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Common conservation works used in Western Australia

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October 1998

COMMON CONSERVATION WORKS USED IN WESTERN AUSTRALIA

AUSTRALIA
Natural
Heritage
Trust
Helping Communities
Helping Australia

Prepared by
Martyn G Keen
Agriculture Western Australia
Northern Agricultural Region
Geraldton

October 1998

Agriculture
WESTERN AUSTRALIA

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Information contained within this booklet is supplied to assist in determining the suitability of various earthwork designs to alleviate certain types of land degradation. Planning and construction using any of these designs must be undertaken by appropriately qualified persons.

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Table of Contents

Introduction - Conservation works, such as earthworks and structures, form the basis of most coordinated farm and catchment rehabilitation work. This booklet is presented to assist proponents and planners of conservation works by describing the common types used in Western Australia. For each common type, design criteria are listed along with the variables affecting increased risks associated with degradation or structure failure. This information will be useful in choosing appropriate conservation works and to alleviate specific degradation in a safe manner.

Conservation Works Types

- There are a number of conservation works designs and structures, which are commonly used to alleviate various types of land degradation. Certain designs combat water erosion, while others reduce waterlogging/flooding, with further designs being used to reduce the effects of high watertables in saline areas.
- Each design has a specific use and location within the landscape. One conservation work cannot alleviate all degradation types. The choice of an inappropriate conservation work may result in a greater degradation risk than the earthwork was meant to alleviate. Appropriately used, these designs can be integrated with other whole farm and catchment ‘best practices’.
- Conservation works are basically divided into three types. Firstly, there are banks that are constructed earth embankments incorporating an up-slope channel. These are constructed to control surface water and typically traverse sloping land. Secondly, there are drains that are constructed channels used to intercept and remove surface and subsurface water. These are constructed on a grade and most of the designs are used in the lower part of the landscape. Thirdly, there are structures such as dams, evaporation basins and flumes. These are generally used to compliment other conservation works.
- Each of the various conservation works has a set of design criteria for minimum risk planning. Divergence from these design criteria can increase the risk of conservation work failure or the likelihood of degradation from that conservation work.
- Design criteria relate to maximum grades at which conservation works are built, minimum cross sections of the construction, maximum permissible velocities of flows in channels and where in the landscape that particular conservation work is best suited. Peak flows are calculated to assist in determining the minimum size of the conservation works. The peak flows used in the planning of banks and drains are calculated from 10 year Average Recurrence Intervals. Peak flows from 20 year Average Recurrence Intervals are used in the planning of waterways, dams and structures.
- There are certain legal aspects under Common and Statute Law that must be satisfied before any conservation works proposal is implemented. Common law aspects relate to changing the characteristics of water flowing from one property to another. Diversion of flows, increasing flow velocities or increasing quantity of flow could cause damage to neighbouring properties for which the drainage proponent may be responsible. Statute law aspects include responsibilities for degradation threat or degradation created. There is the need to notify some types of drainage and pumping under Statute Law in Western Australia.

Levee and Leveed Waterway

Banks constructed from outside flow lines to confine surface water flows. Single levee can be used to confine surface water flows to prevent flooding. Leveed waterway can be used to dispose of surface flow where no natural waterway exists. Constructed anywhere in the landscape.

Design and Construction

- Single levees can be constructed, by a grader or bulldozer, through low areas to confine flows in streams and creeks thus preventing flooding from overflows.
- A double leveed waterway can be constructed, by a grader or a bulldozer, to provide a safe disposal for surface water flows on sloping land where no natural waterway exists.
- Levees are planned from waterway design formula incorporating estimated peak flows from catchment information, soil types, vegetative cover and maximum permissible velocities.
- A compacted freeboard of 0.2 metres is required on levees above the maximum estimated peak flow depth.
- With careful planning, waterways can be constructed on land sloping up to 10%.
- Leveed waterways can be constructed on land with very little slope. On low slope the waterway functions by depth of flow providing velocity.
- On more steeply sloping land, flow width between levees is increased, thereby flow depth is decreased to reduce velocity.
- Safe disposal into natural waterways is required for leveed systems.
- Leveed flow lines are a very safe disposal point for discharges from bank systems.
- Earthworks can be seeded with pasture species.
- Trees can be planted outside the levees and clear of any earthwork borrow areas.

