Guideline 1: The strategic planning process

Primary benefit

- The strategic planning process addresses catchment-wide issues in a logical, integrated and cost-effective way.

Other benefits

- Helps management agencies in budgeting and planning resources.
- Helps proponents of projects in the catchment see how their projects contribute to overall catchment objectives.

What is it?

- A strategic review assesses all issues related to the priorities of the management agency. Categories covered include:
  - Geophysical (soil conservation, bank stability, salinity and acid sulfate soils)
  - Hydrological (river flows, flooding and water quality)
  - Ecological (biodiversity, wildlife habitats and weed control)
  - Cultural (heritage, recreation and scenic resources)
  - Social (community involvement, employment opportunities and environmental education).
- As part of the strategic review, management strategies are developed that address the issues, and project proposals are costed. Also, priorities are set for implementing strategies and a schedule is developed for their implementation.

Guidelines

- Ensure that catchment management addresses the full range of issues (including biodiversity, water quality, soil conservation and cultural values) and identifies actions and priorities.
- Define a community consultation program that effectively involves all individuals and organisations with a legitimate interest in the outcomes of the planning process.
- Develop and implement a Strategic Planning Process (similar to the one in Figure 11) that incorporates both spatial and chronological dimensions.
- Ensure that rehabilitation works in the catchment are planned with an overall view to ensure that:
  - The most urgent issues are addressed first
  - Projects complement each other and contribute to an overall knowledge base
  - Individual actions contribute to the achievement of a long-term vision for the whole catchment.

Limitations

- Total catchment management requires an overall view of management issues. There may not be enough information to effectively address all issues.
- Identifying these issues can delay the initiation of projects, leading to community frustration in the short term.

Table 3 – Sources of historical information for streams in NSW

Location	Information held	Comments
Lands Department	Portion plans	Contain vegetation information and comments on available surface water.
	Bridge surveys	Occasionally nothing at all except the types of trees used as portion markers.
	Surveyors' field books	Invaluable for assessing changes in channel structure, i.e. width, depth.
	Parish maps	Show portion numbers, boundaries and first property owner.
	Aerial photographs	Recent photos for inspection.
	Topographic maps	Date back to 1940s. Problems include delays and poor indexing.
Mitchell Library, Sydney	Maps, books, letters, journals, picture files, laser disk photographs, newspapers.	A lot of information kept here, but there is a certain amount of 'pot luck' in finding it.
State Library of NSW, Sydney	Books, journals, newspapers.	The best place for looking up newspapers.
Archives Office of NSW, The Rocks, Sydney/Kingswood.	Maps field notebooks, journals.	
Land Titles Office, Sydney	Portion plans.	All on microfilm.
Bureau of Meteorology, Sydney	Rainfall data - monthly means; Daily temp., wind, frost etc data from most stations.	Length of records for daily data generally less.
DIPNR	Aerial photographs, records of stream work.	
AUSLIG	Aerial photographs.	
National Library of Australia, Canberra.	Books, journals, maps, newspapers, early aerial photographs, oral histories	
Historical societies.	Newspaper clippings, letters, journals, photographs	Often hold unexpected information, but very 'hit and miss'.
Local museums and libraries.	All sorts of information.	

Source: Brierley et al (1996), based on Herron (1993).

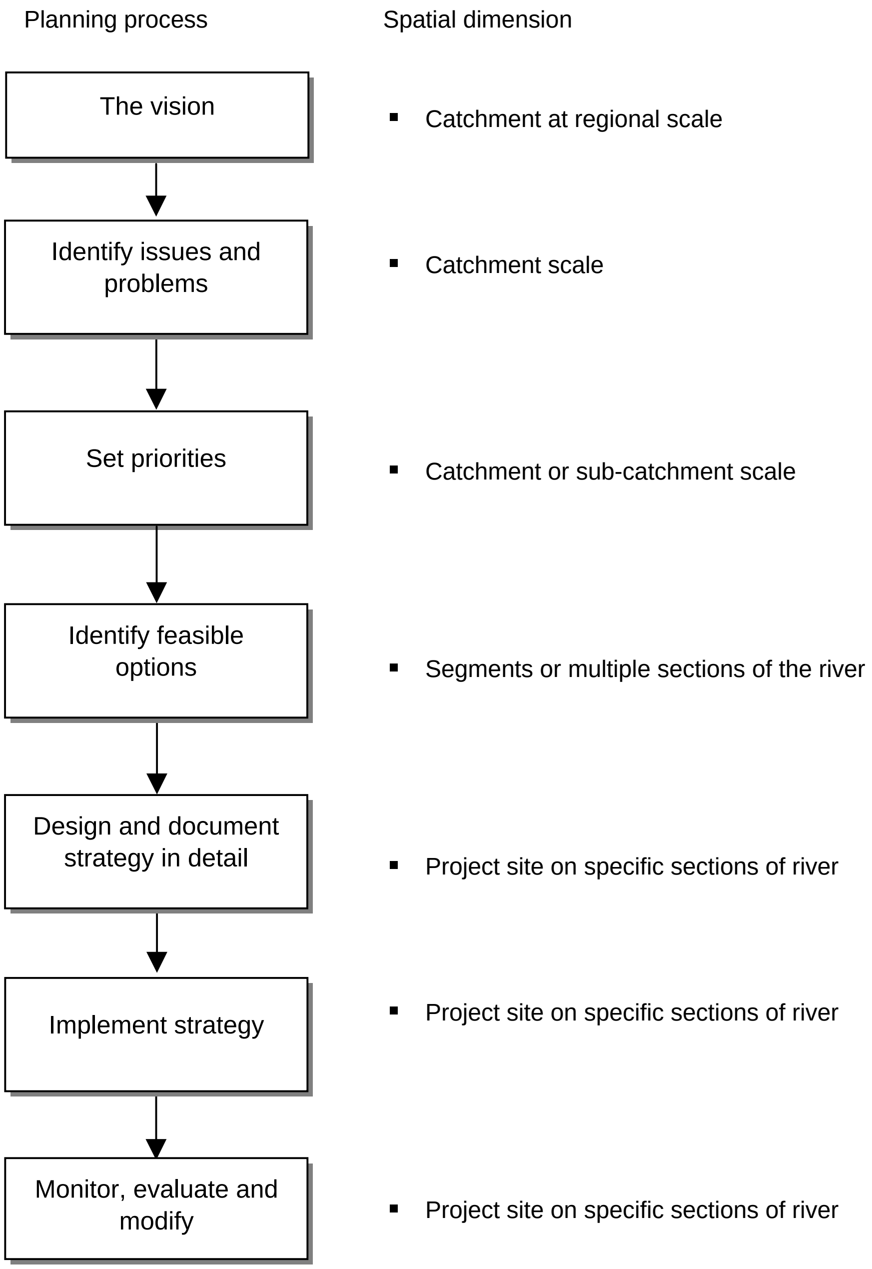
Information sources

- Department of Infrastructure, Planning and Natural Resources: www.dipnr.nsw.gov.au. Particularly work relating to regional land use planning in the Georges River catchment and Botany Bay.
- Historical information (see Table 3).
- Managing Urban Stormwater — Soils and Construction, NSW Department of Housing, 1998.
- Acid Sulfate Soil Manual, Acid Sulfate Soil Management Advisory Committee, 1998.

Materials

- A strategic review involves making systematic assessments of regional and site-specific issues. These are done by ecologists, geomorphologists and engineers.
- Strategic planners develop an action framework in association with natural resource economists.
- A wide range of legislation applies to strategic planning and management throughout the Georges River catchment.
- The following legislation is mostly applicable to riparian management (note - background information on a number of these acts can be found in Appendix A):
  - *Catchment Management Authorities Act 2003*
  - *Crown Lands Act 1989*
  - *Environmental Planning and Assessment Act 1979*
  - *Local Government Act 1993*
  - *Native Vegetation Conservation Act 1997*
  - *Rivers and Foreshores Improvement Act 1948*
  - *Soil Conservation Act 1938*
  - *Water Administration Act 1986*
- The following legislation may also be applicable:
  - *Coastal Protection Act 1979*
  - *Coastal Protection Amendment Act 1998*
  - *Commons Management Act 1989*
  - *Fisheries Management Act 1994*
  - *Forestry Act 1916*
  - *Irrigation Act 1912*
  - *National Parks and Wildlife Act 1974*
  - *Protection of the Environment Operations Act 1998*
  - *Rural Fires Act 1997*
  - *Rural Lands Protection Act 1989*
  - *Threatened Species Conservation Act 1995*
  - *Water Act 1912*
  - *Water Management Act 2000*
  - *Wilderness Act 1987*

Figure 11 – Suggested process for strategic planning



Management and monitoring

- A key component of the natural resource management reform program announced by the NSW Government in October 2003 is the establishment of Catchment Management Authorities (CMAs). This is based on the recommendations provided in the Final Report by the Native Vegetation Reform Implementation Group, chaired by the Right Honourable Ian Sinclair AC (DIPNR, 2003).
- It is proposed to set up 13 CMAs across the state including a Sydney Metropolitan CMA to cover the Sydney Harbour and Botany Bay catchments.

- CMAs will be constituted as statutory authorities with a responsible and accountable board and will report directly to the Minister for Infrastructure, Planning and Natural Resources.
- It is proposed that the- Sydney Metro CMA will prepare a Catchment Action Plan that will incorporate and build on the Catchment Blueprints developed by the former Southern Sydney and Sydney Harbour Catchment Management Boards. The aim of a blueprint is to:
  - provide strategic direction for natural resource management on a catchment-wide basis
  - identify, prioritise and set targets for management actions
  - cover issues relating to foreshore management.

Guideline 2: Defining the riparian area

Primary benefit

- Defining the riparian area gives a clear definition of the extent of 'streams' and 'rivers' for the purposes of the Rivers and Foreshores Improvement Act 1948.

Other benefits

- Identifying the riparian area facilitates planning and management that restores and maintains riparian values.

What is it?

- The riparian area is defined as the part of the landscape adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within them. It includes the stream banks and a strip of land of variable width along the banks.
- Identifying and mapping the riparian area involves aerial photography combined with field checking to accurately determine boundaries. It needs to address a range of issues including the need for environmental corridors and open space linkages, terrestrial and aquatic habitats, bed and bank stability and water quality.

Limitations

- Often complexities arise when it comes to defining the width of the riparian area. This is because of the diversity of environments that are riparian, the transitional nature of the boundary between these non-riparian environments and the objectives trying to be attained. Resolution of these complexities requires a multi-disciplinary approach.
- How much the riparian area directly influences the aquatic ecosystems of the adjoining section of river or creek varies with the seasons and climatic cycles

Guidelines

- Undertake an assessment to map riparian area widths for the watercourses and wetlands throughout the Georges River catchment.
- Map the existing and potential biological corridors along each watercourse.
- Identify and map existing and potential links between riparian and other remnant native vegetation, including linkages to reserves, to enhance regional biological connectivity.
- Identify and map existing constraints to linkages. These may include roads, stream crossings, railway lines, electricity easements and pipelines that sever and fragment connectivity along the riparian area.
- Engage an experienced ecologist to determine the minimum riparian corridor width. This should take account of fauna species using the corridor, connectivity potential, geomorphological stability, the watercourse, and site conditions such as flooding and sea level rise, predicted to be up to 0.2 m over the next 50 years (CSIRO, 1998).
- Along watercourses classified as stream orders of 3 or greater (by applying the Strahler Method) the recommended minimum width (measured from the top of the bank) is 40 m.

- Along watercourses classified as stream orders of 1 or 2, as well as wetlands, a minimum riparian area width of 20 metres is recommended on either side of the stream or surrounding the wetland.
- The minimum riparian area width should be extended to include any adjoining remnant native vegetation.
- In tidal areas the riparian area width should be measured from the top of the high bank (or from the point of tidal influence as determined by an ecologist) and should take into account the soil and vegetation types and available survey information.

Information sources

- Department of Infrastructure, Planning and Natural Resources (2004). Riparian Corridor Management Study: Covering all of the Wollongong local government area and Calderwood Valley in the Shellharbour local government area. This study provides general principles and processes for defining and managing riparian land.
- DIPNR has mapped the riparian area for the upper Georges River catchment. Contact DIPNR’s Parramatta office (phone: 9895 6211) for further information.

Guideline 3: Managing water quality

Primary benefit

- Managing water quality contributes to a healthy river system that supports natural ecological functions while allowing appropriate community uses.

Other benefits

- Avoids pollution of the waterways and Botany Bay and associated public health risk.
- Allows all forms of water-based recreation and aquaculture

What is it?

- Water quality in the Georges River system can be defined in terms of a combination of biological, chemical and physical characteristics.
- The Australian and New Zealand Environmental and Conservation Council (ANZECC) has defined water quality standards in the Australian Water Quality Guidelines for Fresh and Marine Waters that form part of the National Water Quality Management Strategy.
- Water quality is influenced by natural characteristics of the catchment (geology, soils, vegetation, and climate) as well as land use and development (agriculture, urban development, industrial uses, mining) and storage and removal of water for part of Sydney's water supply.
- The main sources of pollution affecting water quality in the river system include:
  - Stormwater run-off from urban areas, roads and roofs (metals, oils and greases), residential land and open space (nutrients and pesticides) and construction and building sites (sediments).
  - Wet-weather sewer overflows (nutrients).
  - Contamination of land and sediments from landfills and industrial areas, (metals and toxic organic compounds).
  - Stormwater run-off from rural areas (nutrients and microbiological).
  - Dry-weather leakage from the sewerage system (nutrients and microbiological).
  - Illegal discharges and stormwater run-off from industrial premises (various contaminants).

Guidelines

- The Draft Report on the Independent Inquiry into the Georges River-Botany Bay System, produced by the Healthy Rivers Commission of NSW (Oct 2000), identified the current water quality condition of the river system and the primary factors impacting on it. The primary recommendations of the Commission are summarised here to provide a strategic framework for implementing foreshore improvement works in the catchment.
- To protect natural areas:
  - Defer the decision to remove the O'Hares Creek catchment from lands owned and protected by the Sydney Catchment Authority (SCA).
  - Transfer pockets of crown land containing high conservation upland swamps to the DEC.

  - Place planning restrictions on mining and extractive industries that threaten the O'Hares Creek catchment and the Woronora Dam catchment.
  - Manage crown land on urban fringe areas to a standard comparable to that required of private landholders and local councils.
  - Manage Commonwealth lands, particularly Holesworthy military lands, to acknowledge their relationship to Heathcote National Park, SCA drinking water catchments, the Woronora River estuary corridor lands, the Georges River Open Space and Scenic Protection corridor and the Georges River State Recreation Area.
  - Obtain state government assistance to restore land that is reverting to Aboriginal ownership where that land was degraded while under crown ownership and management.
- To protect riparian corridors:
  - Rehabilitate and manage urban streams with a focus on protecting the natural stream ecosystem (although modified to varying degrees), which should be integrated with stormwater management plans by local councils.
  - Ensure urban redevelopment proposals include an appropriate mix of regulation incentives and partnership opportunities to improve the environmental and visual amenity of waterways.
  - Incorporate measures that aim to maintain natural values of urban streams within any new urban development.
  - Ensure there is channel management or flood mitigation works within existing urban development to protect the ecological, geomorphological and hydrological values of the drainage corridor.
  - Identify opportunities and implement works to enhance or rehabilitate waterways that are currently channelised and/or degraded.
  - Establish mechanisms to prevent further alienation of foreshore lands, such as those along the Georges River between Harris and Mill Creek. This includes lands along the tributaries in these areas.
- Carry out planning and control of development at a broad strategic level in relation to the location of development within the catchment and associated environmental impacts. This should also be done at a site-specific level.
- Use the Georges River Regional Environmental Plan (REP) to provide councils with a uniform set of rules to assess development proposals.
- Ensure individual councils control the potential impacts of development by requiring soil and water management plans and attaching conditions to development applications when approved.
- Carry out management of stormwater within the framework of the stormwater management plans prepared by councils in accordance with Section 12 of the Protection of the Environment Administration Act 1991. (Plans have been prepared for the Upper, Middle and Lower Georges River, Liverpool Area, Prospect Creek, Saltpan Creek, Woronora River).
- To improve stormwater management:
  - Ensure that integrated management of sewage and stormwater is made obligatory by specifying appropriate licence conditions within the regulatory programs of the Department of Environment and Conservation.
  - Clarify and strengthen accountability for stormwater management by establishing clearer distinctions between 'local area' management goals and broader goals that apply across the whole metropolitan area.

  - Clarify and strengthen the accountability for stormwater management of the Roads and Traffic Authority (RTA) (particularly in relation to the contribution of vehicles to stormwater pollution) and the Rail Infrastructure Corporation (RIC) particularly in relation to the contribution of litter and weeds along railway corridors).
  - Review funding mechanisms for urban stormwater management to ensure that costs are more appropriately shared among groups that contribute to the problem, particularly stormwater pollution generated by vehicles and road run-off (a portion of revenues from vehicle related taxes should be allocated to stormwater management).
  - Increase community awareness and understanding of stormwater management by providing relevant information with council rates notices and in annual reports.
  - Conduct independent audits of stormwater management.
  - Recognise stormwater management costs in new development proposals that identify cumulative impacts on waterways, provide for regular monitoring as well as installation and maintenance of stormwater management facilities.
- Establish an integrated framework for managing the sewerage system to achieve closer coordination of Sydney Water's sewer overflow and stormwater management programs.
- Ensure that waste management in the catchment is related to existing and former landfill sites that are potential sources of pollution in the river system.
- To maintain environmental flows in the river:
  - Commence releases from Woronora Dam (as recommended by the Commission's Expert Panel), monitor the results and adjust the releases over time as necessary.
  - Incorporate the requirements for the releases from Woronora Dam into the water management licences issued to the SCA by the Department of Infrastructure, Planning and Natural Resources (DIPNR).
  - Review water extraction and farm dam licences issued by the DIPNR on Bardwell, Bunbury Curran, Bow Bowing, Cabramatta, O'Hares, Prospect, Clear Paddock and Orphan School creeks, as well as the upper Georges River.
- To ensure water quality is improved enough to allow primary recreation contact (swimming) throughout the river system and Botany Bay:
  - Protect aquatic ecosystems in O'Hares, Stokes, Punchbowl, Williams, Harris and Deadmans creeks, the Woronora River sub-catchments, the main section of Georges River, throughout Botany Bay and any other creeks where natural river conditions exist or can be restored.
  - Protect and manage modified aquatic ecosystems in other areas of the catchment that are subject to urban development.
  - Continue to supply high-quality water in the upper Woronora River, enough to supply a safe and reliable source of drinking water with appropriate treatment at the Woronora water filtration plant.
  - Continue to provide water suitable for recreational, industrial and agricultural uses in the upper catchment (Cabramatta, Bunbury Curran, Bow Bowing, O'Hares, Prospect, Clear Paddock and Orphan School creeks, and upper Georges River).
- Ensure these water quality improvements are achieved through integrated programs. It should be acknowledged in the programs that achieving one objective will rely on achieving others (e.g. protecting aquatic ecosystems requires protecting

existing natural areas, protecting and/or restoring riverside vegetation, maintaining natural channels, and protecting low flows and water quality).

Limitations

- The following limitations on the accuracy and extent of water quality data available for the Georges River system were noted by the Healthy Rivers Commission:
  - Multiple agencies (at least a dozen) collecting water quality data with very little coordination of timing, location, indicators used or methods of collection.
  - Severe limitations on using data in a statistically valid way.
  - Not all data being readily available to the public or even other collecting agencies.
  - The data collection programs not being adequately structured or related to the needs of planners and others responsible for management decisions, in respect to water quality or integrated river health.
- The Georges River Water Studies Database review, prepared by Carla Gonossin in November 1996, noted major deficiencies in the data available. Particular note was made of the sources, circulation and effect of water pollutants and the role of aquatic macrophytes and fauna and the effects of pollutants on them.

Information sources

- Healthy Rivers Commission of NSW (2000) ‘Independent Inquiry into the Georges River — Botany Bay System’, Draft Report, October and Final Report, September 2001. Prepared by the.
- Healthy Rivers Commission of NSW (1999) ‘Independent Inquiry into the Woronora River System’, Draft Report.
- Australian and New Zealand Environment and Conservation Council, 2000
- Department of Environment and Conservation (incorporating the NSW Environment Protection Authority) ‘Water Quality and River Flow Interim Environmental Objectives’, www.dec.nsw.gov.au.

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Guideline 4: Ecological restoration and remediation projects – planning and implementation

Primary benefit

- Ecological restoration projects restore and maintain biodiversity values and the health of restored ecosystems. They also enhance wildlife habitat values.

