Buntine-Marchagee Recovery Catchment
Surface Water Catchment Management Plan

Prepared for
Department of Conservation and Land Management
Coorow LCDC
Catchment Landholders

Prepared by:
Noel Dodd
Systems of Landcare
Buntine Marchagee Demonstration Catchment
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ACKNOWLEDGEMENTS

Technical input and support from

Jodie Watts Buntine Marchagee-Recovery Catchment Officer
Martyn Keen Senior Technical Officer, Dept of Agriculture Bunbury
Lindsay Bourke Technical Assistant, Buntine Marchagee-Recovery Catchment
Gavin Mullins Revegetation Development Officer

Gary Sherry CEO Coorow Shire

Special thanks to the Landholders involved in the catchment.

John & Robin Stacy
Michael & Julia O'Callaghan
Frank & Jeanie Crago
Vern & Jan Muller
Jack & Kathy Stone
1. INTRODUCTION

1.1. Overview

The aspirational goal of the Buntine-Marchagee Recovery Catchment (BMRC) is to “maintain the native species in a range of representative wetlands within the Buntine-Marchagee catchment by 2020”.

The Buntine-Marchagee Natural Diversity Recovery Catchment (BMRC) is the fifth natural diversity recovery catchment declared under the State Salinity Strategy. The BMRC is located in the northern agricultural zone between Dalwallinu and Coorow and covers an area of 181,000 ha. The BMRC falls within the Moore River hydrological zone of the Moore River Catchment (Alderman and Clarke, 2003).

In March of 2002, the BMRC Steering Committee determined the following objectives to provide direction for the Recovery Catchment project;

1) Identify high priority biodiversity values within the catchment where resources may be focused, by December 2003.
2) Understand and identify how groundwater and surface-water hydrology within the catchment contributes to secondary salinity.
3) Develop and promote community understanding of the value and importance of the natural environment.
4) Increase public awareness and participation in conservation works aimed at protecting biodiversity values at risk of secondary salinity.
5) Develop methods for integrating sustainable farming systems and conservation works
6) Develop a system of monitoring and evaluating the overall effectiveness of the project

To fulfil part of these objectives it was determined that demonstration sites could be implemented to illustrate best management practices and their benefits to the protection of natural biodiversity values.

The project involves numerous stages from the original conceptual planning through to construction on-ground.

The project commenced in September 2002 with Sinclair Knight Merz (SKM) producing a “conceptual” Surface Water Management Plan (SWMP) for a sub-catchment (Demonstration Site) with in the BMRC.

The subsequent course of action was to identify where water crosses the Buntine-Marchagee Road down slope of the demonstration catchment. This was required to verify a safe outlet for any proposed works within the area. Systems of Landcare completed this in 2004.
The Coorow Shire is responsible for road construction and maintenance, therefore before undertaking conservation earthworks upslope from the road, the Shire will be required to construct a suitable and appropriate crossing either using a floodway, culverts or a combination. The crossing will need to be capable of handling a peak flow equivalent to a 1in20 Average Recurrent Interval (ARI).

Systems of Landcare (Sol) was contracted by the Department of Conservation and Land Management (the Department), through the BMRC to verify the SKM ‘conceptual’ SWMP on ground ready for implementation. This would involve a detailed site assessment and production of a workable surface water management plan using best management practise guidelines. The plan would have to be geared up to be placed on the ground for construction of the proposed earthworks.

1.2 Extent of Study Area

A number of criteria were used to select a suitable demonstration site. These included:

- A site with a common problem encountered across the Northern Agricultural Region (NAR) which has the potential for broad-scale application
- Proximity to a major road – observation
- Suitable catchment size
- Proximity to wildlife corridors, and
- Willingness of farmers to participate.

A site which adequately met these and other objectives was then selected.

The site chosen suffers from water management problems with surface and stream channel erosion, water logging and salinity. Soil profiles and the geology are typical of the eastern area of the Northern Agriculture Region and the Yilgarn.

The Buntine Marchagee road passes through the lower sections of the selected catchment and as such is one of the issues complicating the surface water flows.

The catchment area of 870ha is appropriate / suitable in size for the purpose of demonstrating an integrated surface water control system.

There are sufficient remnant vegetation areas in the catchment to build on for wildlife corridors. The majority of this bush is high in the landscape and along the catchment divide. The site was originally proposed by the landholders and the willingness of the land holders to participate was never in question. Their continued contribution and participation in the process has lead to a strong ownership of the final plan.
2. BACKGROUND

CALM contracted Sinclair Knight Merz (SKM) in 2002 to complete a “conceptual” Surface Water Management Plan (SWMP) for a catchment area within the BMRC. This contract included a more detailed review of the site selected to demonstration water management (SKM, 2003). The report provided an indication of the willingness of farmers to participate in the project and the likely success of implemented works.

In order to fund the implementation of the demonstration site, the Department of Conservation and Land Management (CALM) assisted the Coorow LCDC in obtaining funding through the National Landcare Program (NLP). The successful application was in-part attributed to the financial and in-kind contributions from the Shire of Coorow, relevant landholders and CALM.

Subsequent to the SKM (2003) report and prior to the confirmation of NLP funding, Systems of Landcare (Sol) was contracted by CALM to identify where surface water crosses the Buntine-Marchagee Road down-slope of the nominated demonstration catchment. This was required to verify a safe outlet for any proposed works within the area. This report was completed in 2004 (Sol, 2004).

The next phase of the project was the final design and implementation of on-ground works. Sol was contracted by the Coorow LCDC to verify the SKM ‘conceptual’ SWMP on ground ready for implementation. The aim of this project is to implement an integrated surface water management plan that demonstrates current best practice thereby increasing community awareness, understanding, and adoption of what is considered, for the most part, a manageable land degradation issue contributing to significant loss of agricultural and natural resource values in the BMRC.

Analysis in this report focuses on the surveying and designing of appropriate earth works for surface water management at the demonstration site within the BMRC. This report also includes recommendations for changes to farming practices and implementation of appropriate revegetation strategies.

The information for this report was collated and recorded by Systems of Landcare (Sol).
3. SURVEY AND DESIGN OF CONSERVATION EARTHWORKS

Best Management Practise standards provide the framework for the design of conservation earthworks. The main implements utilised are grade banks and grassed waterways for which industry standards are applied. The planning of conservation earthworks is enclosed and detailed in the national competency standards for conservation earthworks industry as part of the conservation and land management training package. This is listed as RTD5204A – Plan Conservation Earthworks.

3.3.1 Location
The demonstration site is 870 ha in area and is located on the Buntine-Marchagee Road, east of the Vanzetti Road intersection, 14 km east of Marchagee (Figure 1). It is the southern headwater for the centre sub catchment of the Innering Hills neighbourhood. In turn the Innering Hills is the eastern section of the Koobabbie Sub Catchment which lies in the North West corner of the Recovery Catchment. The demonstration catchment system joins the main flow line of the Buntine-Marchagee catchment 3500m downslope from the Buntine – Marchagee Road crossing.

3.3.2 Climate
The BMRC experiences a warm temperate to semi-arid climate with hot, dry summers and predominately winter rainfall. January is the hottest month and July the coldest. Average maximum / minimum monthly temperatures range from 39/16°C to 20/5°C in these months.

The Ytiniche weather station is located nearest to the demonstration site. Rainfall records have been recorded since 1918 and the average annual rainfall since this period is 342 mm (Bureau of Meteorology, 2005). Although the majority of rainfall is received in winter, highest daily rainfall totals are commonly recorded in summer or early autumn. Significant summer rainfall events occur in association with thunderstorm activity and the passage of cyclonic low-pressure systems. Evaporation in the catchment far exceeds rainfall and is typically 2500 mm per annum (Farm Water Supply Reference Data for Raintanks and Surface Water.- E.J Hauck and N.A Coles February 1995)
Figure 1: State Map
Figure 2  Regional Map
Figure 3: Catchment Map
4. METHODOLOGY

4.1 Prior to field assessment

Aerial photograph interpretation was enhanced by using a stereoscope and a stereo pair of aerial photographs at a scale of 1:25 000 of the assigned area. The catchment area geology was reviewed using the Moora sheet for the Geological Series 1:250,000 scale with explanatory notes (Carter and Lipple, 1982). A series of satellite images (1980-2000) were accessed to provide an indication of the changes occurring to the catchment area over time. This was an invaluable tool in assessing temporal changes to productivity, and the progression of land degradation across the catchment area.

