Weeds of National Significance

Willows

Management Guide

Current management and control options for willows (*Salix* spp.) in Australia

State Government Victoria Department of Primary Industries

National Willows Taskforce

Australian Government

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November 2007

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Front top left: female *Salix cinerea* catkin (Matthew Baker, Tasmanian Herbarium)

Front top right: male *Salix fragilis* catkin (DPI Victoria)

Front bottom: *Salix* x *sepulcralis* var. *chrysocoma* at Castlemaine Botanic Gardens (Sarah Holland Clift, DPI Victoria)

Back top: *Salix babylonica* growing along the Murray River, South Australia (Sarah Holland Clift, DPI Victoria)

Back bottom left: Excavator removing willows (DPI Victoria)

Back bottom right: Greencorp volunteers controlling willows (Jeffrey Cottrell, Willow Warriors Inc.)

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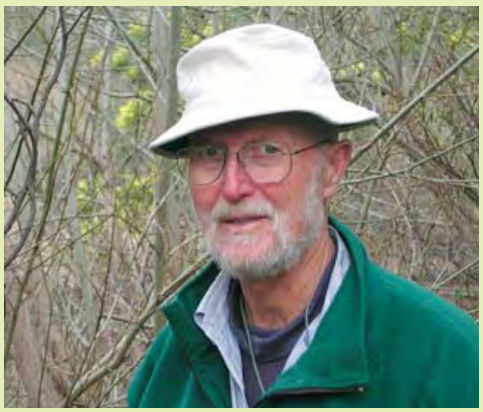
A dedication

This manual is dedicated to the late Kurt Cremer, who passed away in July 2005. Kurt was the original champion of the willow cause, pushing willows into the national spotlight and leading the way in willow research in Australia. Anyone who has ever been involved with willows will likely know Kurt's name and many knew him personally. His dedication to willow research and assisting people in the management of willows across Australia was impressive. Kurt has left a great legacy, and will be greatly missed.



We need your feedback!

We want to know what you think of this manual. What parts do you find most useful? What parts are least useful? What might be added? How could the presentation be improved?

We also want to know your experiences in willow management, so we can develop a data bank of case studies on willow management in Australia.

By sharing, evaluating and recording the successes and failures of our willow management efforts we will gain the confidence needed to most effectively manage willows across Australia and restore and protect our waterways for the future.

To provide any feedback on this manual, please lodge it at www.weeds.org.au/WoNS/willows or contact the National Willows Coordinator (contact details at that website).

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Foreword

Through my involvement with the National Willows Taskforce, I have come to realise the complex issue of managing willows in their many different situations around Australia. The taskforce has taken the time to engage a large number of people, in their many different situations and locations, to produce this *National Willows Management Guide.*

Willows (*Salix* spp.) are among the most serious riparian and wetland weeds in temperate Australia. There are more than 30 different types of willows now growing and spreading naturally and these willows can spread in different ways and cause different levels of impacts depending on where they establish.

For many years, willows have often been a controversial weed to manage. The National Willows Taskforce recognises the need to develop a balanced approach to management that considers which willows need to be targeted, where and when in order to reduce their negative impacts and potential to spread into other important environments.

This *National Willows Management Guide* brings together detailed information about willows and their management to help you determine why, what, where, when and how willows should be managed. By reading this document, you will discover that there is no one best method, but rather a range of factors that need to be considered and weighed up for each particular situation.

The guide is a living document that will need to be reviewed and adapted over time, as we gain better understanding and knowledge of the systems we work in. The management and control methods outlined are primarily based on the experience of people currently managing willows in Australia. As new information becomes available, we will endeavour to place it on our web page, so that you have the most up-to-date information at your finger tips.

It has been a challenging task to develop this guide, given the diversity of views and situations in which willows are managed. We hope you find it useful and welcome any feedback you may have that will help improve future editions.

Finally, I would like to say a huge thank you to everyone who has contributed to developing the guide. The level of input has been incredible and is greatly appreciated!

Drew English

Chair, National Willows Taskforce

Using this manual

The information presented in this manual is based on published information, existing research and the experiences of individuals and organisations currently managing willows in Australia.

Our current understanding of willow management, however, is by no means the final word. As further research unfolds and the experiences of trial and error by land managers grow, strategies for willow management can be expected to evolve.

This manual contains 6 sections:

Section 1 Understanding willows

Key information on why you may want to manage willows and how to effectively respond to community concerns. This section outlines why willows were introduced into Australia, the problems they cause, how they spread and their perceived benefits.

Section 2 Managing willows

Guidelines for how to plan a willow management program, including where to prioritise your management efforts, what you plan to achieve and why, who to involve, when and how to conduct works and how to review your program.

Section 3 Controlling and removing willows

Detailed descriptions of available control and waste management methods, including when to use them and their benefits and disadvantages.

Section 4 Site rehabilitation

Important information on how to ensure that long-term improvements to the site are achieved and that it does not revert back to a willow-infested or other degraded condition. This includes follow-up monitoring and control of willows and other weeds, managing for erosion and other structural changes, fencing and stock access, re-establishing suitable vegetation and monitoring, evaluation and reporting of program outcomes.

Section 5 Case studies

Case studies of different approaches taken by land managers and community groups, including different control methods and strategies for managing willows in different situations and with different management goals.

Section 6 Further information

Weed contacts across Australia, references and further reading.

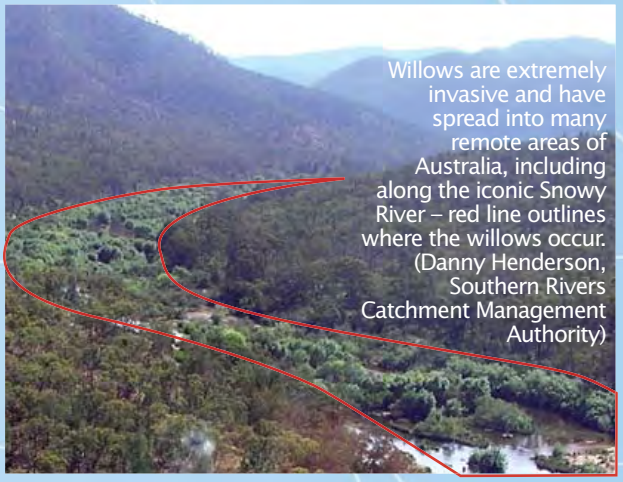
Note on referencing:

Key references or additional resources that complement this guide are listed under 'additional resources' at the end of the relevant section. All references are then also presented in alphabetical order in Section 6 of the guide.

Contents

Section 1

Understanding willows



Willows are extremely invasive and have spread into many remote areas of Australia, including along the iconic Snowy River – red line outlines where the willows occur. (Danny Henderson, Southern Rivers Catchment Management Authority)

form

Understanding willows

Why do you want to manage willows? How will you convince your community to support your willow management program?

Willows (*Salix* spp.) are a highly complex plant group. To effectively manage them, it is important to first get to know their characteristics as a plant group, understand why they were introduced into Australia and how they spread, as well as their perceived benefits, their impacts and their future threat. This will help to clarify exactly:

- why a willow management program is needed
- how landholders and the broader community may be convinced that a willow management program is needed, and
- how to prevent the further spread of willows and their impact.

Introducing willows

Willows: A complex group

Willows are an extremely diverse and complex plant group, consisting of more than 300 willow taxa worldwide. Of these, approximately 100 have been introduced into Australia and over 30 taxa are now growing and spreading naturally in the environment (naturalised).

Most willow plants are either male or female, with a few rare exceptions where both male and female flowers occur on the one plant. Plant features (such as form, bark, stems, leaves, flowers and roots) can vary dramatically among willow taxa. For example, willows can be either trees or shrubs, weeping or upright and single or multi-stemmed. They can have rough or smooth bark, long or short leaves, fragile or strong branches, be early or late flowering, and the list goes on.

All willows belong to the genus *Salix*. Within this genus there are two major groups (or subgenera) that are naturalised in Australia:

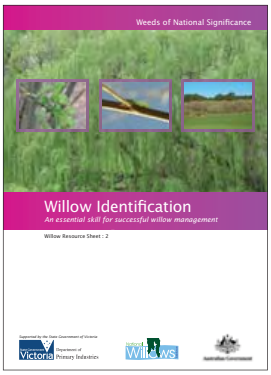
- 'tree' willows (subgenus *Salix*), and
- 'shrub' willows (subgenus *Vetrix*)

Within each of these two groups, there are many species, sub-species, varieties, hybrids and cultivars. Some of these have been selectively bred, while others have developed through natural hybridisation between different taxa established in Australia.

