Lower Murray River

Foreshore Stabilisation Guidelines

For Shire of Murray
June 2019

SYRINX ENVIRONMENTAL

Document Control

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VISION STATEMENT

The Shire of Murray and its community aim to protect, restore and sustain the use of the Murray River and its surrounding foreshore environments.

The stakeholders will work together to manage and preserve the rivers natural and amenity values for future generations and all future activities will foster habitat creation, revegetation and solutions that are adaptable to change.

Future growth and development will see sustainable and state of the art boating facilities surrounded by sustainable landscapes.

PART 1: INTRODUCTION

The Murray River is a significant and important part of the Shire of Murray's natural assets.

The river embankments and foreshore have been subject to long term degradation due to increased surface water runoff resulting from vegetation clearing for agricultural practices, increased urbanisation and boat traffic.

The Shire of Murray and the Department of Water and Environmental Regulation (DWER) recognise that in addition to natural phenomena such as climatic influences, tides and river flows, the increased use of the river, particularly boating, is resulting in the adverse effects to the shore stability.

Recent community surveys within the Shire of Murray have highlighted that riverbank deterioration and erosion are the primary concerns for the local community and the Shire receives many enquiries and proposals from residents seeking approvals and/or assistance about riverbank erosion.

To address this, the Shire in discussion with DWER, have identified the need for a standardised approach to guide erosion treatment measures along the Murray River.

Example of private jetty leaseholds along public foreshore reserve

1.1 PURPOSE OF THE GUIDELINES

This document is to assist the Shire of Murray and the landowners in planning for foreshore stabilisation treatment responses for typical situations where stabilisation and rehabilitation is required.

This document is the first step in establishing a consistent approach to erosion stabilisation along the Lower Murray River, considering both local environmental and amenity values.

The guidelines are based on general observations of the existing erosion features and limited information on geomorphology, hydrology and soils of the Lower Murray River.

The guidelines have been developed in line with the best practice methods currently implemented within the Swan and Canning River catchments as well as the river foreshore stabilisation and restoration techniques used nationally and internationally.

The purpose of this document is to:

- Provide the Shire and Landowners with an easy to follow decision making tool to assess existing scenarios and decide appropriate responses
- Provide a series of typical conceptual responses that can be utilised by the Shire to set rehabilitation standards along the Lower Murray River
- Provide guidance on materials and planting to ensure consistency and coherency along the river frontage
- Outline clear processes for future implementation considerations and construction.

Example of current mooring

1.2 OBJECTIVES

The following objectives have been developed to guide the recommended stabilisation responses and ensure consistency along the river foreshore:

- *Provide consistent and adaptable foreshore stabilisation options*
- *Aim for medium longevity (e.g. up to 15 years) of natural or permeable structures to reduce and absorb wave energy*
- *Preserve natural character/ visual integrity of the river landscape*
- *Provide visual coherency to positively contribute to amenity value of the river*
- *Balance foreshore access for recreational/ boat usage with natural values of the river*
- *Accommodate existing infrastructure including existing foreshore stabilisation structures and jetties*
- *Protect and enhance environmental assets including biodiversity, natural geomorphology and the river floodplain from further degradation and increase value of fauna habitats*
- *Maintain current views to the river*
- *Utilise materials for construction that are readily available, affordable and come from a sustainable source wherever possible*
- *Minimise cost for construction and maintenance*
- *Use stabilisation techniques that are easily implemented (i.e. do not require high skill labour or specialised equipment/ machinery).*

Delta Islands

1.3 LOCATION AND CONTEXT

The Lower Murray River occupies a 9 km section of the river from Murray River Bend in Ravenswood to the Peel Harvey Estuary.

The area is characterised by relatively flat terrain with high groundwater tables, surface inundation in winter, and wetlands of conservation significance.

Riverine flooding occurs periodically during years of high rainfall and/or very high mean water levels associated with strong La Nina conditions.

The river embankments are heavily urbanised in many parts with most of the development being within the floodplain of the river. The Murray delta islands (Yunderup, Cullenup and Balee islands) have also been subject to urban pressures and boat wave erosion particularly in the last five to ten years.

Given the long-term disturbance in the area, the riparian vegetation along the banks of the Lower Murray River is largely degraded to completely degraded with remnant native trees and very little to no understory in the urbanised sections.

The islands retain mostly remnant vegetation characterised by a high abundance of exotic flora including common garden plants, trees and large patches of Watsonia bulbifera.

The lack of riparian vegetation and the heavy use of the foreshore for boating and docking has accelerated erosion and prompted residents to use a variety of materials and methods to stabilise/ reduce erosion. While some of the methods have worked well at reducing erosion, others have exacerbated the problem and reduced environmental and amenity values in addition to being unsafe.

Figure 1: Lower Murray River Showing Delta Islands

1.4 CURRENT FORESHORE MANAGEMENT

Management and ownership of the foreshore is shared between Shire of Murray and private landowners.

The majority of foreshore frontage is managed by the Shire of Murray, however a significant portion of the North Yunderup comprises privately owned properties that have a direct frontage to the river.

Shire managed frontage includes all of the foreshore public open spaces and reserves lining the Lower Murray River. Directly abutting this public open space boundary, are private properties and road reserve.

Currently, residents with properties abutting the public open space and who have private jetties along the foreshore have taken “ownership” of the foreshore to varying extents.

This is particularly evident where the sections of the public reserve are very narrow between the top of the bank and the abutting property or road reserve. Various foreshore stabilisation treatments have been implemented by private landowners, in some instances further detracting from the natural feel of the river embankments.

Public access to the foreshore in these areas is limited to larger areas with footpaths.

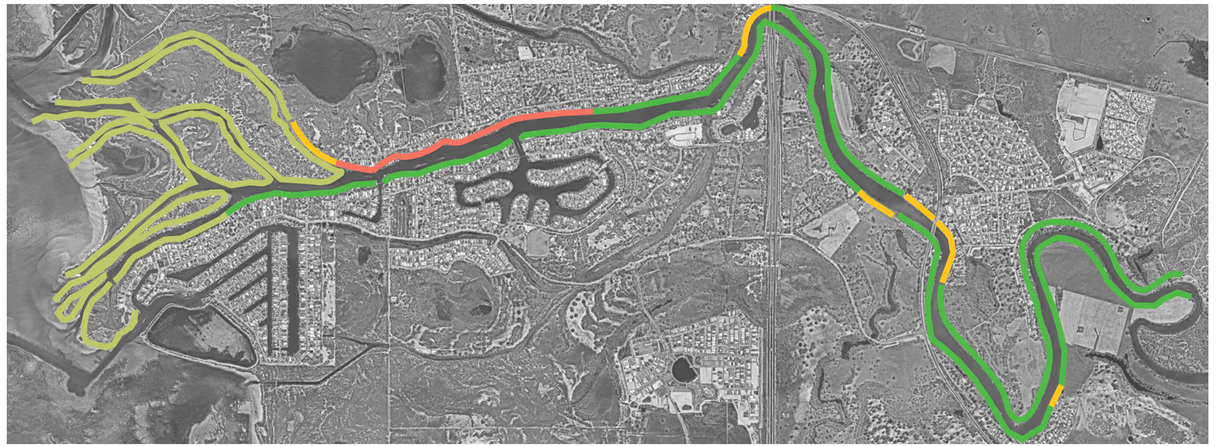


Figure 2: Current Foreshore Management
(Refer to Shire of Murray for further details on land ownership /boundaries)

PART 2: EROSION PROCESSES

River banks are subject to dynamic processes of natural erosion and deposition and as a result of anthropogenic (human) activities.

Several environmental factors need to be considered when investigating the erosion processes that are likely to affect a site.

There can be considerable variation in the type and extent of erosion within relatively short distances along the foreshore due to natural and human influences.

2.1 NATURAL INFLUENCES

The dominant natural factors influencing erosion are:

- River bed morphology (e.g. bank height, bathymetry, soils, natural meanders)
- River flows and flooding (e.g. tides, climate change, rainfall)
- Prevailing winds, currents and waves
- Vegetation type and condition
- Presence of silty sands/ fine particle soils
- Influence of tides and high, low water levels due to rainfall variation and/ or climate effects such as La Nina.

