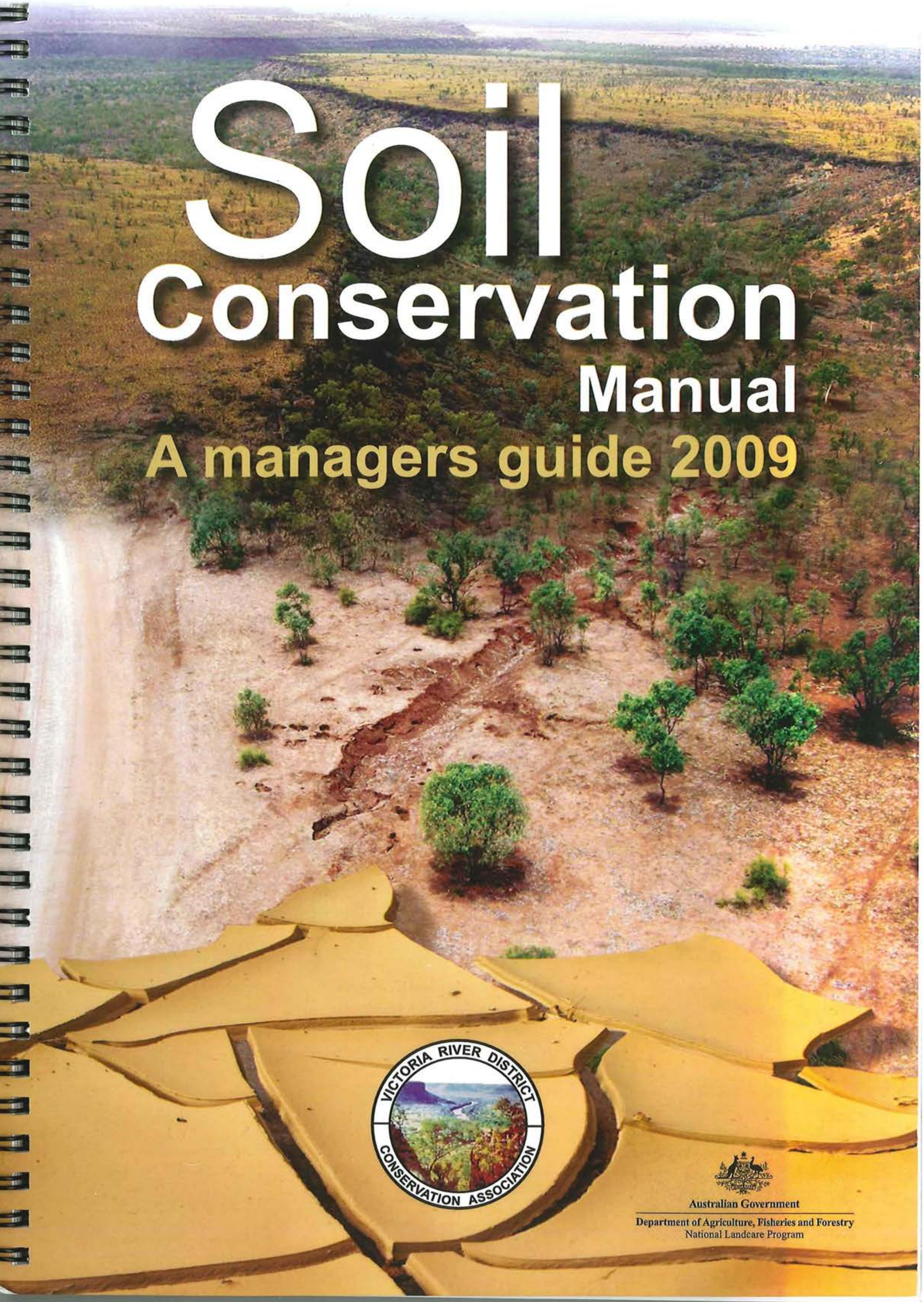
Soil Conservation Manual

A managers guide 2009



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Introduction

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This manual was originally conceived as part of an ongoing program by the Victoria River District Conservation Association (VRDCA) to provide practical information to members on ways to tackle soil erosion. Erosion on roads, tracks, firebreaks and fencelines (hereafter abbreviated to RTFF), is usually the most evident form of erosion on a property and this is the main focus covered by this manual. Other forms of erosion found in the Victoria River District (VRD) will also be discussed. A lot of the information on other forms of erosion was originally published in a report on erosion in the VRD in 1986 (Condon, 1986) with a follow up report (Condon, 1989). The first report by Condon was the catalyst for the formation of the VRDCA.

It is essential to remember that the most important resource on a property is the soil. There is a very close relationship between the soil and its vegetative cover. Without soil there would be no vegetation but conversely without a vegetative cover the unprotected soil would rapidly erode. Rates of soil formation vary quite significantly, depending on many factors. For the VRD the rate of soil formation is probably around 15-20 tonnes per hectare per 1000 years (Charman et al, 2007). Considering that it is possible to lose 20 tonnes per hectare in just one intense storm it can be seen that once the soil has gone from a property it will never be replaced in our lifetime.

Soils are taken for granted by so many people and yet they are the basis of all agricultural enterprises. For the VRD it is the medium for the production of native pastures. If the soil is lost the property's ability to run a pastoral enterprise is gone.

The main nutrient load of the soil is in the top few centimetres. The value of these nutrients and the cost to replace them if they are lost is inestimable. No pastoral enterprise could possibly survive if it was necessary to fertilise large tracts of land and yet there are so many times when huge amounts of irreplaceable nutrients are simply allowed to wash away. The preservation of the soil should be one of the guiding principles of all agricultural operations.

Sustainable farming and best management practices are the "buzz words" of the agricultural industry in present times. There is a shift throughout Australia both within government and the general public to gradually have more involvement in and regulation of the agricultural industry. If the property owners are not perceived to be practising sustainable farming or adopting best management practices then there is a strong likelihood that the government will legislate to enforce such practices. To avoid this interference it is essential that the agricultural industry moves towards the adoption of sustainable farming and best management practices as a matter of urgency.

This manual has been designed to provide property managers with the knowledge to avoid and/or manage erosion on RTFFs through the correct siteing of the RTFFs and the implementation of soil conservation works.

2

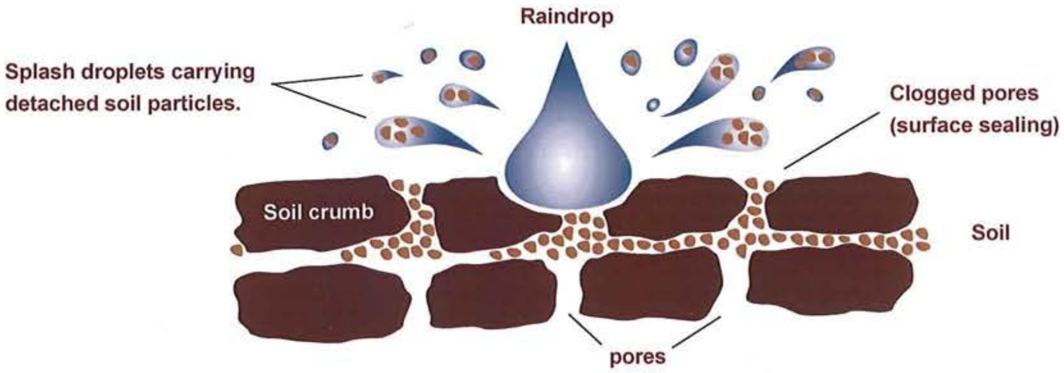
What is soil erosion?

Soil erosion is the detachment of soil particles, their transportation and finally their deposition at another site. This basic process is the same for both wind and water erosion.

2.1 Water Erosion

This process is initiated when rainfall hits bare, unprotected soil and detaches the soil particles. At the same time the raindrops compact the soil and splash soil particles into the air. Some of the detached particles are washed and pushed into the surface pores of the soil. This immediately decreases water infiltration leading to increased runoff. This increased runoff carries the detached soil particles away. The runoff will carry the detached soil particles away for as long as it has sufficient energy. When the runoff no longer has sufficient energy to carry the soil particles deposition will occur.

Figure 1.
A raindrop hitting bare soil, detaching soil particles and blocking pores.



2.1.1 Factors affecting the degree of water erosion

A. **Soil type** - degree of erodibility

The soils of the VRD range from the extremely erodible duplex textured soils of the Victoria, Humbert and Wickham Rivers area to the fairly stable grey-brown cracking clays of the southern areas of the VRD. There is no hard and fast rule for determining a soil's erodibility by simply observing its colour or structure. It is expected that the Northern Territory Department of Natural Resources Environment the Arts and Sport will soon be completing a detailed land unit map of the VRD. This map will show the occurrence of all soils in the VRD and their degree of erodibility. This mapping will be invaluable in assisting property managers in their decision making.

Plate 1.
A raindrop hitting bare ground.

B. Vegetation cover - protection from rainfall impact and overland waterflow.

A vegetative cover presents a barrier to the destructive power of raindrop impact. The greater the vegetative cover the less soil that is exposed to this erosive force. Even when soil particles are detached if there is enough cover it slows the runoff down to a speed where it is unable to transport the soil. This applies to all areas on the property including RTFFS and pastoral lands. It is essential that sufficient vegetation remains at the start of the wet season to ensure the safety of the soil.

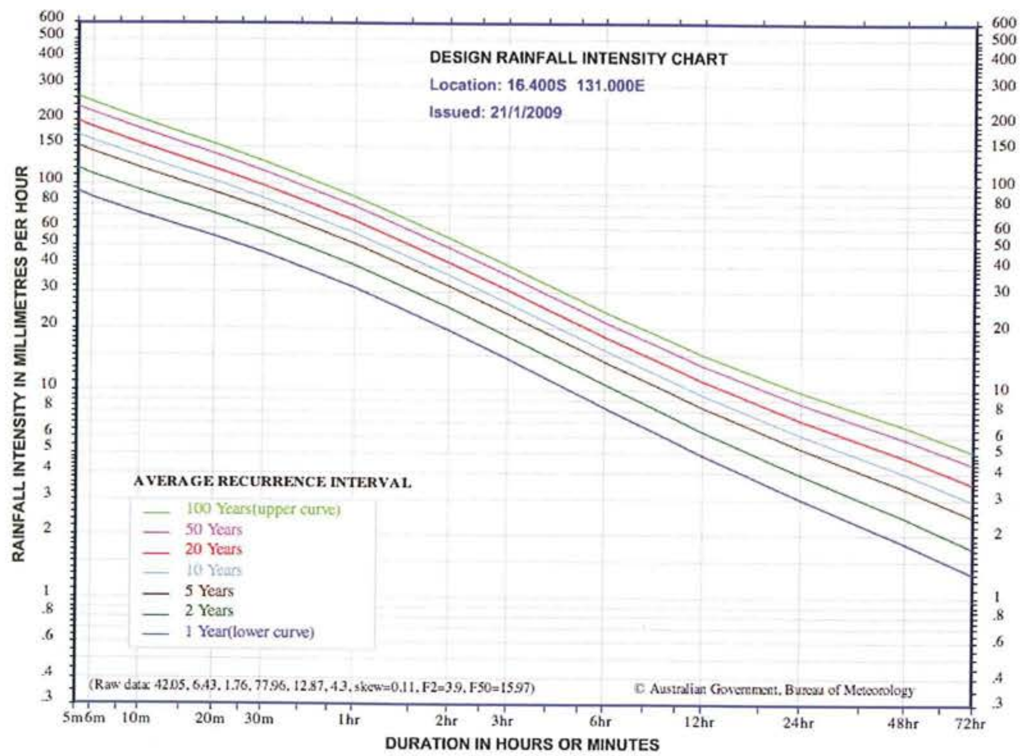
C. Slope - increases or decreases the speed of overland waterflow.

Increases in the degree of slope lead to a rapid increase in the speed of overland waterflow. As the speed of the water flow increases its kinetic energy increases. This allows the water to carry detached soil particles more easily.

D. Intensity and duration of rainfall events.

Storms in the VRD are often very intense and of long duration. This leads to a high volume of sustained runoff with the potential to cause significant soil erosion. The rainfall from the early stages of a storm rapidly soaks into the soil. As the storm continues the ground eventually becomes saturated and most of the water flows across the ground. As the amount of runoff increases its ability to carry detached soil particles is increased. This leads to a greater potential for erosion. The following chart shows rainfall intensity probabilities for Victoria River Downs. The average recurrence interval shows the chance that rainfall of a particular intensity will occur for a certain length of time. For example it is likely that a storm with an intensity of 50mm per hour lasting 25 minutes will occur every year.

Figure 2. Rainfall intensity chart for VRD Station.



Rainfall Intensity Chart, Bureau of Meteorology website, 'copyright Commonwealth of Australia reproduced by permission'.

E. Concentration of overland waterflow.

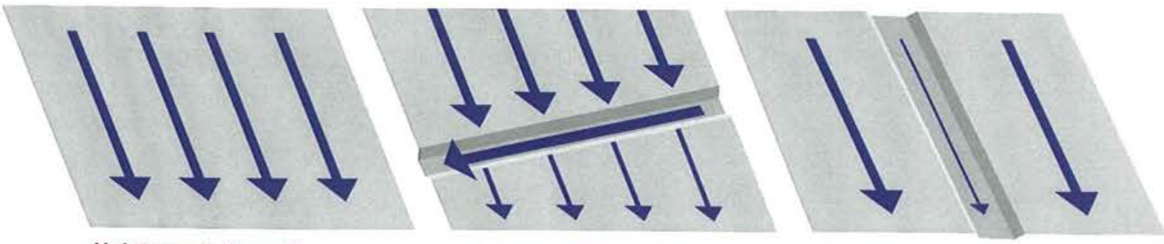
a. Water initially flows in a broad sheet across the land. Eventually it is channelled into stable drainage lines. Any structure which obstructs the natural flow will concentrate the water and lead to an increase in soil erosion.

b. Windrows – a mound of soil, rock or vegetation left at the side of RTFFs by grader or dozer operations. In some cases these may be up to 60 – 70cm high;

c. Wheel ruts – wheel ruts are often left along RTFFs when they are used during or immediately after wet weather. The wheel ruts channel water down the RTFFs often leading to rilling or gullying.

e. Cattle pads – cattle walking along RTFFs gradually wear a pad which will channel water leading to soil erosion.