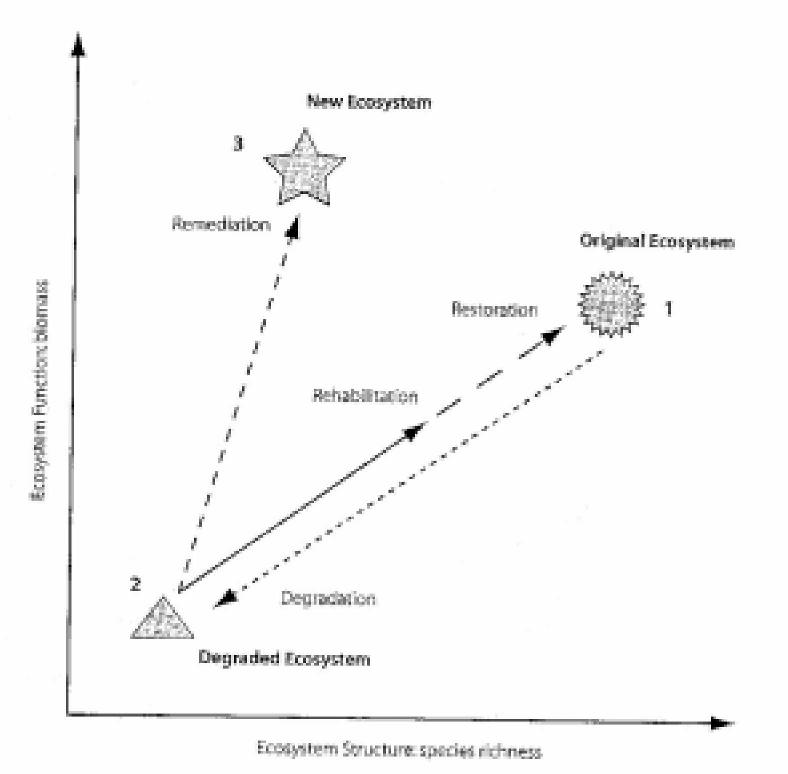
Other benefits

- This guideline shows how to plan and implement projects to minimise the risk of omissions and inappropriate works and to make the best use of available resources. These measures significantly increase the probability of achieving successful outcomes for the projects.

What is it?

- ‘Ecological restoration is the process of assisting the recovery and management of ecological integrity. Ecological integrity includes a critical range of variability in biodiversity, ecological processes and structures, regional and historical context, and sustainable cultural practices’ — Society for Ecological Restoration (1998).
- The aim of ecological restoration is to re-establish a functional ecosystem of a predefined type that has enough biodiversity to continue the maturing process via natural processes and to evolve in response to changing environmental conditions over the longer term.
- There are three types of projects — restoration, rehabilitation and remediation. Restoration involves re-establishing an ecosystem to a high ecological integrity. To do this, rehabilitation is used. Sometimes, due to fundamental changes to environmental conditions, it cannot be restored and a new ecosystem will need to be created; this is remediation (see Figure 12 below, from A Rehabilitation Manual for Australian Streams, Vol 1, LWRRDC, 2000).
- Ecological restoration at a project site aims to improve ecological community structure and restore and maintain the richness of both fauna and flora species to achieve a condition similar to a substantially undisturbed site.
- Success of the ecological restoration process is generally measured by comparing the site to a similar but undisturbed reference ecosystem located nearby.
- Remediation may include any of the following:
  - Repairing a damaged ecosystem.
  - Creating a new ecosystem of the same kind to replace one that has been entirely removed (e.g. in a mining area).
  - Creating another kind of regional ecosystem to replace one that was removed from a landscape that was irreversibly altered (e.g. due to urban development).
  - Creating a replacement ecosystem where an altered environment can no longer support any previously occurring type of regional ecosystem (e.g. at former landfill sites).
  - Creating a replacement ecosystem because no reference ecosystem exists to serve as a model for restoration (e.g. areas that have been densely populated for centuries and all remnants of the original ecosystems have been obliterated).

Figure 12 – Restoration, rehabilitation and remediation



Limitations

- The aims of ecological restoration cannot always be achieved. This is often due to the severity of disturbance and degradation, or a lack of adequate resources. Projects that produce ecological benefits but cannot achieve the aims of ecological restoration should be referred to as rehabilitation.
- If a reference ecosystem is not available near the site, then evaluating the success of the project will be difficult and subjective.
- Even if a reference ecosystem is available, that ecosystem itself is likely to have changed over time.
- Planning, implementing and monitoring ecological restoration and remediation depends on the involvement of an ecologist with extensive knowledge of the ecosystems being restored.
- Restoration and remediation works need to be carried out by people with adequate knowledge and skills to avoid damage to the remnant vegetation and wildlife habitat values of the ecosystem.

Guidelines

- A Strategic Plan is essential for determining how feasible it is to carry out ecological restoration and remediation in a particular area.
- The Strategic Plan should incorporate enough information to allow an informed decision to be made about the feasibility and resources required to successfully complete the project. It should identify:

  - The project site boundaries.
  - Ownership and zoning.
  - The need for ecological restoration.
  - The type of ecosystem to be restored.
  - The goals of restoration that relate to social and cultural values.
  - Physical site conditions (e.g. slope, soil type, depth to groundwater table).
  - The factors causing stress on the ecosystem (e.g. fires, weed invasion, poor water quality).
  - Biotic factors that need to be reintroduced (e.g. plants or animal species) or removed (e.g. weeds).
  - Landscape restrictions both present and future (e.g. adjoining land uses that are incompatible with restoration, or poor water quality that may be created by upstream land uses).
  - Funding sources.
  - Human and physical resources required.
  - Approvals and permits required.
  - Load restrictions on the land within the site.
  - Project duration and staging.
  - Long-term protection and management of the site.
- As a guide, the following preliminary tasks should be carried out before starting a restoration project:
  - Involve a restoration ecologist with specific knowledge of the ecological system being restored.
  - Assemble a team that includes people with the necessary skills and experiences.
  - Prepare a budget that includes a series of stages.
  - Document the existing conditions and ecological values of the site.
  - Document the site history and factors that have led to the need for restoration.
  - Collect baseline data such as water quality and flow rates, over a period of time if required.
  - Identify a reference ecosystem nearby that will allow the success of the project to be evaluated.
  - Gather information about the recruitment (i.e. population reproduction cycle), maintenance and reproduction of key species, and if necessary carry out trials and tests before starting restoration.
  - Carry out trials to test the effectiveness of any untried restoration techniques that may be proposed for the project.
  - Determine if the proposed restoration goals are realistic, and modify them if necessary.
  - Prepare a list of objectives designed to achieve the restoration goals.
  - Secure all approvals and permits that may be required.
  - Establish liaison with relevant government authorities and other organisations.
  - Plan and implement a program of community awareness, consultation and involvement.

  - Install infrastructure, such as access tracks, storage areas, power and water supplies.
  - Engage staff to supervise and carry out the restoration works.
- A Project Implementation Plan is needed that describes how the restoration will be carried out. As a guide, the Implementation Plan should:
  - Describe the works that will be implemented to achieve each of the stated objectives.
  - Define performance standards for assessing the project's success.
  - Schedule the restoration works, identifying tasks required to achieve each objective.
  - List the resources to be procured, including equipment, supplies, plant material and other materials.
  - Define the boundaries of the project area and install signs and/or fencing as required.
  - Outline requirements for installing monitoring components, such as permanent transect lines.
  - Explain the restoration tasks to carry out (with adequate supervision and involvement of a project ecologist).
- As a guide, follow-up tasks should include:
  - Protecting the project from vandals, pests and inappropriate access and use of the site.
  - Maintenance works, including erosion repair, weed control and public access control.
  - Regular site inspections by the project ecologist to assess the effectiveness of the restoration and to identify any modifications that may be required.
  - Monitoring in accordance with the program as defined in the Implementation Plan.
- Evaluating the project should include:
  - Assessing the monitoring data in relation to the defined performance standards.
  - Describing the components of the restored ecosystem that are not covered by monitoring data.
  - Evaluating the level of success in achieving the restoration goals.
  - Publishing the results of the project to contribute to the body of ecological restoration knowledge and to assist others doing similar projects.

Information sources

- Clewell A, Rieger J and Munro J (2000) Guidelines for Developing and Managing Ecological Restoration Projects. Available on the Society for Ecological Restoration website, www.ser.org.
- NSW Government Blue Mountains Urban Runoff Control Program, (2003*)* Bush Regeneration: A Practical Guide to Contract Management, DIPNR, Sydney.

Guideline 5: Assessing habitats and species

Primary benefit

- Habitat and species assessment ensures an accurate description of existing species composition and wildlife habitat types.

Additional benefits

- It provides a baseline against which the results of ecological restoration and remediation (see Guideline 4) can be assessed.

What is it?

- Habitat assessments describe the condition and significance of habitats in relation to the flora and fauna species in each habitat type. They include assessments of:
  - In-stream vegetation and snags as habitat for fish
  - Riparian vegetation as habitat for terrestrial and water birds
  - Stream corridors as habitat for woodland or grassland fauna, and
  - Identification of rare or threatened species or communities.
- Sometimes exotic vegetation (e.g. blackberries and lantana) may provide habitat for native fauna, such as birds and bandicoots. In such cases restoration works should minimise habitat disturbance by providing a gradual transition from exotic to native vegetation.
- Habitats should be assessed when considering management issues or when restoration works are being planned.

Purpose

- To improve habitat values.
- To protect habitats from impacts of nearby works.
- To describe the elements of a functioning habitat as an example for restoration works elsewhere.

Limitations

- Habitat assessments are limited by the time available and the cost to carry them out.
- Although the best assessments are usually done by trained ecologists, there is also an important role for both rapid assessment (coarse information for catchment-wide decision-making) and community-based environmental monitoring. This also applies to guidelines 6–18.
- General trends in habitat use will develop in regions, so it is important to collate assessment information in a database and to use the information to simplify future assessments.

Information sources

- Ausrivas website, www.ausrivas.canberra.edu.au, NSW Sample and Processing Manual.
- DEC (Department of Environment and Conservation), www.dec.nsw.gov.au:
  - Threatened species conservation (including lists)
  - Biodiversity survey and monitoring (field guides and identification references).
- Biodiversity of the Georges River catchment, DIPNR website, www.dipnr.nsw.gov.au.

Materials

- Existing databases include
  - Distribution of habitats
  - Distribution of rare or threatened species or communities
  - Habitat requirements of flora and fauna.

Guidelines

- Carry out assessments during the planning stage of restoration projects.
- Engage a suitably qualified and experienced ecologist to carry out the assessment. If necessary, engage specialist ecologists to deal with specific fauna and flora species.
- Ensure that all available relevant information is obtained and assessed before designing the field survey program.
- Ensure the habitat and species assessment is carried out in accordance with all relevant legislation, as well as DEC guidelines.
- Adopt field survey procedures that are generally accepted by ecologists.
- Ensure that data analysis is scientifically rigorous and the conclusions can be readily understood by community representatives.

Management and monitoring

- Results of assessments carried out by councils and other organisations within the Georges River catchment should be made available to DEC and the Sydney Metro Catchment Management Board so they can be used to assist ongoing management decisions.

Guideline 6: Riparian buffer areas

Primary benefit

- Riparian buffer areas will reduce impacts on the Georges River and tributaries by processing stormwater run-off and absorbing ‘edge-effects’ on ecology, including the impacts of public access ways.

Other benefits

- Reduce erosion.
- Stabilise stream banks.
- Provide wildlife habitat
- Provide shade to reduce water temperature in adjoining sections of waterway.
- Improve aesthetic values.

What is it?

- The riparian buffer area is a strip of land that is “sacrificed” to protect the riparian area itself from the impacts pollutants, nutrients and other edge effects.
- The vegetation includes a ground cover of grasses and herbs, together with a ground litter layer. This slows surface run-off and filters out sediments and pollutants before they enter the river and affect water quality.
- A buffer area may consist of remnant vegetation or new plantings of vegetation, including trees, shrubs and groundcover.
- It reduces the amount of phosphorous, mostly transported as an attachment to sediments, entering the river.
- It also reduces the amount of nitrogen, mostly transported in soluble form in stormwater run-off, entering the river.
- It increases the rate of water infiltration into the soil to assist groundwater recharge and plant growth through improved soil moisture.
- Riverside trees provide shade, reducing water temperature to assist the survival of fish and other aquatic species.
- Leaves and other fallen organic matter and invertebrates provide food for many species that are critical to the aquatic food chain.
- Tree logs and branches falling into the river provide habitat for many aquatic organisms.
- Vegetation in the buffer area provides habitat for birds and other wildlife and may provide linear corridor connections for wildlife.
- Grass mowing should be limited to intensive recreation areas and sporting fields. Most foreshore community open space should not be mowed, or mowed at higher to allow a buffer area to grow, with potential for the natural regeneration of local native vegetation.

Limitations

- The amount of filtering of sediments in the buffer area depends on how much the run-off velocity is reduced, allowing sediment to be deposited. The buffer area may not be able to slow the flow rate enough for very fine silt, suspended in the stormwater, to be deposited.

- To be effective in trapping sediments the flow of run-off needs to be shallow, uniform and slow, to disperse it evenly throughout the buffer area.
- Run-off containing nutrients and sediments may adversely affect the growth of native vegetation in the buffer area.
- Where possible, run-off containing high levels of nutrients and sediments should be directed through vegetated swales or wetlands to improve water quality before entering the riparian zone.
- Livestock and public access to the zone should be controlled to stop groundcover damage.
- The exact form and width of the vegetated buffer area is dependent on the slope, substrate material and available space between existing development and the waterway.
- Stormwater run-off should not be channelised but dispersed to maximise the effect of surface vegetation in filtering sediments and nutrients. It is important to take account of the tolerance of the riparian vegetation to absorb water and nutrients without compromising the ecological integrity of the community.

Materials

- Planting trees and a groundcover layer will be required where the original vegetation has been cleared and replaced with exotic grasses.
- Management and planting may be required to create an effective groundcover.
- Remnant vegetation with a groundcover including native grasses is preferable.

Guidelines

- Assess the stormwater run-off pattern of the area and identify overland flow from turf-covered slopes and landscaped areas that directly enter the river.
- Determine the extent to which grass-lined swales or constructed wetlands could be established to improve run-off quality before entering the buffer area.
- Implement these water quality improvement mechanisms where possible.
- Implement works to distribute surface run-off evenly into the buffer area.
- Implement bushland regeneration in sections of remnant native vegetation adjoining the river.
- Plant where needed to establish indigenous vegetation in the buffer area.
- Implement measures such as off-line flood detention basins and rainwater tanks. This will reduce run-off and flood risk so that healthy riparian zone vegetation is not compromised when flooding problems caused by urban development and vegetation clearing need to be solved.
- Ensure that calculations for flood modelling assume that vegetation in the riparian zone is fully structured (i.e. contains trees, shrubs and groundcover).
- Plan revegetation works in areas of urban development to be compatible with flood management requirements.
- Determine an effective width for the buffer area, taking account of location, erosion potential, length of slope and gradient of slope. Typically buffer areas range from 10 m to 60 m or more in width. Ensure the buffer area is wide enough to prevent transported sediments entering the river.
- Figure 13 gives an example of a riparian buffer area.

Information sources

- Karssies LE and Prosser IP, 'Guidelines for Riparian Filter Strips for Queensland Irrigators', CSIRO, www.clw.csiro.au/publications/technical99.
- Riparian Land Management Technical Guidelines Vol 2, LWRRDC, 2000, Ch 2.
- Urban BM, 'Water Related Best Management Practice in the Landscape', Watershed Science Institute, US Department of Agriculture, http://gneiss.geology.washington.edu.
- 'Stormwater Management for Parks and Gardens', DEC website, www.dec.nsw.gov.au.
- Land and Water Resources Research Development Information, www.rivers.gov.au, Publications, Fact Sheet 3 — Water Quality.

Guideline 7: Managing estuary habitat

Primary benefit

- Managing estuary habitat enhances aquatic biodiversity values.

Additional benefits

- Improves aesthetic values.
- Enhances fishing values.

What is it?

- The lower reaches of the Georges River provide an estuarine habitat for a wide variety of aquatic life, including fish, molluscs, invertebrates, birds, mangroves, reeds and trees. These depend on the intertidal environment of the estuary, which includes:
  - Intermediate salinity
  - Access to the sea and upper reaches of the catchment
  - Tidal movement.

Purpose

- The estuary habitat is linked to habitats upstream and downstream and is a major part of the biodiversity of the catchment.
- Estuaries provide nursery grounds for fish as well as feeding and breeding grounds for wetland birds and sea birds. They provide access for fish that migrate between the upper catchment of the river and the sea.

Limitations

- Mangroves and mudflats, which generally have high biodiversity, may be affected by public access and recreation activities along estuary foreshores.
- Recreation activities, particularly boating, limit the extent to which aquatic biodiversity may be restored and protected.
- Reduced quality of stormwater run-off from urban development areas impacts on estuary habitat values.
- Estuary habitats often contain acid sulfate soils, which can affect the aquatic environment if disturbed.
- Assessing the potential presence of acid sulfate soils is needed before any works are carried out that involve soil disturbance in the estuary zone.
- Sea level rise means that estuary habitats will have to move inland.

Guidelines

- Promote estuary habitats by preserving the variety and value of the in-stream and riparian habitat. Habitat promotion should include preserving and enhancing:
  - A variety of vegetation types, including seagrass, mangroves, reeds and riparian trees
  - A variety of substrates, including soft sand and mud sediments, rocky shores and snags
  - Water quality
  - An environment that is not subject to harmful disturbance from boats, dredging and filling.
- Protect mangroves and mudflats in the estuary by controlling foreshore facilities, including construction of sea walls, boat ramps and marinas.
- Protect seagrass beds from damage from dredging, boating, submarine cables and other infrastructure.

Management and monitoring

- The hydrodynamics of the estuary needs to be better understood through a program of monitoring and research, as recommended by the Healthy Rivers Commission Draft Report (see above). This would include water quality monitoring in the estuary area of the Georges River, Woronora River and Botany Bay.
- Integrated planning controls are needed on a catchment-wide basis to prevent further degrading of estuary habitat values by physical disturbance (dredging, filling, infrastructure, construction) and reductions in water quality.
- Restoring estuary habitat that has already been degraded by inappropriate land use is needed to re-establish a sustainable level of ecosystem health.

Information sources

- Native Fish Australia, www.nativefish.asw.au.
- NSW Fisheries Policy and Guidelines, Aquatic Habitat Management and Fish Conservation (1999).

Guideline 8: Wildlife corridors

Primary benefit

- Wildlife corridors help restore and protect biodiversity and the exchange of genetic material between major habitat remnants.

Additional benefits

- Reduce erosion.
- Improve water quality.
- Provide local wildlife habitat.
- Moderate local climate

What is it?

- A wildlife corridor is a strip of native vegetation or nodes of vegetation that link major remnants, such as national parks, conservation reserves and areas of native vegetation on private land. Wildlife corridors can be horizontal as well as vertical. Fauna needs to move from water to the land (horizontal corridors) and also from riparian land to hill tops (vertical corridors). The requirement for wildlife corridors should be incorporated when defining and mapping the riparian area.

Purpose

- To assist in avoiding local extinctions of native plants and animals that may result from insufficient genetic diversity and to allow migration after local extinctions. This will help sustain populations during periods of stress (e.g. insect attack, fires etc).
- To encourage the migration of animals between major vegetation remnants.
- To assist genetic material exchange through transfer of native seeds/pollinators.

Limitations

- Fragmentation can reduce biodiversity if remnants are too small to sustain animals with a large home range. The extended ‘edges’ of corridors can aid weed invasion.
- Feral predators such as foxes and cats can hunt native animals more effectively because there is limited vegetation cover along corridors.
- Some native animals may not use corridors as part of their habitat.

Information sources

- Riparian Land Management Technical Guidelines Vol 2. LWRRDC, Ch. F.
- DEC website, www.dec.nsw.gov.au.
- Biodiversity of the Georges River catchment, DIPNR website, www.dipnr.nsw.gov.au.

Materials

- Remnant vegetation along watercourses, especially if a broad riparian zone is included.