Scheduled discussions were held with Department of Agriculture WA Senior Hydrologist, Russell Speed, who has relevant and local experience and the proficient knowledge of the hydrological processes of the demonstration catchment and surrounding region.

Rainfall records were obtained from the Bureau of Meteorology and assessed for rainfall events that would have produced run-off. The difference between summer and winter events and their intensity as mm/hr was explored. This was later discussed with each individual land holder with regard to the size of flows observed.

Points of interest were marked on the photographic base map for further analysis and scrutiny during the field investigations.

The pre project tools used allowed the identification of any geological lineations, geomorphology, soil types, vegetation types, general farming practices, and the historical formation of the area.

A conceptual model of the surface water processes and function within the catchment was able to be developed for assessment upon inspection in the field. Obtaining this information was essential to the development of the catchment plan.
4.2 Field Assessment

The intention in this phase is to ground truth the 1:10,000 aerial photograph base map and further develop the understanding of the natural resources and the processes involved in the movement of water.

Each landholder was consulted prior to commencement to discuss and gather their thoughts and ideas into the plan. Their historical knowledge is crucial to the understanding of the many processes occurring on their property and within the catchment. Neighbours views of the same area under discussion can vary sufficiently to provide more creative ideas to address the associated land management hazards. Their ideas and judgment on which tools are required and where in the landscape provides an agenda for the draft plan. During the site assessment each idea is assessed for technical and management standards.

The course of action involved in carrying out a site assessment is to travel around the catchment scrutinizing the geology, slopes and soil types for their effect on surface and ground water hydrology. A method of separating each toposequence to understand the processes that are happening is employed.

Each toposequence has a varied degree of land management issues and hazards with the history of formation determining the types of problems.

A typical sequence is begun with a granite outcrop along the divide, surrounded by a shallow laterite or coarse sandy loam over clay along the upper slopes. Slopes up to 8% add to the high run-off feature. The mid slopes are deeper profiles of sands, gravels and clays. Wind erosion becomes an issue along with recharge and hillside seepages from bedrock highs and intrusions. Slopes are settling down to 3% with a gentler undulation. Of particular importance is the boundary between the two slopes where surface becomes sub-surface flows.

The tools to manage the process now change as potential control of the water is lost beneath the surface.

The lower slopes tend to shallow out with duplex clays in the company of a laterite hardpan closer to the break of slope where the fall drops dramatically to less than 1%. This point is crucial in the system as there is a natural collection of seepage along this concave line. The seepage flows have been passing through coarser material with a strong elevation head down the slope. They now come up against finer clays and alluvium in a shallow profile with
a slope drop of around 75% thus pressurizing the catchment structure. The timing of the coloured aerial photography indicated seepage flows, faults and intrusions across several sections.

Existing land management hazards along with developing and potential problem areas were inspected and scrutinized. Visual signs of water management hazards were not just surface water erosion but also vehicle bog marks and the growth of various flora species. The density of plant life and vegetation along with specific species in some areas indicated a ground water quantity. An example of this is the increased stems per hectare of Eucalyptus Loxophleba growing upslope of a geological intrusion crossing the main channel on Crago’s property.

The process of ground truthing involves looking for shapes and silhouettes within the toposequence, such as breaks of slope, both convex and concave. Each change indicates a change in geomorphology and the process of water flows from the catchment. Checking the shape of drainage lines and any stream channel erosion along with ordering the streams was fundamental in the search for safe disposal points. The requirement for secure points to discharge flows emanating from surface water control structures is to ensure that in solving one problem another is not created.

A soil auger was used to verify soil profiles down to 1m where necessary to further develop the decision making process. Basic properties were evaluated such as texture, gradation, plasticity, structure and permeability. Any compaction or hardpan was identified in this process or using a penetrometer rod. A small magnifying spy glass was employed to view closer any soils or geological samples of interest. Assessing the soil characteristics with this approach stems from the unified soil classification system.

A collection of ideas and potential key points for any engineering structures, revegetation, fencing or other appropriate land management tools was collated and recorded on the base map for further development.

Management systems need to be kept in mind at all times as the plan is being developed for the catchment. These issues include paddock size with some uniformity of soil types and access for machinery and stock movement. Where paddocks are already limited in shape and size by areas of remnant vegetation or granite outcrops, the inclusion of any major earthworks is going to be of a significant hindrance.
4.2.2 Occupational Safety and Health

Service lines such as telephone, power and water supplies are inspected for their positioning and occupational health and safety issues observed. A cable locator will be required on Mullers property along the north side of the road.

4.4 Off Site – Defragmenting

The base map was positioned over the light table where the compilation of ideas was assembled into a structured conceptual plan. This began with determining safe disposal points for the required peak flows down the catchment.

Previous investigations had shown that the existing channel south of the B-M road had limited capacity to handle 1:20 ARI events. Dispersive soils are evident in sections of the eroded conduit. This means a new leveed waterway will need to be constructed from the B-M road 1800m south to the existing vegetated channel. From here to the top, the existing natural channel is capable of handling the required flow. A small 100m section across to O'Callaghan’s boundary with Crago’s will need to be reconstructed to provide a safe outlet for flows from the southern part of O'Callaghan’s.

North of the B-M road either a leveed waterway or trapezoidal channel can be used to transport the flow across the paddock, down to the regional drainage system. The landholder had previously stated that the use of excavation was not the preference therefore a leveed system is suggested. The construction of levees is also cheaper than excavating a trapezoidal channel with the necessary dimensions.

A new waterway will need to be constructed from O'Callaghan’s down to the main channel in Stacy’s for flows from the northern section of O'Callaghan’s. The existing passage in Stacy’s does not match the waterway position coming down the catchment. This eroded channel developed with run-off from a discharge site behind a dolerite dyke near the boundary and will require filling along with revegetation of the discharge. Works will be obligatory upslope to control the inflow of seepage to this site.
Dimensions for the proposed waterways were calculated to ensure they could fit into the landscape.
All constructed and natural waterways are to be revegetated, fenced and stabilized with access crossings at suitable points.

Grade banks were then drawn on to the base map at the appropriate spacing from the industry standards. Adjustments were then made to match any erosion, soil type changes, breaks of slope, management and safe disposal issues. Each change necessitated recalculating the dimensions to ensure that the capacity of the bank was not breached.

Grade banks arrangements provide prevention as well as cure with a reduction in the peak flow. An example from the catchment plan is a natural flow from Crago’s into Stacey’s of 600m down a 3% slope to the main waterway. A grade bank takes this flow 850m across the slope at 1m/second to discharge into the natural creekline before traveling a total of 1700m down to the original discharge point. This flow tended to fade away into a sub-surface arrangement in small rainfall events through Stacy’s before appearing as water logging along the main creekline. The density of earthworks decreases down the slope as the landscape changes from shallow profiles and steep to gentle and stable. The upper slopes are where surface flows begin with the greatest momentum, obtaining mass and velocity expediently as long as one or more conditions facilitate growth of the flow.

It is anticipated that the implementation of the surface water management plan will reduce peak flows by a proportion of 30%. This would be most noticeable at the foot of the catchment with the road crossing.

The running of a R.A.F.T.S model with the catchment plan specifications should confirm this once the plan is finalized.

The option of using deep drainage on a discharge site was explored with regard to industry standards and best management practice. The main limitation to this option is the requirement for a safe disposal point followed by the cost of construction. The use of revegetation and surface water control upslope of the hillside seepage should provide the seepage control required.
5. WATERWAYS

5.1 Waterways Map

LEGEND
- Constructed Waterway
- Natural Waterway
5.2 Waterway Comments

A Double leveed waterway or trapezoidal channel capable of managing $9\text{m}^3\text{s}^{-1}$. The channel is to be sown to a pasture such as Dalkeith clover to stabilize the floor. A natural small depression exists on a soil change between the fresher, deeper profile on the western end of this paddock and the shallow, saline country to the east of the proposed new structure. The construction will require surveying for cross slope and fall to the disposal point.

B A new road crossing will need to be constructed capable of discharging $9\text{m}^3\text{s}^{-1}$. The involvement of the Main Roads department through Jerome Goh is advisable as part of the planning process.

C The double leveed waterway is to continue for 1800m south from the road. This first section of 400m will require cut and fill before surveying to fill the existing drain and level the alluvial deposit. The next 800m to the end of the paddock will be built to east of the current channel before crossing into the scalded area. From this point on to the end of the constructed area, cut and fill will be required.

