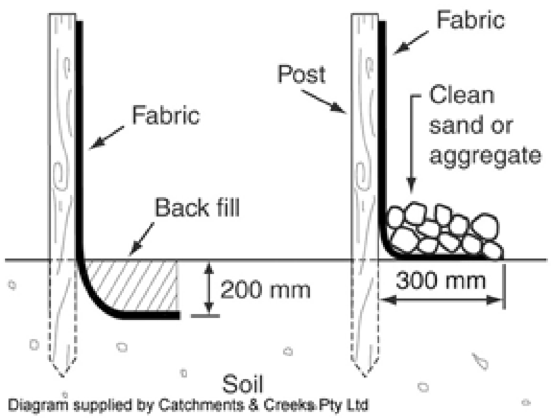
- The ends of a sediment fence **must** be turned up the slope (known as a 'return') to prevent water simply passing around the end of the fence.

Toe of fabric incorrectly anchored

Inappropriate anchorage of fabric

- The bottom of the fabric **must** be anchored to prevent wash-outs.
- The bottom 300 mm of fabric must be suitably anchored either in a 200 mm deep trench, or under clean sand or aggregate (below), but **not** randomly spaced rocks (as shown left).
- The support posts must be placed down-slope of the fabric (<u>not</u> as shown bottom left).

Post placed on wrong side of fence



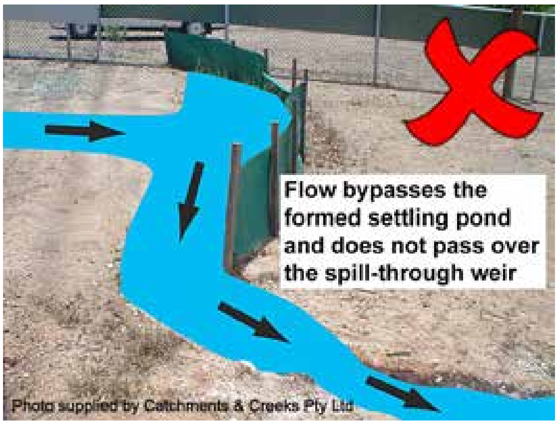
Recommended installation options

U-Shaped sediment traps – suitable for minor concentrated flow (Type 3)

U-shaped sediment trap

U-shaped sediment trap in steep drain

Inappropriate installation



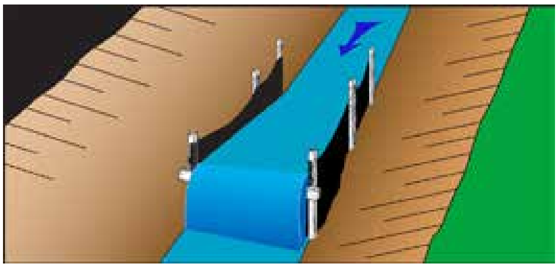
Inappropriate installation

U-shaped sediment traps

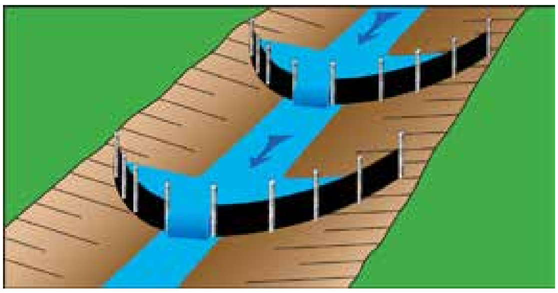
- A Type 3 sediment trap.
- U-shaped sediment traps are commonly used as coarse sediment traps within table drains on medium to steep gradients.
- The sediment fence **must** be constructed in a U-shape, **not** formed in a shallow arc, or placed straight across the drain.
- A spill-through weir is usually required to prevent flow bypassing in drains placed on a medium gradient.
- The width of the sediment trap is usually determined by the width of the excavator bucket used for sediment removal.
- Filter tubes can be integrated into the trap (forming a *Filter Tube Dam)* to increase the trap's hydraulic capacity and to improve the treatment of low-flows.
- On low-gradient drains, preference should be given to the use of *Check Dam Sediment Traps*.
- **Note:** spill-through weirs are only effective if the weir crest is at least 300 mm high, and the weir crest is below the height of the ground at the trap's inlet.

Installation of U-shaped sediment traps

- A sediment fence must **not** be placed straight across the drain.
- The correct flow condition is shown below.



- A U-shape sediment trap must not be formed in a 'shallow' arc across the drain as shown (left), but if the drain is wide, a semi-circular shape trap with spill-through weir can be used.



Kerb inlet sediment traps (Supplementary sediment traps)

Sag inlet sediment trap

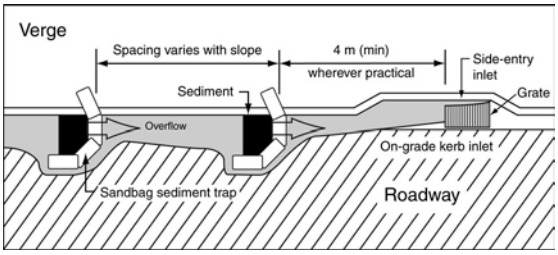
Sag inlet sediment traps

- 'Sag' inlets exist at low points along a road profile.
- A sag inlet sediment trap must allow water to pool on the road adjacent to the inlet in order to achieve particle settlement.
- Sag inlet sediment traps should **not** block the inlet opening, but should be set back from the inlet (normally using spacers) to allow the drain to function, especially during periods of heavy rainfall.

On-grade kerb inlet sediment trap

On-grade inlet sediment traps

- An on-grade sediment trap consists of one or more U-shaped sandbag traps constructed up-slope of the inlet.
- Typically more than one such sediment trap is required up-slope of the inlet.



Gully bag sediment trap

Gully bag sediment traps

- *Gully bag sediment traps* (i.e. special filter bags installed below the inlet grate) can be used on both 'sag' and 'on-grade' kerb inlets.
- These types of gully traps include the flexible filter bags (left) and solid filter boxes lined with filter cloth.

Flooded road surface

Safety issues

- Public safety must always take priority.
- If the installation of the sediment trap is likely to result in an unmanageable and/or unacceptable safety risk, then an alternative sediment trap must be used, such as a gully bag.
- Roadside sediment traps can also be damaged by road traffic; thus operators must exercise extreme care and caution when placing these devices on public roadways.

Field (drop) inlet sediment traps

Field inlet located within median strip

Fabric wrap inlet protection

Filter sock drop inlet protection

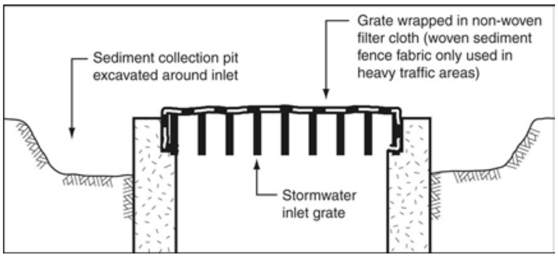
Excavated drop inlet protection

Safety first

- Field inlet sediment traps are commonly used in the construction of dual-carriageways.
- The selection of the type of sediment trap depends on the following issues:
  - safety issues—do not use any sediment control system if that system represents a safety risk to persons or property
  - flooding issues—use of the sediment trap must not result in flooding of neighbouring properties.

Fabric wrap inlet protection

- Only suitable for very small catchment areas.
- Its use is uncommon in road construction.
- Formation of the excavated pit is critical.