Figure 3.
Shows direction of uninterrupted water flow and obstructed water flow.



Uninterrupted runoff.

Runoff diverted by track. Potential for erosion.

A track running straight up and down the slope. Only a small catchment therefore only a small amount of runoff to be diverted by banks or drains.

Plate 2.
Photo of cattle pads beside a fenceline.

Plate 3.
A windrow beside a fenceline

Plate 4.
A series of windrows beside a track.

2.2 Wind Erosion

Wind erosion can occur when the lifting power of the wind is greater than the force of gravity and the cohesive forces of the soil particles. Wind erosion consists of three processes. The smallest particles can be lifted and held in suspension as evidenced by dust storms. Larger particles are carried by the wind in a series of bounces. This process is called saltation. Even larger particles can be rolled along the ground pushed by the wind or other particles. This process is called soil creep.

2.2.1 Factors affecting the degree of wind erosion

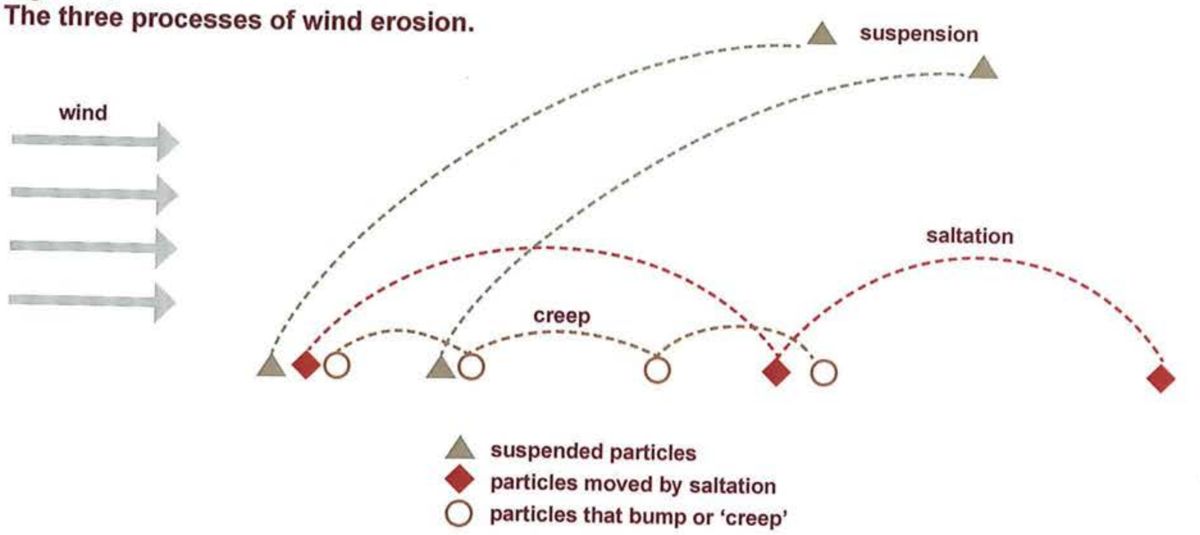
A. **Soil type**. Sandy soils which lack the cohesion of clay soils are more prone to wind erosion.

B. **Wind speed**. Wind erosion will not occur if the wind speed does not provide the lift necessary to overcome both gravity and the cohesive force of the soil particles.

C. **Land use**. The removal of a vegetative cover by stock or cultivation will leave the soil bare and exposed to wind erosion. Stock trampling the soil cause it to break up allowing the wind to pick it up more easily.

D. **Rainfall frequency and timing**. Long periods without rain allow the bare soil to dry and crack making it easier for the wind to detach the soil particles.

Figure 4.
The three processes of wind erosion.



Although wind erosion needs to be considered in the VRD, its effects are usually fairly localised. Areas of high disturbance, such as yards or laneways, may be subject to wind erosion. However soil loss in these areas is relatively insignificant. Areas that have been overgrazed, leading to a loss of vegetative cover, may be at risk of wind erosion. Light sandy soils or fine textured heavier soils are most likely to suffer the effects of wind erosion. The removal of the nutrient rich topsoil will expose the subsoil which is a much more hostile environment for plant growth. The drop in soil condition and the resultant fall in land condition will lead to a marked decrease in productivity. If the land has reached its worst condition which would be evidenced by the exposure of the subsoil it would be extremely difficult to rehabilitate. Mechanical methods of rehabilitation are expensive. The obvious control measure in this case is to ensure that optimum pasture utilisation rates are never exceeded in the first place.

Plate 5.
Dust storm, visible evidence of wind erosion taking place.

3

Types of soil erosion

The depletion of soil through erosion is a major problem facing all agricultural enterprises. The threat of soil erosion should never be taken lightly as soil is one of the most important property resources. Once the soil is gone it never returns.

All pastoral operations should be undertaken with this thought in mind. The question should always be asked before making any changes to property management practices. What effect will this change of operation have on the soil? If the answer is that it will have a detrimental effect, the benefits of the operation need to be weighed against the soil loss. There are occasions when it may be necessary to have a minor sacrifice of the soil, for example at watering points and yards. However if an alternative can be found it should be used. This could for example involve the use of portable yards to lessen the risk of erosion by allowing the yard area and the land around it to revegetate before it is used again.

In this section we will only look further at water erosion as this form of erosion has the greatest impact on properties throughout the VRD.

Erosion by water is a natural process. It is usually only where vegetation has been disturbed and/or the inappropriate siting and construction of RTFFs, that erosion is likely to form at an accelerated rate. There are many forms of soil erosion by water. The most prevalent forms found on the VRD include:

- **Sheet erosion.**
- **Rill erosion.**
- **Gully erosion.**
- **Stream bank erosion.**
- **Tunnel erosion.**

3.1 Sheet Erosion

Sheet erosion is evident when layers of topsoil are removed and washed down slope. It is not always obvious that sheet erosion is taking place until significant amounts of nutrient rich soil have been removed. One sign that sheet erosion is taking place is the exposure of plant roots or the formation of plant pedestals. One result of sheet erosion is the lowering of the rate of water infiltration. This leads to both a decrease in available water for the pasture and an increase in runoff which leads to further erosion.

On heavier red soils sheet erosion occurs where sufficient vegetation has been removed so that the soil is no longer protected from rainfall impact or wind. This can lead to a uniform soil loss over the area. The remaining bare area (scald) is not very permeable thus leading to increased runoff and poor plant growth. This increased runoff improves the growth and quality of the pasture at the edge of the scald. Cattle tend to preferentially graze these edges causing the scald to increase in size. These scalds are often initiated by bushfires which cause a concentration of cattle on the burnt areas as the sweeter green pick emerges.

Plate 6.
Sheet erosion

3.2 Rill Erosion

A rill is an erosion channel up to 30 cm deep. Rill erosion is usually initiated on bare soil in areas where there is a concentration of runoff. On grazing lands it may be one of the first signs that sheet erosion is taking place. Rilling is also one of the first signs of erosion on roads, tracks, firebreaks and fencelines. If you identify any rilling, this is now the time to take action before the rills turn into gullies which in turn increases your repair costs.

Plate 7.
Rill erosion on a cattle pad.

3.3 Gully Erosion

A gully is an erosion channel that is deeper than 30 cm. On most pastoral properties gully erosion is usually a problem on disturbed areas such as roads, tracks, firebreaks or fencelines. If the layout of the roads, tracks, firebreaks and fencelines is considered carefully before they are constructed the risks of erosion can be minimised. On existing roads, tracks, firebreaks and fencelines and on new layouts where it is not possible to exclude an erosion risk, appropriate erosion control measures will need to be undertaken.

Plate 8.
Gully beside a track.

In this discussion so far the emphasis has been on gully erosion on man made structures such as tracks, firebreaks and fencelines. It is relatively easy to overcome the erosion risk on these structures or to repair any gullies that already exist. There are however other forms of gully erosion which occur in the VRD which cannot be so readily avoided or rehabilitated. These forms of gully erosion are:

- **Fan gullies -** is a type of gullying that works both upwards and sideways giving the appearance of a fan. As these gullies have highly dispersible subsoils they continue to erode on all sides even with light intensity rainfall events.
- **Finger gullies -** start off as narrow deeply incised gullies found on alluvial soils. Over time they tend to widen but they always maintain a characteristic "U" shape. Finger gullying often occurs as a secondary stage of erosion in fan gullies.

Plate 9.
Fan gully

Plate 10.
Finger gully

Plate 11.
Finger gully

Rehabilitation of fan and finger gullies initially requires the total exclusion of stock from the area. This will initiate a natural process of revegetation. In areas where there is a fairly large catchment above the gully system it would be beneficial to use an opposed disc plough or check furrow plough to create a series of banks and furrows. The banks and furrows would slow down any runoff letting more water infiltrate. Pasture seed can be planted in the banks and furrows. If the area above the gully system is scalded it would be worthwhile to put in a series of waterponding banks.

Another option which could be considered is the use of a vegetative hedge. One grass species, vetiver grass (*Chrysopogon zizanioides*) has been trialled extensively throughout the tropics and the semi arid tropics. The results have been very good with the grass found to be effective in a wide range of soils and rainfalls. Refer to section 5.5.5 for the steps required to establish vetiver hedges both above and within the gully system.

Stabilisation of gully erosion can sometimes be achieved through the use of rock baskets or gabions. The rock baskets consist of sausages of rock wrapped in a wire netting. Care must be taken in their construction as a poorly constructed rock basket can actually increase erosion at the sides if the basket does not extend far enough. Landholders are advised to seek professional advice from a soil conservation officer to appropriately locate the rock baskets.

One method of gully erosion control which should **NEVER** be used is the filling of the gully with rubbish or car bodies. In most circumstances the dumped material will cause eddies which will erode under the rubbish and actually accelerate the erosion process. If gullies are ever used as rubbish dumps it will be necessary to completely cover the dump with wire netting before the commencement of the wet season to prevent rubbish being washed into the creeks or rivers.

3.4 Stream Bank Erosion

Where livestock or feral animals have access to the banks of rivers and streams they often remove the protective vegetative cover. As a consequence increased wet season flows will erode the bare banks. The easiest solution is to exclude the livestock from the river banks. This solution has been undertaken in many areas. Stream bank erosion is still a problem in some areas. However with the increasing practice of fencing off riparian areas the extent of the problem is decreasing. With the intense rainfall events that occur in the VRD, stream bank erosion will always be a part of the natural processes. The contribution from stock, through ground disturbance and vegetation removal will however no longer be significant.

Plate 12.
Stream bank erosion

Plate 13.
Stream bank erosion

3.5 Tunnel Erosion

Tunnel erosion is the result of holes or slumps on the surface connected with horizontal underground tunnels. Tunnelling occurs when water reaches a dispersible lower layer, usually through a crack in the soil, and carries the dispersed material to a gully head. Tunnels are slow to start but once they break through the gully head their advance can be quite rapid. The surface soil will collapse into the tunnel when the tunnel has increased in size and is no longer able to support the material above it.

The only means of stopping tunnel erosion is to prevent water entering the tunnel system. The only way to do this is to intercept overland water flow before it reaches the tunnel system and direct it to a safe disposal area. If there is no stable area where the water may be safely directed it may be necessary to construct a soil conservation structure such (as a flume) to direct the water safely to the base of a gully.

Plate 14.
Tunnel erosion

Plate 15.
Tunnel erosion

3.6 Other forms of erosion recognised in the VRD

Condon in his 1986 report on erosion in the VRD recognised eleven forms of erosion. Most of these have already been discussed however for completeness other forms of erosion found in the VRD include:

A. Loamy soft scalding.

This form of erosion is found where an area of land has had the fine sandy surface removed by wind and/or water leaving an exposed clay layer. It is found on near level to slightly sloping duplex soils. Duplex soils have a surface horizon of fine sand underlain by a horizon of light clay. As the soils are high in sodium they produce a sweeter feed which is preferentially grazed. This leads to a rapid loss of vegetative cover and the subsequent removal of the fine sand layer. The exposed light clay horizon is nearly impermeable and provides a very hostile environment for plant growth. As a consequence these scalds are fairly difficult to rehabilitate. Once they have formed, even the exclusion of stock will not ensure their rehabilitation. A good example of these scalds is found on Kidman Springs.

Rehabilitation trials of loamy soft scalds using waterponding banks have taken place at Kidman Springs and Saddle Creek on Auvergne Station. These trials have proved to be very successful on both Kidman Springs Research Station and Auvergne Station. Rehabilitation trials using cultivation techniques only have also been undertaken at Kidman Springs. These trials have all eventually failed with all cultivated areas sealing up again (Sullivan et al, 2001).

Plate 16.
Loamy soft scalds

Plate 17.
Loamy soft scalds

Plate 18.
Waterponding banks.
(1989)

Plate 19.
Waterponding banks.
(1991)

Plate 20.
Same area.
(2008)

Plate 21.
Sloping scald.

B. Sloping scalds with associated rilling and gullying.

This form of erosion is the same as loamy soft scalding but on areas of land that have a slope of between 1-3% (refer to Section 5.4.2 to determine slope of land). Because of the increased slope the overland runoff soon erodes the scalded area leaving a network of rills and gullies.

Destocking will allow the gullies and rills to revegetate however the scalds will need some form of disturbance before they will revegetate. Condon (1986) suggested check furrowing of the area but this has yet to be trialled.

C. Wind sheeting on calcareous clay soils.

Condon assumed that the original pasture in these areas was dominated by limestone grass. This would have been preferentially grazed leading to the removal of a vegetative cover. The bare disturbed area would then have been susceptible to wind erosion. One of the problems with this form of erosion is that it often contributes to the formation of various forms of gully erosion on the down slope edge.

Plate 22.
Wind Sheeting.

The main rehabilitation option for this form of erosion is to exclude stock. Unless the eroded area was fenced separately it would be necessary to keep stock out of the whole area as the eroded area is preferentially grazed. It may be advised to use opposed disc ploughing and to construct small waterponding banks above any gully erosion.