Example of Vegetation Loss

Example of Recreational Boating

Example of Informal Access

2.2 HUMAN INFLUENCES

The main anthropogenic (human influenced) factors influencing erosion by amplifying natural processes are:

- Clearing of native vegetation
- Type and size of adjacent infrastructure or foreshore stabilisation treatment such as walls, revetments, jetties, slipways etc.
- Dredging
- Activities/ use of foreshore areas
- Boat wake (particularly the frequency and magnitude of disturbance)
- Numerous public informal access tracks impacting on foreshore vegetation

Unlike natural processes causing erosion that are often infrequent, human induced erosion can be frequent and often increases in severity with intensified urbanisation and demands for use of waterways for recreational boating.

2.3 CONSEQUENCES

While foreshore erosion rates have not been quantified, it is understood that at some locations the foreshore has retreated in the order of few metres within the past five years.

Combined with seasonal influences such as the high or low water levels, the erosion can be exacerbated via undercutting or overtopping of banks.

The consequences of foreshore erosion are:

- Fragmentation and reduction of foreshore habitats particularly the understory species and the tree cover
- Potential loss of public and private land
- Localised degradation of water quality
- Loss or reduced access along the foreshore for recreational use
- Increased maintenance and stabilisation cost for the Shire of Murray and landowners
- Reduced aesthetics especially due to ad hoc erosion protection works and a reduction in the natural character of the site.

Figure 3. Typical summer pattern of boating activities showing numerous vessels (Source: Nearmap, 28th December 2018)

To assist the reader in better understanding how the guidelines apply to current scenarios along the Lower Murray River, the following section identifies common terminology used to describe foreshore profiles and how this applies to existing foreshore profiles.

3.1 RIVERINE FEATURES - TERMINOLOGY

Riparian Zone Width:

- This is a minimum width of riparian (riverine) vegetation required for ongoing banks stability.
- The riparian zone should consider the floodway as a minimum and work towards 1 in 100-year flood levels.
- The riparian zone width varies with bank height and the bank erosion rate (often associated with soils comprising the area). In general, the higher the bank the more likely it is to erode.

Channel Width:

- This is the width of the river measured from crest to crest.

Bank Crest:

- This is the junction of the river channel with the floodplain or the point above which consider the river to be in flood.

Bank Toe:

- This is the junction of the bank with the bed of the channel (usually bottom of the slope).

Bank Height:

- This is a measure of river channel depth measured vertically between the bank toe and bank crest.
- The bank height along the Lower Murray River varies due to natural sand deposition (sand dunes) and the artificial infill as well as the location (i.e. bend or meander of the river).

Bank Slope:

- This is the bank area between the bank toe and bank crest. The slope erodibility is a function of soil type, hydraulic conditions, slope angle and the existing vegetation cover.
- The best practice manual (SRT, 2009) states that the 'stable' bank slope varies on the frequency of impacts such as those of the boat wake and or wind waves:
  - Slope on an upper bank with no wave action should preferably be flatter than 1V:4H and no steeper than 1V:3H
  - Slope on a bank exposed to occasional wave action should be preferably flatter than 1V:6H;
  - Slope on a lower bank exposed to regular wave action should be from 1V:12H to 1V:30H, depending on soil type.

Erosion Rate:

- This is the rate at which the bank slope moves (metres/year). This will be an average rate over at least 10 or 20 years to encompass years of high flood.
- The erosion rate should be determined by existing evidence (aerial photos, distance from fence lines, etc) however can be estimated as 1.6% of channel width per year.

PART 3: CURRENT SCENARIO

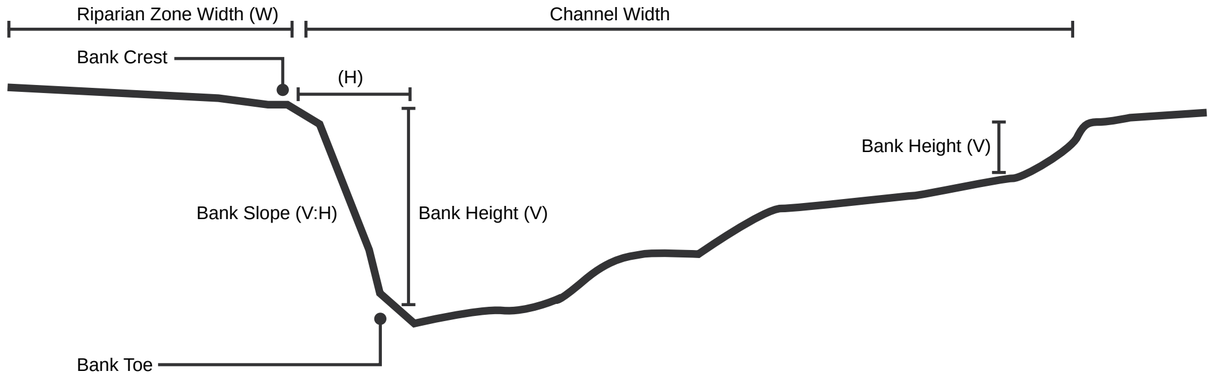


Figure 4. Terminology used to describe riverine features in these guidelines.
Note: V = vertical height, H = horizontal distance

3.2 TYPICAL EXISTING RIVERBANK SCENARIOS

In order to develop consistency across the foreshore area, these guidelines contain a set of stabilisation responses that are considered most appropriate to address the range of natural and/or modified foreshore conditions along the Lower Murray River.

The riverine features defined previously are used to identify a range of common and typical existing scenarios, and then decide the most appropriate response for each of these.

To assist individuals in identifying the most appropriate stabilisation response for their land, the range of existing foreshore conditions are broadly categorized into three general typical scenarios. These are:

1. **Areas typically with a 'soft' edge, no existing erosion control measures**
2. **Areas typically with a rock revetment as erosion control measure**
3. **Areas typically with a hard wall as erosion control measure**

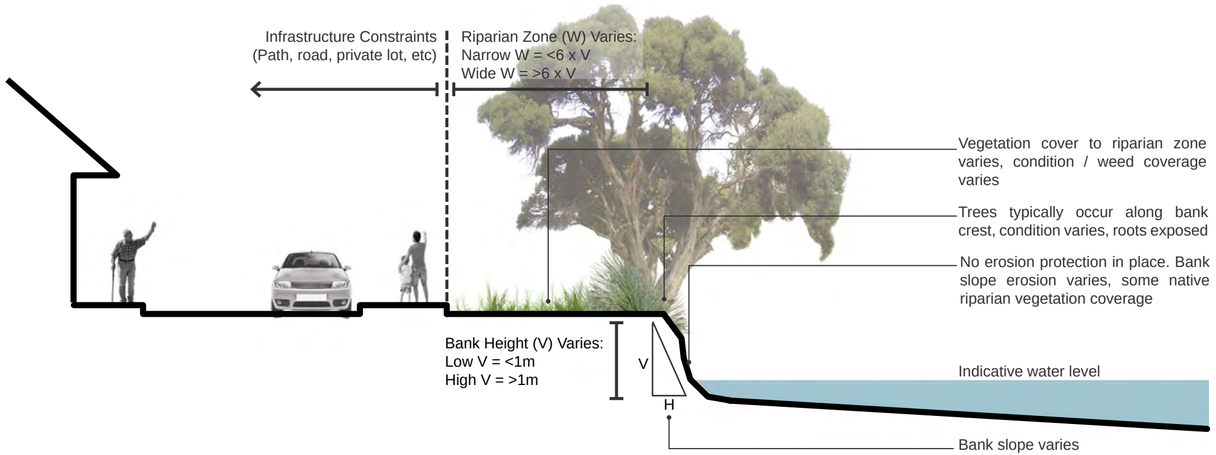
Refer to the following diagrams for further explanation on these typical scenarios.