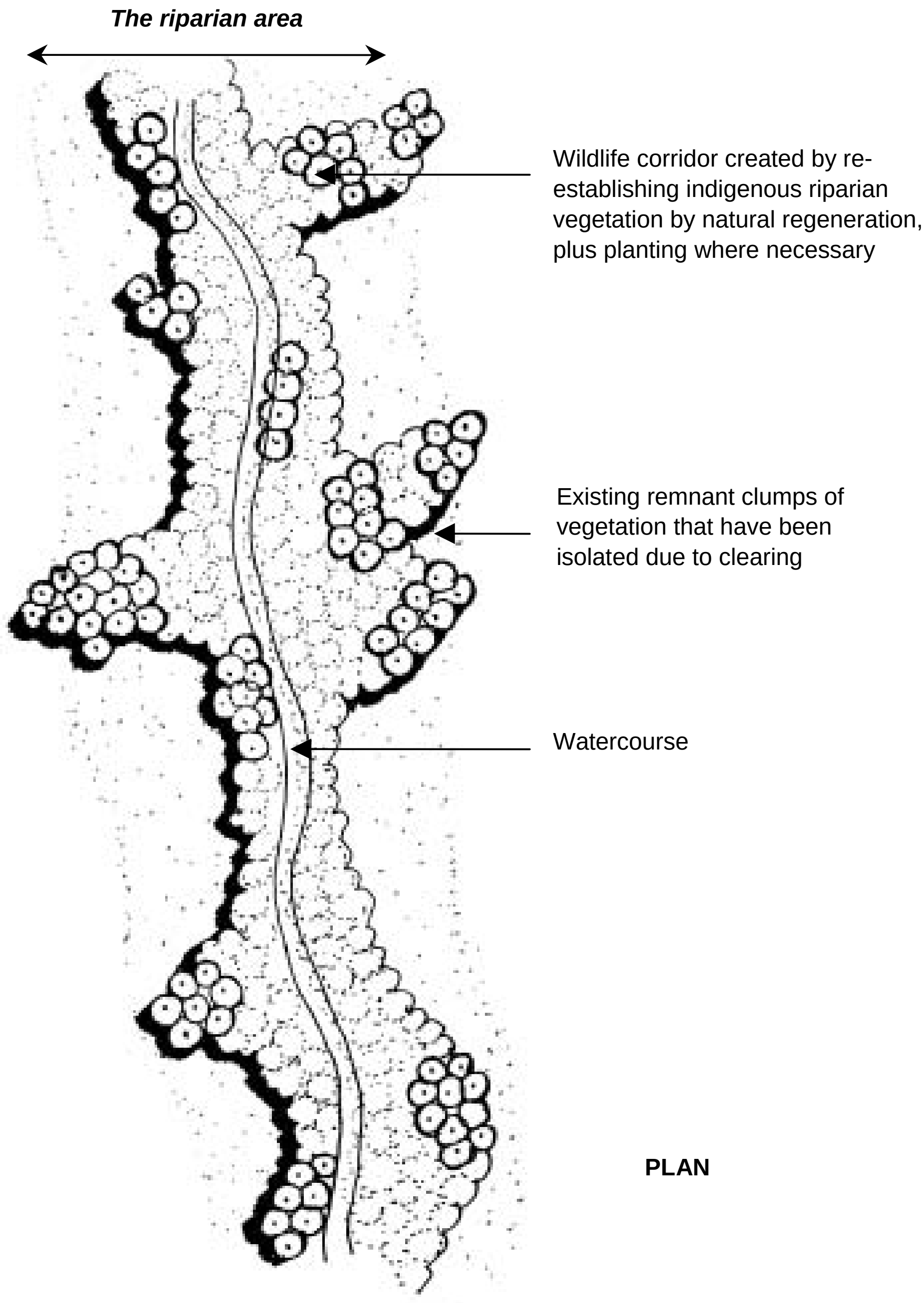
Guidelines

- Engage a wildlife biologist familiar with native fauna and their habitat requirements to help plan the establishment and/or restoration of wildlife corridors.
- Clearly identify the species that use or may use the corridor, and find information on how they might use it (feeding, breeding, movement, shelter).
- Determine to minimise effective width of the corridor in relation to the wildlife species that will use it as a habitat and how they will use it. Width may vary from 20 m along minor drainage lines to several hundred metres. A minimum width of 40 m on either side of a major watercourse is recommended.
- Maximise connectivity between remnant stands of vegetation, and across the total area or width of the wildlife corridor.
- Implement a weed control program to maximise the success of natural regeneration and any supplementary planting in the corridor.
- Plant indigenous native species only where natural regeneration will not be able to re-establish vegetation structure that existed before clearing.
- Plant the full range of species that existed before clearing, including ones that form the habitat of wildlife using the corridor. Establish the appropriate vegetation structure.
- Manage the corridor for different stages of vegetation that relate to different fauna groups and species.
- Retain and/or add dead trees and woody debris to provide habitat for invertebrates, reptiles, amphibians, birds and small mammals.
- Create corridor linkages between major habitats by making the greatest use of existing remnant native vegetation.
- Maintain the genetic integrity of the vegetation in the corridor by encouraging and managing natural vegetation and planting with material collected or propagated from remnant indigenous species.
- Develop a revegetation program to fill in the gaps between patches of remnant vegetation.
- Figure 14 demonstrates how to establish a wildlife corridor.

Management and monitoring

- Carry out a baseline survey of vegetation and fauna at the start of any restoration works to allow assessment of their effectiveness over time.
- Monitor corridors for:
  - Use by native fauna, including native birds, bats, arboreal and terrestrial mammals, and reptiles.
  - Invasion by weeds, which should be controlled, especially if they are absent in the major remnants.
  - Feral animal numbers, particularly for animals that pose major threats to native fauna.
  - Changes to plant species composition and vegetation structure.

Figure 14 – Establishing a wildlife corridor



Guideline 9: Rare or threatened species management strategy

Primary benefit

- Strategies for rare and threatened species assist to manage biodiversity.

Additional benefits

- Protects cultural and aesthetic values.
- Threatened species tend to be surrogates for other ecosystem values. By protecting the threatened species the rest of the ecosystem will generally be protected.

What is it?

- The strategy involves a review of rare and threatened native plants and animals present in the catchment. This provides a basis for preparing a strategic plan for protecting and enhancing their habitats in catchment programs.
- Protecting rare and threatened species will prevent a significant reduction in biodiversity.
- Many threatened species are associated with watercourses and provide a basis on which projects can be prioritised.
- Priority may be given on the basis of regional issues, such as protection of reedy vegetation as nesting habitat for a specific threatened species, or for local issues, such as the protection of a rare plant in a specific location.

Limitations

- The habitat requirements of many species are poorly known, and may only be general.

Information sources

- DEC databases, www.dec.nsw.gov.au, Science & Research — Biodiversity Survey and Monitoring — Urban Bushland Biodiversity survey — Tables and References.
- Biodiversity of the Georges River catchment, DIPNR website: www.dipnr.nsw.gov.au.
- Recovery plans prepared under the *Threatened Species Conservation Act 1995*.
- State of the Environment Reports by councils in the Georges River catchment.

Guidelines

- Consult with the DEC to obtain a list of rare and threatened species in the relevant portion of the catchment and any applicable recovery plans.
- Consult the GIS database of known locations of species (DEC).
- Review and implement those actions in relevant recovery plans that may be applicable to the catchment.
- Obtain descriptions of habitat requirements of rare and threatened species not yet addressed in recovery plans.

- Engage an ecologist familiar with the rare and threatened fauna and flora species in the catchment (if not already addressed in applicable recovery plans).
- Ensure the ecological restoration strategy in the catchment (see Guideline 4) gives priority to conserving and enhancing rare and threatened species.
- Take action to protect existing populations, increase population size and promote suitable habitat.

Management and monitoring

- The Director-General of the Department of Environment and Conservation is required to prepare a Recovery Plan for each endangered and vulnerable species (other than a species presumed extinct), population and ecological community after it has been listed on Schedule 1 of the *Threatened Species Conservation Act 1995*.
- Public authorities and Councils identified in a recovery plan as responsible for implementation of measures identified in the plan must report on any action taken to implement those measures within its annual report in accordance with the *Threatened Species Conservation Act 1995*.
- Descriptions of habitat requirements of species covered by the management strategy should be revised as improved information becomes available, e.g. the management strategy should be linked to DEC databases to reflect the most recent information on the distribution of rare and threatened species.

Guideline 10: Designing constructed wetlands

Primary benefit

- Constructed wetlands bring improvements to the water quality of stormwater run-off from urban, suburban and agricultural areas.

Additional benefits

- Create aquatic habitat.
- Restore biodiversity.
- Create environmental education venues.
- Enhance aesthetic values.

What is it?

- Constructed wetlands are stormwater detention areas that improve water quality and provide wetland habitat.
- They do this by removing sediment, reducing bacterial contamination and reducing dissolved contaminant loads.
- They usually include a number of basins with reed beds that slow water velocity in order to extract polluting sediments.
- Open areas of water help remove bacteria through the action of sunlight.
- Reed beds assist in denitrification and entrapment of other nutrients.
- Wetlands can incorporate gross pollutant traps at inflow points but these require regular maintenance to remain effective.
- They include open water and reed beds, which provide habitat for fish, birds and other animals.
- Many constructed wetlands include visitor access and have a high aesthetic value.

Limitations

- To be effective, constructed wetlands generally need a large area. This may not be available where urban stormwater discharges into watercourses.
- They must be designed to fit into the landscape, to avoid the risk of public safety by drowning or access to polluted water.
- They must be effectively managed if they are to continue to improve water quality.
- They should be designed to have no adverse impact on flood behaviour on a catchment-wide basis.
- Lots of sun is required to sustain macrophyte growth in the wetland. Shading by trees and tall shrubs should therefore be avoided.
- Depending on the type and design, they can be very expensive.
- Figure 15 shows an example of a constructed wetland.

Information sources

- The Constructed Wetlands Manual, Vols 1 & 2, DLWC, 1998.
- Compensatory Wetlands: Discussion Paper under the NSW Wetlands Management Policy, DLWC, 2002.

Materials

- Wetlands are usually constructed from material on site.
- Contaminated soil cannot be used in wetlands if they are to improve water quality, and such soil may need to be removed.
- Topsoil may need to be imported for planted areas, or organic material may need to be added to available site soil, to create satisfactory growing conditions for macrophytes.

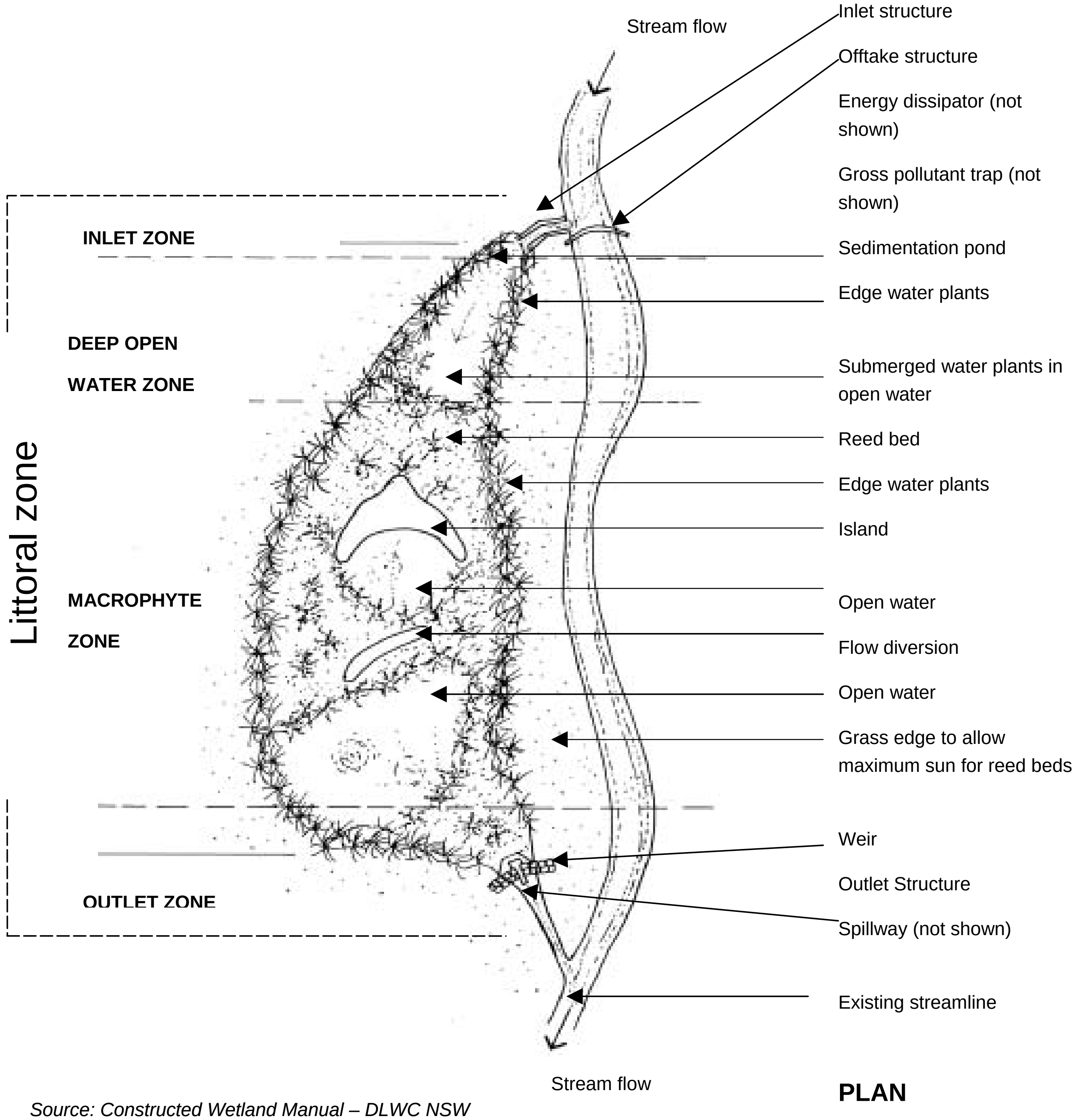
Guidelines

- Determine the priorities for the proposed wetland for each specific site (water quality improvement, aesthetics, habitat).
- Identify and define the water quality improvements to be achieved by the proposed constructed wetland.
- Assemble a multidisciplinary team to look at all issues. These may include hydrology, water quality, aquatic vegetation, aquatic micro and macro fauna, aesthetics, public access, recreation, environmental education, health and safety issues, and management.
- Decide on the size and shape of the basins based on the hydraulic characteristics of the sub-catchment, the space available and the design requirements.
- Establish a community consultation program during the planning and design process. This will ensure community involvement in deciding on a preferred option, setting priorities for implementation, and ongoing monitoring and management.
- Determine the most effective location for the constructed wetland, taking account of the stormwater run-off pattern, existing vegetation, public access, aesthetic issues and ecological values.
- Avoid locating wetlands in natural drainage lines, and preferably out of the riparian zone.
- Design the wetland, taking account of ecological, social, hydraulic, cost and maintenance factors.
- Design the wetland to take account of the full range of floods up to the PMF. This will minimise the risk to life and property from operation of the constructed wetland.
- Incorporate a mechanism for draining the wetland to allow maintenance, including removal of aquatic weeds.
- Submit the design for planning approval.
- Implement environmental management measures to minimise construction impacts.

Management and monitoring

- An ongoing monitoring program is essential to allow improvements to water quality to be assessed and additional measures to be taken if necessary to achieve the required water quality standard.
- Regular inspection is needed for detection and early eradication of aquatic weeds.

Figure 15 – a typical off-stream urban stormwater wetland



Source: Constructed Wetland Manual – DLWC NSW

Guideline 11: Constructed wetlands management plans

Primary benefit

- Constructed wetland management plans ensure the improvements to water quality provided by the wetlands are maintained.

Additional benefits

- Enhance and maintain wildlife habitat values and biodiversity.
- Enhance and maintain aesthetic values.

What is it?

- A Wetland Management Plan (WMP) provides a schedule of monitoring and maintenance actions to ensure that the required wetland performance is achieved and maintained.

Purpose

- WMPs monitor the performance of constructed wetlands against their design criteria and specify actions to achieve or improve performance.

Limitations

- Wetlands are often costed as a one-off activity, with no budget provided for ongoing monitoring and maintenance.

Information sources

- The Constructed Wetlands Manual, Vols 1 & 2, DLWC, 1998.

Materials

- A WMP should be developed as part of the wetland design process.
- It should be adopted and implemented by the wetland manager.

Guidelines

- Prepare a WMP for each wetland that covers:
  - Regular cleaning of gross pollutant traps.
  - Removal of rubbish overspilling gross pollutant traps.
  - Maintenance of structures and the integrity of flow paths.
  - Actions to manage contamination by toxic waste or hydrocarbons in the wetland.
  - Sampling flows and water quality at wetland inlet and outlet points.
  - Weed and pest fauna management.
  - Monitoring native flora and fauna.
  - Periodic removal of silt from detention basins.
  - A Health and Safety Plan that addresses issues such as hypodermic needles, visitor management and contaminated water.

- Ensure the WMP addresses all of the potential sources of pollution (see Table 4).
- Ensure the WMP prescribes actions to enhance wetlands, such as staged vegetation, and additional facilities for visitor use.

Management and monitoring

- Wetland performance data should be collected in a form that allows decisions to be made on wetland management and on the design of future wetlands.
- Monitoring should include periodic surveys of fauna and flora to assess biodiversity and the health of the ecosystem.

Table 4 – Type, source and impact of typical wetland pollutants

Type of pollutant	Source	Impact
Gross pollutants (organic and inorganic and sediments)	Street litter, leaf litter, construction sites and erosion	▪ Aesthetically unpleasing ▪ Chemical and biological breakdown releases pollutants ▪ Sediment smothers benthic organisms and plants and reduce biodiversity
Organic matter (DO, BOD)	Vegetation and sewage	▪ Leads to oxygen depletion, which results in the death of aquatic wildlife ▪ Efficiency of phosphorus removal is reduced
Nutrients (nitrogen and phosphorus)	Sewage, chemical spills, erosion, fertilisers and detergents	▪ Eutrophication and excess algal and macrophyte growth ▪ The ratio of orthophosphorus to particulate P is important in design
Trace metals (lead, cadmium, zinc, copper)	Stormwater, agricultural run-off, industrial and mine drainage	▪ Food chain contamination ▪ Accumulation in sediments ▪ Important if habitat enhancement is a major objective
Faecal coliforms	Sewage, animal droppings and septic seepage	▪ A public health risk
Oil/grease	Road surfaces, detergents, food preparation outlets and industry	▪ Oxygen depletion ▪ Surface scums and films
Organic compounds	Pesticides	▪ Accumulation in sediments and food chain ▪ Toxic poisoning of fish and molluscs ▪ Important for overall ecosystem and wetland health
Salinity (EC)	Groundwater inflows, soils, estuarine and industry	▪ May kill wetland plants and cause changes in species composition
Suspended sediments	Organic or inorganic substances, construction, land degradation, industry	▪ Light depletion ▪ Fish kills and destruction of invertebrate habitats ▪ Water temperature increases ▪ Smothers plants, benthic organisms

Source: The Constructed Wetlands Manual — DLWC NSW

Guideline 12: Managing snags and large woody debris

Primary benefit

- Effective management of snags and large woody debris (LWD) helps restore and maintain aquatic biodiversity.

Additional benefits

- LWD provides organic matter and algae as food for aquatic invertebrates and fish.
- Water flowing over snags can help reoxygenate the water to improve water quality.

What is it?

- Snags include LWD such as logs and branches that fall into rivers and streams to provide aquatic habitat for fish and aquatic invertebrates.

Purpose

- To manage LWD in a way that maximises its value for aquatic fauna while preventing the debris from contributing to bank erosion and affecting navigation.

Limitations

- The supply of LWD, which is dependent on trees and limbs falling into the river or stream, may be limited by the type of vegetation growing along the edge.
- Tree trunks and large limbs may pose a hazard during flood conditions if they are carried down stream into areas used by boats or to the estuary zone where there are jetties and other structures.
- LWD can form a hazard for boats and water skiers. A risk assessment is therefore needed to determine the feasibility and desirability of replacing LWD along sections of the river or stream.

Materials

- Anchoring tree trunks to prevent them from being swept away by floods may sometimes be required, and will involve the use of steel chains or cables.

Guidelines

- Contact the NSW Department of Primary Industries to discuss the potential removal or replacement of LWD along the edge.
- Determine the likely natural load of LWD that would have existed in the section of river or stream before it was cleared for agriculture land use and urban development. This is done by assessing sections of river or stream where disturbance has been minimal. If no information is available the general rule is that the volume of wood should be approximately 0.01 cubic metre of LWD for every square metre of river channel bed area.
- Restore an appropriate amount of LWD to sections of the river or stream where it has been removed.
- Do not lop or remove overhanging branches as they provide LWD.
- Figure 16 shows how LWD can be placed.