Variables Leading to Risk of Degradation or Structure Failure

- As depth of flow increase, so does velocity of flow. Erosion of channel floor occurs once maximum permissible velocity is exceeded.
- Stock remove vegetative cover if waterway is not fenced, increasing erosion threat.
- Vegetative cover height does need regulating on fenced leveed areas so as to reduce obstruction to surface water flow.
- Deviation from flat bottomed or slightly parabolic channel shapes will create areas of greater depth with proportionally greater flow velocities, resulting in channel erosion.

Grade Bank

Bank with uphill channel, constructed to control surface water flows from sloping land. Can be used to control run-off causing erosion, flooding and waterlogging. Constructed in the middle and upper parts of the landscape.

Design and Construction

- Constructed on a grade, by a grader or a bulldozer, to collect and dispose of surface flows from sloping land.
- Grade bank systems can be constructed on sloping land up to 10%. Bank systems are surveyed with inter bank spacings dependent on landscape slope, degradation risk and annual rainfall. These spacings range from 50 to a maximum of 250 metres.
- The banks can be surveyed at grades between 0.2% and 0.5%.
- Bank channels are flat. The standard width of a grade bank channel is 3.5 metres.
- Bank lengths can be up to 1 000 metres.
- Grade banks reduce peak flows and lengthen time of concentration thereby reducing flooding.
- Bank systems discharge into stable natural or leveed waterways. Banks discharging into dams can add to stored water supplies.
- Bank channel capacities can be reduced as inter bank spacings are reduced.
- As slope of land increases, so must the height of the bank so as to maintain freeboard when bank channel flows full.
- Trees can be planted below the bank and clear of any area likely to be disturbed during bank maintenance and rebuilding.

Variables Leading to Risk of Degradation or Structure Failure

- Construction in sandy soils can reduce grade banks effectiveness in reducing waterlogging below banks because of leakage through the channel floor.
- Steep grades and narrow channels increase threat of erosion of channel.
- Reduced bank height and freeboard increases threat of overtopping of bank.
- Inter bank spacings greater than those recommended increase the threat of inter bank paddock erosion and bank overtopping.
- Use of other than flat channels increases threat of channel erosion.

Broad Based Bank

Bank with uphill channel constructed to control surface water flows from sloping land. Can be used to control run-off causing erosion flooding and waterlogging. Low profile allows tillage along the length of the bank batters and channel. Constructed in the lower and middle parts of the landscape.

Design and Construction

- Constructed on a grade, by a grader and a bulldozer or a bulldozer, to collect and dispose of surface flows from sloping land.
- The banks can be surveyed at grades between 0.15% and 0.3%.
- Broad based bank systems can be constructed on sloping land from 2 - 6%.
- Bank channels are flat. The width of a broad base bank channel is 5 metres or greater.
- Batters are commonly 1:6.
- Bank lengths can be up to 1 000 metres.
- Bank systems are surveyed with inter bank spacings dependent on landscape slope, degradation risk and annual rainfall. These spacings range from 100 to a maximum of 250 metres.
- Banks reduce peak flows and lengthen time of concentration thereby reducing flooding.
- Bank systems discharge into stable natural or leveed waterways.
- As slope of land increases, so must the height of the bank so as to maintain freeboard when bank channel flows full.

Variables Leading to Risk of Degradation or Structure Failure

- Construction in sandy soils can reduce bank effectiveness in reducing waterlogging below banks.
- Steeper grades and narrower channels increase threat of erosion of channel.
- Reduced bank height and freeboard increase threat of overtopping of bank.
- Inter bank spacings greater than those recommended increase the threat of inter bank paddock erosion and bank overtopping.
- Channel floors with a shape other than flat increase threat of channel erosion.

‘W’ Drain

Two parallel channels with spoil bank between constructed on a grade to remove water from flooded areas. Surface water flows in the two channels either side of the common spoil bank. Constructed in lowest part of landscape.

