Wetland Rehabilitation Guidelines

for the Great Barrier Reef catchment

Australian Government

wetlandcare australia

Queensland
Wetlands Programme

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Author

WetlandCare Australia

WetlandCare Australia is a not-for-profit, non government organisation dedicated to supporting the community to protect and repair Australia's wetlands.

This is the final report for the Great Barrier Reef Coastal Wetlands Protection Programme Rehabilitation Guidelines, a project of the Queensland Wetlands Programme. The Queensland Wetlands Programme is a joint initiative of the Australian and Queensland governments established in 2003 to protect and conserve Queensland's wetlands.

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Introduction

Preparation of the Queensland Wetlands Programme Wetland Rehabilitation Guidelines for the Great Barrier Reef Catchment has been funded by the Australian Government as part of the Great Barrier Reef Coastal Wetlands Protection Programme, a component of the Queensland Wetlands Programme. The Programme is a joint initiative of the Queensland and Australian governments established to support activities that will result in the sustainable use, management, conservation and protection of wetlands.

This document gives practical guidance on wetland rehabilitation for farmers, community groups, local councils, Queensland Government agencies, natural resources management bodies and the community. It covers:

- ways to identify and classify wetlands, and determine their values
- threats to wetlands
- planning for wetland rehabilitation
- practical rehabilitation techniques
- legislative requirements
- maintenance, monitoring and evaluation of rehabilitation.

What are wetlands?

Wetlands are areas that are permanently or intermittently inundated with static or flowing water. The water may be fresh, brackish or salt, and may include areas of marine water that is less than 6 metres deep at low tide. To be classified as a wetland, the area must have one or more of the following attributes:

- at least periodically, the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle.
- the substratum consists predominantly of undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers.
- the substratum is not soil, and is saturated with water or covered by water at some time.

Thus wetlands include rivers and creeks, lakes and swamps, mangrove areas and artificial wetlands such as dams, weirs and canals.

Wetland classification

Wetlands are complex by nature, and it is often helpful to categorise them into groups. This process is termed **wetland classification**. Different classification systems may be required for different purposes. All wetland classifications are based on describing values that can be measured, and which, when combined, help to define the nature of a specific wetland and distinguish it from others.

Queensland's **wetland systems** are often characterised by the following criteria:

- quantity and quality of water
- how long water stays in the wetland (wet/dry periods)
- how often the wetland fills, or how water flows through the wetland.

The five main wetland systems in the Great Barrier Reef catchment are:

- **palustrine** (marsh or swamp)
- **lacustrine** (lakes and dams)
- **riverine** (rivers or deepwater habitats in a channel)
- **estuarine** (brackish waters at the marine–freshwater interface)
- **marine** (saltwater up to 6 m in depth).

Within each of the five wetland systems there are various **wetland types**.

There is a broad diversity of wetland types in the Great Barrier Reef catchment. They include, but are not limited to:

- mangrove forests (estuarine)
- saltmarsh (saltpan/samphire) (estuarine)
- coastal saline swamps (palustrine)
- coastal non-floodplain tree swamps Melaleuca and Eucalyptus (palustrine)
- coastal non-floodplain wet heath swamps (palustrine)
- coastal non-floodplain grass, sedge and herb swamps (palustrine)
- coastal floodplain tree swamps – Melaleuca and Eucalyptus (palustrine)
- coastal floodplain wet heath swamps (palustrine)
- coastal floodplain grass, sedge, herb swamps (palustrine)
- coastal floodplain lakes (lacustrine)
- coastal non-floodplain rock lakes (lacustrine)
- coastal non-floodplain sand lakes – perched (lacustrine)
- coastal non-floodplain sand lakes – window (lacustrine)
- coastal non-floodplain soil lakes (lacustrine).

For more information on these wetland types, refer to the Queensland Lacustrine and Palustrine Wetland Habitat Typology, the Queensland Wetlands Programme Wetland Management Profiles Series and the Queensland Wetlands Programme Science Conceptual Models on Wetland*Info* at www.epa.qld.gov.au/wetlandinfo.

Although these Guidelines focus on natural wetlands, many of the principles also apply to constructed wetlands such as farm dams, canal estates, farm drains, bore drains and aquaculture facilities.

Wetland location

Wetlands in different areas of the Great Barrier Reef catchment have different rehabilitation needs, priorities and techniques. These areas are broadly described below to assist in determining the best rehabilitation techniques for a particular wetland.

Region

The Great Barrier Reef catchment is large and varied. Rainfall varies considerably across the catchment, with corresponding variations in runoff and flow into wetlands. Since rainfall and water are defining factors for wetlands, local rainfall patterns should always be considered when planning for their rehabilitation.

Three distinct regions in the Great Barrier Reef catchment, in terms of topography and climatic zone, have been recognised for the purpose of these Guidelines:

- wet tropics (Cape York to Ingham and an area in the Mackay Whitsunday region)
- dry tropics (Ingham to Rockhampton)
- subtropics (Rockhampton to New South Wales border).

Catchment position

Wetland function is closely related to its location in the landscape. Therefore, it is important to look at where the wetland is positioned in the catchment (e.g. upper and middle reaches or lower floodplain) when determining the potential threats and appropriate rehabilitation techniques. For example, if the rehabilitation plan includes weed control, and the wetland is in the upper catchment, there may be little influence from weeds upstream. On the other hand, if the wetland is mid-catchment, then a look at the weed populations upstream will be beneficial. Weeds in the upper catchment should be controlled first (if possible), so that any weed management in the lower parts of the catchment is not undone by weeds washing downstream.

Upper catchment wetlands are usually in a mountain environment, near the source of the river system. They are often fed by springs or groundwater, and have unique ecosystems. They are predominantly freshwater systems underlain by peat (organic matter).

What are wetlands?

Mid-catchment wetlands are usually on river floodplains. They are often filled by groundwater or rainfall, or fed by overland flow events. They are predominantly freshwater systems, although some brackish wetlands may occur. They are often underlain by ancient floodplain alluvial soils.

Lower catchment wetlands occur closer to the river mouth and the ocean. They can be fed by groundwater or rainfall, and some are tidally influenced. They are predominantly brackish or saline systems, though freshwater wetlands, or wetlands that can only tolerate infrequent saltwater intrusion, may also be found in the lower catchment. They are often underlain by estuarine mud and sandy soils.

Figure 1 illustrates the upper, mid and lower catchment areas and potential wetland positions within them.

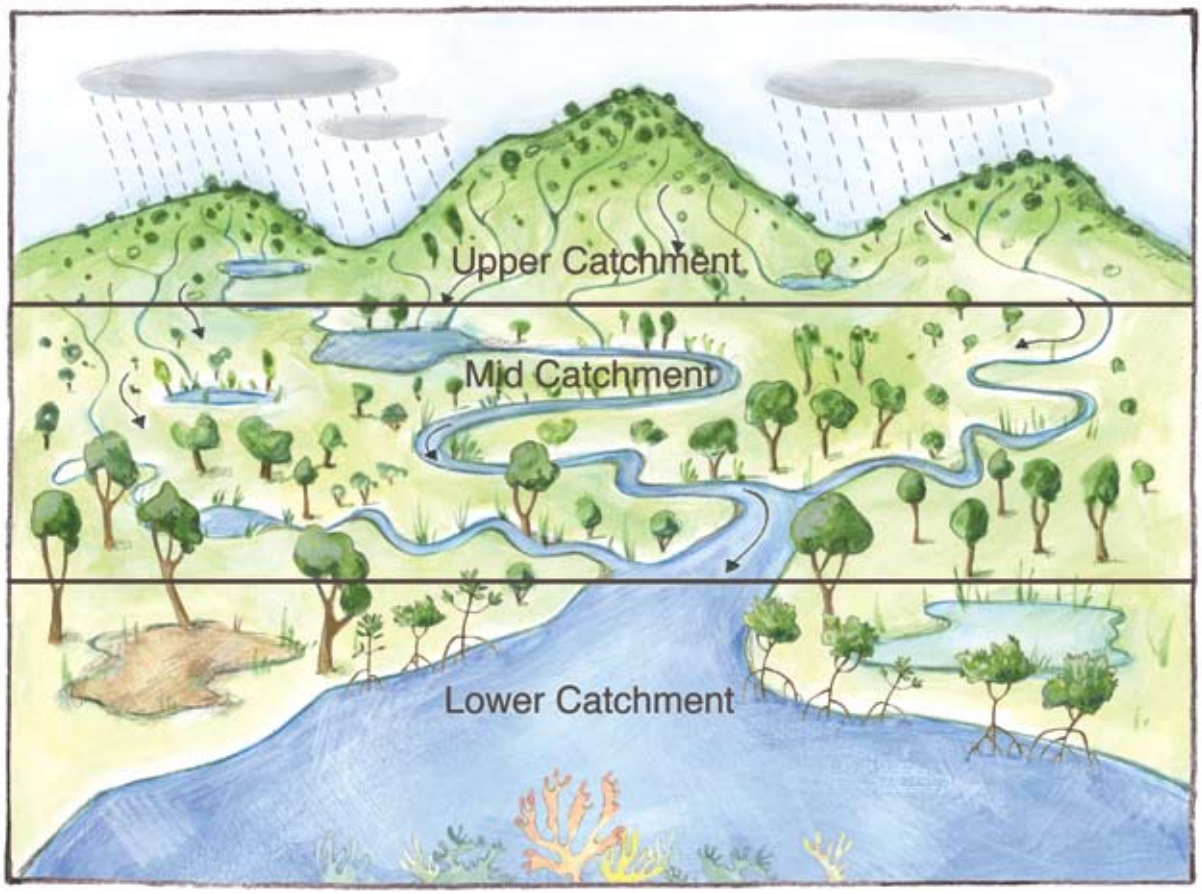

Figure 1. Catchment positions of wetlands

Zone

Each wetland has zones characterised by different types of vegetation. These zones vary greatly between wetland types, but usually fall into the categories riparian/fringing, emergent and aquatic (Figure 2).

The riparian/fringing zone is the zone of water-tolerant vegetation around the edge of the wetland. It often includes larger forest species, as well as smaller plants and understorey species. The riparian zone provides bank stability, shade, wildlife habitat and connectivity to the wetland.

The emergent zone is between the riparian and aquatic zones. The plants in the emergent zone are inundated periodically, and are predominantly reeds, rushes and sedges that can tolerate wetting and drying cycles. The emergent zone is important as a filter for water entering and flowing through the wetland; for bank stability, particularly in high flows; and as a habitat for land and water animals.

Plants in the aquatic zone are usually submerged or floating. They tolerate some drying, but require water most of the time. The aquatic zone is the site of nutrient uptake from the water, and it provides habitat, shelter and a source of food.

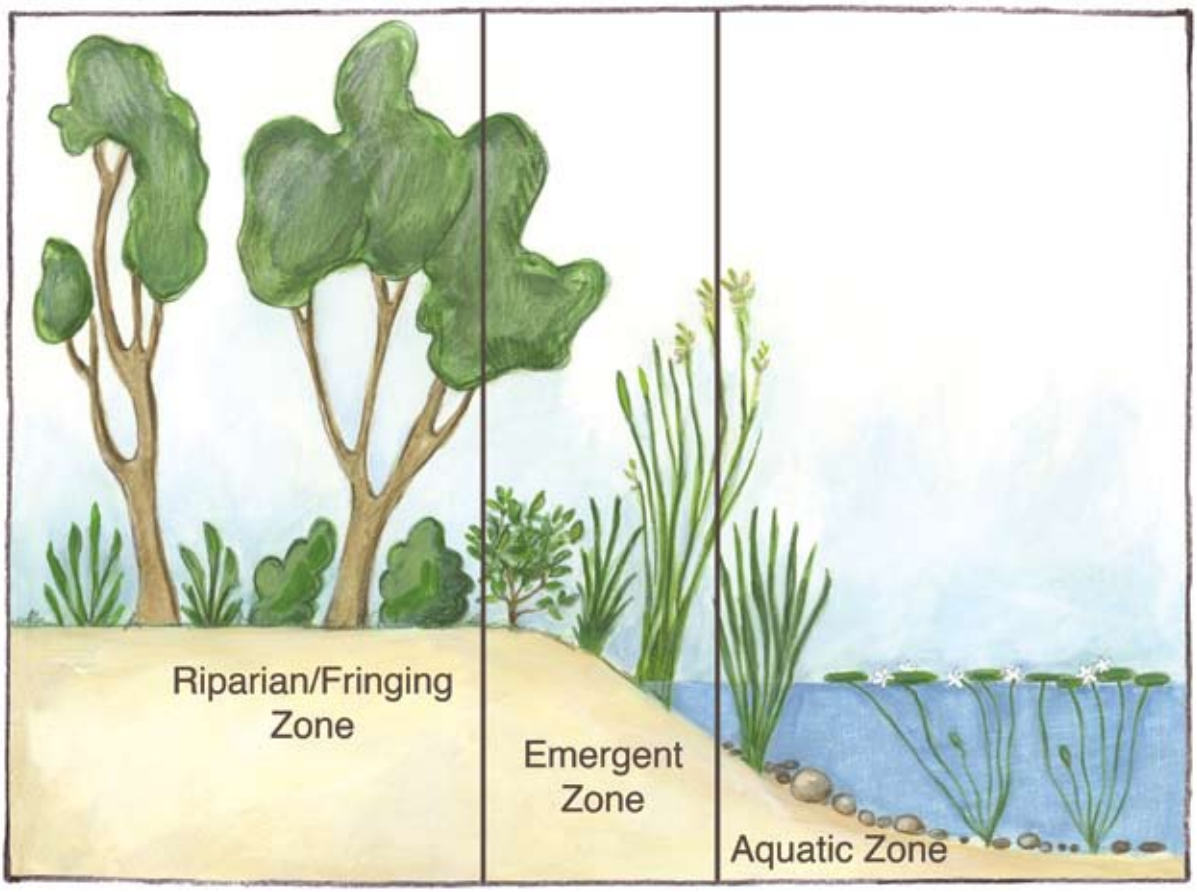

Figure 2. Common wetland vegetation zones: riparian/fringing, emergent and aquatic

What are wetlands?

Wetland values

Wetland values refers to the important functions of a wetland, such as their capacity to protect shores from wave damage, reduce the impacts of floods, absorb pollutants and provide habitat for animals and plants. Wetlands have many values, including:

- environmental and biodiversity values
- cultural values
- economic values
- educational and recreational values.

A full list of wetland values is available in the Summary Information section of Wetland*Info* at www.epa.qld.gov.au/wetlandinfo.

Environmental and biodiversity values

Wetland environmental values are the physical and biological characteristics of the wetland. Worldwide, shallow waters and wetlands provide up to 40 per cent of global renewable ecosystem services. Amazingly, these ecosystems cover only 1.5 per cent of the earth's surface (Zedler 2000).

Locally, wetlands provide a number of valuable ecosystem functions and services to the Queensland community. They support a high level of biodiversity, and provide flood control, groundwater recharge and water purification. A wetland's ability to control erosion and purify water means that it can buffer the impact of pollutants entering rivers, streams and the Great Barrier Reef lagoon.

Wetlands also provide essential habitat for 130 fish species, 150 species of waterbird and more than 3000 plant species, in addition to being valuable fish nurseries. Queensland has the most diverse freshwater fish fauna of any state in Australia, which would not be possible without a diverse range of wetland habitats.

A wetland's ecological processes are considered as the default values that should be protected in any wetland, as they are necessary for maintaining all the other values of the wetland (hydrological processes, food webs, physical habitats, nutrient cycling, sediment trapping and stabilisation).

Figure 3 illustrates how wetlands in a healthy catchment system filter runoff from the catchment landscape, maintaining water quality all the way to the reef and providing habitat areas for a vast array of wildlife.

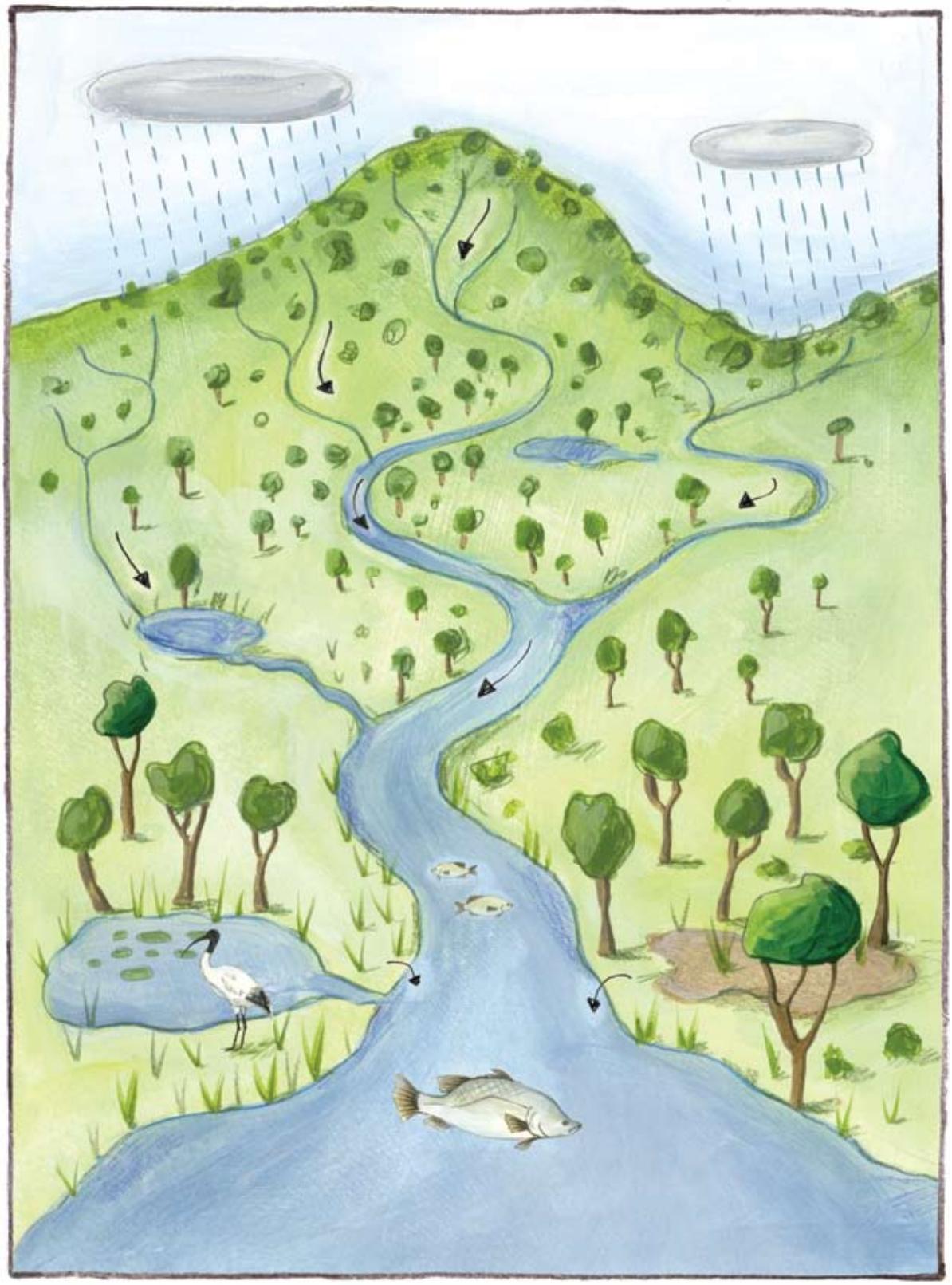

Figure 3. Wetlands in a healthy catchment system act as a filter for runoff from the catchment landscape.

What are wetlands?

Cultural values

Wetlands have historical and cultural significance for both indigenous and non-indigenous Australians. Consideration of these historical and cultural relationships is a fundamental aspect of wetland management.

For thousands of years, wetlands have provided food sources, meeting places and campsites. At many wetlands in coastal Queensland rock painting, ancient tools and scar-trees provide evidence of past Aboriginal activity.

Aboriginal and Torres Strait Islander people are the traditional owners of the Great Barrier Reef region and hold a vast knowledge of the wetlands, their habitats and their ecology. Hunting and fishing in the wetlands are culturally important traditions, and resources from the water are used for a variety of purposes.

Wetlands are significant ceremonial, meeting and teaching places. They are part of the Dreaming and natural beliefs of the Aboriginal people, and most Dreamtime stories and artworks speak of them. Many of the stories feature fish, turtles, crocodiles and great expanses of water. They tell of serpents that created rivers and of creatures that live in the depths of the wetlands.

Economic values

Correctly managed wetlands can have significant benefits in terms of farm productivity. Wetlands are also critical to Australia's commercial and recreational fishing industries because they provide nurseries for fish and other freshwater and marine life. Fishing is a key component of the economy in many coastal Queensland areas, as is tourism.

The beauty of Queensland's natural environment is a major attraction for the vast numbers of tourists who visit each year. Many of these natural attractions, such as the Great Barrier Reef, rely on the protection and restoration of wetlands to maintain their ongoing health. Wetlands themselves, such as Tyto Wetlands in Ingham and the Mareeba Wetlands on the Atherton Tablelands, are also popular tourist attractions.

Educational and recreational values

Wetlands are important for recreational activities. Many Queenslanders enjoy wetlands for fishing, swimming, skiing, bird-watching, canoeing, camping and many other activities. Wetlands are also aesthetically pleasing, and many Queenslanders simply find pleasure in appreciating the view across a healthy wetland.

Natural wetlands provide open-air classrooms for schools, university students, and the community. They must be kept intact to ensure that future generations are still able to benefit from their educational properties.

Interpretive and educational wetland centres have become an increasingly popular experience for locals and visitors, and serve to communicate the complex and intricate nature of the processes underlying wetland ecology. They are also uniquely capable of displaying some of the more elusive wetland creatures, thus fostering an appreciation of the diverse forms of life that exist in wetlands. Many of these educational centres have come about as a result of community involvement in the restoration of a degraded area. They have produced many benefits including improved water quality, increased tourist numbers, scenic amenity and civic pride. These facilities serve to increase awareness of how human activities can damage wetlands and how these special places may best be protected.

Threats to wetlands

Influences such as urban development and agricultural activities pose many threats to wetlands, through:

- introduced species (weeds and feral animals)
- changed land use
- changed hydrology and water quality
- climate change.

The Practical Rehabilitation Techniques section of these Guidelines has been divided into parts based on responses to key threats to wetlands in Queensland's Great Barrier Reef catchment (see Table 1). Key threats were determined through a consultation process with local experts and practitioners currently working in the region's wetlands. They are the threats that are identified as both most damaging and most commonly occurring.

Table 1. Colour-coding for rehabilitation techniques

Retaining and restoring habitats	
Managing weeds	
Managing feral animals	
Restoring native vegetation	
Preventing soil erosion & acidity	
Restoring hydrology	
Improving water quality	
Managing grazing	
Managing fire	

To make best use of these sections it is important to understand how to identify threats to a particular wetland. Use the 'What to look for' checklists to help you determine whether a wetland is threatened.

Example

What to look for

Use the following checklist to assist in determining a management strategy. The things to look for have been split into three sections:

1. Protect the things about the wetland that should be protected.
2. Repair the things about the wetland that could be improved and can be progressed by a local person (i.e. landholder, land manager).
3. Seek expert help with the things about the wetland that should be improved but require some technical assistance or advice.

Protect	**Tick**
From disturbance by feral pests such as pigs or exotic fish (gambusia and tilapia)	☐
Repair	
Evidence of feral pests such as diggings, vegetation damage, or large populations of exotic fish or cane toads in the water	☐
Seek expert help	
Seek help with infestations of feral pests that cannot be managed at the property scale	☐
Landholders unable to control feral pests between their property and their neighbours' should seek local government assistance.	☐

Threats to wetlands

Climate change: a wetland threat?

