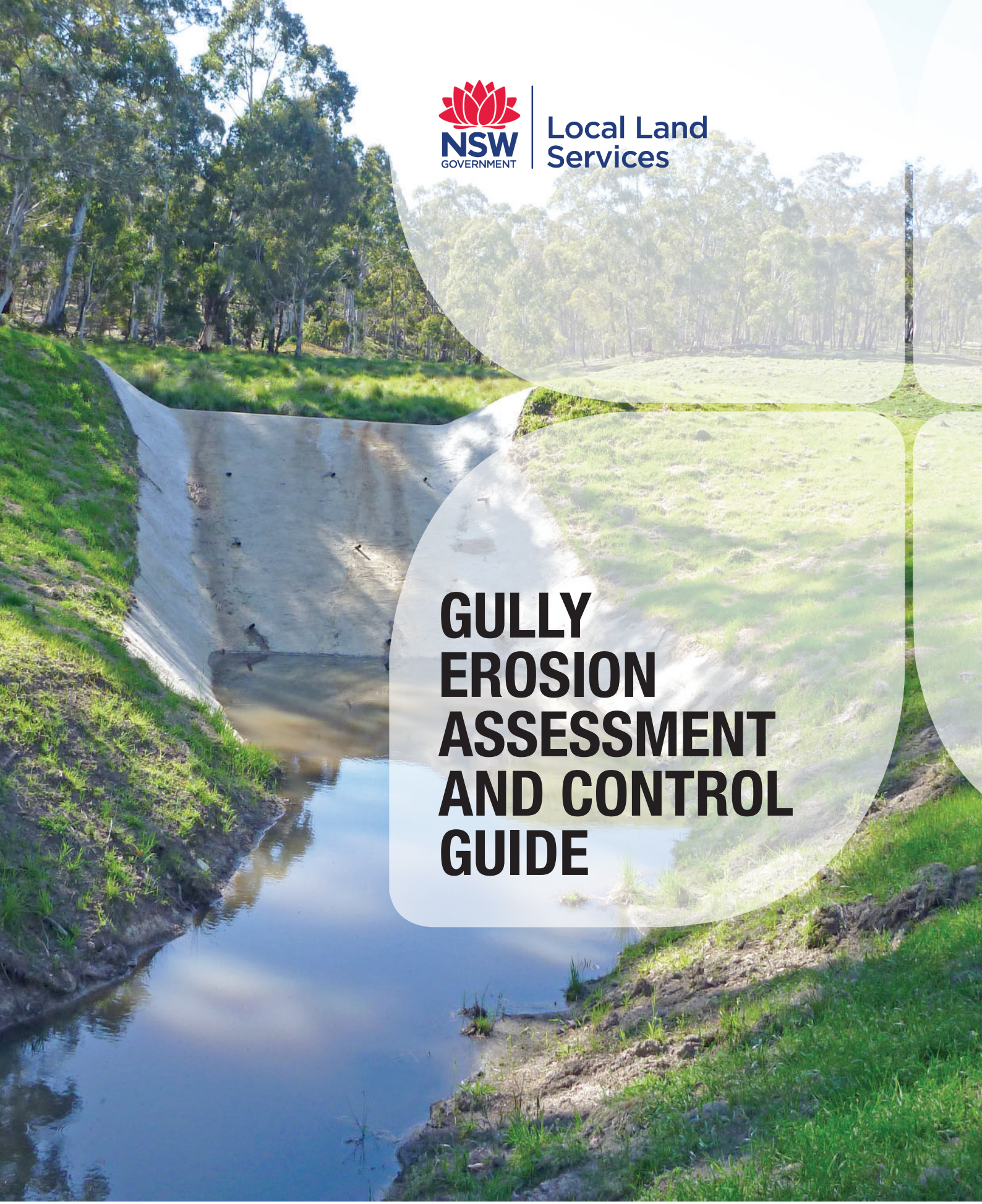

NSW GOVERNMENT | Local Land Services

GULLY EROSION ASSESSMENT AND CONTROL GUIDE

Australian Government | National Landcare Program

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SCOPE

This document is designed to help the reader understand the basics of gully erosion. It will assist users to identify if a gully is actively eroding, identify the severity of the erosion and discuss common management options.

The management options provided address existing gully erosion to minimise future erosion problems. Central to this is a gully erosion classification system, which categorises gully erosion problems and provides management options for each class of gully.

The options provided in this guide are suited to the Tablelands and Slopes landscapes and may not be applicable in coastal landscapes. This document is intended as a guide only. Professional advice in relation to the design of control works should always be sought.

SECTION 1

Background

Erosion is the movement of material via the activity of wind and/or water. This is a natural process which has over time shaped the landscape features seen today, such as river valleys and mountain ranges. The rate at which this erosion occurs depends on many factors including the force of wind and water pressure applied and the resistance of the material to which this pressure is applied to.

Activities such as construction, forestry and agriculture have the potential to reduce the resistance of these landscapes to movement or erosion. This has resulted in an acceleration of erosion in many parts of the landscape associated with agricultural and other human activities such as road and rail construction. One of the most visual forms of erosion is gully erosion.

What is gully erosion?

Gully erosion is the removal of soil from the surface and sub-surface creating permanent channels greater than 30 centimetres (1 foot) deep. Once a gully is formed erosion can continue in three ways:

1. The gully floor can deepen until rock is exposed or the grade becomes flat enough that the flow velocity is too slow to erode the soil any further.
2. The banks can undercut causing them to collapse and wash away. Sidewalls can also simply erode or "melt" away in very dispersible soil types.
3. The gully head can cut back up the slope or other gully heads form on the side of the gully (lateral gullies) as water flows over the edge.