Design and Construction

- Constructed on a grade, by a grader or a bulldozer, to remove water from flooded or waterlogged depressions. Can be used to define surface drainage in areas of meandering or sluggish flows. Water can enter both sides of drain.
- Constructed in lowest part of landscape and with flat bottomed channels at grades no greater than 0.2%.
- Manning’s Formula used in the planning of these drains. The formula is used to calculate maximum permissible velocity for drain depth against slope, soil type, vegetative cover and predicted peak flow.
- ‘W’ drains are used with small catchments and have a short length. They are only used on a paddock scale.
- Channel width and maximum permissible depth may not contain all predicted peak flows. Drain will overflow but will continue to function and eventually remove even the overflow water.
- The drain should be of sufficient capacity to remove flooding and waterlogging before loss of vegetative cover occurs on treated site.
- Used where a waterway would be ineffective because of low landscape slope or undulations in flow path.
- ‘W’ drains discharge flows into defined streams or waterways.
- Earthworks can be seeded with pasture species to improve stability.
- Trees can be planted clear of drain and clear of peak flows on both sides of the drain.

Variables Leading to Risk of Degradation or Structure Failure

- As grade of channel increases, so do velocity and the threat of channel floor erosion. At grades greater than 0.2%, leveed waterways are recommended.
- Threat of channel erosion and side batter erosion increases as depth and velocity increases.
- Threat of channel floor erosion increases with choice of other than ‘Flat Bottom Channel’ design.
- Transport of saline discharge can destroy channel vegetation and stability.
- Construction in sandy soils will reduce effectiveness of drain in controlling waterlogging.
- Threat of channel erosion increases with other than small catchments and short channel lengths.

Absorption and Level Banks

Banks with uphill channels constructed to control surface water flows where there is no safe disposal. Constructed in the upper landscape.

Design and Construction

- Constructed by a bulldozer on slopes up to 10%. Channel depths can be up to 1 metre.
- Bank and channel is surveyed and constructed level.
- Designed to collect surface run-off high in the landscape where there is no safe disposal.
- Banks control run-off flowing onto lower land that would otherwise cause erosion, flooding or water logging.
- Level bank has one or both ends of bank left at ground level to allow overflow during heavy run-off periods.
- Absorption bank has both ends turned up to allow maximum storage of surface flows.
- Banks are planned using details of slope, rainfall and erosion hazard. Bank spacing and bank capacity are thus derived.
- In porous soils, banks are clay or plastic sheeting lined to prevent waterlogging below banks.
- Pipes set into bank can be used to drain water from banks at a controlled rate.
- Channel blocks can be constructed at intervals along channel to retain water to alleviate severe damage in case of overflow or breach of bank.
- Trees are planted below bank, clear of any possible disturbance during bank maintenance.

Variables Leading to Risk of Degradation or Structure Failure

- Overflow or overtopping from banks can cause erosion.
- Overflow from top bank can add to stored water in filled banks below and increase threat of system failure.
- Stored water in bank can add to recharge of waterlogged or saline site below.
- Overflows from banks need to be incorporated into layout plan.
- Piped overflows need to have a safe disposal area.

Shallow Relief Drain

Channel constructed to remove water from flooded areas or regulate the depth of water in ponds. Generally constructed in lowest part of landscape.

Design and Construction

- Constructed on a grade by a scraper, excavator, grader or bulldozer, to collect and dispose of surface water from flooded depressions and ponds.
- Drain designs based on channel shape include ‘Flat Bottomed’, ‘V’, ‘U’ and ‘Spoon’.
- Constructed on grades up to 0.2%.
- Manning’s Formula used in the planning of drain. The formula is used to calculate maximum permissible velocity for drain depth against slope, soil type, vegetative cover and predicted peak flow.
- Increasing the cross sectional area of the drain can increase flow capacity, as long as the maximum permissible velocity, which is proportional to depth, is not exceeded.
- A drain constructed with no spoil alongside outside batters and constructed in the lowest part of the landscape can overflow. Drain can continue to function and will remove flooded water as peak flow subsides.
- A scraper can transport spoil from drainage site for disposal as fill in depressions or flooded areas. Other machines run the spoil out clear of the drain.
- Batters can be seeded with pasture species.
- Should be fenced to exclude stock.
- Trees can be planted clear of outer edges of structure on both sides.