D A proposed new waterway from O’Callaghan’s enters the main channel from the east with a maximum velocity of flow of 1m/sec. The extra width required in the design is to reduce the depth of flow across the sandy soil. The channel floor needs to be sown to a mixture of pasture species such as Cadiz Serradella and Dalkeith clover. The right angle method of surveying needs to be employed for all of the proposed new channels in this upper section of the catchment.

E The existing eroded channel needs to be filled so as the landholder can work across the slope to stabilize the area.
The existing channel is to be stabilized with revegetation of the banks and protected by fencing outside the peak flow line to exclude stock. There is sufficient shape and capacity to handle the required 1:20 ARI from where the trees start at the end of the construction area up to where this line of vegetation finishes 100m from O'Callaghan’s boundary.

A double leveed waterway is to be constructed to provide safe disposal for flows from O'Callaghan's south paddock. The channel is to pick the stream as it emerges out of the remnant vegetation and convey the flow down to the start of the natural system. The channel floor needs to be sown to a mixture of pasture species such as Cadiz Serradella and Dalkeith clover.

Natural system is to be enhanced with inlets to stop erosion down the outside of the vegetation along the firebreak and access track. The central flow line needs clarification as the dense vegetation is restricting the velocity of flows. The result is a spreading of the flow onto the firebreaks and farm access tracks down the side of the vegetation. Fencing to remove stock will enhance the stabilization process and integrate the existing works into the catchment plan.
6. GRADE and LEVEL BANKS

6.1 Grade and Level Banks Map

LEGEND

- Proposed Grade Bank
- Proposed Level Bank
- Existing Dam
6.2 Grade and Level Bank Comments

A  The lower slopes of Stacy’s show little sign or history of surface water movement across the slopes meaning any earthworks are to be spaced out picking up flows from strategic and key positions such as the access tracks.

B  An old and degrade surface water management system needs to be upgraded to meet design standards. This will mean that the existing 5 bank array will become 4 banks with the reconstruction of the top and bottom lines and rearrangement of the middle sector. The top line is necessary for any possible overflow of the dam in an extreme event to be transported back to the main creekline. The bottom line is situated conveniently at the top of the main salt scald and as such becomes a key line. The two middle lines have been sited with more emphasis on management and workability.

C  Area of closer spaced earthworks required due to the shallow laterite and granite profiles coupled with sharper slopes. Key dam on Stacy’s hindered the plan with its need for run-off and will necessitate extra earthworks in this sector. The main creekline to the eastern end provides a safe disposal point for the majority of the vicinity. Level banks are required at the top of two slopes as there is no safe disposal point.

D  The northern half of O’Callaghan’s is more about removing water from the system than controlling surface water flows. Two seepage hollows are expanding as flows drop of the shallow laterite and dolerite soils into semi confined perched aquifers. The existing level banks are to be replaced with grade lines to dispose of water into the natural creekline.
E  A small sub-catchment of 12ha is suffering from stream channel erosion and water logging as the first order stream flowline joins the main tributary. The two proposed lines here will be complicated in surveying to make them work and difficult to manage with machinery. This is due to the narrow shape of the system with less than 400m between catchment divides. The process may involve construction of the top bank for a observation period to assess the need for the second grade bank.

F  The existing level banks need to be removed and replaced with a grade bank system. Further lines are required upslope to remove excess water from recharging through the coarse material of the soil and discharging on the lower sections. This seepage and discharge is coming up against dolerite near the boundary and a shallow laterite and saprolite going back up slope. Coloured aerial photos at 1:25 000 show this seepage and was confirmed on site with the soil auger. The area is a high risk toposequence part of the catchment. Having safe disposal points is fundamental to being able to remove this annual supply and the access to the remnant vegetation at each end was crucial. The final positioning of the two top grade lines will need to be refined for management and machinery as the area is already dissected in its natural shape.
7.0 REVEGETATION PLANNING.

Revegetation positions and requirements are looked at from various angles similar to the earthworks, what is the problem and what/where is the result. The aim is for lines of vegetation across the landscape beneath earthworks for general recharge and seepage control with more concentrated planting required around discharge areas. Agro forestry systems of oil mallee’s across the sandplain address both recharge and discharge to some degree but is not always as effective as a strategic system.

A key line for revegetation is the change between the shallow soils in the upper catchment and the porous recharge material on the midslopes.

There is a case for revegetation beneath all grade banks as a long term aim for the landholders. Priority planting areas are the main focus of this plan.

The lines of vegetation if designed correctly can become wild life corridors between the small and separated patches of remnant vegetation.

“Awkward corners” are limited by shuffling works but where they do occur it is an opportunity for planting of commercial value crops. Examples of this in the plan are the proposed planting of oil mallee and salt bush blocks adjacent to the main creekline.

The conceptual or draft plan now had shape and was returned to the paddock for fine-tuning before imparting to the landholders.

Fencing and paddock arrangements with safe all weather access points were now scrutinized. Boundary fire breaks need to be kept clear as an example.

Each property has different access requirements depending on management style, toposquence and shape of the property.

All remnant vegetation is to be fenced for stock exclusion.

The holistic approach to fencing is to use as much as possible the fencing from the resource management plan. The creekline’s now become paddock divides along with individual revegetated grade banks on soil type changes.
7.1 Revegetation Map
7.2 Revegetation Comments

A The area to be sown to a perennial pasture of lucerne. The area is slightly raised and given improved drainage of the profile it provides an opportunity for high water use production among the surrounding waterlogging. An alternative is annual pasture of Dalkeith clover or a mixture appropriate to the region. This area between Mamboobie road and the constructed waterway is approximately 8ha in size.

B This is an area of finer alluvial soils with a shallow hardpan suffering from water logging and the resulting salinisation. Pasture species growing on the site indicate that the area can be renovated into a productive site. Saltbush and Acacia Saligna seedlings need to be planted on pre-ripped mounds, constructed in pairs known as a hedge. The mounds are to be 2m apart and parallel to the waterway with a break in the middle for access. A suitable distance is to be left at the ends for movement of stock and machinery. Each hedge is then separated by a width which is a multiple of the landholder’s machinery widths. For example 2 passes of the spray boom is equal to 5 passes of the seeding bar. Along each mound, Saligna seedlings are to be a minimum of 20m apart with *Atriplex Nummularia* (Oldman Saltbush) and *Atriplex Amnicola* (Rivermoor saltbush) seedlings 2-3m apart in between. The space between the hedges is to be sown to a mixture of pasture species including Tall Wheat Grass, Puccinellia, and Balansa clover. Species such as *Panicum Coloratum* and *Setaria Anceps* could be included to strengthen the water use and cover. The basics of the mix are to be perennial and annual with some legume species. The 12ha area will need approximately 10 hedges each 250m long.

C Oil mallee site with seedlings at 2m intervals along rows within hedge. A double hedge (4 rows) is to be planted along the break of slope at the main soil change from Vanzetti Rd east to the property access track. Hedges are to run north/south from this line at 120m spacing. A distance of approximately 6 500m of hedge is to be planted.
D  The constructed waterway is to have 6 rows of *Eucalyptus Loxophleba* each side planted at 10m spacing with seedlings staggered along rows 5m apart. Between the York gums is to be filled with *Melaleuca* species, *Uncinata, Lateriflora* and *Conothamnoides; Acacia* species *Acuminata, Andrewsii* and *Hemiteles* along with *Hakea Scoparia* and *Grevillea Paniculata*. The waterway length is 2300m for this section on John Stacey’s and 100m on Frank Crago’s.

E  Planting beneath the grade bank of 6 rows for 700m with same species and specifications as the waterway.

F  Planting of approximately 1ha at 1000 stems /ha above the level bank with the same species that is in the remnant vegetation *Eucalyptus Loxophleba* upslope of the proposed bank. The area is a major recharge zone from run-off from Vanzetti road and the small granite outcrops in amongst the woodland.

G  Planting above the grade bank with the same species as in the adjoining remnant vegetation. The dominant species on the shallow laterite areas will be the *Eucalyptus Stowardii* grading to *Eucalyptus Loxophleba* on the eastern end. The area is in two sections north (3ha) and south of the dam (7ha) to be planted at 1000 stems/ha.

H  Supportive planting along the creekline of *Eucalyptus Loxophleba* the same species as in the existing remnant. Planting will be used to strengthen and fill gaps in the natural system along with addressing the waterlogging in several areas. Planting of 4 rows each side for 1800m from John Stacey’s through Frank Crago’s to O’Callaghan’s boundary.
I Two hedges of oil mallee’s to be planted beneath the grade bank for a distance of 1400m.

