Rural Earthmoving in the Sydney Drinking Water Catchment

A Sydney Catchment Authority Current Recommended Practice

NSW GOVERNMENT

SYDNEY CATCHMENT AUTHORITY

Publication

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Acknowledgements

This current recommended practice 'Rural Earthmoving in the Sydney Drinking Water Catchment' has been developed by Alison Kniha and Jim Caddey of the Sydney Catchment Authority with the cooperation and endorsement of the NSW Soil Conservation Service.

Unless otherwise stated and referenced, all information in this manual is material sourced from the 'Earth Movers Training Course' manuals (Soil Conservation Service, 1991).

Disclaimer

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Earthmoving of one kind or another will be required for most developments in rural areas of the catchment, including for the construction of farm dams and conservation earthworks. Failures in these earthworks, leading to water quality impacts, can arise in part due to the lack of readily available information on aspects of design and construction, including when to seek professional advice.

The Sydney Catchment Authority (SCA), in conjunction with the NSW Soil Conservation Service, has prepared 'Rural Earthmoving in the Sydney Drinking Water Catchment' (the manual) as a current recommended practice for the protection of water quality under State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011.

The manual identifies a range of water quality sensitive development principles, practices and solutions, providing information to assist those involved in the design, construction and assessment of rural earthworks in the catchment that are consistent with the requirements for achieving sustainable catchment health outcomes and water quality protection principles in accordance with the SCA's 'Neutral or Beneficial Effect on Water Quality (NorBE) Assessment Guideline 2011'.

This manual is to be read and the principles applied in conjunction with relevant council planning policies, legislative requirements and other current recommended practices and performance standards.

Chapter 1

Rural Earthmoving in the Sydney Drinking Water Catchment

1 Rural Earthmoving in the Sydney Drinking Water Catchment

1.1 Introduction

Earthworks of one kind or another will be required for most developments in rural areas, including the construction of dwellings or farm dams, pipe laying and access roads. Earthworks also have a role in rehabilitating erosion that has occurred as a result of previous land management practices, and in preventing erosion from occurring.

'Rural Earthmoving in the Sydney Drinking Water Catchment' (the manual) deals primarily with rural earthmoving for agricultural activities, and has been created as:

- a handbook for developers, rural and earthmoving contractors in the design and construction of earthworks
- a tool for use by local government, the Sydney Catchment Authority (SCA) and other authorities in the assessment of such development proposals, and
- an educational document for both the SCA and local government staff, and any member of the community involved in rural earthworks in the drinking water catchment.

This manual does not concern issues covered elsewhere such as safety in earthmoving operations, the mechanics or maintenance of tractors and other earthmoving machinery or mining rehabilitation or to matters relating to earthmoving covered by any council's local environmental plan (LEP); this manual must be read in conjunction with the relevant council planning policies and legislative requirements.

For information regarding safety, mechanics and machinery, the reader should refer to the 'Earth Movers Training Course' manuals (Soil Conservation Service, 1991). For site-specific technical advice, the reader should contact the Soil Conservation Service (see Section 1.5).

Table 1.1 summarises the earthmoving topics discussed in this manual.

Table 1.1 Manual Topics

Type of Earthmoving	In this Manual	Refer to
Structural earthworks for erosion control	Chapter 2	-
Small farm dams for sediment and runoff control	Chapter 3	-
Larger farm dams and dams for stock watering and domestic supply	N/A	Soil Conservation Service / NSW Office of Water
Contour and graded banks	Chapter 4	-
Rehabilitation of gully erosion	Chapter 5	-
Flumes	Chapter 5	-
Access tracks and other unsealed roads / Rural dwelling construction / Urban construction	N/A	'Managing Urban Stormwater: Soils and Construction Vol.1 4th ed.' (Landcom, 2004) – the 'Blue Book' Volume 1 'Managing Urban Stormwater: Soils and Construction Vol.2' (Department of Environment and Climate Change, 2008) – the 'Blue Book' Volume 2C Unsealed Roads 'Environmental Practices Manual for Rural Sealed and Unsealed Roads' (ARRB Transport Research Ltd, 2002)
Safety in earthmoving operations	N/A	'Earth Movers Training Course', Soil Conservation Service, 1991
Mechanics and maintenance of earthmoving machinery	N/A	'Earth Movers Training Course', Soil Conservation Service, 1991
Site-specific technical advice	N/A	Soil Conservation Service
Quarrying for construction materials	N/A	'Managing Urban Stormwater: Soils and Construction Vol.2' (Department of Environment and Climate Change, 2008) – the 'Blue Book' Volume 2E Mines and quarries

1.2 The drinking water catchment

The drinking water catchment comprises five catchments including Warragamba, Metropolitan, Blue Mountains, Wingecarribee, Shoalhaven and Woronora rivers (Figure 1.1).

The catchment covers an area of almost 16,000 square kilometres, is home to approximately 110,000 people and supplies water to more than four million people – representing about 60% of the NSW population. The catchment also includes over 485,000 hectares of agricultural land and supports many native plants and animals.

The catchment extends from the headwaters of the Coxs River to the north of Lithgow, to the source of the Shoalhaven River near Cooma in the south, and from the source of the Wollondilly River near Crookwell and east to the Woronora River near Heathcote.

The SCA is a NSW Government agency created in 1999 to manage and protect Greater Sydney's catchment and supplies bulk water to Sydney Water and a number of local councils and water utilities. The SCA has identified that a healthy catchment is the first step in protecting the quality of the water supply. If catchment health is allowed to deteriorate, then water quality in rivers and streams may deteriorate in turn. This impacts on the quality of the drinking water supply, as well as on activities such as stock watering, irrigation and recreation, and the ecological health of native plants and animals.

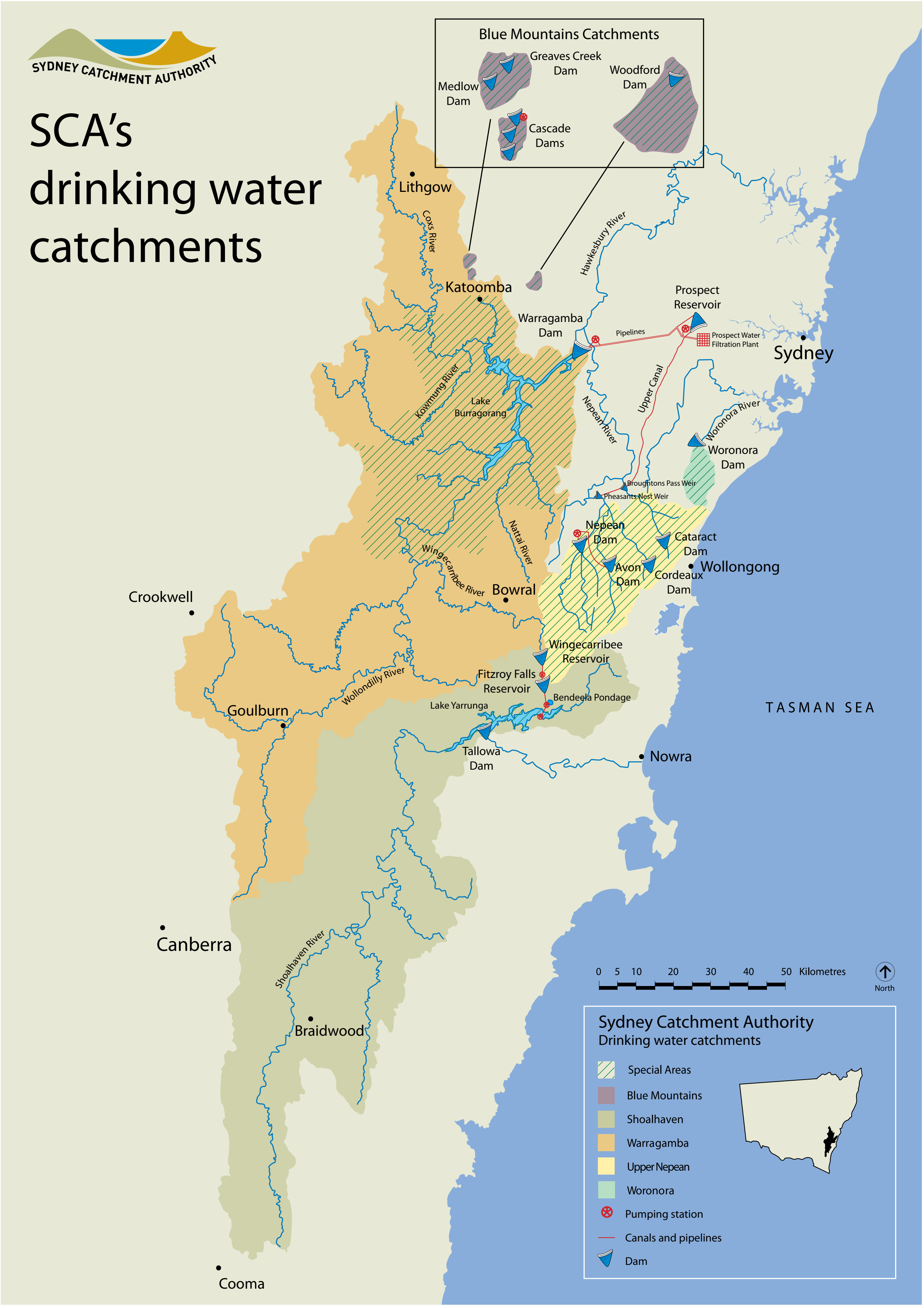


Figure 1.1 Sydney's drinking water catchment

1.3 Requirements of State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011

State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011 (the SDWC SEPP) is a legal instrument that sets out obligations relating to development matters, including the planning and regulation of new development in the catchment.

Under the SDWC SEPP, proposed developments that require consent under a council's local environmental plan (LEP), including development relating to rural earthworks, must have a neutral or beneficial effect (NorBE) on water quality and should incorporate current recommended practices and performance standards endorsed or published by the SCA that relate to water quality.

Neutral or beneficial effect on water quality

Under the SDWC SEPP, development consent cannot be granted unless NorBE is satisfied, ie if the development:

a. has **no** identifiable potential impact on water quality, or

b. will **contain** any such impact on the site of the development and prevent it from reaching any watercourse, waterbody or drainage depression on the site, or

c. will **transfer** any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.

The SCA's 'Neutral or Beneficial Effect on Water Quality Assessment Guideline 2011' provides clear direction as to what is meant by a neutral or beneficial effect, how to demonstrate it, and how to assess an application against the NorBE test.

For assessment purposes, earthworks, including farm dams, are classified according to the size of land area being disturbed:

- for a total disturbed area of less than 2,500 square metres, councils complete the assessment under delegation from the SCA
- for areas larger than 2,500 square metres, the proposal will require the concurrence of the Chief Executive of the SCA under the SDWC SEPP.

It is a statutory requirement for all developments relating to rural earthmoving requiring consent under an LEP to have a NorBE. Development applications that do not meet the NorBE requirements will not be granted consent by council or the SCA if concurrence is required. Check with your local council to determine whether the earthworks you are planning are exempt, or will require consent – this varies depending upon the types of earthworks and the local government area involved.

Current recommended practices and performance standards

Current recommended practices (CRPs) provide solutions to manage the water quality impacts of a range of land uses, developments and activities, including agriculture, industrial developments, stormwater and wastewater management.

The SDWC SEPP requires new developments to incorporate CRPs and performance standards endorsed by the SCA or, alternatively, adopt innovative approaches that achieve the same or better water quality outcomes.

This manual is a CRP developed and endorsed by the SCA in response to the requirements of the SDWC SEPP. It identifies a range of water quality sensitive development principles, practices and solutions that are consistent with the requirements for achieving sustainable catchment health outcomes in accordance with the SCA's 'Neutral of Beneficial Effect on Water Quality Assessment Guideline 2011'.

1.4 Other approvals and legislation

As well as possibly requiring the consent of council or the concurrence of the SCA, some rural earthworks may also require approvals or licences from local, state or federal governments, including the Department of Primary Industries (Lands and the Office of Water) or the Department of Premier and Cabinet (Office of Environment and Heritage). For instance if the earthworks occur on waterfront land, a controlled activity permit may be required. It is the responsibility of the landholder to determine any other requirements and obtain any necessary approvals or licences. Further information on approvals can be found in the Appendix at the end of this manual.

1.4.1 Native vegetation and State protected land

Under the *Native Vegetation Act 2003*, some areas of the State are 'protected' from the clearing of vegetation. The intention of this legislation is to retain and improve tree cover on the designated areas by placing restrictions on clearing. Three criteria are used to determine which areas should be classed as State Protected Land (SPL):

1. land within a designated catchment area (such as the Sydney drinking water catchment) having a slope of more than 18^{o} (32%; about 1:3)
2. land that is within 20 metres of a 'prescribed' river or lake
3. land that is environmentally sensitive or susceptible to soil erosion, siltation or land degradation.

The Act prohibits cutting, poisoning, injuring, removing or destroying trees on SPL unless an authority has been issued. These areas of SPL are marked on maps held by Local Land Services offices. There are also restrictions on clearing of dead timber in certain instances.

Clearing of native vegetation associated with development consents, eg for rural earthmoving activities that require the consent of the local council, will require approval from Local Land Services under the Act, and must be carried out in accordance with the development consent or a Property Vegetation Plan. The construction, operation and maintenance of farm dams may be Routine Agricultural Management Activities (RAMAs) under the Act, and may not require approval – check with Local Land Services before undertaking any clearing.

For more information on native vegetation and clearing on SPL, visit your Local Land Services office http://www.dpi.nsw.gov.au/locallandservices, or see the Office of Environment and Heritage website at http://www.environment.nsw.gov.au/vegetation/stateland.htm.

1.4.2 Controlled activities

A number of earthmoving and related activities are defined as 'controlled activities' under the Water Management Act 2000 when they occur in a watercourse or in the riparian zone. These include works such as the design and construction of stormwater outlets and spillways, instream works such as channel realignment, and watercourse crossings.

The Act is administered by the NSW Office of Water (NOW). A Controlled Activity Approval must be obtained from NOW before starting the controlled activity. For more information on controlled activities, see NOW's website www.water.nsw.gov.au.

1.5 The Soil Conservation Service

The Soil Conservation Service (SCS) is part of the NSW Department of Primary Industries, which is a division of the Department of Trade & Investment. The SCS provides a commercial environmental consultancy specialising in land rehabilitation, environmental audit, advice and project management. They provide conservation earthmoving plant and advisory services to rural NSW, offering property inspections and advising on soil erosion control on a fee-for-service basis, with specialities including dam and bank construction and the restoration of severely degraded lands. The SCS operate from a number of centres in or close to the Sydney drinking water catchment:

SCS Lithgow
Marrangaroo Road, Lithgow NSW 2790
02 6351 3989

SCS Moss Vale
Suite 11, Clarence House
Clarence Street, Moss Vale NSW 2577
02 4877 3202

SCS Goulburn
Goulburn Office Building
159 Auburn Street, Goulburn NSW 2580
02 4824 3724

SCS Cooma
26 Soho Street, Cooma NSW 2630
02 6452 1455

SCS Nowra / Wollongong
Government Office Building
Level 1, 5 O'Keefe Avenue, Nowra NSW 2541
02 4428 9129

Information regarding conservation earthworks can also be found on the SCS's website at http://www.lpma.nsw.gov.au/soil_conservation/conservation_earthworks.

Chapter 2

Erosion Control and Design Principles

2 Erosion Control and Design Principles

2.1 Types of soil erosion and causes

Soil erosion is the result of a force, such as rainfall, breaking the bonds holding a soil particle to the larger aggregate. The level of soil erosion that occurs at any site is the result of a combination of factors, including:

- the strength of the force applied ie the intensity of rainfall for an area
- the soil's ability to resist that force
- slope steepness and length of slope
- the percentage of groundcover at the site
- land use practices.

Soil Conservation Service research shows that once ground cover drops below 70%, significant levels of erosion may result; generally freshly cultivated or exposed soil is at the greatest risk of erosion. In order to minimise soil erosion a combination of land management practices (to maximise ground cover) and earthworks (to control how water flows across and down a slope) should be employed.

Eroded soil not only adds sediment to waterways and dams, but also carries large amounts of nutrients and organic matter that can pollute water and reduce the potential productivity of farms (I&I NSW, 2009).

There are five major types of erosion by water: sheet, rill, gully, streambank and tunnel erosion. In 2007, approximately 11% of the drinking water catchment was estimated to have a very high or high risk of sheet and rill erosion, and there was approximately 770 hectares of gully erosion (DECCW, 2007).

Wind erosion causing soil loss typically occurs in high wind and more marginal agricultural areas. In the drinking water catchment, wind erosion may be a factor contributing to sheet erosion (Section 2.1.1) and scalding (Section 2.1.5).

2.1.1 Sheet erosion

Sheet erosion (Figure 2.1) is the removal of a shallow and uniform layer of material by sheet flow, usually a fairly thin layer of soil. Water sheet flow and wind commonly remove fine material, leaving coarser material behind. Sheet erosion is also known as hillwash, sheetwash and slopewash, and is not as visible as gully erosion (I&I NSW, 2009).

Figure 2.1
Sheet (and rill) erosion (SCS, 2007)

2.1.2 Rill and gully erosion

During and immediately after heavy rains an eroded channel may be caused by the concentrated but intermittent flow of water. Rill erosion is less than 30 centimetres deep (Figure 2.2) and usually occurs on recently cultivated soils.

Figure 2.2
Rill erosion on a batter (SCS, 2000)

Gully erosion (Figure 2.3) is rill erosion that is greater than 30 cm deep. This rill erosion can lead to bank undercutting and collapse, resulting in the creation of a gully head.

Figure 2.3
Severe gully erosion resulting from tree clearing and overgrazing (M Knowles, SCA, 2004)

2.1.3 Streambank erosion

Streambank erosion (Figure 2.4) occurs when the soil is removed from streambanks by the direct action of the streamflow. It can also be caused by the bank undermining as a result of stream bed lowering (ie eroding of the stream bed). It is associated with large water flows (watercourses) and can occur under any flow conditions, particularly where the streambank material is not stable and the riparian vegetation has been removed. Contact your Local Land Services office regarding advice and permits for addressing streambank erosion.

Figure 2.4
Streambank erosion from a headcut with channel incision (A Spinks, SCA, 2010)

2.1.4 Tunnel erosion

Tunnel erosion (Figure 2.5) is the removal of subsurface soil while the surface soil remains relatively intact. This produces large cavities beneath the soil surface that usually collapse resulting in a gully. This form of erosion is a common symptom of sodic or dispersive soils, and is also known as piping (I&I NSW, 2009). It is sometimes a problem in dam walls built using dispersible soils (see Section 3.8.1).

Figure 2.5
Tunnel erosion exiting into a gully with a sinkhole
(J Caddey, SCA, 2006)

2.1.5 Scalding

Scalding (Figure 2.6) is erosion caused by the action of wind blowing away a sandy topsoil layer exposing the heavy clay subsoil layer underneath, which is often saline and forms a surface crust when wet. The crust reduces infiltration causing most of the rainfall to run off.

Figure 2.6
Saline scalding
(J Caddey, SCA, 2006)

2.2 Erosion control and design principles

Soil erosion control depends on managing the soil in such a way that the soil is retained on the site and can be used to its productive potential. This involves using the land within its capability, locating property infrastructure such as roads and fences where they will not cause erosion, and identifying any specific erosion control measures that are needed to complement land management.

2.2.1 Land capability

The classification of land according to its capability depends on factors including the land's fertility, stoniness, depth and stability of the soil, as well as the landform, slope and climate of the area. For the purposes of rural earthmoving, land capability can be broadly categorised using the NSW Class system into the following:

- land suitable for cultivation and grazing – Classes I-III
- land suitable for grazing but not cultivation – Classes IV-VI
- land suitable only for timber – Class VII
- land not suitable for rural production – Class VIII.

In general, as the land slope increases above 2%, cultivation management practices alone are not sufficient to prevent erosion, and soil conservation works such as banks and waterways will also be required. Earthworks such as diversion banks and dams may be required to stabilise hilly grazing land. Some land is best left under timber or replanted because of the erosion hazard, steepness, shallow soil or infertility, and should not be disturbed. Cliffs and swamps cannot be used for rural production.

2.2.2 Farm tracks and other farm improvements

Roads, fences and other improvements have the potential to cause serious erosion if not located correctly, and can result in excessive maintenance requirements and inefficient operation of a property.

The incorrect location and construction of farm tracks and access ways can cause gullying of the surface, and unwanted flow concentration or diversion (Figure 2.7). Farm tracks and access ways, and associated drainage and erosion control structures, should be located and constructed in accordance with the recommended practice 'Managing Urban Stormwater: Soils and Construction Vol.2C Unsealed Roads' (DECC, 2008; http://www.environment.nsw.gov.au/resources/stormwater/0802soilsconststorm2c.pdf).

Figure 2.7
Farm access with erosion – the mitre (turn-out) drains constructed are not adequate for the slope and/or soil type – suitable drains or a lined channel should be constructed as part of the access (J Caddey, SCA)

2.2.3 Structural works for erosion control

Structural soil conservation works are primarily for controlling runoff and to rehabilitate areas affected by erosion. They are a means of both reducing existing erosion and preventing future erosion, and must therefore be compatible with good land management practices. The type of structural works used depends on the site's requirements, but all must be properly hydraulically designed. Structural works discussed in greater detail in this manual include:

- dams and gully control structures (Chapter 3)
- graded and level banks (Chapter 4)
- grassed waterways and fencing (Chapter 4)
- gully filling and shaping (Chapter 5)
- pipes and flumes (Chapter 5).

2.2.4 Design principles for structural works

Knowledge of historic rainfall and runoff patterns and the behaviour of the local soils, when combined with experience in the location should all be considered when determining the design specifications. Incorrect design procedures leading to mis-sizing structures may lead to legal consequences if these structures subsequently fail.

A fundamental input to the design of erosion control works is an estimate of the volume and rate of runoff, including the volume expected annually. Also, to minimise the chance of failure, works are to be designed to carry the peak discharge, which is influenced by catchment area, rainfall intensity and physical features of the catchment eg slope.

Runoff estimation can be complex and methods vary widely; a full description of the methods is beyond the scope of this document. Professional assistance from the SCS should be sought for estimating these figures (see Section 1.5 of this manual). The SCS uses the accepted rainfall peak discharge calculation methodology from 'Australian Rainfall and Runoff' (Pilgrim, 2007).

Since it is not reasonable to expect structures to last indefinitely, or handle the heaviest probable storm, an appropriate design return period for a structure should be selected. This design return period is related to the acceptable probability of the structure not failing within its desired lifetime. It is selected by considering the cost of repairs or replacement and the implications of a failure; a high cost structure or one that would cause serious damage through failure should be designed using a longer return period. Commonly used return periods for various types of soil conservation works are:

- contour banks 5 years
- diversion banks 10 years
- watercourses 15-20 years
- dams 20-50 years.

These return periods are calculated for the long-term viability of the structure, and should not be confused with the short-term return periods for temporary structures used during construction, such as detailed in Landcom's 'Managing Urban Stormwater: Soils and Construction Vol.1 4th ed.' (2004) – also known as the 'Blue Book' Volume 1.

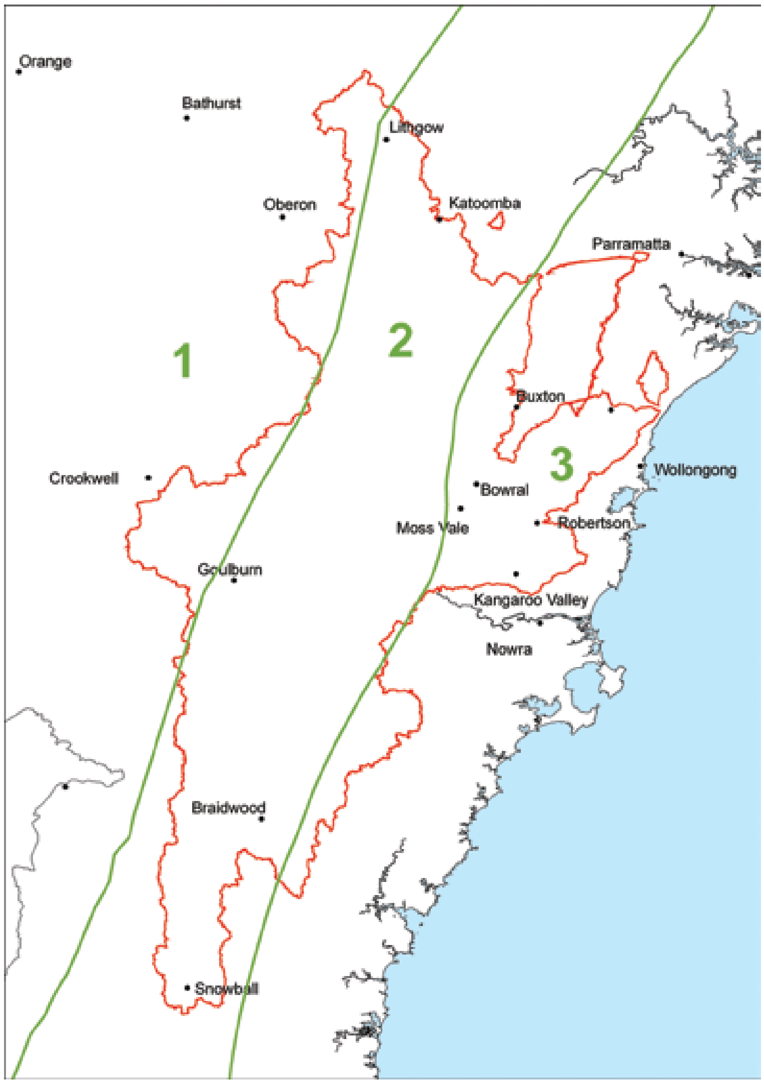
The longer the design life the higher the peak discharge the structure is likely to experience. For example, the peak discharge from the heaviest storm likely to occur on average every five years (ie a five-year return period) would be less than the peak discharge from the heaviest storm likely every 20 years.