In some gully systems these processes occur concurrently. Gullies can interfere with normal farming operations such as cultivation, mustering stock, general access and water supply. They present many problems to landholders as they are a continuing source of soil loss.

Sediment transported from gullies may be deposited in dams leading to a reduction in capacity and often has additional detrimental effect on other man-made drainage infrastructure such as the blocking of pipes and culverts. Sediment mobilised in drinking water catchments by erosion can reduce water quality for downstream users. Water quality is affected by the increased turbidity and the nutrients adsorbed on the sediments can pollute the water potentially leading to algal blooms. In-stream habitat for aquatic plants and animals may also be degraded by the smothering of the river bed with silt and sand. Sediment covers vegetation and inhibits growth.

What causes gully erosion?

Gully erosion often begins as a small "nick point" which are shallow and discontinuous. These slowly get larger until they begin to join up creating larger continuous gullies. These nick points often correspond to areas where groundcover has been disturbed by any number of natural or unnatural events.

The deepening or eroding of larger water courses (incising) can lead to smaller, lateral drainage lines being "perched" above the main water course. This creates a nick point where lateral flowline drops over the creek bank to join the larger watercourse which can lead to erosion of the lateral drainage line.

Gullies often form as a result of a disturbance that has led to a change in the groundcover. Groundcover is the key to soil stabilisation. A reduction in groundcover can expose bare soil leading to higher run off volumes and velocity of these flows. For example, stock tracks reduce both the protective groundcover and concentrate water flow. Property layout should consider the location of vehicle tracks, fence lines, watering points and gateways with respect to their influence on stock movement and the potential to initiate erosion and gully development.

What influences the rate of gully erosion?

Factors that impact directly on the development of gully erosion are ground cover, erodibility of soils and volume and velocity of flows. The following influences these factors:

Rainfall / runoff

Most erosion is caused during heavy storms rather than during prolonged light showers. Heavy storms can produce more water on the soil surface than can be intercepted by vegetation and infiltrated into the soil leading to surface runoff. In addition, heavy raindrops can break up soil particles into smaller fragments which then block up the pore spaces. This reduces infiltration capacity and leads to more surface runoff which can further increase erosion risk.

Trickle Flow

Trickle flow is consistent low level flows that wet up the soil. They are commonly spring fed and can persist for a time after periods of rainfall. If they occur in the floor of a gully they can be beneficial in providing a moisture source for sedges and reeds to stabilise the floor. However, if they occur above a headcut they can increase the movement of the erosion.

Soil type

Soils that are well structured with high clay content are generally less susceptible to erosion. Soils that are made up predominantly of coarse particles (gravel, sand and silt) and do not have sufficient clay to bind these particles together are more prone to erosion if disturbed and the protective vegetation cover is removed.

Soils that are unstable when wet, such as sodic soils, can erode very quickly when groundcover is reduced and the topsoil is exposed. These soils often have very low strength when wet and can slump under their own weight when saturated. Vegetation cannot establish naturally on these soils and can remain bare and prone to erosion for generations.

In some areas with sodic soils, tunnel erosion can be a major problem. Tunnel erosion is an insidious form of gully erosion that can remain unseen until the topsoil slumps in forming an instant erosion gully. The salinity of a soil can affect the amount of groundcover present, limiting the ability for growth and exposing bare areas to erosion.

Slope and topography

Steeper slopes cause the flow velocity of runoff to increase which yields more force to detach and transport soil particles. The length of slope is also important. As the slope gets longer the opportunity for runoff to concentrate increases. Often there is greater erosion on long low slopes than on short steep slopes. The topography of the landscape impacts on the concentration of flows and an assessment of topography can be used to predict the likelihood and location of gully erosion.

Land use

Farming practices that reduce ground cover and expose the soil surface will significantly increase the risk of erosion. Cultivation and stock trampling can break down soil structure resulting in compaction and less infiltration of rainfall. The breakdown of soil structure also reduces the cohesion of soil particles or the ability to resist erosive forces.

Break down of soil structure (through farming or grazing practices), and other land use changes such as road construction or other development, can increase the frequency and volume of runoff from storm events, consequently adding pressure to drainage lines and increasing the rate of erosion.

Gully erosion and water quality

In the South East Local Land Services (LLS) region, soil and stream bank erosion have a major influence on water quality. Eroding riverbanks and connected gullies represent the largest contributor of sediment in the region. Through a range of strategic programs and initiatives, South East LLS has focussed on improving river and tributary health, particularly through an improvement in riparian and aquatic habitat and ecological process.

Management of erosion to reduce sedimentation will improve in-stream water quality and the productivity and diversity of aquatic ecosystems as well as reduce the incidence of blue-green algal blooms.

Rehabilitating areas that are contributing high loads of sediment and nutrients is of particular importance where there are downstream areas of high conservation value or infrastructure at risk. Treatment of active gullies that are contributing sediment is critical to achieving river and tributary health in the catchments of the South East.

The South East Local Strategic Plan 2016-2021 has been developed incorporating the growing knowledge of the region's natural, social and cultural resources. As a strategic resource, it will play a critical role in planning natural resource management through building healthy diverse and connected natural environments.

SECTION 2

Land management options for erosion prevention

Land must be managed to prevent erosion. The prevention of soil erosion depends on managing the soil in such a way that it is retained on-site and can be used for its productive purpose.

Developing an erosion control plan that considers such factors as land capability, systems of management, location of improvements and specific erosion control measures provides a good starting point.