There are rehabilitation actions available to combat most threats to wetlands. The threat of climate change, however, is an exception.

Potential impacts of climate change in Queensland may include increased temperatures, changes in rainfall patterns and increases in extreme weather events such as cyclones. Average annual temperatures across Queensland are predicted to increase. Annual rainfall for coastal areas south of Cairns has already declined at a rate of about 50 mm each decade since 1950, while the annual average intensity of coastal rainfall has increased.

The number of cyclones is not expected to change, but they are expected to become more intense (with higher wind speeds and more intense rainfalls); and the path of cyclones may extend southwards. Predicted increases in mean sea-levels, and changes to sea-level extremes as a result of storm surges, will increase the risk of inundation of low-lying land. Consequences of these climatic changes for wetlands include the potential for:

- saltwater intrusion into freshwater wetlands
- reduced surface water flows
- increased frequency and duration of toxic algal blooms
- increased soil erosion
- increased sediment and nutrients flowing into watercourses
- damage to fish habitat areas such as mangroves and mudflats.

What can be done?

Healthy wetlands will be better able to adapt to the uncertain impacts of climate change. Follow the wetland rehabilitation guidelines to ensure your wetlands are in the best possible health.

Further information

Environmental Protection Agency 2006, *Climate science, impacts and adaptation*, Environmental Protection Agency, Brisbane, viewed [2008], <www.epa.qld.gov.au/environmental_management/sustainability/climate_change_and_greenhouse/climate_science_impacts_and_adaptation/>.

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Australian Greenhouse Office (AGO) 2005, *Living with climate change: an overview of potential climate change impacts on Australia*. Commonwealth of Australia, viewed [2008], <http://www.greenhouse.gov.au/impacts/overview/index.html>.

Planning for wetland rehabilitation

This section of the Guidelines will help you plan for wetland rehabilitation; there are also some templates at the back of the Guidelines to help simplify the process.

The key steps in planning are listed below.

1. **Assembling background information:**
    a. What type of wetland is it?
    b. Where is it located in the catchment?
    c. What values does the wetland have? (What is already there?)
    d. What are the threats to the wetland?
2. **Action planning:**
    a. What can be done to protect the values?
    b. What can be done to mitigate threats?
    c. What can be done to rehabilitate damage?
    d. Do I need any technical advice?
    e. Do I need any permits or permissions?
    f. How do these actions fit into my property plan?
3. **Prioritising actions:**
    a. What is the ultimate goal for rehabilitation?
    b. What are the most important actions to achieve that goal?
    c. What is the budget and timeframe?
    d. What can be achieved within the current budget and time?
4. **Implementing priority actions:**
    a. What is the best order in which to undertake actions?
    b. When is the best time of year to undertake actions?
    c. Do I need additional equipment or people?
5. **Monitoring and evaluation:**
    a. Has the rehabilitation been a success?
    b. What priority actions still remain?
    c. What are the next steps for further rehabilitation?
    d. What needs to be done to maintain the wetland?

Assembling background information

Use the introductory sections of these Guidelines, historical information and a site visit to inform you about the wetland. An aerial photograph and a topographic map are also useful for background information and planning; these can be found using the Queensland Wetlands Programme wetland map server available on Wetland*Info* at www.epa.qld.gov.au/wetlandinfo.

Template 1 at the back of these Guidelines is a **wetland threat score card.** It is designed to summarise the threats to the wetland's health and provide guidance as to the appropriate response. Use the following star rating system to rate the intensity of each threat to the wetland:

very low	★
low	★ ★
moderate	★ ★ ★
high	★ ★ ★ ★
very high	★ ★ ★ ★ ★

For example, if the wetland has a wide buffer of surrounding vegetation it may score ★ (i.e. very low) in the 'lack of vegetation' box. If the wetland has no surrounding vegetation buffer, it may score ★ ★ ★ ★ ★ (i.e. very high).

See below for an example of a completed wetland threat score card.

Action planning

Remember that **prevention is better than cure**. Options for early intervention and prevention of threats to wetlands are outlined in the Practical Rehabilitation Techniques section of these Guidelines. It is always better to prevent threats than to rehabilitate wetlands after they have been damaged. This is particularly important in relation to weeds, feral animals, erosion and fire.

Use the techniques suggested throughout these Guidelines to determine the possible actions you could take to rehabilitate the wetland. Look out for the 'Who to contact for advice' boxes if you need more information or technical assistance.

Wetland threat score card — example			
Wetland name	Lots-a-ducks wetland		
Wetland catchment location (circle):	Upper	Mid	Lower
Rainfall region (circle):	Wet	Dry	Sub
Wetland type (from page 3):	Coastal floodplain lake		
Threat	Intensity Rating (★s)		
Lack of habitats	★★		
Weeds	★ ★ ★ ★		
Feral animals	★		
Lack of vegetation	★ ★		
Soil erosion and acidity	★		
Changed hydrology	★ ★ ★		
Poor water quality	★		
Grazing damage	★★★		
Fire damage	★		

Planning for wetland rehabilitation

Refer to the Legislative Requirements section of these Guidelines to determine whether you require any **permits or permissions** for your actions. If you are in any doubt, contact the Department of Natural Resources and Water for further advice.

Incorporate wetland management and rehabilitation as part of overall **property planning**. This will ensure that wetland management and rehabilitation fits in with the current and future plans for the property. Property planning is:

- a strategy to meet financial, production and personal goals
- a management tool for developing a property sustainably and profitably
- a record demonstrating that environmental obligations in natural resource management are being met.

For more information on property planning, go to the Department of Natural Resources and Water's OnePlan initiative at www.nrw.qld.gov.au.

Prioritising actions

It is important to have a **management goal** as the overall aim of wetland rehabilitation in order to:

- avoid using rehabilitation techniques that conflict
- keep works focused
- prioritise rehabilitation works
- evaluate rehabilitation success.

Goals should be clear, specific and achievable, and should have a timeframe (e.g. 1 year, 3 years or 5 years). The values of the wetland and the threats to it will both assist in determining the management goal(s). The goal(s) may reflect protection of one or more of the values, or may concentrate on only one or two of the threats to the wetland. Constantly referring to goals will keep planning and rehabilitation action on track.

Implementing priority actions

There are some constraints that may limit your ability to carry out high-priority actions, so make sure you include them in your planning:

- timing (wet or dry weather; season; month of year)
- relevant legislation (i.e. permits)
- capacity (what equipment and how many people required)
- availability of technical assistance
- cost (approximate) and financial assistance required
- maintenance costs.

Once your planning is done, it is a matter of getting out there and doing the work! But be prepared for a few unforeseen delays and hurdles.

Monitoring and maintenance

It is essential to the success of wetland rehabilitation that monitoring and maintenance of the site is ongoing and long-term. Monitor changes in the wetland that are relevant to the management goal. For example, if the goal was to improve fish passage, then monitor fish movement and abundance.

Be sure to include a monitoring and maintenance plan for the site. There are tips throughout these Guidelines that indicate the timing of monitoring activities. Also refer to the Maintenance, Monitoring and Evaluation section of these Guidelines for techniques for monitoring the site.

When **look and touch symbols** are indicated for a rehabilitation technique throughout these Guidelines, this is a reminder to monitor by sight and by feel (e.g. check soil moisture), both during rehabilitation and in the long term.

Template 2 at the back of these Guidelines is a **planning table** to assist in bringing together all the steps in wetland rehabilitation planning (see example next page).

Wetland rehabilitation planning – example

Management goals: Reduce floating aquatic weeds by 80% in one year.
Reduce riparian weeds by 50% and replace with native vegetation.

Threat	**Intensity Rating (★s)** (high to low)	**Rehabilitation techniques** (chosen from Guidelines Sections)	**Timing**	**Permits** (Y/N)	**Capacity** (H/M/L)	**Tech Assist** (Y/N)	**Cost** (~$)
Lack of habitats	★	Assisted revegetation	Dry season	N	M	N	$1000
Weeds	★★★★★	• Mechanical control • Herbicide Biological control	Dry season	Y	M	Y	$5 000
Lack of vegetation	★★★★★	Natural regeneration by selective weed control in riparian areas	–	N	L	N	$0
Poor water quality	★★★	Monitor changes	Before and after weeds removed	N	L	N	$0
Feral animals	★★	• Ground baiting pigs (1080) Neighbourhood control program	Dry season	Y	M	Y	$1000
Soil erosion & acid sulfate soils	★	Assisted bank revegetation	Dry season	N	M	N	$2500
Changed hydrology	★	• Remove block in tidal channel • Install dish drains and silt trap • Monitor change Protect where possible	Dry season	Y	L	Y	$10 000
Grazing damage	★	• Fence out wetland area • Crash graze in dry season • Monitor change Protect where possible	Dry season	Not if you own the land	L	N	$10 000
Fire damage	★	• Mosaic burning of weed areas • Fire breaks where possible Monitor change	Consider local seasonality	Y	L	Y	$1000

Long-term maintenance plan HOW? Refer to the Maintenance, Monitoring and Evaluation section of these guidelines Refer to the rehabilitation actions being completed Consider how they need to be maintained; e.g. watering, weed monitoring, replacement plants Consider the timeframe maintenance will be required Consider how often monitoring should be undertaken (enter this in the 'timing' box ➜) Also consider any permits, capacity, technical assistance and cost (over all years), also enter these	**Maintenance actions:** Watering	6 monthly for 1 year	N	M	N	$5 000
	Weed control	1 monthly for 3 years	N	M	N	$7 500
	Plant replacement		N	M	N	$10 000
Monitoring and evaluation HOW? Refer to the Maintenance, Monitoring and Evaluation section of these guidelines Refer to the goal of your rehabilitation Choose the appropriate monitoring technique(s) for your goals. Enter them in the box to the right ➜ Consider when BEFORE and AFTER monitoring needs to occur (it may need to be on a regular basis for a number of years) Consider the needs for permits, capacity, technical assistance and cost to undertake monitoring Use the results of before and after monitoring to evaluate the success of the rehabilitation toward the goals NOTE: A measurable change may take some years to occur	**Monitoring techniques:** Aquatic weed area measure (m2)	Once before and bimonthly after	N	H	N	$5 000
	Riparian weed number (stems)	Once before and once after	N	L	N	$1 000
	Native plants established or naturally regenerated (m2)	Once before and once after	N	L	N	$1 000

Practical rehabilitation techniques

The following pages outline practical rehabilitation techniques, hints and tips, examples and further contacts for a range of wetland threats facing wetlands in the Great Barrier Reef region (Figure 4).

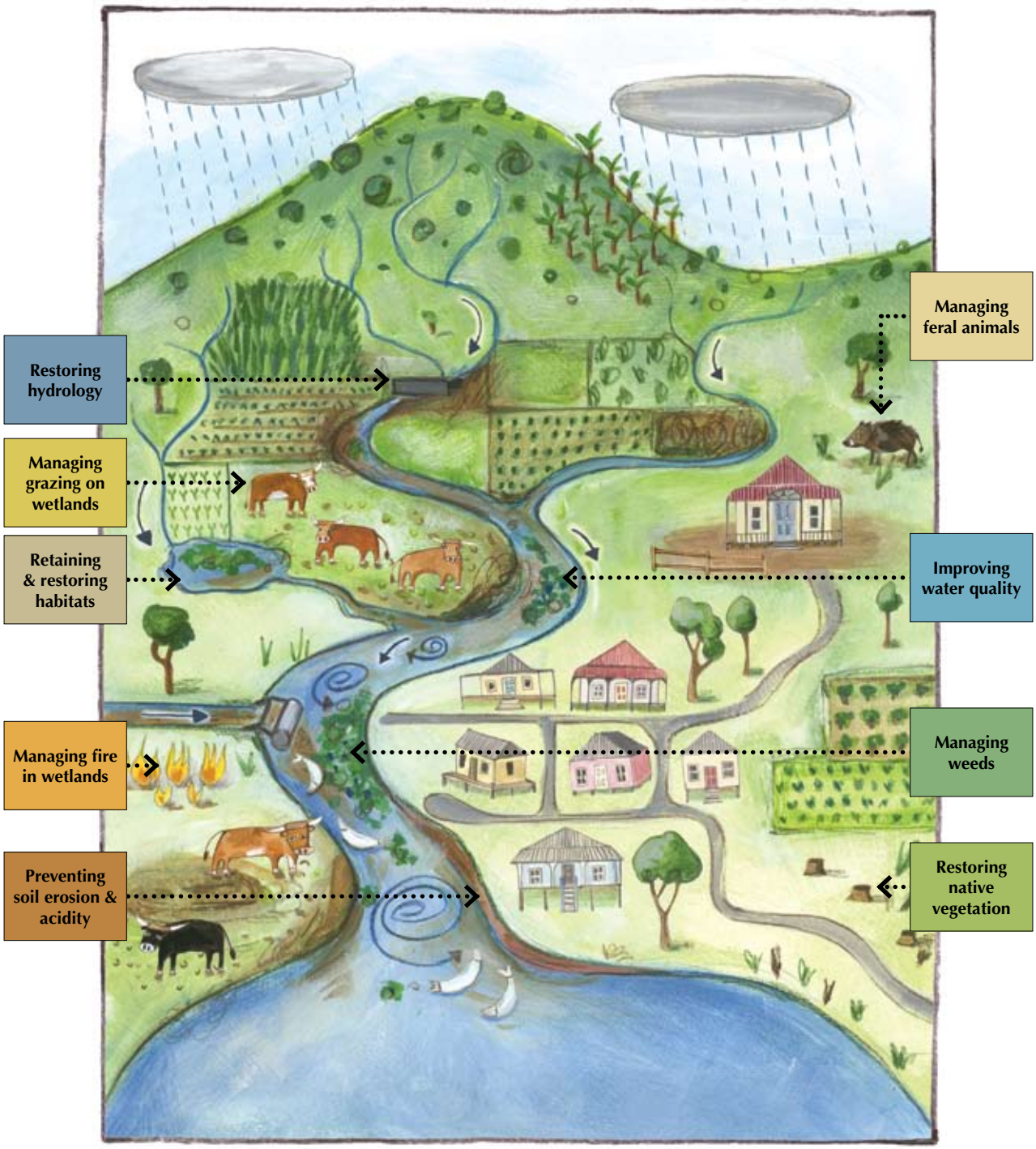

Figure 4. Rehabilitation techniques for potential threats to coastal Queensland catchments. Section names are indicated on the diagram above.

Retaining and restoring habitats

What are habitats?

Habitats are areas that provide wetland animals with adequate food, water, shelter and living space. The three habitat zones found in most wetlands are:

- aquatic in-stream (i.e. in the water)
- emergent (i.e. around the edge of the water)
- riparian/fringing (i.e. around the edge of the wetland)

These wetland zones all work together to provide the essential habitat features of a wetland. The essential habitat features of wetlands include:

- water (of good quality and natural hydrology)
- a range of vegetation types and species
- connectivity (through the water and over land)
- in-stream features (including snags and islands).

The seasonal availability of these habitat features is also important, particularly to migrating birds and fish that move into particular habitats in large numbers at certain times of the year.

Why is habitat important?

It goes without saying that wetland habitats are essential to the survival of all wetland species. Even species that do not live in the wetlands permanently may spend a critical part of their life cycle in a wetland habitat.

Habitat structure in the Great Barrier Reef catchment wetlands has undergone dramatic changes through broad-scale clearing, burning, grazing, cropping, and associated increases in sediment and nutrient loads, water resource development, introduced species and urbanisation. All of the issues covered in these Guidelines affect wetland habitats in some way, so it is important to plan holistic rehabilitation techniques when improving wetland habitats.

What to look for

Use the following checklist to assist in determining a management strategy. The things to look for have been split into three sections:

- **Protect** the things about the wetland that should be protected.
- **Repair** the things about the wetland that could be improved and can be progressed by a local person (i.e. landholder, land manager).
- **Seek expert help** with the things about the wetland that should be improved but will require some technical assistance or advice.

Protect	Tick
In-stream snags (logs and other debris make good habitat)	☐
Native vegetation: floating, emergent and riparian	☐
Diversity of native animals	☐
Threatened species	☐
Habitat corridors connecting to other wetlands (overland and via water)	☐
Natural hydrology and hydraulics (water flow and depth)	☐
Vegetation buffer between the wetland and surrounding land uses	☐
Repair	
Human access damage (rubbish, 4WDs, motorbikes, boating)	☐
Gaps in corridors, barriers to connectivity	☐
Poor water quality	☐
Seek expert help	
Encroachment of urban development	☐
Landscape-scale loss of habitats	☐

Retaining and restoring habitats

What to do about habitats

Wetlands themselves are regarded as a series of interconnected habitats. It is important that each of these habitats does not exist in isolation or become cut off from the others. Different wetland types have different habitat features, and include more or less of each of the habitat zones described above.

Steps in rehabilitating wetland habitats:

1. Determine what the rehabilitation goals for habitat are. For example, what elements of the wetland habitat complex most need restoring, and is the aim of the restoration works to serve waterbirds, fish or overall biodiversity (i.e. many different species)?
2. When planning to rehabilitate habitat, ensure that any existing on-site habitat values are protected, and seek to consolidate these values with planned rehabilitation.
3. Plan to restore a range of different habitats, because no wetland habitat type should exist in isolation. (See Table 2 below for information on habitat features of different wetland types.)
4. Plan to retain and improve habitat features in a logical sequence. For example, if an island is to be created, make sure it is complete before you add fringing plants, because further construction would disturb the bank.
5. Consider the timing of rehabilitation. Ensure that there is limited disturbance to species in the area (i.e. breeding and nesting times) and that any earthworks or revegetation activities consider the constraints and benefits of the annual wet season.

Note: Any construction within watercourses requires a permit under the *Water Act 2000* and possibly the *Integrated Planning Act 1997*.

Table 2. Habitat features likely to be found in each wetland system

Wetland system	Habitat features
Estuarine (e.g. mangroves and saltmarsh)	Shallow marine waters Snags Submerged vegetation (seagrass) Small hollows, leaf litter and fallen branches
Palustrine (swamps)*	Shallow water Riparian and fringing vegetation Emergent and floating aquatic vegetation Snags Islands Drying cycle Small hollows, leaf litter and fallen branches
Lacustrine (lakes)*	Deep water Shallow water Riparian and fringing vegetation** Emergent and floating aquatic vegetation** Snags Islands Drying cycle

* For more information on these wetland systems, refer to the Queensland Lacustrine and Palustrine Wetland Habitat Typology, the Queensland Wetlands Programme Wetland Management Profiles Series and the Queensland Wetlands Programme Science Conceptual Models on Wetland*Info* at www.epa.qld.gov.au/wetlandinfo.

**Lacustrine wetlands can be fringed by, or contain, components of palustrine (vegetated swamp) habitat.

Figure 5. Range of habitats and values commonly associated with wetlands

The following paragraphs contain rehabilitation techniques for the essential habitat features of a wetland (Figure 5).

Water

Water is one of the most essential components of wetland habitat. It is important for two reasons:

- water quality—turbidity, available oxygen, nutrient loads and temperature
- hydrology—inundation time, seasonal wetting ad drying cycle, depth, inflows and outflows.

Water quality can be adversely affected by various factors including erosion, stock access, point-source pollution, and chemical and nutrient pollution in runoff. Poor water quality means poor habitat in a wetland. See the Improving Water Quality section of these Guidelines for rehabilitation methods.

Hydrology can be affected by blockages to flow such as road crossings or floodgates, by water extraction, water storage, rainfall and drought. Unnatural hydrological regimes mean poor habitat for wetlands. See the Restoring Hydrology section of these Guidelines for rehabilitation methods.

Retaining and restoring habitats

Vegetation

Vegetation, including in-stream, emergent and riparian, are all important habitats for a wide range of animal species. Vegetation provides excellent habitat when it:

- is native, and representative of the region
- is structurally diverse (i.e. many levels, including grasses, shrubs and trees)
- encompasses all three habitat zones—aquatic, emergent and riparian
- provides habitat connectivity from one wetland to another
- provides a buffer between the wetland and surrounding land uses (e.g. urban areas or farming).

See the Restoring Native Vegetation and Managing Weeds sections of these Guidelines for further information on improving native vegetation for habitat.

Vegetation can provide a protective buffer for wetlands against damage and pollution from neighbouring land uses. Vegetative buffers also protect against wind and erosion, as well as reducing the effect of high temperatures by providing shade.

Aquatic and terrestrial connectivity

It is important for aquatic and terrestrial animals to be able to move freely between feeding, breeding and resting areas along sheltered areas, whether by land or water. Breaks in this shelter can significantly impede their capacity to move between habitats (Figure 6).

Restoration of connectivity requires gaps in riparian vegetation to be filled by revegetation, and barriers to water flow to be modified to allow fish movement.

Habitat connectivity is important for terrestrial animals such as birds and frogs that move from wetland to wetland. The vegetation allows the animals to move between wetlands and other areas, and ensures they find breeding mates and maintain populations, thus supporting genetic and species diversity.

There are two main ways to improve terrestrial connectivity between wetlands:

- increase riparian vegetation
- revegetate habitat corridors.

Broad riparian zones

Increasing the vegetation around a wetland can connect it to other riparian areas of nearby wetlands. This provides continuity of vegetation through to neighbouring wetlands and safe passage for animals.

Habitat corridors

Habitat corridors are 'trails' of vegetation connecting one wetland to another. They can be a cost-effective way of connecting wetlands that are further apart. A broad line of trees, at least 10 m wide, can provide safe passage for animals to move from one wetland to another.

When planning revegetation of a wetland for the purpose of habitat retention, consider the location of neighbouring wetlands and how best to connect to them. When planning for connectivity, consider the placement of roads and fences, continuity of riparian vegetation, and potential for maximising the total vegetated area around the wetland.

Hydrological connectivity

Barriers to fish passage and hydrological connectivity include dams, weirs, bunds, floodgates, weed chokes and poor water quality (often associated with weed chokes). In addition, high flow velocities associated with road crossings and other in-stream flow-constricting structures can prevent fish from reaching upstream areas if they are not able to bypass the high-flow velocity areas.

The loss of connectivity between freshwater and marine habitats is one of the main threats to the fish communities of Queensland's coastal wetlands. Connectivity is essential for maintaining viable fish populations, and it is most important to prevent localised extinction of fish in freshwater habitats.

Solutions include:

- removing flow-constricting structures
- installing fishways
- minimising water flow velocity associated with in-stream flow constrictions
- minimising free-fall areas (such as culvert aprons)
- installing 'rest zones' for fish moving upstream in constructed drain environments
- removing chemical barriers

Note: Seek expert advice from the Department of Primary Industries and Fisheries for the best possible outcomes in relation to fish passage and hydrological connectivity.