A useful estimate of peak discharge for areas up to 260 hectares in the Sydney drinking water catchment can be determined from Figures 2.8 and 2.9. After using Figure 2.8 to determine the appropriate runoff zone for a particular location, Figure 2.9 is used to estimate the peak discharge, based on a 10-year return period. Table 2.1 provides factors to estimate peak discharges for return periods other than 10 years. Extrapolation for areas greater than 260 hectares should not be attempted using this method and figures, as this may lead to inaccuracies. It is strongly recommended that professional advice from the SCS be obtained to aid in the accurate design of any earthworks project.

Table 2.1 Conversion factor for return periods

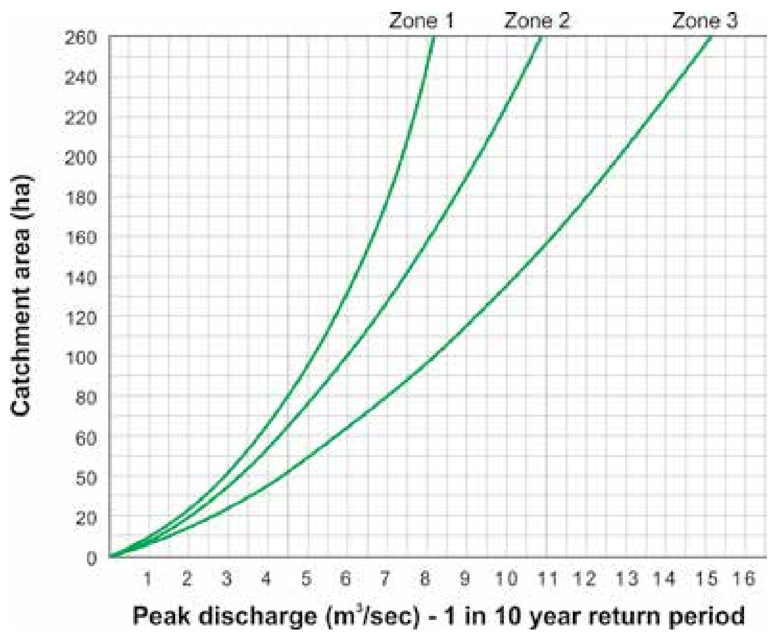
Return period (Years)	Factor
2	0.7
5	0.9
10	1.0
20	1.1
50	1.3
100	1.5

Figure 2.8
Runoff zones* for small rural catchments in the Sydney drinking water catchment



*If the property appears to be on the boundary between zones, use the more conservative (ie larger) figure

Figure 2.9
Estimate of peak discharge



Note: Increase discharge by 30% where catchments are continuously farmed or for soils that have low infiltration rates. Decrease discharge by 20% for catchments not farmed or for soils with high infiltration rates.

Chapter 3

Farm Dams

3 Farm Dams

Most farm dams are compacted earth structures built in depressions or gullies on hillsides. Sound design and construction is vital to achieving a dam that should require little maintenance and remain an asset for many years (Figure 3.1). Poor design and construction methods can lead to excessive construction costs, severe downstream erosion and a high failure rate (Figure 3.2).

Figure 3.1
A well designed and constructed dam (although stock should preferably be fenced out; SCS, undated)

Figure 3.2
A failed dam (SCS, 2010)

The information provided in this manual only applies to small earthen dams and spillways for **sediment and runoff control measures**, generally between 800 - 1,000 cubic metres (or 0.8 – 1.0 megalitres) in volume (see also Table 3.1). These smaller farm dams can be useful in controlling soil erosion by:

- reducing flows below a dam through storage of runoff
- providing a trap for sediment that could otherwise silt up watercourses or spread over the land
- blocking the water flow, for diversion in a bank to a stable outlet area
- inundating an active gully head or area of severe erosion with stored runoff water.

The manual does not focus on larger structures or dams that have the primary purpose of providing clean water supply for stock or homesteads. Professional advice should be sought when proposing these kinds of structures and dams, and should be considered as one component of an integrated water management plan for a property.

3.1 Approvals and licences

Most catchment councils will require a development application to be submitted and consent to be obtained to build a farm dam – check with your local council to determine whether you need to submit an application.

Farm dams that have a maximum aggregate surface area of water of more than 0.5 hectares that are located either in or within 40 metres of a natural waterbody, wetland or environmentally sensitive area, or in an area of high water table or acid sulphate, sodic or saline soils are known as 'designated development' under the Environmental Planning and Assessment Regulation 2000, and therefore must be granted consent from local government (Local Land Services can also provide advice on dams proposed for these areas). The council may be required to consult with State government authorities such as the NSW Office of Water (NOW; part of the Department of Primary Industries) to confirm their permissibility, placement, size and construction.

All farm dams must comply with the NSW Government's Farm Dams Policy. A licence from NOW may also be required to build a farm dam if it is greater than the maximum harvestable right for the property (usually 10% of the average regional rainfall runoff from the property), or the proposed location is on a larger watercourse (ie higher order using the Strahler stream ordering system).

Dams for the control or prevention of soil erosion (gully control structures) from which no water is reticulated or pumped, and where the size of the structure is the minimum size necessary to fulfil the erosion control function, do not have to be included in a property's harvestable rights storage volume. More information is available from NOW's website www.water.nsw.gov.au, with Fact Sheets available on when a licence is required, where and to what size farm dams can be built without a licence.

Local Land Services may also need to be consulted if clearing of native vegetation is involved for farm dam construction. Some farm dams may also need to provide fish passage. Expert advice regarding dam design and location should be sought even if a licence is not required to help minimise impacts on neighbours and the environment.

3.2 Types of dams

There are many types of farm dams to choose from depending on the source of the supply, the topography of the farm and the purpose of the dam. However, the most important types of farm dams in the Sydney drinking water catchment for sediment and runoff control measures are gully (embankment) dams and hillside dams.

3.2.1 Gully (embankment) dams

A gully or embankment dam is an earth embankment, either curved or straight, built across a gully, stream or drainage depression (Figure 3.3). It sometimes presents difficulties in design and construction but is the most favoured because of the good storage to excavation (S/E) ratio ie the ratio of the volume of water stored to the volume of earth moved to build the dam. Ratios of up to 10:1 are common with well sited gully dams.

Since the dam is located in a gully there is usually no requirement to construct catch drains to increase the catchment area. A gully dam incorporates an earth spillway or channel on one side and may also have a pipe placed through the embankment to provide a gravity supply or carry trickle flows (see Section 3.7.3).

Gully dams have a significant risk of structural failure from insufficient water, excess water, bank overtopping and bank failure. They are also at risk of excessive seepage or spillway erosion, and quality design and construction are essential, especially regarding the compaction of the bank.

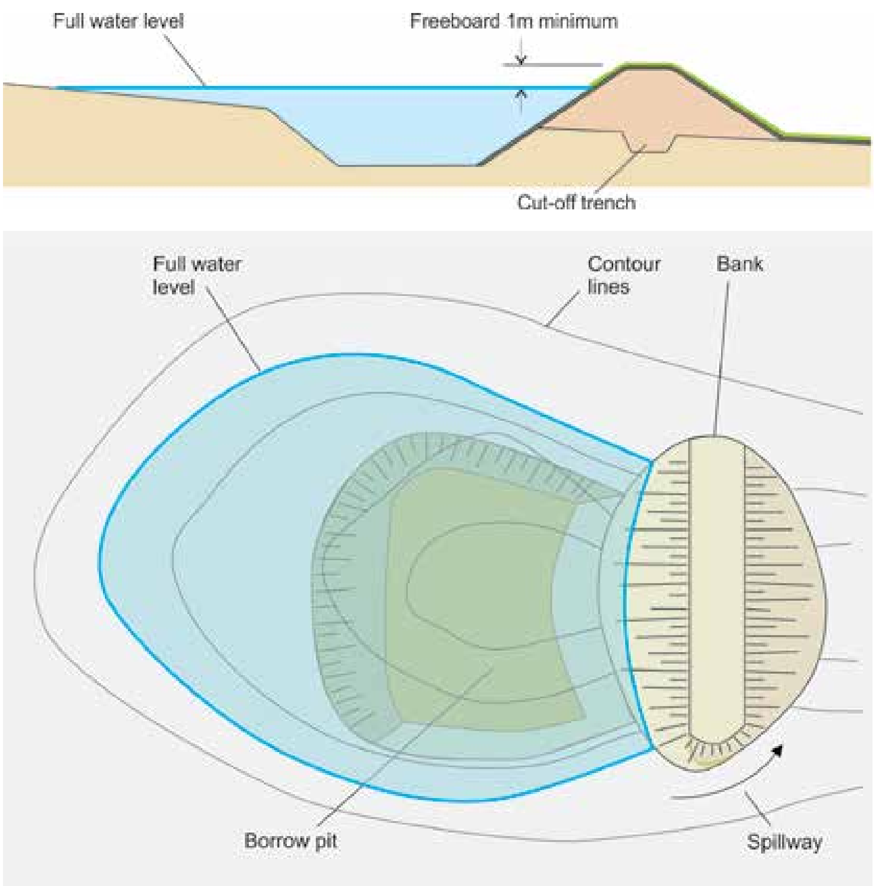


Figure 3.3
A gully dam (cross section (top) and plan view (bottom)) (after Farm Services Victoria, 2013a)

3.2.2 Hillside dams

Hillside dams for sediment and runoff control are usually selected to protect scalded areas further downhill, or to ameliorate rill or surface erosion (for water storage purposes, it is usually because no suitable gully site is available). A hillside dam is one that is built on the side of a hill that has no significant depressions. It generally has a three-sided or curved bank; 'U' shaped banks are constructed from soil materials dug from an excavation within the 'U' (Figure 3.4). Ideally the excavation will be fully contained within the water storage area of the dam. All hillside dams must have a spillway.

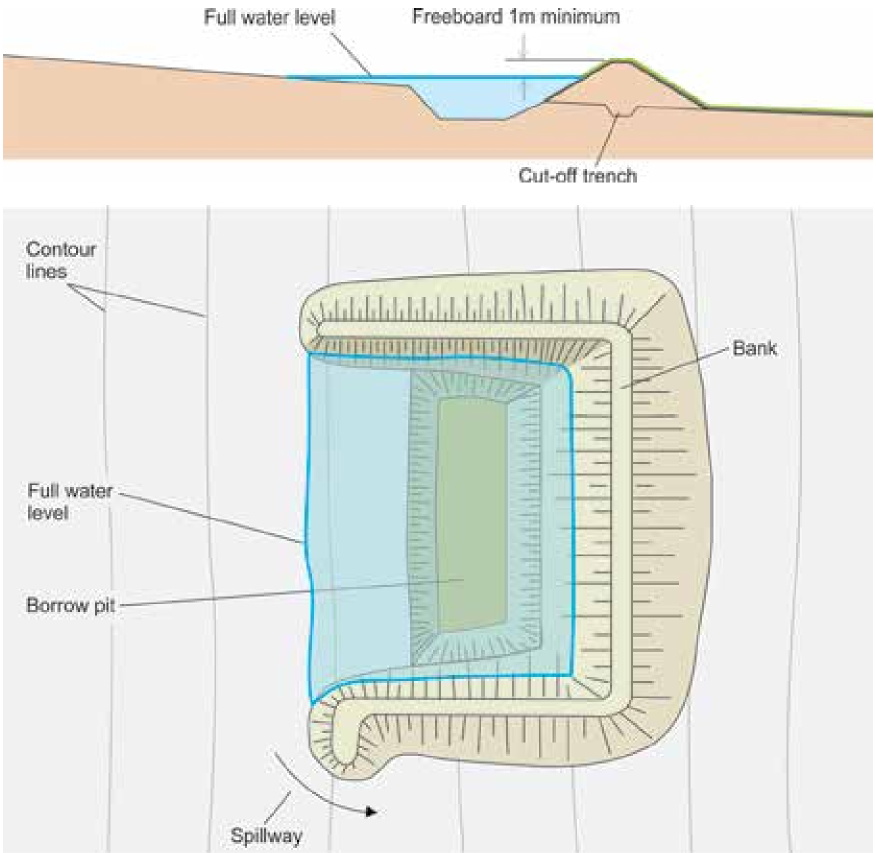


Figure 3.4
A hillside dam (cross section (top) and plan view (bottom)) (after Farm Services Victoria, 2013a)

As the slope increases the S/E ratio also increases, until the volume of earth in the excavation equals that required to build the embankment. The ratio then decreases with increasing slope as more earth needs to be excavated to achieve the embankment specifications.

They are the most important dam type in the drinking water catchment for sediment and runoff control.

3.3 Dam components

Any farm dam includes the following components:

- the excavation
- the embankment
- the outlet channel or spillway
- the cut off trench.

3.3.1 The excavation

The excavation provides the storage reservoir at the same time as providing soil for the embankment and ensuring a good depth of water. It is important that the excavation is deep enough to reach the clay soils that are suitable for sealing the dam. For small farm dams, the excavation should occur adjacent to the embankment and completely within the area to be covered by the water.

3.3.2 The embankment

The embankment should be stable, well compacted and of sufficient width and height above top water level. It is usually constructed using the subsoil sourced from the adjacent excavation. This soil generally has a higher clay content than the topsoil and is therefore more suitable. Using unsuitable material to construct the embankment may lead to tunnel erosion and failure. This type of homogeneous embankment is common for small farm dams (Figure 3.5).

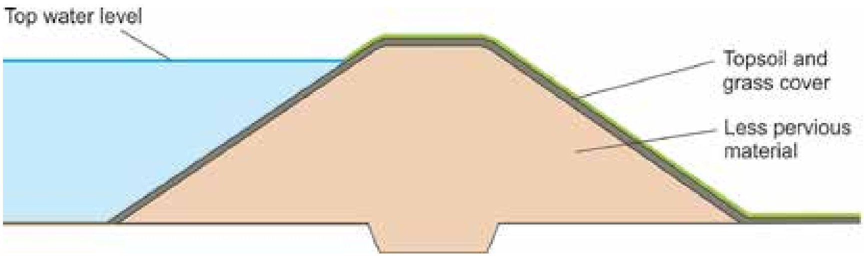


Figure 3.5
Homogenous embankment – the material is all the same

Zoned embankments (Figures 3.6(a) and (b)), where a core of impervious material (usually clay) is incorporated, are the most stable type of embankment and are more resistant to cracking and soil movement. They can be constructed with steeper batter grades reducing the earth volumes compared with homogeneous embankments. They are, however, more difficult to construct and not normally used for small farm dams.

A clay core can also be used if there is not enough suitable material at the excavation area to build a homogenous clay embankment. In these cases, the clay core is used to provide the impermeable barrier and the balance of the material in the embankment provides the structural stability (Yiasoumi and O'Connor, 2009).

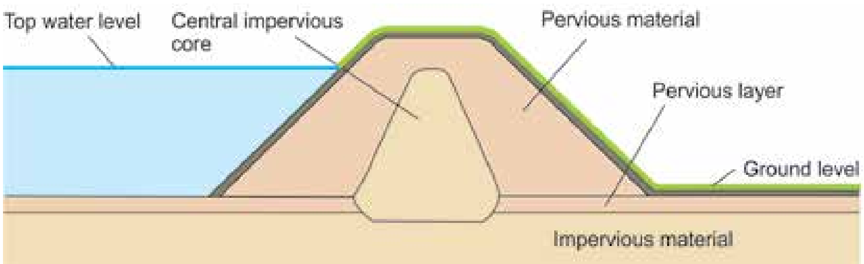


Figure 3.6(a)
Zoned embankment – central core (cross section)

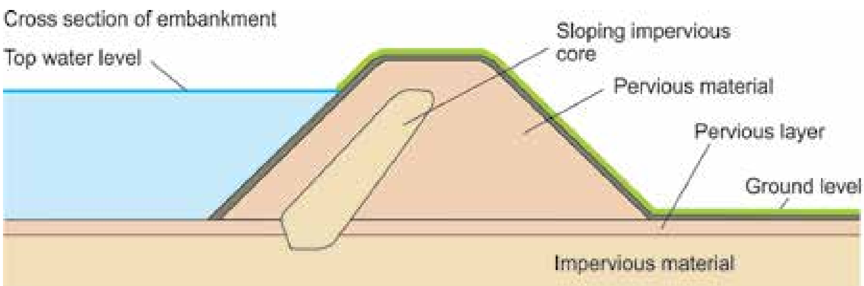


Figure 3.6(b)
Zoned embankment – sloping core (cross section)

A diaphragm embankment (Figure 3.7) is used when the amount of clay available at the site to construct an impervious core is limited or is only encountered at depth in the excavation. This is a common problem with gully sites. The bulk of the embankment is constructed from pervious material and a layer or diaphragm of material with a 20-40% clay content is placed on the upstream batter to provide an impervious section. Placing another pervious layer such as topsoil over the diaphragm can reduce problems of the diaphragm cracking when the water level subsides.

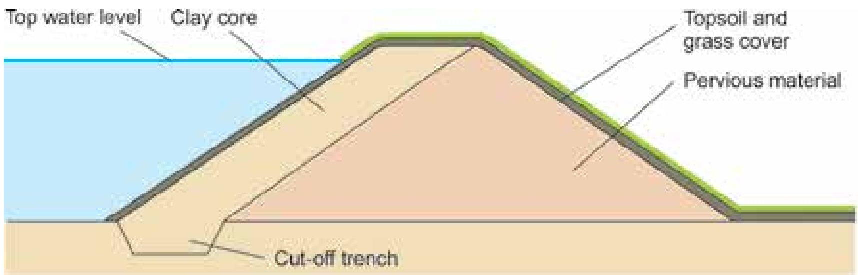


Figure 3.7
Diaphragm embankment

Regardless of the type of embankment proposed, it must:

- not allow excessive seepage of water
- be high enough so as not to be overtopped (incorporating a freeboard of at least one metre)
- be strong enough to hold the water resting against it.

3.3.3 The outlet channel or spillway

Spillways are used to pass floodwater around the dam that would otherwise go over the embankment or erode a new channel around the embankment, reducing erosion damage and helping to prevent dam failure. Most farm dams have a grass-lined earth spillway, but they can also be concrete-lined, cut into stable rock, or made of larger, properly interlocked rocks. All dams **must** have a spillway and an outlet channel.

Spillways may also need to incorporate a channel to take the excess flows from the dam, and a stable disposal area. The channel should have a flat grade and be wide enough to ensure the peak flow will not be more than 500 mm in depth. To provide for adequate freeboard, the bottom of the spillway channel must be a minimum of one metre lower than the crest level of the dam embankment. The disposal area should be a broad, low sloped area with no existing erosion or vertical drops, and with good groundcover. A grade of 0.2% (ie a two millimetre drop for every one metre of length) is typical to ensure that scouring of the spillway is minimised. Detailed sizing information is given in Section 3.5.2 of this manual.

3.3.4 Cut-off trenches

One method to reduce water loss through seepage is to build a cut-off trench along the entire length of the embankment (Figure 3.8). This provides a zone of relatively low permeability compared with the natural soil. The trench should be cut at least 600 mm into impervious soil and backfilled with good clay that is thoroughly compacted (Yiasoumi and O'Connor, 2009).

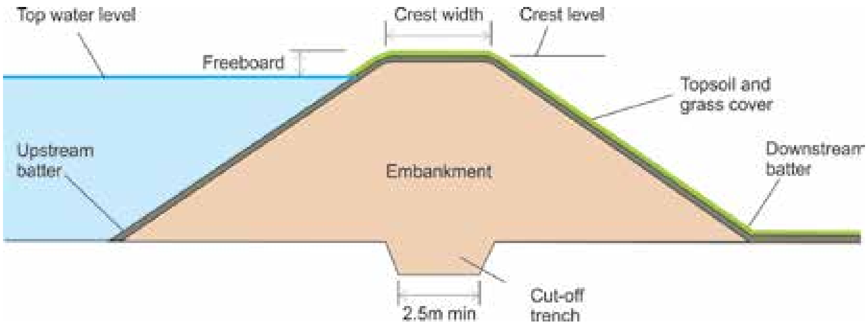


Figure 3.8
Cross section of a typical dam showing the cut-off trench

3.4 Farm dam planning

Choosing an earthmoving contractor who specialises in dam construction or has experience and a good work record will reduce the chances of problems occurring during and after the building of the dam. Advice should also be sought from the NSW Soil Conservation Service (see Section 1.5).

Farm dam planning and design is critical to reducing farm dam failure, and should involve the following steps:

- estimation of the volume and rate (peak discharge) of runoff from the catchment to ensure that sufficient capacity can be provided and an adequate spillway constructed. With large catchments, the runoff stored in the dam becomes insignificant compared with total runoff – the spillway is required to carry most of the runoff and failure is common
- selection of the dam site and shape, considering factors such as S/E ratio, ground slope, stability of spillway and material available
- soil testing for material suitability
- determination of the specifications for the dam borrow area, base widths, top width, batter grades, freeboard and spillway.

3.4.1 Site selection

Ground slope is important when selecting dam sites as it determines how large the embankment will need to be, and how much earth will be available from the excavation for the embankment.

There are significant areas of steep slopes in the drinking water catchment. The best S/E ratio can be achieved by damming a narrow gully where the upstream gully widens and the slope of the gully floor is low eg less than 2%. The higher the ratio the more economically efficient the storage is, implying low capital cost per unit volume of water stored.

- On flat sites the excavation volume is equal to the storage volume and there is sufficient material for the embankment (Figure 3.9).

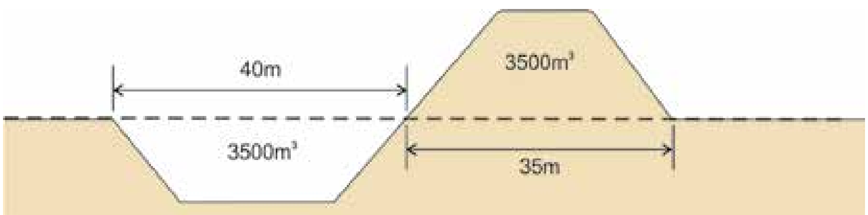


Figure 3.9
Flat site – embankment and excavation balanced

- On sloping sites the same storage volume will provide less volume of material for the embankment, and as the slope increases the material available from the excavation may not be sufficient to reach the standard embankment specifications for freeboard, top width and batter grade. This can be overcome by extending the excavation area to gain more material for the embankment (Figure 3.10).

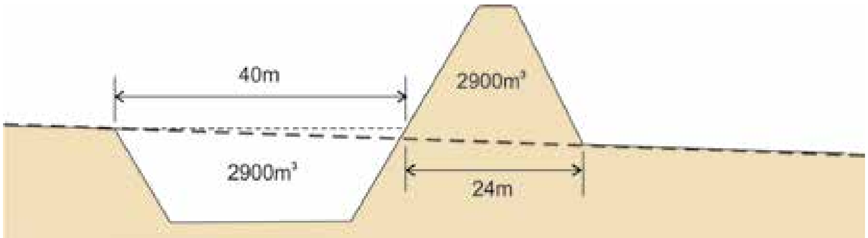


Figure 3.10
Sloping site – decreased earth volumes as slope increases

Excavating above the top water line does not provide additional stored water and results in a poor S/E ratio. More importantly, when the dam is full the inlet batter is often not covered in water, causing it to erode. The size of the embankment needed to cover the inlet batter with water increases significantly with steeper slopes (Figure 3.11). This also increases the costs.

If exposing the inlet batter cannot be avoided during excavation due to the slope, then covering the exposed batter with topsoil and establishing ground cover is recommended. This up-front extra cost will reduce the desilting costs in the future.