J Water logged area each side of the main creek with a total area of 2ha at 100 stems/ha. Same species and specifications as for the main waterway or planted as blocks of oil mallee.

K Remnant planting of 6ha with the same species as in the remnant vegetation on the east side. Planted at a density of 1000 stems/ha. Planting lines will need to be surveyed as the area is a high run-off zone.

L Contour planting of 6 rows of *Eucalyptus Loxophleba* beneath the proposed grade bank leads into 4ha of remnant planting at 1000 stems/ha across the discharge site. Planting will join the area of remnant vegetation with the two creekline systems.

M Oil Mallee planting beneath grade banks of two hedges. Total length on O'Callaghan’s of planting 2800m.

N An area of 1ha is to be planted for seepage control beside the creekline at a density of 1000stems/ha. The relevant species are to be found on site or the area could be planted to oil mallee’s.
8.0 PRESENTATION AND MEETING WITH LANDHOLDERS

Meetings were held with each landholder, in the company of the Recovery Catchment Officer (RCO), where the conceptual plan was introduced and reviewed. Discussion included historical events which had lead to land management problems/hazards and how the conceptual plan addressed these problems and concerns. Also discussed was the management of the property, including tillage, crop rotations, stocking, rates along with land holder ideas for improvements. Alterations were made to the plan during this process; taking it from a conceptual idea to a more detailed draft plan with landholder involvement and ownership.

Changes on O’Callaghan’s south paddock meant the plan went from 5 potential banks to 3 banks and a line of vegetation to replace an existing level bank because there was no safe outlet or disposal point.

Management problems in the northern paddock means the second bank down the slope will not be constructed as the tight curves and corners would make the area very difficult to maneuver machinery around for cropping. Planting of an area in the South-East corner on Stacey’s property reduced the emphasis for earthworks as a tool for water logging on Crago’s property. The additions made by Stacey’s to the revegetation on their property are notable with considerable ramifications for groundwater control in that sub-catchment.

With 10ha of revegetation to be planted across the slope at:

\[1000 \text{stems/ha} = 10,000 \text{stems.}\]

Each stem uses 10litres/day which equates to 100m$^3$/day or 36 500m$^3$/year. (This quantity is similar in size to the existing dam on Stacey’s property.) The water use by this vegetation equates to 1.2% of rainfall input into the catchment. The 10litres/day is a figure based on CSIRO work showing eucalyptus species using 30litres/day.

A small localized intense rainfall event occurred during this timeframe necessitating supplementary additions for surface water control. This event was also valuable in testing the theoretical position of the proposed earthworks.
Some recalculations were required to ensure that technical standards were not compromised as proposed earthwork positions were altered.
Further refinements were added with phone calls from the landholders over the ensuing time frame.
Planning is a continuing process and is to be viewed as an evolutionary development.

9.0 DETAILED WORKS PLAN AND BUDGET

A lengthy meeting was held with the RCO on site in preparing the foundation of a National Landcare Program (NLP) submission for funds to facilitate the implementation of the plan. During the month of September numerous phone calls and e-mails were used to network until the funding proposal was finalized for submission.

A base price of $1 000/kilometer was used for the earthworks including grade and level banks as well as the waterway levees.

A discussion was held with the deputy commissioner for soil conservation with regard to ratifying legal obligations and position to the safe disposal of water within an area under a Conservation covenant.

The advice received was that as long as the disposal area was part of the natural stream system and the capacity of the stream would not be exceeded, then the stream could be used as part of the surface water plan.
10.0 DISCUSSION

The Natural resources of the catchment are typical of the surrounding region and Yilgarn block. The land management problems found in the area are characteristic of the structures and processes created in this type of landscape.

The tools and systems to address these issues are not new with a history well recorded. In a catchment plan the aim is to address all the subjects in the water balance by working at both ends. Works have to first remove the problem safely as well as repair or restore the resulting damage. To achieve this and not just cover with a band aid more than one tool from the toolbox needs to be engaged and employed. Many of the tools will realize multi benefits although they are implemented for a sole workload. Trees planted for seepage control will provide some wind protection, while a drain to remove surface water can sometimes pick up a shallow seepage flow. These are to be viewed as a bonus and not to be relied on.

As part of a resource management plan, the best tool is a change in paradigms. Excess surface water from episodic events can be stored in large key dams for distribution over an annual timeframe. Groundwater systems can be used to provide water supplies or grow perennial pastures.

The basic of the plan is to revegetate and stabilize the main waterways as a prerequisite. Control surface water flows across the catchment where required. Revegetate areas in such a way that management is not going to be severely interrupted. Protect any fragile or priority areas and improve the production of the catchment.

Existing vegetated waterways are to be fenced outside the peak flow line with any gaps filled with the relevant species. This area is the upper and mid slopes. Ensure capacity to handle excess flow – cross section. Concave shape on slopes means usually ok.

New waterways will need to be constructed the last 2000m from the main break of slope to the b-m road and from O’Callaghan’s boundary down to the main channel. Both of these systems will require some cut and fill before construction. The existing eroded channels do not have the capacity to contain a 1:20 ARI event even with the reduction in peak flow from the proposed grade bank system.
APPENDIX

1. Appendix 1 Grade Bank Specification Sheet
2. Appendix 2 Grade Bank Crossing Specification Sheet
3. Appendix 3 Level Sill Specification Sheet
4. Appendix 4 Waterways – Top of Mainstream Specification Sheet
5. Appendix 5 Waterway – Crago Creek Specification Sheet
6. Appendix 6 Waterway – Main Stream Specification Sheet
7. Appendix 7 Waterway – Muller Specification Sheet
8. Appendix 8 Waterway – O'Callaghan Specification Sheet
Site assessments

Martyn Keen, Senior Land Conservation Officer, Department of Agriculture, Bunbury

1. Definition

The processes of collecting and recording site data as part of the preliminary tasks leading to a landscape or project design.

2. Scope

This standard applies to landscape and project designs for catchments of any size. Designs include: the installation of conservation earthworks; revegetation; land use planning; or implementation of erosion and sediment control practices. The design may also include any combination of the above.

Base information will include location, covenants, ownership and Occupational Safety and Health issues. Data collected on site may include climatic, topography, soil, vegetation, run-off, hydrology, environmental health and resource information. All data are collated and documented through plans, maps, reports, schedules and field notes.

Miscellaneous Publication 15/2005
ISSN 1447-4980
March 2005
3. Purpose

Collected site assessment data are used in the planning stage of landscape and project designs. In the case of conservation earthworks, rainfall, topography and soils will assist in the determination of earthwork dimensions. Similarly, topography, soils and climate will aid the selection of appropriate vegetation species for the rehabilitation of a degraded site. The accurate collection and recording of site data assure the likelihood of success of an implemented design.

4. Conditions where this standard can be applied

On any agricultural land, where a landscape or project design is to be prepared. Where a project’s objectives and outcomes are known. Anywhere a site assessment’s purpose can then be identified.

5. Planning considerations

The Occupational Safety and Health Act sets objectives to promote and improve occupational safety and health standards. The Act sets out broad duties and is supported by more detailed requirements in the Occupational Safety and Health Regulations. The legislation is further supported by guidance material such as approved codes of practice through WorkSafe Western Australia. ‘Code of Practice – Excavations’ applies to all workplaces where excavation occurs, and particularly when “a person is required to work in an excavated area or other opening in the ground that is at least 1.5 metres deep.” This is particularly relevant to the installation of soil test pits.

6. Criteria for site assessment

Site assessment purpose – is confirmed. Site assessment criteria are selected in accordance with project informational requirements.

Property details – such as ownership and covenants are confirmed. Approval to access property is obtained from the owner or manager.

Base information – is collected and collated. Information sources include climatic, geological, soil landscape, land capability and topographical surveys. Similarly, vegetation (including ‘rare and endangered’ flora), wildlife (including rare fauna), cultural and historical databases are sources.
Base map – is obtained or prepared. Map has an aerial photo, photo mosaic or satellite raster image as a background. Geological, soil, topographical and vegetation information are overlaid.

Occupational Safety and Health – issues, associated with visiting the site, are identified for potential risk and controls are implemented accordingly.

Site characteristics – are accurately identified, measured and recorded.

Site assessment 3

Services – present within and/or adjacent to the design area are identified and recorded. Type, location, direction and responsible authority are to be recorded.

Infrastructure – is located and recorded. The locations of access roads, houses, sheds, fences, dams, conservation earthworks etc. are included.