Variables Leading to Risk of Degradation or Structure Failure

- As grade of channel increases, so do velocity and threat of channel floor erosion. For grades greater than 0.2%, leveed waterways are recommended.
- Threat of channel erosion increases as depth and velocity increases.
- Side batter erosion threat increases as batter slope increases.
- Threat of erosion of channel floor increases with choice of other than ‘Flat Bottom Channel’ design.
- Safe disposal of discharge into streams or waterways required.
- Saline discharge from drain can cause degradation of disposal site.

Open Deep Drain

Deep excavated channel constructed to remove surface and sub-surface water from land with low slopes. Frequently used to drain in saline areas. Constructed in the lower part of the landscape.

Design and Construction

- Constructed on a grade by an excavator, to collect surface and sub-surface water from waterlogged or ground water discharge areas. Spoil placed on one side or alternated on one side or the other.
- Reduces quantity of water stored in soils with high hydraulic conductivity. Drain can reduce watertable to level near bottom of drain and could draw down up to 100 metres either side of the drain under the most ideal conditions. In soils with low hydraulic conductivity, draw down may only be 10 metres either side of the drain.
- Hydraulic gradient also effects the quantity of ground water released into the drain.
- Surface flows can enter the drain and can be removed from drainage site by same structure.
- Discharge into a safe disposal area is required where flow quantity and quality will not cause degradation.
- Drain dimensions planned using Manning’s Formula to predict velocities of flows and can be constructed on grades up to 0.2%, dependent on all factors affecting Manning’s Formula.
- Depth of drain can be up to 1.8 metres with spoil placed on alternate sides.
- Depth of flow calculation critical as velocity of flow increases when flow depth increases.
- Drain can be a good adjunct to an alley farming or revegetation proposal in a saline area.

Variables Leading to Risk of Degradation or Structure Failure

- Large catchment surface water run-off can cause erosion of drain batters and floor. Velocity increases as depth of flow increases. Large surface water flows entering drain can cause erosion of drain’s batters.
- In soils with a high hydraulic conductivity, slumping of batters into drain can occur.
- In soils with low hydraulic conductivity, draw down can be minimal.
- Saline discharge from drain can cause degradation of disposal site.
- Detailed survey of hydraulic properties of the drainage site required.

Leveed Open Deep Drain

Deep excavated and leveed channel constructed to remove sub-surface water from land with low slopes. Frequently used to drain in saline areas. Drain's spoil formed into levees either side of drain to exclude surface flows. Generally constructed in the lower part of the landscape.

Design and Construction

- Constructed on a grade by an excavator, to collect sub-surface water from waterlogged or groundwater discharge areas.
- Surface flows cannot enter the drain as spoil is placed to form levees on both sides of drain.
- Reduces quantity of water stored in soils with high hydraulic conductivity. Drain can reduce watertable to level near bottom of drain and draw down up to 100 metres either side of the drain under the most ideal conditions. In soils with low hydraulic conductivity, draw down may only be 10 metres either side of the drain.
- Hydraulic gradient also effects the quantity of ground water released into the drain.
- Pipes can be used to discharge small surface flows or ponds into drain.
- Discharge into a safe disposal area is required where flow quantity and quality will not cause degradation.
- Drain dimensions planned using Manning's Formula to predict velocities of flows. Can be constructed on grades up to 0.2%. Dependent on the other factors effecting Manning's Formula, grade may be greater if surface flows are excluded.
- Depth of drain can be up to 1.8 metres.
- Small drain with small highly saline sub-surface flow can discharge into evaporation basin.
- Drain can be a good adjunct to an alley farming or revegetation proposal in a saline area.

Variables Leading to Risk of Degradation or Structure Failure

- In soils with a high hydraulic conductivity, slumping of batters into drain can occur. Spoil can also slump into drain.
- In soils with low hydraulic conductivity, draw down can be minimal.
- Velocity increases as depth of flow increases.
- Saline discharge from drain can cause degradation of disposal site.
- Large catchment surface flows can erode outside batters of spoil or may flood outside of spoil.
- Bottom end of drains discharging to ground level is difficult to construct.
- Detailed survey of hydraulic properties of the drainage site required.