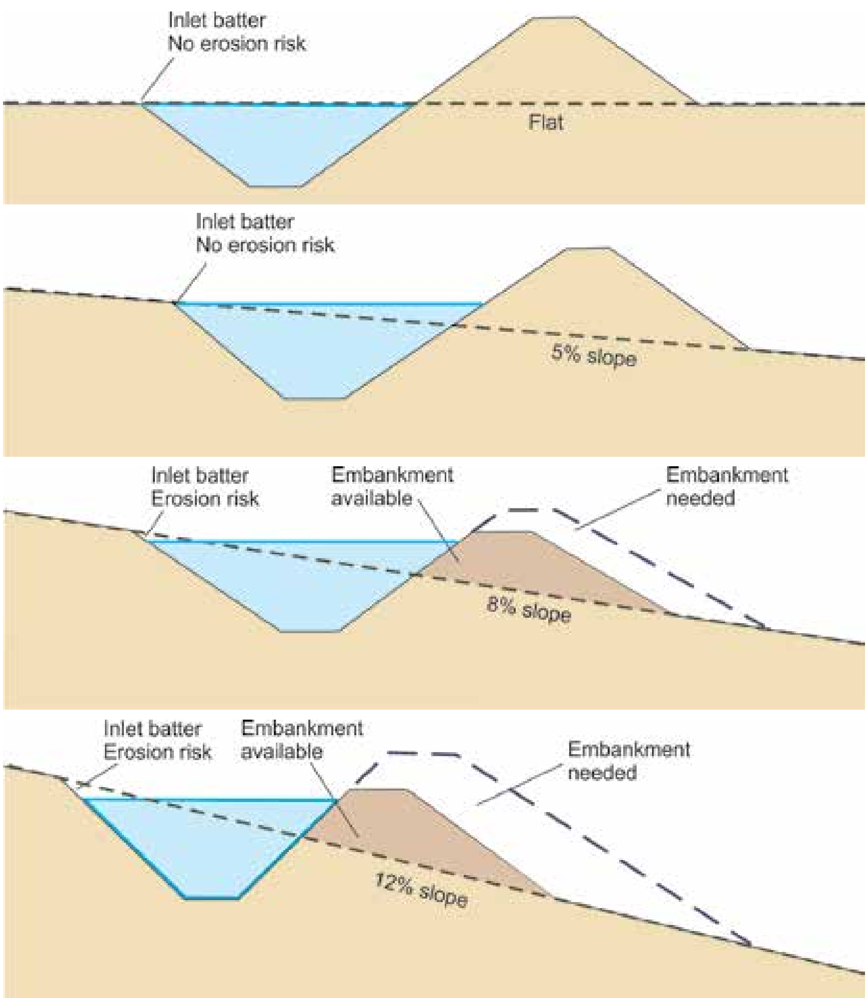
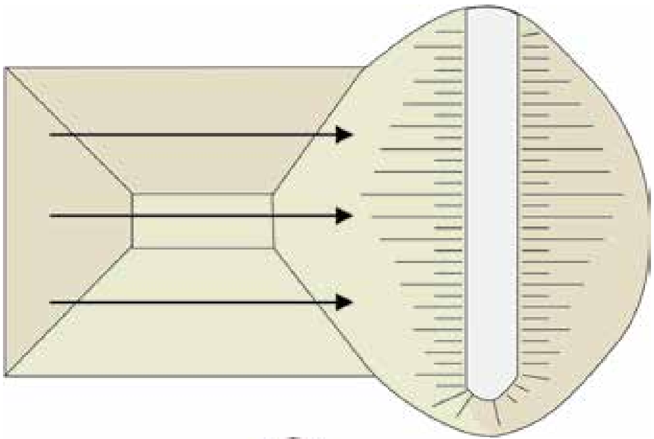
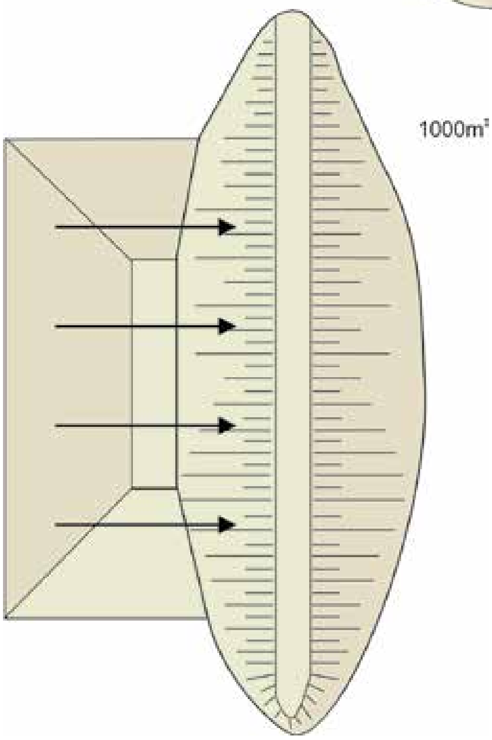


Figure 3.11
Effect of slope on dam construction

- The average push distance (how far a dozer has to 'push' a load of earth) for a three-sided hillside square dam on a sloping site is marginally longer than the same size dam on a flat site. This is because the sloping ground requires more material to construct a higher embankment than that required on flat ground. However, the ground slope encountered for hillside dams requires less earth to be excavated to achieve the same capacity as on a flat site – since some of the capacity is held above the original ground surface on the sloping site.
- When planning gully dams the objective is to locate the embankment where the best S/E ratio can be achieved. High embankments generally produce good S/E ratios but are usually associated with restricted width in the excavation area. This results in longer, less efficient pushing distances (Figure 3.12). Figure 3.12 also shows that lower embankments of the same volume can be constructed with shorter pushes, which is more efficient. This simply means that the higher embankment with the better S/E ratio will be more expensive to build on the basis of cost per cubic metre of earth moved but cheaper in terms of cost per cubic metre of stored water.



In a narrow deep gully, the required pushes add to the cost of earthmoving



In a wide, shallow gully, the required pushes reduce the cost of earthmoving

Figure 3.12
A higher embankment usually requires a longer push distance because of the confined nature of the site (top); a lower embankment usually has shorter pushes (bottom)

- As the spillway is the area responsible for the majority of failures with farm dams, it is critical that it is located on stable, erosion resistant soil, has a vigorous cover of grass or is armoured, does not have any overfalls or irregularities, and has sufficient width to spread the flow to achieve a non-erosive velocity. The designed spillway must be able to pass the design peak discharge through the outlet without causing scouring to the channel. The availability of a safe spillway is the number one factor in selecting a site for any dam.
- Dams and their associated spillways should not be located in the vicinity of existing or planned domestic on-site wastewater treatment systems and effluent disposal areas, as spillways can act as a transport pathway for pollutants, and nutrients from the effluent may cause algal blooms in the dam.

3.4.2 Dam shape

To reduce the size of the embankment required and ensure the excavation is covered by water when full, the shape of the dam can be varied. On lower slopes the dam should be square; on steeper slopes the dam should be rectangular, being longer across the slope, and shorter up and down the slope.

The embankment crest level must be built higher than the design level to allow for settlement of the soil and to avoid the embankment settling to a level where it could be overtopped by water and fail. An allowance of an additional 5% of the height of the embankment (along its length) is generally sufficient to cater for settlement when well-constructed clay dam embankments are constructed (Yiasoumi and O'Connor, 2009). For gully dams where the embankment is to be higher than three metres, the SCS places an extra 10% of the height to allow for settlement.

3.4.3 Soil sampling and testing

Site investigations must be carried out to ensure there is suitable soil in sufficient quantities to seal the excavation and embankment.

For larger dams (eg where the depth of water will be higher than four metres against the wall), soil tests should be conducted by an accredited soil testing laboratory.

There are a number of simple field tests that can be carried out to identify problem soils for smaller dams. These tests include:

- the Emerson Aggregate Test (Figure 3.13)
- the ribbon test for moisture content, where a moist rolled thread of soil is bent into a circle (approximately five centimetres in diameter; Figure 3.14a). If the thread does not break, it should have enough clay to form a seal
- if the thread breaks, the soil should be squeezed together again and worked into a flat ribbon about 30 millimetres long (the hand bolus test; Figure 3.14b). If this cannot be done, the soil is probably not suitable and will leak.

It is particularly important to identify soils that are likely to tunnel where water is stored against the wall above ground level. Dispersible (sodic or tunnelling) soils lack cohesive strength when wet, and will separate and move about freely in water. They can be identified in the field by a wormy appearance and are often bleached grey or yellow, and a cloud will appear around a clod of soil in a dish of distilled water. However, some dispersion is necessary to help form a seal in earth dams as the fine particles move to block voids in the face of the dam.

Slaking soils will break down in water without cloudiness (unless the soil is also dispersible).They do not easily form a seal and are therefore likely to leak. Dispersion, slaking and detachment of soil particles are all components of the process of the breakdown of soil structure.

Figure 3.13a shows a clod of soil first inserted in the water and allowed to stand for at least 30 minutes (up to two hours). Figure 3.13b indicates a highly aggregated (slaking) soil that would probably result in dam leakage. Figure 3.13c corresponds to a soil with the slight dispersive characteristics required to aid in the sealing of a dam as it fills with water. The soil in Figure 3.13d is highly dispersive and will tunnel and breach the dam.

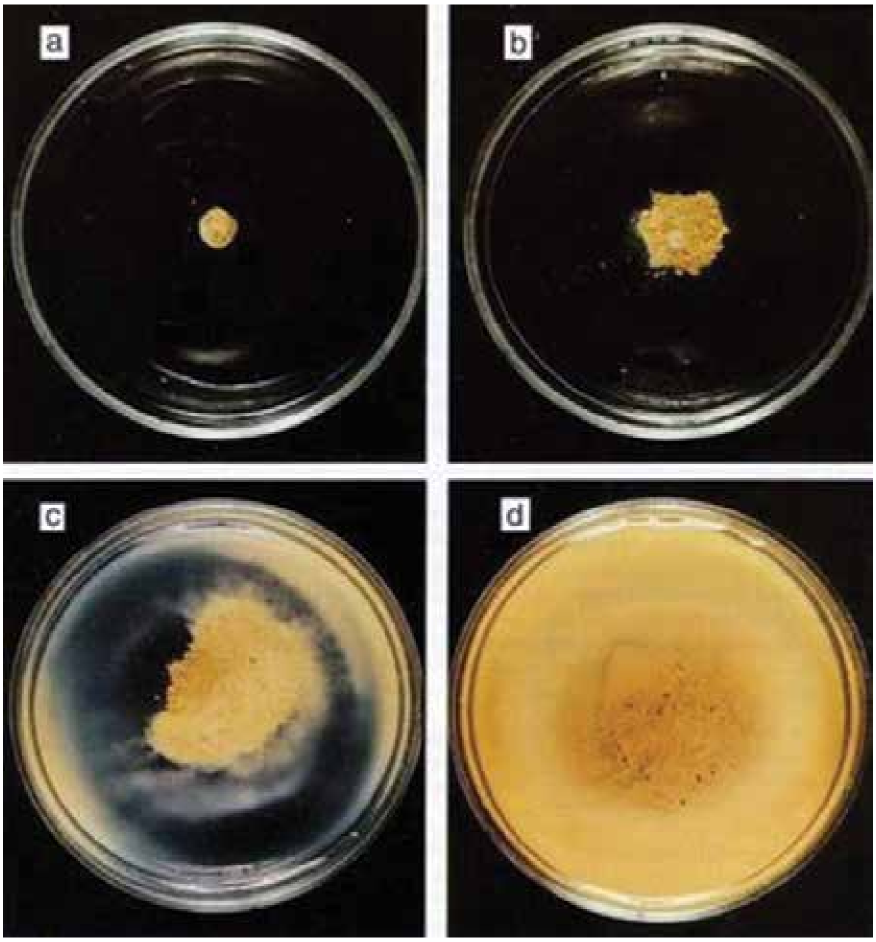
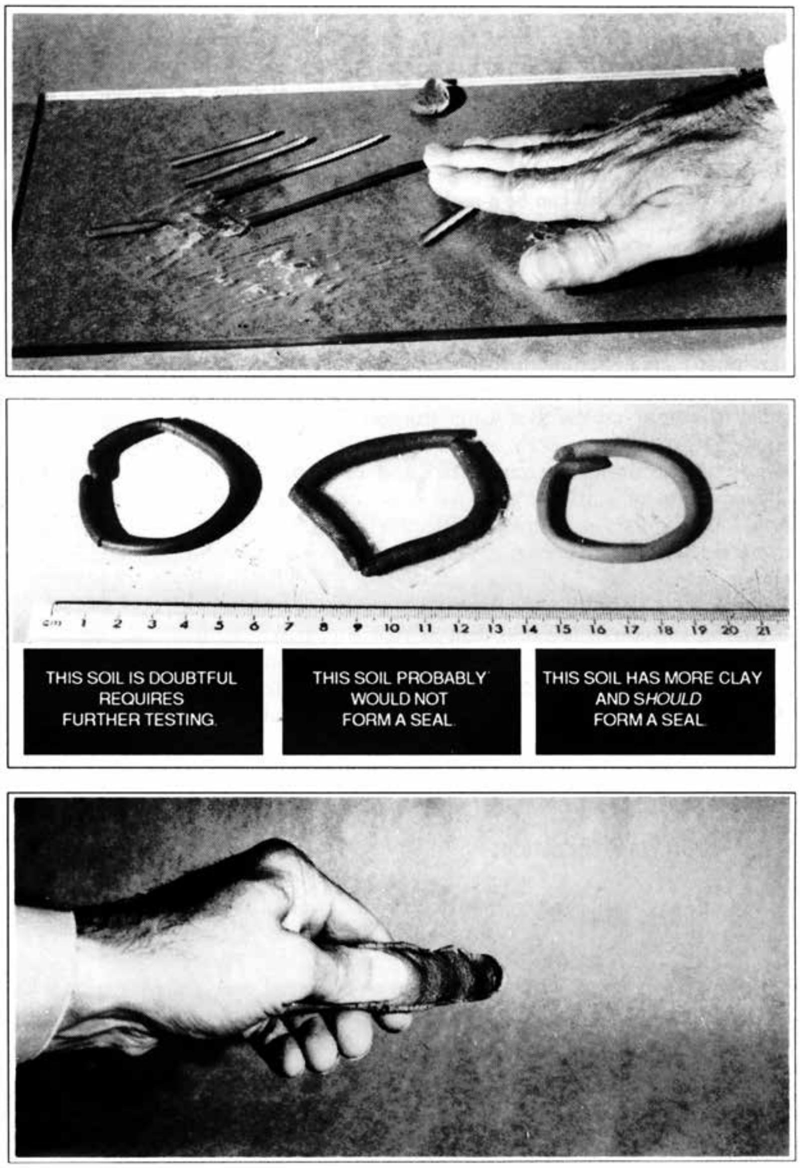


Figure 3.13
Emerson Aggregate Test for dispersible soils – if the soil loses shape and the water becomes cloudy, it is dispersible (SCS, undated)



(a)

(b)

Figure 3.14
Test for clay content
(SCS, 1991)

Other problem soils include:

- poorly graded soils, which lack the correct mix of sand, silt and clay to provide a seal
- the presence of gravel or sand seams through dams, which are common in tablelands areas, and where dams are constructed in old flow lines. It is essential that all seams be dug out and plugged with a minimum of 600mm of clay in these instances.

The type and size of a proposed dam will determine the amount and location of soil investigations. The investigations required for an excavated dam should be confined to the excavation area, with test holes ideally extending to the depth of the excavation. If the test holes identify a layer of impervious material at least 1.5 metres thick near the top this will generally provide enough earth to line the excavation (Figure 3.15). Hillside dams require the same investigations, however a thicker layer of impervious material is required to ensure the excavation and the embankment can be sealed.

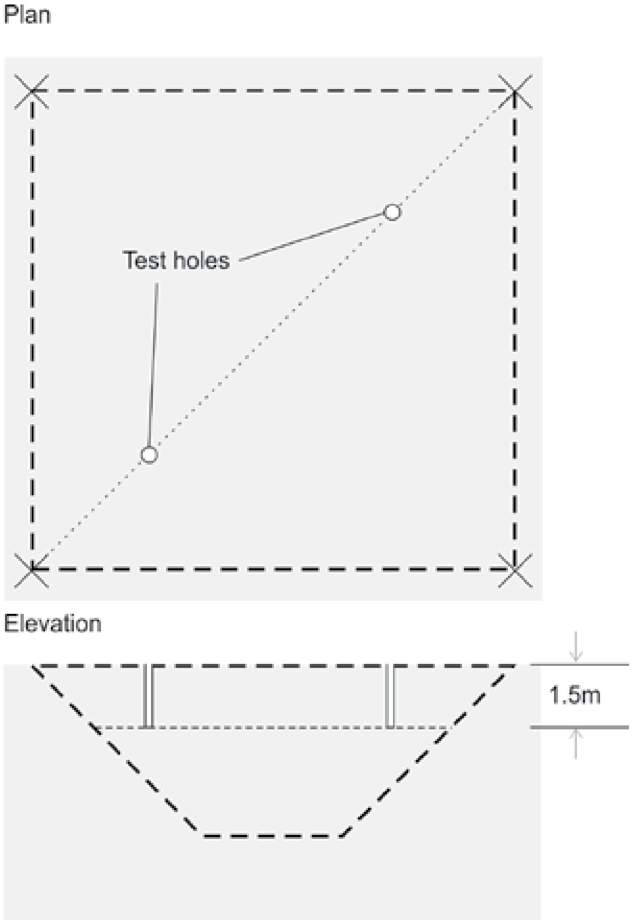


Figure 3.15
Location and depth of test holes for small excavated dams

Investigations for gully dams require a greater number of test holes in different locations:

- Under the base of the proposed embankment – either along the centre line for central core embankments, or along the base line of the embankment on the upstream batter for diaphragm embankments (Figure 3.16). The cut-off foundation should have continuous clay along the length of the embankment to a point level with the proposed top water level of the dam.

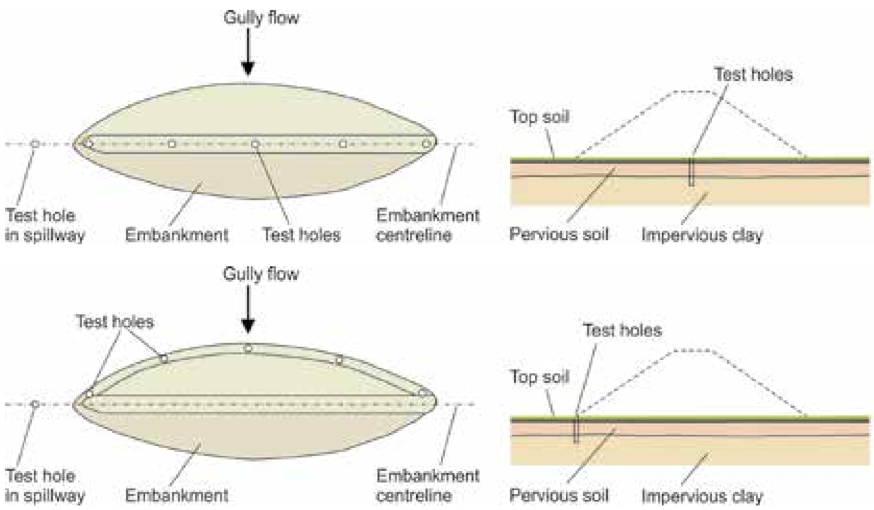


Figure 3.16
Test holes for gully embankments – central core embankments (top) and diaphragm embankment (bottom)

- In the excavation area (Figure 3.17) – investigate the quantity of impermeable soil in the same way as for a hillside dam.

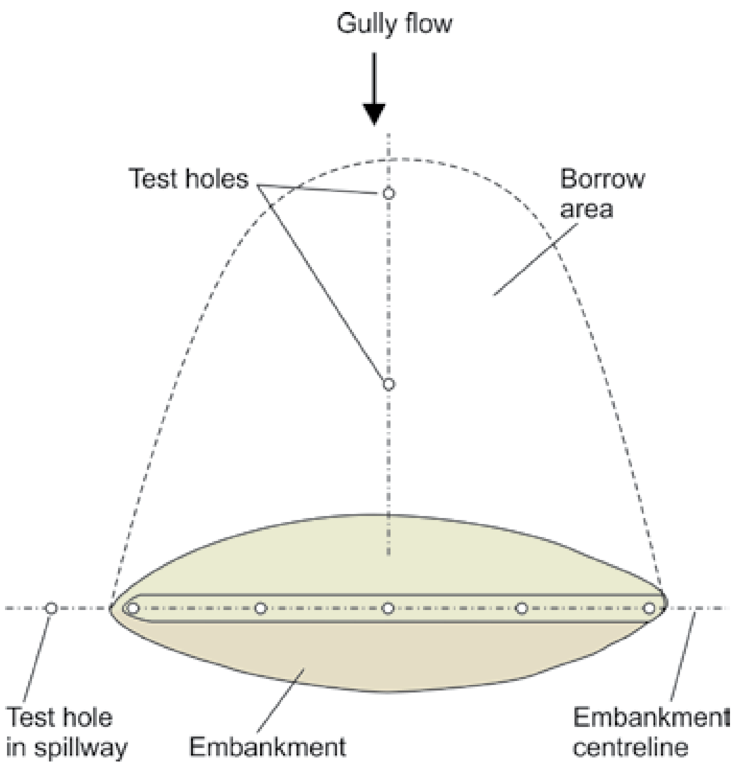


Figure 3.17
Test holes for gully dam excavation

3.4.4 Soil profiles in excavations

Soil profiles will vary for each site, posing different problems and requiring differing construction techniques.

Figure 3.18 shows a typical soil profile found on both level sites and hillsides. Layers A and B in this profile will not hold water, however water can be stored in layer C. The upper layer of pervious material should be removed and replaced with an impervious layer from the excavation (Figure 3.19). The recommended thickness of the impervious layer will vary depending on the quality of the material. As a guide, a minimum of 600mm should be layered and compacted to form the required batter grade and prevent leakage through the surface layer.

Figure 3.18
A soil profile with one impervious layer

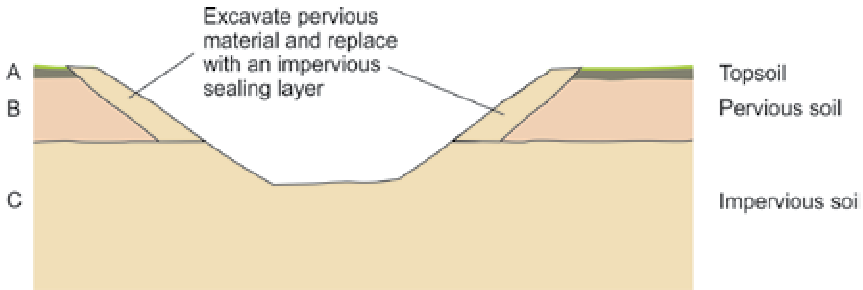


Figure 3.19
The surface pervious material is replaced to prevent seepage loss

The profile in Figure 3.20 will be able to store water due to the impervious nature of layer C. However, if the excavation continues into layer D all of the water will be lost through seepage. The same technique to place an impervious layer to prevent leakage is used where two pervious layers need to be sealed as for one. The final cross section is shown in Figure 3.21.

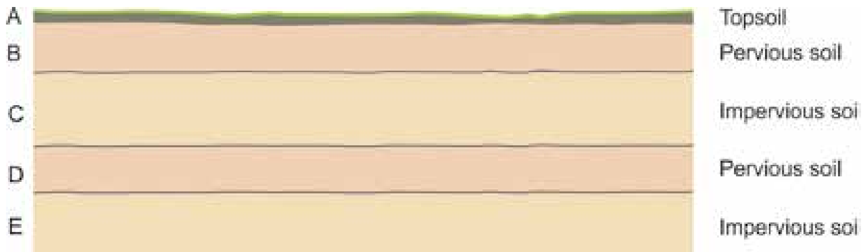


Figure 3.20
A soil profile with two pervious layers

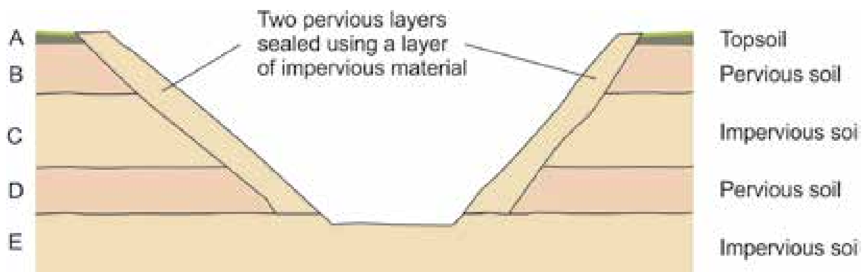


Figure 3.21
Replace two pervious layers with impervious material

Both profiles in Figures 3.19 and 3.21 can hold water successfully to ground level if the correct construction technique is used. Excavations that can cause problems are not digging deep enough to expose the required amount of sealing material, or excavating past the impervious layer into leaky (pervious material). In these cases it is necessary to bring clay in from another site to seal the excavation or to use a flexible membrane. Any clay liner must be well compacted to prevent it slipping and exposing the pervious layers underneath.

3.4.5 Soil placement

Hillside dams store water against the embankment, and correct placement of the soil followed by good compaction are essential. The placement of soil in the embankment will depend on the profile of the soil in the excavation. The main consideration is to use impervious material on the upslope segment of the embankment. The different quantities of impervious material encountered in the excavation will determine the placement patterns in each embankment. Figure 3.22 illustrates soil placement patterns for differing depths of pervious material.

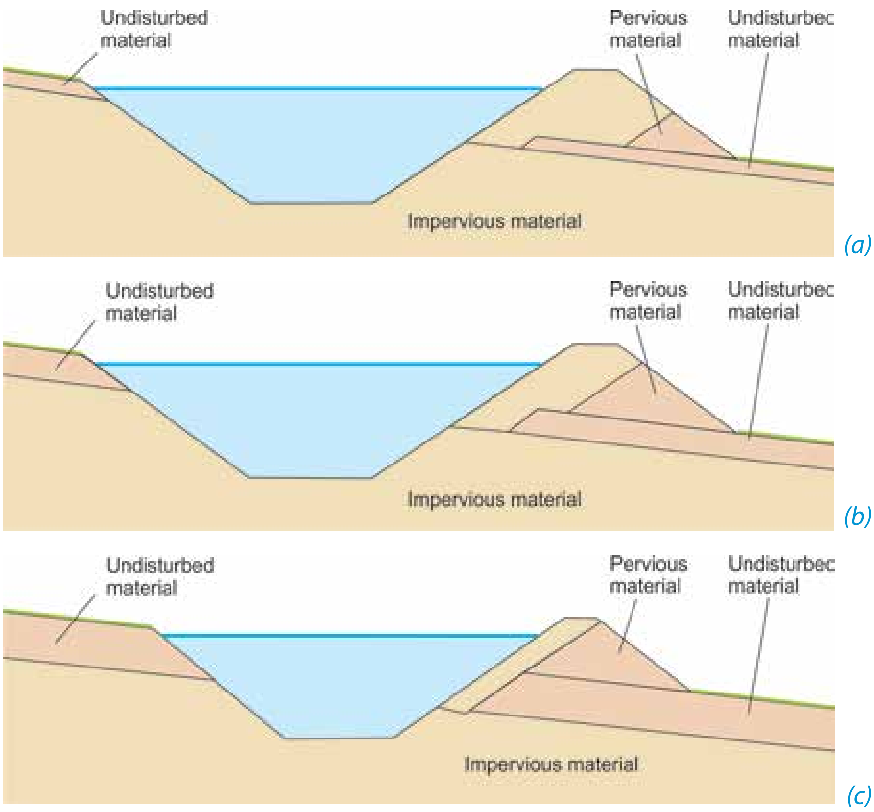


Figure 3.22
Soil placement for: (a) a shallow pervious layer, (b) a thicker pervious layer, and (c) where the majority of material is pervious

Soil profiles can vary greatly at gully dam sites. Generally sand, silt and gravel have been deposited in the gully line at various depths and these are often the materials that have to be used to construct the dam. Gullies require a thorough investigation to reveal all the pervious and impervious layers. All pervious layers should be intercepted by an impervious cut-off to seal the gully dam and embankment. Figures 3.23(a-d) show examples of gully site soil profiles that can be encountered.