Soil types – are sampled, tested and classified according to project’s design. Classification systems may include: Unified Soil Classification System for soil engineering properties; or the Australian Soil Classification, which has become the standard for classifying agricultural soils.

Slope – measured, with a ‘clinometer’ or a level and staff, and recorded.

Remnant vegetation – species and/or plant communities are confirmed. Locations of remnants are recorded on base map.

Remnant health is assessed and recorded. Species diversity and regional representation are established and recorded.

The value of the remnants as wildlife habitat, corridors or ‘stepping stones’ is established and recorded.

Current land use – is confirmed with the land manager/s.

Future land use – is discussed and confirmed with the land manager/s.

Stream flows – are confirmed or mapped and recorded.

Wetland – location and health are recorded, if present.

Catchment area – is determined, for the prediction of run-off for conservation earthwork planning, and recorded.

Degradation – is identified; severity and extent determined; and recorded. Water erosion, wind erosion, salinity, eutrophication, siltation and flooding are examples of degradation. By degrees of severity, water erosion can be rill, sheet and gully. There are also varying degrees of severity for the other forms of degradation.

Areas of cultural and historical significance – described and recorded.

Note: The list above is not complete for site assessment criteria, nor are all of the criteria
relevant to all assessments. Criteria can be added and/or subtracted to satisfy the purpose of the assessment.

7. Legal aspects

Outline the purpose of the site assessment to the land owner and/or manager. Obtain approval from land owner and/or manager, to access the site. Confirm likelihood of restricted areas or special precautions required within the site.

4 Site assessment

8. Plans and reports

Plans and reports shall conform to this standard and shall describe what is required to ensure the practice achieves its intended purpose. Field notes are to be retained. A copy of the final report and maps are to be presented to the client with a copy retained ‘on file’.

9. Reference material

Department of Agriculture (1989-2003). *Various publications in Land Resources Series*. Department of Agriculture and Agriculture Western Australia, Perth, WA.

10. Support materials

11. Skills

National units of competency exist for the conservation earthworks industry and are detailed as part of the Conservation and Land Management Training Package (RTD 02). Those pertaining to this standard are:

RTC3218A – Undertake a site assessment.

Personnel operating to this unit are competent in preparing for, undertaking and documenting site assessments.

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Grassed Waterways
Number 001 (updated 21/10/02)

1. Definition
A natural or constructed channel that is shaped to required dimensions and established with suitable vegetation to allow stable movement of temporary run-off.

2. Scope
This standard applies to broad, shallow, natural or constructed channels that are to be established with vegetation cover and used for water disposal. Often they are called grassed waterways.
Waterways with earth levees are included.
Construction may be carried out with a grader or bulldozer.
Miscellaneous publication 31/2002
ISSN 1447-4980
November 2002
3. Purpose

To convey run-off from grade banks, diversions, dam overflows or other water concentrations, without causing erosion or flooding.

4. Conditions Where Grassed Waterways can be Applied

All sites that can be modified by increasing the water capacity and/or adding vegetation cover. Using this practice alone or combined with other conservation practices. Waterways are generally constructed where overland flows lead to first order streams. First and second order streams may be reconstructed to increase capacity and stability. Additionally, levees can be constructed on streams of first and second order where catchment areas are no greater than 2,500 hectares. People with appropriate stream engineering skills are to undertake treatment of streams that have a greater order or a larger catchment area.

5. Planning Considerations

Grassed waterways planned to discharge into first order streams. Discharging into streams of greater order must not interfere with stream flood peak flows or damage the stream banks. Identify any services likely to be affected by the construction of planned works. Discuss the plans with the service provider to confirm ways of avoiding any disturbance or damage. The most critical time to install a grassed waterway is when vegetation cover is being established. Species selected for vegetation cover should be appropriate and able to endure the range of operating conditions that the waterway may be subjected to. Waterways are to be fenced on both sides of the channel or outside of levees. Provide livestock and vehicular crossings as necessary to prevent damage to the waterway and its vegetation. If trees and shrubs are to be incorporated, they should not be planted in the waterway channel. Bends should be avoided. Where this is not practical, they must not be acute as this places undue hydraulic stress on retaining banks and waterway surface. Sharp bends may make fencing difficult.
6. Design Criteria

Site characteristics - are accurately measured.

Soil types - at the construction site are determined and tested to ensure the stability of the proposed structure.

Channel slope – can be on any slope or combination of slopes up to 10%.

Catchment run-off peak flow – to be determined by a recognised method, such as, the Flood Index Method or the Rational Method.

Channel cross sectional shape - is trapezoidal or parabolic in shape. Side slope ratio of waterway bank to be no steeper than 2 : 1.

![Typical Cross-section](image)

Trapezoidal shaped cross section  Parabolic shaped cross section

Roughness coefficient – selected from the list in Attachment 1. The choice of roughness coefficient must be appropriate for the section of channel being planned. Channel depth and width must be calculated for each change in channel condition.

Velocity – design not to exceed those obtained using Attachment 2.

Planning methodology – use Manning’s formula and roughness coefficients to calculate waterway flow depth and width for peak flow. Correct method of calculating hydraulic radius must be used with the appropriate cross sectional shape. In the case of a shallow trapezoidal cross section, hydraulic radius in Manning’s formula may be substituted by average depth.

Capacity – sufficient to contain the peak flow run-off from a 20 year ARI storm. Once design ARI is exceeded, waterway will overflow. Greater capacity can only be built into the waterway by replanning for a greater ARI. This may be necessary where overflows, from a planned waterway, will cause other than superficial damage.

Vegetation cover – on waterway channels and banks to be annual or perennial grass pasture species, or a mixture of both. Dependent on soil type, clover or medic additions to the grass mix are encouraged. Seed at double pasture and fertiliser rates.

Outlets - shall be stable and of sufficient capacity to prevent ponding or erosion. The outlet can be another vegetated channel or natural waterway.
Width – not to exceed 30 metres without allowance for multiple or divided channels.

Channel cross fall between banks or levees – ideally to be zero. For short distances, up to 40 metres, it is acceptable to have a maximum of 0.10 metres, however, this must be within design limits.

Levees – when required, to have a maintained 0.20 metre freeboard above design peak flow. Side slope of levee adjacent to the flow to be no steeper than 2 : 1. Side slope of levee outside of waterway to be no steeper than 6 : 1.

Bank inlets – are incorporated in each levee sufficient to allow overland flows, outside the levee, to enter the waterway. Generally, inlets are not required where a grade bank system is installed in conjunction with the waterway. However, on steeply sloping land or where paddock run-off is excessive, additional inlets are recommended. If there is no grade bank system, inlets are required along the levee at spacings no greater than that of grade banks for the equivalent slope. Upslope opening of inlet has a freeboard of 0.2 metres above design peak flow.

7. Legal Aspects - Relating to Downstream Properties

Waterways must not divert flows from one catchment to another catchment that would not naturally receive that flow.

Flow velocity must not be increased by the inappropriate use of additional freeboard to provide extra flow capacity.

Due care must be taken during construction and maintenance to stop the loss of disturbed material from the site.

8. Environmental Aspects

Flows of poor quality water can degrade downstream channels, watercourses and wetlands. Eroded material from poorly planned, constructed or maintained waterways, can reduce flow capacities when deposited in downstream channels.

9. Construction

Alignment and width of the waterway are to be pegged, as detailed on the plan, using appropriate survey techniques. Cross sections are to be surveyed and cut and fill pegged as required.

Topsoil to be stockpiled when filling or shaping and re-spread over disturbed areas.

Allow machinery weight to compact fill or shaping.
Levees to be constructed from outside the channel, using appropriate techniques, resulting in the levees being compacted to the correct height including freeboard.

Bank inlet positions to be surveyed for correct spacings and positions. Set the ends of the inlet to eliminate back flow out of waterway.

Check level of the waterway channel surface to determine the accuracy of construction.

Use levelling to confirm the levee freeboard.

10. Operation and Maintenance

Vegetation cover to be maintained at a height between 0.1 and 0.2 metres.

Mow or periodically graze vegetation to maintain flow capacity.

Damaged channel floor and levees are to be reconstructed to original specifications.

Do not use waterway as an access track or firebreak.

Control noxious weeds.

11. Plans and Specifications

Plans and specifications shall conform to this standard and shall describe what is required to ensure the practice achieves its intended purpose. Copies of the plan are to be presented to the land holder and construction contractor.

12. Reference Material

Bligh, KJ 1989, Soil conservation earthworks design manual, Department of Agriculture, Western Australia.


Pilgrim, DH 1987, Australian rainfall and runoff, The Institution of Engineers Australia, Barton ACT.