Land capability

The Land Capability Classification System groups like areas of land into categories and suggests what each area may be used for without damaging the soil. Generally land can be classified into four broad categories:

- A - Land suitable for cultivation and grazing
- B - Land suitable for grazing but not cultivation
- C - Land suitable only for timber
- D - Land unsuitable for rural production.

Classifying landscapes into capability classes is the first step towards developing an erosion management plan for a property.

These four categories are a simplified version of the Eight Class Land Capability System. For more information on Land Capability Classes see Appendix 1.

Management systems

Effective erosion control can rarely be achieved by using soil conservation earthworks alone. When preparing an erosion control plan it is essential to recognise the complementary role land management and earthworks play. Good land management can significantly improve the effectiveness of an earthworks program. Factors to consider in grazing enterprises are:

- Strategic pasture management: spelling pastures during critical stages is imperative. Ground cover levels should be close to 100% most of the time in all pasture land, the only exception being when new pasture is being established.

  Runoff levels increase quickly once ground cover levels drop below 70%.

  Low ground cover is also closely correlated to lack of plant root development, low water use, loss of productivity and potential for weed invasion.

- Control of vermin: vermin will compete with stock for pasture and affect ground cover levels.

- Management of stock access to riparian areas: this will encourage vegetation cover and bank stabilisation.

Factors to consider in cropping enterprises are:

- Conservation tillage: retaining stubbles and reducing tillage assists in maintaining or improving soil structure.

- Crop rotation: using leguminous crops can build up soil nitrogen levels and break disease and weed cycles.

- Weed control: substitution of cultivation with herbicides or grazing for weed control can preserve soil structure and reduce the time that the ground is exposed to the impact of rain.

Location of infrastructure

It is important to locate infrastructure such as roads, fences and watering points where they will not cause erosion.

- Farm tracks: these are often bare and below natural ground level due to compaction. They can easily divert runoff and concentrate flows resulting in rilling and gullying. Where possible locate tracks along ridge lines or on contours to allow for drainage. Flow lines should be crossed at right angles.

- Fencing and gates: fencing aimed at separating different land capabilities allows areas to be managed in a way that suits each capability. As with farm tracks, ridge crests are ideal for fence lines as they are well drained and provide good sites for gates. Otherwise, run fences across the slope on the contour or straight up and down the slope. Fences angling across the slope may divert water and cause erosion.

- Watering points: these can be subject to heavy stock traffic which can cause erosion. Troughs should be located where the area around the trough can be drained and will not become boggy. Avoid encouraging stock tracks from camps down slope to watering points.

Farm planning

A farm plan allows you to make more strategic decisions when considering development or improvements to the farm and gives a birds eye view of the property layout. Farm plans can take into consideration the points previously mentioned in relation to land capability, management systems and location of infrastructure.

Farm plans can be developed using digital imagery which is readily available on the internet. Layers of information can then be added such as:

- permanent features such as roads, sheds, power lines and boundaries

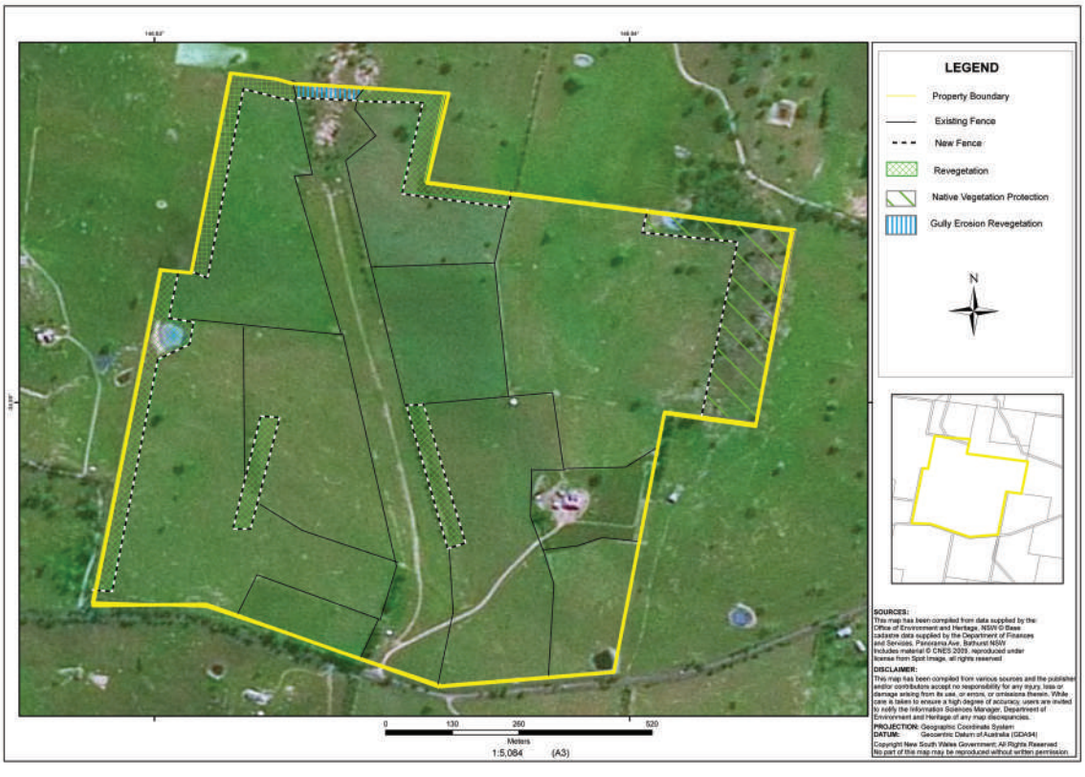
- natural resources such as soil types and land capability, drainage lines, vegetation

- existing infrastructure such as fencing, water points, pipe lines

- issues such as gully erosion, salinity, water logging, lack of water, access issues, weeds

- improvements and any future projects

This will allow you to potentially address several issues at once. The plan will also allow you to cost works out such as fence lengths, paddock and vegetation areas.