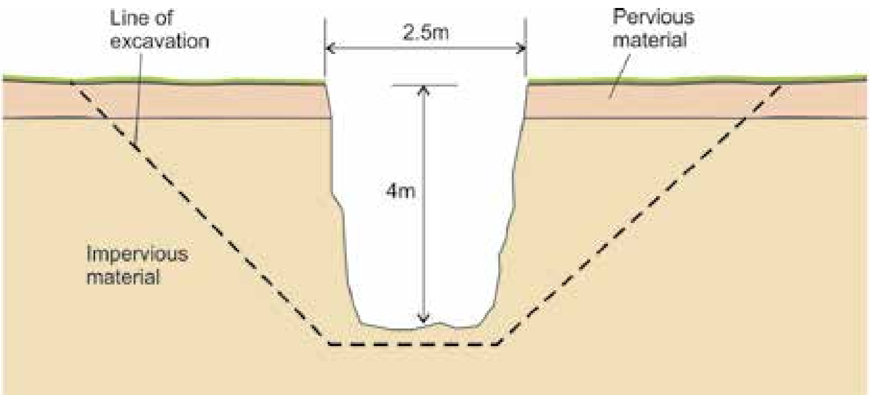


Figure 3.23(a)
The soil profile in a narrow vertical sided gully with a flat bottom

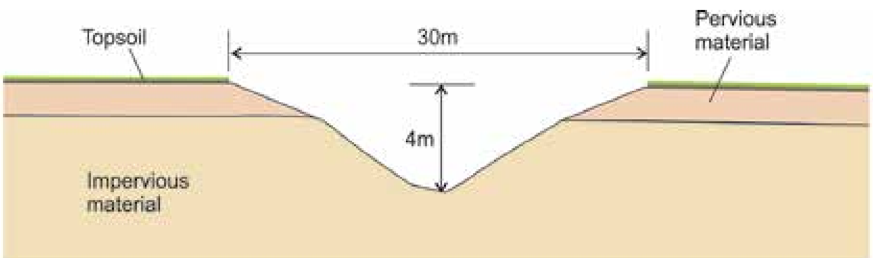


Figure 3.23(b)
The soil profile in a V-shaped gully

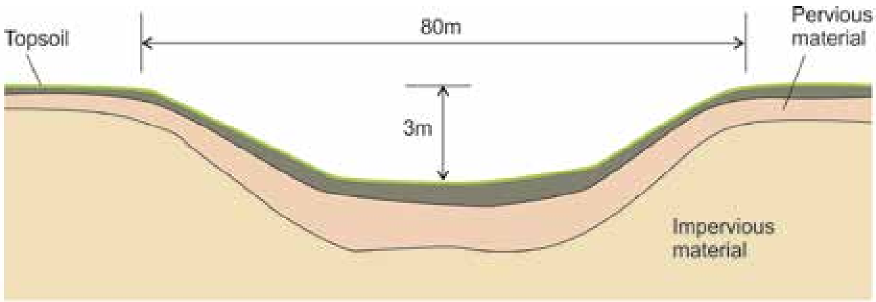


Figure 3.23(c)
The soil profile in a wide shallow gully

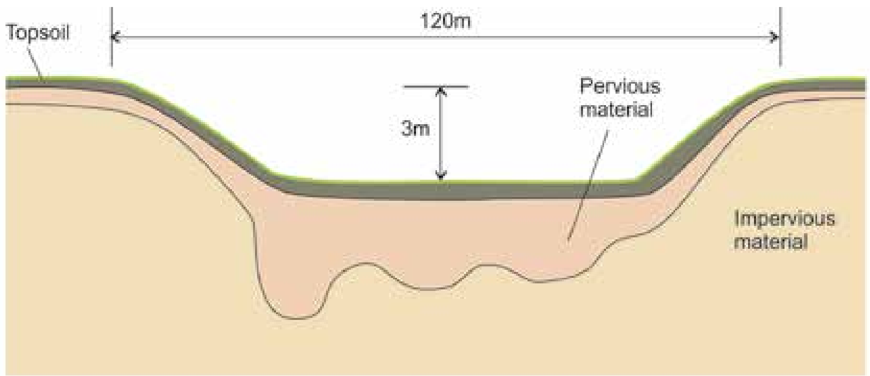


Figure 3.23(d)
The soil profile in a wide gully with porous material deposited over an irregular surface

3.4.6 Soil compaction

Soil compaction helps to provide structural stability to the embankment by increasing the density of the soil. Good compaction is essential in minimising seepage, the risk of tunnel failure as well as excessive settlement of the embankment over time. This is especially important for gully and hillside dams where the embankment itself creates the dam pondage.

The soil used to backfill the cut-off trench and to form the embankment should be placed in layers, with each layer moistened (if too dry) and thoroughly compacted before the next layer is placed. The soil should not be too wet or too dry when being compacted.

The amount of effort required to compact the soil varies according to type of equipment used and the number of passes of the machine, the thickness of the layer being compacted, and the soil type and texture eg sandy and gravelly soils can be compacted to a higher density with less effort than the plastic clay soils.

3.4.7 Topsoil

The embankment should be completed with 100 mm or more of compacted topsoil and the spillway should be cut about 100 mm below the top water level and built back to that level with topsoil. If the stripped areas do not provide enough topsoil, then it should be imported. The embankment, spillway and spillway outlet should then be planted with a good holding grass (Yiasoumi and O'Connor, 2009).

3.5 Dam specifications

3.5.1 Batter grades

The most common (and recommended minimum) batter grade for dams is 1:3 (V:H), which is suited to safe bulldozer operation. For dam structural integrity a minimum batter grade of 1:3 also provides a level of protection against dam failures through the emergence of the seepage (phreatic) line on the downstream face. The aim is to make the wall thick enough so that seepage through the dam wall does not appear in the downstream face of the wall at a point above ground level (see Figure 3.37).

On flatter sites, it is advantageous to flatten the batter grades and reduce the wall height. For a given volume, however, this will lead to an increase in the required surface area and therefore an increase in evaporation losses. Any dam has a theoretical maximum depth depending on the batter grade, beyond which construction is not possible with bulldozers.

For a constant grade, a change in the slope of the ground will shorten or lengthen the batter (Figure 3.24); for construction on steep slopes, the downstream batter should be extended to achieve a 1:3 batter grade.

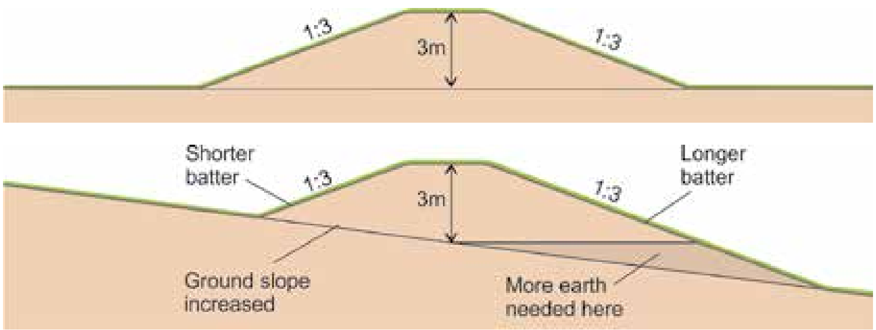


Figure 3.24
Effect of a slope on batter length – on steeper slopes the upstream batter will be shorter and the downstream batter will be longer

3.5.2 Dam dimensions

The storage volume should be calculated first to ensure the storage to excavation (S/E) ratio is cost effective. The volume can be easily determined for regular shaped storages such as square, rectangular or circular dams, using the formula:

$$V = \frac{D(A + 4M + B)}{6}$$

where V = volume (m^3)
A = the top area (m^2)
B = the bottom area (m^2)
M = the area at ½ the depth (m^2)
D = depth (m)

Table 3.1 should be used to determine the volume of square and rectangular storages. Calculating the volume of a proposed embankment during the planning stage is also important to avoid costly modifications during construction. Table 3.2 can be used, along with embankment height and better grades, to calculate the volume of a wall, particularly across an irregularly shaped gully, noting that in such gullies the dam depth will vary from one side of the dam to the other.

Table 3.1 – Volume (m^3) of square and rectangular storages

(Numbers in brackets are the depth in metres. For rectangular storages assume the lowest number)

Width (m)	20 (3)	24 (3.5)	28 (4)	32 (4.5)	36 (5)
20 (3)	440	580	700	840	980
24 (3.5)	580	760	960		
28 (4)	700	960			
32 (4.5)	840				
36 (5)	980				

Table 3.2 – Volume (m^3) of earth in wall in one metre sections (three metre top width)

	Batter Grade				
Height (m)	**1:3 – 1:3**	**1:3 – 1:3.5**	**1:3.5 – 1:3.5**	**1:3.5 – 1:4**	**1:4 – 1:4**
1.00	6.00	6.25	6.50	6.75	7.00
1.20	7.92	8.27	8.62	8.99	9.36
1.40	10.08	10.54	11.00	11.50	12.00
1.60	12.46	13.09	13.73	14.36	15.00
1.80	15.10	15.68	16.72	17.53	18.34
2.00	18.00	19.00	20.00	21.00	22.00
2.20	21.12	22.33	23.54	24.75	25.96
2.40	24.48	25.92	27.36	28.80	30.24
2.60	28.08	29.75	31.46	33.15	34.84
2.80	31.92	33.88	35.84	37.80	39.76
3.00	36.00	38.25	40.50	42.75	45.00

The top of the embankment (the **crest**) must have sufficient width to prevent the dam failing when it is filled to the surcharge level ie during peak inflow. Minimum top widths for various wall heights are given in Table 3.3:

Table 3.3 – Minimum embankment top widths

Height of Wall (m)	Top Width (m)
Up to 2	2.5
2.1 – 3.0	2.8
3.1 – 4.0	3.0

The **base width** can be determined from the formula

$B = T + H (X + Y)$ where B = base width

T = top width

H = height of wall

X = upstream batter (1:X)

Y = downstream batter (1:Y)

The dimensions are shown in Figure 3.25.

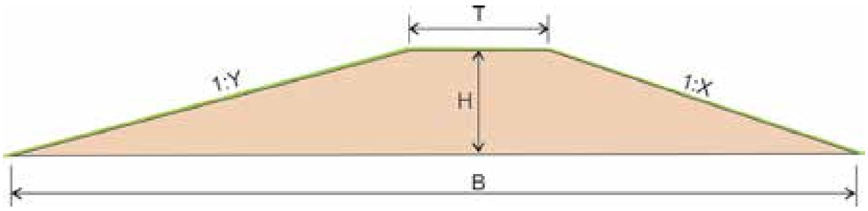


Figure 3.25
Base width of an embankment

For sloping sites, the downslope batter dimensions can be calculated by multiplying the calculated base width (B) by the relevant downslope correction factor in Table 3.4.

Table 3.4 – Downslope correction factors (CET, 2012)

Slope (%)^	Downslope correction factor
0	1.00
1	1.03
2	1.06
3	1.10
4	1.14
5	1.18
6	1.22
7	1.27
8	1.32
9	1.38
10	1.44
11	1.51
12	1.57

^ Note that design and construction of a dam on slopes of greater than 8% is ***not*** *recommended due to exposure of the inlet batter, the required extra earth volume required for the embankment, and the reduced storage volume (an S/E ratio of less than 1). Refer to Figure 3.11.*

Freeboard (Figure 3.26) is the height of the embankment above the top water level (or spillway level). The freeboard must be sufficient to prevent water overtopping the embankment when the spillway is working and/or when winds cause waves on the storage. The minimum freeboard for small farm dams is one metre.

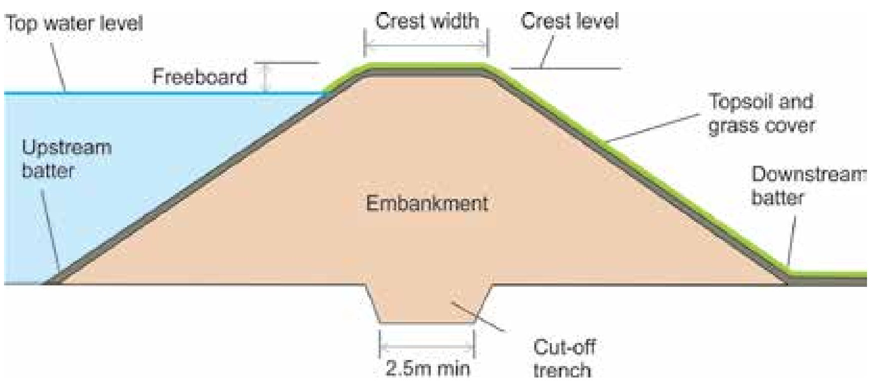


Figure 3.26
Cross section of a typical dam showing the freeboard

The spillway is designed and constructed in a similar manner to a bank outlet. A level sill is constructed to spill flows onto a stable, grassed area. The width of the spillway is calculated to ensure that flow velocities down the spill area are kept below an erosive level (1.2 – 1.5 metres a second). Table 3.5 is used to determine spillway widths:

spillway width = spillway coefficient x peak discharge

For example, if the peak discharge from a dam is 6.5 m^3/s, and the slope of the grassed area below the spillway is 3%, then, assuming a safe velocity of 1.2 m/s on the spill area[1], the spillway coefficient will be 4.9 m of width / 1m^3 /sec of flow (**highlighted** in Table 3.5). Therefore the required spillway width is 32 metres (4.9 $m/m^3/s$ x 6.5 m^3/s).

[1] Note that this safe velocity is for a well vegetated channel (+90% grass cover) with even grade and correct width. Bare ground can only cope with flow velocities of less than 0.5 m/s before significant scouring occurs.

Table 3.5 – Coefficient for spillways (in metres per m^3/s peak discharge)

Slope below sill (%)^	Velocity of flow (m/s)*					
	1.0	1.2	1.5	1.8	2.0	2.5
1	4.0	2.9	1.9	1.4	1.0	0.7
2	5.3	4.0	2.6	1.9	1.5	1.0
3	6.7	4.9	3.2	2.3	1.9	1.3
4	7.1	5.5	3.9	2.8	2.3	1.4
5	8.3	6.4	4.5	3.1	2.6	1.7
6	9.1	6.9	4.8	3.5	2.9	1.9
7	10.0	7.5	5.2	3.7	3.1	2.0
8	11.1	8.3	5.6	4.0	3.3	2.1
10	12.5	9.2	6.7	4.7	3.6	2.4

**Velocities above 1.5 m/sec should only be used on erosion resistant soils with a dense covering of grass or other manner of stabilisation.*
^A typical grade is 0.2% (or 2mm drop per metre length) to ensure that scouring of the spillway is minimised. Slopes above 10% (8% for dispersive soils) should be armoured.

Checking for a stable spillway is essential; **if one is not available the site should be abandoned, or a rock or concrete flume should be constructed to handle the design discharge** (See Chapter 5 Flumes, Chutes and Gully Rehabilitation).

3.6 Farm dam construction

3.6.1 Construction techniques

The techniques to construct farm dams vary from site to site, however three aspects must be considered before any construction begins.

1. The principles of farm dam construction must be considered with the specific site in mind to ensure each site is treated in the appropriate way. Check for:
   - a stable, well compacted embankment of sufficient width and height above top water level to include a minimum freeboard of one metre
   - a spillway constructed to the appropriate level and dimensions to carry excess flow without damage to the embankment or spillway surface
   - the use of efficient construction techniques and equipment capability
   - knowledge of soil types, properties and degree of soil compaction required to achieve a seal
   - accurate pegging and familiarity with pegging locations
   - completion of dam in a neat and tidy condition.
2. Consideration of the proposed cross-section of the embankment, the location of the cut-off trench and clay core if incorporated, and the correct soil placement is critical for the operator to understand what is required during different stages of construction.
3. The operator must consider a mental picture of the completed farm dam, including the spillway, to ensure that only the minimum area is disturbed during site preparation, and to complete the dam to the required dimensions and specifications.

3.6.2 Steps in construction

- Accurately peg the area to clearly locate and identify the following features:
  - the centre-line of the embankment (across the narrowest part of the natural channel)
  - the upstream and downstream toes of the embankment
  - the spillway inlet and outlet widths
  - the top water level
  - the crest level
  - the extent of the excavation area and borrow pit (Yiasoumi and O'Connor, 2009).
- First clear the site of all debris and vegetation, taking care not to disturb the area below the spillway. For a gully dam, the sides must be battered back from the floor of the gully underneath the proposed embankment.
- Remove and stockpile the topsoil beyond the proposed embankment, stripping at least three metres under the embankment to prevent seepage, and to obtain sufficient topsoil for covering the entire downstream batter, the crest and the inside batter down to the top water level, if required. Ripping to a depth of 20 centimetres will make it easier to remove the topsoil. Only sufficient topsoil should be removed to cover the embankment to the depth required, with the remainder placed in the downstream toe of the embankment (Figures 3.27 and 3.28).

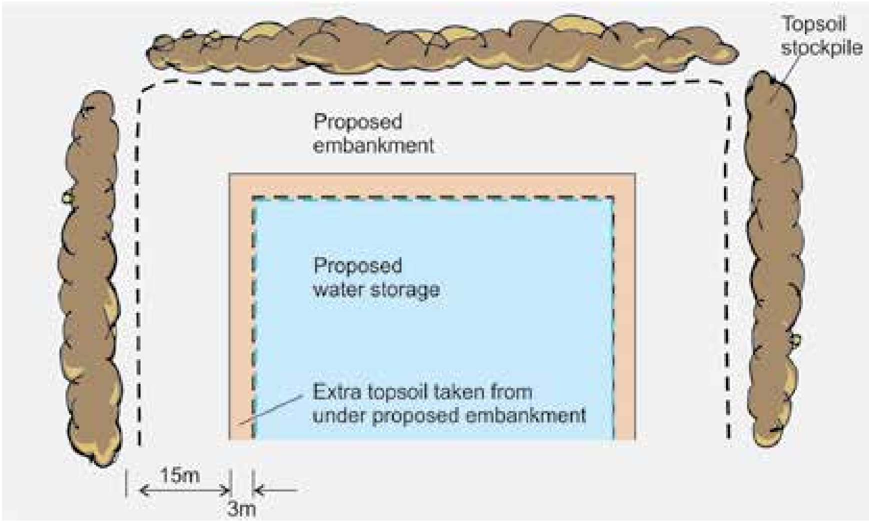


Figure 3.27
Removing topsoil from the excavation area

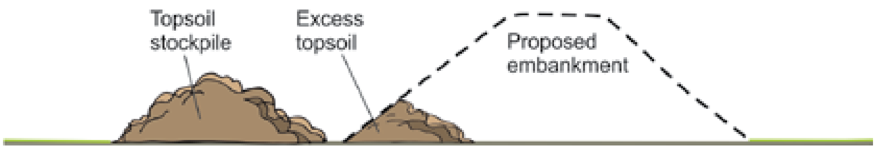


Figure 3.28
Placing excess topsoil in embankment

- Rip the excavation as deep as possible (at least 30 cm) and cross-rip if necessary. Identify the areas in the excavation that will be pushed into specific sections of the embankment, placing any pervious soil to the rear of the embankment, and confirm the batter grade. When the majority of the ripped material has been removed from the excavation, repeat the procedure. Use any impervious material to line the batters and seal off any pervious layers (Figure 3.29). Each layer placed in the wall should be around 150-200 mm thick, track-rolled and runoff before the next layer is placed. Soil moisture of each layer should be at an optimum level to maximise compaction in the wall.

  Do not allow the toe of the batter to creep outward beyond the designed location for any given depth. Peg the completed embankment profile at different stages of construction as a guide for the operator, ensuring no adjustments are required at the end of construction. Complete with an impermeable layer of soil over the excavation and embankment.

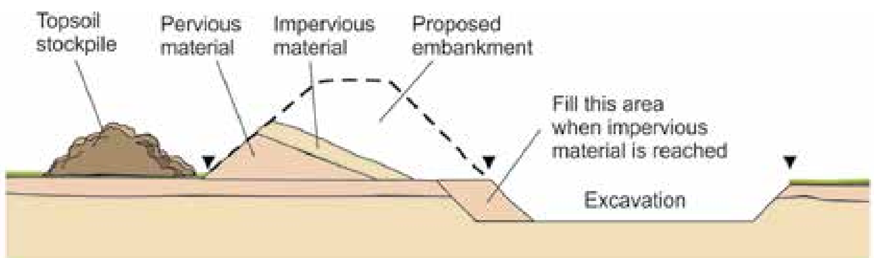


Figure 3.29
An excavated batter lined with impervious material to prevent leakage

- Use the excavated material from the outlet channel to form an extension of the embankment to the constructed outlet. The floor of the channel should be even, consistent in width and have very little grade towards the level sill. The excavation of the channel starts beyond the marker pegs, which only show the floor width, to provide a batter down to the channel (Figure 3.30). Groundcover on the spill area is critical to the long-term integrity of the dam; an eroded outlet system will result in a gully line eroding into the spill area and then into the spillway channel and eventually breaching the dam. Note: if the required ground cover cannot be achieved for the spill area then a rock or masonry flume must be considered to safely transport the flow to the floor of the gully.

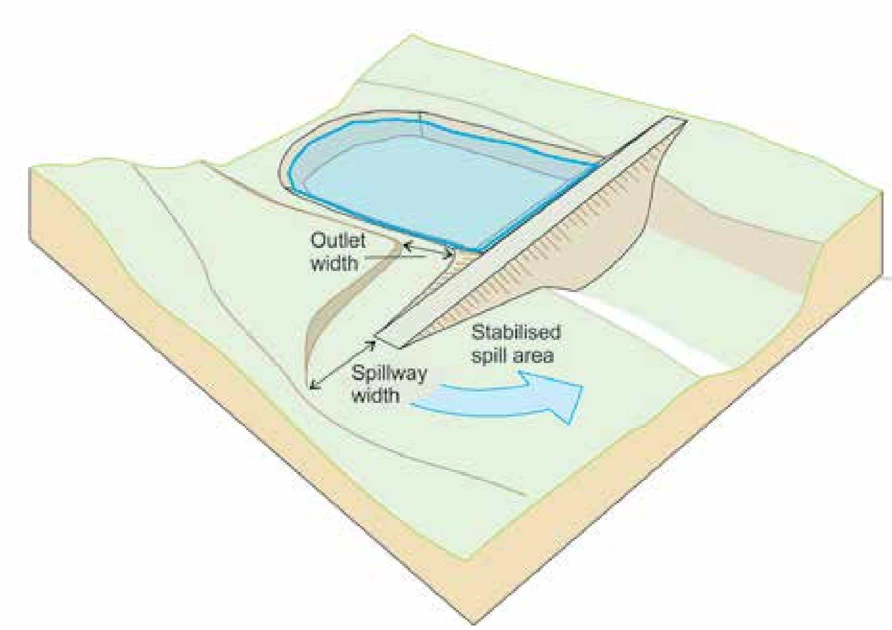


Figure 3.30
Typical dam spillway showing outlet width, spillway width and spill area

- Cut and shape the batters to the required grade, using reference points such as batter profile stakes or a battometer. Clean up any loose material, leaving the dam tidy for topsoiling.
- Spread stockpiled topsoil up the embankment, across the crest and down the inside of the embankment to top water level, to a depth of 10-20 centimetres. Do not compact the topsoil. Sow and harrow with a suitable seed mixture that will quickly establish groundcover.

3.6.3 Construction of a gully dam

For many operators the starting point for the construction of a gully dam is often difficult to identify. Wrong decisions can lead to inadequate preparation for the embankment base and poor compaction due to the machinery not being able to work the material correctly.

The construction of a gully dam is the same as other types of dams except for a greater emphasis on site preparation, particularly in deep gully locations. The cost per cubic metre of an embankment will be greater for construction of small gully dams because of the greater difficulty in preparing the construction site. The potential for failure is also greater.

The sides of the gully should be battered to create a base for the embankment, and to avoid the risk of failure through poor compaction, and slumping and cracking of the dam embankment that may lead to tunnelling or overtopping (Figure 3.31).