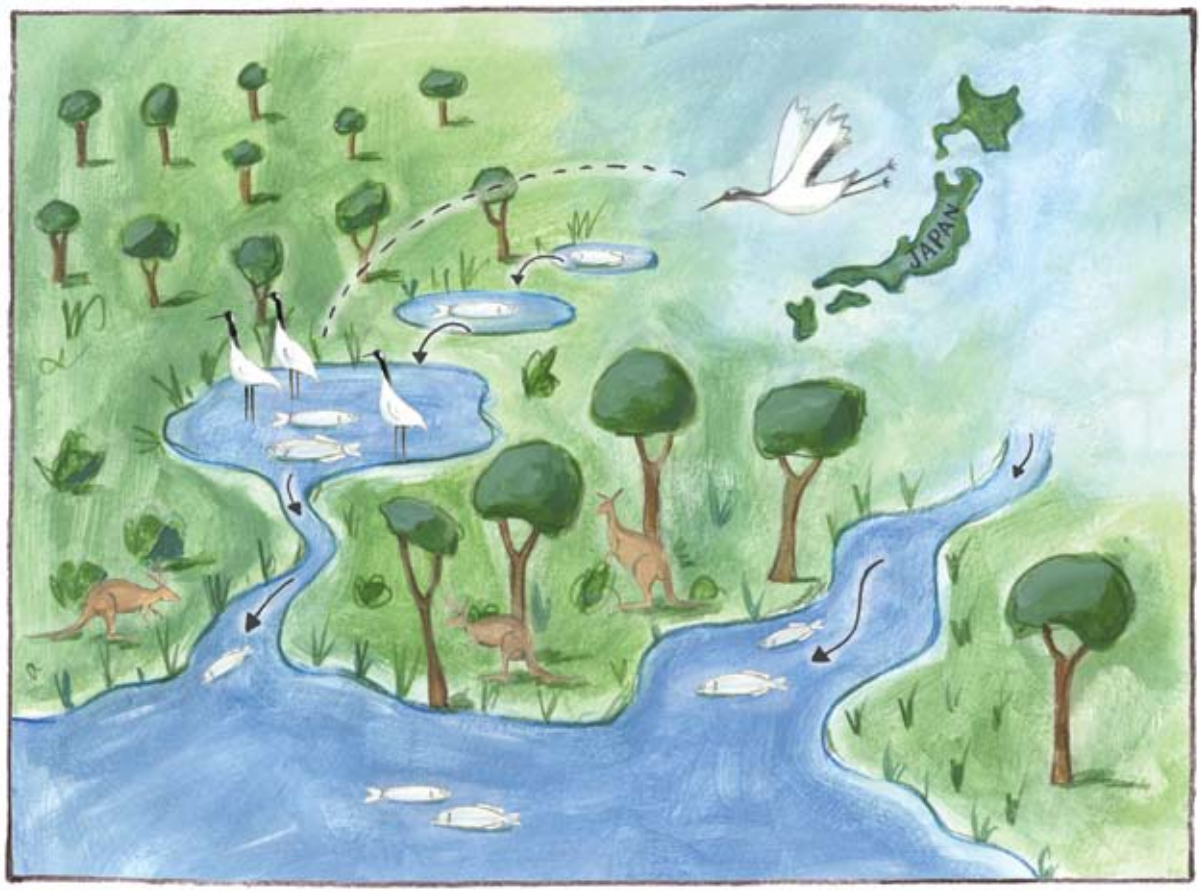

Figure 6. It is important that wetlands are well connected not only to other wetlands and forested areas in the catchment.

Structure removal

Barriers to fish passage should be removed where possible. Other options are to change the type of the barrier to one that has less impact on flow and fish passage. If this is not possible, a fishway should be considered. If the barrier is on a stream, it will be necessary to obtain a permit to remove it. Barriers such as weirs or barrages may be licensed under the *Water Act 2000* and the *Integrated Planning Act 1997* and their removal may be subject to conditions.

For further information refer to 'Opening or lowering flow blockages' in the Restoring Hydrology section of these Guidelines.

Care with installation of new barriers

New barriers should be installed only if absolutely necessary. If the barrier is to be constructed in a stream, you will first need to obtain a water licence under the *Water Act 2000* and a development permit under the *Integrated Planning Act 1997*. Do not place barriers in areas of bends or riffles in a waterway; and avoid works that may change the shape or flow of the waterway or damage existing vegetation or stream-banks.

Waterway crossings should have a minimum impact on flow, should not increase flow velocity (it should remain below 0.5 m/sec) and should have no upstream or downstream 'drop'. Incorporate rocks in the base of the culvert and avoid floodgates where possible. If the crossing is to be constructed in a stream, you will first need to obtain a permit under the *Water Act 2000*.

High-flow areas can act as a barrier by making it impossible for fish to swim against the flow, thus blocking their access to upstream areas. However, boulders positioned in the wetland or stream can assist by allowing fish 'rest zones' for their upstream migration. If you are planning to place boulders in a stream, contact the Department of Natural Resources and Water, because a permit under the *Water Act 2000* may be required.

Altering drainage design

Fish will use farm drains in the same way as they use a stream if conditions are suitable. Drains connecting to streams should therefore be designed to facilitate fish movement, by providing fish with shelter and good water quality. There should be no restriction to fish movement into and out of drains. This can be achieved by maintaining a minimum depth of 30 cm.

For more information see 'Redesigning constructed drainage' in the Restoring Hydrology section of these Guidelines.

Removing chemical barriers

Chemical barriers to fish movement include low dissolved oxygen and acid sulfate soil drainage water. These barriers, which are often invisible, can limit fish movement just as effectively as physical barriers. Refer to techniques outlined in the Improving Water Quality section of these Guidelines for techniques to prevent and remove chemical barriers.

Aquatic Habitat Structures

Snags are solid surfaces within the wetland, such as fallen trees, branches or rock assemblages. Snags provide a range of habitats to many aquatic organisms. Aquatic species may colonise hard surfaces or lay their eggs there. They find shelter in the many small spaces provided by the snag or they use it to ambush prey.

Snags can provide important aquatic habitats (photo by Cassie Price)

Snag management includes:

- ensuring remnant snags are left in place
- reorienting (not removing) the snag if it is in a riverine wetland and causing flow erosion or stream blockage
- improving the riparian zone to encourage future woody snags—by revegetating with a variety of snag-bearing trees such as river red gum, swamp box and wattles. This management approach may take 30–100 years to be effective, but is the best long-term solution.

Islands are important wetland habitats. They provide safety from predators for roosting and nesting birds, they shade the water, and they increase the availability of shallow-water areas for aquatic plants, wader birds, small fish and insects.

The most common form of island is called a 'whaleback', sloping up gently on all sides with different water depths around its margins (Figure 7). See the Constructed Wetlands section of these Guidelines for further information. To construct an island in a stream, you will first need to obtain a permit or licence under the *Water Act 2000* and possibly the *Integrated Planning Act 1997*.

Spits are bars of sand protruding from the bank to deeper water. They are important to wader birds, particularly for feeding. Many Australian wader bird species are also migratory birds. Migratory birds from China, Japan and Korea are listed under agreements between these countries and Australia to protect the birds and their habitats.

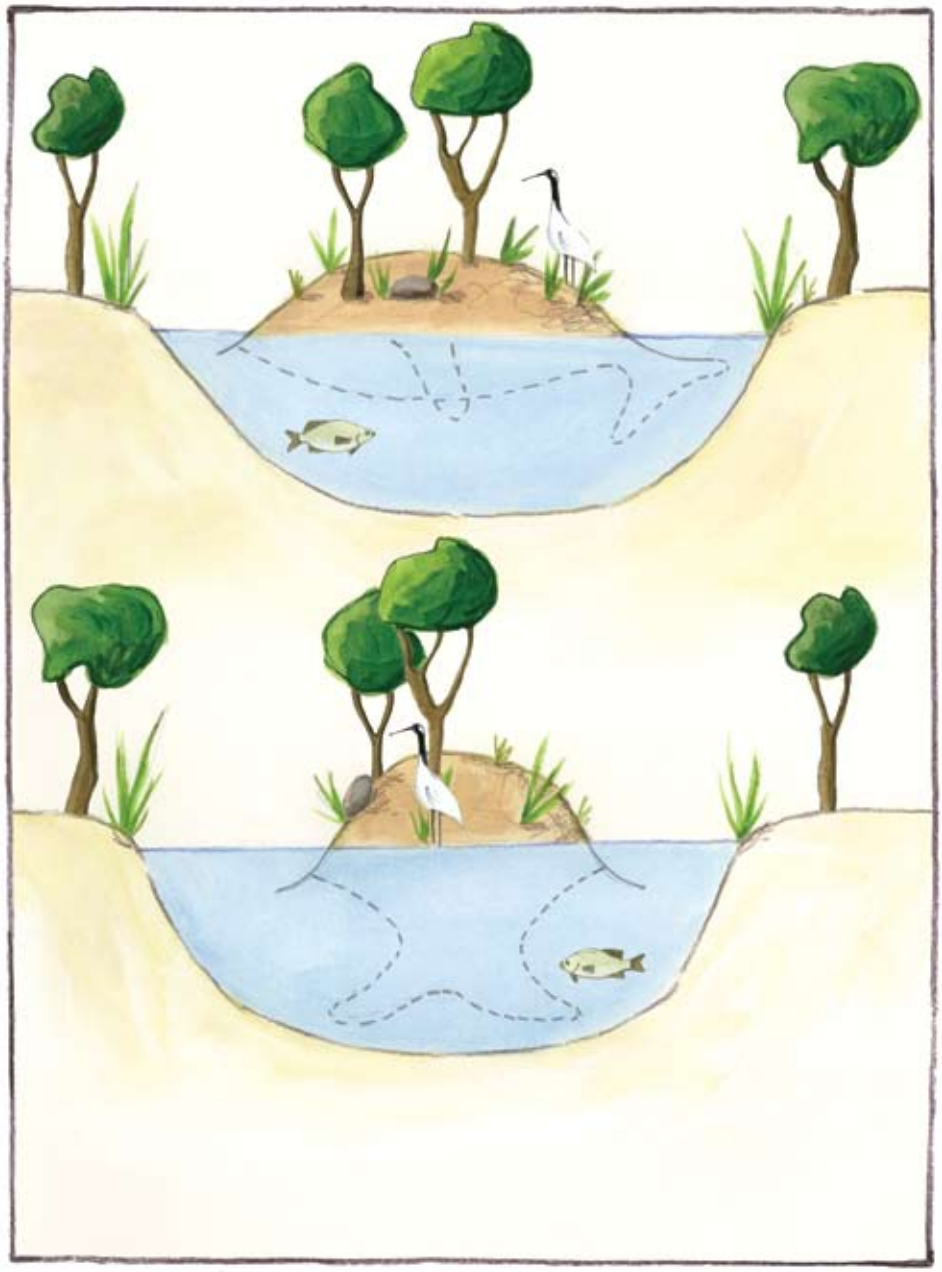

Figure 7. Whaleback design for wetland habitat islands.

Other habitat features

Tree hollows

Tree hollows provide shelter for possums, gliders, ducks and other birds. It is important that some hollows are near the ground and others high in trees. It is also important that hollows have different entrance sizes and shapes. To provide additional hollows in a wetland, attach constructed nesting boxes to trees or fallen dead trees, or import hollows from other areas (but ensure that the hollow is not removed from an area where it is already providing habitat).

Bird hides

Bird hides, walking paths and boardwalks are key management features for wetlands that have high human traffic. Introducing walking paths and bird hides will ensure that wetland wildlife become comfortable with the movement of people in those areas.

Bird hides are excellent educational features in a wetland, as the more people have access to wetland environments the more likely they are to recognise and appreciate their values.

Line of sight and flight paths

Line of sight refers to clear visibility across open areas surrounding a wetland, allowing birds and other animals to see predators from a long distance and giving them time to escape. Line of sight is achieved by planting low-level vegetation such as grasses or shrubs around the wetland. If the aim of the habitat rehabilitation is to attract birds that require line of sight, consider planting a few random stands of taller trees to provide shade and nesting habitat, but keeping the majority of plantings short.

Similarly, some birds favour wetlands with low vegetation where they are easily able to take off and land, particularly when a predator approaches. Once again, this means planting predominantly low-level vegetation types with the occasional stand of tall trees.

Further information

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Vallance, T & Hogan, A 2004, *Final report: Riversdale-Murray Valley SIIP fish biodiversity enhancement*, Department of Primary Industries and Fisheries, Brisbane, Queensland.

Veitch, V & Sawynok, W 2004, *Freshwater wetlands for fish*, Sunfish Queensland Inc., Brisbane, Queensland.

Who to contact for advice
(Contact details provided page 81)

- Environmental Protection Agency
- Regional NRM body
- Department of Primary Industries and Fisheries

Managing weeds

What are weeds?

Weeds have been defined by the Australian Government as *'plant species that have established self-propagating populations in native vegetation, terrestrial or aquatic, outside their natural range'*.

Weed infestations in wetlands can indicate that there is an imbalance in the wetland such as poor water quality, changed hydrology and invasion from upstream or neighbouring wetlands. Aquatic weeds are most commonly a problem in lagoonal wetlands with abundant nutrients, high light intensity and high temperatures. On floodplains, invasive exotic grasses pose a considerable problem. Aquatic weeds are very mobile and often transported considerable distances by waterbirds.

Weeds of National Significance

Under the National Weeds Strategy, 20 introduced plants were identified as Weeds of National Significance (WONS), on the basis of the following criteria:

- invasive tendencies
- impacts
- potential for spread
- socioeconomic and environmental values.

National management strategies have been published for all of these species, 17 of which are known to occur in Queensland.

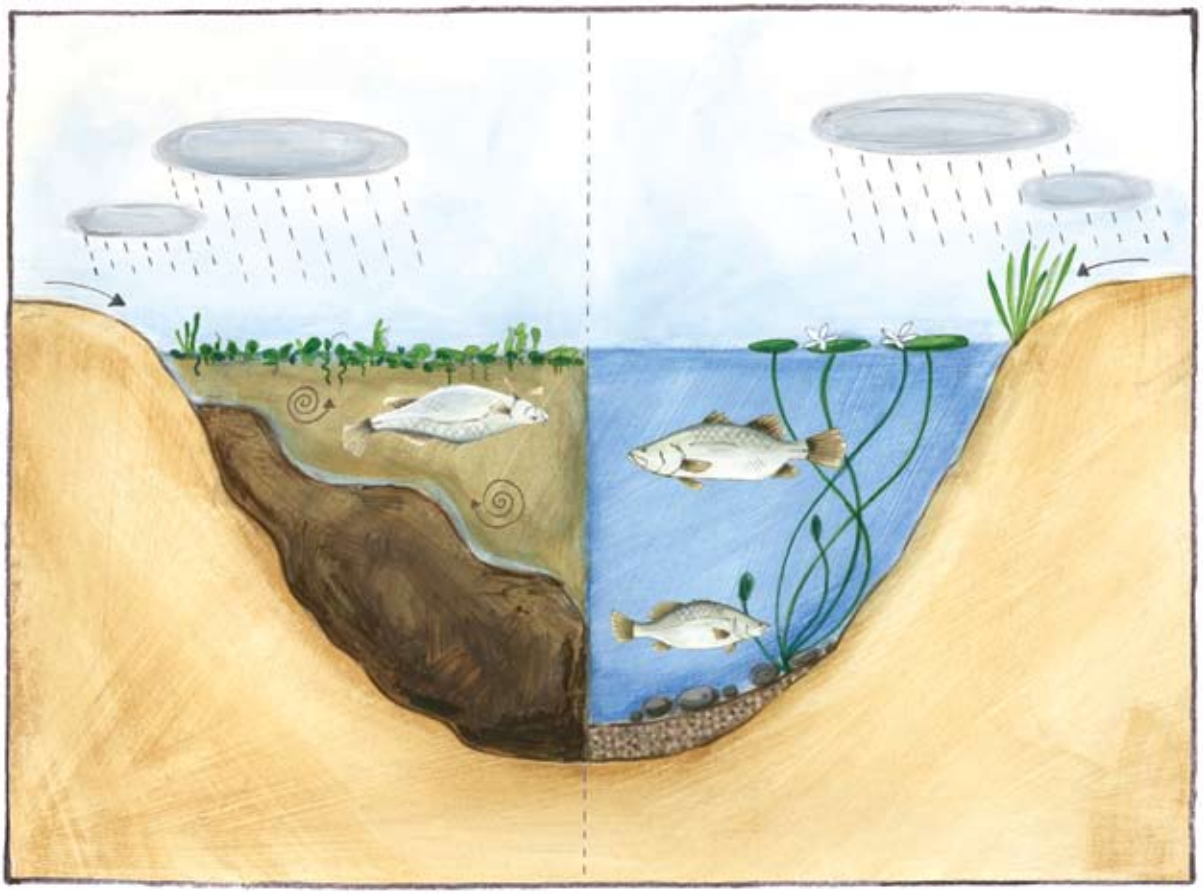

Figure 8. Weed mats on the wetland surface cause turbidity and a reduction in dissolved oxygen, ultimately resulting in fish kills.

Managing weeds

Why manage weeds?

Weeds are widely recognised as the major threat facing the coastal wetlands of the Great Barrier Reef catchment, because they:

- compete with native plants
- change the fire regime (usually by increasing fuel loads and raising the frequency and intensity of fires)
- reduce habitat diversity and productivity, and associated biodiversity
- alter the natural flow regimes of the wetland
- reduce dissolved oxygen levels in the water as a result of large decaying organic loads, often resulting in fish kills (Figure 8).

Managing WONS

Individual landowners and managers are ultimately responsible for managing WONS, while the Queensland Government is responsible for overall legislation and administration. There is a separate strategic plan for each WONS, outlining strategies and actions required to control it and setting out responsibilities for each action. There is a Management Coordinator and a National Management Group/Steering Committee to oversee implementation of the goals and actions of each WONS strategic plan and to develop and coordinate priority actions. For further information and detail go to www.dpi.qld.gov.au.

Water hyacinth in Lagoon Creek (photo by Alf Hogan)

Recognising weeds

Floating aquatic weeds grow prolifically in the Great Barrier Reef catchments. Two of the floating weeds that grow and spread most rapidly are water hyacinth and salvinia. Together or on their own, the two can be found spread across many wetlands, often forming a raft (a large weed mat) over expanses of deep water. Such rafts provide a platform on which other weed species, particularly exotic grasses, can grow.

Most of the Great Barrier Reef floodplain areas are under threat from **invasive grasses** such as para grass and guinea grass, and there is increasing concern about hymenachne. These grasses have major ecological impacts by competitively excluding native wetland plants and choking waterways, and they cause the water quality in stream channels to deteriorate. Exotic grasses also provide a large dry season fuel source for hot fires in riparian areas, particularly where grazing is moderate or non-existent.

Some of the common aquatic weeds in the Great Barrier Reef catchment wetlands include:

- water hyacinth
- salvinia (WONS)
- cabomba (WONS)
- water lettuce.

Some of the other common weed species in the emergent and riparian zones include:

- woody weeds:
  - chinee apple
  - pond apple (WONS)
  - prickly acacia (WONS)
- vine weeds:
  - rubber vine (WONS)
  - sickle pod
- grass weeds:
  - parkinsonia (WONS)
  - hymenachne (WONS)1♦
  - para grass2♦
- herb weeds:
  - Singapore daisy.

For information on these weeds go to www.dpi.qld.gov.au.

Hints & tips

For a more comprehensive list of the weeds that occur in Queensland, refer to the Biosecurity Queensland website for more weed information for all areas, not only wetlands. Most NRM bodies have developed comprehensive lists of weeds occurring within their region. Contact your local NRM for assistance.

Having trouble identifying your weed? Consult the *Australian weed identification guide* or contact your nearest local government weed management officer.

Other online weed management resources:

- www.weeds.gov.au
- www.weeds.org.au
- www.weeds.crc.org.au
- www.dpi.qld.gov.au

Towing a weed mat during clean-out of Lagoon Creek (photo by Bob Smith)

Hymenachne (photo by Cassie Price)

What to do about weeds

Weed-management methods include:

- early intervention and competition
- biological control
- manual control
- mechanical removal
- herbicides
- mulching and smothering
- low-intensity fire
- controlled grazing.

The choice of one or more of these techniques will depend on the site situation and the weeds that are prevalent. The sections that follow outline these techniques and include a guide to when they are best used. The weeds fact sheets (see link above, under Hints & Tips) also specify the most appropriate techniques for tackling the particular weeds at a site.

To achieve best results it is often necessary to employ a range of techniques on a particular site. Table 3 below shows the range of management techniques and the weed type that each technique controls most effectively. Choose a combination of techniques for a particular wetland; this is often referred to as 'integrated weed management'.

Hints & tips

Landowners, including State agencies, may be required to control declared pest plants in a manner that is consistent with the *Land Protection (Pest & Stock Route Management) Act 2002*.
Go to www.dpi.qld.gov.au.

Declared plants: www.dpi.qld.gov.au

Local government pest management plans: talk to your local council.

Queensland Weeds Strategy 2002–06: www.dpi.qld.gov.au

Hints & tips

Weeds can act as a corridor and a habitat to wildlife, so removal should be gradual and coupled with the replacement of native species. Weeds may also be stabilising the soil by trapping sediment in and around the wetland; so interim soil stabilisation methods may be required between weed removal and revegetation.

Managing weeds

Table 3. Combinations of effective management techniques for common weed groups.

Management techniques	Floating weeds	Invasive Grass Weeds	Riparian weeds
Prevention	✓		✓
Competition		shading	✓
Biological controls	✓		✓
Manual control	✓		✓
Mechanical removal	✓		✓ *
Herbicides	✓ (do not spray large areas)	✓	✓
Mulching & smothering		✓ (after slashing)	✓
Fire		✓	✓ ** (cool controlled burn only)
Grazing		✓	

✓ – should be used with caution

* Any related excavation of material (e.g. soil) may require a Riverine Protection Permit issued by the Department of Natural Resources and Water, if the works are carried out in the freshwater sections of a watercourse as defined under the *Water Act 2000*.

** Destruction of vegetation may require a Development Permit issued by the Department of Natural Resources and Water, under the Vegetation Management Act 1997

Hints & tips

Working together

Weed infestation is often a catchment-wide problem, leading to poor water quality, a decrease in species diversity and high maintenance costs for the farmer. Weed management should be done in cooperation with neighbours to avoid continual reinfestation from upstream sources.

Integrated weed management should be considered, to prevent reinfestation. Where possible, begin weed control in upstream regions of the catchment, to reduce the amount of weed travelling downstream into clean or previously treated areas. This approach will ensure that all sites are effective in maintaining weed control.

Avoid dispersal of both seed and vegetative parts of weeds. Figure 9 demonstrates how easily weeds can be dispersed by people in vehicles, in boats and on their shoes and clothing. Dispersal can also occur by water, wind and animals.

Hints & tips

The flood advantage

In the tropics, where there are regular flood events, flood flows can remove a large proportion of fringing and floating weed infestations.

Post-flood can be a good time to implement control activities that seek to maintain the gains provided by the flood flow, particularly if the bulk of the weed mat has been dislodged or moved downstream. Smaller areas of weed can be manually removed or sprayed as they recur.

Note also, however, that weeds are easily spread throughout river systems during flood events. Landholders need to be vigilant in identifying and quickly acting upon new weed infestations. An ongoing maintenance program will help keep the wetland free of these weeds.

Early intervention and competition

Weed introduction to wetlands should be prevented wherever possible. The best prevention techniques include:

- maintaining natural flow and hydrology where possible to avoid weed outbreaks (see the Restoring Hydrology section)
- avoiding disturbance to any existing native vegetation, as this is where weeds will invade
- reducing nutrient loads entering wetlands (refer to Improving Water Quality section)
- planting shade-providing trees around the wetland (refer to Restoring Native Vegetation section)
- using a mix of plant types when revegetating the wetland (ground cover, understorey and overstorey), because the competition will help reduce weed invasions at all levels (refer to Restoring Native Vegetation section).
- Prevent the spread of weeds where possible

Did you know?

Effective shading (100% canopy cover) can be achieved within two years in coastal areas and within three years in the upper catchments of the wet tropics. It has been proven that guinea grass & hymenachne will not grow under 100% canopy cover.

Hymenachne infestation in the Goorganga plain wetlands in an unshaded riparian area (photo by Jim Tait)

Managing weeds

Figure 9. Weed dispersal methods include birds, boots, boats, vehicles, wind and water.