Example of a Farm Plan

SECTION 3

Gully erosion assessment

This method of assessing gully erosion problems has been developed to standardise prioritisation of actions for gully control for the purposes of protecting water quality in streams.

This assessment tool will allow priority projects to be developed and targeted to funding opportunities as they arise.

Classifying gullies using this methodology will enable effective identification of appropriate management options for different types of gullies in different landscapes.

The assessment is a four step process:

1. assessment of gully erosion
2. allocation of Gully Erosion Class Rating
3. identification of options for gully erosion management
4. prioritisation of gully rehabilitation for water quality and off-site benefit.

Step One: Assessment of gully erosion

Inspect the gully to determine which components are stable or active. The three components to consider are the gully head, gully floor and gully sidewalls. If the stability of the components varies along the length of the gully, break the system into smaller sections and develop management options for each section, or assess only the area where you will implement erosion controls.

Erosion Classification Class 7-8

Erosion Classification Class 1-2

Erosion Classification Class 1

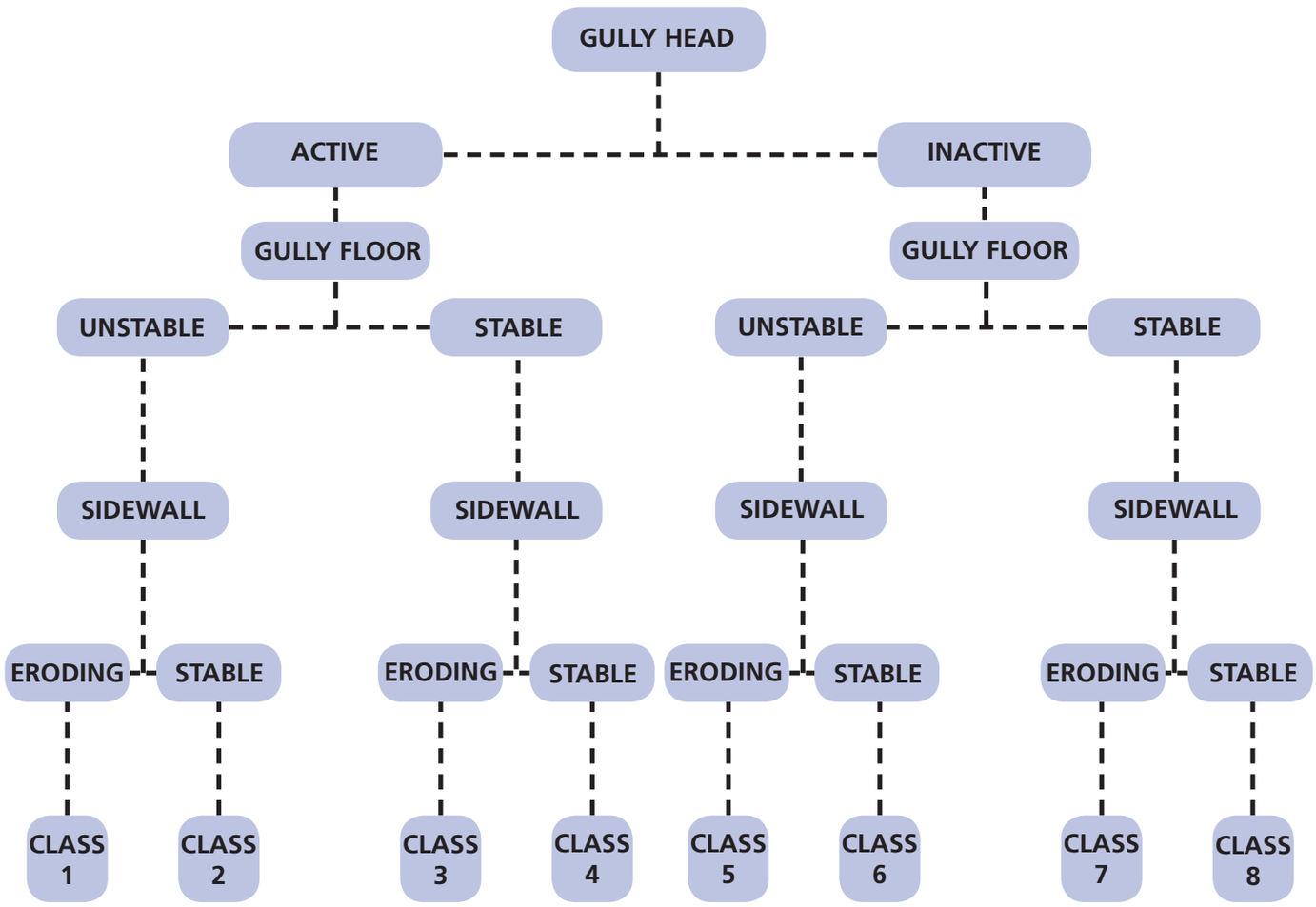
Step Two: Gully erosion class rating

Using the Gully Erosion Classification System, assess the gully and allocate an erosion class rating (Class One to Class Eight). A gully erosion class rating can be determined from assessing the stability of the components of the gully (gully head, gully walls, gully floor). It is an Eight Class System with Class One being the most active and unstable gully and Class Eight being the most inactive and stable gully.