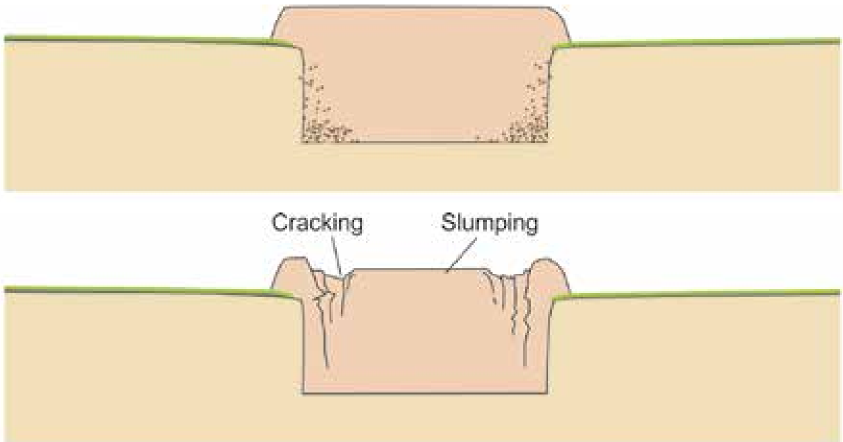


Figure 3.31
Gully sides are left steep leading to poor compaction near sides (top) or cracking and slumping (bottom)

The following steps should be used in the construction of all gully dams:

- A section of gully about 30-40 metres below the downstream toe of the embankment should be shaped from both sides to a depth that allows reasonable access into the gully for preparation of the embankment foundation.
- Remove the topsoil from the proposed excavation area and stockpile along the length of the proposed embankment toe. In most cases the topsoil under the embankment is also required as the rest of the site may not yield enough material for spreading.
- Batter the gully sides under the proposed embankment by ripping a pre-determined area from the gully edge that will produce the required batter grade for the embankment base. Prepare the area under the embankment by breaking in the gully sides to the required batter grade, and dozing the material at an angle to the downstream embankment toe in the floor of the gully. Spread the material in thin layers (150-200 mm) and compact well. In narrow gullies where it is not possible to spread the material in thin layers, compaction (preferably with a sheepsfoot roller) will be required at regular intervals. Repeat the procedure until the embankment is battered to the required grade from the top to the gully floor. There should be no loose fill in the gully.

  Continue to push in from the sides over the prepared batters and the gully floor. The point where the gully floor and upstream embankment toe meet will require extra effort to ensure there is no build-up of uncompacted material. Any loose material should be dozed up and down the batter spreading and compacting the material onto the prepared sides of the gully.

  In narrow gullies care should be taken that the embankment does not gain height too quickly, ensuring adequate compaction and an acceptable batter grade. Where the gully is wider, the earth from the battered sides of the gully is often insufficient to construct the embankment and additional earth from the excavation will be required.
- Incorporate a cut-off layer into the upstream section of the embankment to prevent seepage, possibly as high as the top water level (Figure 3.32). This phase of the construction will vary depending on access to the gully floor, availability of suitable sealing material and the height of the embankment. The cut-off layer should extend into an impervious layer along the length of the embankment ie across the gully floor (Figure 3.33).

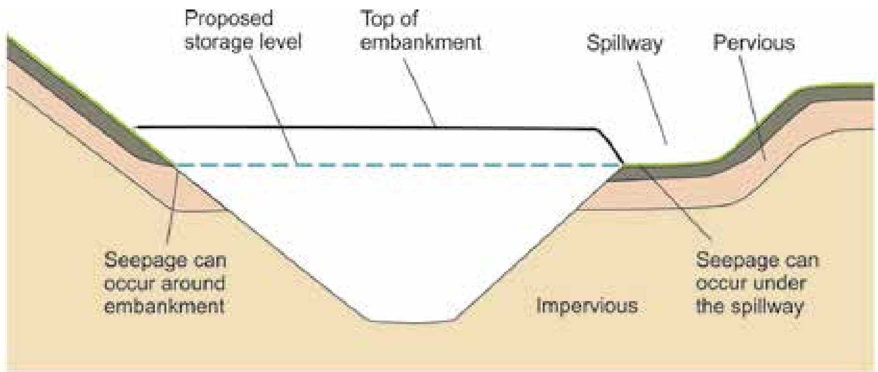


Figure 3.32
Example of a poor construction (dam section)

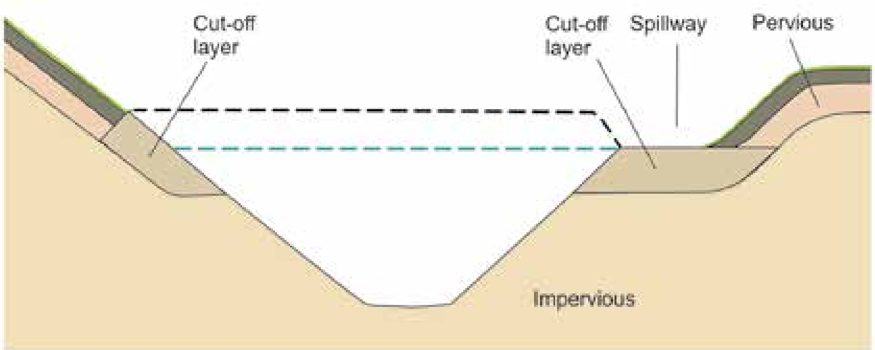


Figure 3.33
Intercept the seepage with a cut-off layer extended into both ends of the embankment

Where the pervious material is deeper than the proposed excavation depth, the trench should be excavated across the gully floor under the upstream embankment toe, extending into the impervious material on both sides. The trench is then back-filled with selected impervious material from the gully sides and joined to the blanket of impervious material in the constructed embankment to provide a continuous barrier. In highly dispersive soils, gypsum should be incorporated into the material going into the trench and into at least three 150-200 mm consecutive layers in the wall. In certain instances, a plastic membrane may need to be installed.

- Where a dam has a wide spillway and material from the spillway excavation is required for the embankment, it is advisable to excavate the spillway material and construct the embankment simultaneously to ensure consistent compaction is achieved throughout the embankment. Otherwise the spillway is generally completed after the embankment has been constructed to the correct batter grades, crest height and crest width. Care should be taken not to damage the area below the level sill.
- The embankment and other disturbed areas must be topsoiled to a depth of 10-20 centimetres. Do not compact the topsoil. Sow with a suitable seed mixture that will quickly establish groundcover. In areas where there is little topsoil, mulch or geofabric may be used instead.

3.7 Pipes in earthworks

There are a number of different uses for pipes in farm dam construction and operation, including for primary outlets, carrying water supplies through banks of the dam, and the protection of primary spillways from trickle flows.

3.7.1 Primary outlets

In small catchments pipes may be used as a primary outlet to carry peak flows through to a stable outlet area (Figures 3.34 and 3.35). The use of pipes may be the only practical solution in steep gullies or down steep batters.

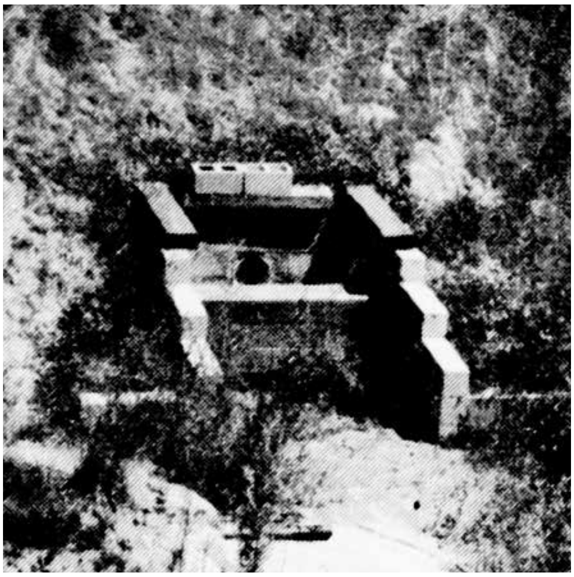


Figure 3.34
A pipe serving as a primary outlet, with dissipater (SCS, 1991)

Figure 3.35
A riprap outlet (Landcom, 2004)

3.7.2 Spillway protection

Small diameter pipes, commonly up to 300 mm in diameter, are often installed in the walls of earth dams, detention basins, gully control structures or banks to reduce the frequency of flows through the primary outlet or spillway. In dams, a pipe allows the full supply level to be maintained below the spillway level, helping to prevent the spillway becoming sodden and prone to erosion (see trickle pipes below). If the top of the embankment is being used as an access way by vehicles, a concrete causeway may need to be constructed over the spillway to protect it from damage.

3.7.3 Trickle pipes

Trickle pipes are high water level outflow pipes that are used to safely discharge the continued flow or seepage of water that occur (trickle flows). They are essential where these consistent small overflows keep the spillway permanently wet, making them susceptible to failure when a large flow passes through.

The control of trickle flows over grassed spillways is important to prevent killing the vegetation and erosion along and below the outlet. Trickle pipe installation should occur through a narrow part of the embankment, so the majority of the pipe is laid in in-situ material. The trickle flow pipe (Figure 3.36) should incorporate the following:

- An inlet pit, set into the turn-up end of the embankment (the other end to the spillway), and set at 100-150 mm below the full supply level of the dam. Where there are trees in the catchment of the dam, a trash rack should also be installed at the top of the pit. Pits should be checked regularly for blockages.
- A pipe of a diameter not less than 150 mm, with either a fall throughout the length, or an initial rise then a fall to produce a self-priming siphon. Trickle pipes can block easily with debris, resulting in damage to the spillway, and should be kept clear.
- Baffles or cut-offs located along and perpendicular to the trickle pipe to stop water seepage tunnelling around the pipe. They can be made out of bentonite clay or plastic to reduce the chance of seepage flows along the length of the pipe, hence creating a tunnel through the wall. Some are constructed out of concrete. They should be three times the diameter of the pipe (eg 900 mm for a 300 mm pipe), and placed approximately 8-10 m apart in the more sodic or dispersive soils. It is critical to achieve good compaction (eg by using a 'wacker packer') along the entire length of the pipe.
- An outlet system, which must have a mechanism dissipating the energy of the outflow and reducing the chances of erosion and scour.

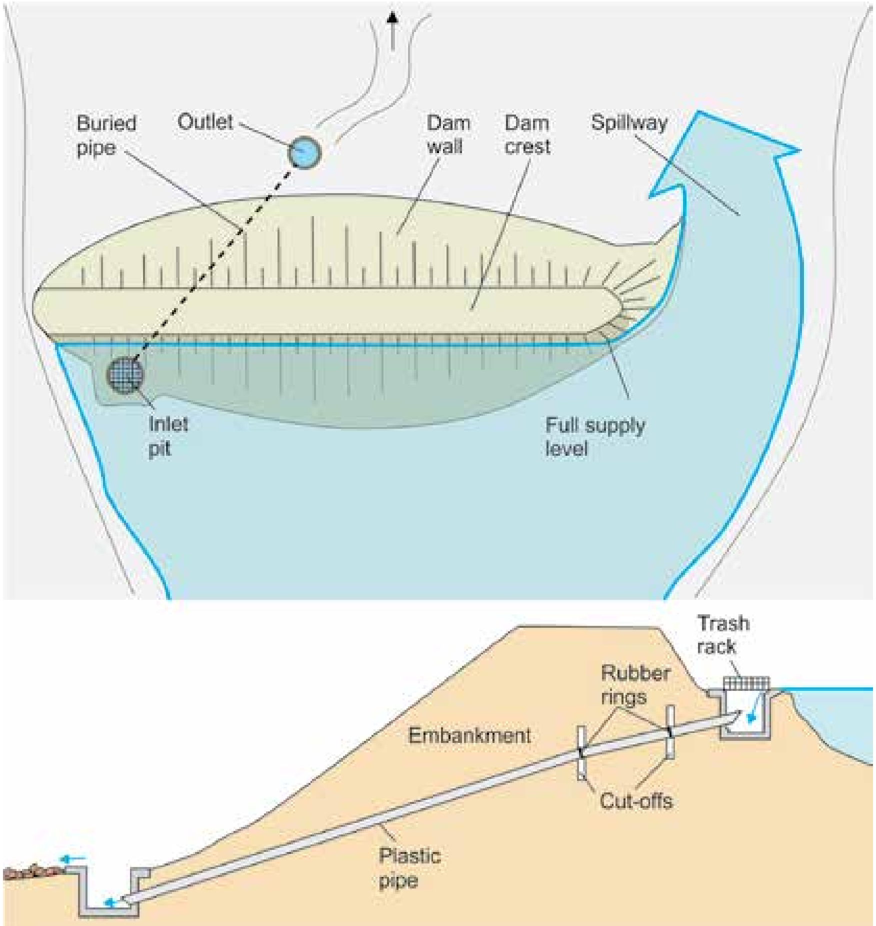


Figure 3.36
Placement of a trickle pipe through a dam wall – plan view (top) and section view (bottom) (after Farm Services Victoria, 2013b)

3.7.4 Location of pipes in earthworks

A number of factors must be taken into consideration when choosing the location for pipe structures, including availability of a stable outlet, the ability to direct water to the inlet of the pipe, and the availability of suitable material on which to lay the pipe and to use as backfill around the pipe.

3.7.5 Farm dams and detention structures

Pipes in dams and detention structures should be located in the embankment in such a way so that if the pipe fails, or a failure occurs in the material around the pipe, then the entire embankment is not lost. Ideally in large structures, pipes should be located to the side of the embankment and trenched into in-situ material with a minimum height of embankment over the pipe. This may require a longer pipe and a bend to discharge the pipe onto a stable outlet. However, the likelihood of a failure is significantly less and, in the event of a failure, repair costs are likely to be lower.

Structural failure along the pipe may occur where the soil is dispersive or where compaction around the pipe is inadequate. To minimise this possibility collars set at regular intervals along the pipe should be installed during construction (see Section 3.7.3 above).

3.7.6 Banks and outlets

The main criterion when locating pipes in banks is to ensure the pipe outlets onto a stable area to prevent erosion. Such an outlet should not restrict the flow of water away from the pipe and may need to be armoured to prevent erosion.

The outlet should be located at a stable level, low enough so that it will not cause erosion of the flow line or gully floor downstream from the outlet. In banks, the best location for a pipe is a natural depression. If a natural depression is not available, any position along the bank with a stable outlet may be used.

Stilling ponds, rock riprap and gabion structures installed at pipe outlets should always be designed by an engineer or other suitably qualified and experienced person, as correct dimensions are essential for their successful operation. More information on using rock riprap can be found in the document 'Guidelines for Stabilising Waterways: Rock Riprap' (The Standing Committee on Rivers and Catchments, Victoria, 1991), which can be found on the SCA's website under Additional References (www.sca.nsw.gov.au).

3.8 Embankment failure

There are three main types of embankment failure – tunnel failure, overtopping, and embankment and foundation collapse.

3.8.1 Tunnel failure

As a dam fills, water wets the embankment. If there are no voids in the embankment the soil on the surface will seal through the natural process of particle dispersion. This process is critical in determining whether a dam will hold water. If there is a void in the embankment, the water will enter and soil particles begin to slake (dissolve or collapse) from the sides and roof of the void and then disperse. Larger particles will settle in the bottom of the void while the finer particles disperse in the water (Figure 3.37(a)). In time, this process exposes more dry particles in the void which in turn slake and disperse. The water takes these particles away, enlarging the void and gradually making a tunnel or pipe (Figure 3.37(b)). This process continues in the direction of least resistance which explains the erratic path of tunnels (Figure 3.37(c)).

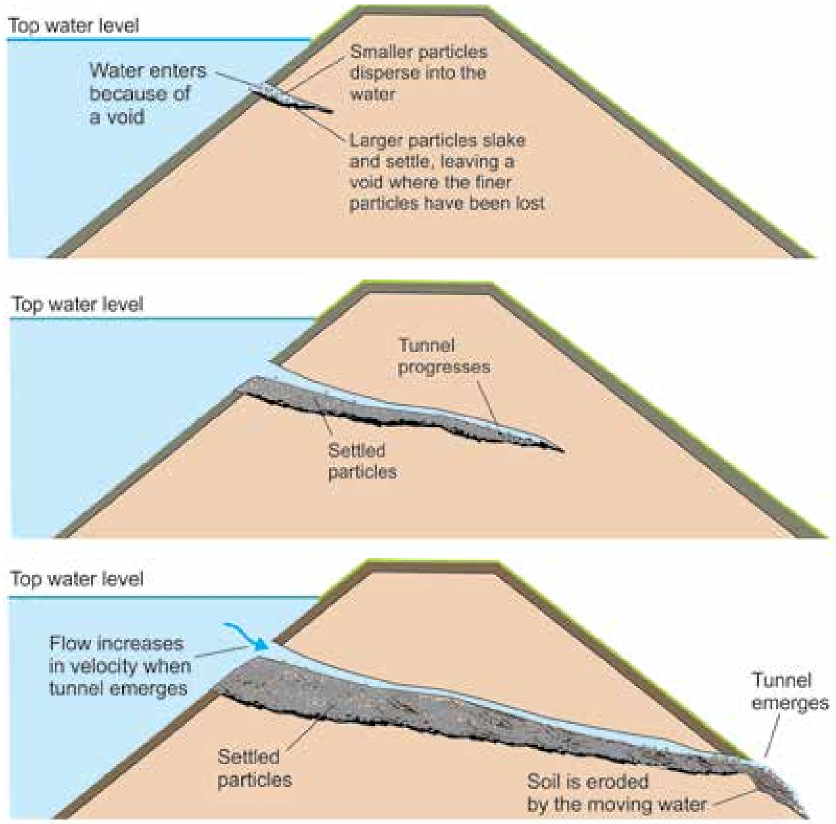


Figure 3.37
The first stage of tunnel formation (a), the tunnel progressing through the embankment (b) and the tunnel emerging on the downstream batter (c).

Certain soils are at a greater risk of tunnelling than others, particularly dispersible and erodible soils. The risk of tunnelling is also greatly increased when dry soil is used to construct the embankment. This is because it is more difficult to achieve good compaction (eliminating voids and points of weakness) in dry soils; rapid wetting is more likely to lead to slaking and dispersion in poorly compacted soils.

The chance of tunnelling in an embankment is also increased where the dam is only partially filled, resulting in the lower 'wet' section of the embankment settling away from the top, leaving a void between the wet bottom and dry top for water to move into if the dam is subsequently filled.

The tunnel may not emerge from the downstream batter if the weight of the soil in the embankment collapses into the tunnel blocking the flow, or the slaking process stopping the flow of water if it is very slow. In these cases it is sensible to seal the tunnel entrance eg by breaking the entrance with a shovel and filling the subsequent void with properly compacted soil.

A number of measures can be taken to control the rate of seepage within an embankment, and reducing the risk of tunnel failure:

- **Compaction** of the soil eliminating voids and lowering permeability – this should be used in conjunction with other techniques, as compaction alone is unlikely to guarantee no failures.

- **Increasing the embankment width** – by using flatter batters and a wider embankment crest, the length of the seepage path is increased, the seepage gradient is flattened and the velocity of flow is reduced. As a guide, the seepage line located on a 1:4 gradient should not intersect the downstream batter (Figure 3.38). On sloping sites the embankment is a critical part of the storage and the effort required to achieve sufficient compaction to prevent tunnel failure maybe more costly than the advantage gained from the higher S/E ratio. A better option may be to construct a larger dam on a flatter site where the embankment is not an important factor.

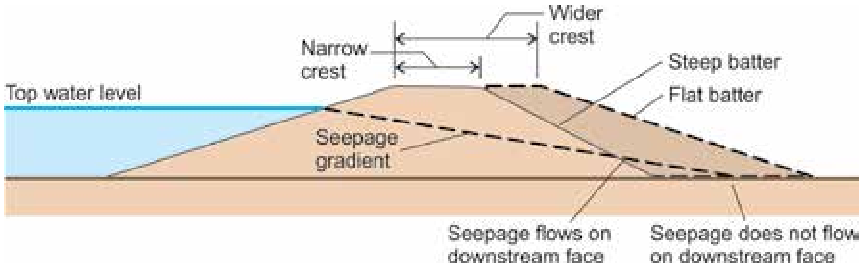


Figure 3.38
Seepage gradients through an earth embankment

- **Using zoned embankments** – strategically placing zones of non-tunnelling material within the embankment (eg as a clay core or diaphragm) may reduce the risk of tunnelling (see also Section 3.2 above). A layer of impervious material on the upstream batter that has been pulverised to promote sealing and lessen flows through the embankment may also be effective.
- **Using plastic membranes** (Figure 3.39) create a physical barrier that intercepts seepage on the wetted batter of the dam before a tunnel can progress, and when installed correctly with compaction of the embankment, success of the dam is virtually guaranteed.

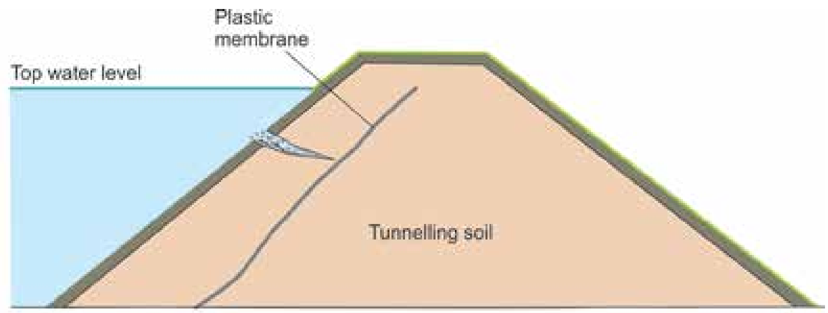


Figure 3.39
A plastic membrane located in a dam embankment to prevent tunnel failure

- **Incorporating soil ameliorants**, such as gypsum and hydrated lime, may be used to prevent slaking and dispersion in dispersible or unstable soils. They cannot be relied upon to eliminate tunnel failure, and hydrated lime is not effective in alkaline soils at all. Ameliorating the soil is more likely to have a positive effect on the long term stability of the dam rather than the initial filling in a new dam.

3.8.2 Overtopping

Overtopping of an embankment usually results in the complete failure of the dam. A farm dam embankment is vulnerable to this type of failure when it has recently been constructed and before the embankment has time to establish a stabilising ground cover. Overtopping of the embankment can occur for the following reasons:

- no adequate spillway has been constructed
- the specifications for the crest level of the embankment did not provide sufficient freeboard to allow for wave action and surcharge
- slumping of the embankment occurred because of poor compaction, resulting in inadequate freeboard
- the spillway was not wide enough to carry storm runoff causing excess surcharge in the dam.

3.8.3 Embankment and foundation collapse

In isolated cases embankments have failed as a result of the foundation material not being able to support the weight of the embankment – the foundation settles, lowering the crest level and causing the embankment to overtop. This is a particular problem where the foundation material is excessively wet and high in organic matter.

An embankment may also collapse due to excessive seepage making it saturated. Construction of the embankment to the recommended batter grades for the soil type and with sufficient compaction to control seepage should eliminate this problem.

3.9 Maintenance

Damage to farm dams can result from a lack of maintenance. Signs to look out for (Figure 3.40) include:

- **earth settlement** – all new earth walls will settle, but if the height of the wall above top water level falls below one metre, the wall should be built up or the spillway lowered. Settlement cracks near the waterline should be filled by ramming.
- **spillway** – care of the spillway is needed to prevent blockage by debris, damage by stock or vehicles, and lack of grass cover, all of which may lead to failure. Damage should be repaired by sodding, or heavy seeding, straw mulching and watering. Small rills should not be allowed to develop into a gully before repairing them.
- **seepage** through or below the wall may be dangerous, and soft spots or tunnel entrances on the upstream batter must be immediately rammed and filled.

- **grass cover** – a good cover of grass will prevent rilling of the wall and spillway erosion, and all disturbed areas should be sown with heavy applications of seed and fertiliser as soon as construction is completed. The wall and spillway should be fenced out where required to quickly establish and maintain the grass cover. If stock is allowed to access the dam, compaction and damage will occur. Avoid having trees and shrubs with deep roots on the dam wall as these can cause it to seep, leak or even collapse (NSW Government, 2011).
- **rabbits and wombats** – burrows should be dug out and packed with clay, and rabbits in the vicinity should be eradicated. Wombats should be excluded after first seeking advice from the National Parks and Wildlife Service.

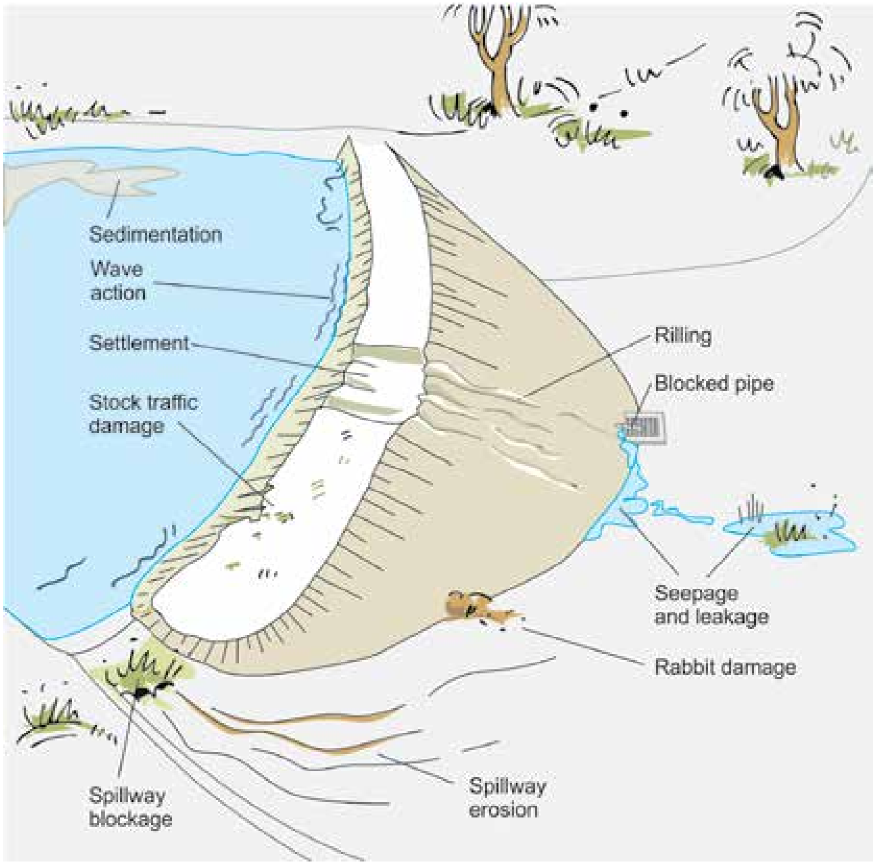


Figure 3.40
Issues that could require maintenance attention

Chapter 4

Contour and Graded Banks

4 Contour and Graded Banks

4.1 Function of banks

Banks are the most common structures used to direct water flows on farms (Figure 4.1). They are constructed earth embankments, incorporating a channel on the upslope side, and typically traversing a slope. Banks are a key component in controlling and/or preventing erosion of that slope. They slow the speed of water to a non-scouring velocity, increase the length of flow through the catchment (increasing the time of concentration) and reduce the peak storm discharge.