Filter sock drop inlet protection

- A Type 3 sediment trap.
- Filter socks (including straw or compost-filled *Fibre Rolls*, and *Compost Berms*) are only suitable for small catchments.
- Fibre (straw) filled socks are mostly suited to sandy soils.
- Compost berms or compost-filled socks work best in clayey soil areas.
- Compost-filled socks can adsorb some dissolved and fine particulate matter.

Excavated drop inlet protection

- Excavated drop inlet protection is used in locations where water pooling around the stormwater inlet is not allowed to reach a level significantly higher than the existing ground level.
- These traps allow water to filter through aggregate and then drain through holes drilled through the inlet chamber.
- Safety issues may require the excavated pit to be surrounded by appropriate safety fencing.

Sediment sumps (Type 3)

Excavated sediment sump

Sediment sumps

- A Type 3 sediment trap.
- Unlike many urban projects, rural road construction often provides the opportunity to use simple *Sediment Sumps* as sediment traps.
- Sediment sumps can come in several forms, but the simplest is just an excavated pit at the end of a diversion drain.

Excavated sediment sump

Operation of sediment sumps

- As flows pass over the sediment sump, flow velocities slow, allowing coarse sediments to settle out.
- Site inspections must check that:
  - the sediment sump does not represent a safety risk, and
  - the side walls of the excavated pit are not subject to scour or slumping.

Excavated sediment sump

Enhanced treatment

- The degree of sediment capture can be enhanced through the incorporation of a Type 2 sediment filter into the outlet of the sediment sump.
- Suitable Type 2 filters include:
  - *Filter Tube Dams*, and
  - *Rock Filter Dams* lined with filter cloth.
- Rock filter dams with aggregate filters should <u>not</u> be used as outlet structures because the aggregate usually fails to function properly as a sediment filter.

Sediment sump formed in dispersive soil

Complications caused by erodible soils

- Sediment sumps cannot be formed in highly erodible soils such as:
  - dispersive (sodic) soils
  - slaking soils, and
  - non-cohesive sandy soils.
- In the case of slaking or non-cohesive sandy soils, geotextile filter cloth can sometimes be used to stabilise inflow points.

Sediment control techniques suitable for 'minor' concentrated flow

Check dam sediment trap

Check dam sediment traps

- A supplementary sediment trap.
- Check dams are primarily used to control flow velocity, but can also be used as minor sediment traps within table drains.
- These structures may be constructed from rock, sand bags, or geo-logs.
- Check dams can operate as both drainage control and sediment control devices.

Coarse sediment trap

Coarse sediment traps

- A Type 3 sediment trap.
- Coarse sediment traps are best used in sandy soil regions.
- These sediment traps can be used at the low point of a *Sediment Fence* operating within a medium-sized rural catchment.
- Can be used as an alternative to a spill-through weir on a *Sediment Fence* placed on a medium-sized catchment.

Filter tube dam sediment trap

Filter tube dams

- A Type 2 sediment trap.
- Filter tube dams are typically used to trap sediment in diversion drains.
- May need to be placed down-slope of a Type 3 sediment trap to reduce sediment deposition in the filter tubes.
- *Filter Tubes* can be integrated into various instream sediment traps used at waterway crossings (e.g. *Rock Check Dams, U-Shaped Sediment Traps, Rock Filter Dams*, and *Sediment Weirs*).

Modular sediment trap

Modular sediment traps

- A Type 3 sediment trap.
- Modular systems are the modern replacement for *Straw Bale Barriers*.
- The filtration system is only capable of treating minor flows, but the units can be structurally sound in higher flows if adequately anchored in place.
- Can be difficult and time-consuming to construct, but most of the components are re-useable.

Managing Soil Stockpiles

Soil management

Soil pH testing

Topsoil management

- Best practice topsoil management includes:
  - testing topsoils for their nutrient properties and revegetation potential
  - appropriate application of soil ameliorants prior to stockpiling
  - appropriate stripping and stockpiling
  - scarification and treatment of subsoils prior to topsoil replacement
  - application of the remaining soil ameliorants prior to revegetation.

Topsoil stripping

Topsoil stripping

- Stripped topsoil should be preserved for reuse wherever possible.
- Highly contaminated topsoil may need to be buried.
- Topsoil should **not** be stripped when it is either too wet or too dry:
  - too wet means water can be squeezed from the soil
  - too dry means the soil readily crumbles when handled, or the soil cannot be formed into a clump when compressed.

Replacement of topsoil

Management of subsoils

- Ensure exposed subsoils are suitably covered as soon as practical.
- Non-dispersive subsoils should be covered with:
  - a suitable layer of topsoil if the area is to be revegetated, or
  - mulch, or a suitable chemical soil binder, if final earthworks are delayed for an extended period.
- Batters that expose dispersive subsoil should be covered with a layer of non-dispersive soil before revegetation.

Scarifying the soil surface

Surface roughening

- Ensure the soil surface is scarified before replacement of the topsoil to break up any excessive soil compaction, and enable the appropriate keying of the soil layers.
- On slopes less than about 1:3 (V:H), scarify lightly compacted subsoils to a depth of 50 to 100 mm, and heavily compacted subsoils to a minimum depth of 300 mm.
- On banks steeper than 1:3 (V:H) break any surface-sealed or crusty soil surfaces.

Topsoil management

Covering of long-term soil stockpile

Topsoil management

- Ensure topsoil is preserved for reuse on the site wherever possible.
- The practice of removing topsoil from a site should be avoided unless the soil is contaminated or otherwise cannot provide a long-term benefit to the site.
- Ensure that the stripping and respreading of topsoil is stages such that the duration of exposure of the subsoil is appropriate for the site's erosion risk.

Table 4 – General recommendations for the management of topsoil stockpiles

Condition of topsoil	Recommended stockpiling requirements
Topsoils containing valuable native seed content that needs to be preserved for plant re-establishment	· The upper 50 mm of topsoil should be stockpiled separately in mounds 1.0 to 1.5 m high. · Topsoil more than 50 mm below the surface stockpiled in mounds no higher than 1.5 to 3 m. · The duration of stockpiling should be the minimum practical, but ideally less than 12 months.
Topsoil containing minimal desirable or undesirable seed content	· Maximum desirable stockpile height of 2 m. · The duration of stockpiling should be the minimum practical, but ideally less than 12 months.
Topsoils containing significant undesirable weed seed content	· Seek local expert advice. · Consider burying the topsoil or integrating the topsoil into non load-bearing fill. · Consider the economic viability of replacing the contaminated topsoil with a compost blanket.
Topsoils containing weed seed of a declared noxious or otherwise highly undesirable plant species	· Suitably bury the topsoil on-site, or remove the soil from the site for further treatment in accordance with local and state laws. · Stripped soil must **not** be transported off-site without appropriate warnings and identification.
Previously disturbed sites where the existing surface soil consists of a mixture of topsoil and dispersive subsoil	· Mix the soil with gypsum, lime or other appropriate ameliorants (refer to soil testing) **prior to** stockpiling in either high or low mounds according to required protection of its seed content. · Adding the ameliorants prior to stockpiling allows time for chemical changes to occur.
Arid and semi-arid environments	· Collect and stockpile the natural surface gravels **separately** from the underlying topsoil. · Replace the gravels and organic litter over disturbed surfaces that are to remain unvegetated in a manner consistent with the original surface condition of the soil.

Stockpile management

Stockpile placed up-slope of road works

Location of stockpiles

- Ensure that sand/soil/earth stockpiles are not located in a position where the material could cause harm or be washed into a gutter, drain or water body.
- Do not locate stockpiles:
  - on a road pavement
  - along an overland flow path
  - adjacent to stream banks
  - within the 'drip zone' of protected trees (long-term stockpiles).