Seepage Interceptor Drains

Channels constructed to remove surface water flows and sub-surface seepage from sloping land. Can be constructed as Seepage Interceptor Drain and Reverse Bank Seepage Interceptor Drain. Constructed in the middle of the landscape.

Design and Construction

- Constructed by a grader or a bulldozer, on sloping land as a ‘V’ shaped channel with bank, to intercept surface flows and seepage causing waterlogging.
- Depth of channel can be to 0.8 metres.
- Can be constructed on land with slopes up to 6%.
- Surveyed on grades of greater than 0.5% and up to 0.8%. High grades are used to increase drainage effect for seepage flows.
- Drains are constructed at spacings less than those for grade banks. Depending on landscape slope, these spacings range from 50 to a maximum of 150 metres.
- Maximum drain length is 500 metres.
- A S.I.D. is a ‘V’ channel intercepting seepage and surface flows in channel. Spoil is downhill forming a bank.
- A R.B.S.I.D. is a ‘V’ channel intercepting seepage flows, with spoil uphill forming a bank and separating surface flow from seepage in channel.
- Clay subsurface is required to seal channel floor and channel downhill batter.
- Safe discharge into waterway is required.
- Reverse Bank Seepage Interceptor Drain overcomes problem of erosion of batter by surface flows into structure.
- Trees can be planted below structure and clear of any disturbance during maintenance.

Variables Leading to Risk of Degradation or Structure Failure

- With S.I.D., surface flow into structure can erode batter.
- With R.B.S.I.D., surface flow along bank can cause erosion of bank because grade of structure is high.
- In deeper duplex soils, saturated batters and banks tend to slump into channel.
- In sandy duplex soils, bank of R.B.S.I.D. tends to saturate and slump into channel.
- Deep sandy or loamy soils reduce bank’s effectiveness in seepage interception.
- ‘V’ shaped channel leads to erosion with steeper grades.

Creek Restoration

Work completed to remove obstructing banks of silt and sand from a natural waterway. Work can include removal of fallen vegetation.

Design and Construction

- A bulldozer or excavator is used in the removal of accumulated banks of silt or sand from creeks and streams thereby improving water flows.
- De-silting of obstructed creeks and streams can improve flow characteristics thereby reducing adjacent flooding during large peak flows.
- Removal of fallen vegetation reduces obstruction behind which silt and sand can accumulate.
- Health of vegetation in creek or stream often improves with reduced waterlogging and removal of root burying silt.
- Fencing of waterway allows the natural process of vegetation re-establishment to occur.
- Revegetation or replanting of vegetation should be with species already present in waterway and should be confined to banks.
- Treatment of the whole catchment is desirable to reduce peak flows and lengthen time of concentration. Thus catchment erosion and silting are reduced.

Variables Leading to Risk of Degradation or Structure Failure

- Lack of fencing of creek or stream can result in stock destabilising completed work.
- Leaving spoil of silt and sand near stream banks can lead to material reentering waterway.
- Waterways tend to meander. Extensive earthworks in channel can interfere with this action and cause degradation of waterway banks.
- Vegetation needs to be left intact during work.

Tile and Mole Drains

Sub-surface drainage constructed to remove water from waterlogged soils or saturated soil layers. Frequently used in saline areas. Constructed in lower part of the landscape.

Design and Construction

- Buried or created herringbone fashioned drainage, used to reduce waterlogging and drain shallow groundwater watertables.
- Excavators, ‘backhoes’, trench diggers or pipe layers used for placement of tile and slotted drainage into saturated layers.
- Tile drainage into excavated trenches can be bedded in an envelope of course sand prior to back filling.
- Bulldozers and heavy tractors, pulling machines with torpedo shaped cylinders through saturated clays, create mole drainage.
- Constructed on a grade no greater than 1%.
- Discharge into open drains or sumps and into evaporation basins.
- Drainage effect dependent on hydraulic conductivity of soil treated.
- Pastures and crops can be planted over the back filled drainage.
- Trees can be planted clear of the site and clear of root interference with the drainage.

Variables Leading to Risk of Degradation or Structure Failure

- Detailed hydrological site survey is required to plan drainage.
- Fine particles block slots in piping.
- In iron rich soils, precipitates block slots in piping.
- Tree roots can block or break piping.
- Mole drainage is effective for only a short period of time because of slumping.
- Safe disposal for saline discharge required.