13. Support and Extension Material


Keen, MG 1998, *Common conservation works used in Western Australia*, Agriculture Western Australia, Geraldton, Western Australia.

14. Planning, Pegging and Construction Skills

National competencies exist for the conservation earthworks industry and are detailed as part of the *Conservation and Land Management Training Package*. Those pertaining to this standard are:

- RTD3205A – *Construct conservation earthworks*.
  Personnel demonstrating competency gained in the variable ‘waterways’ have the skills necessary to undertake waterway construction.

- RTD4205A – *Set out conservation earthworks*.
  Personnel demonstrating competency gained in the variable ‘waterways’ have the skills necessary to undertake waterway pegging.

- RTD4207A – *Supervise on-site implementation of conservation works*.
  Personnel demonstrating competency gained in the variable ‘waterways’ have the skills necessary to undertake supervision of waterway construction.

- RTD5204A – *Plan conservation earthworks*.
  Personnel demonstrating competency gained in the variable ‘waterways’ have the skills necessary to undertake waterway planning.
### Attachment 1: Suggested values for Manning's Coefficient of Roughness

<table>
<thead>
<tr>
<th>Waterway type</th>
<th>Typical min</th>
<th>Manning's 'n' Values design</th>
<th>Typical max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bare soil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine sand colloidal</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandy loam non-colloidal</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loam</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine gravel &gt;2 mm</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse gravel &lt;60 mm</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low plasticity (stiff) clay</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soils with stony surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- rounded</td>
<td>0.035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- angular</td>
<td>0.040</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grassed, constructed waterway, in sand to fine gravel soils</strong></td>
<td>0.025</td>
<td>0.030</td>
<td>0.030</td>
</tr>
<tr>
<td>Average depth of flow is 2 or more times grass height</td>
<td>0.030</td>
<td>0.040</td>
<td></td>
</tr>
<tr>
<td>Average depth of flow is 1 to 2 times grass height</td>
<td>0.045</td>
<td>0.070</td>
<td></td>
</tr>
<tr>
<td>Average depth of flow is similar to grass height</td>
<td>0.070</td>
<td>0.120</td>
<td></td>
</tr>
<tr>
<td><strong>Grassed, constructed waterway, with pasture species,</strong></td>
<td>0.025</td>
<td>0.030</td>
<td>0.035</td>
</tr>
<tr>
<td>Average depth of flow greater than height of grass</td>
<td>0.030</td>
<td>0.035</td>
<td>0.050</td>
</tr>
<tr>
<td>Low grass (&lt;250 mm)</td>
<td>0.025</td>
<td>0.030</td>
<td></td>
</tr>
<tr>
<td>Tall grass (250 – 500 mm)</td>
<td>0.030</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td><strong>Grassed, constructed waterway, in stiff (low plasticity) clay and coarse gravel soils</strong></td>
<td>0.030</td>
<td>0.035</td>
<td>0.035</td>
</tr>
<tr>
<td>Average depth of flow is 2 or more times grass height</td>
<td>0.035</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>Average depth of flow is 1 to 2 times grass height</td>
<td>0.050</td>
<td>0.075</td>
<td></td>
</tr>
<tr>
<td>Average depth of flow is similar to grass height</td>
<td>0.075</td>
<td>0.125</td>
<td></td>
</tr>
<tr>
<td><strong>Minor natural streams &lt;30 m wide</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight bank, full stage, no rifts (shallow stony sections) or deep pools</td>
<td>0.025</td>
<td>0.030</td>
<td>0.033</td>
</tr>
<tr>
<td>Straight bank, full stage, no deep pools, some weeds and stones</td>
<td>0.030</td>
<td>0.035</td>
<td>0.040</td>
</tr>
<tr>
<td>Winding bank, some pools and shoals</td>
<td>0.033</td>
<td>0.040</td>
<td>0.045</td>
</tr>
<tr>
<td>Winding bank, some pools, shoals, weeds and stones</td>
<td>0.035</td>
<td>0.045</td>
<td>0.050</td>
</tr>
<tr>
<td>Light shrubs and trees – natural vegetation</td>
<td>0.040</td>
<td>0.060</td>
<td>0.080</td>
</tr>
<tr>
<td>Medium to dense shrubs and trees – natural vegetation</td>
<td>0.070</td>
<td>0.100</td>
<td>0.160</td>
</tr>
<tr>
<td>Scattered shrubs, grasses and weeds – degraded natural vegetation</td>
<td>0.035</td>
<td>0.050</td>
<td>0.070</td>
</tr>
<tr>
<td><strong>Major natural streams &gt;30 m wide</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular cross section with no boulders or shrubs</td>
<td>0.025</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>Irregular and rough cross section</td>
<td>0.035</td>
<td>0.100</td>
<td></td>
</tr>
</tbody>
</table>
Attachment 2: Suggested Maximum Permissible Velocities of Flow

<table>
<thead>
<tr>
<th>Material</th>
<th>Bare to light grass cover</th>
<th>Medium grass cover</th>
<th>Very good grass cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.4</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>0.6</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Clay loam</td>
<td>0.75</td>
<td>1.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Medium to heavy clay</td>
<td>1.2</td>
<td>1.4</td>
<td>2.0</td>
</tr>
<tr>
<td>Clay loam/coarse gravel mix</td>
<td>1.2</td>
<td>1.4</td>
<td>NA</td>
</tr>
</tbody>
</table>

Grass cover defined:

i) bare to light grass cover - bare soil or poor annual grasses. Use for temporary waterways.

ii) medium grass cover – topdressed annual grass and clover/medic mix with height maintained. Use under average wheatbelt conditions.

iii) very good grass cover – topdressed annual and perennial grass mix in higher rainfall areas. Use for high rainfall areas of the South West of Western Australia.

Notes

a) Only use velocities exceeding 1.5 ms⁻¹ where grass cover is good and can be maintained. Reduce velocities for flows over easily eroded soils by 20% (i.e. multiply suggested velocity by 0.80), whether bare or vegetated. For flows on slopes greater than 5% reduce velocities by 15% (i.e. multiply suggested velocity by 0.85).

b) Coarse gravel < 60 mm in diameter.

c) Unlikely to form very good grass cover.

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This document has been written for Western Australian conditions. Its availability does not imply suitability to other areas, and any interpretation is the responsibility of the user.

Details in this publication are for use by competent conservation industry practitioners. Users should obtain independent advice and conduct their own investigations and assessment relevant to particular circumstances.
Grade Banks
Number 003 (updated 21/10/02)

1. Definition
An earth embankment with uphill channel surveyed and constructed on a grade to control surface water flows.

2. Scope
This standard applies to grade banks constructed by both bulldozers and graders. Includes single banks and multiple banks planned and constructed as a system.

Miscellaneous publication 27/2002
ISSN 1447-4980
November 2002
3. Purpose
Can be used to control run-off causing erosion, flooding and waterlogging. Grade banks:
❖ reduce slope length;
❖ reduce rills;
❖ prevent development of paddock gullies;
❖ reduce sediment content in run-off;
❖ intercept and conduct run-off at reduced velocity to stable outlets;
❖ improve farmability;
❖ increase crop and pasture yields;
❖ control flows from sloping land and reduce waterlogging of flatter land below; and
❖ reduce flood peak flows.

4. Conditions Where Grade Banks can be Applied
Constructed in the middle and upper parts of the landscape; on any sloping agricultural land.
On any land sloping greater than 2%; where:
❖ erosion is a problem;
❖ flood peak flows need to be reduced;
❖ topography allows the practice to be implemented; and
❖ a stable outlet can be provided.

5. Planning Considerations
Identify any services likely to be affected by the construction of planned works. Discuss the plans with the service provider to confirm ways of avoiding any disturbance or damage.
Grade banks are usually planned and constructed on land sloping between 2% and 10%.
Common bank channel grades usually preclude construction on land sloping less than 2%.
Using a flat grade in these areas may allow the construction of banks on land sloping as little as 1%.
Grade banks are not usually constructed on slopes greater than 10% because of the depth of cut of the uphill side slopes of the channel. Stable construction of the bank is also difficult to achieve on these slopes.
If trees and shrubs are planned to complement these works, they are to be planted below the bank and clear of any areas that machinery will need to access when reconstructing the bank.
6. Design Criteria

**Design interval** – is 10 year Average Recurrence Interval or greater depending on the purpose of the grade bank. For instance, grade banks planned to reduce flood peaks may require a 20 y ARI or greater design interval.