When determining the relevant existing scenario applicable to an individual area, landowners are encouraged to use these three broad scenarios as a starting point and to further consider the following:

- Current boat traffic and wave energy – *is it **high** or **low**?*
- Current erosion rate – *is it **high** or **low**?*
- Proximity of navigation channel
- Bank height (V) – *is it **high** (>1m) or **low** (< 1 m)?*
- Width of riparian zone - *is it **narrow** (< 6 x V) or **wide** (>6 x V)?* (Practical workable area for implementing erosion control measures, considering proximity of infrastructure such as jetties, roads, pathways, housing and other infrastructure)
- Bank slope – *is it **steep** (>1V:3H) or **gentle** (< 1V:3H)?*
- Bank toe – *is it **wide** (>2m) or **narrow** (< 2 m)?*

Note: V = vertical height, H = horizontal distance

SCENARIO 1: AREAS TYPICALLY WITH A *'SOFT' EDGE*, NO EXISTING EROSION CONTROL MEASURES

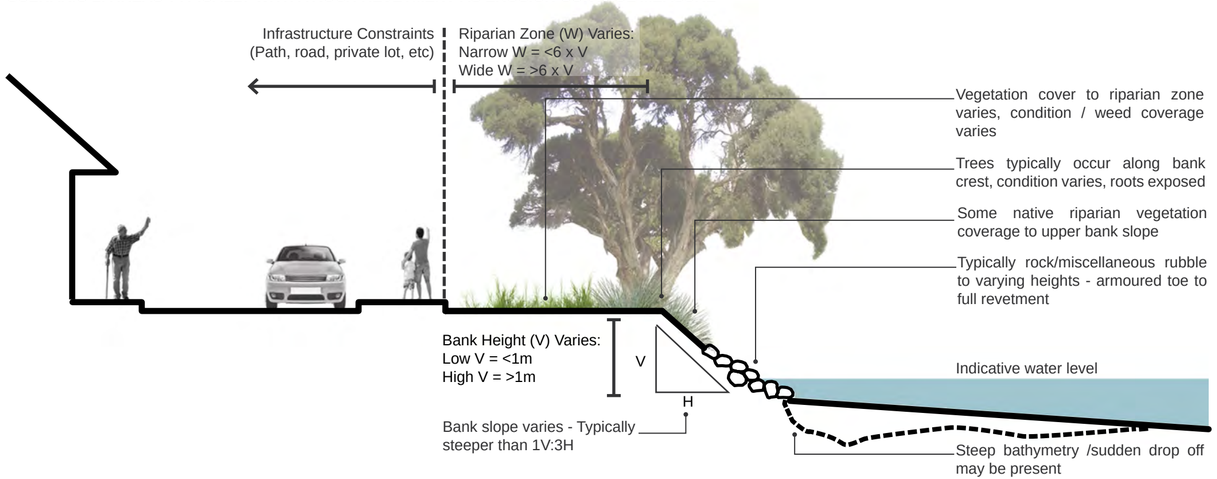


Island reserve frontage - High bank, high wave action,

Island reserve frontage - Low bank

Island reserve frontage - Low bank

SCENARIO 2: AREAS TYPICALLY WITH A *ROCK REVETMENT* AS EROSION CONTROL MEASURE

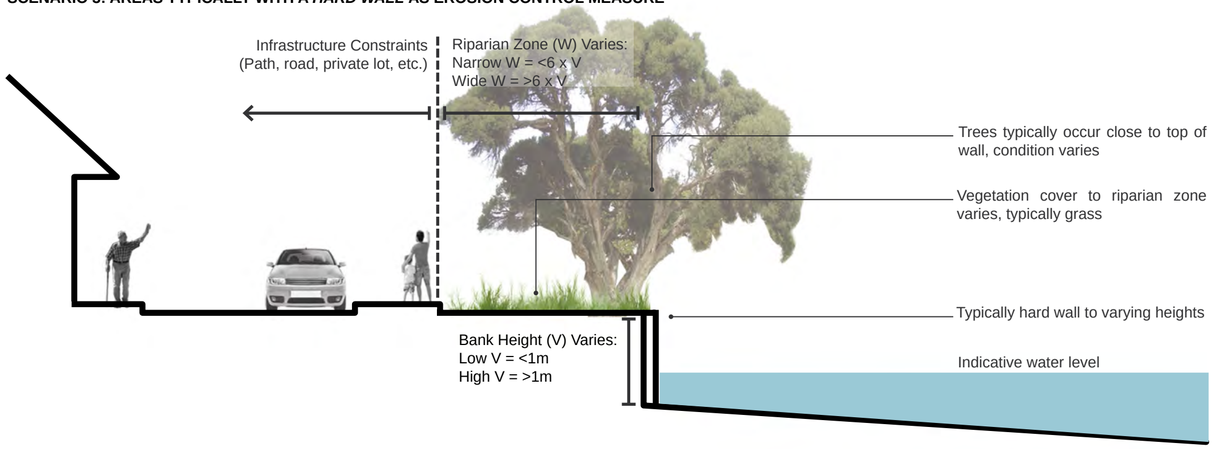


High Bank Height, rock armoured toe

Low Bank Height, limestone rock revetment

Low Bank Height, mixed rock toe

SCENARIO 3: AREAS TYPICALLY WITH A *HARD WALL* AS EROSION CONTROL MEASURE



Timber log wall, low bank, wide riparian zone

Limestone block wall, high bank, narrow riparian zone

Metal shoring, high bank, wide riparian zone

Based on the three typical existing scenarios identified, stabilisation responses have been selected to reduce the risk to infrastructure, safety, amenity and environment.

The following four (4) approaches are considered most appropriate for implementation in the Lower Murray River. These approaches are derived from best practice stabilisation techniques and approaches to foreshore stabilisation currently implemented in Western Australia and internationally.

4.1 APPROPRIATE STABILISATION RESPONSES

1. Managed Retreat (Revegetation):

- Re-establishing local native vegetation to stabilise bank sediments by generating a network of roots and partially absorbing wave and current forces.
- This technique is recommended in areas where the riparian zone is wide, and foreshore access is limited.

2. Bioengineering:

- Using vegetation, wood and biodegradable products to reduce surface erosion and provide toe protection while revegetation is established.
- The recommended technique for the Lower Murray River is to use brush walling (bundles of brush secured by hardwood stakes combined with Coir matting and revegetation).
- This approach is recommended for banks of the Lower Murray River that have gentler slopes and are subject to lower impacts of boat traffic.

3. Revetments:

- A structure that provides a protective cover on an embankment of earth designed to maintain the slope or protect it from erosion.
- The recommended technique for the Lower Murray River is to use limestone revetment incorporating a core constructed from the smaller rock and an outer section constructed with larger rocks (armour rock).
- This approach is recommended in areas subject to high boat traffic and need to withstand greater movement by river flows or public intervention.

4. Walling:

- Generally rigid vertical structures installed to retain a higher elevation of foreshore by providing a barrier to the loss of material from the bank.
- The recommended technique for the Lower Murray River is to use reconstituted limestone block or a cut limestone wall.
- This approach is recommended in areas where the riparian zone is typically less than 5 m wide and infrastructure is within 10 m from the bank crest, and is subject to high boat traffic and access requirements.

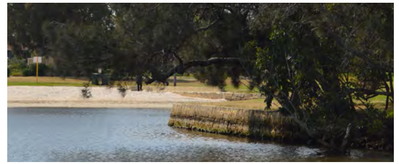
4.2 SELECTING AN APPROPRIATE RESPONSE

The following section provides a decision tool, outlining key considerations to assist individuals in identifying appropriate responses for specific areas of the foreshore.

1. Example: Managed Retreat - Revegetation

2. Example: Bioengineering

3. Example: Revetment



4. Example: Walling

4.2 DECISION TOOL FOR SCENARIO 1: EXISTING '*SOFT*' *EDGE*

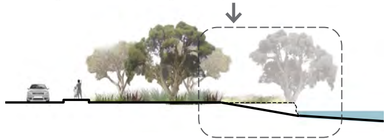
Key Considerations for All Scenarios:

- *High or low boat traffic / wave action?*
- *Bank Height (V): high (>1m) or low (<1m)?*
- *Width of riparian zone: narrow (<6 x V) or wide (>6 x V)?*
- *Infrastructure in proximity to bank crest?*

Site Influences: Low boat traffic / wave action

Typical Features:
- Wide riparian zone
- No spatial constraints
- No infrastructure / or located away from bank crest

Response:
- Managed retreat (revegetation). *Refer to Section 4.3*



Typical Features:
- Spatial constraints
- Infrastructure located near bank crest

Response:
- Bioengineering. *Refer to Section 4.4*

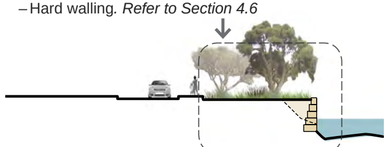
Site Influences: High boat traffic / wave action

Typical Features:
- Infrastructure located near bank crest
- Shallow bathymetry / no sudden drop off at bank toe

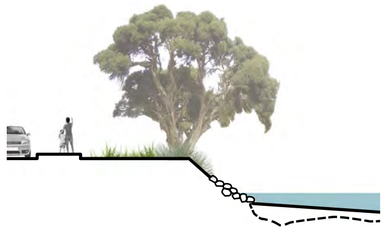
Response:
- Revetment. *Refer to Section 4.5*