- Fallen timber, or tree limbs and trunks which must be lopped for safety reasons, can be placed at the base of the bank or aligned to flow to avoid eddy and flow deflection problems.
- Avoid using introduced species such as willow and artificial material such as old car bodies and tyres or concrete/clay pipes that do not contribute organic matter to the aquatic ecosystem.
- Where LWD needs to be restored to the river or stream, make sure it is not obtained from the riparian zone.
- When restoring LWD place it at a variety of locations, generally on the outside and downstream of bends.
- Place LWD at various orientations to the channel to create a variety of habitats. The maximum angle to the shoreline should be 40°.
- Place LWD so that branches extend into the water but are partly above the surface.
- Assess the need for anchoring the LWD. Anchoring can be achieved by burying part of the trunk into the bank and securing it to a fixed point some distance from the bank with steel cables or chain.
- Ensure that fences, bridge abutments and other structures on the edge are not threatened by localised scouring by LWD of the riverbed and banks. Provide adequate separation from the LWD.
- Commence LWD restoration in the river or stream before restoring the adjoining riparian zone.

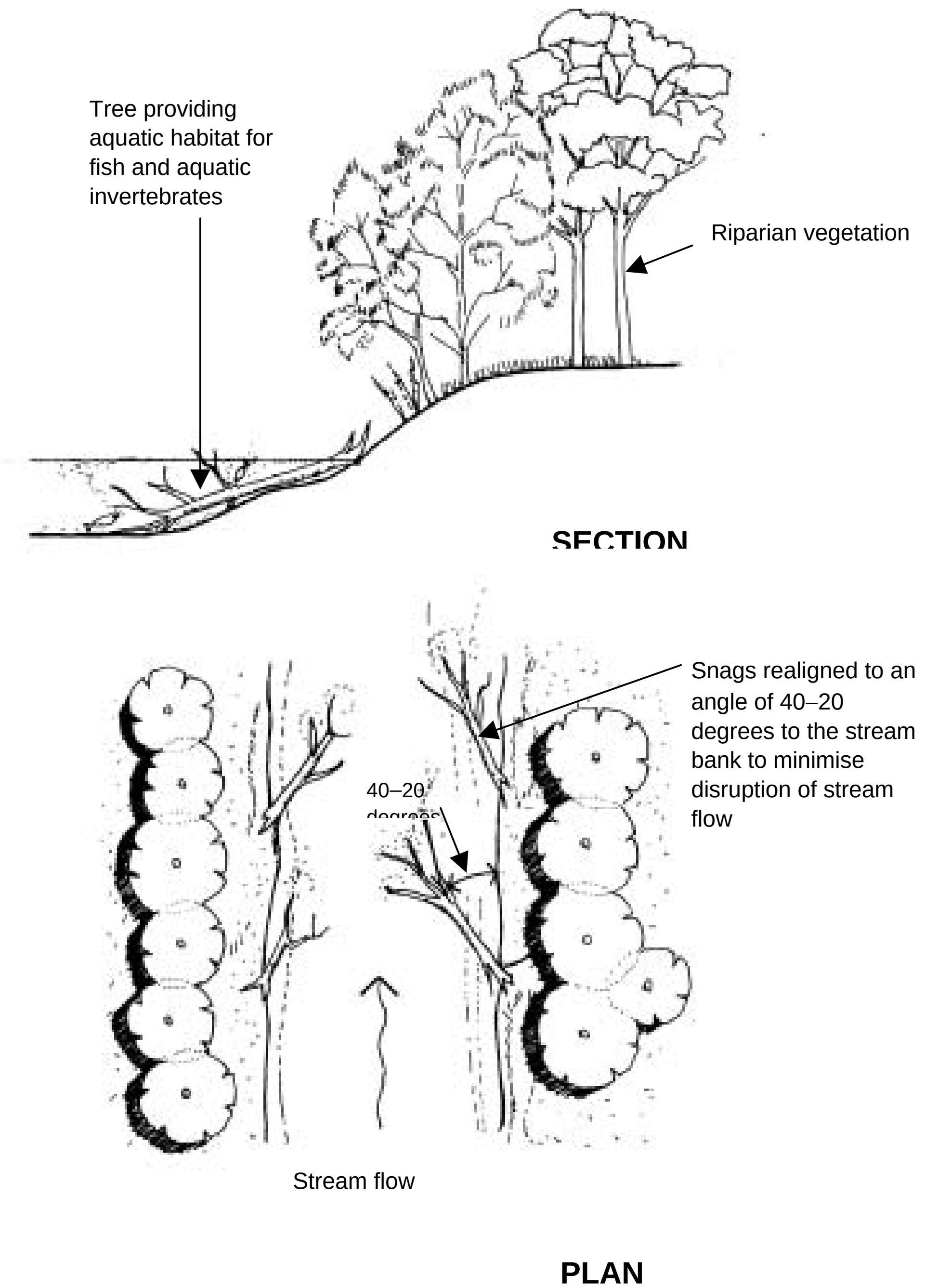
Management and monitoring

- Managing LWD realignment, reintroduction and/or removal should include a comprehensive assessment of the likely environmental impacts, and should be supported by hydraulic calculations.
- Monitoring should include regular inspections to identify any significant scouring that may result in riverbank instability.

Information sources

- Riparian Land Management Technical Guidelines, LWRRDC, 2000, Vol 2, Ch B.
- ‘A Rehabilitation Manual for Australian Streams’, Vol 2 (pp 72 and 313), LWRRSC, www.lwrrdc.gov.au.
- Managing Snags and Large Woody Debris, Rip Rap, Edition 16, 2000, LWRRDC.
- Managing Snags in Rivers, LWRRDC, www.rivers.gov.au.

Figure 16 – Snags and large woody debris



Guideline 13: Planning riverbank stabilisation

Primary benefit

- Effective riverbank (or stream bank) stabilisation planning helps protect assets such as open space, infrastructure and riparian zone vegetation on or near the riverbank.

Additional benefits

- Prevents loss of riverbank and associated reduction in ecological values.
- Involves the community in the planning process to set priorities.
- Ensures an opportunity to budget works over a number of years.
- Enhances ecological values through the application of ESD principles.
- Minimises public risk associated with vertical or steep embankments adjoining the river.

What is it?

- Riverbank stabilisation planning is an options decision process that will produce an integrated strategy for bank stabilisation works along eroding sections of Georges River and its major tributaries.
- It works through a mechanism called a 'decision tree', which provides stakeholders with a shortlist of foreshore protection options for the site based on hydrological considerations only.
- The decision tree assumes a basic level of understanding of hydrological processes, and some explanation is therefore needed to allow stakeholders to participate in making decisions.
- The strategy sets priorities and defines the most effective sequence of works.
- Community consultation allows local communities to get involved in setting priorities.
- The strategy defines the process of planning, design, documentation, approvals and implementation. It also identifies responsibilities for each component.

Purpose

- To provide a clearly defined decision process that will identify a strategy to carry out riverbank stabilisation works along sections of the river and major tributaries.

Limitations

- The level of information available on riverbank erosion occurring at specific locations will greatly influence the accuracy of the stabilisation planning.
- A diversity of responsibilities for implementing and maintaining riverbank stabilisation works may limit the ability to implement an integrated strategy.
- Riverbank stabilisation works can be relatively expensive compared to revegetation and other landscape works.
- Erosion of riverbanks is a natural process and it is unrealistic and undesirable to attempt to completely control it.

Information sources

- Riparian Land Management Technical Guidelines, LWRRDC 2000, Vol. 2 Chapter C.
- 'Water Related Best Management Practices in the Landscape', ftp://ftp.ftw.nrcs.usda.gov
- Raine and Gardiner (1995) provide a matrix for selecting the appropriate management option for riverbank protection based on the existing morphological and vegetation conditions.

Materials

- Information from detailed site investigations is needed. This includes geotechnical conditions, the geomorphological process of the river, flooding pattern, river profile and flow information.

Guidelines

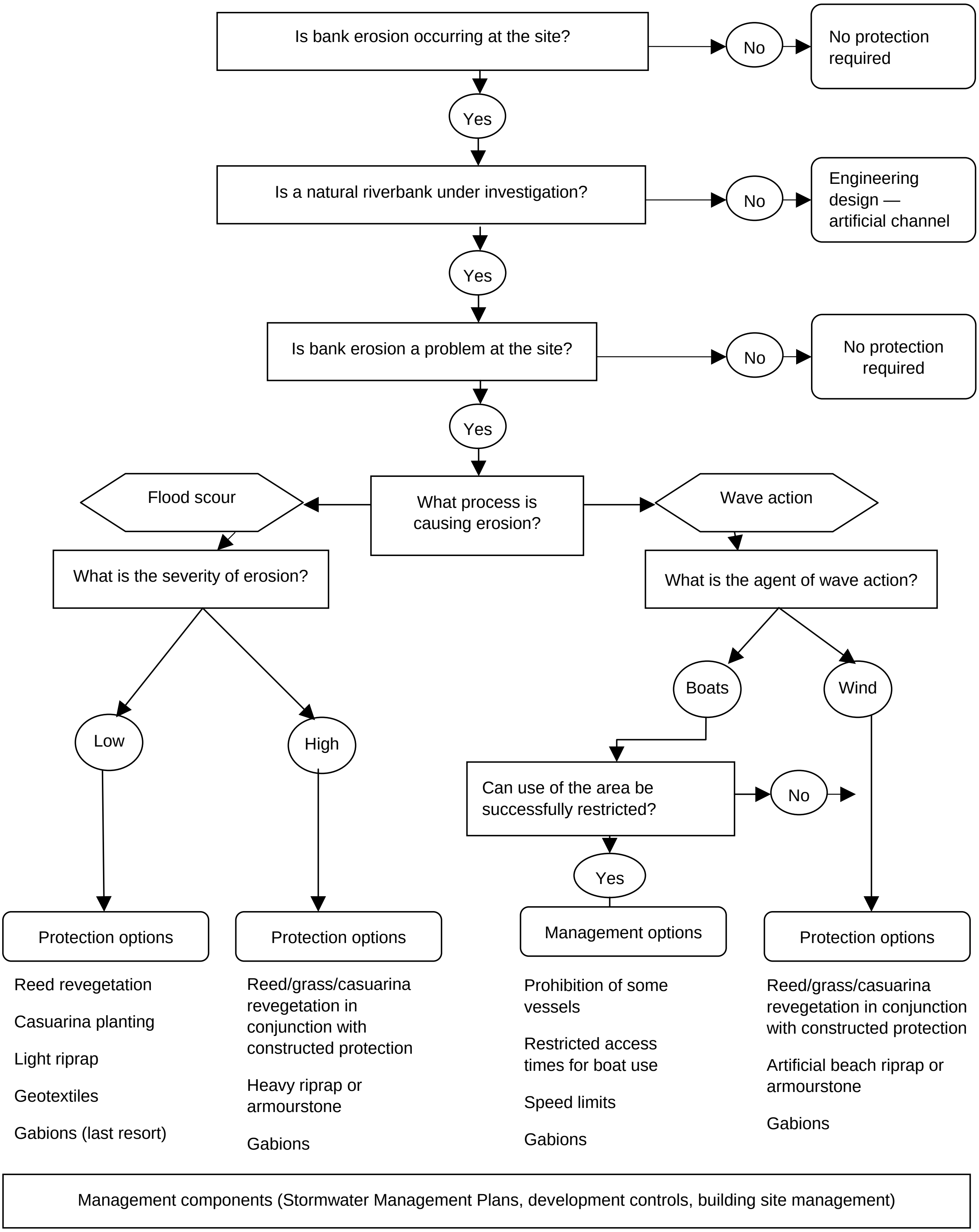
- Establish a program of consultation to allow local community members to be involved in setting priorities for the works.
- Follow the decision process diagram (Figure 17) to identify a range of potential options that would be suitable for each situation of the river. Gabions should be used only as a last resort as they can encourage weed growth (if they become filled with sediment), can interfere with vertical wildlife corridors and can be prone to vandalism and decay.
- Look at a range of feasible stabilisation options and determine the most appropriate.
- Take account of factors such as cost, material availability, aesthetics and ecological values when determining the most appropriate method of foreshore protection for each location.
- Address the three preliminary questions about foreshore protection works:
  - *Is bank erosion occurring at the site?* If erosion has occurred it may not necessarily continue — a new stable equilibrium (or regime) may be achieved. For example, bank erosion will stop when all of the erodable material below the water level has been removed and the bedrock is exposed. Equally, restrictions on boating activity or changes to the flow rate upstream may stop erosion. A clear understanding of fluvial processes at the site is required, together with enough time to observe and assess the processes over time.
  - *Is bank erosion a problem at the site?* Bank erosion may occur in situations where foreshore protection works would generally be unnecessary and uneconomical. In such cases it may be best to leave the bank to meander naturally, provided buildings, property or infrastructure are not threatened.
  - *Is the riverbank under investigation in a natural condition?* In areas where dredging of the river has already occurred or in constructed channels, the flow behaviour can differ substantially from that of a natural section of river. When bank protection is considered necessary, specialist professional skills are required to assess the situation and provide the most suitable management option, taking account of engineering, ecological, aesthetic and economic factors.
- Assuming the section of river channel being assessed is natural, the next step is to determine what is making the bank erode. This must be known before a stabilisation strategy can be finalised and implemented.

- If boat traffic is the cause of wave attack, then management and control (e.g. restricting use to weekends, designating areas where stopping and starting is prohibited) may be good options.
- Liaise with Waterways Authority to identify and assess options for managing boating and water skiing to reduce the erosion risk.
- Where protection works are needed, engage a hydrological engineer as a member of the design team, together with an ecologist and a landscape architect to address all relevant issues. Escarameia (1998) (Chapter 3) provides a thorough review of the design process, which consists essentially of three stages:
  - *Conceptual design:* evaluating the condition of the site under consideration, determining the impact of erosion control options and selecting the most suitable stabilisation treatment.
  - *Outline design:* collating detailed design information and defining predominant loads. Environmental, cost and accessibility factors need to be assessed and the most appropriate solution identified.
  - *Detailed engineering stage:* devising stabilisation works that are designed and specified in detail, defining maintenance requirements and costing the solution (for both capital and maintenance works).
- Consult with the DIPNR and NSW Fisheries to discuss options for riverbank stabilisation during the design process.
- Check the Total Catchment Management (TCM) Plan for the area before planning stabilisation works.
- Develop a Rivercare Plan incorporating any TCM requirements for the particular section of river.
- Adopt vegetative protection as the preferred option where possible. Only use constructed protection where the erosion is severe and the energy too high for a vegetation solution.
- Prepare detailed design documents for the stabilisation works where they are required.
- Obtain all approvals from the DIPNR, the relevant council and other authorities.
- Pre-tender suitable contractors with demonstrated experience in implementing similar stabilisation works.
- Implement project management arrangements to ensure close supervision of the works so that the design objectives are met and the environmental impacts are minimised.

Management and monitoring

- Set up a program of regular inspections by a qualified person to monitor the effectiveness of the works or management program, and implement remediation works if necessary.

Figure 17: decision process for protecting foreshores



Guideline 14: Protecting riverbanks with vegetation

Primary benefit

- Protecting riverbanks with vegetation helps retain ecological values while protecting buildings, infrastructure and open space against damage from bank erosion.

Additional benefits

- Maintains or restores biodiversity.
- Maintains a natural appearance along the river edge.
- Minimises cost compared to constructed solutions such as rip-rap or gabions.

What is it?

- Using vegetation to stabilise and protect banks is a form of bio-engineering that differs from conventional forms of engineering in two main ways:
  - Bio-engineering involves considerable practical experience and judgement, in contrast to the application of quantitative design theory or rules used in conventional engineering.
  - Careful management is required not only in the establishment of vegetation but also later, particularly during the initial growing seasons.
- Natural methods of protection generally have a lower capital cost compared to constructed protection, but ongoing costs may be higher.
- Current guidelines and manuals provide very general guidelines to bio-engineering techniques.
- Grasses aid bank stabilisation and flood scour protection by providing flow interference, soil surface cover, root reinforcement and soil restraint.
- The surface root structure forms a composite soil/root mat that increases the erosion resistance of the bare subsoil, which is anchored into the subsoil by deeper roots.
- Grass may be used in conjunction with a geotextile or a three-dimensional mat or grid to reinforce and form a composite protection of the bank.
- Pioneering work in this area was undertaken by Cornish et al (1969) and Yong and Stone (1967). Their work forms the basis for subsequent work.
- It was found that established grasses can withstand velocities of 3 m/sec for short periods and lower velocities for more extended periods.
- Grass is commonly used in bank protection operations in the zones above the normal water level. Most grass roots cannot however tolerate prolonged submergence.
- Grass may be eroded itself by the scouring of soil from plant roots, weakening its anchorage until the drag of flowing water or wave action removes it from the bank.
- Grasses can also fail when water flows through shrinkage cracks, piping or tunnels formed by burrowing animals, causing internal collapse.
- It is preferable to use indigenous native emergent and marginal aquatic plants for protection purposes along banks at the waterline. These plants can absorb current energy, encourage siltation and reduce the sediment-carrying capacity of the flow.
- Research from bio-engineering trials on the Murray River suggests that reeds, particularly Phragmites australis, are most effective in protecting banks where

erosion is caused by exposure of unstable sediments to wave action or currents. The trials also suggest that reeds cannot protect against bank slumping failures (Frankenburg and Tillard 1993).

Limitations

- Using vegetation alone for stabilisation is generally limited to a maximum slope angle of 1:2 (horizontal to vertical), depending on the nature of the soil material forming the bank. For steeper slopes vegetation needs to be combined with a stabilisation system such as three-dimensional mats or grids.
- Erosion forces at the toe of banks caused by flows and wave action are often too high for vegetation to provide adequate erosion protection, so more resilient forms of protection such as rip rap are required.

Information sources

- Department of Water Resources (DWR) (1993) provides a good introduction into bio-engineering applicability and options.
- Raine and Gardiner (1995) also provide a good introduction, with a greater emphasis on bio-engineering case studies and using native vegetation for riverbank protection.
- More detail about the information required prior to design and implementation can be found in Hemphill and Bramley (1989).
- Whitehead (1976) provides an outline of a suitability analysis and design approach. Other useful references include DCE (1990), Hemphill and Bramley (1989), Hewlett et al (1987), Raine and Gardiner (1995) and Temple et al (1987).
- Department of Land and Water Conservation Guidelines for the Hawkesbury Nepean River.
- Table 5 summarises the most recently published results of work in this field.

Table 5 – Effectiveness of reeds and seagrasses in reducing waves

Plants tested	Findings	Reference
Seagrass sods	Tests on a 1 m wide strip of seagrass meadow found a 40% reduction in wave height when total water depth was similar to the plant height.	Fonesca and Calahan (1992)
Seagrass *Thalassia testudinum* Marsh grass *Spartina alterniflora*	For waves ranging in height 13–23 cm, over a distance of 20 m wave heights were reduced by a maximum of 40% and wave energy by a maximum of 67% For waves ranging in height 1–4 cm, over a distance of 20 m the wave heights were reduced by a maximum of 71% and wave energy by a maximum of 92%.	Wayne (1976)
Emergent reeds	The ratio of transmitted wave height to incident wave height was 0.5–0.8 over 5 m meadow length and 0.6–0.8 for a 20 m meadow length.	Hall and Silander (1997)
Emergent reed stands	A vegetated zone eroded slower than a non-vegetated zone and most of the eroded sediment settled at the toe of the lower slope.	Delft Hydraulics (1993)
Artificial seaweed	Waves of periods between 2.6-8.2 secs were run over 21 m of bed. The 2.6 sec wave recorded a reduction in wave height of 12.5% and was the only wave to record significant reductions.	Ahrens (1976)
Wetland reeds *Phragmites australis* *S. lacustris*	Plant growth following wave attack found the mean stem height and density of *Phragmites australis* was unaffected by wave attack, unlike *S. lacustris* reeds, which were greatly reduced following wave attack. Erect dead stems of *Phragmites australis* were found to remain over several growing seasons and were found to support each other and divert wave forces protecting emergent plants Wave heights of 10 cm and 23 cm, with wave periods of 1.9 secs were run over the reeds. Average wave heights in the vegetated bank were between 80% and 137% of the incoming wave height, results that included the shoaling, reflection and attenuation of waves.	Coops et al (1996a & b)

Guidelines

- Prepare an Operational Plan as follows:
  - Select plants, which may be aquatic plants, grasses, shrubs or trees. Selecting should take account of the purpose of the vegetation, ecological values, environmental conditions (including soil and competing species), aesthetic values and maintenance requirements (for examples see Figures 18 and 19).
  - Determine soil requirements for plants which generally need soil depth of at least 0.5 m. Plant requirements of the soil (e.g. low compaction) should not conflict with soil slope strength and stability required to prevent erosion.
  - Consider establishment of vegetation, including methods of seeding, accessibility for equipment, and contingency plans if delays occur as a result of the seasonal nature of plant growth.
  - Set long-term management objectives and programs, which must be accepted by all parties involved to ensure the vegetation can fulfil its intended purpose.
  - Consult a geomorphologist and a geotechnical engineer to determine a riverbank cross-section profile and slope angles to provide an embankment stable enough to allow establishment of vegetation that can withstand erosion and provide stability.
  - Consult a qualified ecologist to determine the most appropriate combination of indigenous native plant species to provide riverbank protection so that restore biodiversity along the river edge can be restored.
  - Consult the DIPNR about the proposed stabilisation works to obtain the necessary approvals.
  - Arrange for propagation of indigenous native species vegetation for use in stabilisation works.
  - Complete detailed design and prepare tender documents for the works.
  - Pre-qualify contractors with proven experience in carrying out similar riverbank stabilisation works, and issue the tender documents.
  - Appoint the preferred contractor.
  - Program the works to minimise the risk of flood damage during the implementation period.
  - Carry out the works with regular site supervision to ensure successful completion and establishment of vegetation.