Flow diversion using a catch drain

Diversion of up-slope runoff

- Ensure, where necessary, a *Flow Diversion Bank* or *Catch Drain* is placed up-slope of a stockpile to direct excessive overland flow around the stockpile.
- Flow diversion around sand/soil/earth stockpiles is generally considered necessary when rainfall is possible and the up-slope catchment area exceeds 1500 m^2.

Long-term stockpile covered with jute

Erosion control measures

- Ensure that long-term stockpiles of material containing some degree of clayey matter (e.g. most soils, but not necessarily imported sand) are:
  - ideally covered with an impervious cover (not always practical)
  - covered with hessian (jute) blanket if not located within the drainage catchment of a sediment basin.
- Ensure appropriate dust suppression exist for all stockpiles.

Sediment control down-slope of stockpile

Sediment control measures

- Ensure an appropriate sediment control system is located down-slope of sand/soil earth stockpiles, such as:
  - *Filter Fence* or composite *Sediment Fence* for clayey soils
  - Woven *Sediment Fence* for washed sand
  - *Sediment Basin* wherever practical.

Stabilisation of Road Batters

(Erosion Control)

Short-term batter stabilisation

Batter stabilisation

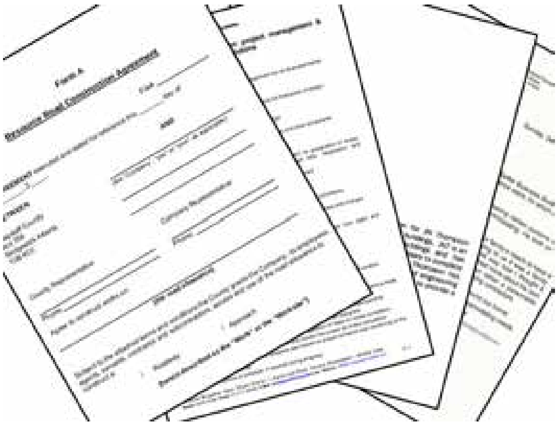
Control of soil erosion on road batters

- ‘**Batter stabilisation**’ is the application of <u>short-term</u> erosion control measures to recently formed road batters for the purpose of stabilising these batters while awaiting the application of final site revegetation.
- ‘**Batter revegetation**’ is the application of the final batter treatment, which can be implemented by the main earthworks contractor, or more commonly, by a specialist revegetation contractor.

Road batter awaiting stabilisation

Batter stabilisation

- It is <u>**not**</u> appropriate to leave finished earthworks exposed to adverse weather conditions without appropriate erosion control measures being applied.
- If road batters are not scheduled to be immediately vegetated, for example if site revegetation has been contracted to a company that is currently not on-site, then the earthworks contractor must be required to apply temporary erosion control measures that are appropriate for the site conditions and erosion risk.



Construction contracts

Setting appropriate contract conditions

- The **KEY** to effective erosion control practices is the preparation of appropriate construction contracts.
- Road authorities <u>**must**</u> ensure that the construction contracts clearly identify which contractor is responsible for the application of batter stabilisation measures in the event that site revegetation does not occur immediately after each stage of earthworks is completed.
- The **timing** of treatment measures is critical.

Straw mulching

Short-term batter stabilisation

- Short-term batter stabilisation measures consist of those erosion control techniques that can be applied immediately after earthworks are completed, but don’t interfere with proposed site revegetation.
- These measures include:
  - mulching (straw mulching)
  - brushwood mulching
  - erosion control blankets
  - soil binders (e.g. Polyacrylamide)
  - gravelling (arid & semi-arid regions).

Temporary erosion control measures

Straw blower

Temporary erosion control measures

- Straw mulching is a common form of batter stabilisation as well as a component of batter revegetation.
- It is important to anchor the mulch so that it is not displaced by strong winds or stormwater runoff.
- Straw can be anchored with:
  - a light coating of anionic bitumen
  - mechanical crimping
  - jute mesh
  - wire mesh (long-term application).

Temporary grass cover

Crimped straw mulch

Brushwood mulching

Batter stabilisation techniques

- Site-generated **brushwood** can be useful if the proposed batter revegetation consists mainly of hand-planted seedlings.
- Many different forms of **soil binders** exist, and most can be used for short-term batter stabilisation, but specialist advise is strongly recommended.
- **Erosion control blankets** can be applied in association with site revegetation or as a separate process prior to site revegetation.

Soil binder (e.g. Polyacrylamide)

Erosion control blankets

Erosion control blankets

'Fine' jute blanket

'Thick' jute blanket

Jute mesh

Synthetic-reinforced blanket

Thin biodegradable blankets

- Organic-based blankets have low shear strength, and thus a low allowable flow velocity.
- 'Fine' blankets are placed over seeded soil, while 'thick' blankets can be used to temporarily suppress weed growth.
- Blanket placement requires:
  - good soil conditioning
  - good surface preparation, and
  - intimate contact between the blanket and the soil (i.e. no 'tenting').

Thick biodegradable blankets

- Weed control features can be incorporated into some erosion control blankets.
- 'Thick' organic-based (jute) blankets be used to suppress the establishment of weed seed contained within the original topsoil.
- Rather than placing these blankets over seeded soil, a seed/mulch mix is sprayed over the surface of the blanket, and the germinated seed are allowed to root down through the blanket.

Open mesh-type blankets

- A 'mesh' is an open weave blanket made from rope-like strands of hessian (jute) or coir (coconut fibre).
- Mesh has a design life in dry environments of around 12 to 24 months.
- In isolation, a mesh does not provide adequate protection against rainfall.
- Meshes can also be used to anchor loose mulch, such as straw.
- Once installed, a mesh can be sealed with a light spray of anionic bitumen emulsion.

Temporary synthetic-reinforced blankets

- Erosion control blankets with temporary synthetic reinforcing have a low to medium shear strength.
- These blankets typically have a design life of less than 12 months.
- The plastic mesh can represent a threat to wildlife, potentially entrapping animals such as lizards, snakes and birds.
- Synthetic-reinforced blankets should be used with extreme caution in rural and bushland setting due to the potential hazard to wildlife.

Common problems experienced with erosion control blankets

Blankets displaced by winds

Poor anchorage of blankets

- Erosion control blankets are normally anchored with metal staples (pins), or barbed plastic pegs.
- Metal pins achieve their anchorage to the soil through the 'rusting' of the metal.
- Blankets anchored solely with metal pins are susceptible to disturbance by strong winds, especially if the soil is soft to firm, and the pins have not rusted.
- Additional anchorage can be provided by placing rocks or tree debris on the blanket, or using timber pegs.

Jute mesh anchored with rocks

Brushwood used to stabilise a batter

Inappropriate anchorage pegs

Blankets placed on dispersive or slaking soil

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

Mats overlapped in wrong direction

Blankets and mats overlapped against the direction of flow

- Erosion control 'blankets' (meant for areas subject to sheet flow) and erosion control 'mats' (meant for areas subject to concentrated flow) **must** overlap in the direction of water flow.
- On road batters this normally means the up-slope blanket overlapping any lower, down-slope blanket.

Site Revegetation

Long-term batter stabilisation

Revegetated road batter

Key issues

- A stable road batter can be achieved through the appropriate management of the following issues:
  - compaction of earth fill
  - appropriate batter drainage
  - management of dispersive subsoils
  - reapplication of the topsoil
  - temporary erosion control measures
  - revegetation of batters
  - protection of the batter toe during road maintenance.