For simplicity, throughout this guide we will use the term willow 'taxa' to refer to the many species, sub-species, varieties, hybrids and cultivars.

To develop a more detailed understanding of the willow genus and to learn how to identify willows, refer to the *National Willows Program Resource Kit, Willow Resource Sheet 2: Willow Identification, an essential skill for effective willow management.*

This is included as an insert to this manual and is also available for download at www.weeds.org.au/WoNS/willows.



Friend: Willows are often well loved for their aesthetic value. (DPI Victoria)

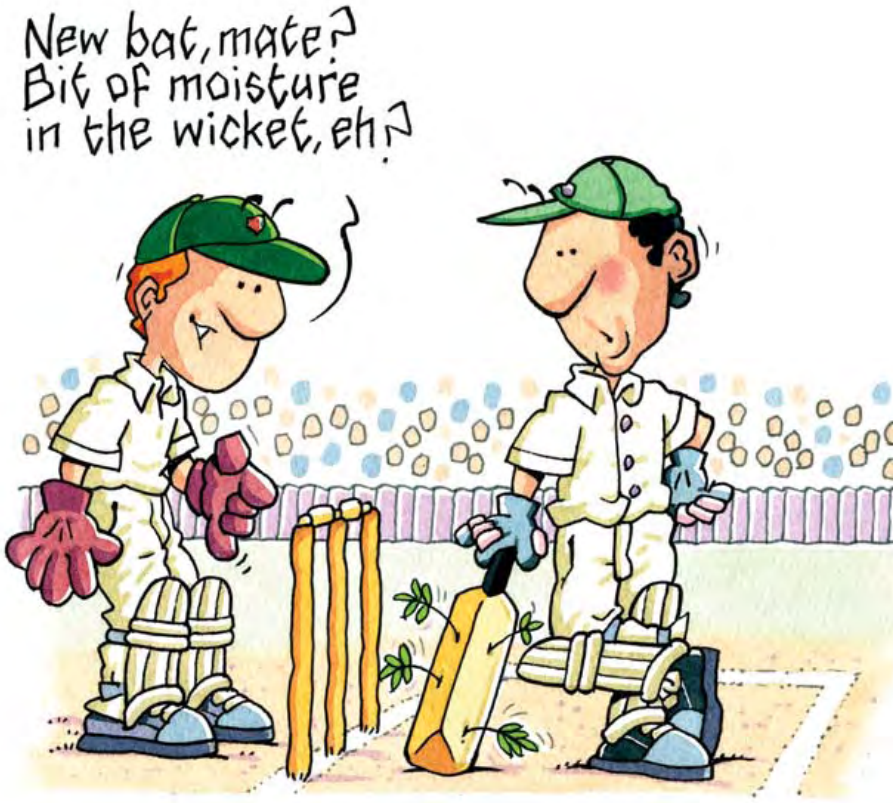
Foe: Willows now cause many problems along waterways and wetlands. (Melbourne Water)

The introduction of willows into Australia

Willows were originally introduced into Australia from Europe, Asia, North America and South America for a variety of purposes, such as stream stabilisation, shelter, basket making, cricket bat production, and their use as ornamental plants.

There are no native willows in Australia.

Planting of willows began soon after European settlement and was most extensive from the 1950s to 1970s as an erosion control measure to negate the effects of streamside vegetation loss and clearing in catchments. Unfortunately, willows proved to be extremely invasive and have had a negative impact on the hydrology and biodiversity of waterways.



From friend to foe

It is only over the past 20 years or so that the problems with willows have been broadly recognised, and now the same organisations that originally promoted their use often conduct extensive willow removal operations. Given this relatively dramatic shift in waterway management, it is not surprising that people still advocate the planting of willows or resist their removal.

After all, why should such a useful and beautiful tree so suddenly become a target for those wishing to rehabilitate the environment?

The effects of planting willows along waterways

The planting of willows was most extensive from the 1950s to 1970s as an erosion control measure to negate the effects of streamside vegetation loss and clearing in catchments. Although willows appear to provide temporary stability to the river bank, over time they cause increased erosion and flooding and can completely alter the course of the river. For example, along a narrow river, willows may gradually encroach into the centre of a waterway, creating a shallower, braided stream with mid-stream islands. The following diagrams depict the development of a mid-stream island along a narrow Australian river.

Original watercourse

Native vegetation prevents erosion by allowing fine sediment to accumulate on the river bank.

Native vegetation has fine, shallow roots that won't encroach into the watercourse.

Cleared watercourse

Little or no vegetation to prevent erosion.

Bank erodes rapidly.

Willows planted

Easy to propagate.

Rapid establishment.

Value of willows only temporary

Bank temporarily stabilised

Mat-forming roots trap coarse sediment.

Willows encroach towards centre of watercourse.

Waterflow impeded as channel capacity is reduced.

Problems begin

Floodwaters

Water diverted around willows.

Erosion occurs behind willows.

Watercourse structure changed

Mid-stream island formed.

Multiple islands result in 'braided' stream.

Watercourse becomes shallower and wider.

Erosion occurs on new bank.

Risk of flooding increased.

Narrow rivers (Melbourne Water)

Wide rivers (DPI Victoria)

The problem with willows: Why manage willows?

Impacts of willows

Willows are now regarded as one of Australia's most serious riparian and wetland weeds and, in 1999, were listed as one of Australia's 20 Weeds of National Significance (WoNS) [1]. They currently infest thousands of kilometres of waterways across south-east Australia and cause substantial social, economic and environmental impacts, including:

Increased erosion and flooding

Although willows were originally planted along waterways to combat bank instability, such stability tends to be only temporary. Willows can grow in continually wet sediment and hence encroach towards the centre of waterways. Fallen debris and the dense mats of willow roots then trap silt, build up the level of the stream bed and divert water flow into the banks, thereby increasing erosion and flooding.

Narrow rivers: As willows grow into the stream channel, narrow streams tend to become wider and shallower, leading to increased flooding until the channels have expanded. Long overhanging branches or numerous trunks growing in the water encourage the collection of silt and debris, which can lead to complete blockages of the stream. Eventually, waterways may change course to flow around willows, creating 'braided' streams with mid-stream islands.

Wide rivers: Along wide, deep rivers, willows cannot easily encroach into the centre of the river, except by colonising on already existing mid-stream islands. Instead, willows quickly colonise the banks and trap course sediment, which causes a narrowing affect along the river and increases the chance that erosion and flooding will occur.

Reduced quality and flow of water

In contrast to native evergreens, willows are deciduous [2]. Dense shade in spring and summer and heavy leaf fall in autumn and winter suppress indigenous vegetation and river fauna. The massive leaf drop, rapid break down of these leaves and extreme variation in leaf cover across the year can alter the temperature and oxygen content of the water. As a result, water quality is significantly reduced and sensitive aquatic life can be killed.

Reduced availability of water

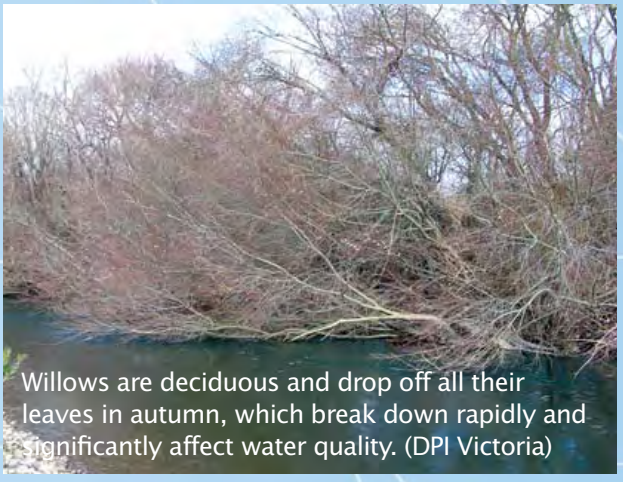
Willows are water guzzlers. When they extend their roots into the waterway, they can consume significant amounts of water and dry out small streams and swamps. In a recent study near Jerilderie, New South Wales, it was estimated that if willows situated in the stream bed with permanent access to water were removed and replaced with native eucalypts on the river bank, there would be potential water savings of 3-4 megalitres per hectare per year. This is equivalent to approximately 1-1.5 olympic-sized swimming pools full of water!

"This country was originally bare with the creek actually running consistently. Thanks to the willows, it's called Mandurama Ponds now. Where the willows are, we have no water left. Where the willows have been cleared, the creek has started to run again."