Management and monitoring

- Carry out regular inspections (monthly) during the first two years to ensure the vegetation is successfully established.
- Arrange for any repairs that may be needed as a result of flood damage or death of plants.
- Carry out ongoing inspections (minimum twice a year) after flood events and arrange any necessary repairs to riverbank works.

Figure 18 – Using vegetation to stabilise a low bank (with berm)

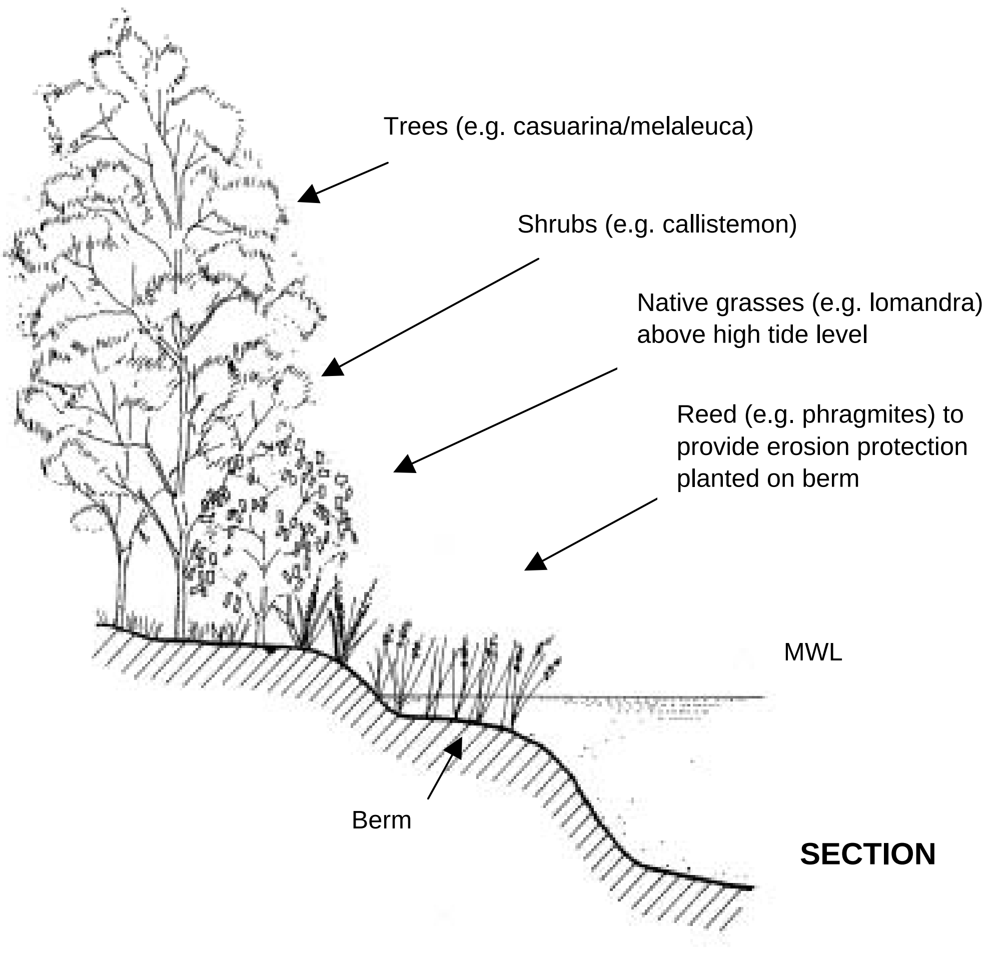
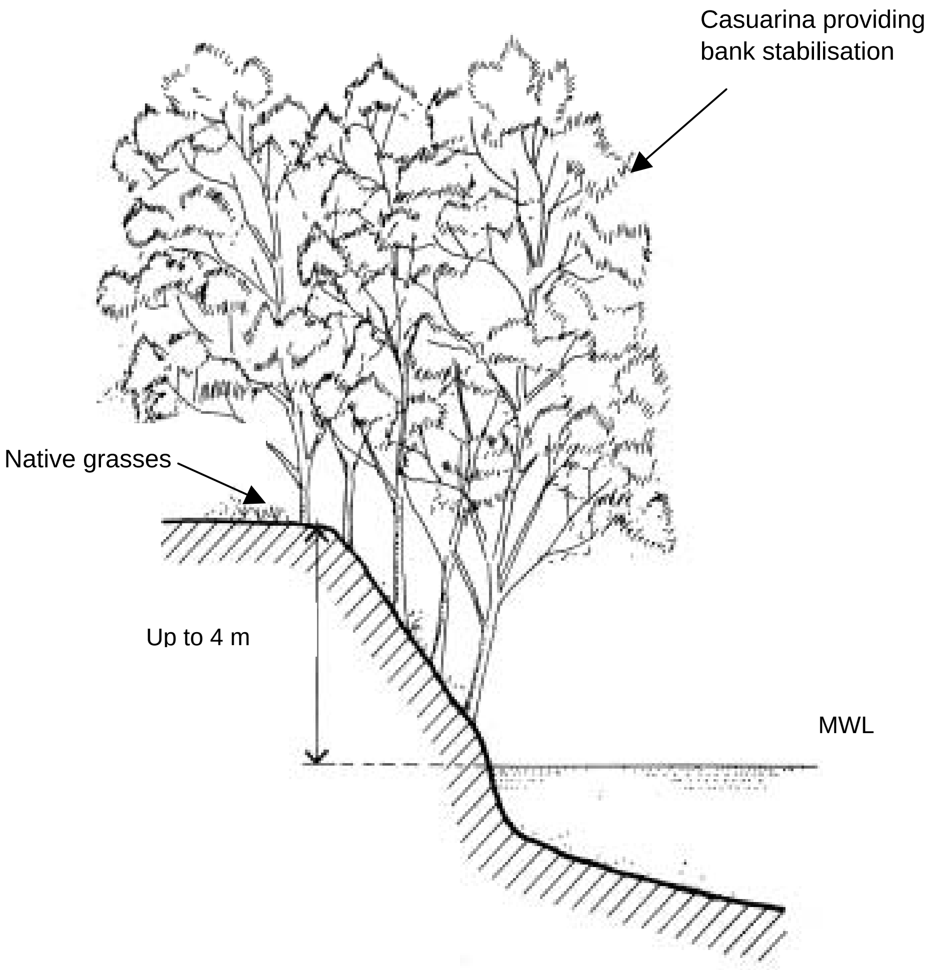


Figure 19 – Using vegetation to stabilise a steep bank (without berm)



Guideline 15: Protecting riverbanks with rock

Primary benefit

- Rock can provide effective protection of structures, facilities and natural vegetation on the Georges River and its major tributaries.

Additional benefits

- Controls sediment loads.
- Improves public safety due to a reduction in the height and stabilisation of existing vertical banks on parts of the river.
- Improves wildlife habitat as a result of native vegetation establishing itself on regraded banks.

What is it?

- Flood scour protection along riverbanks that aims to protect and stabilise the surface from erosion by currents and wave action. It can be done in various ways, such as riprap, geotextiles or gabions (as a last resort).
- Riverbank erosion is a natural process that provides minerals and organic matter to the aquatic ecosystem. However, the natural rate of riverbank erosion has been greatly increased by changes to the river flow resulting from sand and gravel extraction, changes to the flooding pattern caused by urban development, and wave action from boats.
- Development in the riparian zone, including buildings, bridges, roads, services and recreation facilities, exposes the zone to potential damage if the adjoining riverbank is being eroded.
- It is best to use indigenous native vegetation to protect banks as it provides habitat and maintains biodiversity. In some situations, however, the energy created by river flow and/or wave action may be too great for vegetation to withstand. Stone, timber or other material may be needed in these situations to withstand erosion.
- Riprap or stone/rock may be needed as a protective layer for riverbank stabilisation in situations where vegetation cannot provide adequate protection.
- Indigenous native plant material is incorporated to provide habitat and maintain biodiversity along the river edge.
- In some situations where there is not enough space to reshape the riverbank for placing riprap, it may be necessary to use gabions or vertical stone walls. However, this is considered to be the least desirable solution.

Gabion is the generic name given to types of revetment that are usually formed by relatively small stones contained in wire mesh baskets:

- The mesh can vary in shape from being cuboid (box gabions) or rectangular of small thickness (gabion mattresses), to sausage-like shapes (sack gabion).
- Gabions have the flexibility and permeability of stone riprap, but, as the mesh restrains the movement of stone, they have more stability than conventional riprap of an equivalent size. This means smaller stones can be used in gabions than for riprap in the same flow conditions. This is a major advantage in areas where large durable stones are in short supply.
- Gabions have the advantage of high permeability, which means that a filter layer may not be required between the gabion and the natural soil, provided it is easily

drained (i.e. granular material). However, gabions can fill with sediment and become weed infested.

- Gabions can be filled by hand or machine.
- Gabions are, however, vulnerable to two types of damage that should be considered when designing stabilisation works:
  - Damage by abrasion from the external action of sediment-laden river flows and rusting of wire mesh.
  - Vandalism, which generally involves cutting the wire boxes and taking the fill material, which can jeopardise the stability of the gabion.
- Gabions can also block the movement of wildlife from the river to the land.
- Due to the problems that can be associated with gabions, they should be used only as a last resort.

Geotextile is the generic name given to permeable textiles, meshes or nets used in contact with rock or soil.

- Geotextiles are either synthetic or biodegradable.
- Biodegradable textiles have a lifetime of a few years, much less than synthetic geotextiles, and are increasingly being used in riverbed and bank protection schemes for environmental reasons.
- Geotextiles can be used for the underlayer of a revetment to provide a drainage layer beneath the riprap and to prevent the movement of soil particles in the natural bank. Synthetic geotextiles are generally used for this purpose.
- When planning, select the type of geotextile based on soil characteristics, flow velocities and environmental conditions such as expose to UV radiation.
- Geotextiles can also be used in the armour layer of a revetment but this is not recommended without another material to provide the required level of stability or protection.
- Geotextiles can be supplied in mats that are pegged or pinned in place along the slope at regular intervals to maintain contact with the soil, but they will fail badly if the pegs or pins fail.
- Geotextile-based systems fall into three categories:
  - Three-dimensional mats are available in thicknesses of 10–20 mm are infilled with gravel or open stone. Filled mats are used as stable armour against flows of about 2 m/sec. They are usually only placed below high-water level. Above this the geotextile can be covered with soil and grass. Design should incorporate available performance data of the material being used.
  - Grid confinement systems are another geotextile containing fill but fabricated in the form of a deep honeycomb. This provides additional resistance to erosion of surface layer material, provided the system itself is adequately restrained from sliding down the slope.
  - Geotextile sausages are bags or tubes containing soil that are made from geotextile materials.

Purpose

- To create a riverbank that can resist the eroding forces of the river, including currents, wave action and flooding, while maintaining ecological values.

Limitations

- Structural solutions to stabilisation can be relatively expensive.
- Hydrologic and hydraulic analysis of the river or stream by a qualified engineer is required for design to be effective.
- Heavy equipment is needed for installation of riprap and this may damage to adjoining riparian vegetation.
- Care must be taken to avoid visually unattractive structural solutions that appear unnatural and reduce the scenic values of the river.

The ecological value of riprap is debatable but it is possible to work vegetation into the treatment. There is little to no ecological value in gabions at all. They are designed specifically for structural stability and hence should not be considered for a riverbank.

Materials

- Indigenous native vegetation that is adapted to river edge growing conditions including regular inundation by floods and the erosion process of the river.
- Riprap, which is the general term given to loose, rock armour, and is widely used because it is:
  - easy to apply by randomly placing light layers of stone, and with proper control it can be placed under water
  - flexible, accommodating small ground movements or loss of particles without total failure
  - of a high hydraulic roughness, reducing wave and current energy
  - able to allow growth of vegetation that provides wildlife habitat and maintains ecological values
  - low maintenance, and
  - durable.
- Suitable quarry rock is angular, dense, durable and sound, ranging in diameter from 100 to 800 mm with at least 50% being in the 150–600 mm range.
- Geotextile fabric is required below the riprap layer.
- The protective layer must also accommodate surface water drainage and subsoil drainage in the underlying bank (Hemphill and Bramley 1989).

Guidelines

- When using riprap for flood scouring, consider these three key criteria:
  - The stones used should be large enough to withstand movement by riverflow.
  - The velocity of water flowing through the riprap should be low enough not to scour the underlayer or subsoil.
  - The hydraulic roughness of the area covered by riprap should not be significantly lower than the natural bank. In such a situation the flow velocity near the bank would increase along the protected section and the downstream end would be vulnerable to scour.
- Use a combination of riprap and vegetation where possible, with emergent and/or established plants such as casuarina being set in place with the riprap. The angle of repose of riprap should be in the range of 35°–42°. Figures 20 and 21 give examples of how to use riprap.

- Consult a geomorphologist and a hydrologist to determine the primary cause of the riverbank erosion, including hydraulic modelling of the river flows and site investigations.
- Engage a geotechnical engineer to design the riprap protection works in consultation with an ecologist to ensure ecological values are restored, and a landscape architect to ensure aesthetic issues are addressed.
- Consult with the DIPNR during the design process.
- Pre-qualify contractors who have proven experience in implementing similar works.
- Obtain all necessary approvals from the DIPNR and other authorities.
- Prepare contract documents and issue them for tender.
- Appoint the preferred contractor to carry out the works.
- Schedule the works to minimise the potential for damage from flooding and wave action.
- Arrange for the propagation of indigenous native vegetation required for the works.
- Establish a program of contract management that allows for close supervision of the works to ensure the design is fully achieved. Adjustments to the design can be made as necessary in response to site conditions encountered during the works.
- When designing use of gabions, determine the stone size required to create a stable rockfill. The mesh openings and design will then be based on the stone required.
- Escarameia (1998) provides a summary of the different types of gabions, their applications and design methodology. Further information required for gabion design can be found in Foster (1987), including design formula for gabion thickness under flood scour conditions.
- Schedule stabilisation works to minimise disturbance to aquatic habitats in the stream or river and disruption of public use of the adjoining riparian zone.

Management and monitoring

- Carry out regular inspections of the stabilisation works, particularly following floods, to identify any areas that need immediate repair.
- Implement a program of weed control and supplementary planting of native vegetation on the riverbank to ensure that the vegetation component of the works continues to be effective.

Information sources

- 'Water Related Best Management Practices in the Landscape', ftp://ftp.ftw.nrcs.usda.gov.
- Riparian Land Management Technical Guidelines, LWRRDC, Vol 2, Ch C.
- Hemphill and Bramley (1989) provide an introduction to riprap design to meet these criteria, explaining how to determine the required size of riprap stone from critical shear stress or mean flow velocity.
- Information of greater technical detail on the design of riprap, including thickness and toe-scour protection, is given in USCE (1977), Maynord (1995), Maynord (1994), van't Hoff et al (1995), Ahmed (1989), Wang and Shen (1985) and Izumi et al (1991).
- Shields et al (1995) and Sotir et al (1995) provide information on the use of vegetation in combination with riprap.

Figure 20 – Using riprap to stabilise a bank

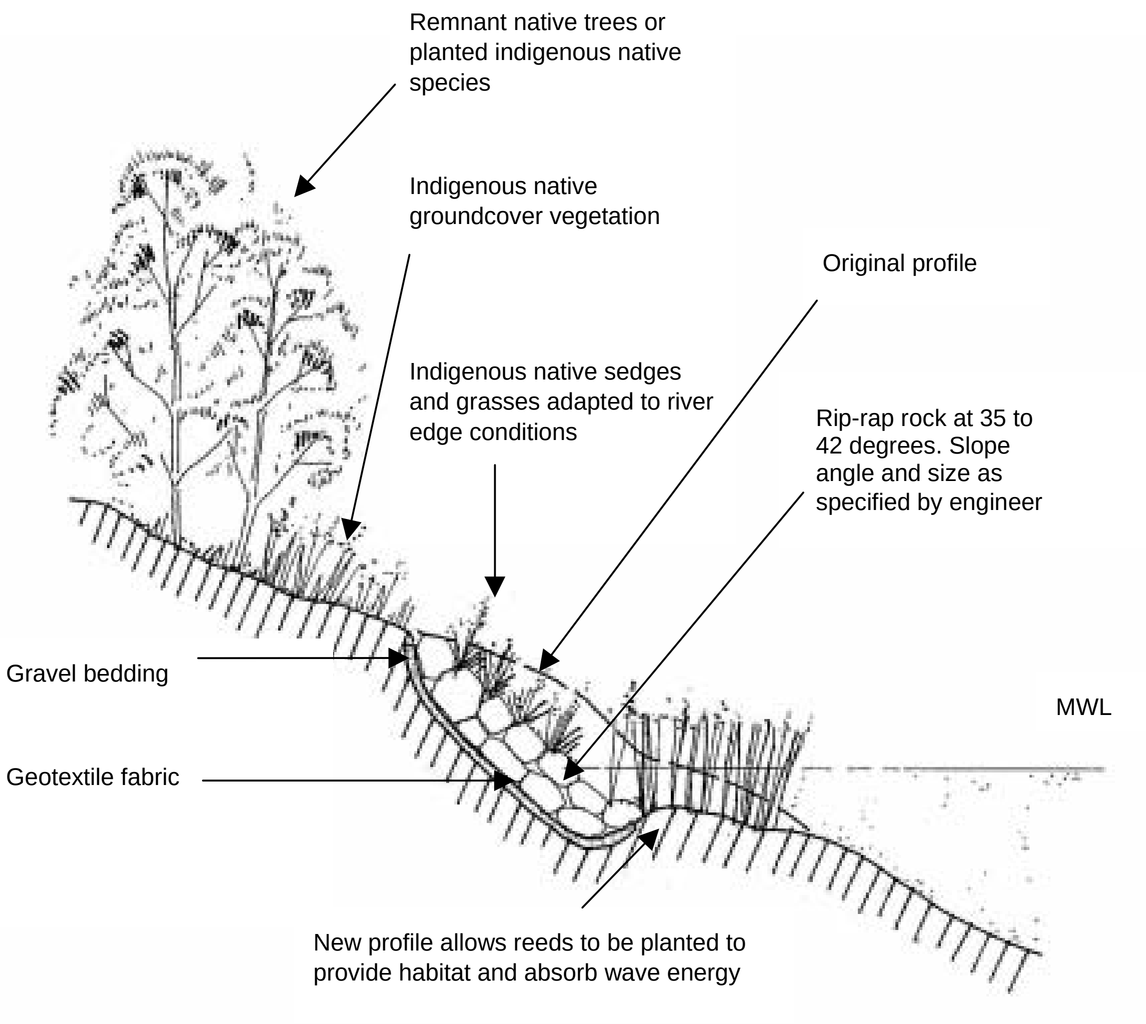
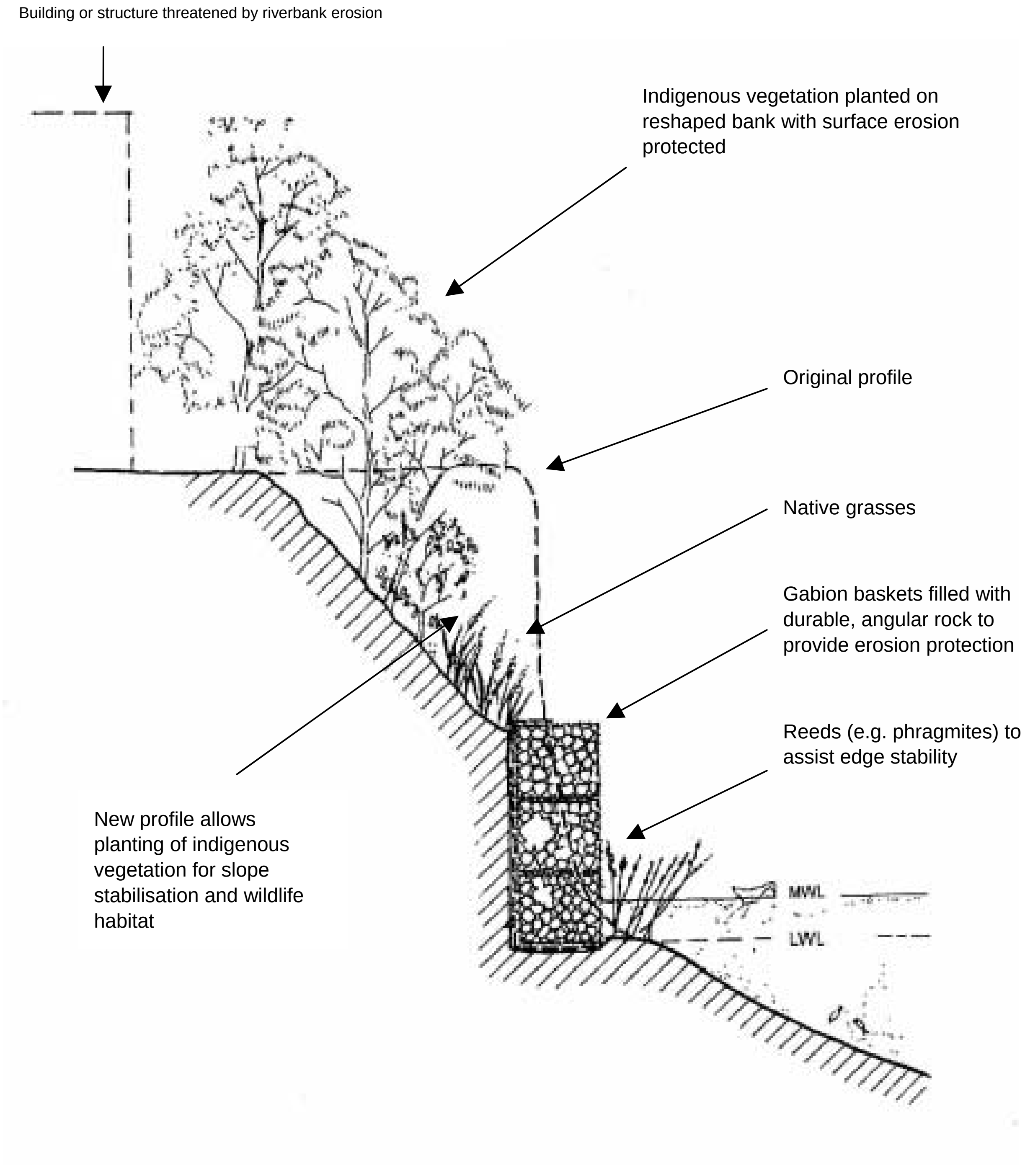