D. Gullying of lower slopes and drainage lines.

This form of erosion is usually found on the lower edge of slopes which are already experiencing sheet erosion. The easiest and most cost effective rehabilitation method for this form of erosion is to fence it and exclude livestock. Natural regeneration of the gully floors should allow the area to recover. Once the area has recovered, limited and controlled grazing should be allowed.

Plate 23.
Gullying of lower slopes.

E. Gullying of unincised watercourses

Gullies up to 2 metres wide and 1 metre deep occur in some of the wide near level drainage channels in the Downs land system. They are fairly stable due to a stony bed preventing further erosion. Rehabilitation is not an issue.

Plate 24.
Gullying of unincised watercourse.

F. New channel formation.

This is usually considered to be a natural phenomenon. Rehabilitation is therefore not a consideration. Fencing off of the drainage system would reduce any impact from livestock.

Plate 25.
New channel formation.

4

The impact of livestock and infrastrucutre on a property's natural resources

The sustainable management of a property's natural resources is essential for the continuation of a successful business, which is ultimately what pastoral production is all about. There are two aspects of a pastoral production operation that can have a significant impact on a property, these are:

1. Impact of livestock.
2. Impact of infrastructure.

4.1 Impact of livestock.

Livestock can have a very significant impact on the land. This impact may be localised or it may be spread over a large area. Areas of localised impact are:

- Yards.
- Holding paddocks.
- Laneways.
- Watering points.
- Cattle camps.

The position of these localised impact areas can have a significant bearing on the amount of erosion that will take place. The siting of this infrastructure is determined by the property manager. Where possible it should be sited in locations that will have the least impact on the land. It should avoid erodible soils, steep or undulating country, river frontage, boggy ground, land subject to flooding or existing erosion. The siting of this infrastructure should be considered as part of a property management plan. (Refer Section 4.2.1)

Plate 26.
Cattle yards situated near the eroded country shown in Plate 28.

Plate 27.
Trough with eroded area in the background.

The location of cattle camps although basically determined by the cattle can be influenced by the siting of watering and supplement (lick block) feeding points. If the watering and supplement feeding points are far enough away from susceptible country it may tempt the cattle to stay close and avoid the walk to their preferred camp.

The impact of live stock is dependent on the stock pressure over time on any given area. Stock pressure is evidenced by the degree of utilisation of the pasture. For any given land type a certain percentage of utilisation will have no negative impact on the land. However if this level of utilisation is exceeded for successive years it will eventually lower the condition of the land. **It is important to be able to recognise land condition.** Depending on the condition of the land the property manager can determine what should be done to maintain or improve that condition.

Plate 28.
Area of erosion near cattle yards and trough.

Plate 29.
Cattle with unrestricted access to billabong.

4.1.1 Assessing land condition

The following definition of land condition is taken directly from the Grazing Land Management workshop manual (Quirk et al, 2003). It is thought that this system could be used by managers to help assess the land condition and to assist in decision making.

> *"Land condition is the capacity of grazing land to produce useful forage; it is about productivity and sustainability. It is a measure of how well the grazing land ecosystem is working, that is how well solar energy is being captured, how well nutrients are being cycled and how well rainfall is being used. Land condition is therefore directly related to carrying capacity."*

There are four categories of land condition:

Category	Features
Good or 'A' condition.	• Good coverage of perennial grasses dominated by those species considered to be 3P grasses (perennial, productive and palatable) for that land type; little bare ground (<30% in general). • Few weeds and no significant infestations. • Good soil condition: no erosion and good surface condition. • No sign or only early signs of woodland thickening.
Fair or 'B' condition.	Fair or 'B' condition has at least one or more of the following features, otherwise similar to 'A' condition. • Some decline of 3P grasses; increase in other species (less favoured grasses and weeds) and/or bare ground (>30% but <60% in general). • Some decline in soil condition and some signs of previous erosion and/or current susceptibility to erosion is a concern. • Some thickening in density of woody plants.
Poor or 'C' condition.	Poor or 'C' condition has one or more of the following features, otherwise similar to 'B' condition: • General decline of 3P grasses; large amounts of less favoured species and/or bare ground (>60% in general). • Obvious signs of past erosion and/or susceptibility currently high. • General thickening in density of woody plants.
Very poor or 'D' condition.	Very poor or 'D', condition has one or more of the following features. • General lack of any perennial grasses or forbs. • Severe erosion or scalding, resulting in a hostile environment for plant growth. • Thickets of woody plants or weeds cover most of the area.

Plate 30.
Good or 'A' condition.

Plate 31.
Fair or 'B' condition.

Plate 32.
Poor or 'C' condition.

Plate 33.
Very Poor or 'D' condition.

Grazing management is the key to maintaining land in 'A' condition or reverting land in 'B' or 'C' condition back to a better condition. Once land has declined to 'D' condition its condition can no longer be improved simply by a change in grazing management. It will often require mechanical repairs such as soil conservation works and/or cultivation. A description of techniques and machinery for rehabilitating degraded rangeland can be found in Section 5 of the manual.

A detailed description of grazing management can be found in the literature from the Grazing Land Management workshop. It is suggested that all pastoralists in the VRD attend the Grazing Land Management workshop run by Department of Regional Development, Primary Industry, Fisheries and Resources.

4.2 Impact of infrastructure.

Roads, tracks, firebreaks and fencelines are the major contributor to soil loss in the VRD. Some people believe that it could account for up to 80% of all soil lost from the property (VRDCA, 1997). Traditionally RTFFs were constructed with very little planning. Often little consideration was given to their impact on the surrounding country. As a consequence many of the RTFFs have been placed in the most inappropriate areas. Many property boundaries ran in straight lines with no consideration of the topography. Where these boundary lines were fenced they often went through country that was very fragile and prone to erosion. Roads and tracks also tended to meander through the country that was most easily traversed. These tracks were often only used during the dry season. When they were needed the following year they were graded to a trafficable state, utilised and then left to face another wet season. When the tracks had eroded to a stage where they could no longer be repaired they were abandoned and new tracks were constructed alongside. Often no steps taken to minimise the erosion taking place every wet season.

This situation has fortunately changed with most property managers now realising that a well planned and maintained system of roads, tracks, fencelines and firebreaks is essential for the efficient running of their pastoral operations. It is unfortunate however that many properties still have a legacy of poorly designed and poorly sited infrastructure. As well as the RTFFs there are also many yards, holding paddocks and watering points which are not positioned in an ideal location. The best way to determine the ideal locations for new infrastructure and to gradually move or replace old poorly sited infrastructure is to develop a property management plan.

4.2.1 Property management planning.

A property management plan (PMP) is essential for the efficient operation of any agricultural enterprise. A PMP is effectively a business plan for the property. It takes into consideration the management of the four main aspects of the business. These are;

- Human resource management.
- Economic management.
- Production and marketing.
- Natural resource management.

The area of interest for this manual is the fourth point, natural resource management. The other points although very important in a pastoral enterprise are well covered by many other media and will not be repeated here.

Developing a PMP is the first step in overcoming the problems inherited from the past and to ensure that further problems are avoided. The PMP should produce a layout of RTFFs that avoids areas with more fragile and erodible soils, steeper or more undulating country, areas that are subject to flooding, boggy areas or existing erosion. It should also incorporate all other property infrastructure including the homestead and outbuildings, airstrips, yards, laneways, pipelines, watering points, turkey nests, bores, dams and holding paddocks.

Plate 34.
Good site-
Very stable soil.

Plate 35.
Good site-
flat country.

Plate 36.
Poor site-
long steep slope.

Plate 37.
Poor site-
rough undulating country.

Plate 38.
Poor site-
very erodible soil.

Plate 39.
Poor site-
boggy ground.

One very important item which is often overlooked is the siting of gateways. The position of gateways should be considered very carefully as they are one of the busiest points in a paddock. The soil at the gateway has a tendency to get carried away by cattle, vehicles and machinery. Rainfall runoff may then concentrate through the gateway and soon create an erosion problem. Gateways should be placed on higher country to avoid concentrated runoff. They should never be placed in drainage lines or near any existing erosion.

Plate 40.
Eroded gateway.

Plate 41.
Eroded Gateway.

The first version of the property management plan should consider the property as an area of land devoid of its entire infrastructure. An ideal layout can then be developed. Obviously the immediate construction of such a layout is not possible as there is existing infrastructure. However as this existing infrastructure becomes unusable and needs replacing the new infrastructure can be sited as per the ideal layout. This may not be possible in the short term for major items such as homesteads and outbuildings or fixed items such as boundary fences but it is a good idea to have the ideal location worked out if the opportunity arises to relocate. For instance, although a boundary fence is supposed to be placed on the exact boundary, it may be possible to have a working boundary fence that follows a more ideal line rather than a straight line drawn on a map. It may also be found necessary to resite homesteads and outbuildings that are too close to rivers and are being continually flooded.

The property manager will need many items of resource information to develop a PMP. This would include:

A. Aerial photography or satellite imagery.

The base map of the property should consist of an aerial photograph or satellite imagery of a scale that allows for meaningful planning.

B. Topographical mapping.

A topographical map is useful for showing contours on a broad scale. Before any works are commenced it would be advised to travel the proposed line to check that there are no problems that are too small to show up on the map.

C. Land system or land unit mapping.

a. Land system maps consist of areas with a recurring pattern of topography, soils and vegetation. They are usually of a larger scale than land unit mapping. Land unit maps show areas of land with homogenous soils, vegetation and topography. Land unit maps could be used to identify areas that have an erosion hazard.

b. Many areas of the VRD are already covered by land unit mapping. There is however no conformity between properties. The Northern Territory's Department of Natural Resources Environment the Arts and Sports (NRETAS) is currently producing uniform land unit mapping for the VRD. Due to the work involved this project will however not be completed for some years.

D. Property map showing existing infrastructure.

NRETAS inspects pastoral properties within the VRD on a triennial basis. At this time they also update their property maps showing existing infrastructure. These maps are available to pastoralists.

E. Determining the location of roads, tracks, fencelines and firebreaks.

When determining the siting of RTFFs it must always be remembered that if they are not located correctly they have the potential to cause serious erosion problems. This in turn leads to much higher maintenance costs. It reduces their trafficability and efficiency. It also leads to higher vehicle repair costs.

RTFFs are usually devoid of vegetation and are often below natural ground level. This may make them act as drainage lines which could lead to rilling or gullying. A track or road that has been formed up may also collect runoff and divert it from its natural flow path. The correct positioning and construction of the RTFFs will lessen these problems.

RTFFs should be located in an area that allows for water to be drained from their surface. Ridgelines are obviously the preferred option as they have no run-on water and are easily drained. Low lying areas, valley floors or drainage lines must be avoided.

Where possible RTTFs crossing a slope should run on the contour, that is, they should be level. This provides for cross surface drainage without the risk of concentrating run off and having an erosion problem.

If RTTFs need to run up a slope they should go straight up and down. This simplifies the construction of any drainage and soil conservation works that are required. RTTFs that cross the slope at an angle are more likely to collect runoff and require more extensive soil conservation and drainage works. (refer to Section 5.4.2 for further information).

Crossing of drainage lines should be minimised. Where they are crossed it should be at right angles to the direction of flow. It may also be necessary to construct diversion banks at the top of the crossing to stop water running down the banks of the crossing.

F. Locating other infrastructure.

Infrastructure that concentrates livestock, such as, yards, holding paddocks or troughs should always be placed where its impact on the surrounding country is minimised. As it is not possible to avoid the complete removal of vegetation that occurs at these sites care must be taken that they are not located where there is the possibility of concentrated water flow such as drainage lines. Ideally they should be located on flat country. If this is not possible they should be placed at the top of any catchment as that is where the water flows will be the lowest. If they have to be built in areas that have the potential to erode it may be necessary to construct diversion banks above and/or below them to divert water to safer areas.

One major consideration for the location of all infrastructure is the likelihood of flooding. This applies to all property assets but particularly to the more expensive items, such as, homesteads and outbuildings. High ground where there is no risk of flooding even with the high rainfall experienced from a cyclone is the logical location.

5

Managing erosion on roads, tracks, fencelines and firebreaks (RTTFS)

When managing erosion, there are three main problem areas that need to be considered for RTFFs.

These are:

- Erosion cutting across the RTFFs;
- Erosion running down the side of the RTFFs;
- Erosion running down the RTFFs.

This erosion can be minor (rilling) or major (gullying).

Plate 42.
Rill erosion along a fenceline.

Plate 43.
Gully erosion beside and across a road.

Plate 44.
Gully erosion along a fenceline.

5.1 Preventing erosion on roads and tracks.

The best prevention for erosion on roads and tracks is to initially site the roads or tracks where the chances of erosion are minimised (refer to Section 4.2.1). Care should be taken to construct the roads and tracks with adequate drainage to quickly and safely remove all run on and run off water. If this is done correctly there should be no or very little erosion and the only maintenance required would be the cleaning out of the drainage system.

There are three aspects of road/track drainage. These are:

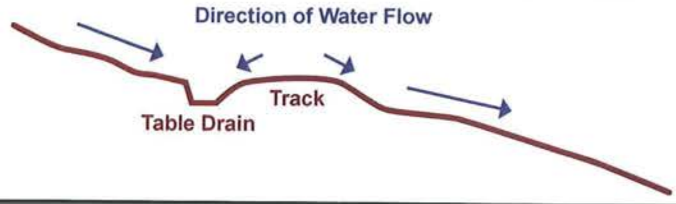
- Surface drainage.
- Side drainage.
- Cross drainage.

5.1.1 Surface drainage

This involves the removal of water from rainfall that has fallen onto the road or track. It does not include waterflow from areas off the road/track. It is comprised of road/track crowning, infall drainage and outfall drainage.

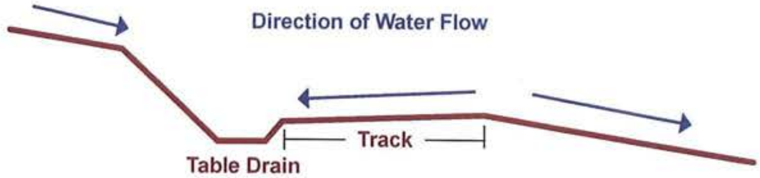
A. Crowning - involves raising of the centre line of road/track allowing water to run to both sides. Crowning should never be used where it will interfere with the natural safe flow of water crossing the road/track.