**Determine slope** – of the land where the grade banks are to be installed. Use clinometer or level and staff. Measure slope at each change.

**Channel cross section** – to be used is trapezoidal with a 3 metre to 3.5 metre wide flatbottomed channel.

**Side slopes** – for land slopes up to 5%, channel’s uphill side slope and bank’s uphill side slope are approximately the same length as the channel width. Bank’s downhill side slope is also of similar length, but shortens as slope increases. For land slopes over 5% all three side slopes are shorter, at approximately 2.5 metres. Side slope shortening at steeper slopes helps maintain bank height.

**Channel depth** – for land slopes of about 2%, 0.4 metres from water level (when bank is full) to floor of channel. For land slopes between 2 and 5%, depth should be 0.5 metres. A depth of 0.6 metres is recommended for land slopes over 5%. This is to provide correct volume of excavated material for bank construction including freeboard.

**Freeboard on bank height** – 0.2 metres above water level, when bank is full.

![Cross-section of Grade Bank Showing Freeboard](image)

**Spacing** – determine the maximum spacing for grade banks from the chart in Attachment 1. Start by selecting the appropriate degree of slope from across the bottom of the chart. Vertically trace the line above the number until it intercepts the diagonal axis line. At the interception point follow the horizontal line to the left-hand side; the number is the maximum bank spacing. The recommended spacing must be adjusted to allow for land that has existing erosion; is easily eroded or produces excessive run-off.

**Channel grades** – depending on the topography, use grades between 0.2% and 0.5%. A standard grade is 0.4%, whilst 0.5% is steep and is used on steep slopes. Use a grade of 0.2% for land with slopes flatter than 2%.

**Bank length** – shall not exceed 1,000 metres.

**Bank capacity** – can be confirmed by predicting the run-off which must not overfill the bank cross section. Predicted maximum channel velocity must not exceed maximum permissible for the particular channel.
Outlets – for all banks must be safe and able to handle all discharge. Waterways used as outlets must be vegetated and of sufficient capacity to handle the bank’s discharge. Dams can also be used as a discharge for grade banks as long as they have sufficient storage capacity and appropriate overflows.

Level sills – are constructed at the outlet end of the bank, where discharge is required to disperse across land before entering a stream. Average sill length is 10 metres. Longer sills, of up to 15 metres, are required for steeper land slopes or where outlet flow velocities are to be lessened.

7. Legal Aspects - Relating to Downstream Properties
Take reasonable steps to prevent harm being caused to another person and/or another person’s property.
Consider what effect planned earthworks will have on other people and seek consent from any person that may be affected.
Grade banks must not divert flows from one catchment to another catchment that would not naturally receive that flow.
Due care must be taken during construction and maintenance to stop the loss of disturbed material from the site.

8. Environmental Aspects
Flows of poor quality water can degrade downstream channels, watercourses and wetlands. Eroded material from poorly planned, constructed or maintained grade bank systems, can reduce flow capacities when deposited in downstream channels.

9. Construction
Use optical or laser level to survey and align the bank on a correct grade. Level to an accuracy of +/- 0.050 metres or better and place alignment marks (pins or pegs).
Survey interval, to establish alignment marks, should be no greater than 25 metres. The survey hand can pace horizontal distances as long as the intervals of a person’s pace are predetermined for each survey and checked at least twice daily.
Extra alignment marks are required on tight bends, particularly when crossing ridges and small depressions. These aid machinery operations.
When no level sill is constructed, extra grade is included at the bank outlet to allow the grade bank channel to return to ground level. This reduces channel ponding at outlet. As a guide, grade is doubled for 60 metres at the outlet end of the grade bank.
Construction machinery should have suitable capacity, horsepower and appropriate attachments. Both bulldozers and graders are suitable. Bulldozers of generally smaller size (equivalent to Caterpillar D5 or D6) with multiple shank rippers are more efficient. Graders of medium size (approximately equivalent to Caterpillar 120G or 12G to 140 or 140G) with rear mounted multiple shank rippers are most efficient.

Construction technique when using bulldozer is:

1. mark alignment with ripper Shank;
2. if any of the channel is to be ripped, rip whole alignment where channel is to be excavated;
3. form uphill side slope with one push and transport spoil beyond survey line,
4. run uphill side slope off;
5. rip channel again if necessary;
6. two or three cross sectional pushes to create flat-bottomed channel and bank. Rolling bulldozer over excavated earth to compact bank; and
7. ‘run off’ to clear excavation and form channel and bank side slopes.

Construction technique when using grader is:

1. mark alignment with ripper Shank;
2. remove topsoil;
3. if any of the channel is to be ripped, rip whole alignment where channel is to be excavated;
4. excavate channel and channel's uphill side slope, battering each windrow into and up bank to form bank's uphill side slope (grader compacts bank with battering of each windrow); and
5. form downhill side slope of bank.

Position of Survey Mark and Rip Mark

10. Operation and Maintenance

Grade bank channel, bank and/or side slopes damaged by stock or run-offs are to be repaired to original construction standards as soon as practicable.

Breached banks are to be repaired as soon as run-off event has passed. Breaches are to be filled with compacted material of the same quality or better than that used in the original bank construction.
Correctly constructed grade banks, with adequate channel capacity, correct side slopes and adequate bank compacted freeboard, may only need reconstructive maintenance at greater than 5 yearly intervals. However, all grade banks should be reconstructed when capacities are less than the original construction.

11. Plans and Specifications

Plans and specifications shall conform to this standard and describe what is required to ensure the practice achieves its intended purpose. Copies of the plan are to be presented to land holder and construction contractor.

12. Reference Material

Bligh, KJ 1989, Soil conservation earthworks design manual, Department of Agriculture, Western Australia.


Pilgrim, DH 1987, Australian rainfall and runoff, The Institution of Engineers Australia, Barton ACT.


13. Support and Extension Material
Keen, MG 1998, *Common conservation works used in Western Australia*, Agriculture Western Australia, Geraldton, Western Australia.

14. Planning, Pegging and Construction Skills
National competencies exist for the conservation earthworks industry and are detailed as part of the *Conservation and Land Management Training Package*. Those pertaining to this standard are:

- **RTD3205A – Construct conservation earthworks.**
  Personnel demonstrating competency gained in the variable ‘grade banks’ have the skills necessary to undertake grade bank construction.

- **RTD4205A – Set out conservation earthworks.**
  Personnel demonstrating competency gained in the variable ‘grade banks’ have the skills necessary to undertake grade bank pegging.

- **RTD4207A – Supervise on-site implementation of conservation works.**
  Personnel demonstrating competency gained in the variable ‘grade banks’ have the skills necessary to undertake supervision of grade bank construction.

- **RTD5204A – Plan conservation earthworks.**
  Personnel demonstrating competency gained in the variable ‘grade banks’ have the skills necessary to undertake grade bank planning.

8 Grade Banks
Attachment 1: Recommended Maximum Bank Spacings

Note.
The recommended maximum bank spacings must be adjusted to allow for land that:

i has existing erosion - reduce spacings by 10%,

ii is easily eroded, reduce spacings by 10%, or,

iii produces excessive run-off, reduce spacing by 10%.

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This document has been written for Western Australian conditions. Its availability does not imply suitability to other areas, and any interpretation is the responsibility of the user.

Details in this publication are for use by competent conservation industry practitioners. Users should obtain independent advice and conduct their own investigations and assessment relevant to particular circumstances.
SPECIFICATIONS FOR GRADE BANK CROSSING

Grade bank cross section - crossover

Original Ground Level

Channel _3.8_metres wide

Water Level

Freeboard 0.2 metres

Side slope 1: 10

Side slope 1: 10

Original Ground Level

Channel Depth 0.3 metres

Construction Specifications
Alignment of bank is surveyed on correct grade using optical or laser level. Level to an accuracy of +/-0.050m or better and place alignment marks (pins or pegs). Survey interval, to establish alignment marks, should be no greater than 25mts. Extra alignment marks are required on tight bends, particularly when crossing ridges and small depressions. When no level sill is constructed, extra grade is included at the bank outlet to allow the grade bank channel to return to ground level. Construction machinery should have suitable capacity, horsepower and appropriate attachments. Both bulldozers and graders are suitable.

Maintenance
Grade bank channel, bank and or side slopes damaged by stock or run-offs are to be repaired to original construction standards as soon as practicable. Breached banks are to be repaired as soon as run-off event has passed. Breaches are to be filled with compacted material of the same quality or better than that used in the original bank construction. Correctly constructed banks with adequate channel capacity, correct side slopes and adequate bank compacted freeboard, may only need reconstructive maintenance at greater than 5 yearly intervals. However, all grade banks should be reconstructed when capacities are less than the original construction.