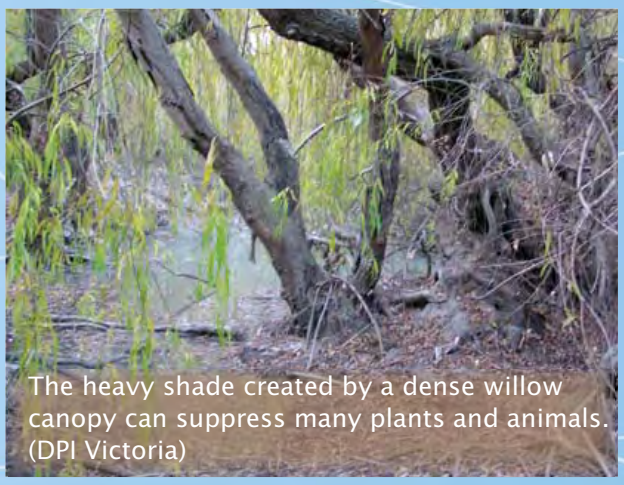
Local landholder, Central New South Wales

1 Except *S. babylonica, S. x calodendron* and *S. x reichardtii.*

2 The Chilean pencil willow (*S. chilensis* – also known as *S. humboldtiana*) is an exception, as it is only semi-deciduous, retaining some of its leaves all year round.



Willows are deciduous and drop off all their leaves in autumn, which break down rapidly and significantly affect water quality. (DPI Victoria)



The heavy shade created by a dense willow canopy can suppress many plants and animals. (DPI Victoria)

Less habitat available for fish, birds, frogs, insects, mammals and reptiles

Willows can spread prolifically, either by fragments or by seed. As such, they are highly invasive and can dominate rivers, streams and wetlands while spreading to other intact areas. This leads to a marked reduction in the natural diversity of flora and fauna and the habitat or conservation values of an area. Willows are poor habitat for hollow-dependent mammals and birds, and snag-dependent fish. Many native fish rely on in-stream snags for habitat. Bare banks beneath willows provide little to no protection for frogs, water rats, snakes and lizards. The mat-forming roots of willows can smother and fill all available rock crevices, thereby destroying critical habitats for endangered aquatic animals, such as frogs. Fewer insects in the canopy mean fewer insectivorous birds and fewer insects to drop into the water to provide food for fish and other animals. The composition of invertebrates in the leaf litter is altered, as willow leaves are softer and thinner and break down more quickly than native leaves.

Obstructing access to streams for fishing and aquatic activities

Willows form dense root mats and stems that encroach into the river and can block access for speedboats, canoes and rafts. Along narrow streams, willows can mat completely across the stream, blocking access along the stream. Along wider rivers, willows can completely dominate the river bank, blocking entry to the river.

Damage to nearby infrastructure

Willow wood is lighter than native Australian woods. Whereas native woods tend to sink where they fall, willow wood floats and can easily drift and take root downstream or accumulate and cause damage to downstream infrastructure.

The widespread planting of willows has come back to bite us – we need to manage willows to protect the social, economic and environmental values of Australian waterways, swamps, wetlands and national parks.

Willows can mat completely across narrow streams, blocking access for aquatic sports such as kayaking. (Terry McCormack, North East CMA)

Willows threaten one of our most important assets in Australia – our water.
(North East Catchment Management Authority)

The value of Australian waterways under threat

Waterways (rivers and streams) make up only a small portion of the Australian landscape, but their overall value to the economy, the environment and the social fabric of Australia is immense. Rivers are important to the Australian community because they:

Environment

- have a complex and unique environment and biodiversity
- support a rich array of plants and animals, many of which are threatened or endangered
- are essential watering, feeding and breeding grounds for many terrestrial animals
- are important in the movement and cycling of sediment, water and nutrients through the landscape and in water purification

Economic

- provide clean, safe drinking water
- provide water for irrigation and for industry
- are significant sites for recreation (for example, fishing and boating)
- are focal points for regional tourism

Social

- have strong cultural and historical associations, particularly for Indigenous Australians
- provide community meeting and recreational places and
- are an attraction for people from outside the region.

Unfortunately, willows degrade the environmental condition of a river. This affects how we are able to use rivers in the future. As the condition of our rivers deteriorates, there will be costs. Some costs will be economic but others cannot be measured in economic terms.

Many scientific studies have been conducted to investigate the effects of willows on streams and wetlands. A list of key references can be found at the end of the manual.

How willows impact on Australian waterways: Willows compared to native vegetation

Native Vegetation

Evergreen trees that provide light shade and gradual leaf drop year-round have the following advantages:

- Australian ecosystems are adapted to this pattern.
- Light shade under the canopy year-round allows a diverse range of plants to grow underneath (for example, grass, shrub and tree layers), providing an ideal habitat for native animals.
- Continuous year-round leaf fall that peaks in summer, as well as leaves that break down slowly, provide a gradual input of nutrients into the waterway throughout the year.
- Native invertebrates are adapted to feeding on the hardened and thickened leaves of native plants.

Native Vegetation

Non mat-forming roots and less tendency to grow into the centre of waterways means that:

- Fine sediments and clays adhere to and stabilise the bank.
- Eucalypts consume less water than willows as their roots do not extend into the waterway and their leaves are resistant to moisture loss.

Native Vegetation

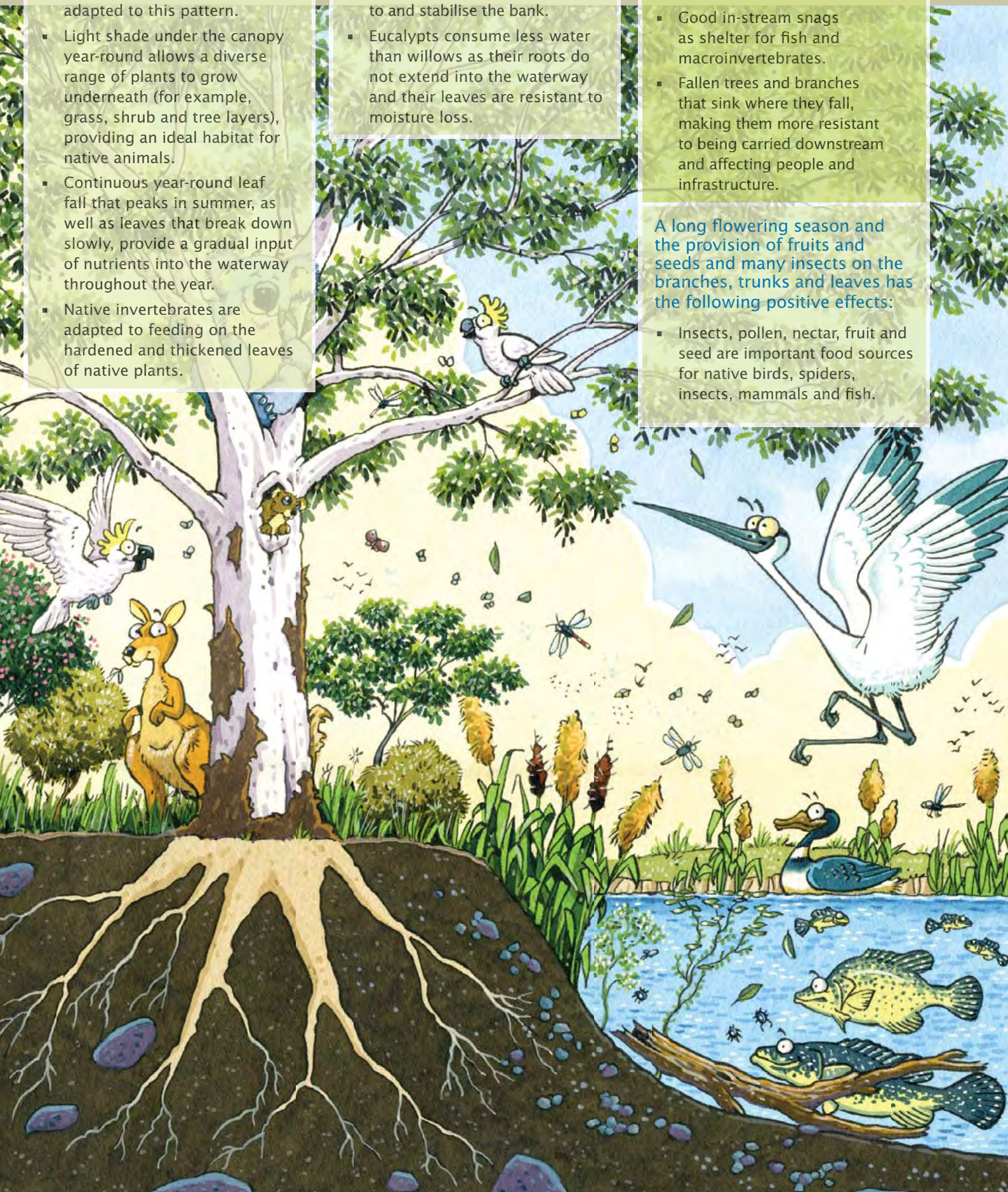
Many hollows for nesting mammals and birds

Heavy wood that breaks down very slowly results in:

- Good in-stream snags as shelter for fish and macroinvertebrates.
- Fallen trees and branches that sink where they fall, making them more resistant to being carried downstream and affecting people and infrastructure.