Figure 5.
Crowning



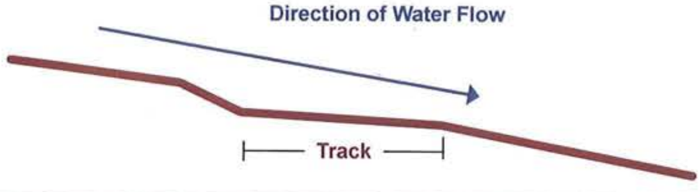
B. Infall drainage - this is where the water is directed to the upslope side. This should be avoided wherever possible as it will necessitate the construction of table drains, culverts or crossbanks to direct water to the downslope side of the road/track.

Figure 6.
Infall drainage



C Outfall drainage - outfall drainage where the water is allowed to cross the road/track to the downslope side unchecked. This is obviously the preferred option as it necessitates no further drainage works.

Figure 7.
Outfall drainage



5.1.2 Side drainage

Involves the use of table drains and mitre drains (runoff drains) to safely collect water and direct it to safe areas away from the road/track. In some areas it may be necessary to construct cut-off drains.

A. **Table drains** - excavated open drains that run beside the road/track. They direct water to safe disposal further down the road/track or to mitre drains. Table drains should be constructed with a flat base. If the area of construction is too constrained and the base of the drain is not flat it will be necessary to decrease the spacing between mitre drains.

B. **Cut-off drains** - flat bottomed drains placed upslope from the road or track. They are designed to intercept runoff before it reaches the road or track and direct it to a safe area away from the track. Cut-off drains are sometimes considered to be a soil sacrifice area to protect the road or track. If it is possible to construct them at the correct grade however this should not be a problem.

C. **Mitre drains** - drains that take water out of table drains or directly off the road batters and discharge it in safe areas away from the road/track. Mitre drains should also be constructed with a flat base of about 1m – 2m width. The spacing of the mitre drains is dependent on many factors: size of the table drain, width of the road or track, rainfall intensities, soil erodibility and the grade of the table drains.

Plate 45.
Poor siting of mitre drain discharging into a very active gully head.

The main thing to consider at all times is that all these drains are required to safely remove water from the road or track and drainage system. If the drains do not seem to be coping with the water flow it will be necessary to construct further drains. It is better to err on the side of caution and have too many drains than to not have enough. A problem often encountered with mitre drains is that the inlet is often higher than the road or track surface. In these cases the drains are obviously not effective. The water will concentrate down the track surface until it is of sufficient depth to top over into the drain. In the meantime it has started to erode the track or road surface.

Mitre drains need to dispose of water in a safe area. They should discharge into a well vegetated site. There should be no ground disturbance or erosion at the discharge site. If it is not possible to find a reasonably safe site it may be necessary to construct a wide level sill at the discharge site to safely disperse the water. (Plate 45)

Mitre drains should have a fall of between 0.5% - 1.5%. The fall is dependent on the erodibility of the soil where they are constructed. The more erodible the soil is, the lower the grade of the drain. The fall of the mitre drains should always be checked with a level as it is sometimes difficult to determine the fall by eye. Often drains constructed by eye will actually run uphill away from the road. These drains will bring water onto the road rather than taking it away. Ideally the mitre drains should be pegged and the discharge site inspected before the grader operator starts their construction.

5.1.3 Cross drainage

This involves the use of culverts, floodways, diversion banks (whoaboys), spoondrains and inverts to collect water from the upslope side of the road/track and safely dispose of it on the downslope side. The water may be collected from natural drainage lines or table drains.

The fall across the road/track for all forms of cross drainage should be at least 0.5% to ensure that there is no build up of transported material. The crossdrains should be constructed with a finished level at the same height as the original ground level. This stops the crossbanks acting as either a dam or a pool.

Diversion banks (whoaboys) are probably the easiest and most effective form of cross drainage on a rural property. They can be quickly pushed up with a grader or dozer and smoothed off to provide a trafficable surface whilst ensuring the safe transit of water across the road or track (refer to Section 5.4 for further information on building diversion banks). They are normally made by pushing up material from the road or track. However if it is difficult to win sufficient material from the road or track site it may be necessary to import material.

Culverts and floodways are less likely to be used on a rural property. If they are required it is best to seek the assistance of a soil conservation officer. The soil conservation officer will be able to give advice on the size of the culvert required and its appropriate placement.

Figure 8.
Table drain and mitre drain layout on a road or track.

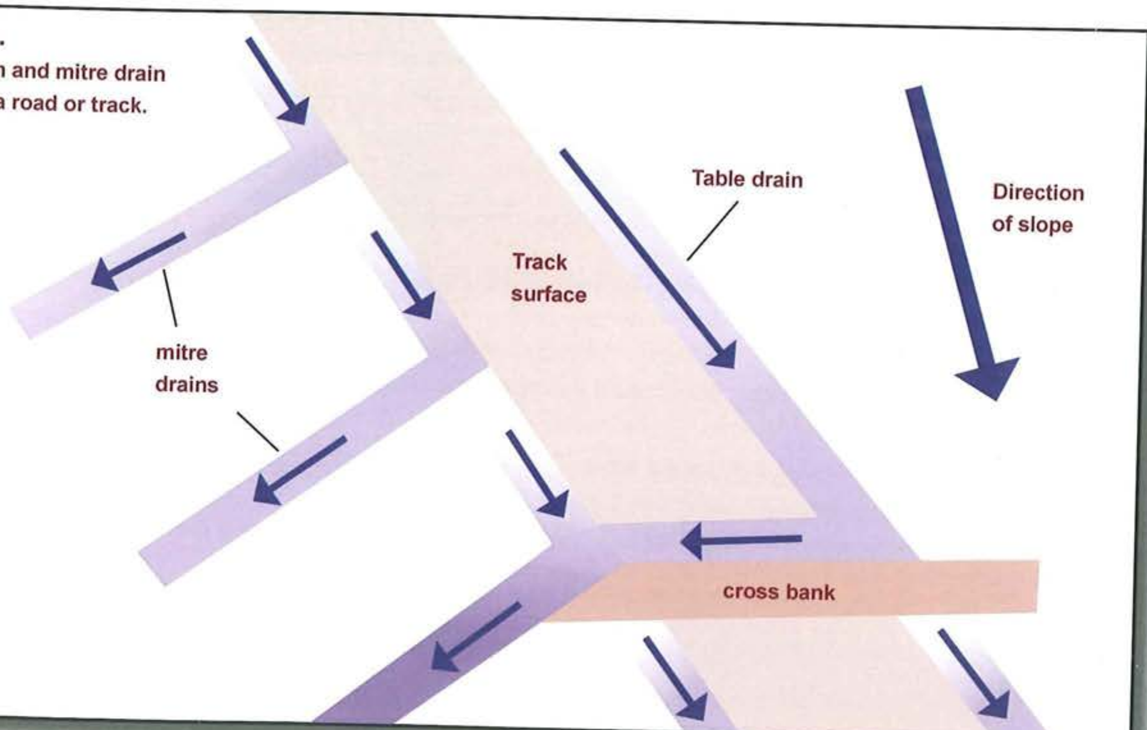


Plate 46.
Steep road. The change in grade, seen in the middle of the photo, would be a good location for a culvert.

5.2 Repair of erosion on roads and tracks.

If there is existing erosion on roads and tracks on the property it may be necessary to repair the erosion before constructing soil conservation and drainage works. Different steps need to be taken depending on the severity of the erosion. If the road or track is eroded to a state where it is no longer trafficable it may need to be abandoned and a new road or track constructed along side or perhaps at a new location. The abandoned track will need protection from further erosion which may be incorporated into the drainage and soil conservation works on the new track if they run parallel to each other. If the track is repairable the following steps will be required to bring it back to a trafficable state:

A. Bring all windrow material onto the track alignment.

B. Grade the track to a trafficable state.

C. Install a series of diversion banks to prevent further problems,

If the track is to be abandoned the following steps will be needed to repair the old abandoned track and have the site ready for the new track:

A. Batter off the sides of the gullies.

B. Bring all windrows into the eroded area.

C. If the erosion is too deep to fill or cross with the new diversion banks it will be necessary to win material from within the eroded area to form a base for the new banks.

D. Push up check banks on the gullied area. These are short banks that act more as a dam to stop water flowing down the eroded area. Construct about three times as many banks as would be needed for the corresponding slope on a normal track. Every third bank will provide the base for a diversion bank running from the new track.

E. Construct a series of diversion banks on the new track which continue across the old track and drop water at a safe site away from the eroded area.

Plate 47.
Battering off sides of a gully.

5.3 Firebreaks and Fencelines.

It is assumed in this discussion on firebreaks, that most firebreaks on a property run alongside fencelines. The comments made for firebreaks are also applicable to fencelines. The use of firebreak/fenceline easements for property access is also desirable as it is better to have one area of disturbance rather than 3 separate areas. The best alignment for a fenceline will also usually be the best alignment for a firebreak or a track.

Firebreaks are essential on pastoral properties to protect both the feed resource and the property infrastructure. There is also a legal requirement to have firebreaks on boundaries to assist in keeping fires from jumping into neighbouring properties. Firebreaks have traditionally been made at the end of the wet season using a grader. The only consideration has been to remove all vegetation off the firebreak and leave it in a windrow at the side. If it was only vegetation that was removed from the firebreak there would be no real concern. However there is usually a large amount of soil that is also cut out and left in the windrow.

Windrows present a major problem on firebreaks by intercepting runoff and concentrating it down the firebreak. This can lead to severe rilling or gullying on the firebreak. Further problems can occur when the windrow acts as a bank on the downslope side concentrating runoff and then breaching and allowing the runoff to exit in a narrow and potentially erosive stream.

It is possible to avoid windrows when grading by running out the final cut. This is achieved by simply lifting the blade to ground level. Any vegetation that is left from this process will break down before the wet season.

Other problems can occur with firebreaks running up and down the slope. The potential for erosion on the bare ground is fairly high particularly if the firebreak is also used as an access track. To overcome the problem diversion banks (whoa boys) need to be constructed at regular intervals along the slope.

The spacing of the banks will depend on the degree of slope. Although other authorities advocate the use of banks once the grade of the land exceeds 2 percent this is considered to be too high particularly if the slope is fairly long. Even at 0.5% it would be advisable to have banks at intervals of about 500 metres just for insurance. At lower grades it may be possible to wait for signs of erosion before constructing banks. However banks would need to be constructed at the first sign of rilling on the firebreak. This option would not be available if the firebreak was being installed in conjunction with a new fence as the banks would need to be constructed before the wire was strung. Although it is possible to cut the fence and construct the banks it would be better to have them constructed before any fencing was done.

5.3.1 Bank spacing

Bank spacing is very dependent on soil erodibility. On soils that are more erodible, the banks will need to be closer. Bank spacing will also be dictated by vehicle usage of the firebreak. If the firebreak is regularly used as a farm access track there is a chance that wheel ruts will form along the firebreak either through time or through vehicles accessing the firebreak after rain. Again this would necessitate the construction of a series of banks that are closer together.

Tables 1 and 2.
Suggested spacings for banks on soils of different erodibility.

Low to Moderate Soil Erodibility	
Slope (%)	Bank spacing (m)
2-4	200
5-9	100
10-15	30
>15	15

High Soil Erodibility	
Slope (%)	Bank spacing (m)
1	130
2	90
3	75
4	65
5	60
6-10	40
11-15	30
>15	15

For firebreaks that are only trafficked a few times a year the banks only need to be about 40-50cm high and about 50-80cm wide. They need to extend past both sides of the firebreak by at least 2 metres. If the firebreak is also used as an access track the banks will need to be much larger and more easily crossed. The dimensions for these banks will be the same as for a diversion bank on a road or track (refer constructing a diversion bank in Section 5.4).

For some firebreaks it will be necessary to extend the banks well past the firebreak line to ensure that no water runs back onto the firebreak. It may be necessary to check the fall of the bank's outlet to ascertain the direction of water flow. This could be done using a level and staff to find the contour and from this determine the direction of fall. The direction of fall is at 90° to the contour.

5.3.2 Problems with graded firebreaks.

If firebreaks are maintained by a yearly cut with a grader there are some common problems that need to be avoided. There are many occasions where an inexperienced operator has created the potential for serious erosion on the firebreak. These problems are:

A. **Grading too fast**. This leads to bouncing of the grader and the creation of a series of 'V's on the firebreak. When the points of the 'V's face downhill they direct water to a central channel leading to erosion.

B. **Digging the toe in**. When the toe of the blade is dug in on the second cut it creates a channel in the centre of the firebreak. In this case the operator has already started the erosion process

C. **Leaving windrows**. As previously mentioned windrows are one of the worst contributors of erosion on a firebreak. If the operator is in a hurry to complete the job the sweeping away of the windrow on the second cut may not be completed properly. It is better to have sufficient time allocated for the work to be done correctly rather than have to return and repair erosion rills or gullies.

D. **Lack of soil conservation works**. Many operators do not understand the value of banks and drains on a firebreak. There are many occasions where banks have been graded out simply because the operator either couldn't be bothered lifting the blade or wanted to remove them because they slowed traffic down. The grader operator needs to reinstate any banks that have subsided or breached and make sure that the ends of the banks are not obstructed. The property manager should ensure that all grader operators understand the value of soil conservation works on a firebreak.

5.3.3 Alternatives to graded firebreaks.

There are many other options rather than using graders to install firebreaks. Some of these are:

A. **Ploughing or harrowing**. This could be used on small properties however its value on a pastoral property in the VRD would be questionable. It would be difficult to use a plough or harrow and still maintain the integrity of soil conservation works. Ploughing or harrowing would also create a high erosion risk if used on sloping country. It is not recommended for the VRD.