Hints & tips

Preventing the spread of weeds. Some actions to consider that will minimise the spread of weeds:

- Use integrated weed management techniques to increase the chance of success and reduce the risk of herbicide resistance and other problems associated with single-strategy approaches.
- Thoroughly clean down machinery, vehicles, tools and clothing that have been in weed-infested areas.
- Provide a properly constructed washdown area as near as possible to your farm gate. Insist that any contract equipment or service vehicles be cleaned before entering or leaving your property.
- Get a vendor declaration of the weed status of fodder, hay, road base and seed prior to purchase. Similarly, insist on inspecting the log book of farm contractors entering your land.
- Keep access roads, easements and yards weed-free.
- Move livestock to frequently used holding areas after grazing them on weedy paddocks. This will limit the spread of weeds and allow easy control of new seedlings that may emerge from animal waste.
- Hold livestock that may be infested with seed in a single location until they are shorn, or until weed seeds have had the chance to pass through their digestive system.
- Develop a pest management plan for your property.
- Factor weed control into drought planning: talk to your local agronomist.
- Factor weed control issues into prescribed fire plans.
- Keep an eye out for some of the more serious exotic weeds, and any new weed infestations on your land.

Hints & tips

Managing weeds with Farm Management Systems and best practice

The Queensland Wetlands Programme has developed an extension guide to managing wetlands in intensive agriculture with Farm Management Systems. This guide contains a section on managing wetland weeds.

For further information go to Wetland*Info* at www.epa.qld.gov.au/wetland*info*.

Biological control

Biological control (the use of natural predators or diseases) can be an effective way of managing wetland weeds.

Biological controls that have provided some degree of control in the Great Barrier Reef region wetlands include:

- salvinia weevil (*Cyrtobagous salvinea*) to control floating water weed, salvinia (*Salvinia molesta*)
- rubber vine rust (*Maravalia cryptostegiae*) to control riparian weed rubber vine (*Cryptostegia grandiflora*)
- two weevils (*Neochetina eichhorniae* and *N. bruchi)* and two moth species (*Niphograpta albiguttalis* and *Xubida infusella*) to control water hyacinth (*Eichhornia crassipes*).

Did you know?

Trials of biological controls for terrestrial grasses have not been successful. Trials for aquatic invasive grasses have not been completed but it is thought that the result would be the same.

Biological control of salvinia

The floating waterweed Salvinia molesta has been successfully controlled in wetlands using the salvinia weevil (*Cyrtobagous salvinea*).

The weevil weakens the weed by feeding on the buds and then tunnelling into the rhizome. The weevil is most effective on new growth of salvinia and should be used in conjunction with other controls where possible.

Although effective in tropical areas, the salvinia weevil is not establishing as intensely in cooler southern Queensland, and may take several years to control infestations there. Depending on the size of the infestation and the environmental conditions, the time taken for weevils to control salvinia varies from one to three years. They may take more than five years to get established in cooler areas.

For further information go to www.dpi.qld.gov.au.

Biological control of rubber vine

Rubber vine has been controlled using a 'rust' (*Maravalia cryptostegiae*). It produces yellow spores underneath the rubber vine leaves, which are spread by the wind. Continual heavy infection causes defoliation, decreased seed production and seedling death.

For further information go to www.dpi.qld.gov.au.

Who to contact for advice

Local Government Pest Management Officer or local Biosecurity Queensland Officer (Department of Primary Industries and Fisheries). They can assist with protocols and information on the local collection site for biological controls.

Managing weeds

Manual control

Manual control of weeds is appropriate when there are concerns about the impact of machinery or herbicides on the environment, and where there are smaller areas of weed infestation. It can be quite effective for smaller or isolated weed outbreaks.

Weeds can either be pulled out by hand or dug out. In many situations it will be necessary, and often more effective, to combine manual control with herbicide application to minimise soil disturbance.

Hints & tips

When in doubt, don't pull it out until you have confirmed that it is a weed and not a native plant that is naturally regenerating.

It is important that plants with the potential to reshoot are up-ended and placed where they are not in contact with the ground (e.g. in the fork of a tree). Any seeds should be bagged and removed from the site.	Removing large woody weeds from the riparian zone should be done with care, as this can often increase erosion and sedimentation by removing a large part of what is stabilising the stream bank.	Riparian zone weeds are easier to remove when the ground is moist; they pull more easily, without breaking off at ground level.

Mechanical control

Mechanical removal is appropriate for managing large areas of weed, for inaccessible areas due to thick infestations and for aquatic weeds.

Mechanical control methods include:

- aquatic weed harvester (can be hired with operator)
- slashing and mowing (grass and shrubs)
- excavator, bulldozer and tractor removal (woody weeds).

It is important that care is taken not to damage existing native vegetation or the bank of the wetland. You will need a permit to use mechanical control methods in a riverine wetland; you may also need a permit under the Fisheries Act for estuaries and coastal works. Try to find a machine operator who has experience of working in wetlands for best results.

It is also important to follow up mechanical removal with spot spraying or manual removal of any small infestations left behind; this will reduce reinfestation.

Hints & tips

Use the prevailing winds during weed removal
To limit the movement of any machinery around the wetland, use the prevailing winds to your advantage. When all of the floating weeds are pushed to one area of the wetland, the machine can be positioned in one place and remain relatively stationary to remove the majority of the weed.

Hints & tips

Woody weed removal and keeping the bank stable
If cutting down woody weeds in a riverine wetland, it is best to retain the stump and root system to maintain bank stability until the plant is replaced by a native species. To do this, coat the stump cut surface with a bituminous paint to retard decay. Regularly remove any suckers that sprout from the stump.

Herbicides

Herbicides, which must be used strictly in accordance with the labelling, can form part of a combined approach to effective weed control.

Application methods include:

- foliar spraying—typically large-scale spraying, usually from a vehicle, boat or aircraft
- basal bark spraying—directly on the trunk or stem
- cut/scrape and paint—application of herbicide to cuts made in the bark of the trunk or stem
- stem injection—holes drilled into the base of the plant and filled with herbicide
- stem or leaf swiping with herbicide.

For more detailed information about applying herbicides and safety regulations go to www.dpi.qld.gov.au

Hints & tips

Preventing spray drift

As wetlands typically occupy low-lying parts of the landscape, they are susceptible to spray drift caused by katabatic (also known as cold-air drainage) wind flow. This means that overnight, when air over a slope is cooled by cold ground, it becomes dense and heavy and drains to lower levels.

Risk of spray drift can be reduced by:

- identifying spray drift awareness zones—sensitive areas within 1 km of the ground spray zone or 5 km from the aerial spray zone
- only spraying when conditions are safe (slight breeze, no rainfall forecast that day, low temperature and humidity)
- selecting the correct droplet size and release height to deliver the herbicide
- establishing vegetative buffers between the spray zone and sensitive areas

For further information on safe use of herbicide go to www.dpi.qld.gov.au.

Hints & tips

Herbicide risks near wetlands

Using herbicides near wetlands requires special care, due to the risk of contaminating the waterbody and damaging aquatic life. Avoid herbicide use if possible.

Risk of damage can be reduced by:

- using low-volume methods of application such as knapsack spraying, basal bark application, swiping, cut-stump or stem injection
- progressive spraying, especially if the wetland is large, instead of large-area spraying
- mixing chemicals and cleaning equipment well away from the water, in approved facilities
- only spraying when conditions are safe (slight breeze, no rainfall forecast that day)
- avoiding direct spraying on or towards the water
- carrying out regular follow-up spraying of smaller weed outbreaks to avoid large-scale application later.

For further information on safe use of herbicide go to www.dpi.qld.gov.au.

Managing weeds

Hints & tips

Legislation
Before a weed can be 'declared' there must be a herbicide to control it. All declared plants are listed on the herbicide registration under the Land Protection (Pest & Stock Route Management) Act. Go to www.dpi.qld.gov.au

Declared plants: www.nrw.qld.gov.au

The majority of environmental (non-declared) weeds are not listed on herbicide labels, so an off-label permit has been approved by the Australian Pesticides and Veterinary Medicines Authority (APVMA) to help the Department of Primary Industries and Fisheries, local government and environmental groups manage these pest plants. Contact your local council or Department of Primary Industries and Fisheries office for more information.

Herbicides have been approved for use against a large variety of environmental weeds. It is a requirement that anyone using products covered by this off-label permit comply with the details and conditions listed in the permit and have a copy close at hand.

In a riverine wetland, a permit under the *Water Act 2000* is required if the weed removal involves disturbing the bed or banks or destroying any native vegetation within the stream. Check with the Department of Natural Resources and Water before starting any weed removal, especially if using mechanical, fire or herbicide methods.

Control of exotic grasses through grazing on the Goorganga wetland floodplain (photo by David Pepplinkhouse)

Fire

Fire can be an effective weed control technique under some circumstances. Fire can be used to control weeds such as rubber vine, para grass, hymenachne, sickle pod and small (up to 1.5 m) pond apple in riparian areas and wetlands in the Great Barrier Reef catchment. Fire is most effective for weed control in melaleuca swamp forests, for reducing para grass and for controlling juvenile weed populations in sedge lands.

However, fire can cause the death of native trees in the weed-infested areas, especially those that are fire-sensitive. It is important, therefore, that the burn is carefully controlled. For further information about fire as a management tool and for permit and other requirements see the Managing Fire section of these Guidelines.

Fire used as a control method for weeds on the Burdekin floodplain (photo by Jim Tait)

Controlled grazing

With good management, grazing can assist in controlling weeds. Recent trials have been conducted to assess the usefulness of grazing to control exotic pasture grasses such as para grass and guinea grass, and it has proved to be an effective way of quickly managing them. Grazing can be limited to short 'crash grazing' episodes, best done during dry times so that stock can access the margins of the wetland without damaging the banks. For more information on grazing as a management tool, see the Managing Wetland Grazing section of these Guidelines.

Saltwater inundation

Most aquatic weeds do not tolerate saltwater. If a wetland is within the tidal range, saltwater can periodically be allowed up the waterway and into the wetland to control aquatic weeds. This can be achieved using sills, tidal floodgates or drop-boards. To be effective, inundation is required 2–3 times a year.

Innovative ideas

Brine spraying to loosen aquatic weed mats

Aerial application of a brine solution on a dense aquatic weed mat has recently been trialled. It was successful in weakening the bindings of the weeds, making the task of mechanical removal easier.

Hints & tips

Strangler figs

Native strangler fig trees (there are more than eight varieties) can be planted at the foot of woody weed trees or in a 'planter box' in their first fork. The fig eventually climbs up and takes over the weed tree, effectively replacing it with a native.

For more information on the fig planter box process refer go to the Greening Australia Queensland website at www.live.greeningaustralia.org.au.

Hints & tips

Site maintenance

Weed control in wetlands and riparian areas is an ongoing battle. Weed maintenance of an area should be carried out monthly in the early stages; the frequency of weed control thereafter is determined by local factors. Ongoing monitoring is essential, especially for weeds such as sickle pod that have a long seed-bank life. Through continual weed monitoring, future invasions can be removed when they are still small.

Who to contact for advice

(Contact details provided page 81)

- Weedspotter Coordinators (for weed identification)
- Department of Primary Industries and Fisheries Biosecurity and Land Protection staff
- Local government Pest Control Officers
- Department of Natural Resources and Water for legislative requirement of clearing vegetation and works in a watercourse

Further information

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Managing feral animals

What are feral animals?

Non-native (exotic) animals have been imported into Australia, both legally and illegally, for more than 200 years. Their purpose was varied: for primary production, transportation, pest control, consumption, as pets and to make European settlers 'feel at home'. Species such as the fox have been legally released into the wild whereas others, such as the pig, escaped domestication.

Why manage feral animals?

Feral animals and pests can have significant impacts on the environment. Those affecting the Great Barrier Reef catchment wetlands are feral pigs, cattle, horses, cane toads, exotic fish and translocated native fish. Their ecological impacts include land degradation, disturbance of native vegetation, and spreading of weeds. Native biodiversity and agriculture are threatened through competition, predation, transport of disease and parasites, and habitat destruction. Pest animals also damage crops and infrastructure and harm stock.

For more information on Queensland's feral animals, go to www.dpi.qld.gov.au.

What to look for:

Use the following checklist to assist in determining a management strategy. The things to look for have been split into three sections:

1. Protect the things about the wetland that should be protected
2. Repair the things about the wetland that could be improved and can be progressed by a local person (i.e. landholder, land manager)
3. Seek expert help with the things about the wetland that should be improved but will require some technical assistance or advice.

Protect	Tick
No disturbance by feral pests such as pigs or exotic fish (gambusia and tilapia)	☐
Repair	
Evidence of feral pests such as diggings, vegetation damage, high exotic fish or cane toad populations in the water	☐
Seek expert help	
Infestations of feral pests that cannot be managed at the property scale	☐
Landholders unable to control feral pests between their property and near neighbours should seek local government assistance	☐

What to do about feral animals

The following pages provide information on control techniques for feral pigs, cane toads and exotic fish. For information on the control of feral cattle and horses, please use the management techniques outlined in the 'Managing grazing' section of these Guidelines. For detailed information on fox, cat and dog control see your local government Pest Control Officer for assistance.

Hints & tips

Coordinated approach to pig control

Coordinated action is need to control feral pigs. They are widespread, highly mobile and highly reproductive and without an inclusive, cooperative approach, there is unlikely to be effective management of the damage they cause. There are several groups and agencies concerned with feral pig management that can assist.

Feral pig control

Why pigs like wetlands

The high productivity and seasonality of wetland systems ensures a dependable (though seasonally variable) food source for pig populations. The prime requirement for pigs is a reliable and adequate supply of water, food and cover.

Feral pigs are subject to many infectious diseases and parasites, including some economically important exotic diseases such as foot-and-mouth disease, and endemic diseases and parasites such as leptospirosis, brucellosis and melioidosis, which can affect the health of domestic livestock and people.

Landholders should take the following steps when dealing with feral pig populations:

- determine the best combination of control methods that work locally.
- seek assistance from local government to coordinate at a local or regional level.
- implement control methods.
- monitor and evaluate the success of each method and modify techniques where necessary.

Feral pig control may include baiting, trapping and shooting. A combination of techniques, chosen to suit the local situation and habitat, will work best.

Hints & tips

Communicate successes and failures to local government and local pest control officers. This will assist in future attempts to control pigs in the region.

Baiting

There are two main options for baiting: ground and aerial. In both instances, supervision by authorised local government staff is required.

The best time to bait pigs is during dry conditions. This is because pigs rely on water, and during dry conditions they concentrate around smaller wet areas.

Follow these steps :

1. Seek advice from local pest officers. They will assist in selecting the appropriate bait for the area.
2. Notify neighbours in the area where you plan to set baits, then pre-bait by leaving unbaited feed so that the pigs get used to eating there.
3. Organise for qualified personnel to prepare and lay baits (i.e. compound 1080) near watering points where there are signs of pig activity. In Queensland, compound 1080 can only be obtained from suppliers authorised under the Health Act. Local Land Protection Officers or local councils should be able to assist.

Warning

There are strict restrictions on baiting/poison use everywhere, but especially in close proximity to residences and urban areas, or where non-target species are at risk.

See the Department of Natural Resources and Water publication *Pest animal management in settled areas* for more information.
Go to www.nrw.qld.gov.au

Hints & tips

Hygiene

Feral pigs carry endemic diseases such as leptospirosis, brucellosis and melioidosis. Pigs may also be responsible for the spread of root rot fungus, *Phytophthora cinnamomi*, which causes die-back disease in vegetation.

For further information on leptospirosis go to www.dpi.qld.gov.au, brucellosis www.dpi.qld.gov.au and melioidosis www.health.qld.gov.au.

Managing feral animals

Trapping

Trapping can be an effective method of broad-scale pig control when used with other methods such as baiting. However, it is also very labour-intensive. Trapping has become widely used in some locations due to the efforts of the past Community Based Feral Pig Trapping Program. This type of program promotes a coordinated approach to pig control and can be implemented in any Queensland catchment.

Steps for pig trapping include:

- Investigate areas that are frequented by pigs
- ↓
- Choose an appropriate trap design and speak to local pest control officers
- ↓
- Pre-feed pigs in that area (at least 1 week)
- ↓
- Erect trap in a shaded area
- ↓
- Pre-feed in un-set trap (at least 2 weeks)
- ↓
- Set trap and monitor use
- ↓
- Check traps daily (do not allow dogs anywhere near the trap)
- ↓
- Humanely dispose of pigs

Trapping is considered a humane option for pig control , provided the trap is set in a sheltered area, is checked frequently, and pigs are killed humanely. An ongoing control program is essential.

For more information on humane trap design and placement see the *Code of practice for the welfare of feral livestock animals*, which provides information on the humane requirements of feral pig trapping. Go to www.dpi.qld.gov.au.

Feral pig trap (photo by Tim Price)

Innovative ideas

Trap designs

The Environmental Protection Agency is currently using auto-feed and satellite signal traps in remote areas so that pigs can be removed when trapped.

Traps designed specifically to trap pigs pose little threat to non-target species. For example, prop trap entrances open with a 75 mm diameter stick at snout level. Feral pigs will lift the stick in order to get to the bait, and in doing so close the gate behind them. Birds landing on the stick, however, will not trigger the trap.

Prevent cassowaries from becoming caught in pig traps by using cassowary-friendly trap designs. Go to www.dpi.qld.gov.au.

For more information on trap design and placement go to www.dpi.qld.gov.au or www.nrw.qld.gov.au.

Hints & tips

Timing

When food sources are in good supply it can be difficult to lure pigs into traps. Utilise their feeding instincts by concentrating trapping efforts after nearby crops are harvested. For example, a mob of pigs may have been feeding on a cane paddock for the past few weeks. When that cane paddock is harvested and their food source removed, this is the best time to offer them an alternative: in this case, bait in a trap.

Ground and helicopter shooting

Ground shooting can be effective where there are small groups of pigs, and they are in areas that are difficult to see from a helicopter. However, there are stringent regulations about the use of firearms.

Follow these steps:

1. Investigate pig feeding and shelter areas.
2. If necessary use baits to attract pigs to certain areas.
3. Early morning and late evening are the best times to catch pigs moving between feeding and shelter areas, making them more exposed and often easier targets. They are more likely to be in sheltered areas during the day and in feeding areas at night.

   The best time of year to hunt pigs in floodplain habitats is the middle of the dry season, when they are more likely to be away from the paperbark swamps following the receding water. Walking (rather than driving) into shelter and feeding areas is the best way to target pigs without scaring them off.
4. A head shot is the most humane way to kill pigs (for further information see **Humane code of practice** in the draft code of practice guidelines, which outlines gun calibres and humane disposal methods: www.dpi.qld.gov.au)
5. **Helicopter shooting** is the most cost-effective method of rapidly reducing the density of feral pig populations. The method is most effective on large mobs of pigs, and its success is influenced by vegetation cover, type of terrain and flying conditions. It is important to follow the steps above, investigating the location of the pigs and their movements where possible, and ensuring a clean shot to the head.

The most effective helicopter-shooting is done within the first two hours after sunrise and the last two hours before sunset when pigs are most likely to be away from cover and easily seen.

Hints & tips

Licensing requirements

There are strict licensing requirements for both the pig shooter and the pilot, who must be licensed for low-level flying and must use a nominated helicopter. Contact your local Department of Primary Industries and Fisheries office for more information.

Fencing out

Fencing out pigs has the tendency to merely shift the problem elsewhere. It is often costly (if in large wetland areas) and largely ineffective, because it may impede the movement of non-target species.

Hints & tips

Legislation

In Queensland feral pigs are declared Class 2. animals under the *Land Protection (Pest & Stock Route) Act 2002*. This means that their control is the responsibility of every landholder. For further information, go to www.nrw.qld.gov.au.

Managing feral animals

Cane toad control

Cane toads have been present along the east coast of Queensland since their introduction in 1935 to control beetles infesting sugarcane crops. Cane toads are prolific breeders, laying 20 000–35 000 eggs at once (compared to the 1000–2000 eggs per year that native frogs lay).

Cane toad (photo by Cassie Price)

Cane toads are considered a pest in wetlands because they:

- poison many native animals whose diet includes frogs, tadpoles and frogs' eggs
- eat large numbers of honeybees, creating a management problem for bee-keepers
- prey on native fauna
- compete for food with vertebrate insectivores such as small skinks
- may carry diseases that can be transmitted to native frogs and fishes
- poison pets and injure humans with their toxins.

Did you know?

Keel-back or freshwater snakes (*Tropidonophis mairri*) are the only native snake species immune to cane toad poison. Ibis, crows, kites, estuarine crocodiles, water rats and kookaburras are all known to feed on cane toads, most by flipping them onto their backs and only eating their muscle tissue and internal organs.

Manual removal

Regular cane toad 'round-ups' can contribute to their control. Toads caught in this way can be humanely euthanased in the freezer. Unlike frogs, cane toads lay eggs in long clear strings with small black dots. If these are found they should be pulled from the water and left to dry in the sun. Be careful not to mistake cane toads, tadpoles and eggs for that of native frogs.

Refer to the Frogs Australia publication *Native tadpole or … cane toad?* at www.frogsaustralia.net.au for assistance in recognising toad tadpoles and eggs.

Hints & tips

Cane toad control requires a coordinated community approach, starting at a local level. Contact local government pest officers for further information on programs in your region.

Pest fish control

Pest fish are fish species that have been deemed harmful or produce conditions that are harmful to fisheries resources or habitat. There are 18 species, genera or families of fish that are declared noxious fish in Queensland.

The two most common pest fish in the Great Barrier Reef catchments are tilapia (Oreochromis mossambicus) and mosquito fish *(Gambusia holbrooki)*.

Tilapia reproduce prolifically and compete with native aquatic species for food and shelter. They are listed as a noxious fish under the *Queensland Freshwater Management Plan 1999*.

The mosquito fish is a small, highly reproductive pest fish that also competes with native aquatic species for food and shelter.

Who to contact for advice
(Contact details provided page 81)

- Department of Primary Industries and Fisheries Biosecurity and Land Protection staff
- Local government pest officers

Prevention

The best way to avoid the impact of pest fish is to avoid introducing non-local fish to watercourses (e.g. accidental relocation of fish used as live bait). Avoid stocking non-native species in dams and ponds and, if these fish are caught, it is a requirement of the *Queensland Fisheries Act 1994* that they are not returned to the water.

Species such as tilapia must be disposed of away from any waterway. Tilapia is a mouth-brooding fish, and any young they are carrying may return to the water.

If keeping pest fish is essential, screened overflows that control water runoff and stop possible escapees are a simple yet efficient measure.

For a list of alternative native species to keep in place of the small *Gambusia*, go to www.dpi.qld.gov.au. For larger fish alternatives, consider barramundi, silver perch or golden perch.

Assist the Department of Primary Industries and Fisheries by reporting any sightings of exotic fish.

Restore native riparian vegetation

Anecdotal information and monitoring data indicates that pest fish prefer modified habitats, probably because modified streams usually have few native fish to compete with them. Reinstating natural habitats by removing aquatic weeds and ensuring that native predatory fish have access to sites, is one means of limiting pest fish population density and dominance.

Physical barriers

Multiple barrier systems can be a solution to preventing tilapia from invading streams that they do not already inhabit. A multiple barrier system involves installation of a drum screen and wedge wire screen, and possibly an electrical barrier. Seek assistance from the Department of Primary Industries and Fisheries if this type of control is necessary. Care must be taken to ensure that connectivity for native species is not lost.

Further information

Australian Government – Australian Pest Animal Strategy, <www.environment.gov.au/biodiversity/invasive/publications/pubs/pest-animal-strategy.pdf>.

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Restoring native vegetation

What is native vegetation?

Native vegetation is native to Australia and the region and includes grasses*, shrubs, vines, trees and aquatic plants. All of the native plant types perform their own important function in the wetland landscape they occur in.

Native wetland vegetation occurs in three zones: riparian/fringing; emergent; and aquatic (Figure 10).

Why is native vegetation important?

In the Great Barrier Reef catchment the condition of native wetland vegetation has been modified or impacted by introduced plants and animals, clearing, altered fire regimes and other changed land practices. Modifications to native vegetation in and around wetlands have resulted in loss of habitat, increased erosion, increased sediment and nutrient loading, changed hydrology and decreased water quality.