Typical Features:
- Narrow riparian zone
- High bank height >1m
- Infrastructure located near bank crest
- Deep bathymetry / sudden drop off at bank toe

Response:
- Hard walling. *Refer to Section 4.6*



4.2 DECISION TOOL FOR SCENARIO 2: EXISTING *REVETMENT*

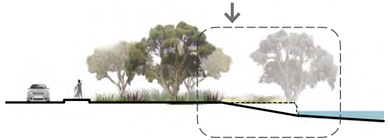


Existing Condition:
- Poor, failing or miscellaneous rock/ rubble material*

Site Influences: Low boat traffic / wave action

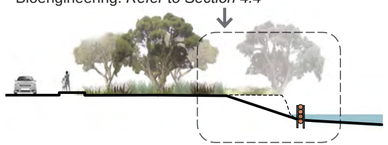
Typical Features:
- Wide riparian zone
- No spatial constraints
- No infrastructure/ or located away from bank crest

Response:
- Managed retreat (revegetation). *Refer to Section 4.3*



Typical Features:
- Infrastructure located near bank crest

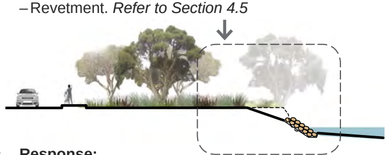
Response:
- Bioengineering. *Refer to Section 4.4*



Site Influences: High boat traffic / wave action

Typical Features:
- Shallow bathymetry / no sudden drop off at bank toe

Response:
- Revetment. *Refer to Section 4.5*

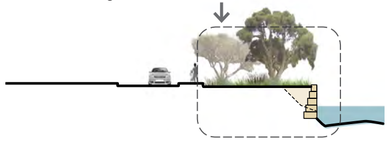


Existing Condition:
- Good, stable with consistent limestone rock*

Response:
- Leave as is. Replace at point of failure.
- Revegetate min. 5m back from bank crest

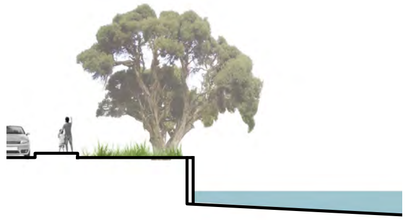
Typical Features:
- Narrow riparian zone / high bank height
- Infrastructure located near bank crest
- Deep bathymetry / sudden drop off at bank toe

Response:
- Hard walling. *Refer to Section 4.6*



*Condition assessment subject to appropriate engineering investigations

4.2 DECISION TOOL FOR SCENARIO 3: EXISTING *HARD WALL*

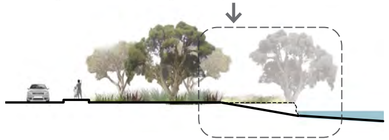


Existing Condition:
- Poor, failing*

Site Influences: Low boat traffic / wave action

Typical Features:
- Wide riparian zone
- No spatial constraints
- No infrastructure/ or located away from bank crest

Response:
- Managed retreat (revegetation). *Refer to Section 4.3*



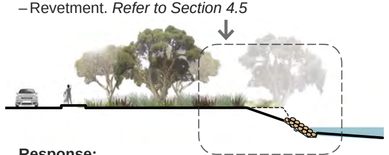
Typical Features:
- Infrastructure located near bank crest

Response:
- Bioengineering. *Refer to Section 4.4*

Site Influences: High boat traffic / wave action

Typical Features:
- Shallow bathymetry / no sudden drop off at bank toe
- <1m retaining required

Response:
- Revetment. *Refer to Section 4.5*

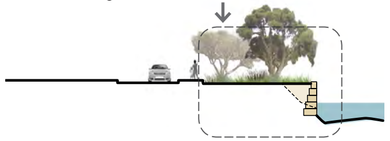


Existing Condition:
- Good, structurally sound *

Response:
- Leave as is. Replace at point of failure.
- Revegetate min. 5m back from bank crest

Typical Features:
- Narrow riparian zone
- High bank height requiring >1m retaining
- Infrastructure located near bank crest
- Deep bathymetry / sudden drop off at bank toe

Response:
- Hard walling. *Refer to Section 4.6*



*Condition assessment subject to appropriate engineering investigations
^Recommended all Shire managed timber walls adjacent wide POS/ island reserve be transitioned to managed retreat

4.3 MANAGED RETREAT - REVEGETATION

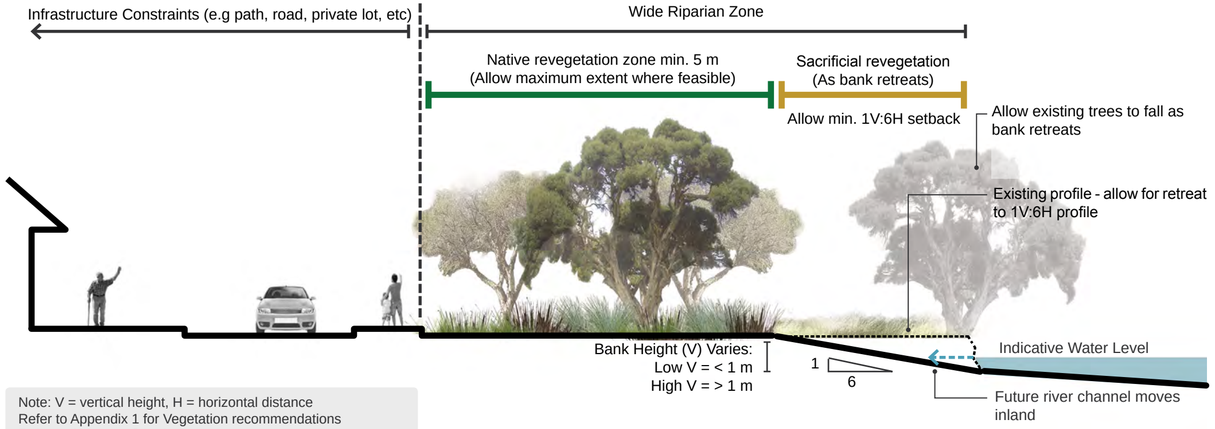
This is a management response that allows the river to flood or move inland in accordance with natural flooding patterns and climate change instead of attempting to hold the current alignment by structural means.

The managed retreat / revegetation method can be used as a sole management response; however, it is often used in combination with other techniques such as bioengineering, revetment, and even limestone block or timber walls to enhance stability, amenity and biodiversity of the river foreshore.

Typical Application

- Low wave heights, frequency and duration of impacts (e.g. wave heights less than 0.3 m. Waves up to 0.5 m are tolerable but only if occasional and of short duration)
- Wide riparian zone, with adequate space available for revegetation
- Infrastructure is located away from the bank crest
- Adjacent foreshore stabilisation treatments upstream or downstream of the area have little to no direct effect on foreshore stability

Example: Managed Retreat - Revegetation



Note: V = vertical height, H = horizontal distance
Refer to Appendix 1 for Vegetation recommendations
Refer to Appendix 3 for further details on stabilisation response

4.4 BIOENGINEERING

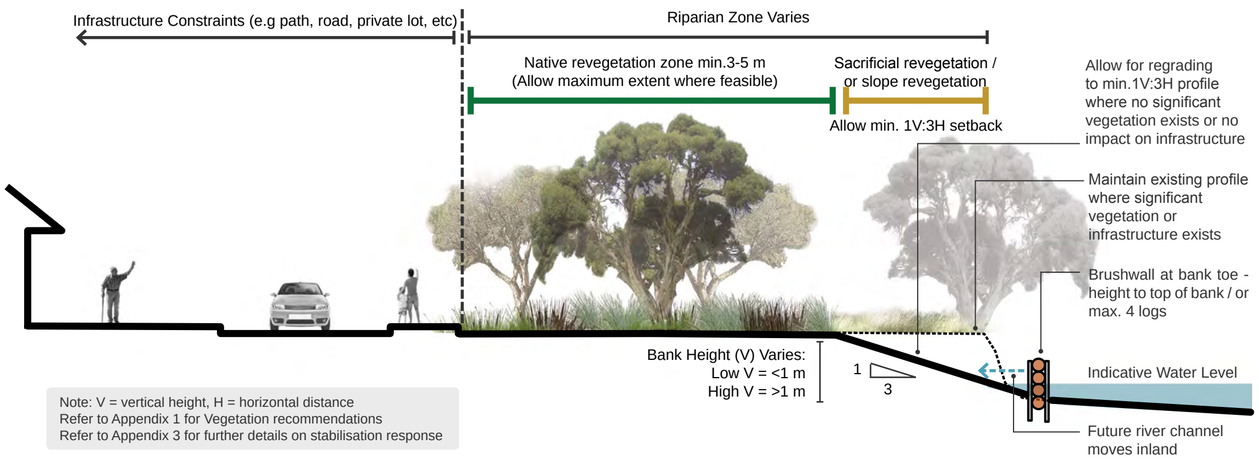
Brush walling is a bioengineering response that uses biodegradable materials such as wood, brush, coir or jute in combination with revegetation to reduce erosion of the river banks.