A long flowering season and the provision of fruits and seeds and many insects on the branches, trunks and leaves has the following positive effects:

- Insects, pollen, nectar, fruit and seed are important food sources for native birds, spiders, insects, mammals and fish.



Willows

Deciduous trees that provide heavy shade in summer and drop all of their leaves in autumn have the following disadvantages:

- Australian ecosystems are not adapted to this pattern.
- Heavy shade under the canopy in spring/summer, prevents understorey plants from growing, thus providing little habitat for native animals.
- Light to no shade in autumn/winter.
- Most leaves fall within a short time period in autumn and break down quickly, resulting in an influx of nutrients into the stream and a sudden change to the temperature and oxygen content of the water.
- Native invertebrates are not adapted to feeding on the thin, soft leaves of willows.

Willows

Mat-forming roots and a tendency to grow into the centre of waterways means that willows:

- Trap more coarse sediment along the river bank, leading to bank instability, reduced channel capacity and diversion of flows.
- May smother and fill all available rock crevices that provide important habitats for animals such as frogs.
- Consume more water than native eucalypts when their roots extend into the waterway – most of this water is used in summer, when water is most scarce for farmers and animals.

Willows

Very few hollows for nesting mammals and birds

Light wood that breaks down rapidly results in:

- Fewer snags to shelter fish and macroinvertebrates.
- Floating branches and trees that can be carried more easily downstream, posing an increased risk to people and infrastructure.

Short flowering season, no fruit or large seed production and very few insects means that:

- Very little food is available to birds, spiders insects, mammals or fish.
- Willow flowers are only known to provide nectar for introduced honey bees.

How willows spread

How can we prevent the future spread and impact of willows? Where should we prioritise our management efforts?

Different willows vary in their ability to spread into and thrive in new environments. It is important to understand how different willows spread and to adapt management programs accordingly.

The main methods of spread are by:

- seed germinating on bare, wet sediments
- twigs and branches, attached or detached, rooting mainly on wet ground or in shallow water

Some willow taxa disperse by one of these methods, while others spread by both means.

Their ease of spread and ability to establish and grow rapidly has allowed willows to infest thousands of kilometres of waterways across temperate Australia.

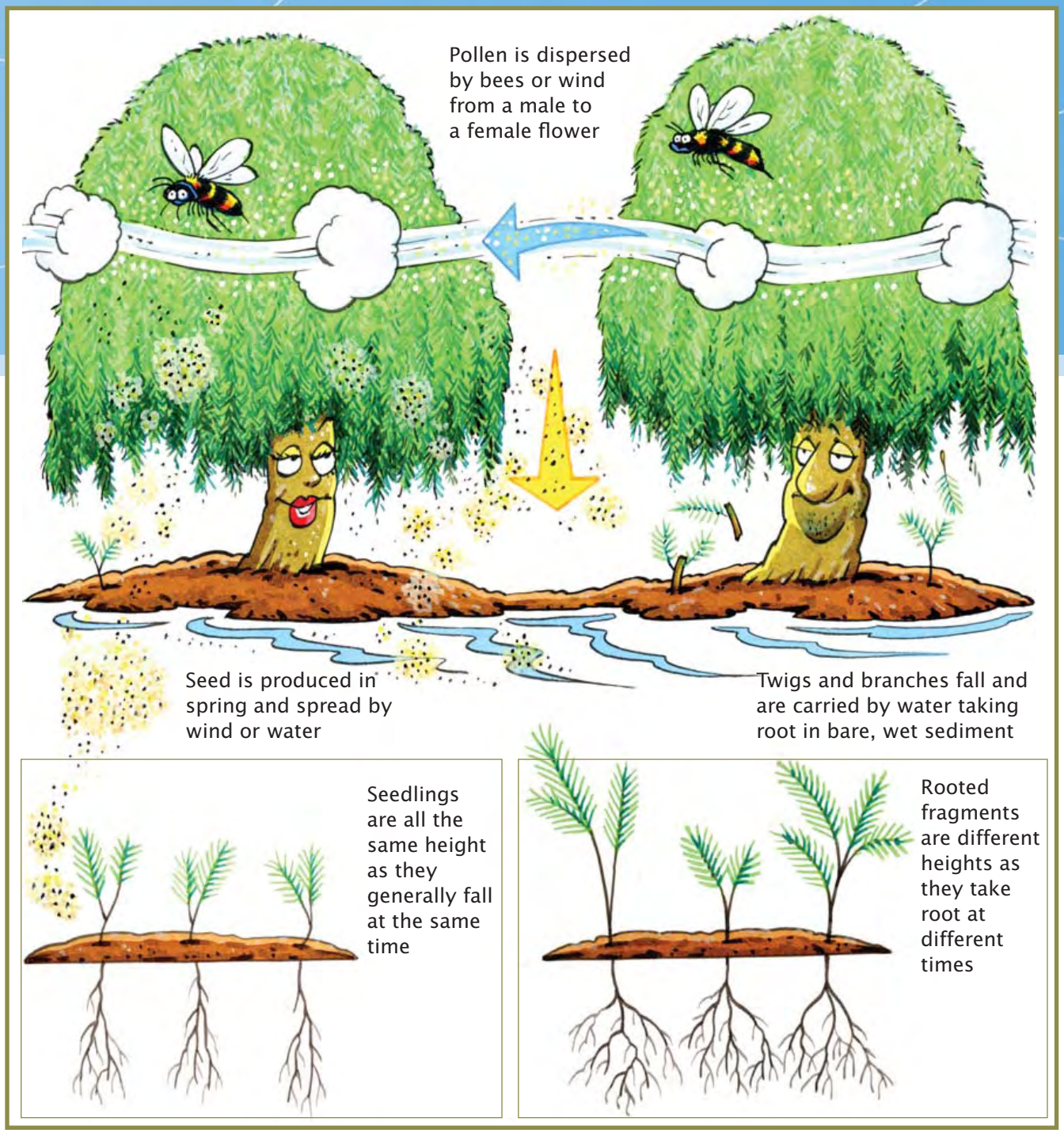
Reproductive methods: Sexual (seed) vs vegetative (twigs/branches) dispersal methods

	Sexual (Seed)	Vegetative (Twigs/branches)
Identifying features	Young seedlings will have a single prominent taproot that descends vertically unless obstructed. As thousands of seed are shed over just one month in spring and seed is short-lived, seedlings are typically found as 'galleries' or masses of seedlings of similar age (with similar heights and trunk diameters) growing in close proximity on suitable seedbeds. See the diagram, 'The willow lifecycle: How willows reproduce and spread', on page 13.	Young, rooted fragments will have a number of roots extending from where the branch fragment has broken from the parent plant. As rooted fragments can break off and establish at any time of year, plants of different ages (with different heights and trunk diameters) will typically be seen in an area. See the diagram, 'The willow lifecycle: How willows reproduce and spread', on page 13.
Dispersal mechanisms	Pollen from a male flower must be deposited on the stigma of a female flower for the seed to set and germinate. **Pollen:** It is uncertain exactly how far willow pollen can travel (by insects or wind) and successfully pollinate a female plant. Bees may range up to 3 or 5 km to collect pollen and nectar. It is thought that cross-pollination is generally restricted to much smaller distances (for example, 50 m), but female plants growing 1 km from the nearest male have been observed producing viable seeds. **Seeds:** Thousands of seeds are released each spring, but these are relatively short lived (only 1-2 weeks). Given the right conditions, germination can occur extremely rapidly (within just 6-8 hours). Seed is quite small (usually <1 mm long) and has distinctive tufts of silvery hairs to facilitate wind and water dispersal. Some willows are known to spread seed up to 50-100 km from their parent plant.	Plants may spread by fragmentation, layering or human-assisted propagation. **Fragmentation:** Branches or twigs can break off and spread progressively over long distances along waterways. The most important feature enabling dispersal is how easily the branches can break off. **Layering:** Trunks can collapse or branches weep down and root where they touch the soil. This usually only occurs within a few metres of the parent plant and is responsible for the expansion of existing colonies. **Human-assisted:** Deliberate or accidental planting (for example, when machinery churns live willow material into wet ground or when fishermen put branches in the ground as fishing rod holders).
Patterns of dispersal – areas at most risk of invasion	Some willows can spread long distances by wind blown or drifting seed and may spread rapidly across regions and states, so even the most remote environments are at risk of invasion. Some seeding willows (such as grey sallow *S. cinerea*) can pose a major threat to off-stream wetlands and are limited only by the opportunities for successful germination and subsequent establishment. Floods may uproot seedlings and distribute them along the river bank.	Twigs and branches can spread rapidly over relatively long distances, but will generally only spread downstream of the parent plant. Where this occurs, cleared areas downstream are at most risk of invasion. Dense infestations along narrow streams can often trap fragments, thereby hindering further spread downstream. Gradual upstream dispersal may occur by layering. Movement and planting of material by humans can facilitate more widespread dispersal.