B. **Slashing**. Slashing is an option on fairly clean breaks although there is a fire risk from sparks from rocks if the break is slashed once the surrounding vegetation has cured. Slashing needs to be done while the vegetation is still fairly green. Once the firebreak has been slashed the trash remaining on the firebreak will need to be removed. This could be achieved through raking or burning. An alternative is to make several cuts with the slasher, throwing the trash to the side.

C. **Use of herbicides**. The use of herbicides is considered to be one of the better options for installing firebreaks. Once a firebreak has been initially installed by a grader and has been protected with a series of banks there is no longer a need to grade the firebreak every year. This operation requires the application of a herbicide and then the burning off of the dead vegetation. If the spraying has taken place before the surrounding vegetation has dried out it will be fairly safe to burn along the firebreak.

There are many ways of applying herbicides. Two of these are:

a. Boom-less spray. This utilises a high pressure pump discharging through a boom-less nozzle. This nozzle can cover up to 19 m in a single pass. The tank and pump can be mounted on a trailer and towed by either a vehicle or quad bike. This allows the spraying

Plate 48.
Boom-less spray.

Plate 49.
Chemical firebreak.

of country while it is still green. It also allows the application of the herbicide to grasses and suckers growing through the wire on the fence. This area has always been a problem when a grader has been used.

Plate 50.
Chemical firebreak.

b. Helicopter. The use of a helicopter is the easiest method of applying herbicides to the firebreak. The helicopter can deliver the chemical at any time and does not have to wait until the ground is dry. It is able to straddle the fenceline and spray both sides in the one pass. A boom width of 10 metres is more than adequate for a firebreak. The timing of the spraying operation by the helicopter will determine what further steps are needed to have a vegetation free firebreak. If the firebreak is sprayed early in the wet season there should be enough mulch to suppress further growth. The mulch however should have broken down by the end of the wet season thus providing a vegetation free firebreak. If the spraying takes place towards the end of the wet season it will be necessary to burn the dead vegetation.

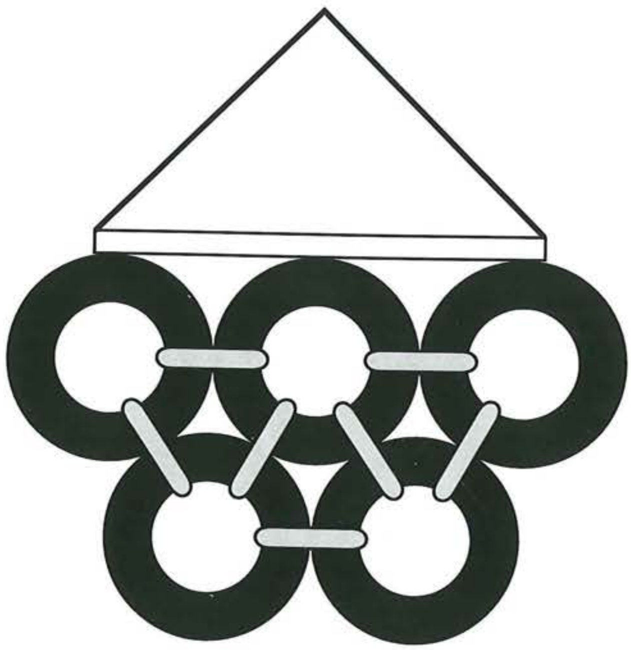
The helicopter is also the logical choice for the application of a pelletised herbicide to suppress the regrowth of trees along the fenceline/firebreak. If there are no suckers growing on the firebreak the cost of herbicide needed to install the firebreak will be greatly decreased.

C. **Flattening**. This can be achieved through the use of:

a. Tyre drag. Tyre flatteners or drags usually consist of a triangle of tyres chained or wired together although a single large tyre will suffice. The tyre drag is towed behind a vehicle. Once the crushed grass has dried out it can be burnt before the surrounding grass has cured. There are many areas where a tyre drag does not have the desired effect as the grass stands back up once the drag has passed.

b. Custom-built roller. Has a similar effect to the tyre drag.

Figure 9.
Tyres chained together to form a drag for flattening vegetation.

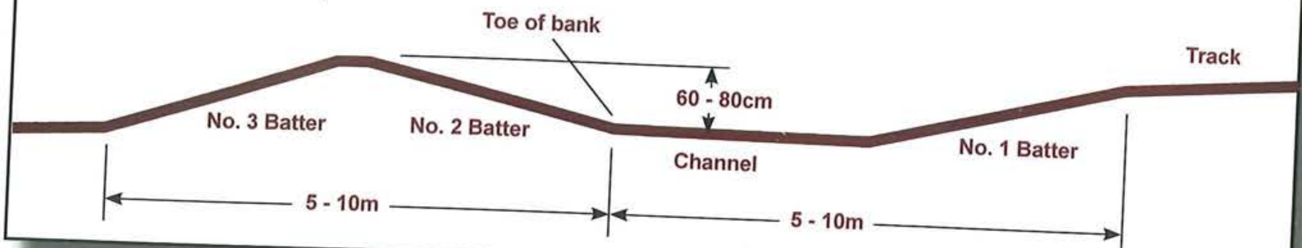


5.4 Designing and constructing a diversion bank.

For the purposes of this manual reference to diversion banks does not include larger banks used on cropping areas or above gully systems. Diversion banks used in those situations are much larger than the banks required to protect roads, tracks, firebreaks and fencelines.

A diversion bank is a structure that is designed to collect overland waterflow and direct it to an area where it no longer poses an erosion threat to a road, track, firebreak or fenceline. Diversion banks have in the past also been known as whoa boys or cross banks. Diversion banks can range in size from small banks about 40cm high to much larger banks up to 60-70 cm high.

Figure 10.
Cross section of a diversion bank showing dimensions and nomenclature of all parts.



5.4.1 Determining the location of a diversion bank.

For all soil conservation works, the one overriding principle is that the work always starts at the top of the catchment. If a series of banks is required on a road, track, firebreak or fenceline the top bank is constructed first. Construction of banks then proceeds down the slope. If the bottom bank is constructed first and there is a rainfall event there is a likelihood of runoff that exceeds the single bank's capacity. This would cause overtopping of the bank leading to further erosion. The reverse applies however when constructing the bank. Construction should always start at the sill end. These rules are not so relevant in the dry season; however they should be followed for any wet season construction.

For existing infrastructure the top bank should be placed at the top of any rill erosion. If the erosion appears to be fairly active it may be necessary to start even further up the slope. The distance between banks working down the slope is dependent on the erodibility of the road or track material, and the slope of the land. The following tables show recommended bank spacings for various slopes for two levels of erodibility. If there is any doubt as to the erodibility of the material it is better to err on the side of caution and construct more banks rather than fewer.

Tables 3 and 4.
Showing bank spacings for two levels of soil erodibility and various slopes.

Low to Moderate Soil Erodibility	
Slope (%)	Bank spacing (m)
2-4	200
5-9	100
10-15	30
>15	15

High Soil Erodibility	
Slope (%)	Bank spacing (m)
1	130
2	90
3	75
4	65
5	60
6-10	40
11-15	30
>15	15

Plate 51.
Series of banks.

The height and length of a diversion bank is dependent on 2 factors.

A. The volume of water to be diverted.

B. The length necessary to ensure that the diverted water will not flow back onto the track, fenceline or firebreak.

The volume of water to be diverted is determined by the size of the catchment above the bank. The larger the catchment the larger the bank required to deal with the runoff. It is always better to build a bank larger than required rather than smaller. A bank height of 60cms and a channel width of 4 metres should be sufficient in nearly all cases. Water should never overtop the bank. If this ever occurs it shows that the bank is not high enough or the channel is too small. It will then be necessary to either widen the channel or increase the height of the bank or both. It may also be necessary to make the channel and the bank wider if the bank crosses a regularly used road or track. A wider and therefore less steep bank can be crossed at a higher speed than a narrow sharp bank.

The bank should start well before the affected area to ensure that no water runs around the top end of the bank. If there is any doubt a wing of the bank leading back upslope should be constructed. The diversion bank should continue to a point where there is no or little likelihood of the discharged water flowing back to the track, although this is not always possible. In areas where the water makes its way back to the RTFF it may be necessary to construct a cut off drain away from the RTFF to prevent the water returning. Alternatively a table drain could be constructed on the downslope side. Mitre drains may also be needed to safely remove the water. (refer road drainage in Section 5.1.2)

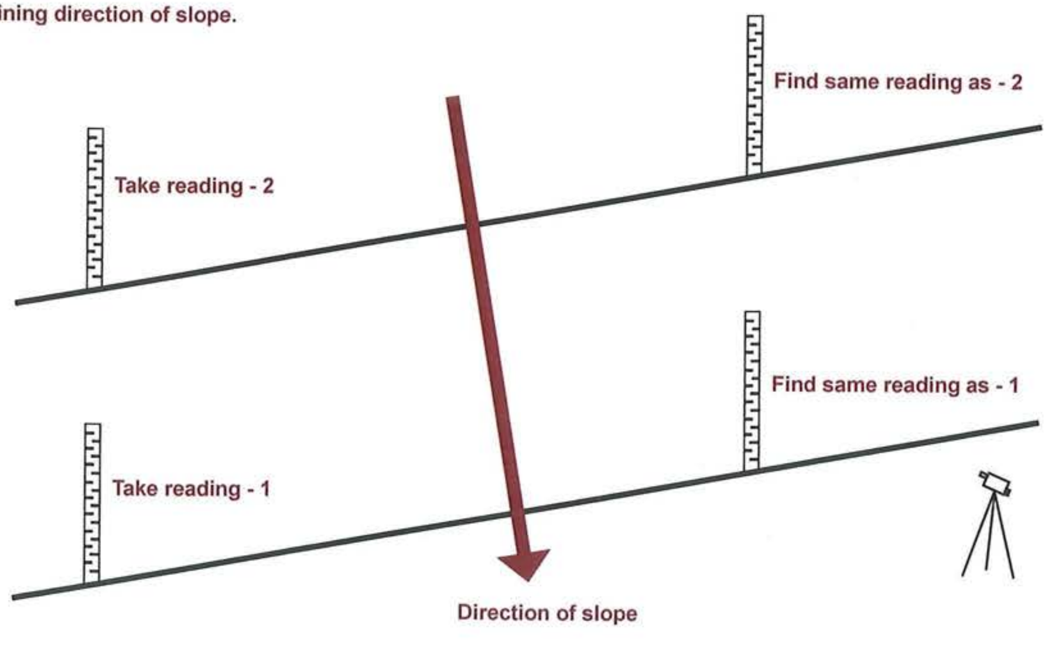
5.4.2 Constructing a diversion bank

The construction technique shown here is different to construction methods that are normally used. The technique shown here has been widely used in the VRD and is familiar to many managers. It has been pioneered in the Top End by Darryl Hill of Soil Save, Katherine. In this method of construction the area above the sill is utilised as a borrow pit to win the material to build the bank. This allows for easier construction than a conventional bank. For a conventional bank it is necessary to have a much longer bank to allow for the deep cut required to win the material for the bank. In a conventional bank the final stage of the bank goes from a full cut at the road/track crossing to a mere levelling trim at the sill end. This necessitates material being pushed from behind the bank towards the sill end. It is a much more complicated, time consuming and expensive method. It is considered that "Darryl's" technique is the preferred option in areas where there is a shortage of skilled operators of earthmoving machinery or people with soil conservation experience.

Steps to be taken in the construction of a diversion bank.

1. Determine the direction of slope of the land above the bank's location.
2. Determine the position of the bank across the road, track, fenceline or firebreak.
3. Determine the area of discharge.
4. Peg the sill of the bank.
5. Determine the grade of the bank.
6. Peg the top of the bank.
7. Rip the area of bank construction.
8. Push up the bank using a dozer, front end loader or grader.
9. Compact the bank and if required construct a traffic crossing point.

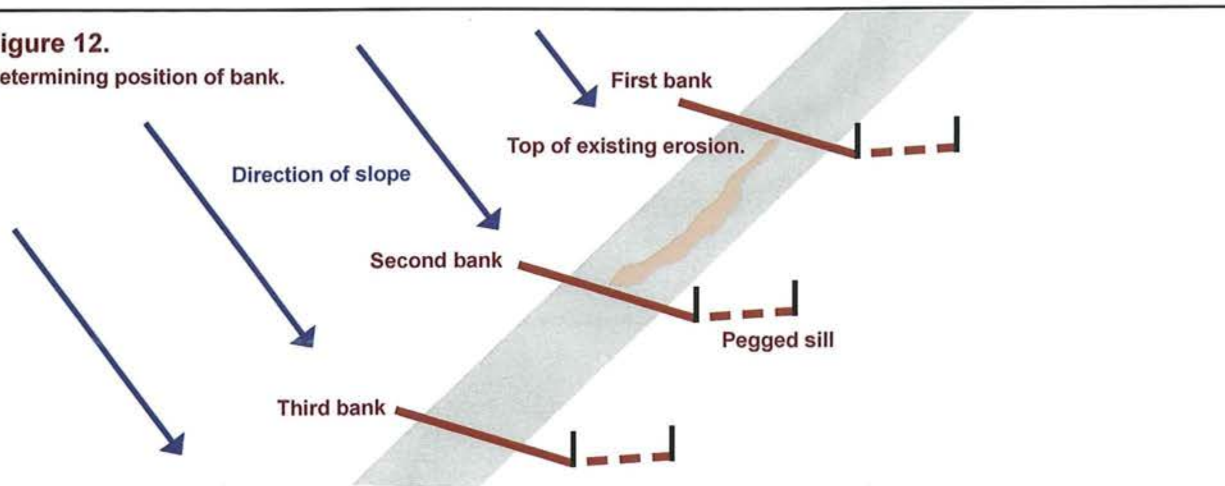
Figure 11.
Determining direction of slope.



A. Slope

To determine the slope of the land above the bank's location readings need to be taken with a level. It is better to find two contours although one should be sufficient on relatively uniform land. A reading is taken about 20 metres or so above the bank site. This reading is recorded. The same reading then needs to be found at a distance of 20 – 30 metres from the first reading. The line between these two readings is the contour. To be more accurate it may be necessary to repeat the process a further 20 metres upslope. The slope runs at a right angle (90°) to the contour. This is the direction of the overland water flow.