The function of the brush walls is to dissipate wave energy across a larger surface area and reduce erosive forces that impact the bank slope or bank toe. The reduction in wave energy facilitates establishment of fringing riparian vegetation (behind the brush wall) creating a soft, more natural edge. Undercutting of the brush wall is less likely as brush allows diffuse flow of water back into the river which is not possible with hard structures such as revetments, baffle boards or limestone wall.

Typical Application

- Limited to areas of low flow velocity
- In areas where wave heights, frequency and duration of impact are low (e.g. wave heights less than 0.3 m. Waves up to 0.5 m are tolerable but only if abundance is occasional and of short duration
- Generally in wider riparian zones, with adequate space available for revegetation
- Adjacent foreshore stabilisation treatments upstream or downstream of the area have little to no direct effect on foreshore stability

Example: Bioengineering



Note: V = vertical height, H = horizontal distance
Refer to Appendix 1 for Vegetation recommendations
Refer to Appendix 3 for further details on stabilisation response

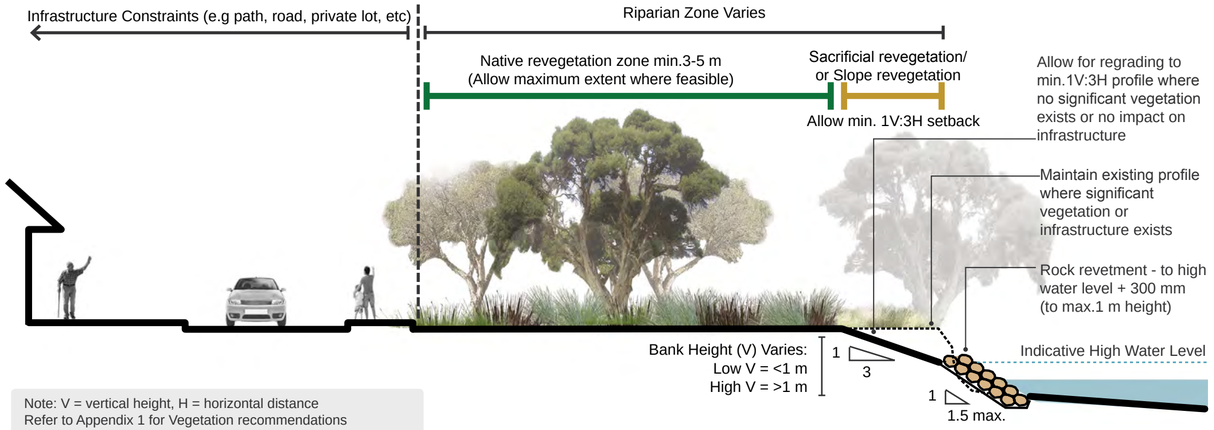
4.5 REVETMENT

Rock revetment is a form of bank protection that uses quarried armour stone placed on embankments to reduce erosive forces of the river stream flows and boat traffic. This technique allows the river to flood in accordance with natural flooding patterns and can accommodate climate change.

Typical Application

- In areas where wave heights, frequency and duration of impact are medium to high (e.g. wave heights of 0.5 m or greater) and the erosion of the banks is high to severe
- Bank slope of 1:3 or steeper
- Infrastructure is located close to the bank crest

Example: Revetment



Note: V = vertical height, H = horizontal distance
Refer to Appendix 1 for Vegetation recommendations
Refer to Appendix 3 for further details on stabilisation response

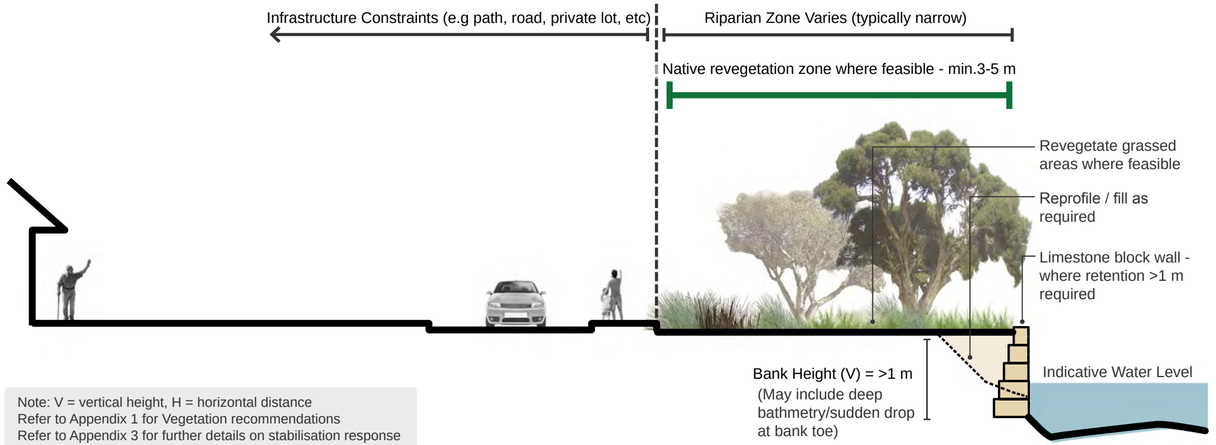
4.6 WALLING

Cut limestone or reconstituted limestone blocks fitted together with cement mortar to form a vertical or near vertical wall.

Typical Application

- In areas where wave heights, frequency and duration of impact are high (e.g. wave heights of 0.5 m or greater) and the erosion of the banks is severe
- In steep areas where access to the water's edge is necessary, such as piers/ jetties that accommodate heavy traffic
- In steep areas where car parks, bike paths, houses or other significant infrastructure are near the bank crest, and where the bank toe is not wide enough to implement other stabilisation techniques such as rock revetment.

Example: Walling



Note: V = vertical height, H = horizontal distance
Refer to Appendix 1 for Vegetation recommendations
Refer to Appendix 3 for further details on stabilisation response

PART 5: IMPLEMENTATION CONSIDERATIONS

5.1 PROCESS

Prior to implementing any foreshore stabilisation works, the following steps should be considered to ensure that the proposed works are in line with relevant legislative, planning and development requirements.

Note: Soft engineering approaches like revegetation and brush walling are preferred. Rock revetments and limestone walls should be limited to high impact areas where soft / bioengineered options would fail.

5.1 PROCESS

Prior to implementing any foreshore stabilisation works, the following steps should be considered to ensure that the proposed works are in line with relevant legislative,

planning and development requirements.

Implementation Considerations

1. Landholders must contact Shire of Murray prior to start of any works including the planning for stabilisation works either as part of development approval process with the Department of Planning Lands and Heritage or as additional works (post development);
2. Bathymetry and elevation must be considered, and a feature survey of the foreshore may be required;
3. Where the foreshore stabilisation needs to be implemented on land managed by the Shire (i.e. POS, Reserves, Crown Land), the Shire shall conduct a site assessment to determine which foreshore stabilisation technique is most appropriate for the site;
4. Consider all stakeholder requirements in the planning and the detailed design;
5. The Shire shall ensure that the proposed works are in line with the existing legislation, guidelines, policies and strategies including:

Federal

- Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is an Act

State

- Aboriginal Heritage Act (1972), Aboriginal Heritage Regulations (1974) and Native Title Act (1993)
- Conservation and Land Management Act (1984)
- Environmental Protection Act 1986 and Environmental Protection (Clearing of Native Vegetation) Regulations 2004
- Planning and Development Act (2005);
- Waterways Conservation Act (1976)
- Wildlife Conservation Act 1950 / Biodiversity Conservation Act 2016;
- Acid Sulfate Soils (ASS) fact sheets and guidelines (DWER);
- Bush Fires Act 1954 and Bush Fires Regulations 1954

Local

- Biodiversity Protection Policy 2018
- Boating Facilities and Moorings Policy 2018
- Natural Landscape in Urban Areas Policy 2018
- Vegetation Management Policy 2018
- Water Sensitive Urban Design Policy
- Telecommunications Infrastructure Policy

6. Shire shall ensure that the proposed foreshore stabilisation does not impact any infrastructure based on Dial Before You Dig (DBYD) information and the infrastructure mapping available within the Shire's GIS mapping system;
7. A specific detailed plan shall be developed for the nominated foreshore area that shows cross section of the site, specifications for implementation including materials, plant lists and the proposed maintenance plan that would ensure success of works. A succinct rationale should be provided to justify use of the selected method over other methods;

REFERENCES

Natural Area Consulting [NAC] (2018) Level 2 Flora and Vegetation Survey – Murray Delta Reserve. Unpublished Technical report for Shire of Murray. June 2018.