Sexual versus vegetative dispersal methods (continued)

	Sexual (Seed)	Vegetative (Twigs/branches)
Conditions needed for establishment	Areas where compatible female and male plants flower at the same time and where bare, wet ground exists for 1-2 months following seed shed (around October / November). Although willows grow rapidly, once established, willow root growth is initially very slow. Major disturbances, such as wildfire or the collapse of a swamp during flood, can promote massive seed germination. Mass recruitment events typically occur on exposed wet sand, gravel or mud. Suitable conditions are likely to occur in most temperate Australian streams every 5 to 20 years.	Shallow water or wet ground. Establishment can occur at any time of year. Disturbances, such as strong winds, floods or willow management activities, or deliberate or accidental planting of stems by humans. Trunks collapsing while retaining their root system or branches weeping and rooting where they touch the soil.
Conditions that limit establishment	Dry conditions. Rising or rapidly falling water levels and floods that uproot or bury the new plants or wash the seed off sand banks	
Willow taxa most likely to spread by this method	Both shrub and tree willows spread easily by seed, so long as compatible female and male plants are located near enough for pollination to occur and seed to be produced. Grey sallow (*S. cinerea*) and black willow (*S. nigra*) appear to be the worst offenders, potentially spreading seed up to 50-100 km from their parent plant. Over the past 25 years, spread by seed has become increasingly common, as new species and both male and female plants have been introduced to Australia and their presence has become more widespread.	Most tree willows spread easily by fragmentation. Shrub willows are less likely, as their branches are more difficult to break off. Crack willow (*S. fragilis*) is the biggest culprit, as it has extremely 'fragile' or brittle branches that break easily at the base. Weeping willow (*S. babylonica*) and golden weeping willow (*S.* x *sepulcralis* var. *chrysocoma*) layer easily, as their branches collapse and root on the moist ground below.
Why dispersal method is important for management	Early identification and control of seeding willows is critical and should be a high priority for management. It is recommended that male plants be separated from female plants by at least 2 km and preferably more if possible. If female and male willows from the same subgenus ('tree' or 'shrub') are found within a few kilometres of each other, all female plants should be removed immediately if possible. In some cases, such willows will need to be immediately controlled in areas where they do not currently cause significant impacts, to prevent them from spreading to other, more important environments.	Identify and manage willows with 'fragile' branches that are growing along waterways. Revegetate cleared sites located downstream of willows. Manage small patches of willows first, as dense clumps may trap fragments and actually slow willow spread. When controlling willows, ensure that all branches and other live material are disposed of and the site is revegetated or regenerates quickly, as removing willows may otherwise expose bare, wet ground that is ideal for seed or fragments to colonise. Shrub willows tend not to spread easily by vegetative means, as their branches are quite flexible at the base and so do not readily break.

The willow lifecycle: how willows reproduce and spread



Hybridisation

Willows have a remarkable ability to form hybrids. Hybrids may be formed when the male of one taxon pollinates a female of another (also known as cross-breeding). Almost all willow taxa are capable of hybridising with one or more other taxa, if:

- they are within the same subgenus[3] (trees or shrubs)
- they flower at the same time
- fertile male and female plants grow near enough for pollination to occur, and
- there are suitable conditions for germination.

While some resulting hybrids may not flourish, some have proved to be more invasive than their parents and there is potential for strains to develop that are even better adapted to local conditions within Australia.

Even the iconic weeping willow (*Salix babylonica*), one of three taxa excluded from the WoNS listing, have been recorded in New South Wales and Victoria hybridising with other willow taxa (for example, *S. matsudana* x *alba* and *S. fragilis*), with some of the resulting hybrids apparently more invasive than *S. babylonica.*

3 One known exception is *S. x mollissima* – a cross between *S. viminalis* (subgenus *Vetrix*) and *S. triandra* (subgenus *Salix*). *S. triandra* is not yet naturalised in Australia, but has been introduced and may occur in gardens.

The iconic weeping willow (*Salix babylonica*) can cause significant impacts to rivers and wetlands. (Left: DPI Victoria, Right: Jim Parrett)

Myth busting: To seed or not to seed?

There is a general belief that willows are either seeding or non-seeding and that there are many sterile willows. For example, many people in Australia believe that the New Zealand hybrids (*S. alba* x *matsudana*) are sterile and so do not require management. This is not true. They can, in fact, reproduce by both seed and twigs or branches, as both males and females are present in Australia and one clone has both male and female flowers on the same plant (bisexual).

There is no recorded evidence of any willows being sterile in Australia.

In other countries, sterility is thought to occur in *S. purpurea* 'Booth', a form of purple osier originating from New Zealand, and *S. x calodendron*, a female tri-hybrid (*S. caprea* x *S. cinerea* x *S. viminalis*).

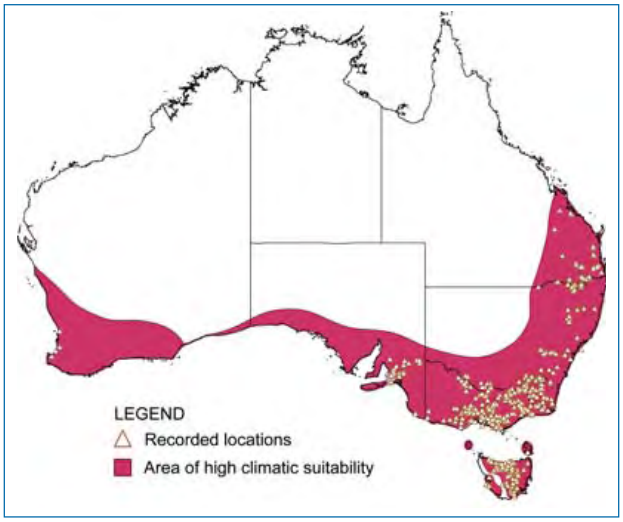
Many willows appear to be sterile in Australia, as only one sex of that species has been introduced. For example, crack willow (*S. fragilis*) only exists as male plants, so no pure *S. fragilis* seedlings are produced in Australia. However, hybrid forms commonly occur in the environment. For example, male crack willow can contribute pollen to female golden willow (*S. alba* var. *vitellina*), which can then produce viable seed.

If a willow is not producing seed it is usually because:

- It is a male and does not have female flowers – but it can still contribute to seed production by pollinating nearby females of the same or another taxon OR
- It is a female but there are no compatible male willows within pollinating distance – but this can easily change.

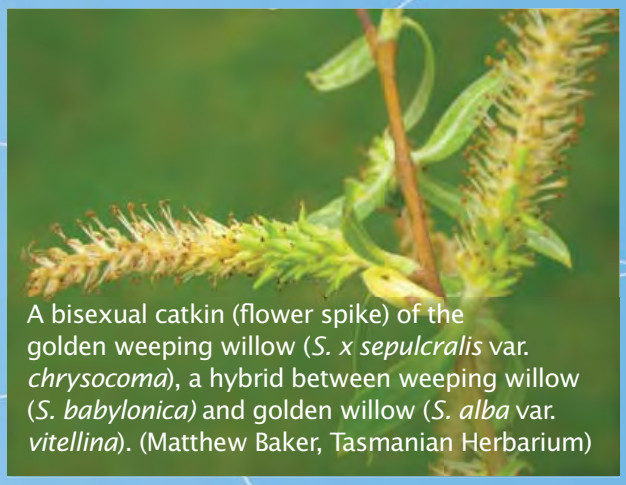
Reproduction of willows by seed is likely to increase as the number and type of compatible male and female willows that come into contact increases, through hybridisation and/or the continued planting or natural spread of willows.