Banks are placed at strategic intervals across sloping land, breaking up the length of slope thereby preventing rilling of the (usually cultivated) slope. The positioning of a series of banks at intervals down the slope is determined by a combination of factors including:

- steepness of slope
- soil type
- rainfall intensity
- ground cover
- land management practices.

For them to work as intended it is essential that banks are properly designed and constructed and that they discharge onto stable ground. Your local Soil Conservation Service office can advise on bank spacings and locations on your farm (see Section 1.5 of this manual).

Figure 4.1
System of banks, waterways and dams (SCS, undated)

4.2 Types of banks

Graded banks run across a slope on a slight grade so that water can drain to a more stable area or watercourse. Design grades normally range from 0.1% to 0.5% depending on soil type and design requirements. The correct grade is such that water flows quickly enough to carry sediment along with it, but not so quickly to erode the channel.

Graded banks are primarily used on arable land, but also on grazing land in some instances. They are generally constructed by pushing the soil downslope so that the excavation forms a channel immediately above the bank (Figure 4.2). The grade can be up to 0.3% for bare earth channels, or steeper if the channel is well vegetated (Alt et al., DPI 2009). Bare earth channels are not encouraged in the drinking water catchment. Where a large concentrated flow of water needs to be carried across a slope or diverted away from an eroded area or gully, a diversion bank is used.

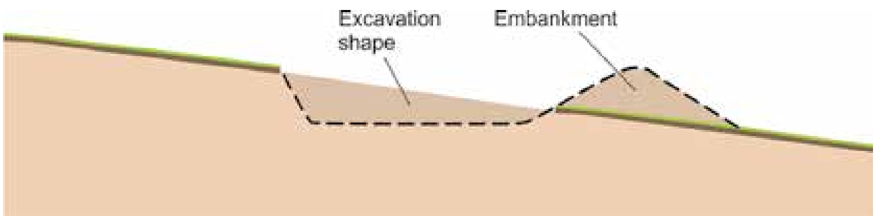


Figure 4.2
A graded bank

Diversion banks are large capacity graded banks built to intercept and convey concentrated runoff from one location to another. They are usually higher and wider than graded banks to carry a larger flow rate. Diversion banks need to be grassed to carry the high speed flows without causing erosion. They are the key type of bank in an erosion control system usually located at the break of slope. The area upslope of a diversion bank is steeper land that is only used for low intensity purposes such as grazing, while the area below it is generally cultivated and may be further protected by a system of graded banks. Careful location, design and construction are essential to avoid failure, especially by eroding out the channel or the outlet.

Trainer banks (Figure 4.3) are (usually) short, straight back-push banks used to direct water away from an unstable area or toward a natural grassed watercourse. These banks are usually constructed with the excavation on the downslope or 'dry' side so that water flows on ground level protected by natural vegetation and is only guided by the bank.

Back-push banks, as the name suggests, are constructed from the back by pushing soil upslope. This allows the bank to be constructed without disturbing the ground upslope of the bank in any way. These banks are usually short with a steeper grade as in the trainer bank illustration in Figure 4.3, or may constitute part of a longer graded bank where that bank has to cross a drainage depression known to carry concentrated flows during high rainfall events. To build a combination back-push/channel bank system requires a thorough understanding of survey levels and construction techniques, and professional assistance should be sought when proposing such a system.

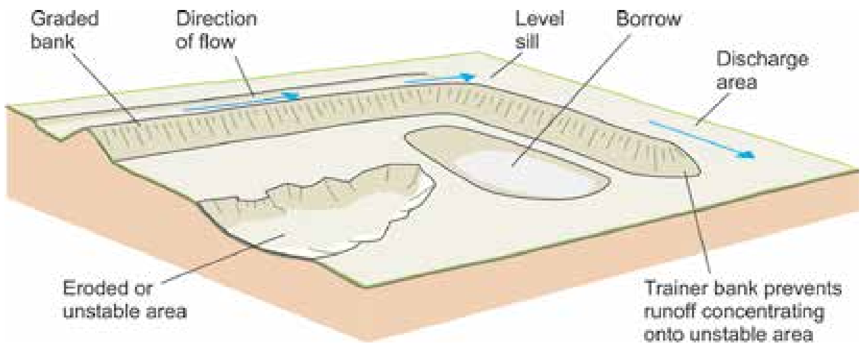


Figure 4.3
A trainer bank used to steer runoff away from an eroded area

4.3 Bank shapes

The shape of a bank depends on the land use and the site. Generally, the flatter the slope the broader the bank.

Semi broad-based banks (Figure 4.4) are widely used on arable lands with a slope greater than 6% and on lower slope grazing lands. They can be driven over by some vehicles (usually 4WDs), and some or the entire bank can be farmed (Alt et al, DPI, 2009) (although this should occur along the bank, not over it).

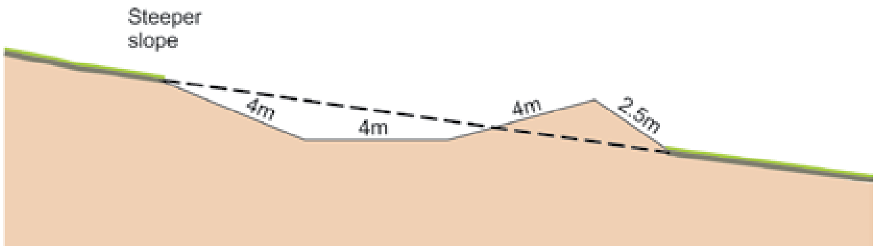


Figure 4.4
Profile of a semi broad-based bank with typical dimensions

Ridge-type banks are narrow-based banks with limited channel capacity, used widely in the Tablelands and Slopes of NSW on land with slopes greater than 10%. They take up the least amount of space but should not be driven over or disturbed (Alt et al, DPI, 2009), or cultivated with normal machinery. They should only be used where the slope of the land is too steep for a broader bank to be used.

The major advantages that semi broad-based banks have over ridge-type banks is that they are less susceptible to tunnelling and cracking, some or all of the bank and channel may be farmed, weeds are easier to control, some vehicle access may be possible and they are aesthetically more pleasing.

4.4 Bank design

The least erodible **channel profile** is one with a flat base with tapered sides (trapezoidal). The sides of the channel should not be steeper than 1:3.

Steep, V-shaped profiles can be constructed cheaply by graders or farm tractors fitted with a blade, but are easily eroded. They are not intended to be permanent structures but can serve a short term seasonal role to break up slope length on well-structured soils cultivated for potato growing (eg in Robertson, Crookwell).

The **grade** of a bank is determined to ensure that, for the estimated peak discharge and channel dimensions, the maximum velocity is not exceeded. The normal grade for vegetated channels is between 0.5% and 1.5%.

The minimum **specifications** for banks are largely determined by bulldozer blade width, safe working slopes for farm tractors and farm machinery width, but must satisfy both the land management and hydraulic requirements. For designing banks:

1. estimate the peak discharge for the catchments
2. determine a suitable channel grade, base width and depth of flow (Table 4.1)
3. select bank dimensions (see Figure 4.5).

For example, a vegetated diversion bank is to be designed for a 55 hectare rural catchment in the Sydney drinking water catchment. The peak discharge for the catchment (for a 1 in 10 year storm) has been estimated at six cubic metres per second. From Table 4.1 using a channel grade of 0.4%, a bottom width of three metres and a flow depth of 0.80 metres is required to safely handle the design discharge (ie 6 m^3/s). Using Figure 4.5, a depth of flow of 0.80 metres (on the right vertical axis) and a 1:6 batter grade requires a bank height of 1.2 metres (left vertical axis), and will result in a batter length of seven metres (horizontal axis).

Table 4.1 – Dimensions for diversion banks – vegetated channels

GRADE %	0.3		0.4		0.6		0.8		1.0	
DISCHARGE (m^3/s)	B	D	B	D	B	D	B	D	B	D
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	0.20	0.55	0.20	0.50
4	-	-	0.20	0.80	0.20	0.75	6	0.40	10	0.30
6	-	-	3	0.80	6	0.55	12	0.35	16	0.30
8	0.20	1.10	5	0.75	12	0.45	18	0.35	24	0.25
10	4	0.95	8	0.70	16	0.45	26	0.30	32	0.25
12	8	0.85	12	0.65	22	0.45	34	0.30	42	0.25
15	14	0.75	18	0.60	30	0.40	44	0.30	54	0.25

B = Bottom width (m); D = Flow depth (m); Batters = 1:6

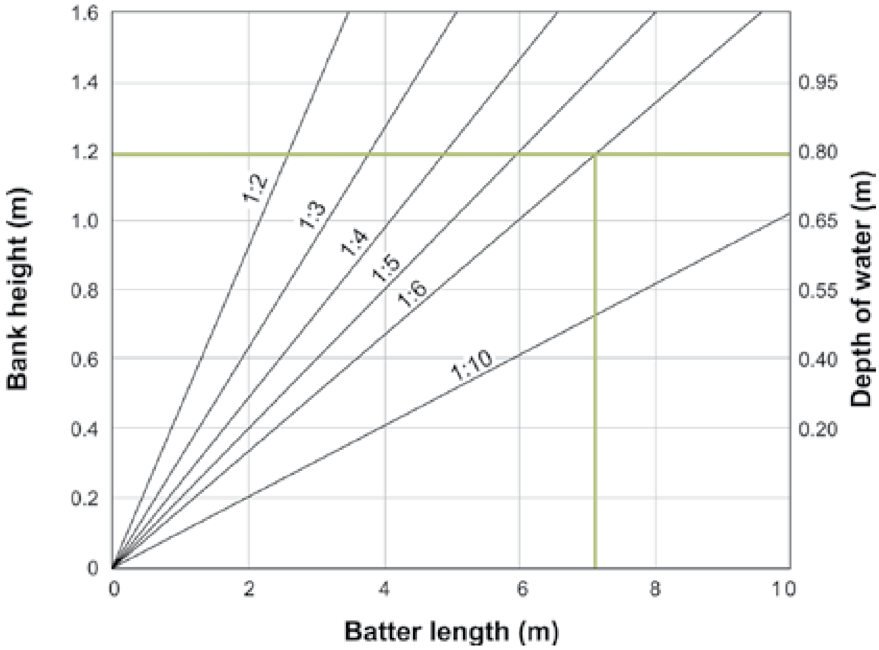


Figure 4.5
Selection of suitable bank dimensions

A crucial aspect of bank location is to ensure that the bank outlet or discharge point is capable of handling the amount and velocity of water without eroding. Depending on the volume of water discharging from the bank, a safe disposal area may comprise anything from a well grassed flat area to a rock or concrete chute or flume (see Chapter 5 of this manual).

All banks discharge to a stable disposal area via a level sill (Figure 4.6), which spread the water out into sheet flow slowing the water before it runs onto the disposal area.

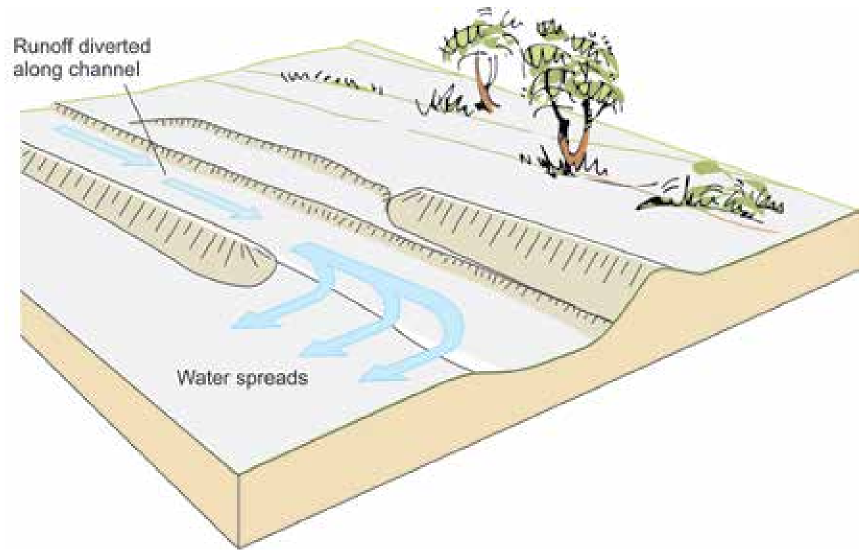


Figure 4.6
A graded bank ending at a spreading sill

Banks should not discharge onto bare earth areas or serious erosion will result. The length of the sill will vary according to the peak discharge, the slope of the area below the sill, and vegetation cover (Alt et al., DPI 2009). Table 4.2 provides sill lengths for a range of slopes and peak discharges. In most circumstances a flow rate of 1.5 m^3/s onto a well-vegetated disposal area will not cause erosion. Sometimes it may be necessary to construct trainer banks to ensure the discharge water does not run onto unstable areas (Alt et al., DPI 2009).

Table 4.2 Length of sill required (in metres) to achieve various flow rates onto the disposal area

	Slope of the disposal area (%)					
Peak discharge (m^3/s)	**1**	**2**	**5**	**10**	**15**	**20**
0.25	0.5	0.7	1.1	1.7	1.9	2.1
0.5	1.0	1.3	2.3	3.4	3.7	4.2
1.0	1.9	2.6	4.5	6.7	7.4	
2.0	3.8	5.2	9.0	13.4		
5.0	9.5	13.0	22.5			

The **bank freeboard** is the height of the bank above its maximum depth of flow (Figure 4.7). The channel capacity must be greater than the peak discharge from the bank outlet, with a minimum freeboard on the bank of 0.2 m or 50% of the depth of the flowing water in the channel, whichever is the greater (Alt et al., DPI 2009). When constructing banks it is important to build them slightly higher than this to allow for bank settlement.

Sufficient freeboard is required to avoid overtopping of the bank during peak flows, loss of bank height due to stock or machinery movement and possible blockages or sediment build-up in the channel. If a bank is overtopped during a major flow event, it is absolutely essential to repair the breach and restore freeboard immediately to avoid major erosion downslope of the break.

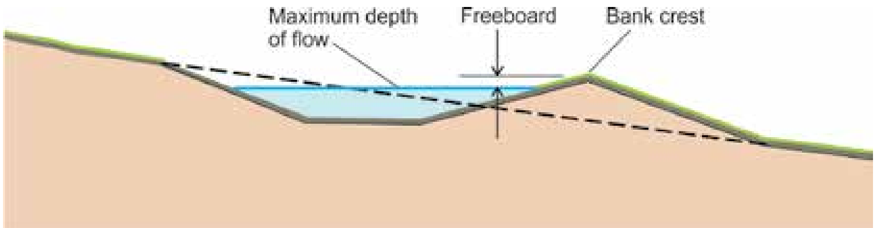


Figure 4.7
Bank freeboard

'Depth of cut' refers to the difference in height between ground level at the survey line and the floor of the completed channel, and its effect on the completed bank must be understood to allow for accurate pegging and construction; as the ground slope increases, the depth of cut decreases.

Furthermore, as the ground slope increases, more earth is required in the downhill bank batter to maintain a specific batter grade. In practice, the downhill batter is steepened to avoid the problem of excessive length. As a result, where batter lengths are kept constant, the depth of cut will reduce as the ground slope increases (Figures 4.8 and 4.9). Variation in the width of the channel will also result in changes to the depth of cut.

When the bank is pegged out prior to construction, adjustments are made to the peg line as the slope of the ground changes to ensure channels are graded correctly and have a constant grade. This avoids ponding, eroding of the channel or overtopping of the bank.

Figure 4.8
On low percentage slopes there is a greater depth of cut and the downhill batter is flatter

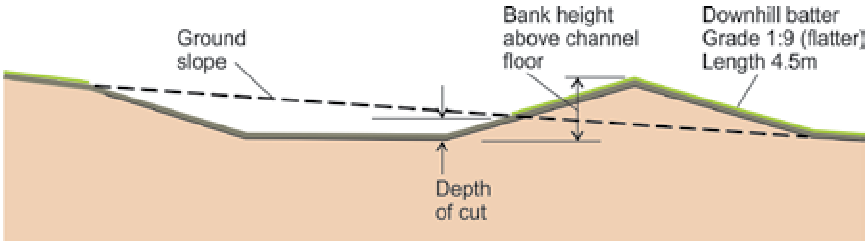
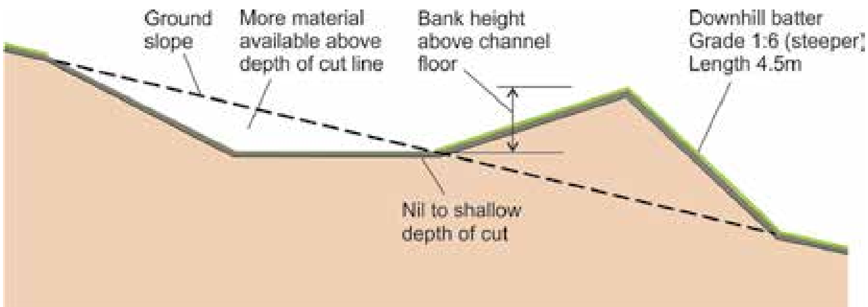


Figure 4.9
As ground slope increases, depth of cut will decrease but downhill batter must be steepened to avoid excessive length. Bank height remains the same.



4.4.1 Access and bank crossings

It is recommended that road crossings are provided over banks to minimise the inconvenience to landholders and encourage use at properly constructed crossing points. Although broad-based banks can be crossed at any point, crossings should be constructed, preferably at the origin (dry) end of the banks. Crossings must be built to suit farm machinery and vehicles, and to ensure they will not become a wet and muddy 'bog' during rain periods.

Crossings should be checked periodically to ensure the crest of the bank retains sufficient height to prevent flows overtopping at this point. If the height has been significantly lowered then the crossing should be repaired.

Where crossings are constructed at the outlet end (not recommended), care must be taken to ensure that no obstruction or damage to outlet occurs, and that the crossing does not restrict the flow in the channel. Where the construction of a crossing near the outlet end of the bank cannot be avoided, it is recommended that the channel at this point be lined with gravel or road base to avoid this section becoming a 'bog'.

4.5 Grassed waterways and fencing

Waterways are used to carry runoff downhill without causing erosion, and are commonly used as outlets for graded banks where there are no natural flowlines, the existing flowlines are eroded, or there are no stable outlets into a flowline.

They are constructed on low slopes as a grassed strip of sufficient width to carry the expected maximum runoff safely downslope, the flow being contained between the two retaining banks. The cross-section of the area between the banks should be level to give an even spread of flow across the waterway. They are often constructed along fence lines to cause minimum inconvenience to farming operations.

Grassed waterways, spillway areas and outlets to diversion banks should be fenced to exclude stock or at least limit their movements. This is especially important on slopes greater than 2% and on fragile or dispersive soils. Fencing of any grassed waterways and discharge points will greatly assist the establishment of vegetative cover and reduce the possibility of erosion occurring.

Chapter 5

Flumes, Chutes and Gully Rehabilitation

5 Flumes, Chutes and Gully Rehabilitation

5.1 Gully filling and shaping

5.1.1 Gullies and their treatment

A gully is an open, incised erosion channel, generally greater than 30 cm deep (Figure 5.1). Although they are generally characterised by steep walls and moderately to very gently sloping floors, they can vary widely in shape, depending on soil type, landform and the runoff characteristics of the catchment. Gullies are a major form of erosion on the Tablelands and slopes, and are a significant source of sediment and nutrient pollution.

Figure 5.1
Gully erosion
(R McGuiness, SCA, undated)

A variety of earthmoving techniques may be used to stabilise gullies and return them to sustainable productivity. They may be shaped or filled to varying degrees, depending on the intended use of the area and the size of the gullies. Complete filling of gullies is usually only cost effective for smaller gullies or for high value land. In most instances in the Tablelands gully shaping is the more practical option.

No filling or shaping of gullies should be undertaken unless the water flow causing the erosion is diverted away from the gully to an alternative safe disposal area by a system of diversion banks and dams. In the case of shaping, the gully head can be stabilised by the construction of a drop-down structure or flume (see Section 5.2 below), or by drowning the head with a dam.

In grazing and cropping lands, gullies may be completely filled, or larger gullies may be shaped to allow reasonable access and for vegetation to grow (Figure 5.2). For very large, steep sided gullies, often only the top edges can be battered to allow vegetation to re-establish.

Some gullies are so large that the only practical treatment is to fence them to exclude stock and allow vegetation to stabilise the area. In such cases, tree planting or the sowing of other soil-holding plants may be recommended to stabilise the eroding sides of the gully. A combination of smaller trees and shrubs that do not inhibit grass growth underneath may be recommended to avoid baring the ground and causing further erosion. In cases where the gully head is active, it must be stabilised with an engineered structure such as a rock or concrete flume (see Section 5.2).

(a) (b) (c) (d)

Figure 5.2
Gully rehabilitation showing (a) before, (b) during shaping, (c) after shaping, and (d) after revegetation (SCS, 2011-2012)

5.1.2 Gully filling

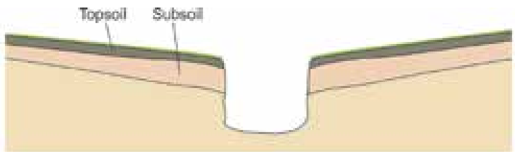
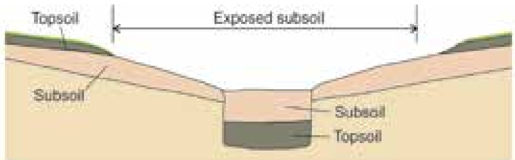
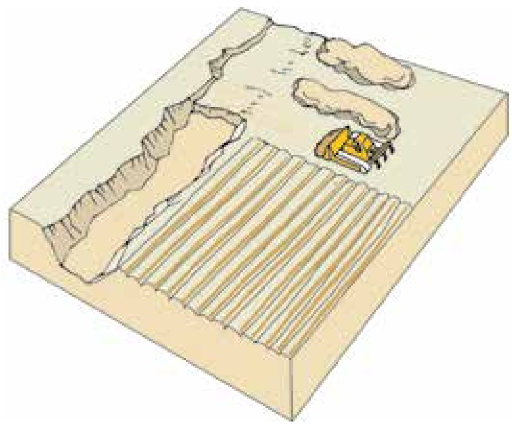
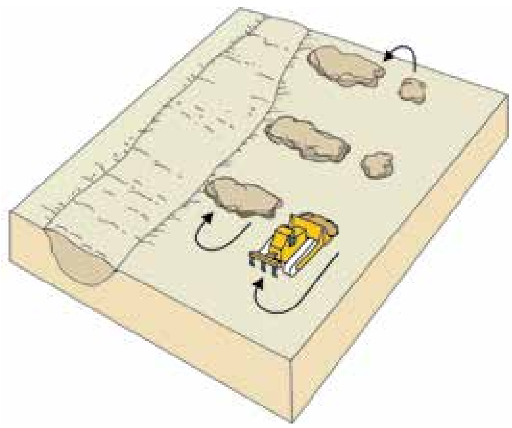
Gully filling is the placing of material in a gully to raise its floor to somewhere near that of the surrounding land, and subsequently shaping it to a uniform cross section to return the area lost to somewhere near its natural state and original productive capacity. The fill may include soil and rock materials, usually excavated within the immediate vicinity of the gully. Items such as household rubbish and other waste including tyres, drums, and car bodies must never be placed in gullies or used in gully filling. Such material will create voids in the fill causing 'sink' holes and tunnelling to subsequently appear, initiating a new round of erosion. The surface layer of fill should be topsoil to encourage plant growth.