Gullies with an erosion Class of One to Four will generally require earthworks to stabilise the active gully head. Gully erosion Classes Five to Eight, have a stable gully head and require management options to deactivate either the gully walls or gully floor or both of these components. In some cases management involves simply maintaining the stability of an area (Class Eight).

Use the Gully Erosion Classification System below to determine the erosion class rating of each gully.

Gully Erosion Classification System



Gully erosion depth rating

Applying the Gully Erosion Depth Rating allows you to prioritise the gully in terms of its severity and potential negative impacts on the environment. Refer to"Step Four Gully Erosion Prioritisation Matrix" to prioritise gullies based on their Erosion Class and Depth Rating.

How deep is your gully?

d	<1.5 metres
c	1.5 - 3.0 metres
b	3.0 - 6.0 metres
a	>6 metres

Step Three: Options for gully erosion management

There are a variety of management options for stabilising active gullies and reducing the amount of sediment entering our waterways. The options depend on the source of the erosion and how the different parts of the gully are interacting with each other. Below are some suggested management options for each of the Erosion Class Ratings. If earthworks are recommended, seek advice on the design, construction and maintenance of such works.

For illustrations of each earthwork option refer to Section 4 - Specific Erosion Control Earthworks.

Erosion Class Rating	Management Options
Class 1	**1. GULLY HEAD:** stabilise gully head by diverting run-on water. This may involve a simple strategy such as diversion banks, or more complex earthworks like a gully control structure or a flume. **2. GULLY WALLS:** if the side wall erosion is caused by run-on water, this will need to be diverted using diversion banks. If stock traffic is causing the erosion, then fencing to exclude stock from the gully system is a more appropriate option. These areas should stabilise over time through natural processes. **3. GULLY FLOOR:** if the gully head has been stabilised it is likely that the floor will become stable also. Regeneration can occur naturally or revegetation can be undertaken to speed up this process if desired. If the gully floor continues to erode after the head has been stabilised, the source of this erosion can be lateral flow (water moving into the gully via underground lateral movement) or could be a secondary head cut in the system. Secondary head cuts should be addressed when stabilising primary head cuts. Install bed stabilisation structures (such as a V-notch weir or rock ramp) in the gully floor. Revegetate gully floor with appropriate species.
Class 2	**1. GULLY HEAD:** stabilise gully head by diverting run-on water. This may involve a simple strategy such as diversion banks, or more complex earthworks like a gully control structure or a flume. **2. GULLY FLOOR:** if the gully head has been stabilised it is likely that the floor will become stable also. Regeneration can occur naturally or revegetation can be undertaken to speed up this process if desired. If the gully floor continues to erode after the head has been stabilised, the source of this erosion can be lateral flow (water moving into the gully via underground lateral movement) or could be a secondary head cut in the system. Secondary head cuts should be addressed when stabilising primary head cuts. Install bed stabilisation structures (such as a V-notch weir or rock ramp) in the gully floor. Revegetate gully floor with appropriate species.

Erosion Class Rating	Management Options
Class 3	**1. GULLY HEAD:** stabilise gully head by diverting run-on water. This may involve a simple strategy such as diversion banks, or more complex earthworks like a gully control structure or a flume. **2. GULLY WALLS:** if the side wall erosion is caused by run-on water, this will need to be diverted using diversion banks. If stock traffic is causing the erosion, then fencing to exclude stock from the gully system is a more appropriate option. These areas should stabilise over time through natural processes.
Class 4	**1. GULLY HEAD:** stabilise gully head by diverting run-on water. This may involve a simple strategy such as diversion banks, or more complex earthworks like a gully control structure or a flume.
Class 5	**1. GULLY WALLS:** if the side wall erosion is caused by run-on water, this will need to be diverted using diversion banks. If stock traffic is causing the erosion, then fencing to exclude stock from the gully system is a more appropriate option. These areas should stabilise over time through natural processes. **2. GULLY FLOOR:** if the gully head has been stabilised it is likely that the floor will become stable also. Regeneration can occur naturally or revegetation can be undertaken to speed up this process if desired. If the gully floor continues to erode after the head has been stabilised, the source of this erosion can be lateral flow (water moving into the gully via underground lateral movement) or could be a secondary head cut in the system. Secondary head cuts should be addressed when stabilising primary head cuts. Install bed stabilisation structures (such as a V-notch weir or rock ramp) in the gully floor. Revegetate gully floor with appropriate species.
Class 6	**1. GULLY FLOOR:** if the gully head has been stabilised it is likely that the floor will become stable also. Regeneration can occur naturally or revegetation can be undertaken to speed up this process if desired. If the gully floor continues to erode after the head has been stabilised, the source of this erosion can be lateral flow (water moving into the gully via underground lateral movement) or could be a secondary head cut in the system. Secondary head cuts should be addressed when stabilising primary head cuts. Install bed stabilisation structures (such as a V-notch weir or rock ramp) in the gully floor. Revegetate gully floor with appropriate species.
Class 7	**1. GULLY WALLS:** if the side wall erosion is caused by run-on water, this will need to be diverted using diversion banks. If stock traffic is causing the erosion, then fencing to exclude stock from the gully system is a more appropriate option. These areas should stabilise over time through natural processes.
Class 8	**1.** Manage groundcover to maintain stability of area.

NOTE: Fencing off gully systems to exclude stock is recommended for all Erosion Class Ratings

Step Four: Prioritisation of gully rehabilitation for water quality and off-site benefits

Working out which gullies are higher priorities for treatment can be complicated and a site specific task. The bigger and more active gullies will contribute higher sediment and associated nutrient loads into the watercourse and therefore have potentially greater downstream water quality impacts. The prioritisation matrix below uses the Gully Erosion Class Rating System and depth factor to determine priority.