The current and predicted distribution of willows in Australia

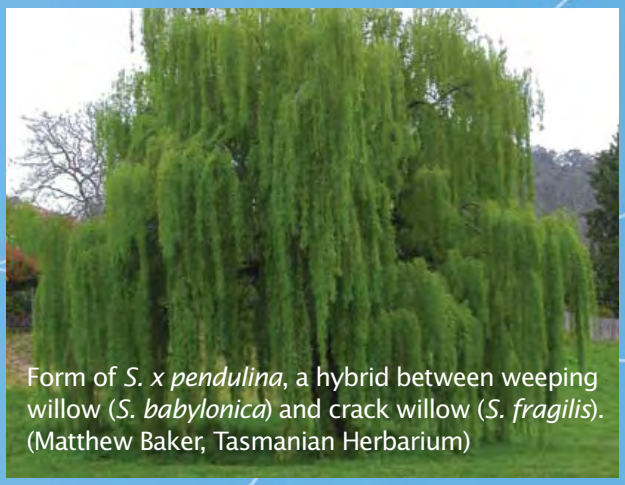


Willows have the potential to invade waterways, drainage lines, wetlands and other moist areas in all states and territories. The largest infestations currently occur in New South Wales, the Australian Capital Territory, Victoria and Tasmania, with smaller infestations in South Australia, Queensland and Western Australia.

Although willows already infest thousands of kilometres of waterways throughout south-eastern Australia, they may continue to spread far more widely, as only a small fraction of their potential habitat has been invaded.



A bisexual catkin (flower spike) of the golden weeping willow (*S. x sepulcralis* var. *chrysocoma*), a hybrid between weeping willow (*S. babylonica)* and golden willow (*S. alba* var. *vitellina*). (Matthew Baker, Tasmanian Herbarium)



Form of *S. x pendulina*, a hybrid between weeping willow (*S. babylonica*) and crack willow (*S. fragilis*). (Matthew Baker, Tasmanian Herbarium)

Identifying willows

What are the worst willow taxa?

Although we know that different willow taxa vary in their invasiveness, impacts and current and potential distribution, we do not yet know exactly which willow taxa are the worst. A detailed weed risk assessment of willows is currently being undertaken and is due for completion in March 2008, to help guide legislation and management of willows at a national level. When complete, this information will be made available at www.weeds.org.au/WoNS/willows.

Are some willows okay?

During willow control efforts, many organisations and groups choose to leave certain willows alive on the basis that they are causing less impacts or are more aesthetically pleasing than other willows in the area. In particular, the weeping willow (*S. babylonica*) is commonly left standing in areas where all other willows are being removed.

As more research becomes available, we are increasingly realising the serious impacts that *S. babylonica* can cause. For example:

- The roots and stems are capable of growing in stream, where they choke up channels, reduce stream flow, consume large amounts of water and increase the likelihood of bank erosion and large scale soil movement over time.
- The massive drop of leaf litter in autumn significantly affects water quality and the dense canopy cover in spring and summer shades out native riparian plants and alters the composition and abundance of insects and other animals in wetlands and streams.

Salix babylonica is extremely fast growing and is tolerant of flooding and waterlogged soils. It is capable of invading a wide range of environments, including wetlands, river banks, flood plains, grasslands, shrub lands, roadsides, rocky outcrops and damp valley bottoms. Although it is only known to exist as female plants in Australia, it can hybridise with other willow taxa (such as *S.* x *sepulcralis* and *S.* x *pendulina*) to produce viable seed. Some of the resulting hybrids are clearly more vigorous than their mothers and include males, females and bisexual plants.

So, are there any willows that I can leave alive?

In general, it depends on a range of factors, including your objectives, available resources and level of community support, as to which willows you control and which ones you leave alive. For example, if your main objective is to prevent the future spread of willows by seed, but you have insufficient resources or community support to remove all willows in the area, you may choose to control all male plants and leave the female plants alive or vice versa. Many people leave the more aesthetically pleasing *S. babylonica* alive in areas where the community is resistant to willow removal, as a compromise to enable the remaining willows to at least be controlled.

Willow management is complex. It is dependent on many different factors and some level of compromise is often needed. To help you prioritise willow management efforts in your area, refer to Section 2 Managing Willows.

Seeding willows: It may not happen overnight, but it will happen

Seeding willows are like a ticking time bomb. Their spread can initially be slow, but under the right conditions, a catastrophic explosion in numbers may occur.

One of the worst seeding willows is grey sallow (*Salix cinerea* – also known as 'wild pussy willow'). *Salix cinerea* has proven to be extremely adaptable, invading just about any boggy and intermittently moist site, anywhere from sea level to above the alpine tree line. Sites most likely to be invaded are areas where bare, wet ground exists for a month following seed shed (around October/November).

Such conditions may not occur on a large scale for many years but, when they do, the results can be devastating, as the following examples illustrate.

The collapse of Wingecarribee Swamp, NSW

A mass germination event occurred at Wingecarribee Swamp in southern New South Wales in August 1998. Heavy rains caused a major collapse of large sections of the peat beds. This resulted in canyons of exposed bare, wet peat, which in itself was a major environmental disaster.

To add insult to injury, mature *S. cinerea* plants were present in the area and the exposed peat beds were invaded by over 100 000 *S. cinerea* seedlings in 1998 and a further million seedlings in 1999.

In just two years, the population exploded from a few hundred mature willows along some sections of the swamp's margin into more than one million plants throughout the swamp.

Wingecarribee Swamp is a unique ecosystem that contains the largest montane peatland in southern New South Wales. It is also part of an important catchment that supplies water to Sydney. This invasion threatens the unique ecology of Wingecarribee swamp and the quality of Sydney's drinking water.

S. cinerea numbers exploded at Wingecarribee Swamp when peat beds were exposed. (DPI Victoria)

Bushfires in Victoria's Alpine National Park

Another more recent example occurred in Victoria's Alpine National Park in early 2003, when major bushfires resulted in significant stands of native vegetation being burnt. The following spring, mature trees of *S. cinerea* (that were already present in the park in low numbers) produced vast quantities of fluffy, wind-dispersed seed. This seed readily germinated in the newly exposed, water-laden, nutrient-rich moss beds that cover much of the area. This threatens the unique ecology of the park and the quality of drinking water for many population centres in south east Victoria.

Grey sallow (*S. cinerea*) growing on the Baw Baw Plateau, part of Victoria's Alpine National Parks system. (Parks Victoria)

Avoiding the expense through early detection and response

Ongoing management of both Wingecarribee Swamp and the Alpine National Park is now required for years to come. This will be a huge cost that could have been avoided by controlling *S. cinerea* infestations while they were still small.

Additional areas in Australia are under threat and proactive management is required if we are to prevent *S. cinerea* and other seeding willows from establishing in new areas.

Seeding willows were recently discovered in Tasmania. Understanding the problems caused by seeding willows on the mainland, the discovery was met with a sense of urgency and the control of seeding willows became the top priority for willow management in the state. A state-wide program for the eradication of seeding willows was subsequently developed and is currently being implemented.

"Seeing Tasmania's first significant naturalised population of seeding willows is like going back in time and standing looking at Australia's first introduced blackberries. We have a chance to do something to protect Tasmania from even greater willow invasion."

Andrew Crane, Regional Weed Management Officer, Tasmania.


form


bark


stems

Willow identification

Basic willow identification skills are essential to prevent further willow spread across many more thousands of kilometres of Australia's waterways.

A basic level of identification is essential when planning willow management and is relatively simple to learn. Precise identification is more difficult, but will allow you to better prioritise management.

To identify if willows are likely to spread by seed, you need to be able to determine:

- Is it a tree or shrub willow?
- Is it male or female or both?
- Does it produce viable seed?

To identify if willows are likely to spread by twigs or branches, it is as simple as doing the 'crack test' to determine

- How brittle are the branches?

To learn how to identify willows, refer to the *National Willows Program Resource Kit, Willow Resource Sheet 2: Willow Identification, an essential skill for effective willow management.* This is included as an insert to this manual and is also available for download at www.weeds.org.au/WoNS/willows.

Understanding your community

What does your community consider to be the benefits of willows and how will you persuade them that management is needed?

Some willow managers believe that all willows are bad and should be removed as soon as possible. Often, however, the community sees willows in a different light. To effectively engage the community, it is important to understand the perceived and real benefits of willows and what your community most values about their environment.