Swan River Trust [SRT] (2009) Best management practices for foreshore stabilisation – Approaches and decision support framework. Accessed on 29th October 2018: https://www.dpaw.wa.gov.au/management/swan-canning-riverpark/ecosystem-health-and-management/habitat-protection-and-foreshore-management?showall=1

Western Australian Herbarium [WAH] (2018). FloraBase—the Western Australian Flora. Department of Biodiversity, Conservation and Attractions. https://florabase.dpaw.wa.gov.au/

APPENDICES

1. VEGETATION RECOMMENDATIONS FOR THE LOWER MURRAY RIVER

The selection of flora suitable for foreshore revegetation along the Lower Murray River was based on flora indigenous to the river foreshore (based on Western Australian Herbarium records (2018) and the NAC (2018) flora survey of the islands (see Table 1).

Given that the river mouth conditions vary along the river length with regard to freshwater input, topography and soils, the species list has been divided into three zones:

1. Zone 1: Pelican Road to the Murray River mouth (Murray River Delta);
2. Zone 2: Pelican Road to South Yunderup Rd./Pinjarra Rd. intersection; and
3. Zone 3: Lander Way to Murray River Bend.

In addition to different zones based on environmental conditions, the species have also been divided in accordance with their position regarding elevation and distance from the river's average water levels:

- Lower bank (area between the bank toe and mid bank slope);
- Upper bank (area between mid bank slope to bank crest and a narrow section of the bank that has same or lower elevation than the bank crest); and
- Upland vegetation (dryland areas rarely flooded).

Indicative species list is presented in the following tables.

Location of Lower Murray River Revegetation zones

Table 1. Recommended Plant species for the Lower Murray River

Species	Common Name	Average plant height (m)	Zone 1			Zone 2			Zone 3			Plant Description (as per FloraBase (WAH, 2018))			
			Lower Bank	Upper Bank	Upland	Lower Bank	Upper Bank	Upland	Lower Bank	Upper Bank	Upland	Flower colour	Flowering time	Habit	Habitat
TREES															
Acacia saligna	Orange Wattle	5										Yellow	Jul to Nov	Dense, often weeping shrub or tree	Variety of habitats.
Casuarina obesa	Swamp Sheoak	10										Red and Brown		Dioecious tree	Along rivers, creeks, salt lakes
Corymbia calophylla	Marri	25										White	Dec or Jan to Ma	Tree with rough, tessellated bark.	Flats, hills, slopes, breakaways, wetlands, fringing salt marches, beside drainage lines
Eucalyptus rudis	Flooded gum	20										White	Jul to Sep	Tree with rough box type bark.	Sandy or loam soils. Wetter parts of landscape, flats, hillsides.
Melaleuca rhaphiophylla	Swamp Paperbark	8										White-cream	Jul - Jan	Tree with white paper like bark	White or grey sand, clay soils. Saltmarshes, swamps, along watercourses.
Melaleuca cuticularis	Saltwater Paperbark	7										White-cream	Aug to Nov		Alluvium, sand, clay. Winter-wet depressions, salt lakes, coastal areas, along watercourses.
Viminaria juncea	Swishbush	3										Yellow	Oct to Dec or Jan	Erect, often weeping shrub	Sandy & clayey soils. Near lakes & swamps, river banks, winter-wet depressions.
SHRUBS															
Acacia pulchella	Prickly Moses	1.5										Yellow	May to Dec	Shrub	Sandy soils, clay loam over laterite. Low-lying areas, swamps, near watercourses.
Acacia applanata		0.4										Yellow	Jun to Oct	Erect or sometimes sprawling, grass-like shrub	Mostly in sand, loam & lateritic soils.
Acacia urophylla		2										Yellow - cream	May to Oct	Erect, slender, open shrub	Often in lateritic soils. Along creeks & rivers, damp places.
Astartea affinis	West-Coast Astartea	2										White/purple/violet	Nov to Dec or Jan	Slender, erect, open shrub	Slightly undulating areas, seasonal wetlands, flats, creeklines, claypans, roadsides.
Astartea scoparia	Common Astartea	2										White	Nov to Dec or Jan	Shrub	Loam, sand.
Boronia crenulata	Aniseed Boronia	0.5										Pink-purple-red	May to Dec or Jan to Feb	Shrub	White-grey sand, clay, clay loam, gravel. Outcrops, salt lakes, coastal areas, wet or swampy sites, valleys, disturbed sites.
Chorizema cordatum		0.7										yellow & orange & red/pink	Jul to Dec	Erect, straggling or climbing shrub	Grey-brown sandy gravel, red-brown sandy loam or clay, over granite or laterite. Near rock outcrops, on hills, along streams and watercourses, winter-wet flats.
Darwinia citriodora	Lemon-scented Darwinia	1										yellow-green/red	May to Dec	Erect to prostrate shrub	Lateritic or granitic soils. Granite outcrops, hills.

Species	Common Name	Average plant height (m)	Zone 1			Zone 2			Zone 3			Plant Description (as per FloraBase (WAH, 2018)			
			Lower Bank	Upper Bank	Upland	Lower Bank	Upper Bank	Upland	Lower Bank	Upper Bank	Upland	Flower colour	Flowering time	Habit	Habitat
Daviesia physodes		1										yellow/orange & red/pink	Jul to Nov	Prostrate to low, bushy shrub	Sandy soils over laterite or limestone. Plains, hills, winter-wet flats.
Gastrolobium capitatum		0.5										orange-yellow	Jun to Sep	Prostrate to low, bushy shrub	Sandy to loamy soils, laterite, granite. Slopes, outcrops, swampy areas, plains.
Frankenia pauciflora	Seaheath	0.5										pink/white	Jun to Dec or Jan to Feb	Prostrate to ascending shrub	Sandy, often saline soils. Coastal limestone, saline flats, salt lakes.
Hakea prostrata	Harsh Hakea	2.5										white-cream	Jul to Oct	Erect to spreading or prostrate shrub	Sandy soils, often over laterite, loam, gravel. Hillslopes, granite outcrops, coastal dunes.
Hakea varia	Variable Leaved Hakea	2.5										white-cream/yellow	Jul to Nov	Erect or spreading shrub	White, grey or red loamy sand, clay loam, laterite. Seasonally-wet flats.
Hardenbergia comptoniana	Native Wisteria	2										blue-purple/white	Jul to Oct	Twining shrub or climber	Sandy soils. Coastal limestone, sandplains, dunes.
Hibbertia racemosa	Stalked Guinea Flower	0.3										yellow	Jul to Dec	Erect or ascending, spreading shrub	Grey, white or yellow sand. Coastal areas: dunes, plains & limestone.
Hovea trisperma	Common Hovea	0.5										purple-blue	May to Nov	Straggling weak to ascending shrub	Sandy soils, laterite, gravel, clay loam.
Hypocalymma angustifolium	White Myrtle	1.5										white-cream	Jun - Oct	Erect, multi-stemmed shrub	Grey to white sand, peaty soils, sandy clay, sandstone. Flats, swamps, along watercourses, near permanent fresh-water springs, outcrops, hillsides.
Jacksonia furcellata	Grey Stinkwood	2										yellow & orange/red	Oct to Dec or Jan to Mar	Prostrate to decumbent or weeping erect shrub	Sandy soils. Sandplains, rises, swampy depressions, river banks.
Jacksonia sternbergiana	Stinkwood	3.5										yellow-orange	Jan to Dec	Erect, weeping shrub or tree	Sandy soils. Along rivers & creeks, near swamps, flats, dunes.
Kunzea glabrescens	Spearwood	3.5										yellow	Oct to Nov	Shrub	Clay, sandy soils. Edges of swamps, lakes, rivers, moist depressions.
Macrozamia riedlei	Zamia Palm	2											Sep to Oct	Cycad small, usually trunkless; leaves few	Lateritic soils
Melaleuca osullivanii		2.5										yellow/pink		Shrub with peeling papery bark	Grey sand to clayey sand, brown clay loam, laterite. Flats, coastal areas, seasonal wetlands.
Melaleuca viminea	Mohan	3										white-cream	Jul to Nov	Shrub or tree	Sandy or clayey soils. Near creeks or wet depressions, along watercourses, rocky coastal areas, flats.
Myoporum caprarioides	Slender Myoporum	0.5										white/white-blue-pink	Feb or Apr or Jun or Aug to Dec	Erect, slender, compact or sprawling shrub	White-grey to black sand, peaty sand, clay loam. Seasonally wet flats, swamps, sand dunes, limestone ridges, coastal areas.