On a site specific scale, a small gully may be a very high priority due to the threat it may pose to infrastructure such as roads. The connectivity of gullies to major water courses will also determine how much of the sediment and associated nutrients mobilised by gully erosion will impact significantly on water quality on a catchment scale. For example, a small gully connected directly to the Yass River may have greater water quality impact than a very large gully in the upper reaches of the catchment, kilometres from the river, where there is more opportunity for mobilised sediment to be caught in pools, dams and vegetation such as in stream wetlands.

A simple matrix is included to assist in prioritising gullies for remedial work on the basis of the potential impact in downstream water quality. This matrix uses the Gully Erosion Class Rating System previously applied in Step Two.

Gully Erosion Prioritisation Matrix

Once you have established the class and depth rating for your gully, use the table below to work out its priority.

		Erosion Class Rating							
		1	2	3	4	5	6	7	8
Gully Depth	a (>6m)								
	b (3.0-6.0 m)								
	c (1.5-3.0 m)								
	d (<1.5m)								

PRIORITY 1 - High Priority

PRIORITY 2 - Moderate Priority

PRIORITY 3 - Low Priority

SECTION 4

Specific erosion control earthworks

This section details specific earthworks options for stabilising active gully head erosion. This relates to gullies categorised as Class One to Four in Step Two.

Before any treatment is considered, the size of the contributing catchment needs to be determined. Generally the larger the catchment size, the less options are available. In smaller catchments (for example, less than 50 hectares), a variety of earthmoving techniques may be used to stabilise gullies depending on the site characteristics and available funds.

On larger catchments works will need detailed design to ensure that they are capable of handling storm events. In most situations structures will need to cater for at least a 1 in 50 year storm event.

Gully Control Structure (dam)

A gully control structure built above the gully head will stop run-off water from flowing over the gully head by storing the run-off in a dam. This structure also provides a sediment trap.

The structure could be built within the gully "drowning out" the active gully head with the stored water. A trickle pipe installed through the gully control structure can release water slowly over time, protecting the main spillway from erosion.

These structures allow a large volume of water to be stored between the pipe level and the spillway level, which can be safely released through a trickle pipe. Such systems are ideal for continuous gully systems where runoff water cannot be handled with a bank and pipe system. This type of structure should be designed to cater for the relevant run off volumes of the catchment.

Diversion banks

Diversion banks divert water away from actively eroding areas either to a safe disposal area or to another structure such as a dam or flume.

For gullies on small catchments, or discontinuous gullies, a diversion bank/s may be all that is required for stability. On larger gully systems, diversion banks may be needed to divert water to another structure such as a flume or gully control structure.

Banks should be designed to cater for storm events, to ensure the banks are not over topped or eroded during a storm event.

Pipes in banks

Trickle pipes are recommended in some situations including:

- On catchments up to five hectares where there is no stable area to divert runoff and no other structure is required. The pipe caters for most small - medium trickle flows.
- Where there is a constant trickle flow that needs to be managed to keep other areas dry.

Gully filling and shaping

Before filling can occur, diversion works must be properly designed and constructed to minimum recommended standards. Filling of a gully should only be undertaken in those areas where all surface run off has been diverted away and there is little or no groundwater on the site.

Once water is diverted away from an eroding area it can be seeded, mulched and stock excluded to stabilise the area.

For pastoral lands and where the soils are highly dispersible, shaping gullies is not usually recommended.

Filling a gully, (for example with clean fill) should only be undertaken after gaining the necessary approvals from Local Council.

Gully control structure (dam) built above gully head.

View of gully below gully control structure.

Pipe through bank of gully control structure (dam) to reduce the frequency of flow through primary spillway. This helps to prevent the spillway becoming sodden and prone to erosion.

Diversion banks safely transporting runoff away from the main gully and lateral gully, both with active walls.

Diversion banks transporting water away from gully head below it into a dam.