Plant features such as (above) form, bark, stems, (below) flowers and roots can vary dramatically among willow taxa and are key features for accurate identification of willows.


female catkin with many flowers


male catkin with many flowers


roots

Responding to community concerns about willow removal

Some of the reasons why people do not want willows removed	Suggested ways you might respond to these concerns
Lack of understanding of the problem	Willows have become an icon of the Australian environment and many people do not realise that willows are not native, least of all that they are extremely invasive and cause significant impacts. Understand the social, economic and environmental problems that willows cause and how they spread and learn how to effectively communicate these to others. By understanding the full range of problems, you can more effectively tailor your message to whoever you are speaking to. In some cases, if the community cannot be convinced of the impacts that willows cause, you might at least persuade them in the short-term to allow you to prevent the further spread of willows by leaving only one sex and non-fragile plants remaining at a site.
Belief in the value of willows for erosion control	Explain that willows were extensively planted in the 1950s to 1970s as an erosion control measure to negate the effects of streamside vegetation loss and clearing in catchments and that, in the short-term, they appeared to do this effectively. However, the stability that willows provided was only temporary and, over time, they caused increased erosion and flooding and, in many cases, have completely altered the course of the river.
Provision of feed for stock during drought	Willows provide nutritious feed for stock. However, willows encroaching into a waterway consume significantly more water than river red gums on a river bank, which becomes a particular problem during periods of drought when water is scarce. While there are several benefits to willows, the many impacts they cause significantly outweigh these.
Aesthetics/heritage value	It is important to recognise that what the community values is still important. Ask further questions about what else they value in the landscape, as you are likely to find that there are other significant community values that willows threaten, or a compromise that can be made. Explain the various impacts that willows cause and how this will affect the community. Demonstrate that, while there are several benefits to willows, the many impacts they cause significantly outweigh these. In many cases you will discover that, while some parts of the community object to willow removal, other parts of the community will actively support it. At times, you may need to compromise and leave some valued trees (for example, weeping willows) at the site, to enable you to remove the most threatening ones (for example, crack or black willow).
The immediate scar left on the landscape when they are removed	Be realistic about what the community should expect to see in the short-term. In most cases, there will be a short term scar left on the landscape, but over time (if the job is done properly) the site will be significantly improved and a greater asset to the community. Take them to a successful demonstration site, and show them photos of what it once looked like. This allows them to visualise what you are trying to achieve.
Have seen too many examples of bad willow management (or willow management gone wrong).	Willow management has been an evolving process over time. We have now learnt from our own and other people's mistakes and understand how to do it effectively. So long as we all work together towards our long-term goal and ensure that fencing, revegetation and follow-up control is done successfully, we will not see the same wasted results of some past efforts. Willow management needs to be seen as part of a broader waterway management program that aims to improve river and riparian health.
Recreational ▪ Some fishermen believe that more fish can be caught under willows. ▪ Some water skiiers believe that waterskiing is safer where willows occur, as roots extending into the water buffer the wake created by boats, thus reducing the wake that would otherwise rebound off the bank.	It is often very specific parts of the community who object to willow control on recreational grounds. Seek support from other parts of the community and demonstrate that, while there may be some impact to their industry/sport, there is a broader public benefit to removing willows.
Willows are providing a carbon sequestration function	People sometimes attach to the greenhouse argument when it conveniently aligns with previous held views (for example - "I like the willows and don't want to get rid of them"). Willows do sequester carbon, as do many other weeds. They should, however, ultimately be replaced with indigenous and longer-lived vegetation, which is likely to sequester more carbon over time, and provide improved biodiversity and river health outcomes. A significant part of carbon storage has to do with the density of the wood (kg/m^3) and the volume of standing timber. As willow wood is considerably less dense than native woods, it would need to have a much greater volume of standing timber to sequester the same amount of carbon.

Strong community support will help to ensure that enduring outcomes are achieved. (Willow Warriors Inc.)

Gaining community support

There are many other potential reasons people may give as to why they do not want the willows removed. Whether or not these reasons are justified, it is important to listen to the community and to try to gain as much support as possible before starting works in their area.

If compromise is needed, it is important to at least remove the plants that pose the biggest risk of further spread, to prevent future impacts from occurring. In some cases, this may only require the removal of a few plants. For example, where there are just a few female plants growing amidst a large stand of males, removing the female plants will help reduce the risk of further spread by seed. Where there are just a few fragile plants present along a waterway, removing them will help reduce the risk of further spread by twigs and branches.

Who is affected by willows?

Willows affect everybody who depends on our waterways. For example:

- Irrigators – willows can reduce flows, use precious water and restrict access.
- Recreational users – willows reduce safety and access to waterways for many recreational users.
- Everyone who drinks water – as willows affect the quality and quantity of our water supplies.
- Flora and fauna - many of our unique animals and plants depend on healthy waterways and riverbanks for survival.

Willows affect us all – we need to manage willows effectively to maintain the health of our waterways.

Additional resources

The following is a list of research papers to help further your understanding of willows and their identification. A detailed list of references is included in the appendices.

The problem with willows: Why manage willows?

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Section 2

Managing willows

If not controlled properly, willows will readily re-sprout. (Sarah Holland Clift, DPI Victoria)

Managing willows

Now that you understand why willows were introduced, the impacts they cause, how they spread and their perceived benefits, it's time to plan your willow management program.

Willow management is extremely complex and to be successful requires detailed planning, follow up and revegetation.

This section will guide you through all the factors you will need to consider before developing a willow management program and prioritising your activities. As every situation is different, you will also need to weigh up each of these factors before deciding on the best management scenario for your particular circumstances.

Planning a willow management program

As with all major projects, a significant amount of planning is necessary before getting started on a willow management program.

Willow management can be expensive and dangerous and, in many cases, control of all willows is not feasible or desirable. Careful planning is essential to ensure that you clearly achieve what you set out to do in a safe and cost-effective way. Poorly planned projects can waste valuable resources and are rarely successful.

"It may be tempting to control and remove a willow infestation straight away, but without pre-planning, site preparation, follow-up controls and site rehabilitation, the site may revert back to a willow-infested or other degraded condition in a short period of time."

– Sarah Holland Clift, National Willows Program

Any willow management plan should be:

- ☑ targeted to achieve both short and long-term objectives
- ☑ flexible to changing conditions which may affect the management plans (for example, flood, drought or fire, or the discovery of a seeding willow population that had not previously been recorded)
- ☑ based on a good understanding of the life cycle and characteristics of the willows present (see Section 1 Understanding Willows, for assistance)
- ☑ based on thorough knowledge of the site conditions, such as climate, water flows, stream morphology, ecology and history
- ☑ cost-effective in the medium to long term
- ☑ part of an integrated project, with broad environmental, economic and / or social outcomes
- ☑ aware of current community perceptions and how the community can best be engaged in the project.

Remember, willows are not necessarily the only problem that needs management, nor should they be the sole objective of your program. Ask yourself what you are trying to achieve by managing the willows and work towards that goal.

The bad, the ugly and the good: Directly following willow removal, the site can look devastating but, in just a few years, it can become a much healthier site, as long as good site preparation, follow-up control and site rehabilitation has been conducted. (The Ovens River, Victoria – Terry McCormack, North East CMA)

Planning generally needs to be carried out at two levels:

Broad-scale planning...

...will help you to determine **where** to undertake willow management works and to develop an investment plan to take to funding bodies.

You will have a greater chance of success if you have a detailed plan and demonstrated support. Planning at this level might be broad enough to cover reaches, sub-catchments, regions or states and should likely also demonstrate links to supporting, over-arching strategies for the region and/or the state you are working in.

Site-specific planning...

...immediately before starting on-ground activities will help you to clarify or determine:

- **what** you plan to achieve
- **why** you want to manage willows
- **who** you should involve
- **when** and **how** you will conduct the works, and
- how you will monitor, **review** and learn from the program.

Broad-scale planning

Where should I prioritise my management efforts?

It is important to think about where willows occur in the landscape and in what order these should be managed in order to maximise environmental benefits, make the best use of scarce resources, increase your ability to maintain action in the long term and enable you to integrate willow management into other riparian management initiatives.

As part of your planning, it will be necessary to:

1. Determine where and what type of willows occur in the landscape.
2. Establish realistic objectives.
3. Set priorities for action, based on:
   - the risk of further spread by seed or branches
   - the current impacts and the value of the site
   - density and location of willows and behaviour of the river
   - ease and cost of management
   - landholder commitment and community support, and
   - current and potential resources.
4. Develop a plan for investment.