Groundwater Pumping

Constructed to lower groundwater tables and remove seepage at depths too great to be intercepted by constructed drainage. Usually used in the lower part of the landscape.

Design and Construction

- Groundwater pumping is used to dispose of saline subsurface water from profiles affecting the landscape surface.
- Effectiveness of the pumping depends on hydraulic conductivity of water bearing part of soil profile.
- Highly saline water can be discharged into an evaporation basin or pond.
- Hydraulic gradient also effects the quantity of ground water released into the drain.
- To be effective, requires an unconfined aquifer in ideally, a deep (at least 10 metre thick) sedimentary profile.

Variables Leading to Risk of Degradation or Structure Failure

- Discharge of often highly saline water can degrade disposal site.
- Salinity of discharge is often as high as twice sea water.
- Favourable hydrogeological characteristics of aquifers are not always likely to be found in required locations.
- Differing bedrock profiles, origins and weathering processes cause irregularities in transmissivity, hydraulic conductivity and storage coefficients of aquifers.
- If pumping from a confined or semi-confined aquifer there is little or no draw down of the watertable.

Dams

Constructed to store rainfall run-off for short or long periods. Usually built in the middle part of the landscape. Short term storage including a piped water release system can be used to control surface water above gullies to alleviate erosion, below eroded areas to trap sediment or as part of a down slope release system to control flooding. A dam designed for long-term storage as part of a paddock water control system helps conserves water for farm use.

Design and Construction

- Constructed by a bulldozer on sloping land near to, but clear of natural waterways. Surface area shapes can be square, rectangular or circular.
- Planned so as to take surface water flows from grade bank systems, roaded or improved catchments . Overflows are taken by grade bank to a waterway or other safe disposal.
- If dam is planned for long term water storage, a circular surface area is preferred. This shape has a smaller surface area than other shapes with the same storage capacity and depth.
- For sediment control, a dam is used for short-term storage of surface water to allow the settling of sediments. Stilled water can be released by pipe to a safe disposal area further down slope. Sediments are left in the dam.
- A dam can be used to store water for a short period for flood control during a storm with a large peak flow. Water is released after the peak flow event.
- For erosion control, a dam is used at the head of a gully with pipes releasing water below the gully head.
- For long-term water storage, a dam's capacity must compliment the area of the catchment treated with grade banks. A treated area of 40 hectares would require a dam of 4 000 cubic metres capacity.
- A dam planned for the long-term storage of water could be useful for some forms of aquaculture.

Variables Leading to Risk of Degradation or Structure Failure

- A dam filled from a grade bank system cannot be considered drought proof, although it would still provide useful supplies.
- Dam may not fill every year, as rainfall to paddock run-off intensity is needed before water flows into the dam.
- A dam with a shallow depth will dry more often than a dam of greater depth. To provide useful farm water storage the dam's depth should be well in excess of twice annual evaporation.
- Overflow water cannot be allowed to discharge around dam's walls. An overflow planned to cater for a 20 year Average Recurrence Interval is required.
- Dams planned for short-term storage of water must still be well engineered even though they have a shallower depth.

Evaporation Basin and Evaporation Pond

Shallow excavated basin or natural pond used to store and evaporate collected sub-surface drainage water. Constructed in the lowest part of the landscape.

Design and Construction

- Constructed, by a bulldozer or an excavator, to control highly saline discharge from closed deep drains or subsurface pumping.
- Design uses large surface area and shallow depth to allow evaporation of water leaving salts within the basin.
- Sites with soils of low permeability are used to reduce risk of groundwater recharge under basin system.
- Constructed basin is planned for 20 year or greater Average Recurrence Interval.
- Saline discharge from deep drainage can be pumped into a basin.
- Saline discharge can flow directly into a pond.
- Basins and ponds should be located away from areas of production in case of leakage.
- Saline lakes could be used as evaporation ponds if it can be established that the lake does not recharge groundwater tables.
- Planned size of basin or pond is determined from amount of water to be disposed, rate of supply of water, evaporation and rainfall into basin or pond.
- Construction can be lined to prevent leakage.