Poor veg growth on heavily-compacted soil

Compaction of earth fill

- Earth works specifications often specify soil compaction standards that are 'ideal' for structural stability, but inconsistent with the revegetation needs of the batter.
- Excessive compaction of the subsoil can:
  - increase the risk of the mass movement (slippage) of the upper topsoil layer
  - delay the establishment of the initial plant cover
  - increase the risk of root-bound plants with stunted growth.

Benched road batters

Effective drainage of road batters

- Effective drainage of road batters requires the following:
  - benching of batters higher than 10 m
  - appropriate management of any dispersive soils exposed during the benching of slopes
  - stormwater released as 'sheet flow' from benches if the stormwater runoff cannot be contained and released from a suitable catch drain.

Erosion of an exposed dispersive soil

Management of dispersive soils

- Cut batters often contain layers of dispersive soil.
- It should <u>not</u> be assumed that long-term stability can be achieved simply by vegetating these dispersive soil.
- Dispersive soils need to be either:
  - covered with a layer of in-situ soil that has been stripped, treated, mixed, replaced, then vegetated, or
  - covered with a layer of local or imported topsoil, then vegetated.

Long-term batter stabilisation

Topsoil placement

Appropriate placement of topsoil on road batters

- Road batters need to be suitably scarified prior to the placement of topsoil.
- Place topsoil at a depth of 40 to 60 mm on slopes steeper than 1:4 (V:H), and 75 to 100 mm on lesser slopes.
- Lightly compact topsoil to a 'firm' condition (i.e. allows the insertion of a car key).
- Ensure the topsoil surface is left in a scarified (roughened) condition to assist moisture infiltration and inhibit soil erosion.

Straw mulching of a road batter

Application of temporary erosion control measures

- Newly vegetated road batters need to be protected from excessive run-on water and raindrop impact erosion.
- The mulching of newly seeded batters helps to:
  - reduce raindrop impact erosion
  - reduce the loss of soil moisture
  - reduce watering requirements
  - improve seed germination and growth.

Staged revegetation of road batter

Revegetation of road batters

- The revegetation of road batters should not be delayed until all earthworks are completed, but should occur in a staged manner, ideally in 3 m lifts.
- If where staged revegetation cannot occur, then temporary batter stabilisation measures should be applied, again in maximum 3 m lifts.
- The staging of batter revegetation in 3 m lifts reduces the risk of sheet erosion and rilling occurring on the exposed soil.

Scour damage to batter toe

Protection of the batter toe during road maintenance

- The maintenance of table drains, including mowing and de-silting exercises, can sometimes disturb (cut into) the toe of an adjacent road batter.
- If this soil disturbance is allowed to expose an underlying layer of dispersive soil, then the resulting soil erosion can ultimately cause the loss of topsoil from the batter, and the full exposure of the road batter to weathering.

Topsoil placement

Surface roughening

Surface preparation prior to topsoil placement

- Prior to the placement of topsoil, the exposed subsoil should be suitably scarified to allow bonding of the topsoil layer.
- If the subsoil is potentially unstable, then suitable ameliorants should be applied prior scarifying the soil.
- After placement, topsoils should be padded to a firm condition, but <u>not</u> compacted to a hard condition that may interfere with revegetation.

Amelioration of subsoils

Placement of topsoil

Slippage of topsoil from steep batter

Placement of topsoil on steep slopes

- In general, the steeper the batter slope, the thinner the application of topsoil (in order to avoid slippage).
- If topsoil is placed over a steep, smooth surface, then there is the potential for the soil to sheet/slip of the slope.
- Stair-stepping steep slopes can greatly assist in the retention of topsoil on steep slopes, and assist in the infiltration of rainwater.

Stair-stepping of steep batter

Revegetated stair-stepped batter

Cellular confinement systems

Anchorage system

Installation on road batter

Cellular confinement systems

- Cellular confinement systems can be used to hold topsoil on steep slopes.
- The pockets may be filled with sand or gravel (arid regions and bridge abutments), or soil (vegetated areas).
- Cellular confinement systems are manufactured with smooth, textured, or perforated sidewalls—each surface texture being used for a specific purpose.
- Perforated, textured surfaces are the most common.
- Typical uses of cellular confinement systems also include:
  - revegetation of steep batters
  - control of erosion on non-vegetated bridge abutments
  - stabilisation of road embankments in arid and semi-arid regions.
- The negative side of using synthetic products, such as cellular confinement systems, is that it introduces a permanent plastic to the topsoil that can interfere with future road works, for example, complicating the removal and reuse of the topsoil during future road works.

Installation on road batter

Final grassed batter

Gravelled car park

Gravelled batter slope

Revegetation practices

Soil coverage with annual grass species

Soil adjustment

Roughened earth batter

On-site training in plant establishment

Cover requirements

- Exposed soil surfaces must be rehabilitated as soon as practical to minimise the risk of soil erosion and the resulting environmental harm.
- To be effective, at least 70 to 80% cover (refer to Figure 1 over page) must be achieved in order to protect the soil surface from raindrop impact.
- In critical locations, 100% cover may be required (refer to the contract specifications or the regulatory authority).

Soil preparation

- The long-term success of a revegetation program depends more on what happens to the soil **before** the seed is spread, than any soil modifications applied after placement of the seed.
- Subsoil surfaces that have experienced excessive compaction during the construction phase must be suitably scarified/ripped prior to spreading topsoil.
- Ideally, soil testing should be used to determine any soil amelioration.

Surface roughening

- On recently vegetated or exposed earth surfaces, erosion protection can be enhanced by roughening the soil surface to increase water infiltration and delay the formation of rilling.
- Surface roughening can also reduce dust.
- Surface roughening can be applied by walking a tracked vehicle up and down the slope (other methods do exist).
- In general, soil surfaces should not be 'smooth' at the time of planting.

Plant species

- Plant species need to be appropriate for the site conditions, including compatibility with local environmental values, and anticipated erosive forces.
- Selecting the most suitable plant species, establishment techniques, seeding rates, planting densities, fertilisers, watering rates, and maintenance techniques, requires the guidance of experts.

Revegetation practices

Grass seeding with mulch cover

Light mulching of seeded areas

- If grass seeding is used, then significant benefits can be obtained from the addition of a light covering of mulch.
- The use of mulch will reduce raindrop impact, water evaporation, and temperature fluctuation within the topsoil.
- The effective percentage cover achieved by newly seeded surfaces can be increased by mowing the grass as soon as the shoots gain sufficient height (>50 mm).
- All site revegetation measures should be monitored, particularly after rainfall.

Turfing

Turfing

- Turfing can be one of the most effective forms of instant erosion control.
- Turf must **<u>not</u>** be placed on excessively compacted soils.
- If high velocity flows are likely/expected over the turfed area within the first two weeks, then the turf should be anchored with wooden pegs.
- Metal staples (commonly used to anchor erosion control blankets) should not be used to anchor turf (for reasons of pedestrian safety).

Poor soil cover by annual grasses

Mowing/slashing of initial grass cover

- Grass seed mixtures often include a percentage of quick growth annual grasses that help to produce an initial grass cover over the soil.
- These annual grasses typically grow as near-vertical shoots that provide minimal protection of the soil from raindrop impact.
- To achieve good soil coverage, these grasses should be mown, with the grass cuttings left to cover the soil.

Mulching of plants

Maintenance of plants

- It is important to monitor planting activities to ensure that the vegetation is controlling erosion and stabilising soil slopes as required.
- In high-risk and steep-slope areas:
  - check and maintain protective fencing
  - re-firm plants loosened by wind-rock, livestock or wildlife
  - replace dead or poor-growth plants
  - control weeds, especially within a 1 m radius of immature trees.