Native vegetation provides habitat and food for a wide range of wetland animals. It provides nesting hollows, leaf litter, snags and shade. The blossoms, rhizomes, fruits and other vegetative matter are food for a number of land and water-based species. Submerged and emergent vegetation is particularly important to wetland birds and fish for nesting, feeding, egg laying and roosting. Connected corridors of vegetation provide safe passage from one wetland to another for species sensitive to disturbance.

Vegetation supports the banks of wetlands, reducing erosion and slumping. The root systems lock in the soil, preventing erosion, reducing siltation in the wetland and ensuring water quality is maintained. Holding the sediment and banks in place also means that the hydrology of the wetland will be maintained; the water flow will continue in the same way that it has previously.

* Grass and non woody herbage are classified as native vegetation under the *Vegetation Management Act 1999*.

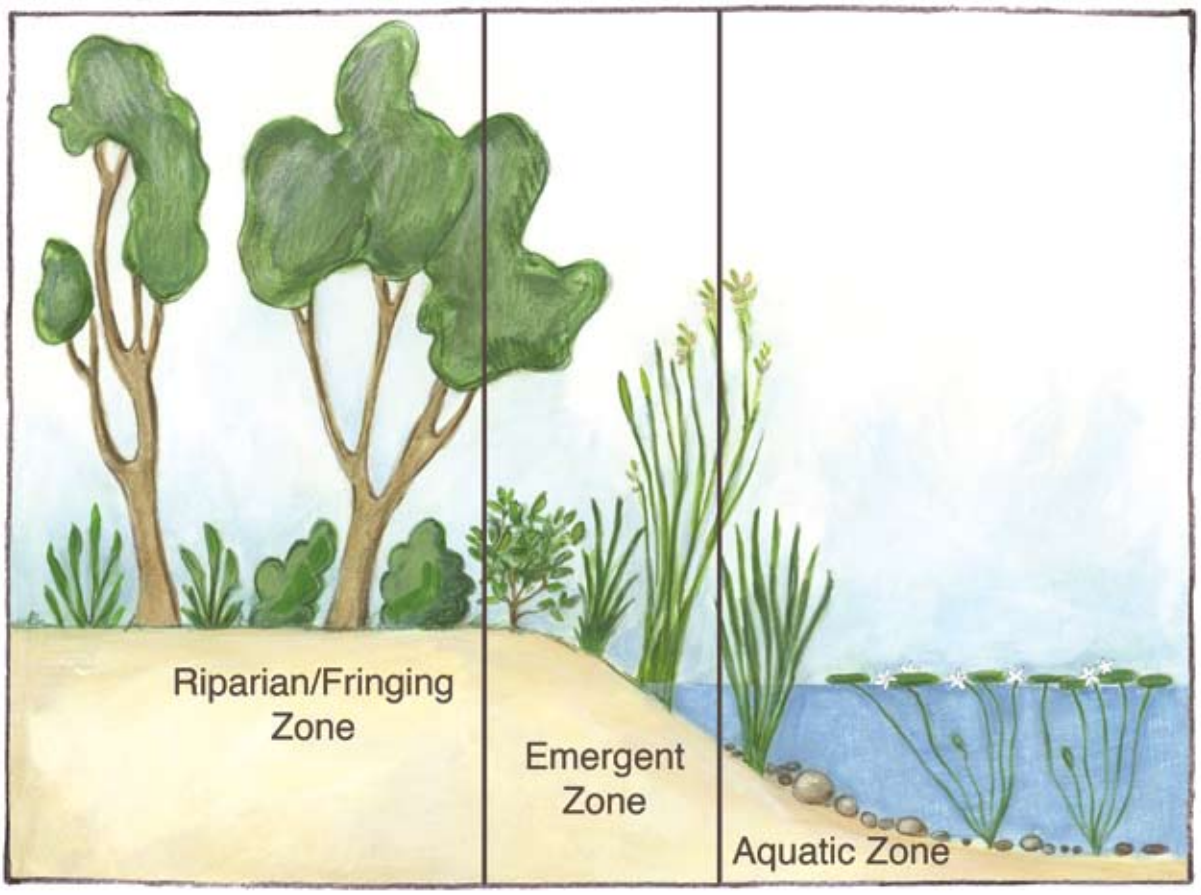


Figure 10. Three main zones of vegetation found in a wetland community.

What to look for

Use the following checklist to assist in determining a management strategy. The things to look for have been split into three sections:

1. Protect the things about the wetland that should be protected.
2. Repair the things about the wetland that could be improved and that can be progressed by a local person (ie. landholder, land manager).
3. Seek expert help with the things about the wetland that should be improved but will require some technical assistance or advice.

Protect	Tick
Healthy, thriving native bank vegetation	☐
Healthy, thriving native floating and emergent vegetation	☐
Natural regeneration of native species	☐
A number of storeys (layers) of vegetation	☐
Repair	
Areas previously cleared of native vegetation	☐
Native vegetation over-run by weeds	☐
Areas covered with only weeds	☐
Stock damage to vegetation	☐
Fire damage to vegetation	☐
Seek expert help	
Banks are being eroded and need stabilising	☐

What to do about native vegetation

Preventing further loss of native vegetation is imperative to the improved health of wetlands in the Great Barrier Reef catchment. Where vegetation has already been lost, there are two main ways to revegetate a wetland –natural regeneration and assisted revegetation. This Guideline outlines how to prevent further damage to native vegetation and the steps involved in planning and implementing revegetation.

Prevention

Preventing any further damage to native vegetation is important and effort should be made to protect exiting stands of remnant wetland vegetation. Native vegetation, including wetland/riparian vegetation, is protected under the *Vegetation Management Act 1999* and the *Water Act 2000*. A permit must be obtained from the Department of Natural Resources and Water to clear native vegetation.

Similarly, marine native vegetation is protected under the *Fisheries Act 1994* and a permit to clear is required from the Department of Primary Industries and Fisheries. All applications are assessed on their own merit.

Further information

Vegetation Management Act 1999: www.nrw.qld.gov.au

Water Act 2000: www.nrw.qld.gov.au

Fisheries Act 1994: www.legislation.qld.gov.au

Any native vegetation areas should be protected from weeds, stock and fire. For more information on managing weeds, stock and fire, refer to the Managing Weeds, Managing Grazing and Managing Fire sections of these Guidelines.

Restoring native vegetation

Revegetation

Revegetating cleared wetlands and riparian areas is the key to rehabilitating wetlands. Revegetation can include 'extensive' approaches using broad-acre tools such as weed control, fire and managed grazing regime that promote natural regrowth, and 'intensive' approaches involving the planting of germinated tube stock.

There are a number of steps involved in designing and implementing a revegetation project:

1. Planning:
    - Costing and capacity
    - Planting design
    - Revegetation method
    - Species selection
2. Site Preparation
3. Planting
4. Site maintenance and monitoring

Planted seedling and mulch, Cairns region.
(photo by Cassie Price)

1. Planning

It is important in planning a revegetation project to research the seasonal site history and seek out local site knowledge (e.g. time and magnitude of floods).

Costing and capacity

Always consider the budget and man-power available to undertake the revegetation work. This will determine the area of revegetation possible, design, the most cost-and-labour effective method, and which species to plant.

There is often funding and assistance for revegetation available through local environmental groups and Natural Resource Management Groups. Contact those in the local area for more information.

$$$

Cost Estimate
$6-$10 per tree – including purchase, site preparation and maintenance

Did you know?

If you have a GreenCorps team in your area they may be able to assist.

A field day involving the local community or a corporate tree-planting day could also be incorporated to assist with large plantings.

Planting design

There are several things to consider when designing a planting:

- planting an appropriate mix of species
- correct plant spacings
- long term maintenance requirements.

Mix of species

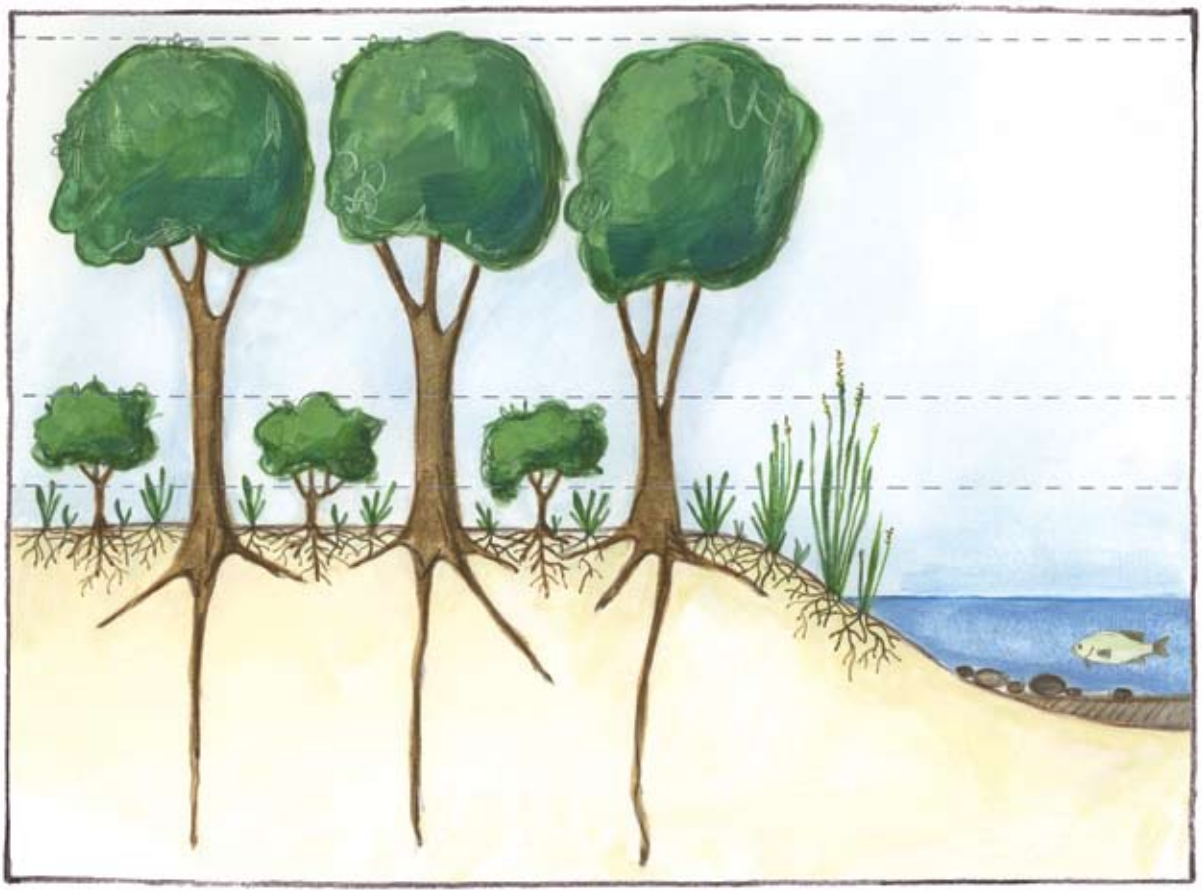
There are some general rules to selecting the mix of species:

- Mix 'fast-growing' and 'secondary' species throughout planting as these will grow at different rates to provide shelter, stability and habitat during the establishment of the planting. Fast-growing species are those that are hardy and tolerant of full sun, but can have short life-spans. Secondary or framework mix species are those generally found in a mature forest; they are more susceptible to drought, fire, frost, often do not tolerate full sun, and are generally slow growing.
- Depending on the type of wetland (refer to Introductory section of these Guidelines) a mix of different plant heights to achieve different storeys and a cross-mat of roots may be appropriate.
- Select plant species that will not interfere with infrastructure, e.g. low growing species under powerlines, non-spreading trees beside roads and cane paddock headlands.

There are three main wetland vegetation storeys to consider (Figure 11) (although not all wetlands have them all):

- understorey – generally consists of ferns, reeds, rushes, sedges, smaller grasses
- mid-storey – generally consists of shrubs and small trees
- overstorey – generally forms the canopy and consists of large trees and sometimes vines.

Figure 11. Vegetation storeys found in forested wetlands and desired cross-mat of root systems in a wetland revegetation.



Plant spacings

There are some general rules to plant spacings:

- Plan row spacings to allow access (e.g. for quadbike or ute) inside a fenced area, taking into consideration the size of the trees when grown.
- Use local native plants found in similar locations and those already occurring at the site as a guide to designing the planting.
- Riparian zones generally have larger plants and broader spacings, where as the fringing zone has smaller plants and closer spacings.
- Work with existing native plants

Riparian/fringing zone

While plantings using 1.5–2 m spacings will have the best rehabilitation potential, up to 3 m is considered acceptable. Wider spacings will generally require more maintenance (weeding and mulching) for longer periods. Closely-spaced plantings are preferred to encourage rapid canopy growth, especially in areas of intense weed competition in the wet tropics.

Emergent zone

Plant spacings of 1.5 m apart at the waterline is ideal.

Figure 12. Planting design considerations for a wetland, working with existing native vegetation, spacings between plants, leaving room for vehicle access and planting a mixture of species.

Revegetation method

Planting can be undertaken through assisted natural regeneration/vegetation manipulation or revegetation.

Natural regeneration/vegetation manipulation

Natural regeneration is often appropriate where a site retains original vegetation that can provide a source of seed and recruiting saplings, if appropriately managed. Appropriate management includes identifying and removing the disturbance factors that are preventing natural recruitment and regeneration. These will be site specific but may include competing weeds, inappropriate fire regime or other forms of disturbance such as stock grazing. Continued monitoring and weed control is necessary. This method can be used in conjunction with a range of other methods.

Natural regeneration results from soil or canopy-stored seed or seed transported to the site by wind, water or animals. If regeneration fails or is poor, then direct seeding or planting seedlings can be considered. Direct seeding into such sites can also be successful for some species under certain site conditions. If successful, extensive revegetation can be the most cost effective approach for broad-acre sites.

Natural regeneration can also be particularly successful for aquatic vegetation. It is considered to be the best way to rehabilitate the floating/submerged zone. However, it is not a viable option in riparian areas that have been dominated by weed species for a long period of time. The seed bank in these areas will likely be severely depleted of native seed stock and often only has viable seed of weed species.

Blackbean tree seed. (Photo by Cassie Price)

Assisted Revegetation

The **direct seeding method** involves sourcing native seeds (local endemic species), then planting them into the pre-prepared soil. Note: This method has been successful in the dry tropics but not in the wet tropics due to the prolific growth of guinea grass.

Brush matting, which has been successful in sandy coastal areas, involves germinating seeds by cutting off seeding branches and laying them in the preferred area.

Planting of seedlings involves sourcing plants from native plant nurseries or growing them on-site then planting them into the pre-prepared soil.

Species selection

There are some general rules to species selection:

- Choose species that already occur in the area or are known to belong to the area (see the Regional Ecosystem mapping available from Environmental Protection Agency at www.epa.qld.gov.au for more information).
- Choose high or low species diversity depending on the site. For example, areas that naturally have a low diversity (low number of different plants) like a saltmarsh area require fewer different plant types (Table 4).
- Ensure that species are native to the local area and, where possible, source seed from the local area for propagation. Plants can be sourced through local native plant nurseries or by propagation from locally collected seeds.
- Use a mix of 'fast-growing' and 'secondary' species (as described above).
- Use plants that are a minimum of 20 cm tall in non-flood prone areas, 30-60 cm tall in flood prone areas.

Hints & tips

Plants for streambanks
Planting on streambanks requires particular attention to plant selection. Plants need to be smaller to assist in stabilisation of the bank. Choose native grasses and smaller trees and shrubs for these areas. Larger trees are better planted back from the stream edge so they are not likely to topple into the waterway, taking part of the bank with them.

Table 4. Species diversity for revegetation of different wetland types

Wetland Types	Many different species (high diversity planting)	Many of the same species (low diversity planting)
Mangrove forests (estuarine)		✓
Saltmarsh (saltpan/samphire) (estuarine)		✓
Coastal **saline swamps** (palustrine)		✓
Coastal **non-floodplain tree swamps** Melaleuca and Eucalyptus (palustrine)	✓	
Coastal **non-floodplain wet heath swamps** (palustrine)	✓	
Coastal **non-floodplain grass, sedge and herb swamps** (palustrine)		✓
Coastal **floodplain tree swamps** – Melaleuca and Eucalyptus (palustrine)	✓	
Coastal **floodplain wet heath swamps** (palustrine)	✓	
Coastal **floodplain grass, sedge, herb swamps** (palustrine)		✓
Coastal **floodplain lakes** (lacustrine)	✓	
Coastal **non-floodplain rock lakes** (lacustrine)	✓	
Coastal **non-floodplain sand lakes – perched** (lacustrine)	✓	
Coastal **non-floodplain sand lakes – window** (lacustrine)	✓	
Coastal **non-floodplain soil lakes** (lacustrine)	✓	

2. Site preparation

There are a number of steps to be undertaken before natural regeneration or assisted planting can begin:

1. protection of existing habitats
2. identification of native trees and seedlings
3. removal of rubbish and weeds
4. preparation of the soil (in erosion-prone areas avoid ripping the soil and do not leave soil bare)
5. mulching (if required, not recommended for flood prone areas)
6. fencing
7. restriction of traffic access.

Site preparation method:

Week 1:

- identify existing native vegetation
- broadscale weeding (tractor and boom spray)
- edge weeding (from 4WD or backpack)
- slashing may be an option(if required).

Weeks 2-6:

- re-spray remaining weeds
- ripping ground (tractor) depending on soil type there may be erosion and compaction risks to consider. Do not use ripping in an erosion prone area.

Note: mechanical reshaping or re-profiling of the streambank may be required. For more information see the Erosion and Acidity section of these Guidelines.

Hints & tips

Preparing streambanks
When revegetating streambanks, leave any weeds in the few metres closest to the water, these will continue to stabilise the bank as the plants get established. Eventually the weeds will be shaded out.

Hints & tips

The annual wet and dry season experienced in the Great Barrier Reef catchment is a key consideration in the timing of successful revegetation both in terms of limiting planting watering requirements and avoiding inundation and flood (Table 5).

3. Planting

Planting can begin once planning and site preparations are complete. It is important to consider the timing of revegetation—ensure it is suitable for the species being planted, and also that factors such as flood, fire and frost are unlikely to affect plants soon after establishment (Table 5).

Hints & tips

Where to start
Revegetation should begin in areas that are in good condition and proceed towards the most degraded areas. This will assist in learning about the natural zonation of plants in the wetland and with planning for the severely degraded areas.

Similarly for streambanks, initially it is important to target areas where stabilising vegetation is likely to establish. The most unstable sections of the riparian zone not often the best place to begin.

Steps in planting include:

- prepare holes or furrows at required spacings
- use slow-release fertiliser and water-in to settle the soil around the plant (if required)
- place the plant in the hole and fill the hole with soil
- mound up around base of the tree to hold water or create a 'saucer' around the plant to hold water
- use tree guards or stakes if necessary:
  - no tree guards in high flood zones, they can end up in the waterway.
- add hydrated water crystals if planting in dry season:
  - one tablespoon each tree on heavier soil, two handfuls on sandy soils.
- water seedlings
- fertilise as necessary
- mulch as necessary (can use grasses slashed on site):
  - no mulch in high flood zones, it ends up in the waterway.

Table 5. Timing of revegetation plantings in the Great Barrier Reef catchments.

Location	Concerns	Best time to plant	Reason	Maintenance
Wet tropics				
Upper catchment	Frost Water availability	Oct -Dec	Planting to occur 6mths before frost	Watering required
Lower catchment / coastal (Light soils)	Concerns: Flooding Water availability	April - Aug	Planting to occur 3mths before floods	After flood maintenance / replacements Watering up until wet season
Lower catchment / coastal (Non flood-prone soils)		Jan - May	Planting to occur after flooding	Watering may be required later. Work from higher ground down to lower ground
Dry tropics				
Upper catchment	Frost Water availability	Oct -Dec	Planting to occur 6mths before frost	Watering required
Lower catchment / coastal	Concerns: Flooding	Sept - Oct	Planting to occur before flooding	Watering Weed control
	Concerns: Water availability	Mar - May	Planting after wet season	Watering
Sub tropics				
Upper catchment	Frost Water availability	Oct -Dec	Planting to occur 6mths before frost	Watering required
Lower catchment / coastal	Plant establishment	Oct-Dec	Plantings in spring have a good chance of establishing	Watering required

4. Site monitoring and maintenance

It is essential that a planting site is monitored and maintained over a number of years. In the first two years after planting the site may require:

- weeding
- watering (particularly in the seasonal dry tropics)
- water retention products
- protection from pests such as pigs
- infilling (replacing dead plants) during the first year
- top-dressing in sandy/loam soils (in the Wet tropics) to promote lateral root growth of plants in a flood-prone area.

Suitable monitoring timeframes are detailed in Table 6.

Hints & tips

Wet tropics growth rates
Trees can grow up to 7 m tall within 12 months without fertiliser. Average growth is 2.5 m in the first 12 months.

100% canopy cover can be achieved within two years in coastal areas and within three years in upper catchment areas when plants are closely spaced (1.5m).

Table 6. Revegetation monitoring timeframes by region

Site maintenance timeframes	
Wet tropics	12 months or until 100% canopy cover 8-9 treatments each year during Years 1 and 2 (at least 4 every year after) November to April – lots of maintenance April onwards less maintenance is required and no watering
Dry tropics	24 months or until 100% canopy cover 2-4 treatments each year
Subtropics	24 months or until 100% canopy cover 2-4 treatments per year

Further information

Bell, R (undated), *Guidelines for revegetating streambanks*, Johnstone River Catchment Management Association Inc., Queensland.

De Steven, D, Sharitz, R, Singer, J H & Baton, C D 2006, 'Testing a passive revegetation approach for restoring coastal plain depression wetlands restoration', *Ecology*, vol. 14, no. 3, pp. 452–60.

Lokkers, D 2000, 'Revegetation strategy for the Townsville City Council Region' (draft) Townsville, Queensland.

Lovett, S & Price, P 1999, *Riparian land management technical guidelines*, vols 1 & 2, LWRRDC, Canberra.

Preventing soil erosion and acidity

What causes soil erosion and acidity?

Erosion of stream banks is a natural and continual process; however, the rate of bank erosion within the Great Barrier Reef catchments has been greatly increased by clearing of riparian zones, hill slopes and associated gullies.

Acidity arising from acid sulfate soils is a regular occurrence in some coastal catchments of Queensland. It occurs on estuarine floodplains and coastal lowlands, including urban areas, grazing and cropping land on floodplains, mangrove tidal flats, salt marshes, tea-tree swamps and tidal lakes.

Acid sulfate soils—soils or sediments that contain iron sulfide minerals—occur naturally. They are part of the world's natural sulfur cycle. Acid sulfate soils were formed within the past 10 000 years, during and after the last major sea-level rise, which followed the melting of the massive polar ice caps after the last ice age. They are created when salty water mixes with sediments containing organic matter, usually from mangroves or other coastal vegetation.

These acid soils are not a problem while they remain where they were formed, beneath the watertable, but when sulfides are exposed to the oxygen in air sulfuric acid starts to form. This acidifies soil water, groundwater and, eventually, drainage waters and streams. The acid can also mobilise toxins such as aluminium and arsenic in the soil.

Why manage erosion and acidity?

Accelerated erosion is one of the greatest threats to Queensland's coastal wetlands, particularly because it is widespread and leads to changes to in-stream hydraulics of riverine wetlands (flow path) and reduced water quality in all wetlands. Increased sediment in wetlands directly results in the loss of habitat for aquatic species, through smothering, water turbidity, severe fluctuations in nutrient levels, and resultant excessive growth of algae.