Figure 12.
Determining position of bank.

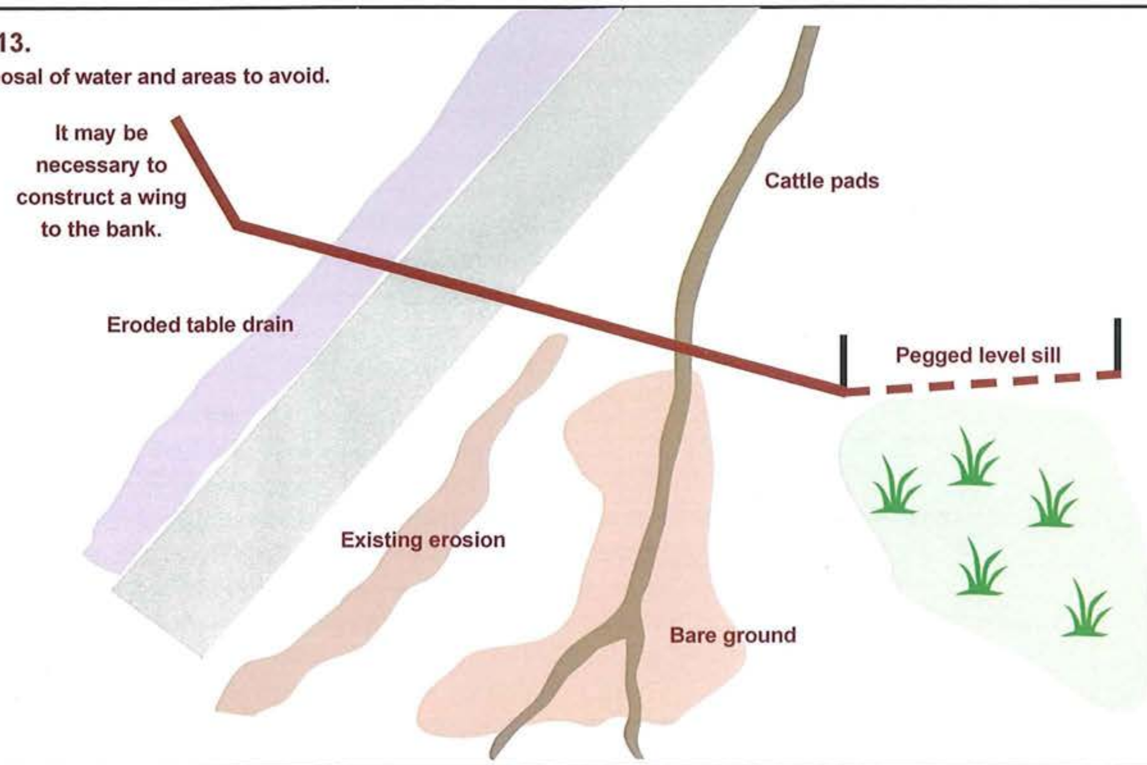


Assume a grade of 3% on the road with soil of high erodibility. From Table 4 we find that our bank spacing is 75m.

B. Position of the bank

Once the direction of the slope has been determined it is possible to work out the position of the bank. The bank must pick up the overland waterflow on the upslope side of the road, track, firebreak or fenceline and discharge it on the downslope side.

Figure 13.
Safe disposal of water and areas to avoid.



C. Area of discharge

The water collected by the diversion bank must be discharged in a safe area. It must avoid existing erosion or disturbed areas. It must avoid other infrastructure. It is of no value to remove a problem from one area and dump it on another. Preferably the area of discharge should be stable and well vegetated.

D. Peg the sill line

The sill is a level line at the discharge end of the bank. It should be at least 10 metres in length to allow the water to spread out and disperse at a safe speed. It must be positioned so as to discharge water onto a stable well vegetated area. A peg should be placed at the end of the bank. A reading is then taken with the level. The same reading is then found 10 metres from the first. This position is then marked with a peg. The line between the two pegs is the sill. Vehicles should never enter the area below the sill. The sill should never discharge into existing erosion or onto other infrastructure. If there are unavoidable areas of erosion on the downslope side of the proposed sill and it is not possible to relocate the bank, it will be necessary to extend the bank well past the eroded area.

E. Grade of the bank

The grade of the bank is determined by a number of factors.

a. Erodibility of the soil. The more erodible the soil the lower the grade required as lower grades lead to slower water in the channel. Water flowing at slow speed is much less erosive than faster flowing water. Conversely the less erodible the soil the higher the grade.

b. Width of the channel. The bank is designed to collect water and divert it at a safe speed to a stable area. If the channel is wider the water will be shallower. The bank can have a lower grade and still safely dispose of the diverted water.

c. Likelihood of scouring. If the grade of the bank is too high there is a risk of the bank and channel scouring.

d. Likelihood of overtopping. If the grade is too low the water in the channel will flow slower. This will lead to a deeper flow which may overtop the bank.

Likelihood of ponding. If the grade is too low there is a possibility that water will pond on the road or track. If the machine operator is very careful and checks the fall with a level before completion this should not be a problem. If the grade is higher the bank can be lower as the water will flow at a higher speed and will therefore be shallower. If the grade is lower the water will flow at a lower speed and will therefore be deeper and more likely to overtop.

Table 5 .
Shows actual falls or rises for different lengths of banks with different grades.

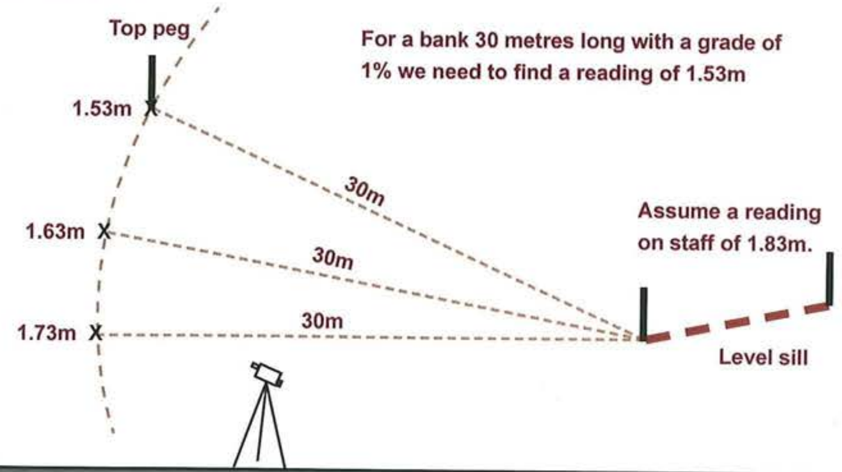
% Grade	Length of Bank or Channel	Actual Fall or Rise (cm)
0.5	20	10
0.5	50	25
0.5	100	50
1.0	20	20
1.0	50	50
1.0	100	100
1.5	20	30
1.5	50	75

The minimum grade of a bank should be 0.5% up to a maximum of 1.0%. Some authorities recommend higher grades, however these recommendations usually refer to southern conditions where rainfall events are not as intense as those experienced in the top end.

F. Peg the top of the bank

Having determined the required grade and length of the bank the rise to the top peg can be calculated. As an example if the bank length is 30 metres and the required grade is 1.0% the rise to the top peg will be 30cms. The reading on the staff at the top peg should therefore be 30cms lower than the reading at the bottom peg. The person holding the staff will need to move the staff in a circle 30 metres from the bottom peg until the reading is obtained.

Figure 14.
Method for determining site of top peg.



G. Ripping bank construction area

The area of bank construction should be ripped to a depth of about 30cms. This should include the area above the sill and the area below the actual bank (i.e. No. 2 and No. 3 batters). Care should be taken to avoid the area below the sill. Under no circumstances should any traffic enter or disturb the area below the sill. Ripping under the bank is required to key the surface material into the bank material and thus avoid water cutting under the bank.

Figure 15.
Areas to be ripped for bank construction.

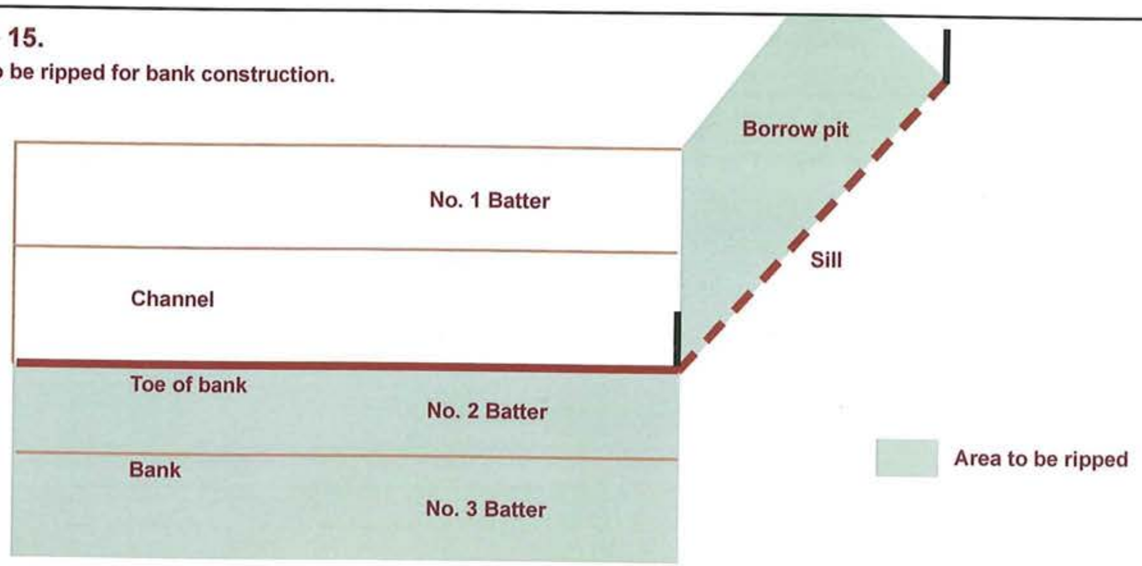


Plate 52.
Grader being used to construct a bank. The two pegs mark the level sill.

H. Pushing up material to form a bank

Once the relevant areas have been ripped the loosened material above the sill can be used to form the bank. The first cut should be along the sill. The material from this cut is pushed onto the bank line. Further material is then won from the area above the sill and pushed onto the bank for its full length. The No. 1 batter and channel will then need to be cut and the material pushed onto the bank. The depth of this cut will vary depending on the slope. For example for a slope of 2% and a channel width of 3 metres the depth would be 6cms at the toe of the No. 1 batter to 0cm at the toe of the No. 2 batter.

I. Compaction of bank

The final step in the bank's construction is the compaction of the bank. The bank is compacted by running the machine along the bank until there is no more noticeable subsidence of the bank. At this time the area of the bank that is to be used by vehicles can be adjusted to provide a gentler crossing if required. This is achieved by cutting back further upslope and lowering the slope of the No.1 batter. The material collected from this cut is pushed into the bank. The machine is then used to cut into the bank with the blade or bucket gradually rising until the required slope is obtained. This will push the crown of the bank downslope however the height of the bank and the position of the channel will not change.

Plate 53.
Grader pushing up material for the bank.

5.5 Pastoral land rehabilitation

A review of pastoral land rehabilitation trials in the semi-arid tropics from 1946 – 1996 was published by Sally Sullivan and Maria Kraatz in 2001. Their conclusions tended to indicate that the most cost effective solution for many areas within the VRD was to exclude stock and allow the area to regenerate naturally. Once the area had regenerated it could be used under controlled conditions for limited dry season grazing. This was particularly true for degraded black soils and non-cracking calcareous clays.

For areas of degraded red soils the use of mechanical rehabilitation was considered a possibility on areas of sheet erosion or surface crusting however the economic return from the rehabilitation was open to question. It was considered that there was certainly no return, apart from an aesthetic one, for the rehabilitation of gullied areas.

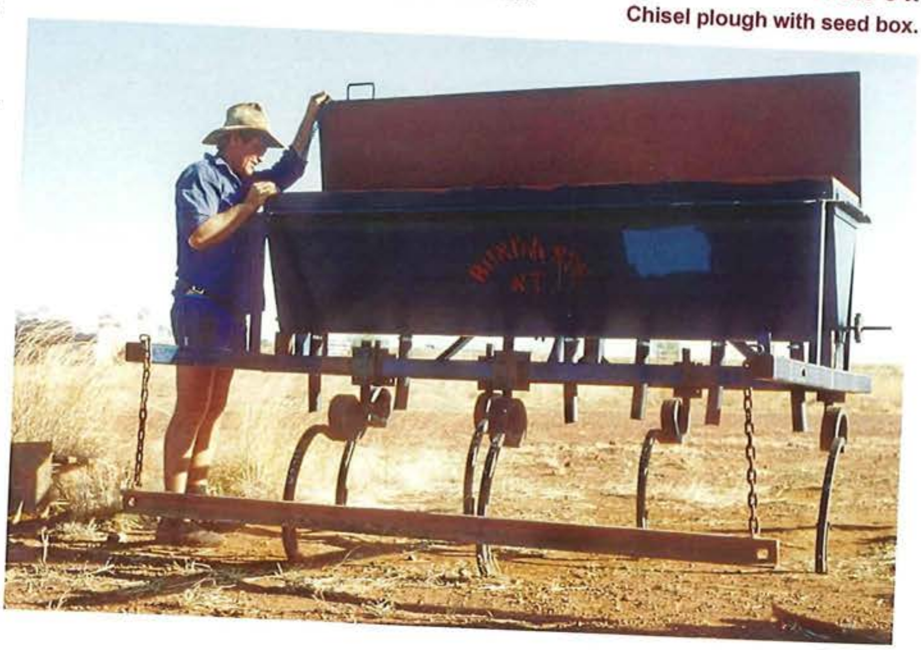
Rehabilitation of degraded red soils has been undertaken using many different plough types. These include:

- Opposed disc plough.
- Pitter plough.
- Check furrow plough.
- Crocodile pitter (pitting roller).
- Chisel plough.
- One-way disc plough.
- Offset disc plough.