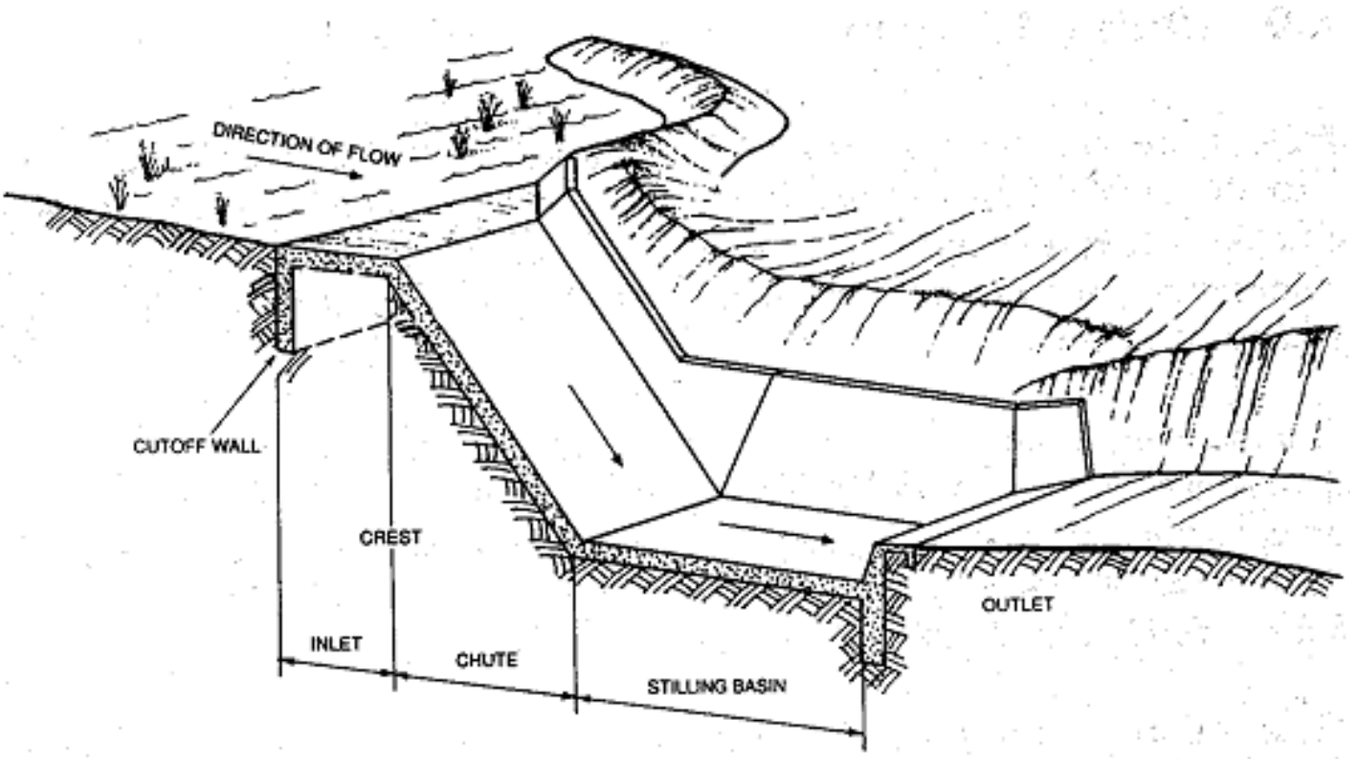
Pipe through diversion bank protecting gully head below.

Lateral gully protected by diversion bank.

Flumes

Flumes are used where it is necessary to convey water to a lower level over a short distance. They are designed in such a way to dissipate the erosive energy generated by dropping the water in this fashion, for example into the stable floor of steep-sided gullies.

All flumes are engineering structures and should be designed by engineers to cater for at least a 1 in 50 year storm event.



Components of a typical concrete flume. Courtesy of Adams, C. and Mitchell, I. *Earthmovers Training Course: Unit 19 Flumes and Chutes,* Soil Conservation Service of NSW (1992).

Concrete flumes

Concrete flumes form a stable, long life structure for conveying large volumes of run-off for long durations to the floor of highly active gullies. They need to be properly designed and constructed. Subsurface drainage may be required.

Concrete flume:
directing flow into stilling pond.

Concrete flume well vegetated.

Grade Stabilisation Structure (rock ramp)

These structures are also used to provide a stable disposal site for run-off water within a gully. Once the storm flow has been calculated then the rock size can be determined. A mixture of sizes is best to key-in the larger rocks and ensure there are no voids creating a weakness in the structure. A cut off trench should be installed to stop any undermining of the structure. The cut off trench is lined with geofabric which extends for the length of the structure. Rocks are then placed on geofabric. Rock is an option for providing gully floor stabilisation.

V-notch weirs

V notch weirs are used to stabilise gully floor headcuts. They are only used to stabilise a drop of 300-400mm. They are constructed from hardwood logs. Two logs are buried into the ground forming the cut off trench. The third log sits above to stabilise the headcut, slow and direct the flow. The V needs to be pointed upstream to ensure the water is directed towards the centre of the gully. Rocks are placed behind the v-notch weir to provide scour protection.

Grade Stabilisation Structure

V Notch Weir

Strategic fencing

In most situations, fencing is recommended for the protection of watercourses. Fencing is recommended for most gully systems where sodic or dispersible soils occur along the flow line. Excluding stock allows for natural regeneration to occur and reduces the possibility of further erosion on the gully edges due to stock tracks concentrating runoff.

Planting of trees and shrubs along both sides of the gully banks is recommended to help stabilise the eroding area. As well as stabilising the soil, this creates a wildlife corridor and windbreak benefits and improves water quality off site.

Gully area has been stabilised by fencing to exclude stock and allow for vegetation.

Guidelines for fencing a gully

- Fence out a buffer zone of at least 10 metres either side to allow for further slumping, tree planting and vehicle access. Many landholders have been nervous about fencing off too much land. However, in the long term it is beneficial to have an extra buffer. These areas can be used in the event of a feed gap, or for stock protection after shearing.

- Use a farm plan to help locate the fence position to ensure vehicle and stock movements, gates and water supply and the like are considered.

Fenced gully to exclude stock and native plantings.

Before and after images showing how a concrete flume can be utilised to safely convey water

Before and after images showing how revegetation can occur if water is diverted and stock excluded.

Before and after images showing how the exclusion of stock and revegetation can repair gullies.

Before and after images showing how the gully floor has been stabilised.

Before and after images showing how a gully can be revegetated following rock positioning in the gully head and stock exclusion.

GLOSSARY

Aggregate

A unit of soil structure usually formed by natural processes and generally less than 10 millimetres in diameter.

Aggregation

The process whereby primary soil particles (sand, silt, clay) are bonded together usually by natural forces and substances derived from root exudates and microbial activity.

Clay

A soil separate consisting of particles 0.002 millimetres in equivalent diameter. See also, soil texture.

Disperse

(i) To break up compound particles such as aggregates into the individual component particles. (ii) To distribute or suspend fine particles such as clay in or throughout a dispersion medium such as water.

Infiltration

The downward entry of water into the soil through the soil surface.

Peds

The natural unit of soil structure formed by the soil's tendency to fracture along planes of weakness.