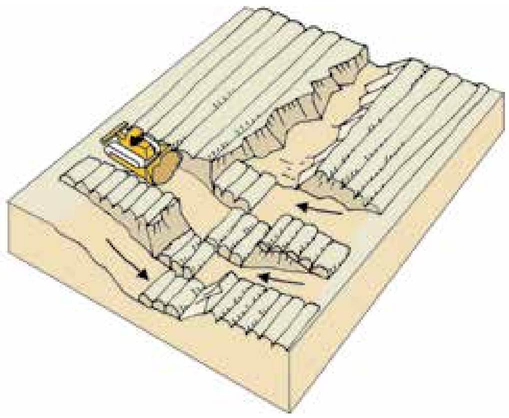
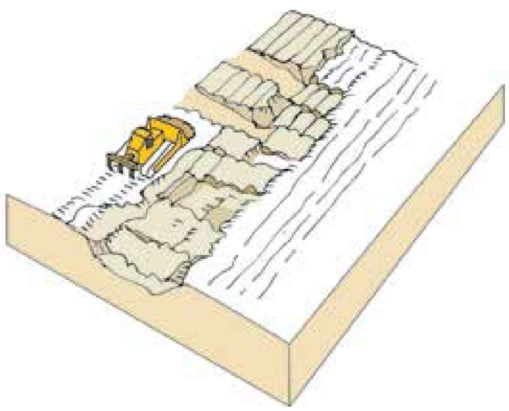
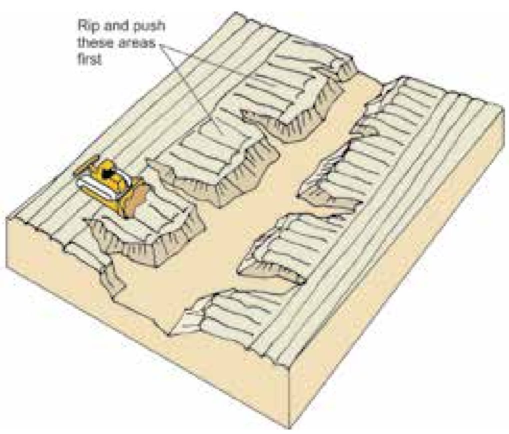
Planning is the vital first step in the gully filling process, and before any work is commenced the following should be considered:

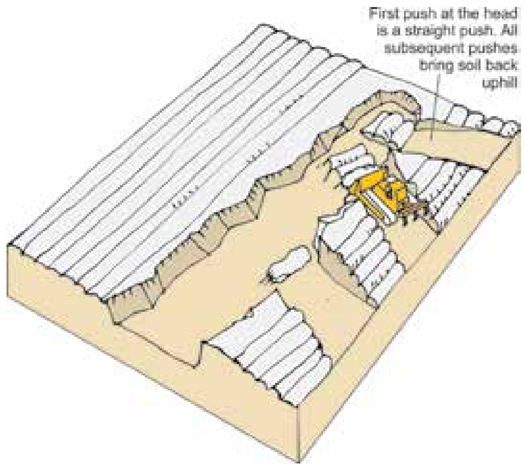
- seek advice from the Soil Conservation Service or Local Land Services
- control the initial cause of the gully, by designing banks to divert water away from the gully and protect newly filled areas from damage by concentrated runoff

- estimate the volume of fill material required. This can be done by measuring and calculating the cross sectional area at measured intervals along the length of the gully, and then multiplying this by the length of the gully. This will help when costing the job and determining borrow widths to achieve the correct batter grades. This is of particular importance when filling large gullies
- check the availability of fill. For example, if the gully runs parallel and close to a fence or a road, the majority or all of the fill may need to be borrowed from one side of the gully. This may not be viable if the gully is very large
- select the method of filling that is the most cost effective and gives the topsoil finish necessary for revegetation and stabilisation (see Table 5.1)
- ensure the work environment is safe.

Table 5.1 – Gully Filling Methods

Method	Considerations	
1. **Traditional** – rip gully shoulders and push material inwards, following with several runs over the fill material to compact and level it, then shallow rip side borrow area to help revegetation. This is the most common method used in the Sydney drinking water catchment, as most gullies are small.	Ideal for small gullies on good soil types. Not suitable for large gullies on poorer soil types (eg do not use where soils are dispersible) or areas with shallow topsoil. Gully shoulders are used for the fill, so topsoil is pushed into the bottom of the gully and consequently covered with subsoil; makes revegetation and stabilisation very difficult.	 Cross section of gully before filling.  Cross section of gully after filling.
2. **Stockpiling of topsoil** – in this method all available topsoil is removed from the borrow area and stockpiled, for later respreading when the gully has been filled. The gully is filled in sections, beginning at gully head and working progressively downhill.	Filling large gullies or gullies in areas with shallow topsoil. Unequal settlement of fill and settling overall to a level 10-15% less than the finished level. To minimise these issues, compact fill as much as possible and use additional fill material to compensate for potential settlement.	 Gully filling progresses downslope of the head.  Topsoil is respread.

Method	Considerations	
3. **Channel dozing** the fill material into the gully from both sides then re-topsoiling the area by using the topsoil left on the undisturbed areas between the channels.	Can be used to fill most gullies. The bulk of the material can be placed exactly where it is required, allowing for good even fill. Also easier for the operator. Unequal settlement of fill, especially in meandering gullies – push in the gully shoulders first in a 'two-stage' method (see below).	 Pushing channels from opposite sides to provide a continuous fill.  Levelling and topsoiling.
4. **Two stage filling** – gully shoulders are ripped, areas protruding into the gully are pushed in first, then gully is ripped, filled and topsoiled in a normal manner.	Best method for meandering gullies, where cut areas are cut lower in the first operation than in normal methods, giving a much more even fill.	

Method	Considerations	
5. **Herringbone pattern** – first push at the gully head is a straight push, then all subsequent pushes bring soil back uphill.	Ideal where the head of the gully is deep and then becomes progressively shallower as the slope flattens out. Deeper parts of the gully are able to be given more dirt to bring them nearer to the original ground surface level.	

Key points to remember when filling gullies:

- Gully fill should be protected by diverting runoff away from the fill area. If the gully is being dammed, the outlet of the dam must not be allowed to discharge over fill areas.
- All gullies should be filled and shaped so they blend in with the surrounding terrain.
- Rubbish dumps, timber or items likely to create future voids should not be filled over (rubbish should be removed).
- There should be sufficient fill to compensate for settlement.
- There should be adequate compaction of fill.
- All exposed surfaces should be topsoiled to allow for revegetation.
- Ponding of local water should be prevented by checking levels along the entire length of the fill upon completion of the job.
- Revegetation and stabilisation should be promoted by seeding and fertilising all disturbed areas as soon as possible after finishing the job.
- All stock should be excluded from filled gullies until the fill has fully settled, stabilised and completely revegetated.
- Long term management of these areas would benefit from permanent fencing.

5.1.3 Gully shaping

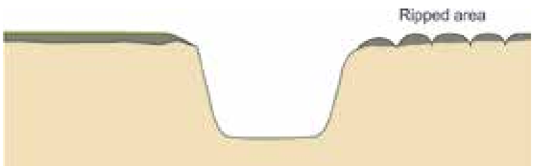
Many gullies are not filled because of their size (and therefore the cost is too great), or because the floor of the gully is still required to accommodate flow. Gully shaping to form gentle batters is an alternative in this situation, and when combined with revegetation, can stabilise the gully sides and floor. It is important that the shaping operation does not push material into the gully floor and restrict water flow, or substantially raise the level of the gully floor.

Key points to consider before shaping a gully include:

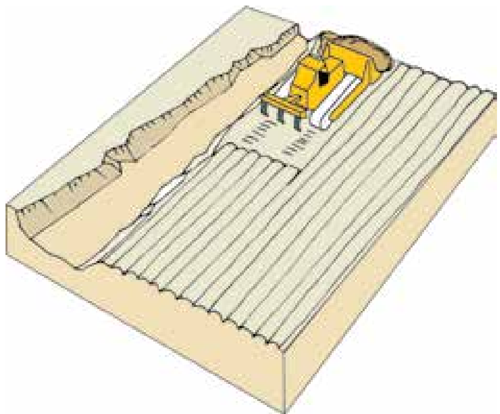
- the need for stable outlets into the gully for all runoff
- protection of newly shaped gullies from damage by water flows, possibly by temporary diversion banks
- topsoil availability
- the borrow width required to achieve the desired batter slope
- areas for disposal of excess soil
- determination of soil type – dispersible soils may require the incorporation of gypsum or lime on the shaped gully batters.

Table 5.2 – Gully Shaping Methods

1. **Using a bulldozer (stockpiling of topsoil)** – This method should be used when shaping small gullies in areas of shallow topsoil. The gully edge is ripped first, parallel to the gully. Then all topsoil is removed from borrow area, stockpiled and respread when gully has been shaped by scraping the gully edge parallel to the gully, cutting down the gully edge.

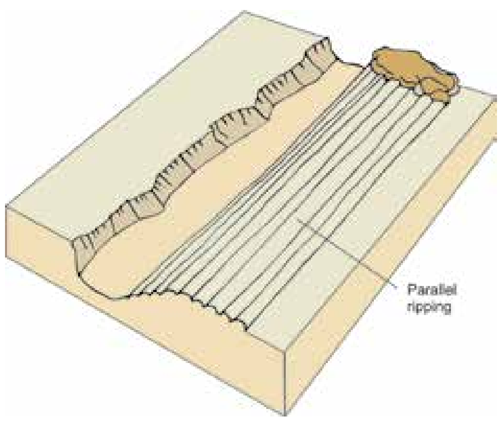


Rip gully edge prior to removal of topsoil



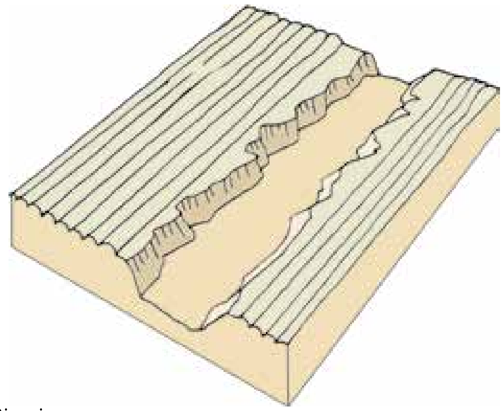
Stockpiling of topsoil

Shaping the batter

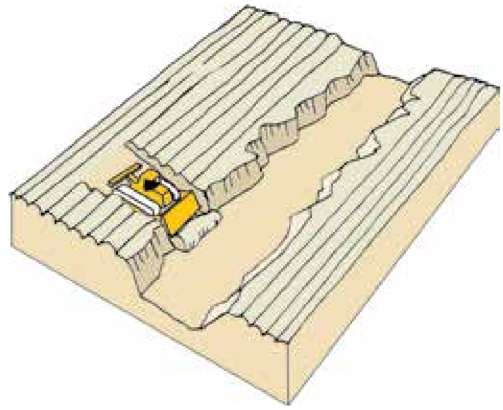


Deep ripping of shaped batter

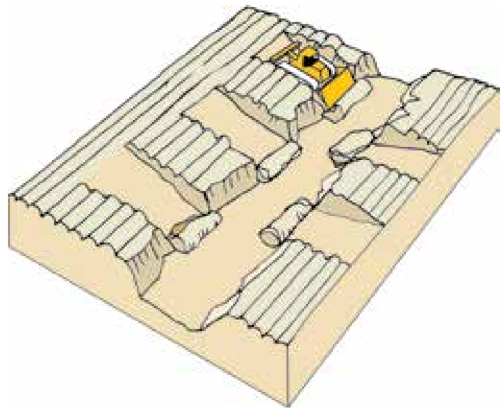
2. **Using a bulldozer (channel dozing)** – This method is suitable for shaping gullies on deep, uniform soil types. Rip the gully shoulders and areas beyond first, after determining the width of the borrow area to form the batters. Then channel doze enough earth to form the batter, and finish by re-topsoiling the area by using the topsoil left on the undisturbed areas between the channels.



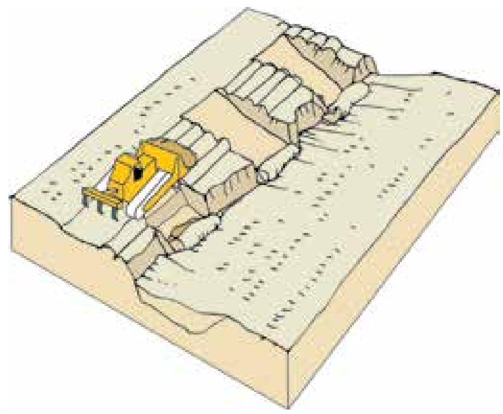
Ripping



Pushing the first channel



Subsequent pushing



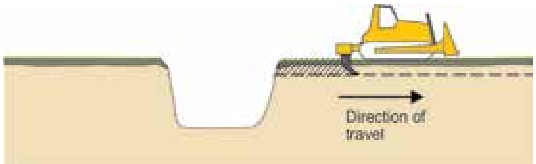
Shaping and topsoiling

Gullies that are particularly deep and with precipitous sides can benefit from having the top edges trimmed or battered to a grade (usually 1:1 or flatter) to allow vegetation to re-establish. This method can also be used to stabilise actively eroding creek banks provided the bed of the creek or gully is not undergoing bed lowering. In such instances the Soil Conservation Service or Local Land Services office should be contacted for advice.

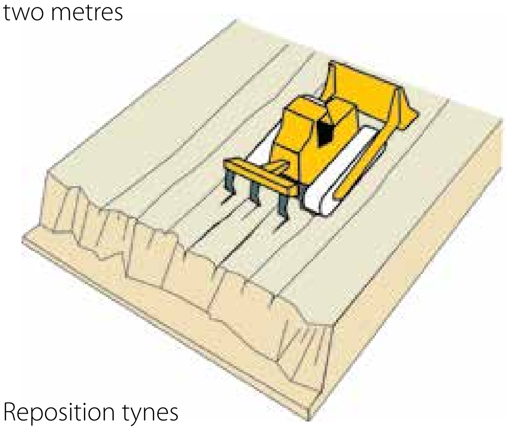
3. **Using a bulldozer (gully edge trimming)** – This method is good for stabilising the gully sides where the cost of complete shaping is not warranted or where there insufficient topsoil available to cover the disturbed areas. Should not be attempted on undercut gully sides or friable soils.

Carefully reverse the dozer to the edge of the gully and lower the ripper tynes. Rip soil while moving forward, then reverse again with tynes placed between ripped furrows. This will mix the topsoil into the subsoils and spill down the gully sides, lodging in indentations on face of gully walls. Repeat along the length of the gully, then heavily seed and fertilise the area.

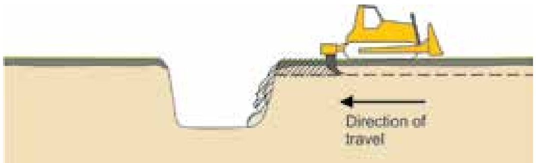
Safely reverse machine to edge of gully



Lower tynes and drive forward approximately two metres



Reposition tynes between previously ripped furrows



The rippers are lowered and the bulldozer reversed to gully edge, pushing soil down gully sides

4. **Using an excavator** – Deep, steep-sided gullies (eg more than three metres) may be more economically shaped by an excavator, or a combination of an excavator and bulldozer.

Remove and stockpile topsoil beyond batter line, then shape the gully sides from the existing gully floor 'toe' to the topsoil line by the excavator operating from the top of the gully. A diversion bank can be constructed from excess material to prevent runoff from the surrounding area entering the gully over the shaped sides. After shaping, cover area with topsoil from the stockpile.

Shaping gully sides with excavator


Cross section of gully after topsoiling

Key points to remember when shaping and edge trimming gullies:

- It is important that the shaping does not restrict water flow by blocking or substantially raising the level of the gully floor.
- All exposed surfaces should be topsoiled to encourage revegetation.
- Provision must be made to protect reshaped edges where overland flow is likely to run over the battered edges. Strategically placed diversion banks may be required to protect these batters.
- The incorporation of gypsum or lime may be required to help ensure the stability of the shaped gully batter in dispersible soil types.
- Edge trimming should not be attempted on gullies in friable soil, or where there is an undercutting of the gully sides.
- Revegetation and stabilisation should be assisted by a heavy seeding and fertilising of all disturbed areas. Straw mulching may also be needed to help plants germinate and get established, particularly where good topsoil availability is limited.
- Where possible, fences should be built to exclude stock and vermin.

5.1.4 Safety

Working in or near gullies with heavy earthmoving equipment can be dangerous. The work described above should only be carried out by experienced operators using machines fitted with rated rollover protection systems (ROPS).

5.2 Flumes and chutes

Flumes are hydraulic, engineered structures comprising an inlet (apron), chute and outlet used to convey concentrated flows of water to a lower level (eg a gully floor or down an embankment) without causing erosion. Flumes are usually used at the head or side of a gully (Figure 5.3) where no alternative natural disposal method or site is available. In many situations they become the most critical component in a scheme of soil conservation works.

Figure 5.3
Concrete flume into a gully (SCS, 2002)

Flumes can be used in a wide range of situations, including the control of on-farm gullies. They are often the final discharge point in an overall runoff control system, and their failure could lead to damage to other parts of the system.

Flumes are usually constructed of concrete or rock or a combination of both. While concrete flumes are often the most expensive to construct properly, they provide a long term solution with a minimal risk of failure. Rock flumes are useful in situations where soils are at high risk of subsiding and undermining and have the added advantage of being easily repaired.

Because of cost and the critical role they play in any erosion control system, flumes are usually designed to accommodate a calculated storm discharge of between a 1 in 20 to a 1 in 50 year rainfall event. These design discharges can be calculated for any catchment using information from the Bureau of Meteorology's website. Once the design storm discharge volume is known, the dimensions of the flume and its various components can be calculated taking into account the characteristics of the site on which it is to be located (ie height and width of gully head, orientation and soil type).

5.2.1 Components of a flume

Different components of a flume act to collect, convey and de-energise the flows that pass over it, and play an important role in ensuring the long-term stability of the whole structure (Figure 5.4).

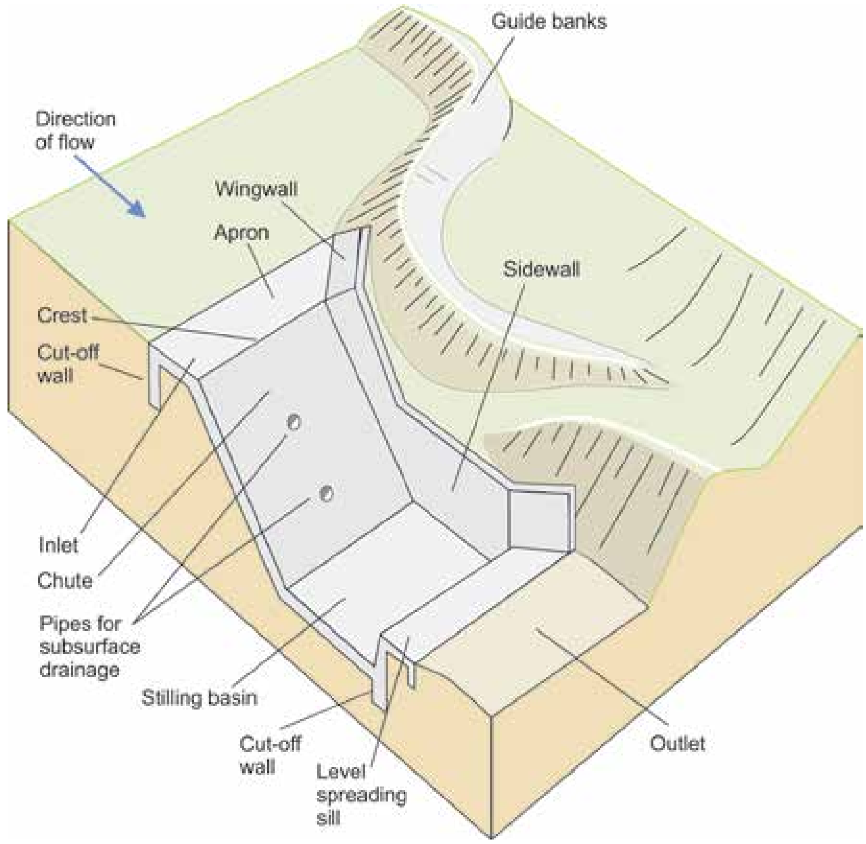


Figure 5.4
Components of a typical concrete flume

The **inlet** comprises two wingwalls, a cut-off wall and an upstream apron. The wingwalls must be set at a horizontal angle of not less than 45 degrees to the direction of the inflow. Recommended apron lengths and cut-off depths are given in Table 5.3.

The **crest** is the section where the flow moves from the horizontal (apron) to the slope (chute).

Table 5.3 – Apron lengths and cut-off depths

Drop from apron to stilling basin (m)	Upstream cut-off depth (m)	Upstream apron length (m)
<2.5	1.0	1.0
2.7	1.1	1.1
2.9	1.2	1.2
3.1	1.3	1.3
3.3	1.4	1.4
3.5	1.5	1.5
3.7	1.7	1.6
3.8	1.8	1.7
>3.8	1.8	2.0

A **cut-off wall** is required at the top of the flume to prevent any seepage moving through the soil reaching the back of the chute, and provide anchorage against downhill sliding. One is also required at the bottom of the flume to prevent undermining of the flume from downstream. Both walls should be located where the masonry or other construction material meets the soil. They should be a minimum of one metre deep under the apron and 0.5 metres deep under the wingwalls. Ideally the thickness should not be more than 0.15 metres as any wider will greatly increase the amount of concrete required and therefore the cost.

The top **apron** is necessary to protect the ground surface at the inlet of the flume from scouring and is most important where vegetation cover on this area is sparse. A 1.5 metre wide apron is generally sufficient. The bottom apron is necessary to protect the base of the flume from the increased velocity and turbulence of the water (after it has gone down the chute) as it exits the stilling basin. A 750 millimetre wide apron embedded into the stable floor is generally sufficient. Both the inlet and outlet aprons must be perfectly level to ensure an even distribution of water flow (and therefore energy distribution) across the structure.

The **wingwalls** are the embankments which extend outwards from the top of the chute at an angle of about 45 degrees to guide the water (slowly) into the chute. Batters exposed to the flow should be lined (with concrete or rock) for a short distance (usually two to five metres) from the chute. This lining will reduce scouring caused by high water velocity under constricted flow conditions. Forming the wingwall banks can be achieved while excavating the structure by pushing the excavated material into the proposed position of the banks.

The **sidewalls** are the walls on either side of the chute.

The **chute** is the steeply inclined section of a flume between the inlet and the outlet that conveys the water to the stilling basin. The grade of concrete chutes varies between 1:2 and 1:3 (vertical to horizontal), depending on the excavation equipment used. The grade of rock chutes is usually flatter – the more water to go over the rock chute, the flatter the grade should be.

The **stilling basin** is the area where the energy in the water flowing down the chute is dissipated. Stilling basin should always be full of water, as it is this pool of water that acts to absorb the energy of the water coming down the chute. This is known as the 'hydraulic jump'. The dimensions of the basin are calculated according to the size of the jump at peak discharge. The depth is set to ensure that an energy balance occurs between the jump and the flow in the downstream channel.

The **outlet** comprises the sill at the downstream end of the stilling basin, the cut-off wall and the tailwalls. The tailwalls must be set at a horizontal angle of not less than 45 degrees to the direction of the outflow. The cut-off wall, except where the stilling basin is founded on parent rock, must extend to a depth not less than 600 mm below the stilling basin floor.

5.2.2 Types of flumes

The type of flume to be used is influenced by the rate and volume of runoff to be handled, together with site constraints such as soil type, slope, depth of gullying, availability of construction materials and finances, and the likely on-site and off-site impacts should failure occur. For design and construction of both concrete and rock flumes, the Soil Conservation Service and Local Land Services should be consulted.

Concrete flumes are particularly useful in providing a stable, long-life means of conveying runoff to the floor of what would previously have been active gullies, thereby stabilising the erosion at that point. They are capable of conveying large volumes of water for long durations. However, faulty design and/or construction will result in costly failure with the potential to jeopardise associated works (Figure 5.5). Concrete flumes are the preferred type in the Sydney drinking water catchment.

Figure 5.5
Failing concrete flumes
(SCA, 2011)

An excavator is generally most appropriate for site preparation, especially where the chute gradient is 1:2 (V:H) or steeper with vertical side walls. Where the gradient is less than 1:2 a bulldozer is suitable.

Rock flumes (Figure 5.6) are low cost structures (if the rock is on site) requiring a minimum of labour input. As they are more flexible and can settle to the surface contours, they are especially suitable where there are problems associated with using concrete flumes due to the nature of the soil (shrink/swell characteristics). However, they should not be designed to carry large volumes of runoff for long durations unless they are properly designed and constructed using the correct rock size and density for the anticipated water volume. Rock size and placement in such situations is determined using specifically developed software. Rock flumes should **be designed by a qualified and experienced consultant**. Faulty design and construction will result in failure.

Figure 5.6
A rock flume
(SCA, 2011)

Rock flumes have been successfully incorporated into soil conservation designs for a variety of field situations, including:

- outlets of dams and contour banks with small to medium catchments where satisfactory natural outlets are not present
- undercut embankments within flow lines
- critical areas within prepared watercourses, such as constrictions caused by roads or railway culverts and redirections of watercourses
- outlets of watercourses for more stable disposal of runoff into flow lines
- gully heads which require stabilisation to enable continued use for water disposal
- for entire watercourses where no alternative water disposal area is present.

When designing rock flumes, the following issues must be considered:

- the design flow velocity adjacent to the protected flume
- the rock type, size and size distribution (larger rocks must be at the bottom of the flume)
- the depth at which the rocks are founded (depth below the current bed level) (Witheridge, 2008)
- incorporation of a vigorous vegetative cover into the flume to help hold the rocks in place.

In certain circumstances, a temporary flume may be required to dispose of runoff during the construction phase, but will not be required when the project is complete. Such temporary flumes can be constructed using materials such as plastic or geo-textile to provide temporary protection. The flume may be replaced later by long-life materials such as grouted rock or concrete if the flume becomes the permanent discharge point.

5.2.3 Flume design and construction

Great care must be given to the design, location and construction of flumes, as they are often the most critical component of the soil conservation works. As the main objective is to construct a flume that will safely carry water from one level in the landscape to a lower level, and to adequately dissipate the energy gained during the drop (in a concrete flume), inadequate provision for energy dissipation in the stilling basin will lead to failure of the flume.