Acid sulfate soil can severely reduce the water quality of coastal wetlands, often resulting in fish kills or disease. Groundwater discharges can also affect water quality and wildlife in other (usually downstream) wetlands, creeks, rivers and the ocean. Soil surface scalding can occur in severe cases, bringing iron and salt to the surface and killing off vegetation. This can also lead to increased soil erosion.

Stream bank erosion where a large tree has been undercut and is falling into the Daintree River (photo by Cassie Price)

What to look for

Use the following checklist to assist in determining a management strategy. The things to look for have been split into three sections:

1. Protect the things about the wetland that should be protected.
2. Repair the things about the wetland that could be improved and can be progressed by a local person (i.e. landholder, land manager).
3. Seek expert help with the things about the wetland that should be improved but will require some technical assistance or advice.

Protect	Tick
Well-vegetated catchment hillsides and gullies	☐
Stream banks with continuous native vegetation	☐
Well-vegetated floodplain wetlands	☐
Floodplain wetlands unaffected by drainage	☐
Repair	
Lack of vegetation protecting stream banks	☐
Intensively drained floodplain wetlands	☐
Seek expert help	
Erosion of stream banks	☐
Signs of 'iron' staining in constructed drains	☐
Scalded areas lacking vegetation showing signs of iron or salt	☐

What to do about erosion and acidity

There are a number of ways to combat soil erosion in wetlands and the impacts of erosion on wetlands, including:

- limiting grazing pressure on fragile soils (particularly stream banks)
- improving on-farm practices using best management practices (BMPs) such as minimum tillage (where appropriate), and green cane trash blanketing
- re-establishing riparian/fringing vegetation
- using engineering solutions, such as installing spoon drains and/or stabilising rock structures
- preventing over-drainage or disturbance, and therefore exposure of acid sulfate soils
- establishing suitable buffers or setbacks.

Limiting grazing

Fencing the wetland and providing off-stream watering points for cattle is a successful way of reducing erosion of wetland banks. Where the grazing pressure is removed, the increased vegetation cover results in reduced soil loss during heavy rainfall and flood events. This in turn reduces the sedimentation into wetland beds and, in the case of riverine wetlands, into downstream wetlands.

It may not always be necessary to restrict stock entirely from the wetland, but it is important to control their access. Used carefully, grazing can be an important management tool for controlling weeds in wetlands (see the Managing Wetland Grazing section of these Guidelines for further information on grazing as a management tool).

Stock-exclusion fencing may be traditional or electric, depending on what is suitable for the type of stock and the flooding regime in the area (i.e. high flood zones may require flexible fencing types). Aim for as wide an exclusion zone or buffer as possible from the water's edge.

Preventing soil erosion and acidity

Revegetation

Revegetation in and around a wetland (including its catchment) is an effective way of naturally reducing soil erosion impacts in coastal wetlands. For detailed information about revegetating wetlands see the Restoring Native Vegetation section of these Guidelines.

Key revegetation areas include the:

- riparian/fringing zone around the water's edge
- toe of the bank (particularly if it is steep)
- adjacent areas to wetland—surrounding hillsides and drainage lines (where water will run off into the wetland).

Engineering solutions

In some cases, vegetation may not be sufficient to rehabilitate severe erosion. Engineering solutions may be needed to stabilise the lower bank while vegetation becomes established on the upper bank. Options for engineering solutions may include:

- stone-toe, where flow-related erosion is severe at the toe of a riverine wetland bank
- battering of a steep bank to provide stability and allow planting
- elbow-dikes, placed in the water, to allow a build-up of silt and mangrove seeds caught behind the dike (often used in estuarine wetlands)
- rock chute at the gully head
- geotextile fabrics on localised erodible areas.

Note: Seek local expert advice if any of the above structures are necessary at a site. It is important to obtain a permit and/or a licence under the *Water Act 2000* for works that disturb stream areas.

For more information on alterations to constructed drains, refer to the Restoring Hydrology section of these Guidelines.

Who to contact for advice
(Contact details provided on page 81)

- Department of Primary Industries and Fisheries
- Department of Natural Resources and Water
- Regional NRM body
- Local council

Preventing disturbance of acid sulfate soils

In their natural state, acid sulfate soils can remain hidden under the surface of the soil or water. It is only when these soils are disturbed or over-drained that they become damaging to their surrounding environment.

In order to avoid inadvertently disturbing these soils, it is important first of all to know whether they exist on the site. This requires a field assessment. If there are indicators of acid sulfate soils, such as scalding or red iron staining, undertake complete **soil tests** before undertaking any excavation or drainage works. Acid sulfate soils are often protected under the soil surface by a **permanent cover of vegetation or water,** or both. It is important to ensure these covers remain intact.

Maintaining high groundwater and surface water levels in acid sulfate landscapes can be assisted by the construction of sills, bunds or modified floodgates downstream of the wetland. These are designed to hold water in the wetland longer and prevent soil drying, and to promote a protective layer of vegetation. Refer to the 'Restoring hydrology' section of these Guidelines for additional information on water retention structures. A water licence under the *Water Act 2000* and a development permit under the *Integrated Planning Act 1997* will be required if sills, bunds or floodgates are to be installed in a riverine wetland.

Redesign of drainage through wetlands containing acid sulfate soils from deep drains to wide shallow spoon drains is widely accepted as a means of avoiding exporting acid groundwater.

Further Information

Gardner, E A, Rayment, G E & Cook, F J 2000, *Distribution, behaviour and management of acid sulfate soils*, CRC Sugar, Queensland.

Johnston, S, Kroon, F, Slavich, P, Cibilic, A & Bruce, A 2003, *Restoring the balance: guidelines for managing floodgates and drainage systems on coastal floodplains*, NSW Department of Agriculture, Wollongbar, New South Wales.

Restoring hydrology

What is hydrology?

The term **wetland hydrology** refers to the behaviour of water within the wetland and includes groundwater movement. Hydrological processes dictate the quantum, timing and frequency of water being delivered to the wetland. The physical nature and shape of the wetland then determines the distribution of water within it and the period of retention.
It covers both freshwater and tidal waters, as well as the mixing (brackish water) zone.

Wetlands can receive their water from rainfall runoff, stream inflows, overland flows associated with flooding, groundwater discharges and tidal flows. Figure 13 (over page) describes the hydrological impacts common in coastal Queensland catchments.

Why is hydrology important?

The hydrological regime is one of the most important factors determining the character of a wetland. Wetlands and their communities are affected by the timing, frequency, duration, rate and depths of inundation. Hydrological regimes consequently determine the values, functions and even the type of wetland. The length of time that a wetland is dry can determine the diversity and productivity of wetland communities. Some animals rely on this flooding and drying cycle as their cue for migration and/or breeding. Hydrological regimes of wetlands can be significantly modified by damming or bunding of flows, water extraction and water storage.

Large weir blocking natural water movement (photo by Jim Tait)

What to look for

Structures such as weirs, bunds, levees, floodgates, culverts and road crossings, paved surfaces and constructed drainage and groundwater extraction all contribute to changes in hydrology. Hydrology is also affected by the extraction of water for consumption, land-clearing, and the increased absorption of soils through ploughing.

Use the following checklist to assist in determining a management strategy. The things to look for have been split into three sections:

1. **Protect** the things about the wetland that should be protected.
2. **Repair** the things about the wetland that could be improved and can be progressed by a local person (i.e. landholder, land manager).
3. **Seek expert help** with the things about the wetland that should be improved but will require some technical assistance or advice.

Protect	Tick
Unobstructed water flow	☐
Repair	
Partially blocked inflow (e.g. build-up of debris)	☐
Weed mat blocking natural flows	☐
Seek expert help	
Changed flow rates (could be higher or lower)	☐
Changes to wetland shape at water inflow point, indicating high velocity flow	☐
Changes in water depth	☐
Draining or extracting water	☐
In-stream structures (culverts, weirs, dams, road crossings etc)	☐

Restoring hydrology

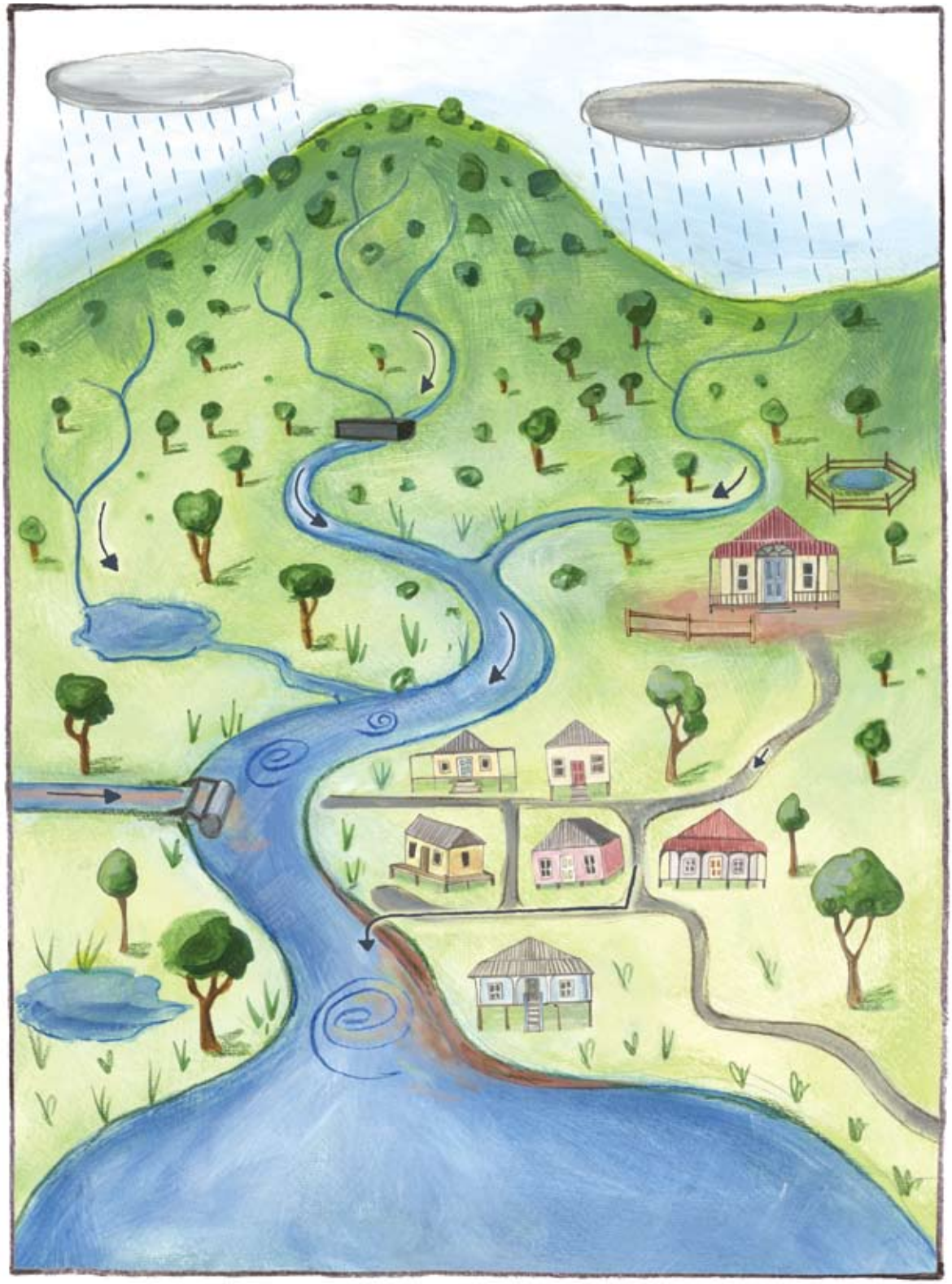


Figure 13. Hydrology in coastal catchments can be altered by in-stream structures, reduced catchment vegetation, urban areas and agricultural drainage.

What to do about hydrology

Over the years wetland hydrology has been altered to assist with agriculture and development. Dams and weirs have been built to hold water, and wetlands have been filled with water for irrigation purposes. Wetlands have also been drained and dried out, many permanently, for cropping and grazing. These changes have reduced the number of wetlands that still function naturally with the wetting and drying cycles that are essential to maintain wetland communities.

Steps towards restoring natural hydrology to a wetland will depend on its level of hydrological modification, what sort of wetland it is, where it occurs in the catchment (refer to 'Wetland location' in the Introductory section of these Guidelines) and how the land around it is used.

Options for controlling the water flow, timing and levels into and out of the wetland might include:

- allowing water exchange between fresh and saltwater systems
- reducing water extraction
- redesigning the constructed drainage to or from the wetland
- removing or lowering blockages to flow
- holding water on the wetlands
- slowing down flow from the upper catchment entering the wetland; and
- reinstating wetland seasonal wetting and drying cycles.

Redesigning constructed drainage

Farm drains are commonly designed to remove surface water that is affecting the productivity of agricultural land. This is generally required for areas that are flat and low-lying, and the drains are usually quite shallow in order to remain above the bed level of the receiving stream.

The deep drains designed to drain natural wetlands and naturally waterlogged land areas are entirely different. Deep drainage lowers groundwater levels in an area, extending the length of time for which any dependent wetland is dry. This potentially increases the production and export of acid sulfate products (for acid sulfate information see the Preventing Soil Erosion and Acidity section of these Guidelines).

There are some general rules for drainage:

- Avoid creating deep drains that rapidly drain surface and groundwater.
- Where possible, alter all drains to be wide and shallow (spoon-shaped), to avoid affecting the watertable and soil chemistry (acid sulfate soils).
- Take a planned and integrated approach to drainage at a catchment scale (e.g. consider the drainage of one catchment holistically in collaboration with other landholders).
- Remove persistently wet areas from production and rehabilitate them as wetlands, thereby possibly improving quality of water leaving the farm.
- Avoid new land development on wet areas where possible.

Drainage redesign, Tully–Murray floodplain (photo by Damon Sydes)

Restoring hydrology

Removing or lowering blockages to flow

Ways to overcome hydraulic blockages and reduce the impact on the wetland's water exchange and flow include:

- opening floodgates that block flow into upstream wetlands, by modifications such as sluice gates, tidal closing floodgates, winch gates and smart gates
- using rock sills in drains or channels to raise the bed level and allow water exchange into the wetlands at a controlled level
- installing culverts in place of a blockage, ensuring low-velocity flow (rocks can be added into the bottom of the culvert to assist)
- removing vegetation growth in silted channels.

Tidally operated floodgate that opens at low tide and closes at mid tide, allowing daily water exchange and fish passage (photo by Amber Kelly)

Holding water on wetlands

In some cases, where wetlands have been deep-drained, it is desirable to hold water on the wetland and reduce outflows. This can be done by constructing low earthen rock weirs or sills on the wetland's outflow channel at a height that mimics the natural depth of the wetland. If the outflow channel is a stream, it will be necessary to obtain a licence under the *Water Act 2000* and a development permit under the *Integrated Planning Act 1997*.

Other in-drain water retention structures are rock gabions or sills. These structures can be used to manipulate drain water levels and reduce groundwater gradients, thus helping contain acidic groundwater in the soil profile. They can also allow water to be retained on low-lying land at a desired level.

Note: Seek expert advice if structures such as these are required.

Rock sill used to hold water over a wetland (photo by Bob Smith)

Slowing flow rates

In general the rate of water flow into a wetland can be substantially increased if vegetation in the contributing catchment is cleared and floodplains are drained. Slowing flow from the wetland catchment is important to ensure that:

- the most natural hydrological regime is maintained within the wetland
- the groundwater recharge/discharge opportunities within the wetland are retained
- the wetland's sediment and nutrient detention/ retention capacity is not overloaded
- fish are not prevented from migrating upstream (if the velocity is too great, fish will not swim into the current).

It is possible to slow flows before they enter the wetland by:

- altering drainage systems
- revegetating areas of the upper catchment (see the Restoring Native Vegetation section of these Guidelines).

Hints & tips

Managing flow
Different wetland types have different hydrological regimes and different flow requirements. Some general rules when attempting to reinstate the hydrology of a wetland area include the following:

- only allow water to flow in natural amounts
- contain the water within the wetland area.

Lowering sills in key flood-runners or creeks, which will allow over-bank flows from smaller floods, will assist in reinstating a wetland's natural water regime. To do such modifications in a stream, it will be necessary to obtain a water licence under the *Water Act 2000* and a development permit under the *Integrated Planning Act 1997*.

Reinstating wetland seasonality

A drying cycle can be as important a part of the water regime as the wet cycle in some wetland types (particularly those that are temporary). Wetland plants and animals are adapted to wetting and drying cycles, some even requiring the cycle to trigger migration and breeding events.

Some wetlands hold more water now than they did naturally, mainly through receiving irrigation waters, tailwater discharge and higher river levels as a result of river regulation. In some cases, it may be necessary to introduce seasonal drying cycles to a wetland to mimic its natural water regime. The timing of this drying is important, and can be best gauged from the drying cycle of similar wetlands in the region. When do they dry out and for how long are they dry?

Hints & tips

Legislation
It is essential that, before any works are performed, you ensure that you have obtained all appropriate licences and permits. Applications for licences and permits are assessed on their own merit sand there is no guarantee that they will be granted, even if the intent is sound. When making any alteration to water flow or structures in waterbodies permits might be required for the following:

- To damage vegetation, excavate or place-fill in a watercourse, lake or spring, a **riverine protection permit** may be required from the Department of Natural Resources and Water. Go to www.nrw.qld.gov.au.
- To clear or destroy native vegetation, **a vegetation permit** may be required from the Department of Natural Resources and Water.
- To interfere with the flow of a watercourse or to alter the banks of a stream, **a water licence** under the *Water Act 2000* may be required.
- The *Integrated Planning Act 1997* may apply to any structure or installation that is deemed to be a development.
- Permits from the Department of Primary Industries and Fisheries are required for the disturbance of any marine vegetation, fish habitat area or blockage to fish passage. Go to www.dpi.qld.gov.au.

Restoring hydrology

Reinstating flow in tidal wetlands: East Trinity Inlet case study

Special care should be taken when allowing tidal flows back into areas where the tide has been excluded for a significant period of time. Tidal exclusion results in freshwater wetlands establishing where there was once an estuarine environment. Introduce tidal flows very gradually and monitor the wetland's response to that change.

In the 1960s East Trinity in Cairns was a natural wetland covered by mangroves and samphire flats with freshwater swamp forests of melaleucas on the edges. Its creeks—Hills, Firewood and Magazine—were considered good fishing areas.

Then, in the 1970s, East Trinity site was developed for sugarcane production. A rock levee—the bund wall—was built around the entire site to exclude saltwater. Tidal gates were included on Hills and Firewood creeks to allow water to leave (but not to enter) the site and drainage systems were constructed to lower the watertable and remove the salt. This exposed acid sulfate soil and caused ecosystem destruction (see Preventing Soil Erosion and Acidity section of these Guidelines).

The Queensland Government purchased the 940 ha East Trinity site in May 2000 to protect the Cairns Scenic Rim from development. Queensland's Environmental Protection Agency is responsible for site management. The Queensland Acid Sulfate Soil Investigation Team (QASSIT) from the department of Natural Resources and Water have been reintroducing controlled, lime-assisted tidal exchange, which uses tidal flushing to push water that has been treated with hydrated lime into areas that are acidic. The tide pushes water into the site through open floodgates on the incoming tide. The number of gates open is restricted so that the water inside the site only reaches a set maximum level.

The results have been encouraging, according to a comparison between a vegetation survey of the East Trinity carried out in 2006 and an earlier on in 2002. When saltwater was excluded from East Trinity 35 years ago, melaleuca trees moved into many areas, replacing the original mangrove communities. The incursion of saltwater associated with the remediation works has now started to reverse that process.

The 2006 survey showed that several mangrove species, including *Avicennia marina* and *Excoecaria agallocha*¸ are reinvading areas of former melaleuca forests. Mangrove ferns *(Acrostichum aureum)* are forming a dense ground cover on the margins of affected communities and are rapidly colonising bare areas. Not all melaleucas at East Trinity have died, however. Natural areas of melaleuca and feather palm forest, situated at the margins of the property, were unaffected when the land was developed for cane-growing and remain healthy. The regrowth melaleucas that occupy the margins of the tidally affected area are also flourishing.

The water quality in the creeks at East Trinity has dramatically improved since the rehabilitation work began. Proof of this is the discovery, in the latest survey, of 38 species of estuarine and marine fish, including recreationally and commercially important species such as barramundi *(Lates calcarifer)* and mangrove jack *(Lutjanus argentimaculatu)*, in the previously barren creeks. They also hold healthy stocks of juvenile mud crabs (Scylla sp.).

For more information on the reinstatement of tidal waters at East Trinity go to www.epa.qld.gov.au.

Further information for restoring hydrology

BSES S*urface drainage design and maintenance*, fact sheet, Accelerated Enhancement of Productivity in the Australian Sugar Industry.

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Tucker, P, Harper, M, Dominelli, S, Wielen, M, & Siebentritt, M 2002, *Your wetland: hydrology guidelines*, Australian Landscape Trust.

Who to contact for advice
(Contact details page 81)

- Department of Primary Industries and Fisheries
- Department of Natural Resources and Water

Improving water quality

What is water quality, and why is it important?

Wetland water quality refers to the ecological condition of the water in wetlands, which must always be suitable for the broad range of species expected to live there (plants, fish, crustaceans, molluscs and insects). It is important to remember that the water quality in wetlands varies naturally, changing in daily, monthly or seasonal cycles and in response to high flow events. It should also be remembered that the water quality of some wetlands is naturally poor (e.g. low pH), providing habitat for specially adapted (and often rare) flora and fauna.

Catchment clearing and land-use changes can cause deteriorations in water quality, because they lead to erosion and increased sediment and nutrient loads. Water quality may also be affected by weeds, altered hydrology, and pollutant loads in runoff or discharges, including stormwater runoff.

Reductions in water quality can emanate from upper catchment sources and cause pollution downstream through creeks and river drainage networks, to wetlands and ultimately to the ocean. In the case of Queensland's coastal catchments, discharged pollutant loads end up in the Great Barrier Reef lagoon. Poor water quality may have a direct impact on the reef, damaging corals and other reef organisms.

For more information on the impact of water quality on the Great Barrier Reef, see the **Reef Water Quality Protection Plan**, www.reefplan.qld.gov.au.

Degraded water quality in wetlands is evident in:

- elevated pollutant loads including nutrients and metals (particularly iron and aluminium)
- high turbidity or suspended sediments
- increased temperature, associated with lack of shade and weed infestations
- reduced dissolved oxygen (often as a result of organic loading, particularly associated with weed infestations)
- changes in pH (low pH equals high acidity; high pH equals high alkalinity)
- changes in salinity or electrical conductivity
- severe algal blooms, as a result of increased nutrients
- high chemical content, as a result of chemical leaching, over-spray or runoff.

What to look for

Use the following checklist to assist in determining a management strategy. The things to look for have been split into three sections:

1. **Protect** the things about the wetland that should be protected.
2. **Repair** the things about the wetland that could be improved and can be progressed by a local person (i.e. landholder, land manager).
3. **Seek expert help** with the things about the wetland that should be improved but will require some technical assistance or advice.

Protect	Tick
Clean, healthy-looking, odourless water	☐
Presence of native fish and other native aquatic life	☐
Repair	
Unusual water colour	☐
Algal bloom	☐
Bad-smelling water	☐
Water with a film or foam on the surface	☐
Farm or urban runoff entering stream untreated	☐
Seek expert help	
Poor water quality resulting from erosion, poor hydrology or aquatic weeds	☐
Dead or stressed native fish in the water	☐
Large amounts of weeds, sediment or turbidity in the wetland	☐

Improving water quality

What to do about water quality

Rehabilitation techniques for water quality in the Great Barrier Reef catchment wetlands should focus on decreasing nutrient and sediment loads, by:

- changing farming practices (see also Preventing Soil Erosion and Acidity section of these Guidelines)
- creating vegetated buffers
- using sediment traps
- establishing aquatic vegetation
- reducing temperatures by providing shade
- improving and stabilising dissolved oxygen levels
- maintaining pH
- controlling algal blooms
- reducing stormwater runoff
- creating constructed wetlands (see Constructed Wetlands section of these Guidelines).