Porosity

The fraction of the total bulk volume of soil occupied by pores.

Sand

A soil particle between 0.05 and 2.0 millimetres in diameter.

Silt

A soil separate consisting of particles between 0.05 and 0.002 millimetres in equivalent diameter.

Sodic

When sodium makes up more than about 5% of all cations bound to clay particles, structural problems begin to occur, and the soil is said to be sodic.

Soil structure

The combination or arrangement of primary soil particles into secondary particles, units or peds. These secondary units may be, but usually are not, arranged in the profile in such a manner as to give a distinctive characteristic pattern. The secondary units are characterised and classified on the basis of size, shape and degree of distinctiveness into classes, types and grades, respectively.

Soil texture

The relative proportions of the various soil separates (sand, silt, clay) in a soil as described by the classes of soil texture.

Run on water

Surface water flowing onto an area or structure as a result of run off occurring higher up the slope.

Run off

That portion of precipitation not immediately absorbed into or detained upon the soil and which thus becomes surface flow. Runoff is the major agent of water erosion. The amount of runoff depends on rainfall intensity and duration, land slope, surface roughness, vegetative cover and surface soil conditions including moisture content.

REFERENCES

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APPENDIX 1: LAND CAPABILITY CLASSIFICATION

Class	Land Use	Management Options
I	**Can be regularly cultivated**	Land capable of a wide variety of uses – vegetables and fruit production, grain crops, fodder, sugar cane. No special soil conservation works or practices necessary.
II		Gently sloping land capable of a wide variety of agricultural uses. Soil conservation practices such as strip cropping, conservation tillage and adequate crop rotations.
III		Sloping land capable of cropping on a rotational basis. Similar to I and II; structural soil conservation works such as graded banks and waterways, together with soil conservation practices as in Class II.
IV	**Grazing**	Occasional cultivation, better grazing land. Soil conservation practices such as pasture improvement, stock control, and application of fertiliser and minimal cultivation for the establishment or re-establishment of permanent pasture.
V		Similar to IV, structural soil conservation works such as diversion banks and contour ripping, together with the practices in Class IV.
VI		Not capable of cultivation, less productive grazing. Soil conservation practices including limitation of stock, broadcasting of seed and fertiliser, prevention of fire and destruction of vermin. This may require some structural works.
VII	**Tree cover**	Land best protected by trees. Adequate ground cover maintained by limiting grazing. Very important habitat areas for protecting biodiversity.
VIII	**Unusable**	Cliffs, lakes or swamps and other lands incapable of sustaining agricultural production.

Courtesy of Cunningham, G., Higginson, A. and Emery, K. *Systems Used to Classify Rural Lands in New South Wales,* NSW Department of Land and Water Conservation (1998).

APPENDIX 2:

For best results use species that are endemic to your area

Scientific Name	Common name
UPPER STOREY	
Eucalyptus blakleyi	Blakleys Red Gum
E. bridgesiana	Apple Box
E. cinera	Argyle Apple
E. dives	Broad-leaved Peppermint
E. gardneri	Blue Mallee
E. goiniocalyx	Bundy
E. machoryncha	Red Stringybark (dry areas only)
E. mannifera	Brittle Gum (dry areas only)
E. melliodora	Yellow Box
E. pauciflora	Snow Gum (colder areas only – frost hollows)
E. polyanthemos	Red Box
E. rossii	Scribbly Gum (dry areas only)
E. camaldulensis	River red gum
E. rubida	Candlebark
E. stellulata	Black Sallee
E. viminalis	Ribbon Gum
Casuarina cunninghamiana	River She Oak (wet areas only)
C. littoralis	Black She Oak
C. verticullata	Drooping she Oak

SPECIES FOR RIPARIAN & EROSION CONTROL AREAS

Scientific Name	Common name
MID STOREY	
Acacia dealbata	Silver Wattle
A. genistafolia	Spreading Wattle (dry areas only)
A. rubida	Red Stem Wattle
A. mearnsii	Black Wattle
A, melanoxylon	Blackwood
A. verniciflua	Varnish Wattle
A. implexa	Lightwood
Callistemon pityoides	Alpine Bottlebrush
C. pallidus	Lemon Bottlebrush
C. sieberi	River Bottlebrush (very wet areas only)
Davesia mimosoides	Bitter Pea
Dillwynia sericea	Parrot Pea
Dodonea viscosa	Giant Hop Bush
Grevillia juniperina	Prickly Grevillea
G. lanigera	Woolly Grevillea
Indigophera australis	Austral's Indigo
Leptospermum obavatum	River Tea Tree (very wet areas only)
Melichrus urceolatus	Urn Heath
Mirbelia platyloboides	Mirbelia
GRASSES	
Lomandra filiformis	Mat Rush
L. multiflora	Mat Rush (wet areas)
Poa labillarderi	River Tussock (Versatile but does very well in wetter areas)

Adapted from Butz, M. and Crombie, R. *Trees for Farms - Species Selection Guide*, NSW Forestry Commission and Yass Area Network of Landcare Groups, Rehwinkel, R. (National Parks & Wildlife Service), Streetfield, S. (Greening Australia), and Weatherstone, J. (Lynfield Park Nursery, Gunning), *Yass Species List (2001).*

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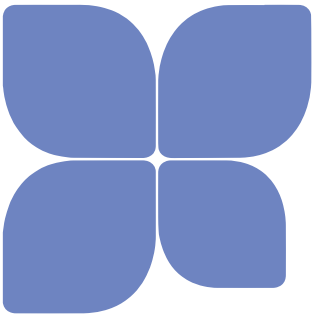

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