Figure 21 – Stabilising a bank where space is limited



Guideline 16: Protecting riverbanks from waves

Primary benefit

- Protecting riverbanks from waves generated by boats and wind provides protection for structures, facilities and natural vegetation along the Georges River and its major tributaries.

Additional benefits

- Reduces sediment loads in the river.
- Protects ecological values at the river edge.

What is it?

- Design of riverbank protection against wave attack is essentially the same as for flood scour but some changes in materials may be necessary.
- Reeds and rushes can provide significant protection by absorbing a substantial proportion of wave energy.
- In order to establish and retain reeds and rushes the cross-section profile needs to provide a relatively flat area at the toe of the riverbank in which macrophytes can grow.
- Sediments are often deposited naturally along sections of the river edge and colonised by macrophytes. Flood events often remove these sediments and deposit them downstream.
- Then protecting against wave attack with riprap, it may be necessary to use heavy rock and a substantial thickness of underlayer within the zone of wave run-up and run-down, while lighter protection may be enough above and below this zone (Hemphill and Bramley 1989).
- Toe stability is critical to the long-term effectiveness of all riverbank treatments with riprap.
- Geotextile tubes have been used for temporary protection works in coastal zones (Jackson 1987; Walker et al 1998) but these should only be used for temporary protection.
- Pattern-placed units (concrete or stone pitching) have been used for wave protection in many coastal areas but these are not recommended for wave protection of riverbanks because they affect ecological values.

Purpose

- To create a river edge that can withstand erosion forces of waves from boats and wind while maintaining ecological values.

Limitations

- Accurate information on maximum wave height and force under all conditions is needed for effective design of appropriate protection. This information may not be readily available.
- Designing riprap to protect against wave action has additional considerations compared to flood scour protection. This is due to competing and interrelated factors that influence stability and performance in the conditions. Factors include

drag forces during the up-rush or down-rush of a wave, and lift forces and excess pore pressures beneath the riprap.

Guidelines

- See Guideline 15 for general treatment recommendations.
- Engage a suitably qualified consultant to carry out engineering assessment and model testing. This will determine the most effective protection treatment for the wave environment at particular locations.
- Consult the DIPNR and NSW Department of Primary Industries during the design process.
- Prepare design options for consideration by council, the community, other stakeholders and relevant authorities.
- Choose the preferred option, taking account of engineering, ecological, aesthetic and cost factors. Figures 22 and 23 give examples of two options.
- Carry out site investigations to determine the most appropriate cross-section profile of the riverbank.
- Carry out detailed design and documentation of the riverbank stabilisation works, taking account of engineering, ecological, aesthetic and economic factors.
- Pre-qualify suitable contractors with proven experience in comparable projects.
- Prepare tender documents, including an environmental management plan, and issue it to pre-qualified contractors.
- Assess tenders and appoint the preferred contractor to carry out the works.
- Establish a system of project management that provides for close site supervision throughout the works. This will ensure the design is achieved and environmental impacts are minimised.

Management and monitoring

- Implement a program of regular inspections, particularly during the first two years after completion of the works and after significant storm periods and flood events. This will identify any damaged sections of bank stabilisation works that require immediate repair.

Information sources

- The Shore Protection Manual (USCE 1977), Hemphill and Bramley (1989) and van der Meer (1995) provide guidelines for design.
- Foster (1980) has a review of design procedures for gabions and pattern-placed concrete units.

Figure 22 – Using riprap to protect a bank from waves

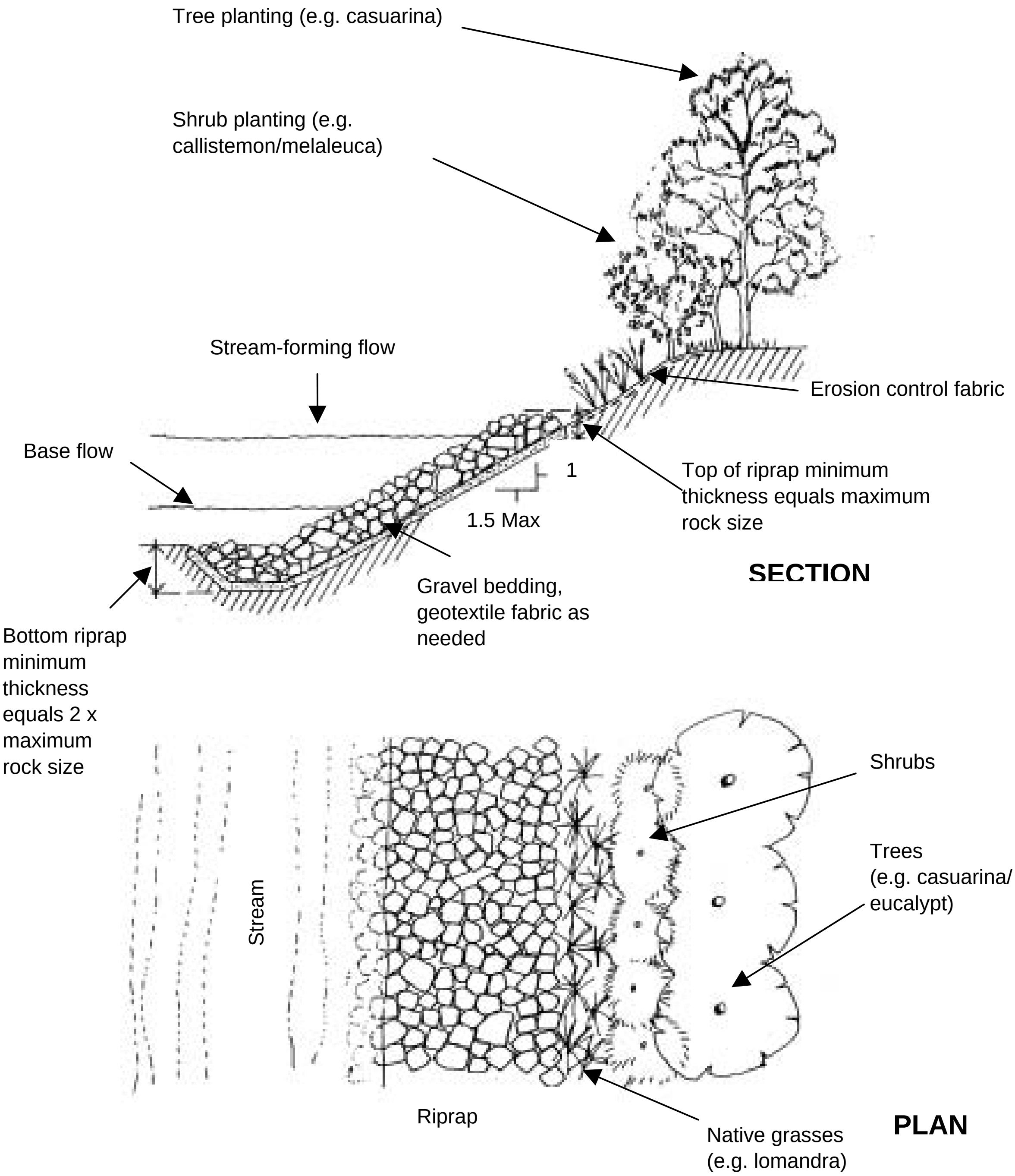
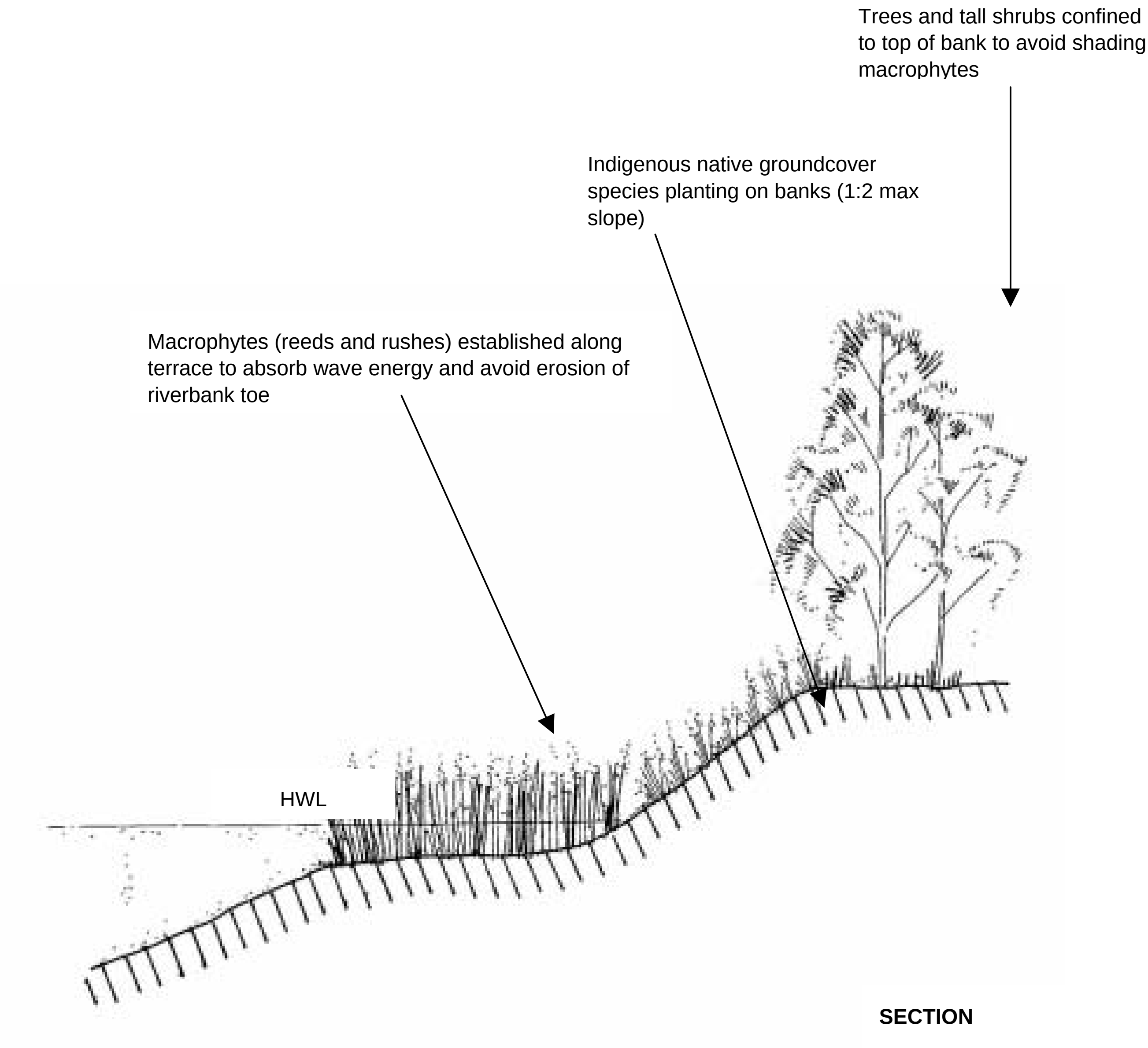


Figure 23 – Using macrophytes to protect a bank from waves



Guideline 17: Creek and drainage line crossings

Primary benefit

- Effective planning of roads, pathways and services can minimise the potential impact over natural drainage lines and creeks.

Additional benefits

- Minimises potential fragmentation of riparian vegetation and associated habitat.
- Avoids potential changes to natural surface flows.

What is it?

- Planning and design for roads, pathways and services (water, electricity, gas, communications) that aims to avoid crossing natural drainage lines and creeks and so to minimise impacts in the riparian zone.
- Minimising the potential environmental impact resulting from construction machinery, introduction of weeds and maintenance access.

Purpose

- To minimise environmental impacts on the natural values in riparian zones resulting from construction of creek crossings.

Limitations

- Avoiding crossing natural drainage lines and creeks may not be feasible in some situations due to the pattern of development and land ownership and the high cost of alternatives

Materials

- Relevant environmental legislation, including tree preservation orders, the EP&A Act, Native Vegetation Conservation Act 1997, Rivers and Foreshores Improvement Act 1948.

Guidelines

- Identify and assess options for locating a proposed crossing.
- Try to locate roads, paths and services outside or on the edge of the riparian zone.
- Decide on the option that has the least environmental impact, including potential removal and fragmentation of remnant native vegetation and biological corridors (existing and potential). For examples see Figures 24 and 25.
- Design the crossing in a way that minimises the amount of disturbance in the riparian zone and along the drainage line.
- Avoid using culverts.
- Use bridges with piered supports where possible.
- Offset negative impacts by enhancing habitat areas up and downstream of crossing.
- Design the bridge deck to allow light and rainwater to penetrate so that vegetation can grow on embankments below the bridge and provide wildlife habitat continuity.

- If there is no alternative to a culvert crossing, then design it with multiple cells to provide multi-levelled inverts, a roughened base and a square or rectangle cross-section. Incorporate light wells where median strips exist.

Figure 24 – Stream or drainage line crossings (bridge)

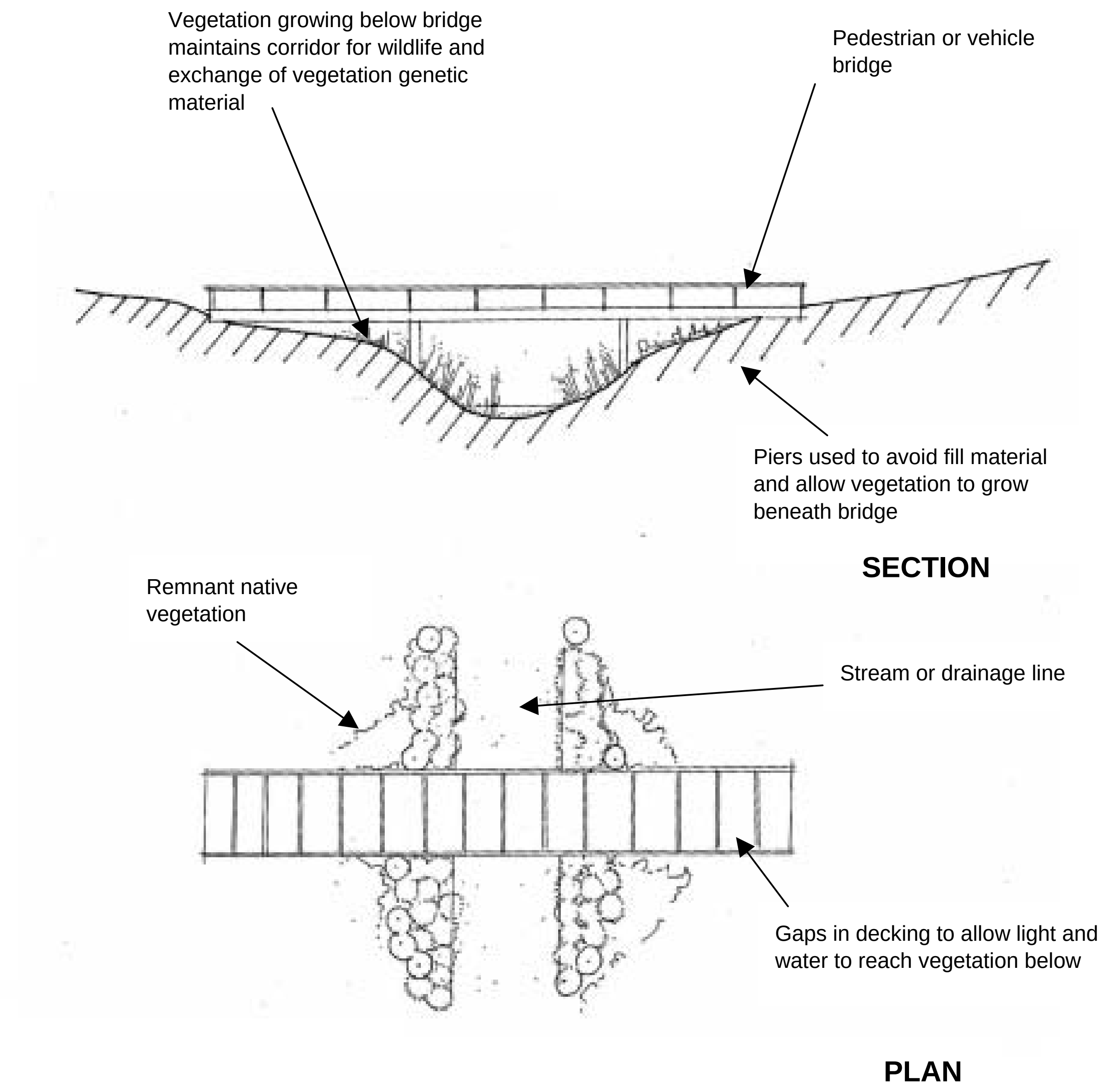
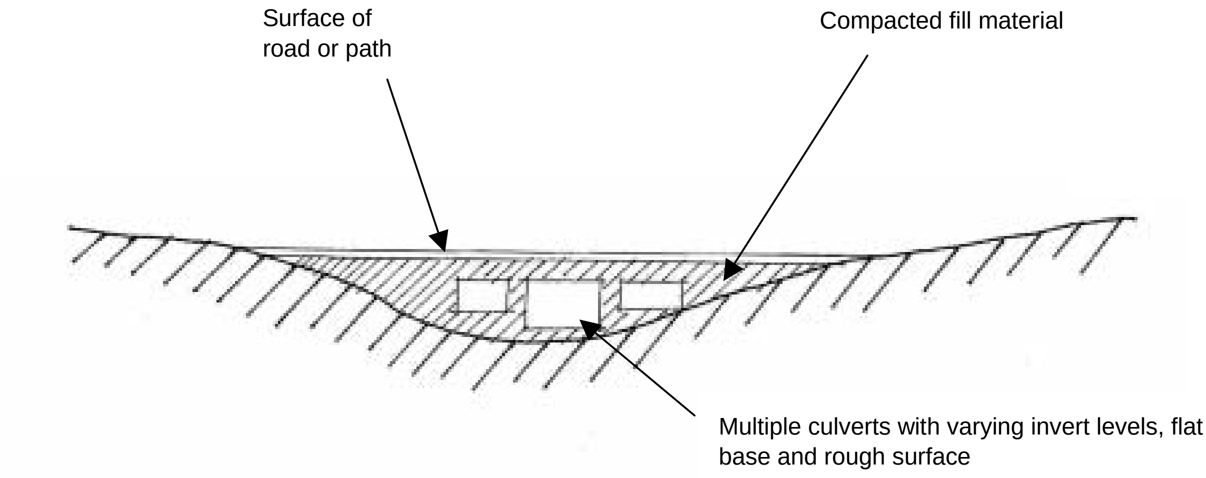
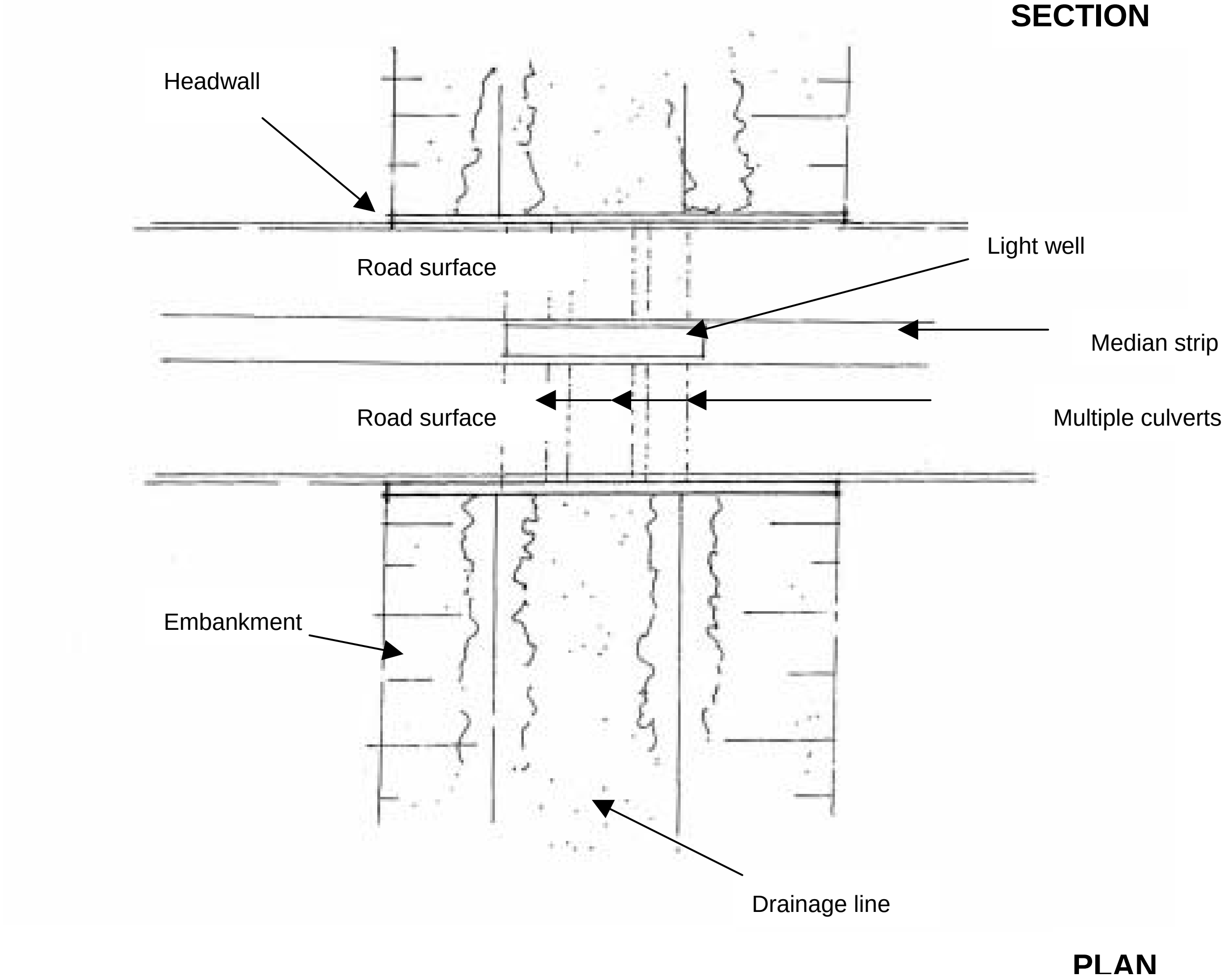