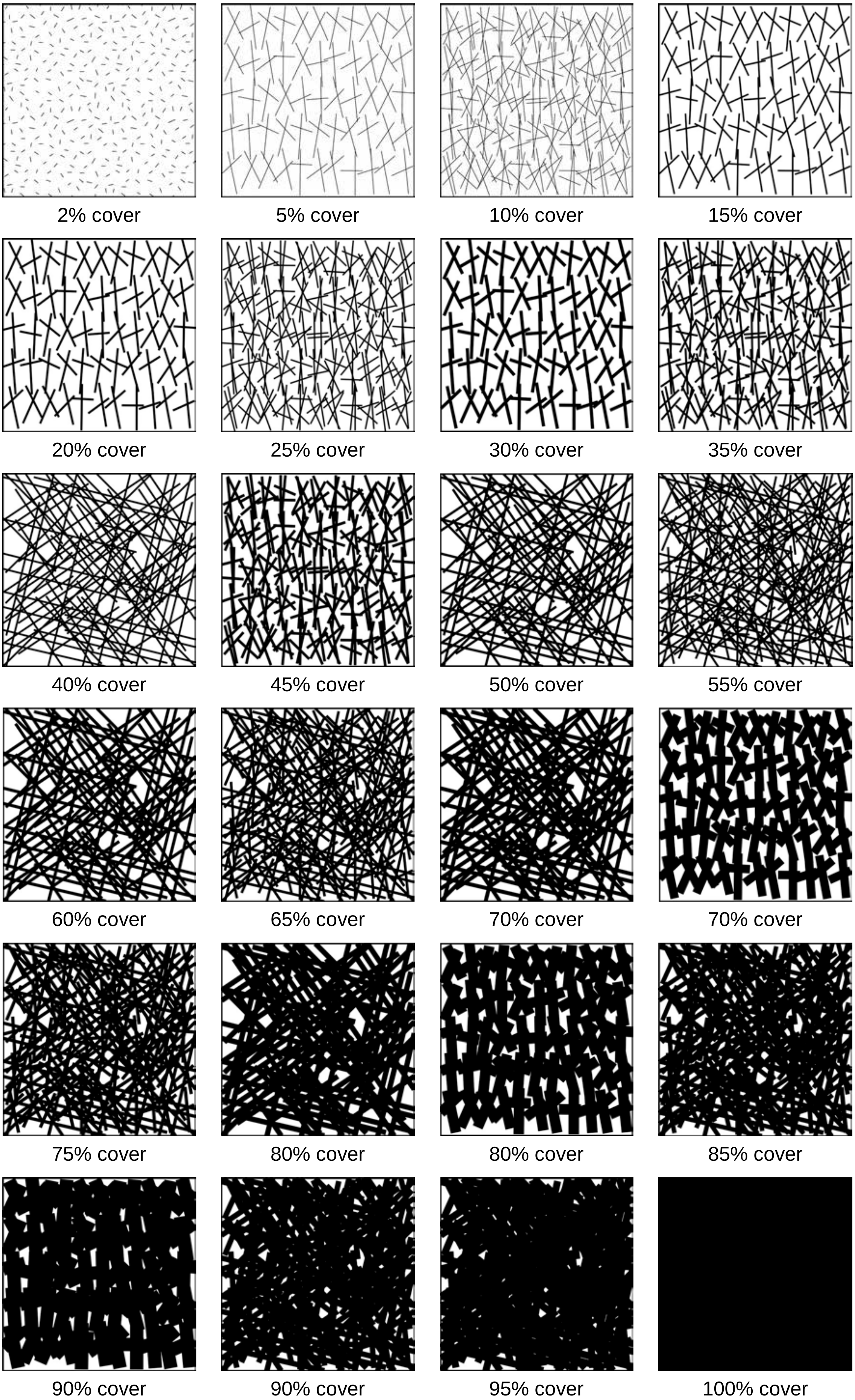


Figure 1 – Visual cover estimation guide

Importance of maintaining soil moisture during grass establishment

Spring water visible on jute blanket

Benefits of maintaining soil moisture

- The importance of maintaining soil moisture during seed germination and early plant growth is often ignored.
- These three images demonstrate the improved grass growth that occurred because of the existence of a natural spring that maintained constant soil moisture levels over a small area of soil.
- Similar grass density could have been achieved over the full embankment if soil moisture levels were maintained.

2 months after seeding

4 months after seeding

Straw mulching

Benefits of mulching seeded soil

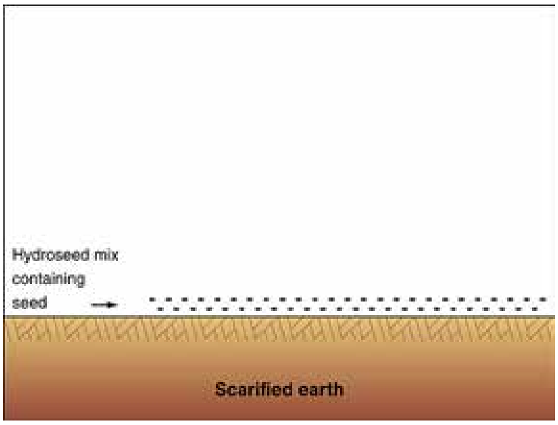
- The mulching of newly seeded surfaces greatly enhances the retention of soil moisture.
- The benefits for mulching increase with increasing air temperature and wind.
- In the tropics during the dry season, and in the dry tropics during all seasons, evaporation levels can be so significant that water cannot be trucked to newly seeded areas at such intervals as to prevent excessive drying of the soil and the loss of newly established plants.

Temporary irrigation system

Benefits of irrigation systems

- In extreme weather conditions, temporary irrigation systems can become the only feasible means of maintaining soil moisture levels.
- Even if an irrigation system has been installed, mulching of the seeded surface is still strongly recommended.
- In general, hydromulching practices fail to provide sufficient mulch density to significantly reduce soil moisture loss relative the *Bonded Fibre Matrix* of *Compost Blankets*.

Grass seeding techniques



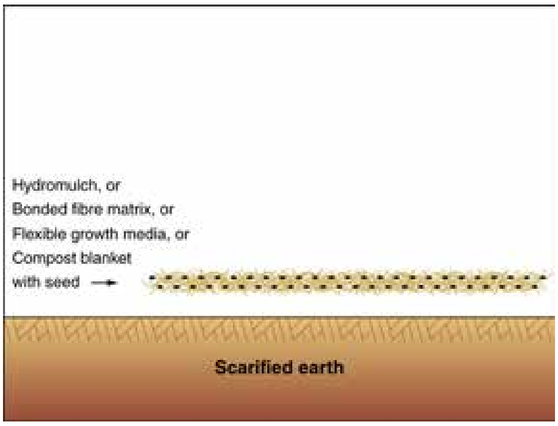
Hydroseeding

Hydraulically applied seed and mulch

- Hydroseeding is the hydraulic application of a liquid mixture containing water, seed and a green dye.
- Hydroseeding does not incorporate mulch fibres, and consequently poor seed germination and survival is expected if the soil surface is allowed to dry under a strong sun.
- Grass cover can be enhanced by covering the treated area with a straw mulch, and/or ensuring soil moisture levels are maintained.