As discussed above, the design of concrete flumes requires the estimation of a design flow, and the sizing of the spillway inlet and stilling basin. An understanding of hydraulic design, including the calculation of catchment discharge, is required to calculate flume dimensions and spillway size. **Either the Soil Conservation Service or the Local Land Services should be contacted for hydraulic design advice and catchment discharge calculations.** An understanding of the design return period (see Section 2.2) is also necessary to ensure the construction of a long-term structure.

Important considerations that will determine the structural design include the thickness of the concrete (minimum 120 millimetres), the incorporation of steel reinforcement (minimum F62 grade mesh), subsurface drainage (Figure 5.7), and minimum cut-off wall depth.

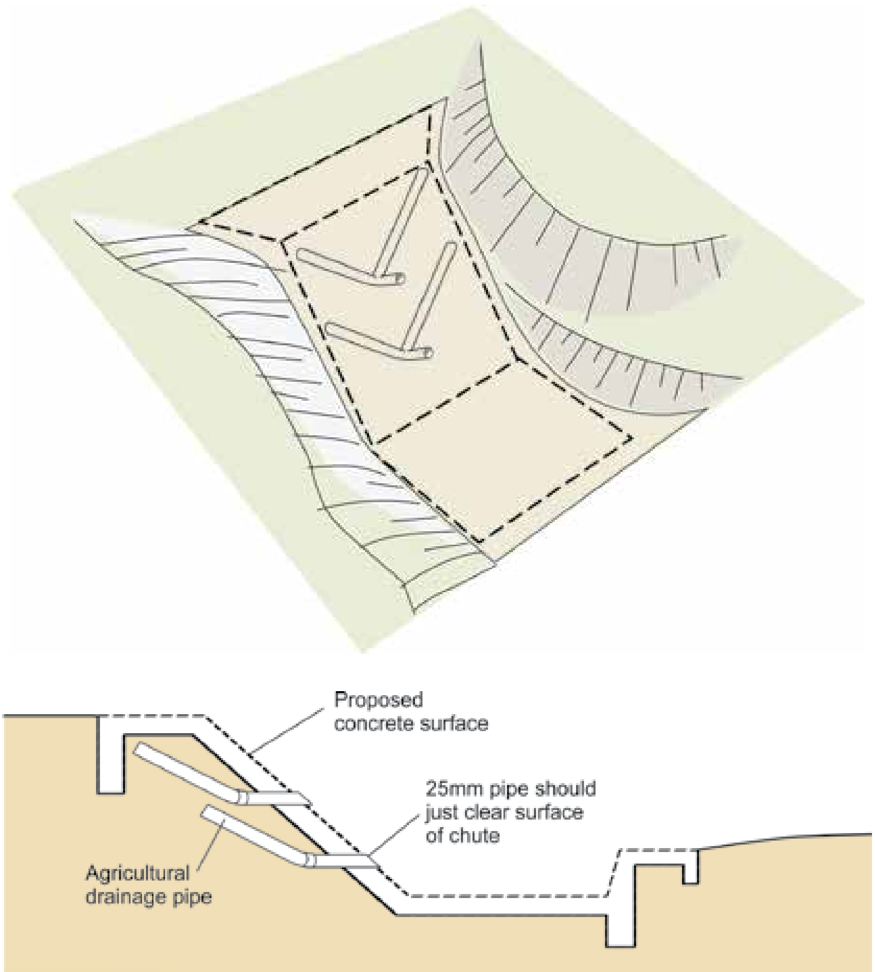


Figure 5.7
Subsurface drainage pipes laid in a herringbone pattern

When siting the flume, care must be taken to ensure that the flume:

- is in line with the direction of flow at both the inflow and the outflow ends (Figure 5.8)
- is at the correct levels at the top and bottom of the chute (flush with the ground surface)
- has the wingwalls in the correct location.

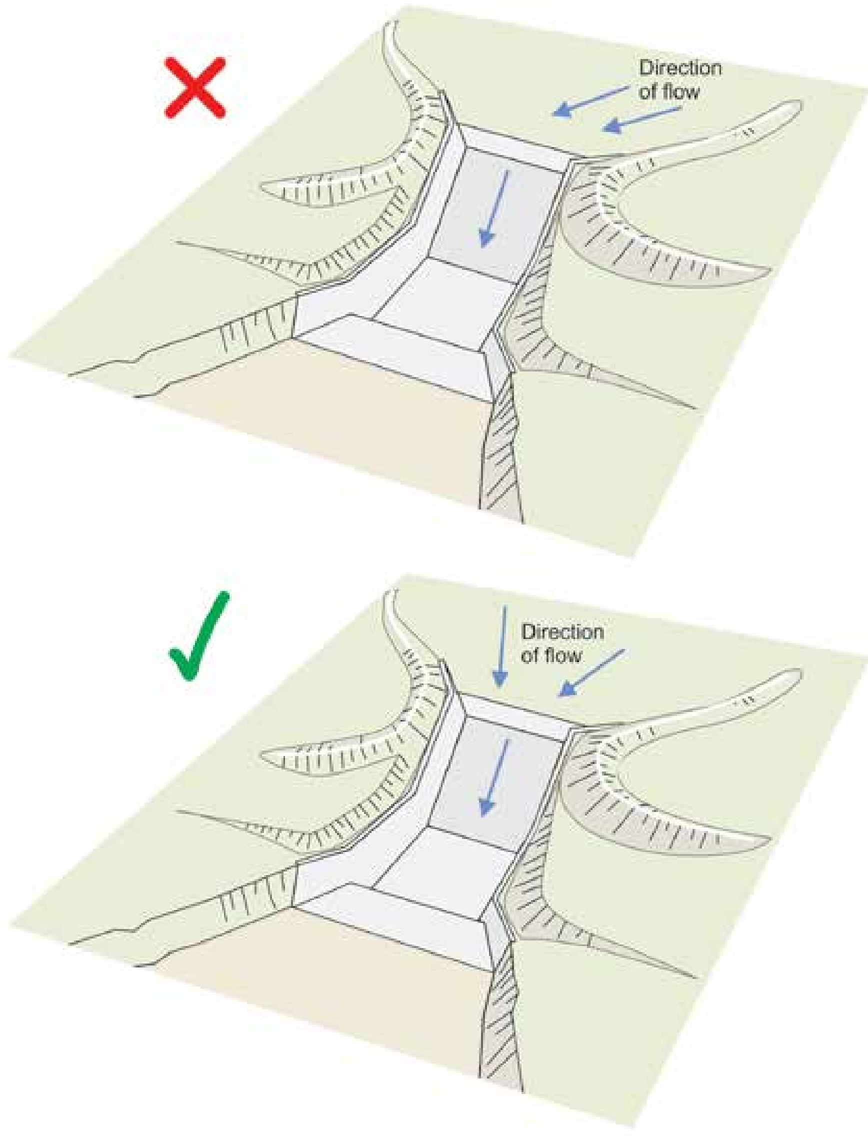
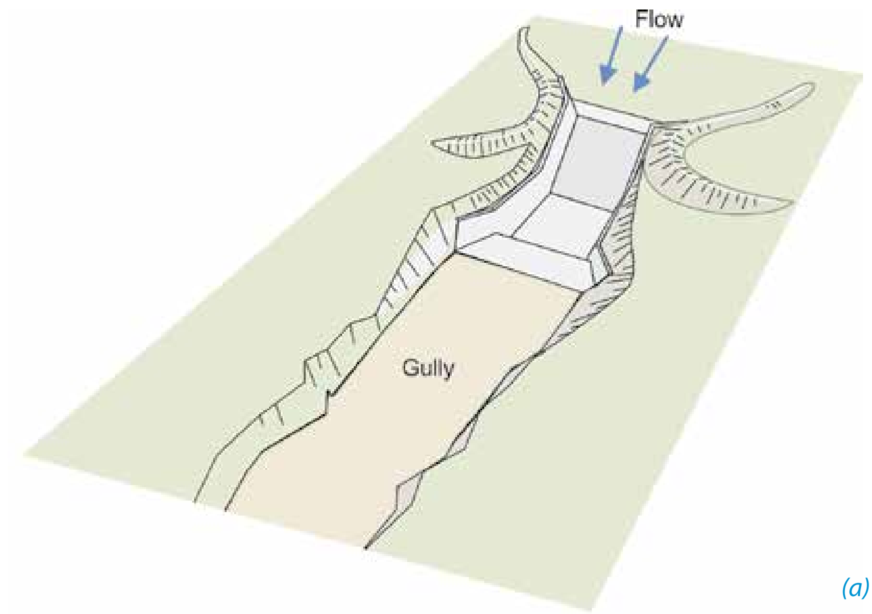
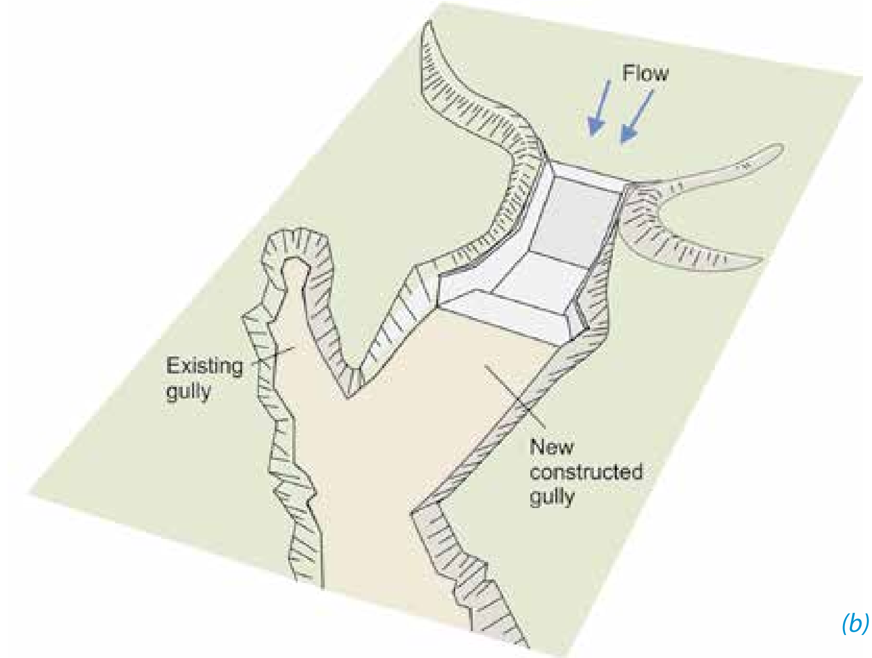


Figure 5.8
Wherever possible, the flume inlet should be in line with the direction of flow

An important component of all flumes is the exit channel which carries the discharge water after it leaves the stilling basin. The channel will be formed by either reshaping the gully floor and sides, or by constructing a channel which then delivers the discharge to the gully floor (Figure 5.9).



(a)



(b)

Figure 5.9
Exit directly into gully (a) and constructed exit channel (b)

Once an outlet has been completed, the chute and the stilling basin construction can begin. Construction proceeds by removing the topsoil and stockpiling it close by for later reapplication to the batters and surrounding disturbed ground. Material from the chute is then pushed down into the stilling basin and then upwards out of the channel area to form the wingbanks before dozing or excavating out the stilling basin, then backfilling and compacting the batter to make a vertical outlet (Figure 5.10).

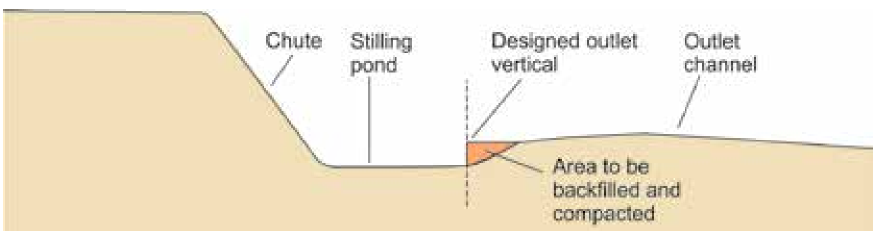


Figure 5.10
Dozing material out of the stilling basin causes a sloping face that has to be corrected.

Acronyms

CRP	Current recommended practice
DECCW	(the former) Department of Environment, Climate Change and Water
DPI	Department of Primary Industries
I&I NSW	Industry & Investment NSW (now part of Trade & Investment)
LEP	Local environmental plan
NorBE	Neutral or beneficial effect
NOW	NSW Office of Water (part of the DPI)
SCA	Sydney Catchment Authority
SDWC SEPP	State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011
SCS	NSW Soil Conservation Service

Glossary

apron — A layer of concrete, stone, timber or other relatively permanent material placed in the channel bed at the inlet or outlet of a hydraulic structure such as a culvert or chute to protect the structure against erosion.

backfill — To place soil or other material in a natural or man-made excavation. Used in the context of refilling gullies that have been eroded.

backpush bank — A bank constructed by moving the soil upslope (from the back) so that the excavation is immediately below the bank. These are constructed where it is necessary to retain a well grassed, undisturbed area on the upslope side, such as where the bank crosses a flow line.

bank — A constructed earth wall or embankment, incorporating a channel on the upslope or downslope side, typically traversing a slope to control and/or prevent soil erosion. This is achieved by intercepting, diverting or storing runoff instead of permitting it to run uninterrupted down the slope. Banks control the volume and slow the velocity of runoff so that serious erosion will not occur.

bank inlet — The point at which water flowing down a slope or from another bank, dam, other conduit or storage enters a bank channel and from which the bank guides the direction of the flow of water.

bank outlet — The point, or points, along the length of a bank or at its end(s) at which water is allowed to flow downslope unguided by the bank.

base width — The width of a bank, dam wall or other structure at its base ie where it rests on the ground surface.

batter — The excavated or constructed face of a soil conservation bank, dam wall, embankment or cutting, produced as a result of earthmoving operations involving cutting and filling.

batter grade — The slope of the batter of a bank or dam wall or other structure measured in terms of the amount of rise or fall in height that occurs for every increment in horizontal distance travelled eg a batter grade of 1:3 means a rise or fall of 1 vertical metre for every 3 metres of horizontal distance.

catchment — An area of land where water is collected by the natural landscape. In a catchment, all rain and run-off water eventually flows into a creek, river, lake, ocean or into the groundwater system.

channel incision — The development of a gully through erosion processes.

coefficient of runoff	The percentage of precipitation that appears as runoff.
concurrence	Agreement by the Chief Executive of the SCA with the consent authority in granting consent to the development proposal.
consent authority	*(Environmental Planning and Assessment Act 1979)* In relation to a development application or an application for a complying development certificate, means: (a) the council having the function to determine the application, or (b) if a provision of this Act, the regulations or an environmental planning instrument specifies a Minister or public authority (other than a council) as having the function to determine the application—that Minister or public authority, as the case may be.
contour	An imaginary line on the surface of the earth connecting points of the same elevation.
current recommended practice (CRP)	Current practice accepted by industry and land management agencies, and endorsed by the SCA, to manage an aspect of the operation or development of a land use to ensure that all activities are carried out in a way that optimises the protection of the landscape.
cut batter	An exposed surface left by excavation.
design return period	The calculated frequency of a storm of a particular magnitude selected to design a structure to withstand failure eg a dam would normally be built with a longer design return period than a bank.
detention (retarding) basin	The pondage volume of a large storage structure designed to hold storm runoff and then release it slowly to reduce peak discharge rates from a catchment.
development	*(Environmental Planning and Assessment Act 1979)* a. the use of land, and b. the subdivision of land, and c. the erection of a building, and d. the carrying out of a work, and e. the demolition of a building or work, and f. any other act, matter or thing referred to in section 26 that is controlled by an environmental planning instrument, but does not include any development of a class or description prescribed by the regulations for the purposes of this definition.

development application	An application for consent under Part 4 of the *Environmental Planning and Assessment Act 1979* to carry out development but does not include an application for a complying development certificate.
dispersive soil	Soil that is susceptible to structural breakdown into individual particles and has the ability to pass rapidly into suspension in water. Dispersible soils greatly limit water movement through the soil resulting in poor drainage and water logging.
diversion bank	A channel with a supporting ridge on the lower side constructed across or at the bottom of a slope for the purpose of intercepting and redirecting surface runoff.
drainage depression	A low point that carries water during rainfall events, but dries out quickly once rainfall has ceased. A gully or incised drainage depression is considered to constitute a watercourse.
embankment dam	A dam usually constructed in a depression consisting of an embankment across the depression that impounds water and stores it all above the ground surface.
erosion	1. the wearing away of the land surface by moving water, wind, ice or other geological agents, including processes as gravitational creep; 2. detachment and movement of soil or rock fragments by water, wind, ice or gravity (ie accelerated, geological, gully, natural, rill, sheet, splash or impact, etc).
excavated dam	A dam with its storage area wholly or almost wholly below the ground surface.
fill	The depositing of soil, rock or other similar extractive material obtained from the same or another site, but does not include: a. the depositing of topsoil or feature rock imported to the site that is intended for use in garden landscaping, turf or garden bed establishment or top dressing of lawns and that does significantly alter the shape, natural form or drainage of the land, or b. a waste disposal landfill operation.
fill batter	The exposed surface created during earthmoving operations by deposition of fill.
flume	A hydraulic, engineered structure made of reinforced concrete or rock incorporating an inlet, chute and outlet to convey water to a lower level (eg from top of gully to the gully floor) without causing erosion.

freeboard	The vertical distance between the top water level and the crest of a bank, dam or similar structure. Freeboard is provided for in designing such structures to prevent overtopping due to surcharge or wave action. In an earth structure, the initial freeboard should include an allowance for settlement.
graded bank	A bank built with a design fall along the channel, to allow water to flow in a specific direction at a non-scouring velocity.
groundwater	Water occurring naturally below the ground surface.
gully erosion	Soil erosion caused by run-off which appears as deep cracks in the ground. Results from the concentration of run-off flow into main drainage lines where channels are scoured out and large amounts of soil are lost.
headwall	A watertight barrier at the entrance to a hydraulic structure to prevent seepage from undermining the structure.
hillside dam	A water storage constructed on a uniform slope or hillside ie not in a depression.
hydraulic capacity	The amount of water, usually runoff water or excess water from a storage that a hydraulic structure such as a pipe can carry when full.
intermittent watercourse	Having banks and beds or ponds or remaining wet for considerable periods between rainfall events and which may be characterised by supporting moisture tolerant vegetation.
level bank	A bank that is constructed along the true contour with a level channel, and which discharges at either or both ends depending on design requirements.
neutral or beneficial effect test (NorBE)	A neutral or beneficial effect on water quality is achieved if a proposed development: a. has no identifiable potential impact on water quality, or b. will contain any such impact on the site of the development and prevent it from reaching any watercourse, waterbody or drainage depression, or c. will transfer any such water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.
nutrients	Nourishing substances, eg phosphorus and nitrogen, that enhance plant growth (including algal growth in water).

permeability	The permeability of a material is the speed of the water that travels through it. To be permeable, a material has to meet three conditions: • it has to be porous, • its openings must be large enough to let water pass through them, and • its openings must be well interconnected.
pervious	Materials (eg soils, membranes) that allow water to pass through; permeable.
rainfall erosivity	The potential for soil to wash off disturbed, devegetated earth into waterways during storms. It is a climatic factor which is determined from local rainfall data. Increased rain erosivity indicates greater runoff erosive capacity.
rill erosion	Occurs when run-off concentrates in shallow (less than 30 centimetres) channels, typically on cultivated slopes.
riparian	Any land and associated vegetation that adjoins, directly influences, or is influenced by a body of water. This includes land immediately adjacent to small creeks and rivers, riverbanks, streams or gullies, and areas surrounding lakes and wetlands on river floodplains that interact with the river during floods.
rip rap	Loose rock or stone used to protect earth surfaces against erosion by flowing water.
runoff	That portion of the water precipitated onto a catchment area that flows as surface discharge from the catchment area past a specified point.
saline soil	Soil that contains sufficient soluble salt to adversely affect plant growth and/or land use.
sediment	Soil, sand and materials washed from land into water, usually after rain.
seepage flow	The process by which water percolates downwards and/or laterally through the soil, often emerging at ground level lower down a slope; often used in relation to the percolation of water through a constructed earth wall.
sheet erosion	Caused by raindrop splash and surface flow over a wide front, usually on gentle slopes under cultivation.
site	The site of a proposed development means the area of land described in the development application.
soil depth	The vertical depth of soil from the soil surface to parent rock material.
steep	Slopes > 20% (11.4°) (for watercourses and gullies)

storage / excavation ratio	The ratio of the capacity of a storage to its excavated volume. The higher the ratio, the more efficient the storage is, implying low capital cost per unit volume of water stored.
stormwater	Rainwater running off a surface.
time of concentration	The shortest time taken for all points in a catchment to contribute water flow simultaneously past a given point (the discharge point).
trickle pipe	A small diameter pipe inserted through the wall of a ponding structure to accommodate trickle flows or to lower the water level in the structure at a controlled rate.
tunnel erosion	The removal of subsurface soil by erosion while the surface remains relatively intact.
waterbody	A waterbody (artificial) or waterbody (natural).
waterbody (artificial)	An artificial body of water, including any constructed waterway, canal, inlet, bay, channel, dam, pond, lake or artificial wetland, but does not include a dry detention basin or other stormwater management construction that is only intended to hold water intermittently.
waterbody (natural)	A natural body of water, whether perennial or intermittent, fresh, brackish or saline, the course of which may have been artificially modified or diverted onto a new course, and includes a river, creek, stream, lake, lagoon, natural wetland, estuary, bay, inlet or tidal waters (including the sea).
watercourse	means any river, creek, stream or chain of ponds, whether artificially modified or not, in which water usually flows, either continuously or intermittently, in a defined bed or channel, but does not include a waterbody (artificial).

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Appendix – Development Assessment and Approvals

1 Planning and legislative context

State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011 (the SEPP)	Under the SDWC SEPP, which came into force on 1 March 2011, proposed developments, including earthworks, must have a neutral or beneficial effect (NorBE) on water quality and should incorporate any current recommended practices (CRPs) and performance standards endorsed or published by the Sydney Catchment Authority (SCA) that relate to water quality. Consent will not be granted by council, or concurrence by the SCA if required, for development applications that do not meet the requirements of NorBE.
Neutral or Beneficial Effect (NorBE) on Water Quality Assessment Guideline 2011	The NorBE Guideline (SCA, 2011) aims to provide a clear direction as to what is meant by a neutral or beneficial effect, how to demonstrate it, and how to assess and application against the NorBE test.

2 Obtaining other approvals

Local government has the primary responsibility for granting development consent for rural developments involving earthworks (where they require consent eg dams); all development applications must be made to the relevant local council. The council will then review the application and refer it to other government agencies that may be required to provide input, or approvals as required by other Acts. All correspondence and communication should be directed through the local council.

Other approvals that may be required in addition to the development consent are summarised in the table below. This is not a definitive list of other approvals as these will be site dependent, but includes those most relevant to rural earthworks. Consultation should be undertaken with relevant approval bodies early in the design process.

Approval	Approval body	When required (summary only)
Local Government Act 1993	Local council	Requires approval of the Minister for Land and Water Conservation (now Minister for Primary Industries) for council works such as constructing or extending dams for impounding or diverting water for public use or any associated works.
Water Management Act 2000	Department of Primary Industries (Office of Water)	A controlled activity approval is required for controlled activities carried out in watercourses or riparian zones. Controlled activities include: • the removal of material (whether or not extractive material) or vegetation clearing from land, whether by way of excavation or otherwise, or • the deposition of material (whether or not extractive material) on land, whether by way of landfill operations or otherwise, or • the carrying out of any other activity that affects the quantity or flow of water in a water source.

<table>
<tr><th>Approval</th><th>Approval body</th><th>When required (summary only)</th></tr>
<tr><td>Water Management Act 2000</td><td>Department of Primary Industries (Office of Water)</td><td>Harvestable rights – rural landholders in NSW can build farm dams on minor streams that capture up to 10 per cent of the average regional rainfall run-off for their property, or are up to one megalitre on small properties, or are gully control structures, without requiring a licence.
<table>
<tr><th>Location of dam</th><th>Used for stock or domestic purposes</th><th>Used for irrigation or commercial purposes</th></tr>
<tr><td>On minor streams and capacity is less than Maximum Harvestable Right Dam Capacity (MHRDC)</td><td>No licence or approval required</td><td>No licence or approval required</td></tr>
<tr><td>On minor streams and capacity is more than your MHRDC</td><td>Not permissible – your harvestable right should provide more than enough water</td><td>Licence or approval required</td></tr>
<tr><td>On permanent creek or river</td><td>Licence or approval required</td><td>Licence or approval required</td></tr>
</table></td></tr>
<tr><td>Native Vegetation Act 2003</td><td>Local Land Services (former CMA, now DPI)</td><td>Vegetation clearing, including on State protected land, requires separate consent in defined circumstances under the Act. The Act states that native vegetation must not be cleared except in accordance with development consent or a property vegetation plan.</td></tr>
<tr><td>Roads Act 1993</td><td>Relevant road authority</td><td>Approval should be obtained for any works within a public road reserve.</td></tr>
<tr><td>Protection of the Environment Operations Act 1997</td><td>Environment Protection Authority</td><td>To control non-scheduled activities for the purposes of regulating water pollution resulting from such an activity.</td></tr>
<tr><td>Crown Lands Act 1989</td><td>Department of Primary Industries (Crown Lands)</td><td>Proposed opening and/or construction of Crown roads.</td></tr>
</table>

Approval	Approval body	When required (summary only)
Water Act 1912	Department of Primary Industries (Office of Water)	Extraction and use of water sourced from rivers and aquifers.
Heritage Act 1977	Office of Environment and Heritage	Discovery and protection of artefacts of Aboriginal or European heritage.

Contact information

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