Species	Common Name	Average plant height (m)	Zone 1			Zone 2			Zone 3			Plant Description (as per FloraBase (WAH, 2018)			
			Lower Bank	Upper Bank	Upland	Lower Bank	Upper Bank	Upland	Lower Bank	Upper Bank	Upland	Flower colour	Flowering time	Habit	Habitat
Rhagodia baccata	Berry Saltbush	1										cream-yellow/green	Feb or Apr to May or Oct to Dec	Spreading shrub	White-grey sand, limestone, granite. Sand dunes, coastal rocky areas, hills.
Salicornia quinqueflora	Beaded Samphire	0.25												Succulent halophytic coastal shrub.	Clayey sandy mud.
Suaeda australis	Seablite	0.4										green	Jan or Mar or Oct	Rounded perennial, herb branching from the base	Sand. Coastal sites, saline swamps & creeks.
Tecticornia halocnemoides	Shrubby Samphire	0.5												Succulent halophytic coastal shrub.	Clayey sandy mud.
Xanthorrhoea preissii	Grass Tree	1										white-cream	Jun or Aug to Dec	Perennial tree-like monocot	Grey to black sands, grey-brown loam, brown gravelly sandy clay, laterite, granite. Ranges, coastal plain, near watercourses.
SEDGES AND RUSHES															
Baumea juncea	Bare Twigrush	0.7										brown/other	Oct to Dec or Jan to Mar	Rhizomatous, colonising perennial.	Streams, swamps.
Baumea rubiginosa		1										brown	Aug to Dec or Jan to Mar	Erect, caespitose rhizomatous, perennial.	Streams, swamps.
Ficinia nodosa	Knotted Club Rush	0.5										brown/cream	Oct to Dec or Jan to Mar	Erect, caespitose rhizomatous, perennial.	Bare white calcareous sand, dark sandy clay, granite, limestone. Coastal dunes, flats, seasonally-wet swamplands, shores of salt lakes.
Gahnia trifida	Coastal Saw-Sedge	1										yellow-brown	Aug to Oct	Rhizomatous, tussocky perennial, grass-like sedge.	Grey or white sand, clay, sometimes saline. Swamps, creeks.
Isolepis cernua var. setiformis	Nodding Club-Rush	0.15										green-brown	Sep to Dec	Rhizomatous, tussocky perennial, grass-like sedge.	Dark brown-black clay loam, saline sands, silt, granite, limestone. Coastal sites, swamp & creek margins, winter-wet depressions.
Juncus kraussii subsp. australiensis		0.8										brown/red	Oct to Dec or Jan	Rhizomatous, colonial perennial.	White or grey sand, clay, alluvium. Swamps, brackish estuaries, saline flats.
Juncus pallidus	Pale Rush	1										green	Oct to Dec	Rhizomatous, robust perennial.	Clay. Swamps, watercourses.
Juncus subsecundus	Finger Rush	0.8											Oct to Dec or Jan	Colonial perennial.	Clay. Swamps.
Lepidosperma longitudinale	Pithy Sword-Sedge	0.8										brown	May to Jun or Aug to Oct	Rhizomatous, tussocky perennial, grass-like sedge.	Black, white or grey peaty sand, clay. Seasonally wet flats, swamps.

Species	Common Name	Average plant height (m)	Zone 1			Zone 2			Zone 3			Plant Description (as per FloraBase (WAH, 2018)			
			Lower Bank	Upper Bank	Upland	Lower Bank	Upper Bank	Upland	Lower Bank	Upper Bank	Upland	Flower colour	Flowering time	Habit	Habitat
HERBS															
Anigozanthos manglesii	Mangles Kangaroo Paw	0.7										green & red	Aug to Nov	Rhizomatous, perennial, herb	White, yellow or grey sand, sandy loam.
Brachyscome iberidifolia		0.25										white-blue-purple	Jul to Nov	Erect, branching annual, herb	Sandy, clay or saline soils. Along watercourses, on sandhills, in depressions over granite.
Conostylis aculeata	Prickly Conostylis	0.3										yellow	Aug to Nov	Rhizomatous, perennial, grass-like herb.	Sand, loam, clay, gravel, limestone, laterite. Winter-wet areas, swamp margins, drainage areas, ditches, sand dunes.
Conostylis candicans subsp. *calcicola*		0.3										yellow	Aug to Nov	Rhizomatous, proliferous perennial, grass-like herb	Calcareous sand. Coastal dunes.
Dampiera trigona	Angled-stem Dampiera	0.25										blue/white	Aug to Dec	Slender perennial herb	Sandy & clayey soils. Winter-wet flats, roadsides.
Dianella revoluta	Blueberry Lily	0.4										blue-purple-violet	Aug to Dec or Jan or Apr	Rhizomatous, perennial, herb	Variety of soils, laterite, granite, limestone.
Kennedia prostrata	Scarlet Runner	0.15										red	Apr to Nov	Prostrate or twining herb/shrub.	Usually sandy gravelly soils.
Lobelia anceps	Angled Lobelia	0.25										blue/blue-purple/white	Sep to Dec or Jan to May	Prostrate to ascending perennial, herb	Dark brown-black sandy loam, grey sand, wet brown peaty sand, ironstone gravel, granite, limestone. Flat to sloping landscapes, hillsides, near wetlands, watercourses, along river banks.
Patersonia occidentalis	Purple Flag	0.4										purple	Aug to Dec or Jan	Rhizomatous, tufted perennial, herb,	Grey-brown sand or sandy clay, red-brown clayey loam, gravel, laterite, ironstone, granite, limestone. Winter-wet areas, dunes, granite outcrops.
Trachymene coerulea	Blue Lace Flower	0.5										blue/white/purple	Oct to Dec or Jan to Mar	Erect annual or biennial, herb	Sand, loam, granite, laterite, limestone, ironstone.
GRASSES															
Sporobolus virginicus	Marine Couch	0.1										green-purple	Jan to Dec	Rhizomatous, soliniferous, tussocky perennial grass	White, yellow or brown sand, clay, peat, often saline. Beach dunes, tidal flats, salt marshes.

APPENDICES

2. TIPS FOR REVEGETATION SUCCESS

These are some key recommendations to ensure revegetation success:

- Use native species that are indigenous to the area;
- Place plant orders at least 9 to 12 months in advance to ensure plants are available and of sufficient size at time of planting;
- Within localised areas of groundwater seeps and surface water runoff focus on species best suited to those conditions: e.g. *Baumea juncea*. While *Baumea juncea* tolerates some salinity it is not suitable for lower embankment planting or on the islands where species such as *Juncus kraussii* and *Gahnia trifida* are more suited;
- Use native species with variable root depths to provide better stability.

Enhance plant survival by:

- Ensuring proper site preparation, such as weed control, addition of water absorbing cyrstals / soil conditioners, jute or coir matting are used or mulch (~50mm in the areas that are not subject to flooding);
- Selecting right species for the right location – this includes correct zonation of species based on geohydrological conditions and vegetation structure;
- Planting in the correct season (e.g. upland plants in winter (June – August) and sedges/ lower banks at the end of spring and in summer (October to December),
- Planting to correct depth and undertake watering to ensure plant establishment;
- Planting at higher densities and with a broader range of species to increase root mass and depth and allow more diverse ecosystems to develop;
- Ensuring regular maintenance and weed control are undertaken by qualified and experienced operators;
- Irrigating (temporarily) newly planted areas in summer/ months of low rainfall to establish plants and minimise plant losses;
- Ensuring access to foreshore/ jetties and other infrastructure is maintained and prevent/ minimise informal access;
- Installing tree protection guards. This is best done for a selected number of plants (not all plants) so as to minimise plant damage;
- Ensuring that planting is done in a strategic manner to reduce river view obstruction, vandalism and trampling of vegetation while maintaining stability of the banks. This can be done by planting more densely in areas that are not accessed by the public, planting in spaces between each building viewshed, maintaining access to foreshore that limits damage, installing temporary fencing etc.