Hydroseeding

Hydroseed



Hydromluching

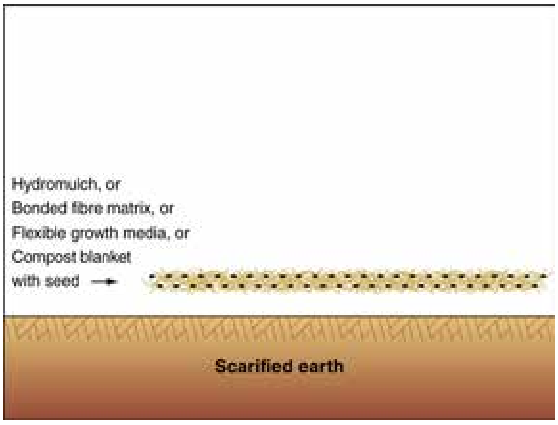
Hydromulching

- Hydromulching can be used for grass establishment and the protection of newly seeded areas.
- Best used on slopes <10% and slopes with a vertical fall of less than 3 m.
- Hydro-mulched surfaces generally have higher watering requirements than surfaces treated with straw mulch.
- Tackifiers incorporated into the mix are normally water soluble and thus easily disturbed by heavy rainfall and concentrated overland flows.

Hydromulching

Hydromulch

Grass seeding techniques



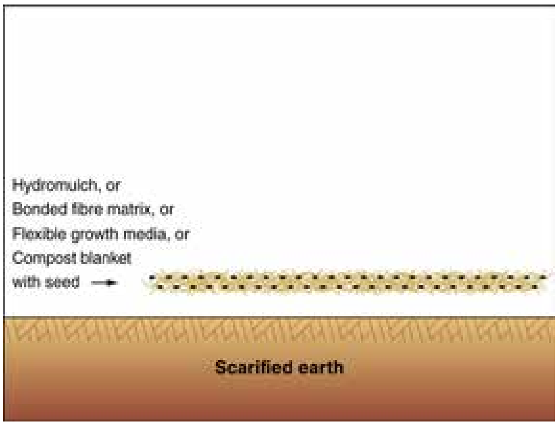
Bonded fibre matrix

Bonded fibre matrix (BFM)

- Bonded fibre matrices are effective for revegetating steep batters.
- Typically it is a highly successful grassing technique, but it requires strict control of application rates and choice of tackifier.
- Often used in wet environments (e.g. the tropics during the wet season, and drainage channels) due to the use of non re-wettable tackifiers.

Bonded fibre matrix

Bonded fibre matrix



Seeded compost blanket

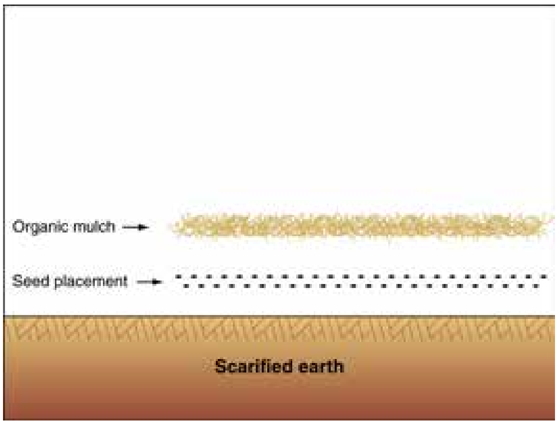
Compost blanket

- Compost blankets are typically used in association with the revegetation of steep slopes using grasses and/or woody species.
- Particularly useful if:
  - the slope is too steep for the placement of topsoil
  - there is insufficient topsoil, or the stripped topsoil cannot be used due to excessive weed content.
- Can be expensive, but usually highly successful.

Compost blanket

Compost blanket

Grass seeding techniques



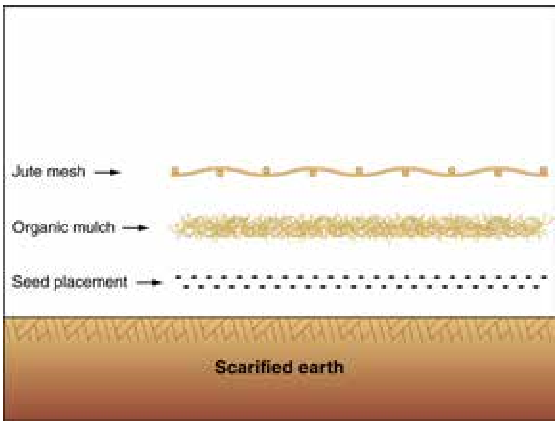
Straw mulching

Straw mulching over seeded soil

- Compared to many other forms of grass seeding, surfaces treated with straw mulch generally require less water to achieve seed germination and growth.
- Straw mulching can be very useful in rural and semi-arid areas where water supplies may be limited, and in urban areas during periods of water restrictions.
- Straw mulches may require the application of a tackifier to reduce the risk of their displacement by wind or water, particularly when applied to steep slopes.

Straw mulching

Straw-mulched surface



Jute mesh and mulch

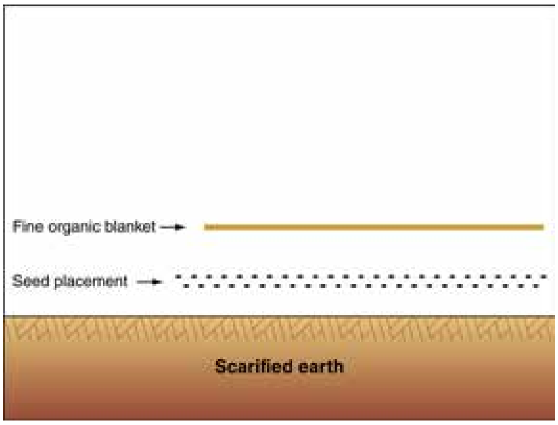
Straw mulching with jute/coir mesh anchor

- This technique is desirable along drainage channels when water supply is limited (e.g. rural roads) and on waterway banks.
- Application: initial water a scarified soil, then spread grass seed, cover with straw, anchor the straw with a well-pegged mesh, and finally apply additional water.
- The mulch controls raindrop impact and reduces water evaporation.
- The mesh anchors the mulch preventing displacement by winds and storm runoff.

Jute mesh anchoring loose mulch

Jute mesh

Grass seeding techniques



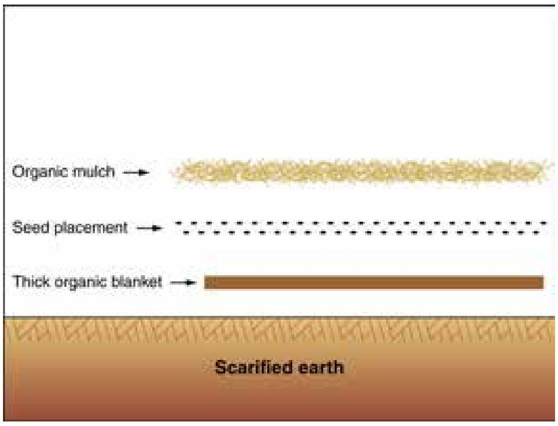
Fine organic (jute) blanket

Fine organic (jute) blankets

- Firstly water the scarified soil, then spread grass seed and cover with a fine blanket, then lightly roll the blanket to achieve good contact with the soil, or heavy water to achieve the same good soil contact.
- This technique can be problematic during hot weather that can dry the soil and kill newly-germinated grass seed.
- Grass will grow up through the blanket.
- This technique will not suppress the growth of weed seed contained within the soil.