The one-way disc plough and the offset disc plough both produce a fine seed bed with fairly fine soil. Surface sealing and crusting often occur after rainfall creating an environment which is not conducive to plant growth. These ploughs are considered to be unsuitable for land rehabilitation work.

The chisel plough although considered unsuitable by itself on badly scalded or eroded areas is quite good when used in conjunction with some of the other ploughs. It can be used to cultivate the soil in the area between rows. The chisel plough is also suitable for the introduction of exotic pasture into reasonably stable areas.

Plate 54.
Chisel plough with seed box.



5.5.1 Opposed disc plough.

The opposed disc plough consists of two inward facing discs that throw soil into a continuous ridge with furrows on either side. They may be fitted with a seedbox or a drum seeder. The opposed disc plough is considered to be suitable for rehabilitation work on most soil types except for black or sodic soils or very hard scalded soils.

Plate 55.
Opposed disc plough with direct seed box.

Plate 56.
Opposed disc plough with drum seeder.

The advantages of an opposed disc plough are:

A. Soil is thoroughly disturbed, assisting water infiltration and providing a good seed bed.

B. Water is intercepted and held in the furrows providing a better environment for plant growth.

C. Runoff is intercepted and stored reducing flows to fragile country below the treated area.

D. The higher profile cultivation of the opposed disc plough has a longer effective life than other cultivation types. This increases the chances of successful pasture establishment before the cultivated area seals up.

E. The chances of successful plant establishment are increased with the range of moisture conditions provided by the ridge and furrows.

Cultivation techniques for the opposed disc plough.

A. A contour line needs to be pegged at the top of the area to be treated.

B. Further contour lines need to be pegged at appropriate distances down the slope.

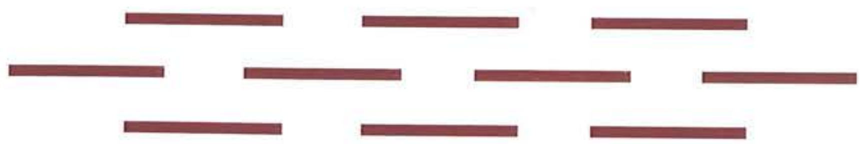
C. Cultivation should start at the top of the work area.

D. The lines must run on the contour.

E. The lines must be discontinuous. 5 metre hills with 2metre runs are suggested although there is no hard and fast rule.

F. Rows need to be staggered so that hills in the run below cover the gaps in the run above. (figure 16)

Figure 16.
Pattern of staggered rows.



5.5.2 Pitter plough.

A pitter plough is a 3 tined plough on an eccentric (off centre) axle. The eccentric axle causes the tines to lift out of the ground at regular intervals creating 3 rows of discontinuous and staggered pits. The pitter plough is usually fitted with a direct seeder from a seedbox. The pitter plough is considered to be suitable for rehabilitation work on most soil types except for black or sodic soils or very hard scalded soils.

Plate 57.
Pitter plough.

The advantages of a pitter plough are:

A. Soil is thoroughly disturbed, assisting water infiltration and providing a good seed bed.

B. Water is intercepted and held in the pits providing a better environment for plant growth.

C. Runoff is intercepted and stored reducing flows to fragile country below the treated area.

D. The chances of successful plant establishment are increased with the range of moisture conditions provided by the ridge and furrows.

E. Not essential to accurately follow the contour. The operator should be able to run the lines by eye once a top line is pegged.

F. Covers a larger area per run than the opposed disc plough.

Cultivation techniques for the pitter plough.

A. Peg a contour line at the top of the work area.

B. Start planting at the top of the work area.

C. Plant as close to the contour as possible.

D. Avoid rills and gullies.

Plate 58.
Eccentric axle on pitter plough.

5.5.3 Check furrow plough.

A check furrow plough consists of 1 to 3 tines with very broad sweeps which leave wide deep furrows. These furrows are cleaned out by a forward facing disc set at 90° to the direction of travel. The disc is lifted up out of the furrow at regular intervals by a spiked, ovoid wheel. This forms banks or "checks" in the furrow which stop water flow down the furrow.

The check furrow plough is suitable for all soil types except for black soil. It requires a powerful tractor to pull it and it is only suitable for smaller areas.

The advantages of the check furrow plough are:

A. Soil is thoroughly disturbed, assisting water infiltration and providing a good seed bed.

B. Water is intercepted and held in the pits providing a better environment for plant growth.

C. Runoff is intercepted and stored reducing flows to fragile country below the treated area.

D. The chances of successful plant establishment are increased with the range of moisture conditions provided by the furrows and windrows.

Cultivation techniques for the check furrow plough.

A. Peg a contour line at the top of the work area.

B. Start planting at the top of the work area.

C. Plant on the contour.

Plate 59.
Check furrow plough.

5.5.4 Crocodile pitter (pitting roller)

The crocodile pitter consists of a hollow steel cylinder with steel, shovel shaped plates welded around the surface. The shovels leave pits in the ground when the implement is rolled over it. Seed can be placed in the pitter and released through holes at the base of the shovels. The crocodile pitter is not suitable for hard or rocky soils. The pits produced have a short life as they silt up fairly quickly.

Advantages of the crocodile pitter are:

A. Relatively cheap and easily obtained.

B. Good coverage of a large area.

C. Can be used in woody weed control.

D. Smaller models can be pulled by a vehicle.

E. Does not require the pegging of a contour line to guide the operator.

Plate 60.
Crocodile pitter

This chapter has concentrated on the use of mechanical rehabilitation of pastoral land. There are however other methods of rehabilitation that do not require machinery. The first and one of the most effective on land that has not degraded to a "D" condition is to exclude stock. Another option on small areas of scalded country is to spread brush or dead fall timber over the scalded area. The vegetation spread over the area acts as a trap for both wind and water borne silt and debris as well as seed. Grasses and forbs will grow well in the microclimate provided and trap more silt and debris and act as a barrier to runoff. If the deadfall timber is large enough it will also protect the area from being trampled by stock.

Plate 61.
Vetiver grass plant

5.5.5 Vetiver Grass

Vetiver grass (*Chrysopogon zizanioides*) may be a plant that is suitable for rehabilitating gullies in the VRD. It has been trialled extensively throughout both the tropics and the semi-arid tropics with excellent results. It has also been trialled in some sites around Katherine with very good results. For further advice or assistance with planting vetiver grass please refer to Section 9.

The grass is planted in a hedge both above the gully and within the gully system. Once a hedge establishes it is able to slow peak overland water flows by up to 47%. Lighter flows are stopped and slowly filtered through the hedge. This allows more water to infiltrate providing a microclimate near the hedge that is conducive to plant growth. The hedge traps silt and debris which also improves the immediate environment.

Within the gully system it may be necessary to construct a silt and debris trap to support the vetiver while it establishes. Once the hedge has established the silt and debris trap may be removed and reused at another site.

Establishing Vetiver Hedges.

The following steps are required to establish a vetiver hedge.

A. To obtain planting material a clump of vetiver will need to be dug up with a spade or if possible a mechanised digger.

B. Tear the clump apart into slips of 4-5 shoots.

C. Cut the top of the slip about 15-20cms above the base.

D. Trim the roots 10cms below the base.

E. Dig a trench or individual holes 10cms deep. If it is possible to only use a mattock, pick or spade this would be preferred. However if the ground is too hard a mechanised digger may be used as long as steps are taken to ensure that there is no damage to the surrounding area. If the hedge is being planted in front of a silt and debris trap the trench dug for the trap can be used. However if the vetiver is being planted as a stand alone hedge the trench will need to be dug on the contour. The ends of the hedge should be turned up at a 45° angle for the last 2 metres to avoid water running around the ends of the hedge.

F. Place the slip in the hole or trench being careful to avoid bending the roots upward.

G. Place soil around the slip and press it down.

H. Proceed to the next hole and repeat the process.

I. Depending on the quantity of planting material available the slips should be planted 10-15cms apart.

J. Fertilise the row with a small amount of diammonium phosphate (DAP) or equivalent.

K. Only a single row of vetiver needs to be planted. However if any of the slips die it will be necessary to replant the resulting gaps.

L. If the vetiver has been planted, in a gully, with a silt and debris trap backing the plants need to be tied to the reinforcing mesh backing.

It is usually necessary to wait until there is sufficient ground moisture to ensure the plants survival. However if a water tanker is available this can be used to help establish the hedge at an earlier stage when access to the hedge site is easier. Once the wet season commences there should no longer be a need to water the hedge. To assist with the healthy growth of the hedge it is suggested that it is trimmed annually to a height of 30- 50cms to encourage tillering.

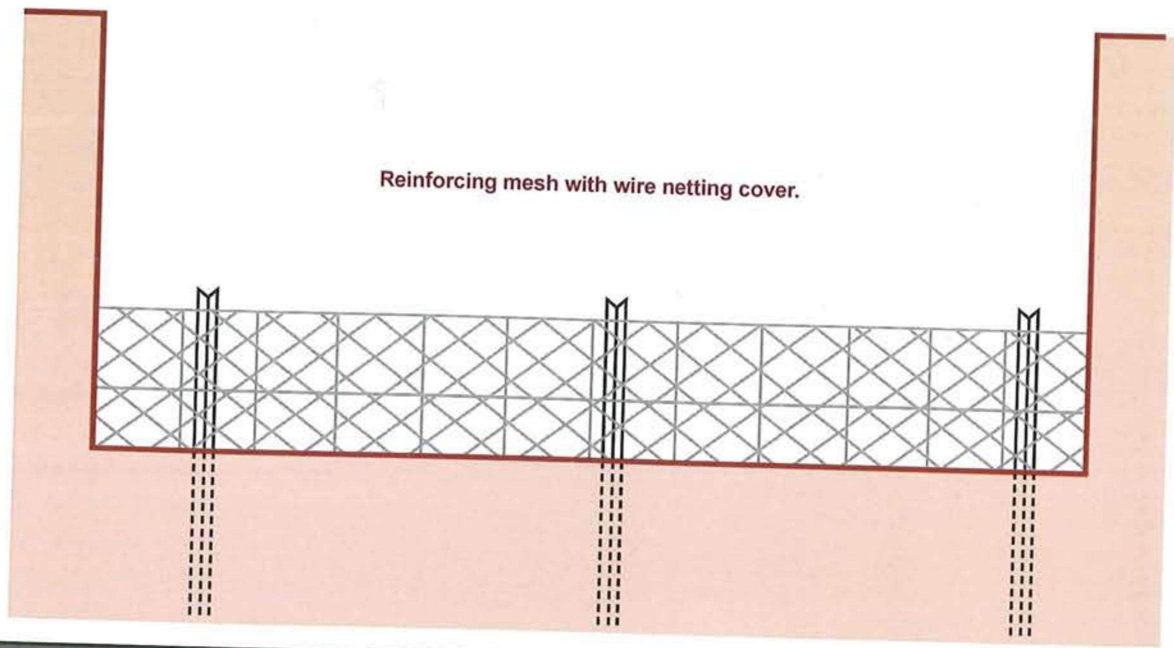
Construction of Silt and Debris Traps for Backing Vetiver Hedges in Areas of High Water Flow.

The materials required for the traps are reinforcing mesh (smallest gauge available), wire netting, star pickets (90cms) and tie wire. The trap will need to extend for the full width of the gully to ensure that there is no flow of unimpeded water around the ends of the trap. A trench should be dug across the gully. The trench should be 10cms wide and 10cms deep. The mesh will be placed at the back edge of the trench with the remainder of the trench being used when planting the vetiver hedge.

The mesh should be cut at a height of 40cms. It will require pickets for support at intervals of 3 metres. The pickets should be driven 60cms into the ground at the back of the trap. The mesh will be tied to the pickets with tie wire. A covering of wire netting will be tied to the reinforcing mesh. This netting should extend into the trench. The Vetiver grass must be planted at the front of the trap.

Plate 62.
Vetiver grass hedge.

Figure 17.
Plan of silt and debris trap.



6

LEVELS

It is essential that all earthworks on a property are pegged accurately to ensure that the required grades are obtained. To aid with this work some type of level will be needed.

There are four types of levels:

Dumpy level

Automatic level

Laser level

Tilting level.

Both the dumpy level and the tilting level consist of a telescope and a spirit level. The telescope is levelled using the spirit level and a horizontal sight can be taken. The tilting level will not be considered further.

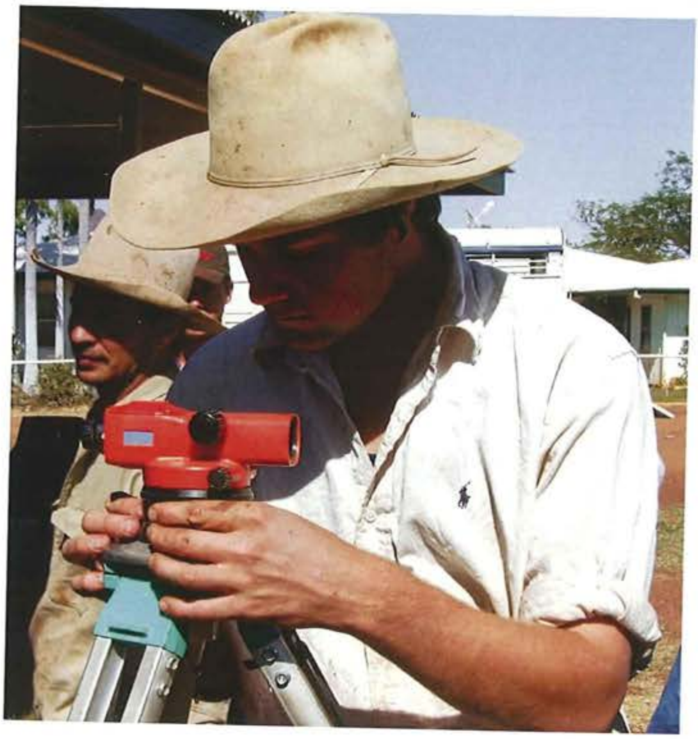
A. Dumpy level.

The main feature of the dumpy level is that the telescope is fixed. Once it is levelled it cannot be altered.