Variables Leading to Risk of Degradation or Structure Failure

- Surface run-off into open deep drainage increases the amount of water to be stored and evaporated.
- Leakage from basins and ponds located within areas of production could result in loss of production capacity.
- Basins constructed in or near waterways and flood plains are at risk of structural damage during floods.

Flumes and Other Gully Control Structures

Shaped structures built of vegetated earth, rock or concrete to convey water to a lower level without causing erosion. Typically used at the head or side of a gully. Constructed anywhere in the landscape.

Design and Construction

- A flume is a hydraulic structure, incorporating an inlet, chute and outlet, used to transport water over the edge of a gully onto the stable gully floor.
- A combination of machinery such as bulldozers, excavators, 'bobcats' and trench diggers are used to assist in the construction of chutes, cutoff trenches and overflows.
- A flume can be constructed from vegetated earth, iron, loose or grouted rock or concrete in the form mentioned above. A verandah design is constructed of wood and iron with a concrete spill pad.
- Flumes can be used within most small and medium sized catchments. Peak flow run-off, gully depth and gully width are used to calculate the finished dimensions of the flume.
- A gully head stop is a simple earth structure in the shape of a small dam. It is constructed at the head of a gully in the flow line. A level sill is constructed both sides of the gully head stop to allow stilled water to overflow into the gully.
- Gully stops with sills are suitable for construction on gullies with small catchment areas and usually only on a paddock scale.
- Gully stops and sills are constructed with a bulldozer and a grader.

Variables Leading to Risk of Degradation or Structure Failure

- All structures must be fenced as stock can damage grassed chutes, overflows and soil supporting concrete parts of the structures.
- Planning must cater for a 20 year Average Recurrence Interval.
- Vegetated earth and loose rock flumes are less stable than concrete and are more prone to failure under severe storms.

Gully Filling

Fill with structures used to stabilise eroded water flow areas. Fill can be undertaken on gullies of small depth, short length and anywhere in the landscape.

Design and Construction

- Gully filling is undertaken by bulldozers and graders, with a grader being used to construct stabilisation structures across the fill.
- Calculations are made as to the quantity of borrowed soil required to fill the gully to make a parabolic shaped channel. The planned channel must have sufficient width to depth ratio so as not to erode.
- Topsoil is stock piled clear of fill and borrow areas.
- Sub-soil is borrowed and used to fill gully.
- Fill area is shaped and compacted by the earth moving machinery.
- Previously stock piled topsoil is then spread across filled area and compacted by the earth moving machinery.
- The whole-disturbed area is then seeded with a pasture species mix and fertilised at twice the recommended pasture seeding rates.
- To aid stabilisation, where possible flows should be diverted from the fill area for at least one winter.
- Alternatively, spreader structures can be constructed across the filled area to reduce the velocity of flows. Spreaders are short diversion banks arranged baffle like down the length of the gully. They divert flows from the filled area and spill clear of the fill. The flow then re-enters the fill area and is diverted again by the next lower spreader, and so on.

Variables Leading to Risk of Degradation or Structure Failure

- Fill into deeper gullies must be compacted in layers.
- The deeper the gully, the wider the borrow area to maintain a suitable width to depth ratio.
- Deep gullies are uneconomic to fill.
- Using the topsoil as filling and then shaping the filled gully with subsoil will result in an area that will not readily stabilise with seeded pastures.
- Erosion of a filled gully, that was not protected by spreaders or diversion of flows, may be even harder to fill the second time.

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Note

- **Average Recurrence Interval is the average period in years between the occurrence of a storm of a given magnitude and one of equal or greater magnitude.**
- **Manning's Formula is used in the planning on most conservation earthworks. The formula is an expression of the relationship between average velocity and factors relating to water flowing in an open channel.**

Manning's Formula is expressed as:

$$v = \frac{1}{n} R^{2/3} s^{1/2}$$

where v = average velocity of flow (ms^{-1})
R = hydraulic radius = $\frac{\text{cross sectional area } (m^2)}{\text{wetted perimeter } (m)}$
s = slope of channel bed in metres per metre
n = Manning's roughness coefficient.

Photographs appearing in this booklet were taken by: Cecilia McConnell, Russell Speed, David Stanton and Martyn Keen.