Changing farming practices

It is possible to reduce the nutrient and sediment loads reaching the wetland from the farm by:

- reducing the amount of fertiliser used
- using caution when leaving green trash, and ensuring that large floods are not likely to wash it into nearby streams or drains
- limiting stock access to wetlands (see Managing Grazing section of these Guidelines).

Chemical use on agricultural lands should be reduced where possible. Chemical sprays should be used with care, ensuring that:

- there is a low likelihood of rain after application
- wind speeds are low during application
- wind direction is such that spray will not blow into waterways during application.

For more information see the Managing Weeds section of these Guidelines.

For more information on the best farm practices for managing wetlands and riparian areas on cane farms, refer to Wetland*Info* at www.epa.qld.gov.au/wetlandinfo.

Vegetated buffers

Native vegetation around a wetland can act as a buffer by trapping soil, nutrients and other pollutants that are carried in runoff. Riparian forests are particularly effective in intercepting subsurface flows.

In situations where it is not possible to establish a riparian forest, or even a strip, around wetlands, creeks or drains, it might be necessary to use **grass filter strips**. These are long, narrow plantings of grassy vegetation beside drains and ephemeral waterways to trap sediment and nutrients in runoff before it reaches the waterway. They are especially important in areas of intensive land use and on moderate slopes. Filter strips are most effective in areas of low to moderate soil loss and on relatively flat surfaces where the runoff flow through them is low or moderate, such as the edges of cane paddocks.

Vegetated strip planted as a buffer to land use (cane crop) around a freshwater wetland in the Mossman Shire (photo by Cassie Price)

Filter strips may consist of a stand of native grasses, which should be planted at the foot of the paddock, where the majority of runoff flow enters the drain, wetland or stream. Filter strips are most effective when 100 per cent grass cover of moderate height is achieved. This is best done using small-stemmed grasses and maintained with occasional high-level slashing.

Table 7 details a range of native grasses that have been trialled as vegetative filter strips to trap sediment and nutrients in runoff from cane farms. It includes information about their maintenance requirements and resilience, to help you select the most appropriate species or mix of species for a particular location and application.

Table 7. Options for vegetative filter strip grasses

Common Name	Native Vetiver	Lomandra	Tassel & Tussock Sedges	Blady Grass	Common Couch or Bermuda Grass
Scientific Name	*Vetiveria filipes*	*Lomandra hystrix,* *Lomandra longifolia*	*Carex fascicularis* *Carex appressa*	*Imperata cylindrica*	*Cynodon dactylon*
Description	Clumping grass Deep fibrous roots Base width to 68 cm Height 0.6–0.7m	Clumping tussocks Broad fibrous matting roots Root depth to 60 cm Base width to 1.0 m Height 0.7 to1.2m	Dense tufting perennials Thick matting roots Root depth to 60 cm Base width to 0.5 m Height 1.0 to 2.0 m Non-invasive.	Dense tufting & blanketing perennials Thick matting roots Root depth to 60 cm Height up to 1.2 m	Dense, low, thick matting grass Produces prolific runners Thick fibrous matting roots Root depth to 30 cm Height prostrate
Habitat	Open riparian zones associated with Sedges, Lomandra, Rushes, Rhodes Grass and Common Couch	Riparian zones associated with Sedges, Lomandra, Rushes, Rhodes Grass, and native and introduced pasture grasses	Riparian zones, temporary swamps & creek banks. Associated with Lomandra, Rushes, Rhodes Grass, native & introduced pasture grasses	Open, sunny areas often colonising disturbed sites. Associated with couch and native and introduced pasture species.	Open, sunny free draining areas often colonising disturbed sites. Associated with Lomandra and Blady grass.
Propagation	Seed Tillering	Seed *L. Longifolia* more prolific seeder than *L hystix*.	Seed	Seed Root nodes	Roots nodes Seed
Tolerance	Drought, Flood, Frost	Drought Flood, Frost, Salt, Light traffic	Flood, Fire, Light traffic	Flood, Fire, Salt, Light traffic	Flood, Fire, Salt, Extensive traffic, High nutrient levels
Care	These are non-migrating plants and require little maintenance if the drain is frequently inundated. All species can be slashed. Monto Vetiver is a sterile cultivar which flowers but does not produce a viable seed.				
Benefits					
Soil Conservation	✓	✓	✓	✓	✓
Bank Stabilisation	✓	✓	✓	✓	✓
Rapid Regrowth	✓	✓	✓	✓	✓
Sediment and Agrochemical Trap	✓	✓	✓	✓	✓
Ideal on Grassed Waterways					✓

Improving water quality

Sediment traps

In-drain sediment traps are being used in constructed drains to trap sediment in runoff from agricultural lands. It must be noted, however, that in-drain sediment traps are not the preferred method of sediment control. It is preferable to stop sediment before it enters a drain or waterway.

Traps need to be monitored, and cleaned when full. Landholders often excavate sediment and place it onto low-lying paddocks to build them up and increase land productivity. A permit under the *Water Act 2000* might be required for this work, if located within a stream. Contact the Department of Natural Resources and Water for advice on requirements

Aquatic vegetation

Establishing submerged and emergent aquatic plants is an effective way of managing nutrients that are already in the wetland or water column, because the plants will take up substantial quantities of the nutrients. The plants can be harvested to remove excess nutrients from the wetland, but this should be done with caution. Harvesting the plants at times of high nutrient levels can result in algal blooms until more plants can be established. It is important to re-establish harvested plants quickly so that exotic or less effective species do not take their place.

See Restoring Native Vegetation section of these Guidelines for more information on establishing fringing and aquatic plants.

Reducing temperature by providing shade

Water temperature is important to fish and other aquatic organisms. It can directly influence their growth and development, egg hatching, larval development and spawning cues. Rising temperatures also greatly reduce dissolved oxygen, which is needed by all wetland species for survival. Low dissolved oxygen levels can lead to reduced populations of aquatic organisms and can result in major fish kills.

Riparian vegetation around wetlands reduces the amount of direct sunlight reaching the water, and therefore reduces the daily and seasonal extremes in temperature. Shading also controls excessive growth of aquatic plants by limiting the availability of light.

The degree of shade created by riparian vegetation is influenced by canopy height, foliage density, wetland width and orientation, valley topography, latitude and season. The effect of shading is greatest in narrow wetlands such as small streams. Research has shown that up to 95 per cent of the incident solar radiation can be blocked by a full riparian canopy cover in a narrow stream.

Sediment trap in an urban wetland environment (photo by Mark Bayley)

Floating and emergent plants established in a constructed wetland (photo by Mark Bayley)

Re-establishing native vegetation on the banks of wetlands is the best way to reduce the water temperature. Even in wider wetlands this will provide shady refuges for inhabitants in the heat of the day.

See the Restoring Native Vegetation section of these Guidelines for further information about establishing native vegetation around the wetland.

Maintaining dissolved oxygen

Many events can affect dissolved oxygen levels. For example:

- rapid inundation, which may lead to sudden death of fringing and emergent plants and result in large loads of decomposing organic matter
- changes in temperature
- changes to flow
- algal blooms.

Solutions to improving and stabilising dissolved oxygen levels include:

- reducing catchment nutrient loads by revegetation, improved on-farm practices and land use controls (see above)
- removing excess weeds, particularly floating and submerged ones, so that at least two-thirds of the wetland surface is clear (see Managing Weeds section of these Guidelines);
- building in-stream riffle structures that introduce turbulence into a stretch of stream (seek the advice of your local Department of Primary Industries and Fisheries office; a permit will be required under the *Water Act 2000* to undertake these works)
- revegetation of the riparian zone to increase shading and regulate water temperature (see above)
- keeping the wetland open to prevailing winds, generally from the south-east, by planting smaller shrubs in that area of the wetland; the winds will aerate the surface of the wetland (this could require removal of vegetation, which will require a permit; see legislation box below for more details)
- artificially aerating with paddle aerators, but only in shallow wetlands where there is little stratification (seek advice of your local Department of Primary Industries and Fisheries office)
- releasing or maintaining artificial flows (in regulated systems) at critical times of the year (i.e. first storm season of summer), provided this is within the parameters of any water resource plan or interim resource operations licence.

Hints & tips

Legislation

Removal of native vegetation requires approval from the Department of Natural Resources and Water under the *Vegetation Management Act 1999* or (if in a stream) the *Water Act 2000*.

Authorisation is required under the *Water Act 2000* to place fill in a watercourse and/or install a structure in a watercourse. You may also require a development permit under the *Integrated Planning Act 1997*.

Maintaining pH

Most aquatic animals will not inhabit water with a pH below 5.0, and aquatic plants are unlikely to establish in water with a pH below 4.0. pH changes are commonly a result of decreased oxygen and increased carbon dioxide in the water, or acid sulfate soils. High pH (i.e. high alkalinity) can also cause significant problems for plants and animals if it is above 9.0.

The causes of changes in pH may often be similar to those that bring about changes in dissolved oxygen:

- rapid algal growth
- sudden plant death, resulting in large loads of decomposing organic matter
- changes in temperature
- changes to hydrology.

However, changes in pH can also result from changes in soil health.

For more information on managing acid sulfate soils see the Preventing Soil Erosion and Acidity section of these Guidelines.

Improving water quality

Controlling algal blooms

Algal blooms are generally a result of high nutrient loads, increased light and stratification in the water column. They can be prevented by:

- ensuring that nutrient loads entering the wetland are low
- reducing the available light on the water by increasing shading vegetation (see 'Reducing temperature by providing shade' above)
- increasing natural flow and flushing (see Restoring Hydrology section of these Guidelines)
- artificial destratification, using paddle aerators on the water's surface only (seek expert advice from your local Department of Primary Industries and Fisheries office).

Reducing stormwater runoff

In addition to agricultural runoff, stormwater discharge is a major contributor to pollutant loads in urban wetlands. There are some ways in which suburban households can minimise pollution from runoff:

- When building a new home, avoid placing buildings near natural waterways, leave a buffer zone, avoid extensive excavation, work with the natural slope of the land, and manage any runoff of exposed soils during construction using sediment fencing.
- When landscaping, keep as many of the original native plants as possible and add to them by planting other native species. Avoid large unvegetated areas that will increase runoff.
- Use water-saving plumbing fixtures, and recycle water where possible (e.g. onto the garden).
- Install a water tank to collect and use the water than runs off the roof, or redirect the gutter and let the water run into the garden.
- Construct detention structures in stormwater drains that collect and hold stormwater for 24 hours before it is released. This will allow any sediment and nutrients to drop out of the water.

Further Information

Bailey, P, Boon, P & Morris K 2002, *Managing nutrients in floodplain wetlands and shallow lakes*, River Management Technical Update no. 2, Land & Water Australia, Canberra.

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Hogan, A 2007, *Sediment trap design*, Queensland, Australia.

Hunter, H et al. 2006, *Managing riparian lands to improve water quality: optimising nitrate removal via denitrification*, CRC Coastal Zone Technical Report no. 57.

Prosser, I & Karssies, L 2001, *Designing filter strips to trap sediment and attached nutrients*, Riparian Land Management Technical Guideline, update no. 1, Land and Water Australia, Canberra.

Smith, RJ, 2008, *Riparian and wetland areas on cane farms: smart sugar best management practice*, Booklet no. 6, prepared by WetlandCare Australia in cooperation with Canegrowers and BSES Inc.

Who to contact for advice
(Contact details provided page 81)

- Department of Primary Industries and Fisheries
- Department of Natural Resources and Water
- Regional NRM body
- Local council

Managing grazing on wetlands

What is grazing?

Grazing is a term used to describe the feeding of stock or wildlife on grasses and herbaceous plants within an area. Cattle and horses commonly have access to wetlands for watering and grazing on nutritious pastures, and they can damage the vegetation and fauna. However, if properly managed, they can also benefit wetlands by reducing invasive grass biomass and fire fuel loads.

The hazards of grazing

Wetland areas are particularly sensitive to stock access. Uncontrolled stock can damage vegetation, disturb native animals (particularly nesting birds), increase bank erosion and compaction, and reduce water quality (through high turbidity and nutrient load). In some cases it can take more than five years for vegetation to recover. However, within the Great Barrier Reef catchment the predominance of invasive exotic pasture grasses means that the total exclusion of grazing from wetlands can also lead to significant

Cattle grazing at Serpentine Lagoon (photo by Bob Smith)

What to look for

Use the following checklist to assist in determining a management strategy. The things to look for have been split into three sections:

1. **Protect** the things about the wetland that should be protected.
2. **Repair** the things about the wetland that could be improved and that can be progressed by a local person (i.e. landholder, land manager).
3. **Seek expert help** with the things about the wetland that should be improved but will require some technical assistance or advice.

Protect	Tick
Riparian and edge vegetation zones	☐
Repair	
Stock access (creating pugging and compaction)	☐
Reduced water quality	☐
Wetland bank collapse or damage	☐
Damaged native vegetation near the edge or in the wetland	☐
Seek expert help	

Managing grazing on wetlands

What to do about grazing

Ways of controlling grazing pressure in wetlands include:

- fencing and separately managing the wetland and providing off-stream or controlled access watering points
- seasonal spelling or rotational grazing of the wetland area
- reducing stock density.

Fencing and off-stream watering

Controlled access of stock to wetlands can be achieved through a system of fencing that rests, or spells, sections of the land and allows the natural regeneration of wetland vegetation. Assisted revegetation may be required to get plants established before invasive exotic grasses become dominant, or if natural seed stores or overstorey vegetation have been lost. For more information on natural or assisted revegetation see the Restoring Native Vegetation section of these Guidelines.

Fencing needs to be suited to the flood regime of the site and be strong enough to control stock. Useful fencing techniques in flood zones include:

- drop fences, which automatically drop as pressure from water and debris builds up
- lay-down fences, which can be manually laid down when flood is imminent
- electric fences, which are a cheaper, more flexible alternative to traditional fencing.

There are a number of design considerations for fencing around a wetland:

- Consider leaving a plant buffer zone that is as wide as possible (see 'Vegetated buffers' in the Improving Water Quality section of these Guidelines).
- Straight fencing is often more practical, but consider mimicking the natural line of the existing riparian vegetation to maximise paddock space and reduce plant clearing.
- It is important to provide access inside the fence. Think carefully about gate placement, and leaving a track width between the inside of the fence and the edge of the vegetation.
- Leave a watering point, or access for cattle from the paddock to the stream or wetland (see Figure 14).

Did you know?

Invasive exotic aquatic grasses such as hymenachne and para grass are fire-sensitive and can also be drowned. In the seasonal dry tropics the combined use of fire and heavy grazing late in the dry season can provide broad-acre control of these exotic grasses.

Watering points

Watering points away from the wetland can decrease the level of stock traffic in the wetland. If the wetland is fenced, it is particularly important to provide off-stream watering points. Infrastructure such as pumps, pipe, troughs and tanks are necessary, and electricity to the site may be needed to run the pump. Alternatively, consider using solar power.

An alternative to off-stream watering points is a limited watering point fenced off in the wetland or stream. For example, the riparian zone may be fenced around the wetland except for an area 10 m wide where it meets the water. This allows stock access to a limited part of the bank and protects the remainder. The bank may need to be stabilised with rock to protect water quality.

To establish an off-stream water point for stock, it must comply with a self-assessable code under the *Water Act 2000*; go to www.nrw.qld.gov.au.

Seasonal spelling

If fencing is not a practical option for the wetland, seasonal spelling can reduce the impact of grazing by minimising damage to usually soft soils and thriving vegetation. This involves monitoring the wetness of the wetland and allowing stock access only when it is at its driest—when the soil is not holding water and the vegetation is dormant. Seasonal spelling may become part of an annual rotational grazing pattern for the property, or grazing may only be allowed under drought conditions (Figure 14).

Reducing stock density

If it is not practical to fence the wetland or remove the stock for a period of time, reducing stock densities will reduce the impact on the wetland. Limiting the number of cattle that have access to the wetland at any one time could also be arranged seasonally or on a rotational basis, as with seasonal spelling (Figure 14).

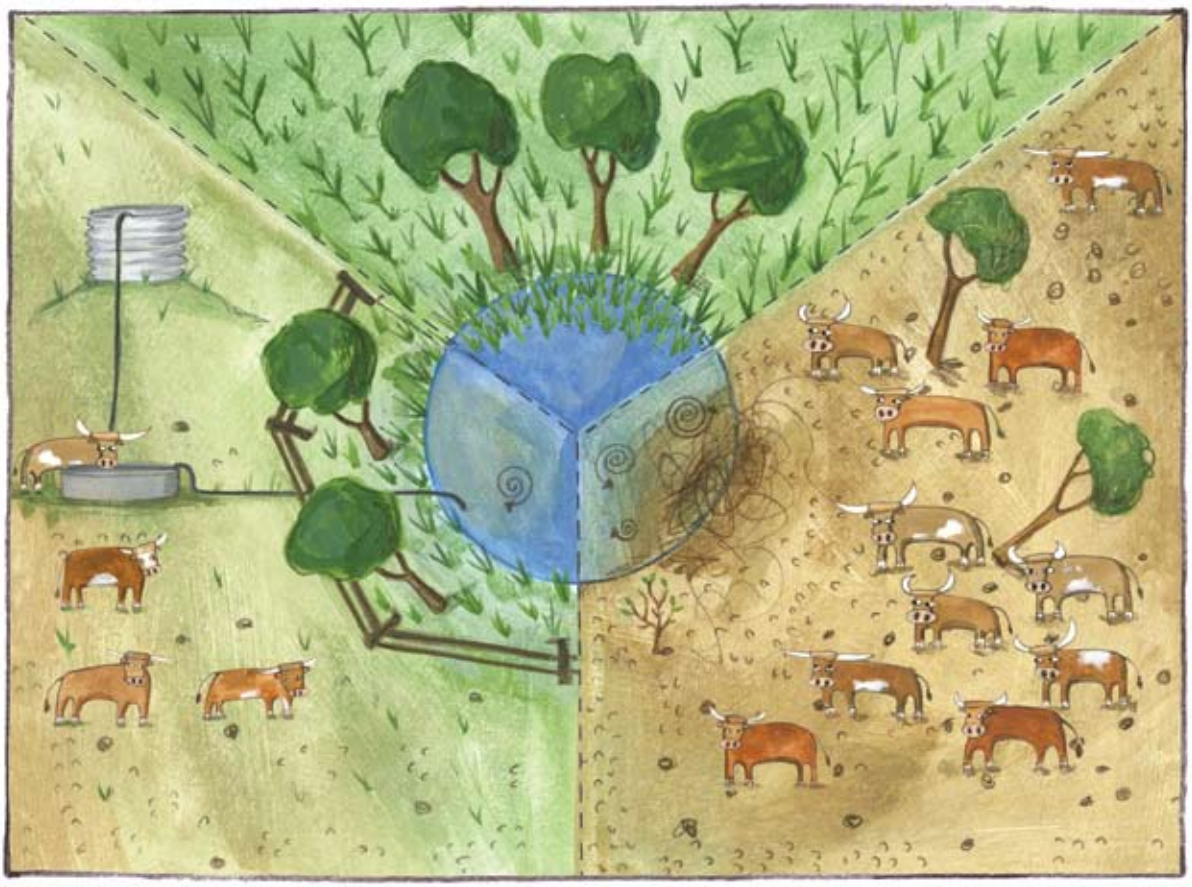

Figure 14. Managed grazing around a wetland is the best scenario for wetland management. Overgrazing can lead to a loss of vegetation and habitat. However, a lack of grazing pressure can result in invasive grass infestations and increased fire fuel loads, both of which are harmful to wetlands.

Hints & Tips

Funding
There is often funding available for activities such as stock control in wetlands. Speak to a local Landcare Group or Regional Natural Resource Management body.

Warning

Grazing of wetlands and riparian areas must be well managed. Overgrazing of these areas can severely degrade wetland ecosystem function, increase bank erosion and reduce water quality in waterways.

Who to contact for advice
Contact details provided page 81)

- Department of Primary Industries and Fisheries
- Regional Natural Resource Management body

Further information

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Managing grazing on wetlands

Innovative ideas

Grazing as a management tool

Although grazing pressure can be damaging to wetlands, the predominance of invasive exotic pastures (major weeds of Great Barrier Reef catchment wetlands) often makes managed grazing a 'lesser evil' than weed impacts associated with total grazing exclusion. Controlled grazing of riparian and wetland areas can be a valuable broad-acre management tool, particularly to:

- control palatable weeds, especially exotic grasses
- and/or reduce fire fuel loads.

The appropriate controlled grazing regime for a wetland will depend on the wetland type, current condition, seasonal climate and hydrology, and constraints associated with site values, landform and adjoining land uses. The effectiveness of grazing as a management tool depends on the fact that most exotic pastures are more palatable to stock than native wetland flora and will be preferentially grazed by them, shifting cover dominance back towards native vegetation. Many exotic pastures, particularly aquatic ponded pastures, are also fire-sensitive and the opportunity to integrate burning with controlled grazing can increase the effectiveness of these broad-acre management tools.

Note: it is also important to couple these management tools with other weed control methods (see 'Managing weeds' section of these Guidelines).

Two main types of controlled grazing regime for wetlands management may be defined:

1. Maintenance regimes are generally more conservative. They are used to prevent further infestation with exotic pasture plants, or reduce their impact, within a wetland that has relatively good existing condition. Examples include:
    - sustained low-intensity grazing, to keep exotic grasses subdominant and reduce dry-season fuel loads
    - seasonal crash grazing, mainly to reduce dry-season fuel loads and the associated risk of hot fires.
2. Transitional regimes are applied to wetlands that are already heavily infested with exotic pastures. Their aim is to improve the wetland from its existing condition. Such regimes may involve the use of more intensive grazing pressure and/or burning, though this will usually only be appropriate in open wetland basins with little remnant native vegetation. Where remnant native vegetation values remain, the grazing regime must be sensitive to the potential impacts of stock browsing and trampling. An example of a transitional regime might be:
    - Heavy grazing late in the dry season, with or without burning; subsequent post-burn grazing, before wet season inundation to 'drown' cropped short grass stems; wet season spelling to allow native vegetation to recover. Where site conditions allow, avoiding wet season spelling in the initial years can reduce the dominance of exotic pasture plants more rapidly.

Transitional regimes should be maintained only for long enough to establish conditions that allow wetlands to undergo natural or assisted succession towards recovery. Once such conditions have been established, grazing may be removed or replaced by a maintenance regime. No single regime of grazing-based management will suit all wetlands, and it is important to keep monitoring the site to gauge the reaction of the wetland and make any necessary adjustments. Key indicators for monitoring include percentage of ground cover, cover composition and bank compaction. See also the Maintenance, Monitoring and Evaluation section of these Guidelines.

Managing fire in wetlands

Fire in a wetland

Fire is a double-edged sword in wetlands; while an inappropriately intense fire regime can be a major threat, it is also a useful management tool for controlling fire sensitive weeds and promoting fire-dependent native vegetation.

Fire has been used by traditional owners as a land management tool for thousands of years. In the Great Barrier Reef catchment the general fire pattern was frequent, low-intensity, patchy, early dry-season burns.

Why do fires need to be managed?

Fire can be a threat to wetlands in two ways:

1. Intense (hot) fires can impact important elements of wetlands including riparian vegetation, faunal populations and organic peat layers.
2. Lack of fire can, in some plant communities dependant on fire, significantly alter the plant species composition of the wetland, often in favour of exotic species.