Figure 25: Creek or drainage line crossing (culvert)





Guideline 18: Flood detention basins

Primary benefit

- Flood detention basins prevent an increase in the rate of floodwater run-off from urban development area that may alter the natural water system downstream.

Additional benefits

- Basin retains soil moisture with a proportion of run-off infiltrating to the groundwater.
- Some improvement to water quality due to silt deposition in the basin.

What is it?

- A flood detention basin is a depression created by regrading an area or constructing a levee that detains stormwater run-off from an urban development area.
- It detains stormwater immediately after a storm event and allows it to slowly drain out of the basin into the adjoining natural drainage line or creek.
- Increased stormwater run-off due to hard surfaces (roads, car parks, roofs, paved areas) in urban areas can cause erosion of the banks and base of streamlines. A detention basin can prevent this increase in the flow rate downstream from an urban area.

Limitations

- The size and capacity of the detention basin needs to match the increase in run-off rate. There may not be enough space.
- Constructing flood detention basin should not result in destruction of either terrestrial and aquatic remnant native vegetation.
- As detention basins are sometimes located in public open space and used for recreation purposes, the design needs to take account of recreational use requirements, including satisfactory surface drainage and public health and safety.

Materials

- Only vegetation species that can withstand prolonged flooding should be planted in the basin.

Guidelines

- Assemble a multidisciplinary team to design the basin. The team should include a landscape architect, a hydraulic/civil engineer, an ecologist and a recreation planner.
- Determine the size and capacity of basin required to accommodate the increased run-off.
- Identify and evaluate various locations for the basin.
- Do not place the basin within a natural drainage line, and where possible place it outside the riparian zone.
- Design the basin at the preferred location in a way that minimises disturbance of the site.

- Design the basin integrating requirements for multiple uses, including recreation and wildlife habitat.
- Ensure that the flood modelling carried out in the design process considers the re-establishment of vegetation in the riparian zone, incorporating all the structural components (e.g. trees, shrubs, groundcover vegetation) that occur naturally.

Management and monitoring

- Establish a maintenance program that covers weed control, removing silt and rubbish, and repairing vegetation that may be damaged in major flood events.

Guideline 19: Managing willows

Primary benefits

- Managing willows effectively can minimise their potential impacts on the riparian zone, such as obstructing or diverting stream flows, which may result in streambank erosion.

Other benefits

- Replacing willows with native plant species increases biodiversity and wildlife habitat values.

What is it?

- Willows are exotic species that have been planted throughout Australia for streambank stabilisation.
- They are well adapted to riparian zones and spread rapidly due to broken branches being transported downstream and through seed dispersal by some species.
- Because willows are brittle and tend to branch, they are very prone to dropping limbs into the stream or being blown over by strong winds.
- The trunks and large limbs accumulate debris during floods. This may block or divert the normal stream flows, often causing streambank erosion and instability.
- Willows are exotic species that provide very little native wildlife habitat value. The also suppress the growth of native species that could provide wildlife habitat and biodiversity.
- Willows are usually propagated from cuttings of one or two clones at a time.
- Male and female flowers usually occur on separate trees. Female trees will usually produce viable seed if a male tree of a compatible species is within a distance of up to 1 km.
- Seeds are easily carried by wind for more than 1 km and some can travel up to 50 or 100 km.
- The main barriers to seedling survival are the lack of suitable seedbed, rising and falling water levels, and floods that uproot or bury seedlings.
- Salix cinerea is a particularly aggressive species that spreads rapidly from seed to invade areas well beyond open riparian sites.
- Most species of willow are declared noxious weeds in NSW.

Purpose

- Managing willows to minimise their potential negative environmental impacts without destabilising the streambank.

Limitations

- Willows growing in the riparian zone can provide streambank stability, and shade for stock and people.
- Mechanically removing willows may cause streambank instability.
- Streambank stability needs to be maintained by replacing willows with suitable native species such as casuarinas.

- To maintain bank stability, removing willows needs to be staged over several years in accordance with a management plan.
- Willows in some locations may have cultural landscape values that need to be considered.
- Tree preservation orders may apply to willows in some urban areas.

Materials

- The DIPNR should be consulted before any willow removal from stream banks starts.
- The 'Willow Clearing Guideline' prepared by the NSW DLWC should be followed when removing willows from state-protected riparian areas. See www.dipnr.nsw.gov.au.

Guidelines

- Prepare an integrated management strategy for sub-catchments or sections of stream banks so that removing willows does not destabilise stream banks, and so that treated areas are not re-invaded by willow seeds coming from upstream.
- Remove willow plants up to 1 m high by hand pulling.
- Do not use heavy machinery to remove larger trees on wet sites or in situations where sections of streambank would be destabilised.
- Avoid felling of willows where possible as this can lead to suckering.
- Avoid ringbarking, due to the ability of willows to regenerate below the ringbark
- Foliar spray willows with glyphosate at concentrations of 3% to be effective. (Roundup Biactive® is registered for foliar spray of all willow species on trees up to 2 m high).
- Carry out stem injection of Willows with glyphosate during the period December to March.
- Use only herbicides registered for willow control, which in most Australian states is limited to glyphosate.
- Check all labels and registrations before using any herbicide.
- Follow the CSIRO recommendations on using glyphosate (360 g/L) by injecting it into cuts made 2–3 cm into the trunk below the branches at 13 cm intervals around the circumference of the trunk.
- Use 'long stem planting' to quickly establish native local species, such as casuarinas, so they can withstand high flows and flood conditions. This will assist bank stabilisation while replacing willows.

Monitoring and management

- Do follow-up inspections to ensure that treated trees have died and to remove dead trees that could cause problems (such as falling in and floating downstream), particularly during floods.

Information sources

- CSIRO Forestry and Forest Products website, www.cbr.for.csiro.au/publicat/articles/willows.
- Guidelines for Clearing Willows', DLWC, www.dipnr.nsw.gov.au.

- ‘Natural Resource Management Special Issue on Willow Management for Australian Rivers’ (December 1999), The Australian Association of Natural Resource Management (Phone/fax (02) 6247 4137, email badenw@ozemail.com.au).
- Trounce B and Cresner K (1997) Willow Control, NSW Agriculture, Orange.
- CRC for Catchment Hydrology/LWRRDC (2000) A Rehabilitation Manual for Australian Streams, Vol 2.

Guideline 20: Controlling weeds in the riparian zone

Primary benefit

- Controlling weeds in the riparian zone helps conserve and regenerate native vegetation.

Additional benefits

- Increases the success of revegetation.
- Increases habitat values for native wildlife.
- Removing obstructions to flood flows may mitigate potential floods.

What is it?

- Controlling weeds involves preventing invasion of new weeds, controlling existing weeds, and rehabilitating native vegetation infested by weeds. It should be done in accordance with a Weed Control Plan.

Purpose

- The primary objective of weed control is to remove introduced species that can suppress or kill native vegetation and prevent natural regeneration or the establishment of planted native species.
- Controlling weeds helps maintain biodiversity and provides habitat for native wildlife species.

Limitations

- Weed control in riparian zones of the Georges River and its tributaries will require intensive ongoing efforts due to the constant supply of seeds and other plant propagation material transported by water flowing in adjoining rivers or creeks.
- The growing conditions in riparian zones (for example, fertile soil, continuing supply of nutrients, and moist soil) often favour weeds. Ongoing management is needed to help native species become established and grow.

Materials

- Non-chemical control requires hand equipment or machinery to remove weeds.
- Chemical control requires herbicides that are non-residual and not harmful to aquatic ecosystems.

Guidelines

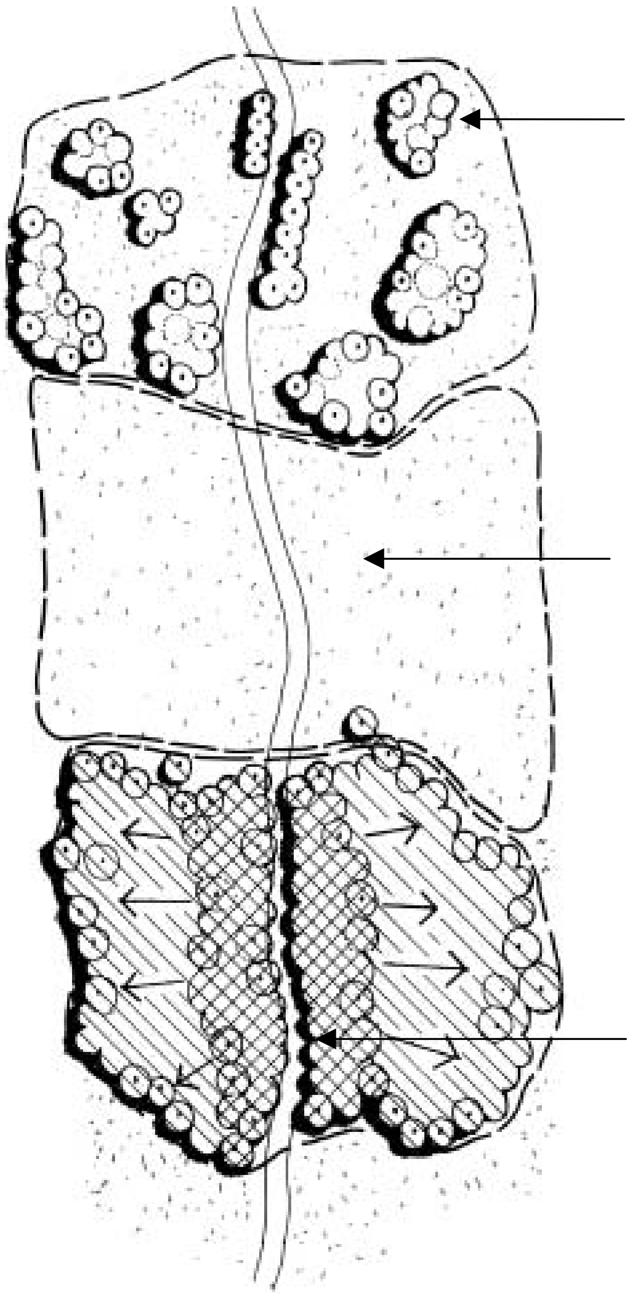
- Prepare a Weed Control Plan for each section of the riparian corridor to be treated.
- The plan should divide the riparian corridor into zones that are relatively consistent in terms of:
  - Remnant vegetation species
  - Degree of disturbance
  - Location in the landscape (stream edge, lower slopes, upper slopes)
  - Soil type

  - Extent and type of weed infestation.
- Define a set of actions for weed control in each zone that includes:
  - Methods
  - Follow-up remediation work
  - Public access control
  - Fire management provisions.
- Set priorities for each zone, taking account of the type and condition of remnant native vegetation, how threatened it is by weeds, and its ecological significance on a local and regional basis. Figure 26 gives an example of a weed control strategy.
- Generally start work in the areas of remnant native vegetation with the lowest level of weed infestation and work towards areas of greater weed infestation.
- If indigenous native vegetation of high conservation significance is at high risk of being destroyed by weed growth, it may be necessary to give the zone high priority.
- Minimise soil disturbance, as this creates conditions favourable to new weed invasion.
- Match the rate of weed removal with the rate of natural regeneration and supplementary planting.
- In areas of severe weed infestation that lack significant remnant vegetation, mechanical and chemical removal methods may be the most cost-effective. Follow this with planting and surface mulching to create conditions suitable for successfully establishing native species.
- Take special care when using herbicides within the riparian zone to prevent them entering the adjoining stream or river and impacting the aquatic ecosystem.
- Obtain all necessary permits from the DEC for using herbicides in the riparian zone.
- Obtain a licence from DIPNR (under the Native Vegetation Conservation Act).

Information sources

- Greening Australia, www.greeningaustralia.org.au, Technical Advice — Weed Management.
- Australian Association of Bush Regenerators website, www.zip.com.au/~aabr.
- Buchanan, RA (1989) Bush Regeneration: Recovering Australian Landscapes, TAFE Student Learning Publications, NSW.

Figure 26 – Example of weed control strategy



Z O N E

Scattered remnant trees

Stage 2

Commence weed control in remnant tree stands while assisting natural regeneration. Carry out supplementary planting where regeneration is not adequate.

Z O N E

Exotic grasses

Stage 3

Remove exotic grass and replace it with indigenous trees, shrubs and grasses by planting and direct seeding.

Z O N E

Remnant woodland

Stage 1

Commence weed control in the least infested area and work outwards into areas of increasing weed cover.

Central core with least weed infestation

P L A N

Guideline 21: Controlling weeds in the aquatic zone

Primary benefit

- Controlling weeds in the aquatic zone helps maintain aquatic ecosystems.

Additional benefits

- Protects aquatic habitats.
- Prevents excessive weed growth that can restrict stream flows and interfere with recreational activities.
- Planting shade trees along edges of waterways provides other benefits, including:
  - A reduction in stream temperatures to benefit native fish species.
  - A source of leaf litter, which is food for aquatic biota.
  - Terrestrial wildlife habitat.
  - Improved aesthetic values.

What is it?

- Aquatic weed control, involving the removal of non-indigenous aquatic plants.
- Raised nutrient levels in the river and tributaries resulting from urban development and agricultural land uses tend to favour the growth of aquatic weeds.
- Aquatic weed control therefore needs to involve catchment management initiatives that reduce nutrient levels to those similar to natural undeveloped catchments.
- Managing the riparian zone also forms part of aquatic weed control. This is because land uses such as golf courses, parks and agricultural activities can directly influence the level of nutrients and contaminants entering the river or stream.
- Removing riparian vegetation leads to increased light levels in the adjoining section of river or stream, which generally favours aquatic weeds.
- Research clearly indicates that shade is the primary factor influencing the growth and distribution of aquatic and semi-aquatic vegetation. Once established, a dense stand of trees can eliminate the need for continued mechanical and chemical control of aquatic weeds.

Purpose

- To remove existing aquatic weeds from sections of the river and tributaries, as well as associated wetlands, so that indigenous species can be re-established.
- To ensure that opportunities for views and water-based recreation are not degraded by aquatic weed growth.
- To prevent the growth of toxic blue-green algae blooms.
- To minimise the growth of aquatic plant groups (macrophytes, filamentous green algae and toxic cyanobacteria) that are not readily eaten by fish and aquatic invertebrates. These plants compete with plant groups that form the food chain of fish and aquatic invertebrates.
- To minimise the accumulation of aquatic plants that decompose to produce high rates of benthic respiration and high oxygen consumption, which contributes to:
  - Insufficient oxygen being available to sustain benthic invertebrate communities.

- Fish dying when oxygen levels in the water column fall below required levels.
- Release of nutrients from axonic sediments (deficient in gaseous or dissolved oxygen), stimulating additional algae growth.
- Release of other contaminants (e.g. manganese and iron) from sediments, resulting in lower water quality.

Limitations

- The growth of aquatic weeds is strongly influenced by water quality conditions, particularly nutrient levels, which are in turn strongly influenced by land uses throughout the catchment area that drains into the river or stream.
- Integrated catchment management is required to achieve catchment-wide aquatic weed control.
- The river readily transports material for aquatic weed growth, which can re-invade sections from which aquatic weeds have been removed.

Materials

- Herbicides that are registered for use in controlling specific aquatic weeds.
- Seedlings for stream-side planting to create shade.