B. Automatic level.

An automatic level only has a circular bubble which is centred using the domed head of the tripod. The footscrews are then used to make the final adjustment. An automatic level includes an internal compensator mechanism (a swinging prism) that, when set close to level, automatically removes any remaining variation from level. This reduces the need to set the instrument truly level, as with a dumpy or tilting level. Self-levelling instruments are the preferred instrument for soil conservation works due to the ease of use and rapid setup time.

Plate 63.
Automatic level.



C. Laser level.

The laser level consists of a transmitter and a receiver. The transmitter emits a level laser beam. The transmitter which is set on a tripod contains a rotating laser beam. The receiver contains a sensor which is activated by the laser beam. The height of the staff when the receiver is activated enables the ground height to be determined in relation to the transmitter.

One advantage of the laser level over the dumpy level and the automatic level is that it can be operated by one person. Both the dumpy and automatic levels require a person at the level and another holding the staff.

A disadvantage of the laser level is that both the transmitter and receiver are battery operated. Murphy's Law dictates that after you have driven 50 kilometres to the work site the batteries will be flat and you will not have any spares.

Plate 64.
Laser level.

6.1 Use of the staff.

The staff is used as a solid reliable vertical ruler. It is usually made of aluminium or fibreglass and consists of 3 or 4 telescopic sections. A fibreglass staff is safer to use than an aluminium staff when working near power lines. To ensure the accuracy of the readings taken through the level there are some important points to remember when holding the staff. These are:

A. Ensure that the sections are fully extended and that the holding clips are properly engaged.

B. Hold the staff vertical.

C. Make sure that the staff is held on the surface of the ground. Never rest it on your boot as this will give an inaccurate reading.

D. Keep your hands away from the front of the staff.

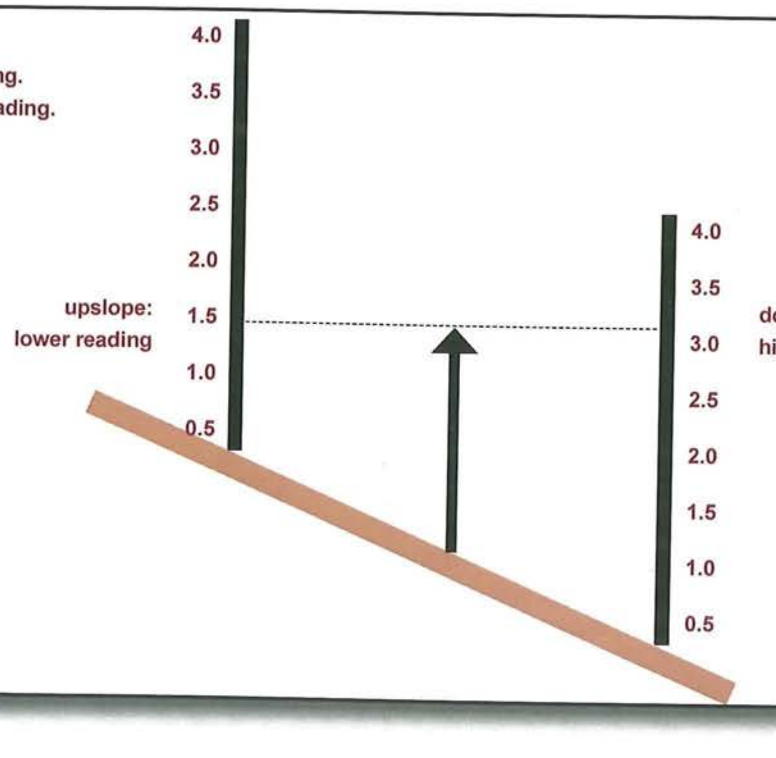
E. On rough country be consistent with the placing of the staff. Always place it either on the rises or the dips. This will lead to more accurate readings where precision is required.

6.2 Using the level.

Set the tripod up at a convenient height with all feet pushed firmly into the ground. The top of the tripod should be set fairly level. Fasten the level securely to the tripod and set to level using the footscrews.

When reading the staff it must always be remembered that the higher the reading the lower the ground, that is, there is a fall to the staff. Conversely the lower the reading the higher the ground, that is, there is a rise to the staff (Fig. 18). Always check that the staff is being held correctly. It is advisable to always write down the readings.

Figure 18.
Upslope -lower reading.
Downslope-higher reading.



6.3 Possible readings on the staff for various grades and lengths.

It is possible to use the level to measure the distance from the level to the staff. The eyepiece on the telescope has a small glass disc. Horizontal and vertical lines are marked on the disc. These are referred to as cross-hairs. There are two extra horizontal lines on the eyepiece. These lines are called stadia. The stadia are the lines that allow us to measure the distance to the staff. A reading is taken on the top stadia line and the bottom stadia line. The difference between the two readings is multiplied by 100 giving us the distance to the staff.

Figure 19.
Using the level to measure distance.

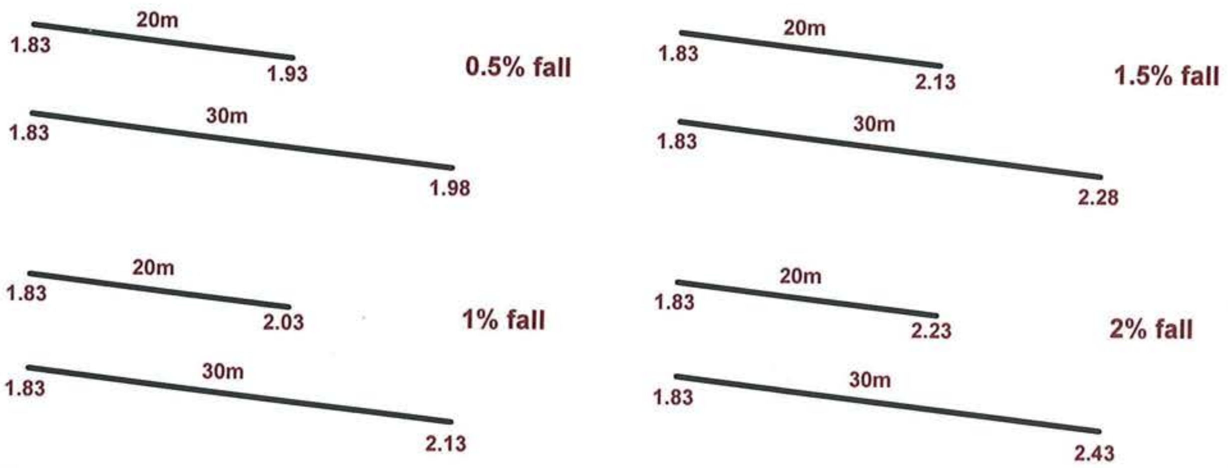
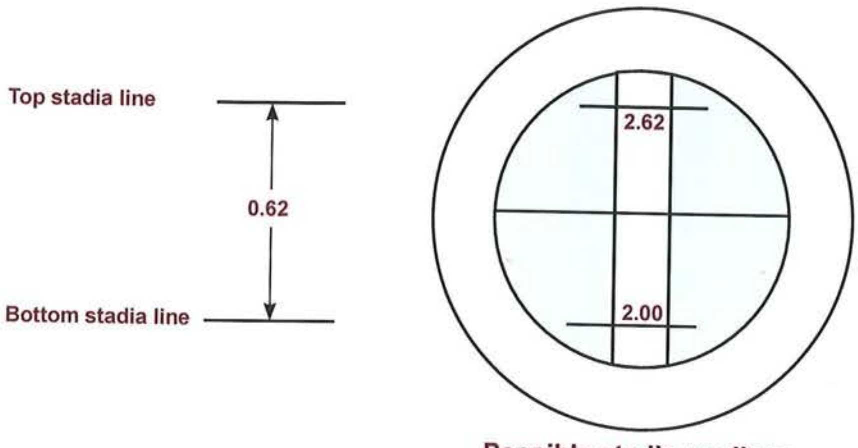


Figure 20.
View of staff through eyepiece showing readings on stadia.



Possible stadia readings

Distance from level 0.62 x 100 = 62 metres

7

Guidelines for borrow pit establishment and rehabilitation

Borrow pits are a feature of nearly every property in the VRD. Many of these pits are still being utilised but there are a great number throughout the region that have been abandoned for quite some time. These pits don't necessarily contribute much to the overall soil loss for the VRD but they are certainly an obtrusion on the landscape. Pits that were established by the Department of Planning and Infrastructure or their contractors should be the responsibility of the department. All other pits should be rehabilitated by the landowner. Although many pits are still being utilised they often just keep getting enlarged with no attempt being made to rehabilitate the exhausted area. It is relatively easy to rehabilitate the disused section of the pit at the same time as new areas are being opened up.

7.1 Steps to rehabilitate an exhausted borrow pit.

A. Clear any standing timber off the area. It doesn't matter if there are trees that are already well established as they are trees growing in an old pit. Once the old stockpiles have been levelled there will be new trees growing on a rehabilitated area.

B. Deep rip the pit to aid infiltration.

C. Batter off the sides of the pit.

D. Flatten out any old stockpiles of overburden or substandard gravel and spread them over the floor of the pit. The overburden being the better topsoil should be spread last over the top of any other material.

E. If the area is likely to erode or is already eroding it may be necessary to construct a diversion bank above the pit to divert runoff away from the pit.

F. If a new area of the pit is being opened up the topsoil from this area could be spread over the old area to provide a source of seed and nutrient. If there is no source of seed available, exotic pasture seed may need to be purchased.

G. Sow seed, if needed, at the commencement of the wet season.

H. Spread any timber over the area to aid revegetation.

7.2 Steps to establish a new borrow pit.

A. Mark out the area of the pit. The area should only be as large as is necessary to provide gravel for that year.

B. Clear the area and pile the timber in a heap nearby or use it to spread over an older rehabilitated pit.

C. Stockpile all topsoil.

D. Push up required gravel.

Plate 65.
Old borrow pit before rehabilitation.

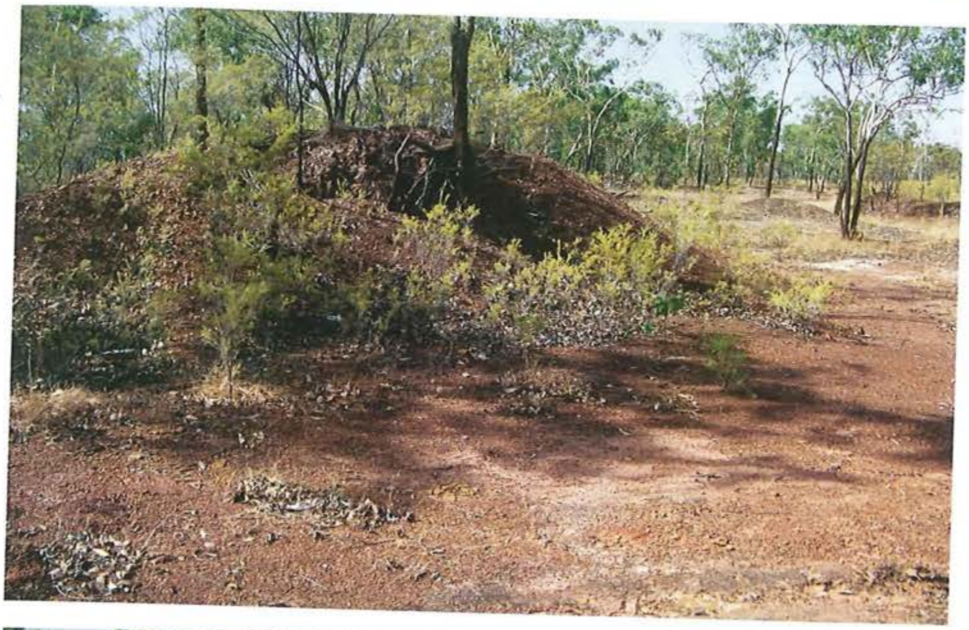
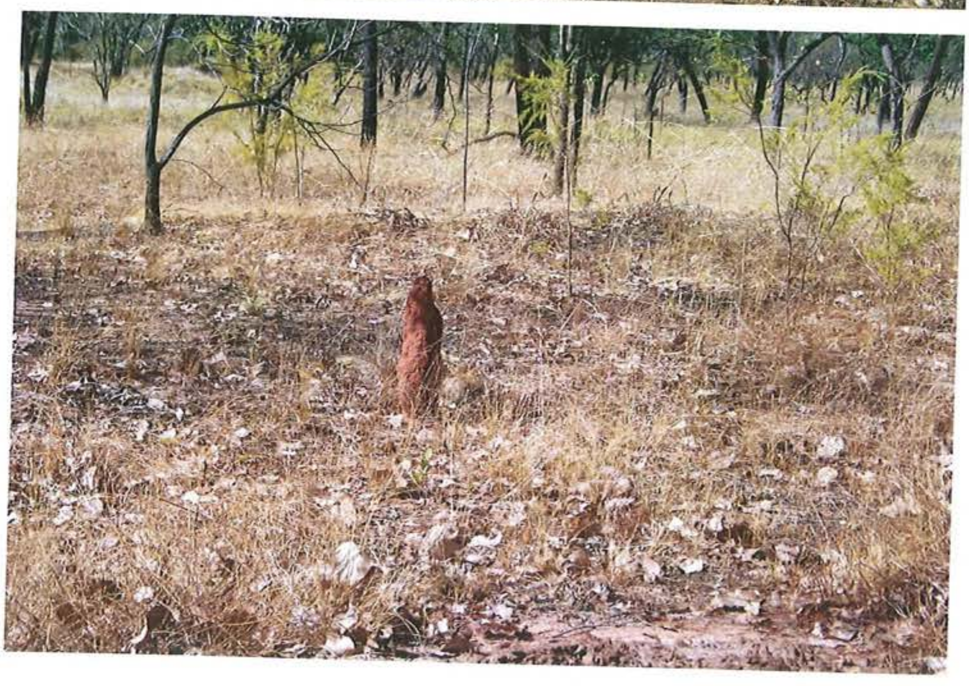


Plate 66.
Old borrow pit before rehabilitation.

Plate 67.
Borrow pit after rehabilitation.



8

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9 FURTHER ADVICE AND READINGS

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