<table>
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<tr>
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Noel Dodd Systems of Landcare 2005
SPECIFICATIONS FOR GRADE BANK

Grade bank cross section

- Side slope 1:4
- Side slope 1:3
- Original Ground Level
- Channel 3.8 metres wide
- Water Level
- Channel Depth 0.3 metres
- Freeboard 0.2 metres

Construction Specifications
Alignment of bank is surveyed on correct grade using optical or laser level. Level to an accuracy of +/-0.050m or better and place alignment marks (pins or pegs). Survey interval, to establish alignment marks, should be no greater than 25mts. Extra alignment marks are required on tight bends, particularly when crossing ridges and small depressions. When no level sill is constructed, extra grade is included at the bank outlet to allow the grade bank channel to return to ground level. Construction machinery should have suitable capacity, horsepower and appropriate attachments. Both bulldozers and graders are suitable.

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SPECIFICATIONS FOR LEVEL SILL

CONSTRUCTION
Sill is to be resurveyed once grade bank construction is completed. Sill is to be constructed at 0% grade. Excavated soil is to be leveled out upslope.

Specifications:
- Sill at 0% Grade
- Channel grade at less than 0.5%
- Compacted grade Bank
- Stable Disposal Area
- Minimum length -20m

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SPECIFICATIONS FOR WATER WAY

Waterway Cross Section

- Levee Height: 0.35 metres
- Depth of Flow: 0.15
- Freeboard: 0.2 metres
- Water level
- Waterway Width: 15 metres
- Side Slope: 6:1
- Side Slope: 3:1

CONSTRUCTION SPECIFICATIONS

- Alignment and width of the waterway are to be pegged, as detailed on the plan, using appropriate survey techniques. Cross sections are to be surveyed and cut and fill pegged as required.
- Topsoil to be stockpiled when filling or shaping and re-spread over disturbed areas.
- Allow machinery weight to compact fill or shaping.
- Levees to be constructed from outside the channel, using appropriate techniques, resulting in the levees being compacted to the correct height including freeboard.
- Bank inlet positions to be surveyed for correct spacings and positions. Set the ends of the inlet to eliminate back flow out of the waterway.
- Check level of the waterway channel surface to determine the accuracy of construction. Use levelling to confirm the levee freeboard.
- Vegetation cover on waterway channels and banks to be a mixture of annual and perennial grasses, clover and medics, dependant on soil type. Seed at double pasture and fertilizer rates.

MAINTENANCE

- Vegetation cover to be maintained at a height between 0.1 and 0.2 metres.
- Mow or periodically graze vegetation to maintain flow capacity.
- Damaged channel floor and levees are to be reconstructed to original specifications.
- Do not use waterway as an access track or firebreak.
- Control noxious weeds.

### Specification sheet-Level and Leved waterways

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Crago Creek
**SPECIFICATIONS FOR WATER WAY**

**Waterway Cross Section**

- Levee Height: 0.4 metres
- Depth of Flow: 0.2 metres
- Freeboard: 0.2 metres

**CONSTRUCTION SPECIFICATIONS**

- Alignment and width of the waterway are to be pegged, as detailed on the plan, using appropriate survey techniques. Cross sections are to be surveyed and cut and fill pegged as required.
- Topsoil to be stockpiled when filling or shaping and re-spread over disturbed areas.
- Allow machinery weight to compact fill or shaping.
- Levees to be constructed from outside the channel, using appropriate techniques, resulting in the levees being compacted to the correct height including freeboard.
- Bank inlet positions to be surveyed for correct spacings and positions. Set the ends of the inlet to eliminate back flow out of the waterway.
- Check level of the waterway channel surface to determine the accuracy of construction. Use levelling to confirm the levee freeboard.
- Vegetation cover on waterway channels and banks to be a mixture of annual and perennial grasses, clover and medics, dependant on soil type. Seed at double pasture and fertilizer rates.

**MAINTENANCE**

- Vegetation cover to be maintained at a height between 0.1 and 0.2 metres.
- Mow or periodically graze vegetation to maintain flow capacity.
- Damaged channel floor and levees are to be reconstructed to original specifications.
- Do not use waterway as an access track or firebreak.
- Control noxious weeds.
SPECIFICATIONS FOR WATER WAY

Waterway Cross Section

Levee Height: 0.5 metres
Depth of Flow: 0.3 metres
Freeboard: 0.2 metres

Water level

CONSTRUCTION SPECIFICATIONS

Alignment and width of the waterway are to be pegged, as detailed on the plan, using appropriate survey techniques. Cross sections are to be surveyed and cut and fill pegged as required.
Topsoil to be stockpiled when filling or shaping and re-spread over disturbed areas.
Allow machinery weight to compact fill or shaping.
Levees to be constructed from outside the channel, using appropriate techniques, resulting in the levees being compacted to the correct height including freeboard.
Bank inlet positions to be surveyed for correct spacings and positions. Set the ends of the inlet to eliminate back flow out of the waterway.
Check level of the waterway channel surface to determine the accuracy of construction. Use levelling to confirm the levee freeboard.
Vegetation cover on waterway channels and banks to be a mixture of annual and perennial grasses, clover and medics, dependant on soil type. Seed at double pasture and fertilizer rates.

MAINTENANCE

Vegetation cover to be maintained at a height between 0.1 and 0.2 metres.
Mow or periodically graze vegetation to maintain flow capacity.
Damaged channel floor and levees are to be reconstructed to original specifications.
Do not use waterway as an access track or firebreak.
Control noxious weeds.

Specification sheet-Level and Leveed waterways

Prepared for: Buntine-Marchagee

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Muller
SPECIFICATIONS FOR WATER WAY

Waterway Cross Section

- Levee Height: 0.45 metres
- Depth of Flow: 0.25 metres
- Freeboard: 0.2 metres
- Water level
- Waterway Width: 35 metres
- Side Slope: 6:1
- Side Slope: 3:1

CONSTRUCTION SPECIFICATIONS

Alignment and width of the waterway are to be pegged, as detailed on the plan, using appropriate survey techniques. Cross sections are to be surveyed and cut and fill pegged as required.
Topsoil to be stockpiled when filling or shaping and re-spread over disturbed areas.
Allow machinery weight to compact fill or shaping.
Levees to be constructed from outside the channel, using appropriate techniques, resulting in the levees being compacted to the correct height including freeboard.
Bank inlet positions to be surveyed for correct spacings and positions. Set the ends of the inlet to eliminate back flow out of the waterway.
Check level of the waterway channel surface to determine the accuracy of construction. Use levelling to confirm the levee freeboard.
Vegetation cover on waterway channels and banks to be a mixture of annual and perennial grasses, clover and medics, dependant on soil type. Seed at double pasture and fertilizer rates.

MAINTENANCE

Vegetation cover to be maintained at a height between 0.1 and 0.2 metres.
Mow or periodically graze vegetation to maintain flow capacity.
Damaged channel floor and levees are to be reconstructed to original specifications.
Do not use waterway as an access track or firebreak.
Control noxious weeds.

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O’Callaghan Creek
**SPECIFICATIONS FOR WATER WAY**

**Waterway Cross Section**

- Levee Height: 0.4 metres
- Depth of Flow: 0.2 metres
- Freeboard: 0.2 metres
- Waterway Width: 30 metres
- Side Slope 1:6
- Side Slope 1:3
- Water level

**CONSTRUCTION SPECIFICATIONS**

Alignment and width of the waterway are to be pegged, as detailed on the plan, using appropriate survey techniques. Cross sections are to be surveyed and cut and fill pegged as required.

- Topsoil to be stockpiled when filling or shaping and re-spread over disturbed areas.
- Allow machinery weight to compact fill or shaping.
- Levees to be constructed from outside the channel, using appropriate techniques, resulting in the levees being compacted to the correct height including freeboard.
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- Vegetation cover on waterway channels and banks to be a mixture of annual and perennial grasses, clover and medics, dependant on soil type. Seed at double pasture and fertilizer rates.

**MAINTENANCE**

- Vegetation cover to be maintained at a height between 0.1 and 0.2 metres.
- Mow or periodically graze vegetation to maintain flow capacity.
- Damaged channel floor and levees are to be reconstructed to original specifications.
- Do not use waterway as an access track or firebreak.
- Control noxious weeds.

**Specification sheet-Level and Leveed waterways**

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