Guidelines

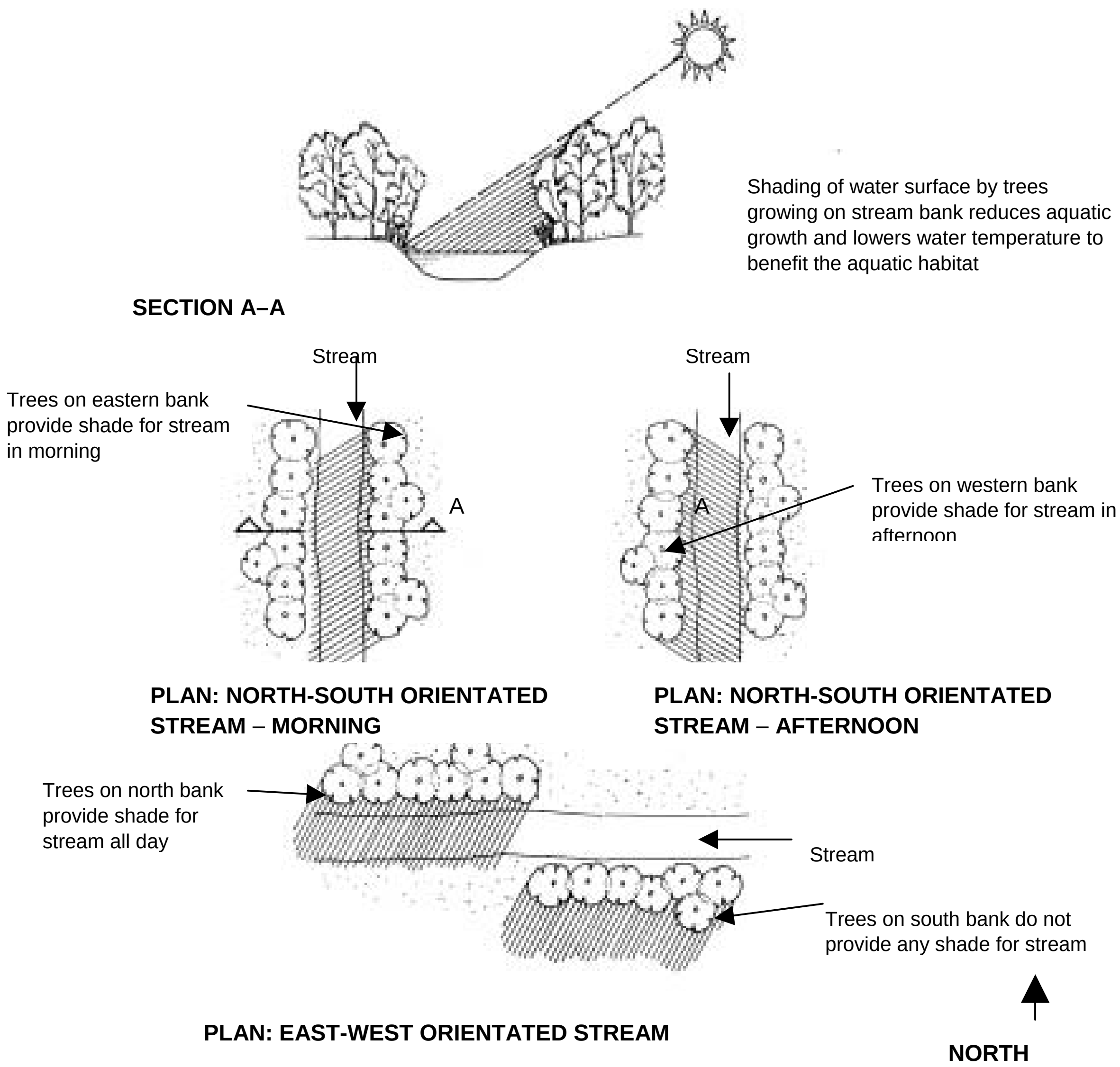
- Carefully consider the long-term economic and ecological costs and benefits of alternative means of aquatic weed control, particularly regarding the combination of factors (land use and water quality) that are contributing to the weed problem.
- Consult with NSW Department of Primary Industries about potential impacts on aquatic ecosystems.
- Mechanical removal of macrophyte weeds may be appropriate in some situations of very heavy infestation but it is unlikely to provide a long-term solution unless combined with other control initiatives.
- Dispose of the aquatic weeds to ensure they cannot reinvade.
- If mechanical removal is being done, implement rehabilitation works that include channel re-profiling, planting desirable plant species, modifying the hydraulic regime and reducing water nutrient levels. This will ensure improvements are achieved over the longer term.
- Avoid using herbicides that are generally not suitable for aquatic weed control, as the effect is relatively short term and there is high potential to impact on desirable aquatic plants and aquatic and semi-aquatic fauna.
- Consult with the DEC before using herbicides in aquatic environments. Only use herbicides registered for such situations, and use them strictly in accordance with the manufacturer’s recommendations.
- When planning to establish shade trees, take account of the stream’s orientation (as shown in Figure 27):
  - Trees on the north side of an east-west section of stream can provide shade throughout most of the day. Trees on the south side will not cast shade on the water.
  - Along a north-south section of stream, trees on the eastern side will shade the water in the morning and trees on the western side will shade the water in the afternoon. They will provide very little shade during the middle of the day.

- When selecting local indigenous tree species, aim to establish those with the greatest potential height and most dense canopy close to the water edge to provide maximum shade.
- Limit the input of nutrients into the stream from adjoining riparian areas by creating vegetation buffer areas (see Guideline 6). These should have a groundcover of grasses and herbs together with trees that provide litter to slow the rate of run-off and trap sediments and nutrients.

Information sources

- The Constructed Wetlands Manual, Vol. 2., Chapter 26, DLWC, 1998.
- A Rehabilitation Manual for Australian Streams, Vol. 2, LWRRDC, 2000, pp. 46–53, 349–350, www.lwrrdc.gov.au.
- Riparian Land Management Technical Guidelines, Vol. 2, LWRRDC, November 1999, Chapter A.

Figure 27 – Using shade to control aquatic weeds



Guideline 22: Collecting seeds

Primary benefit

- Collecting seeds helps preserve and enlarge local gene pools.

Additional benefits

- Increases the success of revegetation programs due to adaptation of local species to prevailing conditions.

What is it?

- Collecting local indigenous seed from nearby remnants of native vegetation.

Purpose

- To grow plants from local provenance seed in order to recreate the best approximation of the pre-existing vegetation.
- To preserve the local genetic characteristics of plants in order to increase the probability of plant survival.
- To propagate plants from locally collected seed, as they are more likely to provide habitat for native fauna.

Limitations

- Using local provenance seed may delay revegetation because there is an additional stage before seedlings are ready for planting.
- The time of year in which seeds can be collected varies between species. An ongoing collection program may be needed to supply seed for revegetation programs and to avoid future delays.
- If a very high proportion of seed is collected from small isolated remnants, the potential for natural regeneration from those remnants may be reduced to an unacceptable level. This may put the remnant population at risk.

Guidelines

- Refer to the 'Best Practice Guidelines for Seed Collection' prepared by Florabank.
- Seek advice from revegetation experts (e.g. Greening Australia) on the most appropriate times to collect seed and how best to store it.
- Collect seed preferably from healthy plant populations, from a variety of planted sites if available.
- Collect seed from sites with similar conditions (rainfall, soil, altitude and aspect) as the revegetation site.
- Collect seed only from groups of healthy plants of the same species that show evidence that they have all flowered and fruit.
- Take some seed from every healthy plant in order to create maximum genetic diversity.
- Do not take more than 10% of the seed of any individual plant.

- Collect seed from several groups of plants growing at some distance from each other. Plants within a small area will probably be closely related and will vary less in generic characteristics than plants growing at some distance from each other.
- Record on the batch sheet the species name, where it came from, the number of plants from which the seed was collected, the date and any particular site conditions that may make the seed especially suitable for similar conditions elsewhere.

Management and monitoring

- A permit will be required for collecting seeds of rare or threatened species, populations or ecological communities.
- The Australian Network for Plant Conservation has guidelines that seek to:
  - Minimise harmful impacts on source vegetation
  - Increase genetic diversity in collected seed
  - Promote viability of seed through proper storage.

Information sources

- Greening Australia, www.greeningaustralia.org.au, Technical Advice — Rules for Seed Collecting.
- The Australian Network for Plant Conservation Guidelines, www.anbg.gov.au/anpc/.
- Florabank, www.florabank.org.au.
- Australian Association of Bush Regenerators, www.zip.com.au/~aabr.

Guideline 23: Direct seeding

Primary benefit

- Direct seeding is a cost-effective way of re-establishing indigenous native vegetation.

Additional benefits

- Improves wildlife habitat values.
- Conserves genetic resources by using locally collected seed.
- Controls erosion.
- Improves aesthetic values of re-established indigenous vegetation.

What is it?

- Direct seeding is the establishment of native vegetation by sowing seed directly into the prepared soil at the final selected location.

Purpose

- To provide a cost-effective way of establishing native plants over large areas. A wide variety of plants can be established at low cost.

Limitations

- Plants can be slow to appear, which can be a disadvantage when community expectations are for quick results.
- Large volumes of seed are required compared to propagating seedlings from seed in a nursery.
- A high level of weed control is essential.
- Results may be patchy depending on site conditions and seasonal variations.
- Availability of good quality local provenance seed may be limited.

Materials

- Large quantities of seed are required. They are best obtained from professional suppliers.
- Non-residual herbicide is required to kill grasses and weeds before sowing seed.

Guidelines

- Weed control is the most critical factor in preparing a site for direct seeding.
- The area to be seeded should be sprayed with a non-residual herbicide (glyphosate) in accordance with the manufacturer’s recommendations.
- Adequate soil moisture is also essential for successful seed germination and seedling growth.
- The area to be sown should be ripped if the soil has been compacted by machinery, vehicles or animals.

- Pre-germination (seed conditioning or trimming) can significantly improve the success rate of direct seeding by bringing about a number of early germination stages.
- To pre-germinate seeds:
  - Place wetted Perlite, which acts as a germination medium, in a re-sealable plastic sandwich bag.
  - Mix the seed so that it sticks to the Perlite beads.
  - Seal the bag tightly while taking care not to expel all the air.
  - Place the bag in an appropriate gemination environment in accordance with Table 6.

Table 6 – Pre-germination of species for hand-sowing

A. Species that give good results	**Method of pre-germination**
Acacia spp. (e.g. *A. dealbata, A. pyracantha, A. melanoxylon*)	Crack seed in boiling water and soak. Combine seed in soil medium and place in a black plastic bag in a warm environment for 4 to 8 days.
Eucalyptus spp. (e.g. *E. tereticornis* (red, grey))	Mix seed with wetted Perlite and place in a clear plastic bag for 4 to 8 days. For higher altitude species (i.e. from alpine areas), it may be beneficial to place seed in the refrigerator (4° Celsius) for about a week before sowing.
Melaleuca spp. (tea trees)	As for eucalyptus.
Callistemon spp. (bottlebrushes)	As for eucalyptus.
Allocasuarina spp (she-oaks)	As for acacia except no hot water treatment needed.
Dodonea viscosa	Quickly crack seed with hot water. Mix seed in soil medium and keep in a warm place for 5 to 8 days.
B. Species also worth trying	**Possible germination hints**
Bursaria spp., *Hymenanthera dentata, Coprosma quadrifida*	Place in wetted Perlite and refrigerate for 5 to 15 days.
Leptospermum spp.	Use Smoke Water to wet the propagation medium.

- On sites where there is little weed seed stock in the soil follow this method:
  - Use a rake-hoe, such as a fire-fighting tool, to scalp a small area of topsoil.
  - Cultivate the exposed soil with the rake part of the instrument.
  - Scatter the seed over the cultivated area.
  - Trim down the soil with the back of the hoe.
- On other sites this method may be used:
  - Create a small hole about 50–80 mm deep by removing a plug of soil with a Hamilton tree spade or similar implement.
  - Place a milk carton or bottomless plant pot over the hole to create a protective guard and assist germination by preventing the soil from drying out.
  - Place a small amount of clean germination medium at the base of the hole (20–30mm depth).
  - Sow the seed and tamp down the soil for good contact with the seed.

- Generally for larger seeds, such as wattle species, about 10 to 15 seeds should be sown at each spot.
- For smaller seeds, such as eucalyptus, it will be necessary to sow 50+ seeds in each hole to ensure adequate germination and survival of seedlings. Natural thinning over time will generally result in a single plant being established at each site but if necessary they can be thinned manually.

Management and monitoring

- Controlling weeds during the establishment period of the seedlings is essential.
- Using tree guards at each planting spot will allow the use of a non-residual herbicide to control weed growth, together with suitable surface mulch if available.
- Weeds should be monitored and controlled, especially in the first two years after the restoration works are carried out.
- Areas of patchy germination should be identified and may require re-seeding or planting with tubestock.

Information sources

- Florabank website, www.florabank.org.au.
- Direct Seeding of Trees and Shrubs — A Manual for Australian Conditions, Dalton, G, 1993, Primary Industries SA.
- Greening Australia, www.greeningaustralia.org.au, Technical Advice — Hand Direct Seeding.

Guideline 24: Managing natural regeneration

Primary benefit

- Natural regeneration is a cost-effective way to revegetate a site with species adapted to the site.

Additional benefits

- Enhances wildlife habitat.
- Produces vegetation that is more tolerant than introduced species to prevailing climate, soils and fire, and able to withstand insect attack and disease.
- Restores biodiversity by natural regeneration of the original range of plant species.

What is it?

- Natural regeneration is the process of germinating seed from remnant vegetation, encouraging natural migration of species back to a site or growth from epicormic shoots (below-ground stems) of species such as eucalyptus.

Purpose

- It provides new plant growth that can extend the area of remnant vegetation. It also provide replacements for over-mature plants when they die.

Limitations

- Natural regeneration requires a source of seed from remnant trees, the soil seed bank or dormant epicormic shoots.
- Existing dense weed growth may limit the ability of seeds to germinate.
- Fire is needed to germinate some species with thick seed coats, while other species may be killed by fire.
- Stock grazing can severely limit the survival of natural regeneration.
- Some species require bare ground to germinate and grow.

Materials

- Non-residual herbicide (glyphosate) is often required to spot-spray weeds that compete with natural regeneration.

Guidelines

- Carry out a survey of remnant vegetation to determine and map the distribution, density, condition, size and species composition.
- Identify the species composition of the remnant vegetation by referring to vegetation surveys, the DEC database, and relevant publications (such as Besson and Howell, Taken For Granted; The Bushland of Sydney and its Suburbs, Kangaroo Press, 1990).
- Prepare a Natural Regeneration Management Strategy that is coordinated with any planting program that may be required. Clearly define priorities and a sequence of management actions, including fire management, weed control, public access, supplementary planting and fencing.

- Identify undisturbed areas that contain vegetation similar to that occurring on the site or nearby. This will provide a benchmark or reference for the regeneration process.
- Identify appropriate the fire regime required to induce germination of particular species if necessary.
- Assess the extent and nature of weed infestation and determine the extent to which it is suppressing germination and growth of remnant indigenous species.
- Devise and implement a Fire Management Strategy in consultation with the relevant fire brigade.
- Devise and implement a weed control plan to provide suitable conditions for germination and growth of indigenous species.

Management and monitoring

- Implement a monitoring program that allows the rate and nature of natural regeneration to be assessed (see Greening Australia Technical Advice Sheet).
- See the Community Rapid Assessment and Monitoring Guidelines for Monitoring Bush Regeneration projects, published by the DIPNR..

Information sources

- Riparian Land Management Technical Guidelines, Vol. 2. Chapter E.
- Greening Australia Technical Advice – Monitoring Natural Regeneration, www.greeningaustralia.org.au.
- Australian Association of Bush Regenerators, www.zip.com.au/~aabr.

Guideline 25: Propagating plants

Primary benefit

- Propagation produces plant material that can be used in revegetation projects.

Additional benefits

- Contributes to the local economy and local development.
- Enhances and maintains the genetic resources and biodiversity of the region.

What is it?

- Propagation is the production of plant material from seed or cuttings collected from remnant native vegetation.
- Seed and cutting preparation is either carried out by specialist plant nurseries, or community groups with the necessary skills and facilities.
- Seeds may need specific treatment, such as smoking or scarifying, to make them ready for propagation.
- Some plants are best grown from cuttings, which may require preparation with plant hormones.

Purpose

- To provide native plants for revegetation projects.

Limitations

- Reliable propagation techniques have not been developed for all native plants, and some cannot be readily propagated.
- The reliability of techniques varies, with some plants best provided by specialist nurseries.
- Collecting seed and other material for propagation may threaten the viability of small isolated stands of remnant indigenous vegetation.

Materials

- For most plants, appropriate potting mix and planting tubes are adequate.
- Irrigation facilities and shade structures are also required for propagation.

Guidelines

- Determine the total requirements for seed and plant material to carry out individual restoration projects.
- Prepare a strategy for collecting seed that does not put at risk natural regeneration of remnant native vegetation in the area.
- Establish a propagation program that will meet the requirements of the project within the defined timeframe.
- Allow enough time for collecting seed and propagating plant material as part of the restoration program (see Guideline 4).

- Allow at least six months between confirming the plant order and the required delivery date.
- Allow for a longer propagation time to produce larger plants and improve their hardiness.
- Share the responsibility for propagation between individuals in a community group so that large numbers of plants can be provided relatively cheaply.
- Ensure plants are grown from local provenance seed.
- Ensure that all necessary permissions are obtained for collecting seed on public and private land.

Management and monitoring

- Accurate records of propagation rates for each species are necessary in order to build a database of the most successful propagation techniques for individual species.
- The database should also provide an accurate record of the source of seeds and the planting locations of seedlings propagated from them.

Information sources

- Best practice advice is available from Greening Australia, www.greeningaustralia.org.au.
- Australian National Botanic Garden, www.anbg.gov.au/PROPGATE/plant01.htm.
- Society for Growing Australian Plants, www.farrer.riv.csu.edu.au/ASGAP/seed.html
- Florabank, www.florabank.org.au
- Australian Association of Bush Regenerators, www.zip.com.au/~aabr.

Guideline 26: Planting

Primary benefit

- Effective planting maximises the success rate for establishing vegetation.

Additional benefits

- Maximises the rate of establishing vegetation from available seedlings.
- Increases the level of erosion control provided by established vegetation.
- Enhances aesthetic values.
- Restores biodiversity.

What is it?

- Planting procedures that maximise the survival percentage and rate of establishing vegetation.
- Planting is a less desirable option than natural regeneration but sometimes is the only option where there is inadequate remnant vegetation or seed sources to allow natural regeneration.

Purpose

- To provide for the successful establishment of native vegetation within the riparian zone by using proven planting procedures.

Limitations

- The period of planting is limited by climatic conditions. These influence soil moisture, soil temperature and solar energy available for plant growth.
- Generally the best conditions for planting in the Georges River catchment will be autumn and spring.
- Competition with weeds is generally the major limitation on the survival and growth of planted seedlings.
- Damage by fire, off-road vehicles and people may also be a major limiting factor.

Materials

- Terrestrial and water edge plants are generally supplied as tubestock.
- Aquatic plants are usually supplied as tubestock, seedling plugs or rhizome fragments.

Guidelines

- During summer or early autumn rip the proposed planting area as deeply as possible (except sandy soils and cracking clays), then level the surface.
- When weeds have started to germinate over the planting area, spray with glyphosate (non-residual herbicide) to control early weed growth.
- Cultivate the surface to create a fine soil tilth; 1 m wide strips at 3 m spacing is generally appropriate but this may need to be varied depending on the requirements for weed control, the presence of remnant vegetation, and existing facilities such as paths, roads and buildings.
- Spray the area again with glyphosate to control any additional weed germination (avoid further cultivation as the aim is to provide a moist, fine tilth soil).
- Plant seedlings from tubes or pots, taking care not to damage the root ball. Apply fertiliser, thoroughly water in and place three guards (polythene tubes with stakes or recycled milk cartons).
- Table 7 provides a summary of planting requirements.

Management and monitoring

- Carry out regular inspections (at least monthly) for the first six to nine months to assess weed growth and identify any insect attack or disease that may require treatment.
- Carry out weed or insect control if required.
- Monitor plantings for at least the first 12 months and carry out weeding or watering as required.
- Keep notes on plant survival to revise future revegetation species selection and proportions, or to plan supplementary planting to replace any that die.

Information sources

- Greening Australia, www.greeningaustralia.org.au, Technical Advice — Small Scale Planting.
- Riparian Land Management Technical Guidelines, Vol. 2, LWRRDC, 2000, Guideline E.
- Murray Catchment Management Committee — Publications, www.murraycmb.org.

Table 7: Planting requirements

Vegetation type	Description	Propagation	Timing	Planting	Watering	Weeding
Tubestock — terrestrial	Tubes	Nursery or community growers	Plant late winter	Apply herbicide to planting area 1 month before planting Excavate 0.5 m diameter bowl Plant in centre	Initially 10 litres Water monthly through summer for first year	Allow four hand-weedings in first year
Tubestock — water edge	Tubes	Nursery or community growers	Plant late winter	Plant in saturated soil with up to 150 mm water cover	None required	None required
Tubestock — aquatic macrophytes	Tubes or plugs	Nursery or community growers	Plant winter or spring	Plant in saturated soil with up to 150 mm water cover	None required	None required
Transplants-aquatic macrophytes	Clumps or rhizomes	Collect from non-sensitive sites with permission	Plant winter or spring	Bury rhizomes below mud surface	None required	None required