Fine jute mat over seeded soil

Fine jute mat



Thick jute blanket used for weed control

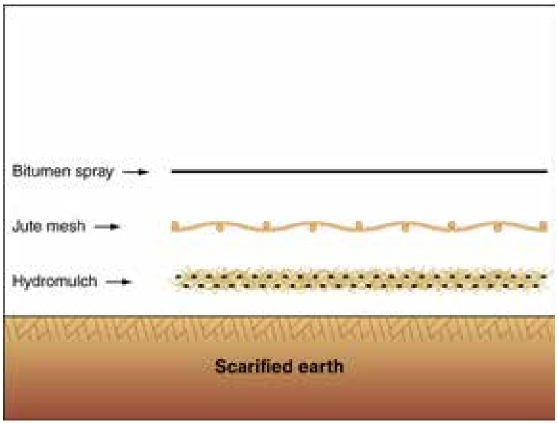
Thick organic (jute) blankets

- Firstly water the scarified soil, cover with a thick blanket, lightly roll the blanket to achieve good contact with the soil, or heavy water to achieve the same good soil contact, then apply a seed/mulch mix.
- This technique is preferred when it is desirable to suppress the growth of weed seed contained within the soil.
- Grass will root down through the blanket.
- WARNING: this technique requires good contact between the soil and blanket with no air pockets.

Thick blanket seeded with BFM

Grass establishing on a thick blanket

Grass seeding techniques



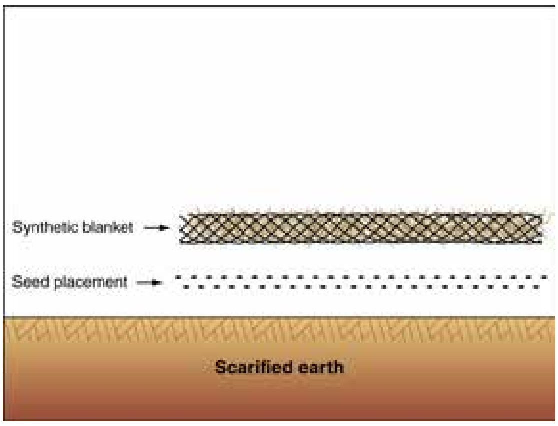
Hydromulch and jute mesh

Hydromulch anchored with jute mesh

- This technique can be beneficial along minor drainage channels, such as table drains.
- Consider the potential benefits of an initial watering of the scarified soil, then apply hydromulch, cover with jute mesh, apply a light spray of anionic bitumen, and finally apply additional water as necessary.
- The jute mesh controls soil scour.
- The bitumen controls raindrop impact and reduces water evaporation.

Jute mesh with bitumen seal

Emergent grass cover



Synthetic erosion control blankets

Synthetic blankets and mats

- Erosion control blankets with temporary, synthetic reinforcing have a low to medium shear strength.
- Temporary (non UV stabilised) blankets have a design life generally < 12 months.
- Permanent synthetic mats (TRMs) are typically used in association with reinforced grass.
- The plastic mesh can represent a threat to wildlife, potentially entrapping animals such as lizards, snakes and birds—do not use along waterways.

Non UV-stabilised synthetic composite mat

Non UV-stabilised synthetic composite mat

Establishing vegetation using jute blankets

'Fine' and 'thick' jute blankets

Placement of erosion control blankets

- Four key requirements exist for the placement of erosion control blankets:
  - control or discourage seepage flows (run-on water) that may pass under the blanket
  - remove surface irregularities from the soil
  - achieve intimate contact between the soil and blanket
  - achieve good anchorage of the blanket.

Good blanket-soil contact

Trim and prepare the soil surface

- Prior to placing erosion control blankets:
  - clear the area of trash and large stones
  - trim or grade the area smooth to eliminate surface irregularities.
- If the intension is to grow grass up through a fine blanket, then apply the seed and soil ameliorants before placing the blanket.
- If a thick blanket is used, lay the blanket, then water heavily to achieve good soil-blanket contact, then apply the seed mix.

Blanket stretched over irregular ground

Achieve good contact between the blanket and soil

- Plants that are established from a hydraulically-applied seed mix (hydroseeding, hydromulching, BFM) cannot:
  - emerge up through a 'fine' blanket if an air gap exists between the soil and blanket, or
  - root down through a 'thick' blanket if air gaps (tenting) exist between the soil and blanket.

Tube stock planted into a thick blanket

Planting tube stock

- Good contact with the soil is not essential if planting consists only of tube stock (i.e. no grass seeding).
- Planting seedlings into a thick jute blanket can be a difficult exercise, especially if the soil is firm and difficult to dig into.
- Alternatively, a jute/coir mesh can be used, which may allow planting holes to be dug prior to placing the mesh, thus allowing the plants to be placed and the holes backfilled after placement of the mesh.

Controlling stormwater runoff during batter revegetation

Rilling on a newly seeded batter

Excessive stormwater runoff

- Batter revegetation measures can be damaged if:
  - excessive run-on water is allowed to discharge down the batter, or
  - the batter is of such height, and the rainfall of such intensity, that rainwater cannot fully infiltrate into the soil, thus causing runoff to occur.
- Batters that exceed a height of 3 m may require temporary stormwater runoff controls.

Grass filter strips

Use of grass filter strips

- Grass filter strips can be placed at a spacing not exceeding a vertical fall of 2 metres.
- The grass strip <u>must</u> be placed along the land contour in order to ensure stormwater runoff passes over the turf a 'sheet' flow.
- Grass filter strips can provide the additional benefit of acting as minor (supplementary) sediment traps on the road batter.

Grass filter strips

Grass filter strip with captured sediment

Fibre rolls

Use of fibre rolls

- Small diameter *Fibre Rolls* can also be used to control stormwater runoff passing down newly seeded road batters.
- Care must be taken to ensure that stormwater runoff is allowed to pass evenly through/over the fibre rolls as sheet flow.
- The possibility of concentrated flow spilling around the ends of the fibre rolls should be discouraged by turning the roll up the slope at the ends.

Controlling stormwater runoff while revegetating road verges

Fully turfed road verge

Use of grass filter beds

- Turf can be used as a 'supplementary' sediment filter.
- Ideally, turf should be placed along the contour to ensure stormwater runoff passes evenly through the turf as 'sheet' flow.

Rilling along the edge of turf

Potential erosion problems

- If the turf is placed across the contour (i.e down a slope), then stormwater runoff can be diverted along the up-slope edge of the turf causing rill erosion.

Rilling along the edge of turf

Rilling along the edge of turf

Placement of lateral turf strips

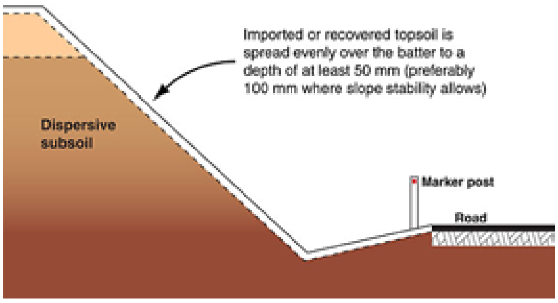
Controlling water flow along the edge of turf filter strips

- In order to reduce the risk of rilling along the up-slope edge of turf filter strips:
  - turf strips can be placed laterally to the main turf alignment
  - sandbags (sand-filled filter tubes) can be placed laterally across the upper edge of the turf.