Removal of existing exotic vegetation such as introduced grasses, trees shrubs and herbs to plant native species may not be warranted in every situation. Introduced grasses can provide a stable transition from the river to shore where the eroded bank is less than 0.2 m high and is most suitable for areas of high frequency access.

Grasses and other exotic vegetation should be removed only a short time prior to revegetation with native plants and/or materials that would limit erosion such as coir or jute matting installed.

Regular monitoring and maintenance is crucial in the native species establishment to limit costs associated with repeated planting and improve the amenity value of the landscape.

Monitoring should occur frequently during establishment to ensure adequate conditions for plant establishment. Taking a set of photographs and notes on a monthly basis in the first year followed by quarterly monitoring would be recommended.

Maintenance may include:

- Weed control
- Supplementary planting to replace any dead or missing plants
- Removal of tree protection bags
- Removal of refuse (debris deposited by river flows)
- Watering
- Fencing repair or installation.

3. STABILISATION RESPONSE CONSIDERATIONS
MANAGED RETREAT - REVEGETATION

Advantages

- Increased bank stability via diverse root structures and root tensile strength;
- Increased potential to trap sediments and decrease erosion;
- Increase in biodiversity with associated benefits for humans (e.g. shade, carbon sequestration, physical and emotional wellbeing etc.);
- Visual amenity, adaptable to climate change; and
- Low cost method of foreshore stabilisation.

Disadvantages

- Protection of vegetation from trampling and other damage is required which will increase cost;
- Restricted viewsheds to the river (where housing present); and
- Restricted river access.

Design considerations

– The success of revegetation is dependent on the following:

- Careful planning including site analysis, confirmation of the most appropriate species list and species distribution with regards to hydrozoning and natural occurrence of specific species;
- Site preparation including weed control, erosion control matting and management of potential acid sulphate soils; and
- Monitoring and ongoing maintenance.

Installation

- Site preparation and revegetation do not require expensive materials and equipment nor highly skilled labour if supervised and planned correctly.
- Site preparation works should be undertaken in autumn prior to winter planting.

Management

Assuming all efforts are taken in site preparation and selection of plant species most appropriate to site, the most important factor to revegetation success is regular maintenance including watering during plant establishment and regular weed management.

Supplementary planting and access control play a major role in plant establishment .

For further details and tips on revegetation management please refer to Appendix 2.

3. STABILISATION RESPONSE CONSIDERATIONS
BIOENGINEERING

Advantages

- Small footprint;
- Has flexibility to curve around banks and vegetation;
- Natural look to the river banks once vegetation is established;
- Light in weight, easy to transport, install and is adaptable to climate change;
- Biodegradable with a medium lifespan (7 - 15 years). Brush material can be grown locally and harvested every 3 – 4 years;
- Increased bank stability via revegetation of bank slopes;
- Increased potential to trap sediments and decrease erosion;
- Increase in biodiversity through plant establishment.

Disadvantages

- Brush material may not be available on short notice;
- Brush material needs to be wired in bundles of suitable length for installation – this can be time consuming, but does not require highly skilled labour; and
- Frequent maintenance is required to ensure no undercutting or loss of brush logs occurs.

Design considerations

- Careful planning including site analysis, particularly river bathymetry, and water levels including tides and flood regimes so that the brush wall is positioned accurately;
- Site preparation including weed control, matting, presence of dredge fill material and acid sulphate soils;
- Confirmation of the most appropriate species list and species distribution with regards to hydrozoning and natural occurrence of specific species; and
- Monitoring and ongoing maintenance.

Installation

- The installation of a silt curtain prior to commencement of works is needed to ensure no shoreline sediment enters the river during works;
- The installation of brush walls can be done by unskilled personnel; however, the supervisor must have training and experience in installing brush walls;
- Works should be undertaken at low tides and during the optimum planting times to allow for revegetation to be conducted directly after coir logs are installed. Normally this would be at the end of spring or start of summer to allow for sedges, rushes and other aquatic plants to establish; and
- Upland planting should be conducted in winter (June – August).

Management

To ensure long term usage and amenity of the brush walls, these should be inspected regularly as part of an ongoing maintenance program. The following tasks should be executed:

- Ensure that brush logs are firmly wired to hardwood stakes and do not become loose;
- Remove river debris caught in brush walls periodically especially during winter months, after major storm events or stream flows;
- Weed control and supplementary planting to replace any dead plants.

3. STABILISATION RESPONSE CONSIDERATIONS REVETMENTS

Advantages

- Flexible to shape of river banks;
- Adaptable to climate change – layout can be altered as required;
- Softer form of hard engineering that looks slightly more natural than hard walling; and
- Increased bank stability for a medium to long term.

Disadvantages

- Large footprint required for installation;
- Likely scour to adjacent soft edges;
- Low amenity value particularly when improperly constructed or if miscellaneous materials used; and
- Limestone rock is not naturally occurring along the Murray River; hence amenity value of the river is reduced.

Design considerations

- Careful planning including site analysis, particularly river bathymetry, sediment bearing capacity (to ensure rock stability), slope grade and height and the water levels including tides and flood regime;
- Site preparation including weed control, acid sulphate soils management, slope regrade of infill (if required) and sequence of works;
- Geotextile type and rock size including core and armour rock size. The thickness of more than one rock is required to allow for wave energy dissipation and to reduce scour. Rock sizes of between 200 mm to 400 mm can be effective in most situations;
- Civil engineer and marine engineer input required; and
- Monitoring and ongoing maintenance.

Installation

- Installation of a silt curtain prior to start of works is needed to ensure no shoreline sediment enters the river during works;
- Skilled labour experienced in building revetments should be engaged for installation as placement of rock (e.g. three points of contact placement) is crucial to its function and stability.

Management

- Revetments require regular biannual or post flood event inspections to identify any areas of potential damage. Maintenance generally involves:
- Ensuring no rock is loose or missing and geofabric is protected and in good order;
- Remove river debris caught on the rocks;
- Remove any weeds that may establish amongst rocks (this includes turf runners that may spread over the rocks).

3. STABILISATION RESPONSE CONSIDERATIONS WALLING

Advantages

- Visual amenity may be considered high;
- Low footprint;
- High durability; and
- Ability to be constructed manually.

Disadvantages

- Creates (near) vertical banks;
- Drainage issues behind walls when overtopping occurs due to high flood levels or boat wake;
- Wave reflection may exacerbate erosion of the adjacent foreshore (both upstream and downstream);
- A rigid structure which has limited capacity to accommodate differential settlement;
- Wave reflection will adversely affect small vessels and kayaks if travelling in close proximity to wall; and
- Limited revegetation opportunities.

Design considerations

The wall design is strongly dependant on site conditions with wall height and width determined by engineering design, with consideration of:

- River bathymetry, low and high mean water levels;
- Adjacent river banks stabilisation and impact of walling on the adjacent structures (upstream and downstream);
- Calculation of earth loads surcharges and hydraulic loads;
- Sediment transport and undercutting;
- Management of acid sulphate soils (if applicable); and
- Drainage requirements.

Installation

- This is a specialist construction subject to engineering design and certification

Management

- Properly installed retaining walls should require little or no maintenance.
- Timber walls can also be installed in areas where the use of rock is low to add to the natural feel of the site. The life span of a timber wall is lower than that of the limestone revetment or limestone wall and requires more maintenance.

4. MATERIALS TO AVOID

Materials mentioned below may induce failure or further foreshore degradation regardless of how well the installation is planned or implemented; subsequently these materials should not be incorporated into any of the proposed designs:

- Metal sheets, tires, crushed concrete or building rubble and other waste material (e.g. glass, tiles etc);
- Concrete blocks or reinforced concrete walls;
- Geotextile alone, carpets or plastic sheets;
- Cables to hold down materials on banks;
- Woody debris such as short logs particularly if not secured; or
- Coir logs on banks with any flow current (coir logs can be used in low impact areas only).