Intense and/or frequent fires are damaging to wetland vegetation as their organic peat soils are not generally well-adapted to frequent and hot burning. Hot fire damage can result in the destruction of peat beds, changes to vegetation composition, exposure of root systems, increased erosion and changes to soil chemistry. Frogs, reptiles and birds can also be aversely affected by fire, especially if it occurs during their breeding seasons.

The majority of wetland vegetation in the seasonally dry tropics has evolved in conjunction with exposure to seasonal burning and has often developed some dependence on fire for germination and recruitment opportunities. A lack of fire can create a change in species composition by reducing the number of fire-dependant plants and increasing the invasion of exotic pasture grasses.

What to look for

Use the following checklist to assist in determining a management strategy. The things to look for have been split into three sections.

1. **Protect** the things about the wetland that should be protected.
2. **Repair** the things about the wetland that could be improved and that can be progressed by a local person (ie. landholder, land manager).
3. **Seek expert help** with the things about the wetland that should be improved but will require some technical assistance or advice.

Protect	Tick
Wetland vegetation that is fire susceptible	☐
Peat areas vulnerable to over drainage and therefore unnatural fire damage	☐
Fire dependant vegetation from excessive build up of invasive exotic grasses	☐
Repair	
Hot fire damage evident in riparian areas	☐
Reinstate seasonal burning consistent with fire dependency of vegetation	☐
Fire breaks and fuel reduction in hazard areas	☐
Seek expert help	
Repeated hot fire destruction of riparian vegetation and organic peat layer	☐

Managing fire in wetlands

What to do about fire in wetlands

Reducing fuel loads

Hot fires are often a result of poorly-timed burns and/or large fuel loads associated with unmanaged growth of exotic grasses. Periodic grazing of a wetland area is a useful tool for reducing dry season fire fuel (for more information on grazing as a management tool see the Managing Grazing section of these Guidelines).

A range of weed control methods are useful in reducing fire fuel loads. There are a number of options that can be used in conjunction with grazing or in-place of grazing where it is not possible. These may include chemical controls, manual control, mechanical control (i.e. slashing) (see the Managing Weeds section of these Guidelines).

Fire exclusion

Landowners can exclude fire from their wetlands by establishing fire breaks around the wetland using fire-break ploughing. However, unless carefully managed, this can increase the fuel loads on the property and result in an extremely high intensity fire when one occurs.

Fight fire with fire?

Hot fire fuel loads can also be reduced by low intensity, mosaic burns at the right time of year without damaging sensitive wetland vegetation and fragile peat soils.

Mimicking natural fire regimes

Management strategies that mimic the natural fire regime must consider the intensity, frequency and seasonality (or timing) of the burn. The appropriate fire regime for a wetland will be largely site and wetland type-specific and will also depend on the condition and management objectives for a wetland.

The fire mosaic method of burning is often most appropriate for wetlands. Pre-burn controlled grazing is another potential approach for managing fire intensity. Hot intense fire will sometimes be an appropriate management approach for controlling fire-sensitive pasture grasses or other weeds.

Fire regime is the manner in which fire is experienced by a particular ecosystem or site. It is described by reference to at least **three characteristics** including:

1. Intensity—describes if a fire is a hot or cool burn determined by fuel load, season, time of day and weather conditions
2. Frequency—describes how often a fire occurs on average i.e. annually, every 3 years, >5years
3. Seasonality—describes whether the fire occurs early or late in the dry season or as an early storm season (post rainfall) burn.

Controlled pre-burn grazing of this riparian area allowed a beneficial 'cool' burn to be introduced in an area dominated by exotic pasture grasses. (photo by Jim Tait)

Mosaic burn method

This method involves a series of small burn areas that are kept at a low intensity. This mosaic, or patchy, effect can be achieved by burning during the start of the dry season (around April). Small areas of the wetland can be burned as they dry out sufficiently. It is important to observe the patterns of the individual wetland and local weather in planning for fire. The surrounding wet areas will act as a natural fire break. Natural fire intensity controls can be achieved by burning at night or shortly after rain to achieve a mosaic and low intensity burn. It is important that established native vegetation and peat layers are kept intact.

Hints & Tips

Legislation

Queensland landholders need to apply for a Permit to Light Fires to light an open fire larger than 2 m. Permits are available from local fire wardens at no charge. To apply for a permit, contact your Rural Fire Service or visit: www.ruralfire.qld.gov.au

Also consult with the Department of Natural Resources and Water in the case where a Development Permit for the destruction of vegetation may be required.

Further information

Leading weather websites:

www.bom.gov.au

www.weather.new.com.au

www.coastalwatch.com.au

www.csiro/services/pps69.html

www.eldersweather.com.au

Marlow, C B, Tucker, R, Sauer, B & Shea, V 2006, 'Broadening the scope of prescribed fires: opportunities to rehabilitate degraded riparian zones', *Forest Ecology & Management* 234S, (S169. Elsevier.

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WetlandCare Australia 2006, 'Pasturage reserve grazing and burning regime management trials', Great Barrier Reef Coastal Wetland Protection Program Project with Burnett Shire Council & Bundaberg Landcare.

Who to contact for advice

(Contact details provided page 81)

- Rural Fire Service (see links above)
- Department of Primary Industries and Fisheries
- Department of Natural Resources and Water

Constructed wetlands

Constructed wetlands such as detention ponds or treatment wetlands have been trialled, refined and applied throughout the world over the past 60 years to improve water quality, restore hydrology and provide habitat. Thus, their application within the Great Barrier Reef catchment for the improvement of wetlands is well justified. From an agricultural perspective, on-farm wetlands can be created in applicable sites to filter water before it enters natural wetland areas, associated streams and larger waterways.

It is important to remember that wetlands should not be constructed for the purpose of collecting water for agricultural use. Constructed wetlands should maintain a natural flow regime into and out of the wetland, which will ultimately create benefits to biodiversity in the catchment.

The following considerations should be kept in mind when constructing artificial wetlands:

- What are the goals of my wetland construction? Water quality? Habitat values?
- Is an existing natural wetland area going to be affected by the construction?
- What existing characteristics of local wetlands can be incorporated into the constructed wetland?
- Will excavation mobilise poor-quality groundwater or acid sulfate soils? (see Warning box below)
- Is approval required? (see Hints & tips Legislation)
- Will there be any potential conflict with other stakeholders (particularly water users downstream)?

Constructed wetlands for the improvement of water quality and habitat require careful planning:

Shape:

- The perimeter of the lagoon should be irregular, with varying depths and bank gradients.
- The surface area of the lagoon should be as large as practically possible, preferably 1–3 per cent of the catchment size.
- The minimum average width should be 30 m.
- The minimum depth during the driest period should be 30 cm and the maximum depth should be 6 m.
- Sixty per cent of the lagoon should be 'shallows'.
- Forty per cent of the lagoon should be deeper (>3 m), and deep enough to be retained during drought.
- The lagoon should have a shallow, well-vegetated basin margin.
- Bank gradients should be between 1:4 and 1:15, or less if possible.
- The resting banks around the edges of the wetland should differ in height.

Inflow and outflow:

- There should be broad, shallow, well-vegetated water-entry points to reduce flow velocity and encourage silt settlement.
- Outflow must be unrestricted.

Position:

- Orientation of the lagoon should be in line with prevailing winds.
- It should not lower the watertable.
- It should not be constructed in areas of acid sulfate soil.
- It should not be constructed within or impacting upon a natural wetland area of any type.

Features:

- There should be a habitat island close to the inlet zone of the wetland.
- There should be submerged, emergent and riparian fringe vegetation.
- There should be buffer and shade trees around the lagoon.
- Snags should be placed or encouraged.
- The topsoil layer should be redistributed in the riparian area after excavation, to improve plant establishment.

Warning

Before constructing a wetland, sample any suspected acid sulfate soils areas to 0.5 m below the intended excavation depth. For wetlands of less than 0.25 ha in area, two test holes are necessary; for wetlands 0.25–1 ha in area, three to four test holes are required. It is also necessary to check the soil type for impervious clays, to ensure that the wetland will retain water.

Constructed wetlands requiring deep excavation should not be built in acid sulfate soil areas.

Further information

Layden, I 2009, *Wetland management handbook*, Department of Primary Industries & Fisheries, Wetland*Info*, <www.epa.qld.gov.au/wetlandinfo/site/ManagementTools.html>.

Department of Natural Resources and Water: <www.nrw.qld.gov.au/water/management/overland_flow/index.html>.

Hints & tips

Legislation

It is also important to consider the following (adapted from Layden 2009):

- Is there a current Water Resource Plan (*Water Act 2000*), or is one being developed, for the region, and/or is there a moratorium on the capture and storage of overland flows?
- If the construction process or the wetland necessitates disturbing marine plants (such as mangroves) will an assessment under the *Integrated Planning Act 1997* be necessary?
- Is a development permit (self- or code-assessable), issued under the *Integrated Planning Act 1997*, required prior to construction?
- Will the proposed works require certified engineering drawings to be submitted to state or local authorities?
- Is a Land and Water Management Plan (LWMP) under the *Water Act 2000* required?
- Are permits for the clearing of native vegetation under the Vegetation Management Act 1999 or Environmental Protection Act 1994 required before site is cleared for construction?
- Does the proposed construction interfere with riparian vegetation on a watercourse, lake or spring and require an assessment to be made under the *Integrated Planning Act 1997*?
- Will the proposed works require a permit to destroy vegetation, excavate or fill in a watercourse, lake or spring as defined by the *Water Act 2000*?
- Are there any local government requirements?
- Will the development affect existing wetlands or riparian areas?

Advice should be sought from the Department of Natural Resources and Water.

Legislative requirements

There are numerous Queensland and Australian Government statutory instruments and international agreements to improve wetland conservation in Queensland. In addition to legislation, there are also policies and strategies to protect wetlands that have been developed at national and state level. These aim to halt further loss of wetlands through wise use that promotes wetland conservation, enhancement and sustainable use.

Australian, state and local government legislation applies to certain activities and works within and around wetlands.

Australian Government legislation

There are two pieces of legislation that are relevant to wetlands:

- *Environmental Protection and Biodiversity Conservation (EPBC) Act 1999*
- *Great Barrier Reef Marine Park Act 1975.*

Table 8 below outlines circumstances in which Australian Government legislation is relevant to wetland rehabilitation.

Table 8. Relevance of Commonwealth legislation to wetland rehabilitation.

Legislation	When is it applied

Environmental Protection and Biodiversity Conservation (EPBC) Act 1999	This act applies when a wetland is:
	• Ramsar listed (see box for more information)
	• World heritage listed
	  • Wet Tropics of Queensland
	  • Great Barrier Reef Marine Park
	  • Fraser Island
	• habitat for migratory birds
	• habitat for rare and threatened species.

Great Barrier Reef Marine Park Act 1975	This act applies when a wetland is within the Great Barrier Reef Marine Park boundary.

Ramsar Convention

The Convention on Wetlands of International Importance, especially as waterfowl habitat, is known as the 'Ramsar Convention'. The objective of the convention is the conservation and wise use of internationally important wetlands. Signatories to the convention must delegate at least one site that meets the Ramsar criteria for inclusion in the List of Wetlands of International Importance. Parties agree to conserve listed wetlands, including providing wetland conservation within national land-use planning, establishing nature reserves on wetlands and promoting wetland education.

Australia has 65 Ramsar sites, five of which are in Queensland. These are:

- Moreton Bay, south-east Queensland.
- Bowling Green Bay, north Queensland.
- Great Sandy Strait, south-east Queensland.
- Currawinya Lakes, south-western Queensland.
- Shoalwater and Corio Bays, central Queensland.

Queensland legislation

There are eight main pieces of Queensland legislation applying to activities and works that may be involved in rehabilitating wetlands:

- *River Improvement Trust Act 1940*
- *Nature Conservation Act 1992*
- *Environmental Protection Act 1994*
- *Fisheries Act 1994*
- *Coastal Management and Protection Act 1995*
- *Integrated Planning Act 1997*
- *Vegetation Management Act 1999*
- *Water Act 2000*
- *Land Protection (Pest & Stock Route Management) Act 2001.*

As wetlands depend most critically on water, it is essential that you consider the requirements of the *Water Act 2000*, in particular, when planning rehabilitation activities.

Table 6 below outlines circumstances when Queensland legislation is relevant to wetland rehabilitation activities. At the time of printing the Queensland Wetlands Programme was developing a legislation and planning support tool to help landholders determine their legislative responsibilities.

For additional information please refer to Wetland*Info*. Go to www.epa.qld.gov.au/wetlandinfo.

Table 9. Application of Queensland legislation to wetland rehabilitation

Legislation	When it applies
Integrated Planning Act 1997	When any 'works' are undertaken in wetlands, development and planning approvals may be required (speak to local council and/or the Department of Natural Resources and Water): www.ipa.qld.gov.au/
Vegetation Management Act 1999	When any change (removal or damage) to native vegetation is to occur, a permit from the Department of Natural Resources and Water is required: www.nrw.qld.gov.au/vegetation/clearing/index.html
Fisheries Act 1994	Wen any change to marine vegetation or fish habitat is to occur, a permit from the Department of Primary Industries and Fisheries is required; exotic fish regulations also apply under this Act: www.legislation.qld.gov.au/LEGISLTN/CURRENT/F/FisherA94.pdf
River Improvement Trust Act 1940	Any change to banks or beds of rivers requires the approval of the local River Improvement Trust: www.nrw.qld.gov.au/compliance/wic/river_improve_trust.html
Water Act 2000	As under the Integrated Planning Act, when any 'works' (including clearing) are undertaken within a non-tidal stream section of a watercourse, or when surface or groundwaters are taken or interfered with in wetlands, development and planning approvals are required: www.nrw.qld.gov.au/water/management/info_brochures.html
Land Protection (Pest & Stock Route Management) Act 2001	Landowners are required to control feral animal populations (e.g. pigs) and declared weeds on their properties, including the bed of adjoining streams. This Act also regulates pesticide use: www.nrw.qld.gov.au/pests/legislation/legislation/lp_act.html
Nature Conservation Act 1992	Applies to any works in protected areas or where there are threatened species. This Act can also provide protection to wetlands (Apply to have the wetland protected.) www.epa.qld.gov.au/about_the_epa/legislation/nature_conservation/
Environmental Protection Act 1994	This Act regulates 'environmentally relevant activities'. www.epa.qld.gov.au/about_the_epa/legislation/environmental_protection/

Legislative requirements

Local government policies and laws

Local governments have primary responsibility for land use and planning in Queensland. Through discretionary power provided under the Local Government Act 1993, local governments can pass local laws for environmental management.

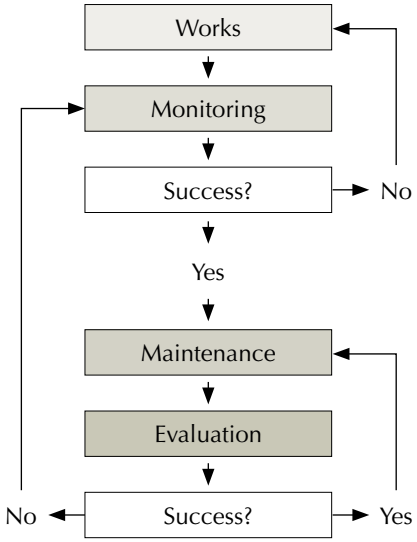
Local governments control strategic land use planning and development approval. Direct regulation through instruments such as local laws, restrictions and conditions on use and land use zoning, and by placing conditions on development approval, can be council-specific.

Check with your local council before undertaking wetland works.

Maintenance, monitoring and evaluation

Maintenance, monitoring and evaluation are important to ensure that rehabilitation works continue to improve the wetland, and to consolidate the lessons learnt from techniques used.

The flow chart below shows the steps in the process.



Monitoring

Regular monitoring of a wetland rehabilitation site will show whether the rehabilitation techniques have been successful, what changes need to be made to the way the site is managed, and whether improvements could be carried out in the future. Monitoring is also invaluable for deciding whether the site requires any maintenance. General monitoring is simply an observation of the site and its condition.

Over time, monitoring is necessary to gauge improvements or otherwise. Determining which indicators are best for monitoring the progress of the site may depend on the original management goal of the rehabilitation.

Conduct monitoring every 6–12 months, making a note of the date, time and season when the monitoring was completed, and recording the names of the monitoring team. It is also worth conducting extra monitoring after a major flood event or other natural disturbance.

Monitoring may include one or all of the following:

- photo-point monitoring
- sample plot monitoring
- bird, fish or other fauna survey
- water quality monitoring.

Photo-point monitoring

This technique involves taking a series of photos from a nominated point over time. Refer to previously taken photos for landmarks in the photo to get the new photo as accurately positioned as possible. It may be necessary to place a marker post where the photo is to be taken, if there are no other significant landmarks. Recording GPS coordinates for the photo point will help to relocate it in the future.

It is a good idea to take the photos in the same season and the same number of hours after sunrise to give true change representation. It is useful to record the species evident in the photo, and any other observations from the time of monitoring.

Sample plot monitoring

This technique involves detailed monitoring of one or several small plots and exclusion cages. Each plot should be clearly marked out. All observations, such as vegetation composition, ground cover percentage, degradation and other features should be recorded for each plot.

Bird, fish or other fauna surveys

Bird, fish and other fauna surveys are a good way of monitoring the progress of wetland rehabilitation, and to keep community volunteers interested in monitoring the site. Bird surveys can be undertaken by observation. Fish surveys can be completed by hand fishing, net fishing (obtain a permit) or electro-fishing (obtain a permit). Surveys of other fauna may also require observation (possibly at night) and/or trapping.

Note: All fishing for scientific use in Queensland requires a permit from the Department of Primary Industries and Fisheries. It will also require animal ethics approval under the *Animal Care and Protection Act 2001*.

Ensure that the time of day, season and weather conditions are all recorded. These could be important in interpreting the results of the surveys.

Maintenance, monitoring and evaluation

Water quality monitoring

Locations for monitoring water quality should be at the site, upstream of the site and downstream of the site. A minimum of two full monitoring events should occur each year, one in the wet season and one in the dry season. A full monitoring event should include laboratory analysis of water samples, where possible, as well as basic readings of pH, conductivity, temperature and dissolved oxygen. Monthly readings should be taken at the site if possible. Basic water quality equipment is not expensive and can be used to carry out many of the simple readings needed to monitor water quality.

For more information please refer to Wetland*Info*. Go to: www.epa.qld.gov.au/wetlandinfo/site/SupportTools.html

Site maintenance

Site maintenance needs to be as well planned as the rehabilitation techniques, to ensure that the work is not destroyed by fire, flood, invading weeds and other threats. Regular observation of the site will allow maintenance to be carried out in a timely manner. Site maintenance may include:

- weed control
- watering
- maintaining firebreaks
- erosion control
- continuing mulching and fertilising
- replacing seedlings that die
- preventing traffic in the area, such as stock or vehicles.

Evaluation

Management goals set at the beginning of the project can be used to evaluate the project's success. Indicators of successful rehabilitation may include:

- self-sustaining ecosystems
- provision of habitat for target species
- stabilised soils
- weeds out-competed by native species
- native species naturally regenerating
- improved water quality
- the presence of sensitive flora or fauna.

Advisory contacts

Department of Primary Industries & Fisheries Queensland

Telephone: 13 25 23 or 07 3404 6999
Email: callweb@dpi.qld.gov.au
DPI&F office contacts: www.dpi.qld.gov.au

Environmental Protection Agency Queensland

EPA Hotline: 1300 130 372

Environmental Operations:
Brisbane Regional Office
Telephone: 07 3224 5641

Rockhampton Regional Office
Telephone: 07 4936 0511

Cairns Regional Office
Telephone: 07 4046 6602

Queensland Parks and Wildlife Service

Brisbane Regional Office
Telephone: 07 3202 0236

Rockhampton Regional Office
Telephone: 07 4936 0511

Cairns Regional Office
Telephone: 07 4722 5211

Contacts webpage www.epa.qld.gov.au

Department of Natural Resources & Water

Telephone: 13 13 04
Email: enquiries@nrw.qld.gov.au

Local service centre contact details available from:
www.nrw.qld.gov.au

Natural Resource Management (NRM) Regional Bodies

Queensland Regional Natural Resource Management Groups Collective (provides links to all Queensland NRM groups)
www.regionalgroupscollective.com.au

Link to NRM groups in the Great Barrier Reef catchment:

Terrain	www.terrain.org.au
Burdekin	www.bdtnrm.org.au
Fitzroy	www.fba.org.au
Reef Catchments	www.mwnrm.org.au
Burnett Mary	www.bmrg.org.au

Local councils

Summary of local council contact details:

www.localgovernment.qld.gov.au/applications/lgDirectory/Summary

or www.localgovernment.qld.gov.au/applications/lgDirectory for searchable directory

Regional Weedspotter coordinators

Townsville

QHerb Cape Pallerenda
Telephone: 07 4722 5265 (Tue) or
07 4781 5738 (Mon, Wed-Fri)

Rockhampton

QPWS Rockhampton
Telephone: 07 4931 5439 (Mon–Thur)
or 07 4936 0528 (Fri)

Gladstone

Tondoon Botanical Gardens
Telephone: 07 4971 4444

Mackay Whitsunday

QPWS Mackay
Telephone: 07 4953 8740

Desert Channels

Desert Channels Qld
Telephone: 07 4652 7823

Wet Tropics

Weed Watch Conservation Volunteers Australia
North Queensland
Telephone: 07 4032 0844

Other useful contacts

Australian Centre for Tropical Freshwater Research
www.actfr.jcu.edu.au

Department of the Environment, Water, Heritage and the Arts www.environment.gov.au/water/environmental/wetlands

Bureau of Sugar Experiment Stations www.bses.org.au

CANEGROWERS www.canegrowers.com.au

CSIRO www.csiro.au/csiro

Conservation Volunteers Australia
www.conservationvolunteers.com.au

WetlandCare Australia http://wetlandcare.com.au

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Templates

Template 1

Wetland threat score card — example			
Wetland name			
Wetland catchment location (circle):	Upper	Mid	Lower
Rainfall region (circle):	Wet	Dry	Sub
Wetland type (from list above):			
Threat	Intensity Rating (★s)		
Lack of habitats			
Weeds			
Feral animals			
Lack of vegetation			
Soil erosion and acidity			
Changed hydrology			
Poor water quality			
Grazing damage			
Fire damage			

Template 2

Wetland rehabilitation planning – example							
Management goals: Reduce floating aquatic weeds by 80% in one year. Reduce riparian weeds by 50% and replace with native vegetation.							
Threat	**Intensity Rating (★s)** (high to low)	**Rehabilitation techniques** (chosen from Guidelines Sections)	**Timing**	**Permits** (Y/N)	**Capacity** (H/M/L)	**Tech Assist** (Y/N)	**Cost** (~$)
Lack of habitats							
Weeds							
Lack of vegetation							
Poor water quality							
Feral animals							
Soil erosion & acid sulfate soils							
Changed hydrology							
Grazing damage							
Fire damage							

Long-term maintenance plan HOW? Refer to the Maintenance, Monitoring and Evaluation section of these guidelines Refer to the rehabilitation actions being completed Consider how they need to be maintained; e.g. watering, weed monitoring, replacement plants Consider the timeframe maintenance will be required Consider how often monitoring should be undertaken (enter this in the 'timing' box ➜) Also consider any permits, capacity, technical assistance and cost (over all years), also enter these	**Maintenance actions:**					
Monitoring and evaluation HOW? Refer to the Maintenance, Monitoring and Evaluation section of these guidelines Refer to the goal of your rehabilitation Choose the appropriate monitoring technique(s) for your goals. Enter them in the box to the right ➜ Consider when BEFORE and AFTER monitoring needs to occur (it may need to be on a regular basis for a number of years) Consider the needs for permits, capacity, technical assistance and cost to undertake monitoring Use the results of before and after monitoring to evaluate the success of the rehabilitation toward the goals NOTE: A measurable change may take some years to occur	**Monitoring techniques:**