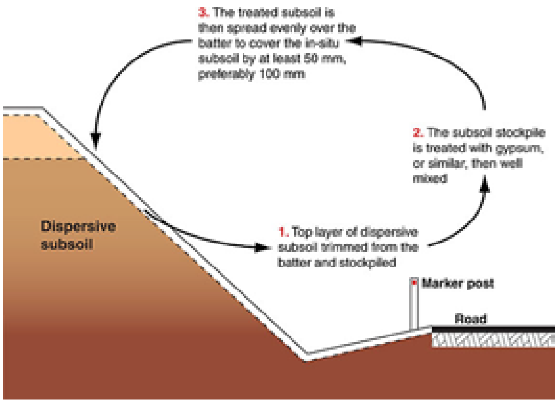
Establishing vegetation on batters containing dispersive soils

Severe rilling within a dispersive soil

Failed revegetation of a dispersive soil



Dispersive subsoil covered with topsoil



Dispersive soil covered with treated soil

Treatment of dispersive soils

- The formation of cut batters often expose multiple subsoil layers (horizons) which exhibit various degrees of erosion resistance.
- Potentially the most unstable and erosion-prone soils are ‘slaking’, ‘dispersive’ or ‘sodic’ soils.
- To achieve long-term stability, slaking or dispersive soils must be covered with a suitable layer of non-dispersive soil, usually a topsoil then vegetated.

Revegetation of dispersive soils

- Slaking and dispersive subsoils can be vegetated, but this vegetation is **unlikely** to prevent ongoing soil erosion from occurring.
- If construction delays prevent the immediate placement of a topsoil layer, or if insufficient suitable topsoil is available, then the surface of the subsoil should be removed, treated with gypsum (or the like), mixed well, then placed over the batter prior to applying any soil stabilisation measures.

Preferred batter preparation

- If a cut batter has exposed layers of dispersive soil, then it is essential that a layer of non-dispersive soil (topsoil) is placed over the dispersive soil prior to:
  - seeding
  - turfing
  - rock placement
  - concrete capping
  - placement of rock mattresses.

Alternative batter preparation

- Exposed dispersive soil should <u>not</u> be directly seeded.
- If a suitable topsoil does not exist on the site, and it is considered undesirable to import a topsoil, then:
  - strip a layer of subsoil from the batter
  - treat the soil with gypsum (or similar) and mix the treated soil
  - place the treated soil over the batter
  - seed the batter with a *Bonded Fibre Matrix* or *Compost Blanket*.

Case study 1: Failed batter revegetation incorporating a dispersive soil

Directly seeded dispersive soil

Failure of direct seeding

- This project involved the rehabilitation of a road batter and table drain that experienced severe erosion of the exposed dispersive soils.
- Parts of the site involved the direct seeding of a dispersive soil using a Bonded Fibre Matrix (BFM).
- Grass was quickly established over the dispersive soil, but without appropriate soil amelioration, the underlying soil continued to erode and undermine the grass cover.

Jute blankets placed on dispersive soil

Jute blankets placed directly on a dispersive soil batter

- A 'thick' jute blanket was pinned directly onto the dispersive soils exposed on the road batter.
- A seeded BFM mix was then applied to the surface of the jute blanket.
- No soil amelioration had been applied to the underlying dispersive soils.

Soil erosion occurring under blanket

Soil erosion under the jute blanket

- Before an even grass cover could be established, significant soil erosion had occurred under the jute blankets resulting in the formation of air gaps.
- Over significant areas, the germinated grass seed could not root into the underlying soil due to the expanding air gaps.
- Over time, the jute blanket decomposed and the dispersive soil batter was left once again exposed and prone to weathering.

Loss of vegetation from the road batter

Fluting of the exposed dispersive soil

Case study 2: Failed batter revegetation incorporating a dispersive soil

Pre works

Revegetation of a highly dispersive subsoil

- Details of the actual soil treatment at this site are not known to the author in this case.
- The embankment was trimmed, covered with a thick jute blanket, then sprayed with what appears to be a Bonded Fibre Matrix (BFM).

Early 2011

Results of the treatment

- The results indicate the following:
  - it would appear that the trimmed subsoil was not covered with a layer of non-dispersive soil
  - some blankets were disturbed by winds
  - poor ground cover was established
  - good shrub cover was established
  - the failure to adequately treat (gypsum) the subsoil, or cover with a non dispersive topsoil, has allowed ongoing rill erosion under the blankets.

Late 2011

2014

2015

Evidence of ongoing rill erosion (2013)

Examples of failed vegetation on dispersive soil batters

Dispersive soil batter

Dispersive soil batter


Dispersive soil batter

Dispersive soil batter

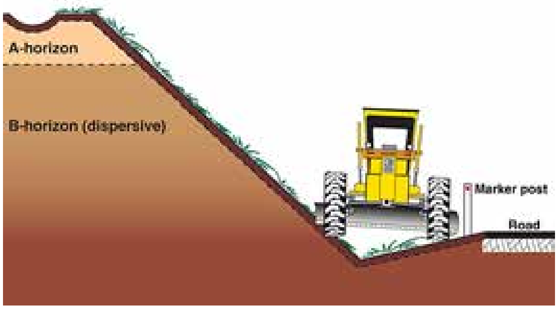
Dispersive soil batter


Dispersive soil batter


Dispersive soil batter

Dispersive soil batter

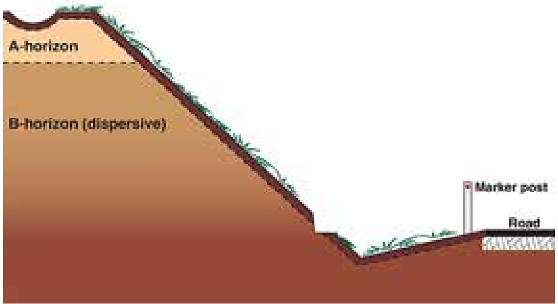
Protection of the batter toe during road maintenance



Mechanical disturbance of batter toe

Potential damage to road batter during road maintenance

- Road maintenance can on occasions cause damage to the toe of road batters, particularly if graders and slashers are required to pass around the inside of road markers (i.e. not move onto the roadway).
- This minor toe disturbance can initiate the erosion of an underlying dispersive subsoil, which can ultimately undermine the topsoil layer and expose the full batter to ongoing weathering.

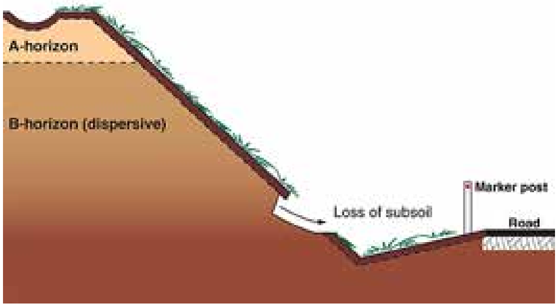


Dispersive subsoil exposed to erosion

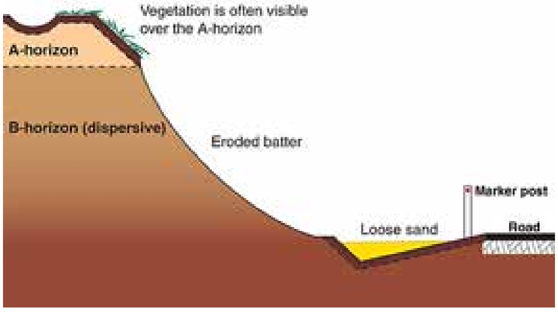
Mechanical disturbance of batter toe

The reasons for poor 'natural' revegetation of these eroded batters

- Road batter containing dispersive soils are unlikely to revegetate 'naturally' because grass seed blown onto the batter by winds will be washed down into the table drain during subsequent rainfall.
- This means table drains are often filled with well-seeded loose sediment.
- The circumstances presented here are just one possible cause for the failure of batter vegetation, and it is unlikely to be a common cause of this erosion.



Topsoil undermined and washed away



Eroded road batter

Eroded road batter