What you will need to consider as you work through each of these steps is broken down into more detail in the following pages.

Marking the density and location of willows on a map will help you plan your willow management program and prioritise works. (DPI Victoria)

The sex of willows can generally only be determined in spring, when willows are in flower. (Sarah Holland Clift, DPI Victoria)

1. Determining where and what type of willows occur in the landscape

Because you can't manage what you don't know.

In most cases, controlling all willows in an area is not feasible or necessarily desirable.

Mapping and collating site information will allow you to decide which willows to control, when and how to control them. It will also allow you to effectively measure progress over time.

Whether you are working on a local, catchment or regional scale, you will need to undertake a thorough assessment to determine:

- which willows are present in your area
- their density, location and impacts
- their potential for further spread, and
- the value of the area and potential effects if willows are removed.

What information to record?

Wherever possible, you should record where all willows occur in the landscape, including trees in parklands and backyards.

Willows along waterways may be the current cause of most problems but willows away from the waterway may be the cause of significant impacts in the future if they are a source of viable seed or pollen that enables their spread into new areas.

For a detailed assessment form that outlines the key information you should record when mapping willows, refer to the *National Willows Program Resource Kit, Willow Resource Sheet 4: Willow and willow sawfly assessment form* and *Willow Resource Sheet 5: Willow infestation classes.*

To determine the type of willows and how they spread, refer to *Willow Resource Sheet 2: Willow Identification, an essential skill for effective willow management.*

The above resource sheets are available for download at www.weeds.org.au/WoNS/willows.

If you don't know where and what type of willows occur in your area, how will you know where to manage them?

How and when to map willows?

There are several ways to map willows, depending on the scale of work planned, the resources available, your access to the site and the extent of the willow infestation.

On-ground inspection by foot or by boat is generally necessary to collect the information needed to set most effective priorities for management.

Aerial photography, remote sensing and use of local knowledge are quick methods to collect crude, broad-scale mapping data that can later be refined through on-ground inspection.

See 'Methods available for mapping willows' in the following pages for a more detailed explanation, including when to conduct each method, what you will need and the advantages and disadvantages of each.

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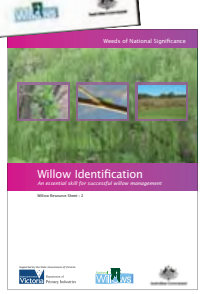

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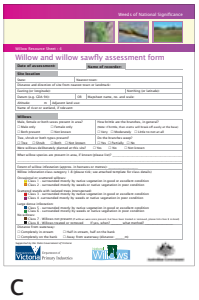

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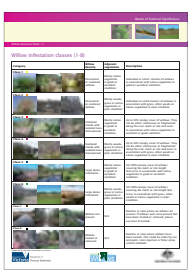
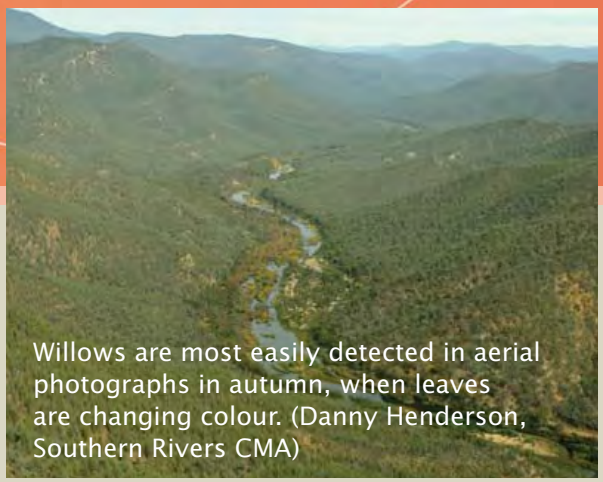


d

a) National Willows Program Resource Kit cover
b) Resource Sheet 2
c) Resource Sheet 4
d) Resource Sheet 5

Available at www.weeds.org.au/WoNS/willows'



Willows are most easily detected in aerial photographs in autumn, when leaves are changing colour. (Danny Henderson, Southern Rivers CMA)

Nice day for a paddle: Willow Warriors Inc. mapping willows along the Murrumbidgee River. (Willow Warriors Inc.)

On-ground mapping of willows provides better outcomes for strategic willow management

Fine-scale, on-ground willow mapping is helping to develop more effective willow management strategies in the upper Murrumbidgee River catchment where volunteers have so far mapped the species and size of more than 16,000 willows.

Members of Willow Warriors Inc. have paddled over 150 km of the Murrumbidgee River in inflatable rubber rafts, mapping the location of each willow they pass.

Ready access to the detailed information collected, including the species, size (large, small or seedling), density and location of willows, has been critical in developing effective management strategies, including:

- The early detection and control of young seedlings and local seed sources, such as preventative control plans to eradicate black willow (*Salix nigra*) at an early growth stage.
- Highlighting areas of risk where crack willows (*Salix fragilis*) are likely to become established from existing populations.
- Monitoring willow spread in relation to 'willow-free' zones and containment points.
- Incorporating other data, such as land use and vegetation, into willow control plans to maximise biodiversity benefits.

Broad-scale mapping techniques, such as aerial photography or satellite remote sensing, although quick and effective ways to collect information over a large area, by comparison tend to detect only large willow trees and are unable to distinguish between willow taxa.

Fine-scale mapping provides an optimum level of baseline information to assist willow managers in planning and implementing strategic management.

Note: The Willow Warriors' activities assisted the Upper Murrumbidgee Landcare Inc. and the Upper Murrumbidgee Catchment Coordinating Committee's projects, with funding assistance from the NSW Environmental Trust and the Australian government's Defeating the Weed Menace program.

Fine-scale, on-ground mapping is needed to determine the type, size, density and location of willows, which are important for planning an effective willow management program. (Willow Warriors Inc.)

Methods available for mapping willows

Method and description	When	What you will need	Advantages	Disadvantages
On-ground inspection Surveying on foot, using a hand-held GPS device or topographic map to record the location of willow infestations *Best for small, accessible areas*	Any time of year, but best in spring, when willows are in flower Identifying if trees are male or female or both is only possible in spring, when flowering occurs, and it is often easier to determine the willow taxa at this time, based on when the flowers and leaves emerge As different taxa flower at different times, more than one visit to the site may be needed	Site assessment forms Willows infestation class table Hand-held GPS unit Topographic maps / aerial photographs Camera Willow identification guide Sample bags and labels (for collecting plant specimens)	Provides detailed information needed for setting effective management priorities Relatively inexpensive	Labour intensive (2 people can survey about 1-6 km per day) Limited by accessibility Requires landowner consent If landowner wants to be with you on site, will need to coordinate access times
Rafting or canoeing Surveying from the river, using a hand-held GPS device or topographic maps to record the location of willow infestations *Best for remote areas, easily accessed by water*	As above Two to three weeks after a flood can be an opportune time to survey for willows, as they can appear bright green amidst the native seedlings	Site assessment forms Willows infestation class table Hand-held GPS unit Topographic maps / aerial photographs Camera Willow identification guide Sample bags and labels (for collecting plant specimens)	Provides detailed information needed for setting effective management priorities Relatively inexpensive Allows access to otherwise remote areas Does not require landowner consent, once on river Only need to organise access at a couple of points along the river	Labour intensive Requires specialised rafting equipment and training Limited by suitable conditions and accessibility (for example, not suitable when rivers are in flood or are too narrow or dry)

Method and description	When	What you will need	Advantages	Disadvantages
Using local knowledge Local people asked to record on topographic maps where they know willows to occur (an acetate overlay may be used, so that the maps are not permanently marked) *Useful when needing to quickly gain broad-scale mapping information at low cost*	Any time of year. In combination with community education and awareness activities.	Topographic maps (minimum of 1:100,000) Acetate sheet to cover map Willow infestation class table 8 markers in the 'willows infestation class' colours	Quick and easy Low cost Draws on local knowledge Engages the community, so can be combined with education and awareness activities	Relies on people's memory Lacks important detail, such as type of willow, method of spread and location in the waterway Often difficult to attain information on minor tributaries
From the air Use of a helicopter or light plane using aerial photography or video *Useful for gaining broad scale mapping information.*	In autumn, when the leaves are turning yellow, as this makes them easier to distinguish from evergreen native vegetation.	A helicopter or light plane Aerial photography or video equipment, with attached GPS technology	Large area mapped in short timeframes Can provide a good overview of larger infestations over a large area Not limited by access	Lacks detail (e.g. small infestations may be missed, cannot determine willow type or seed production) Expensive Mainly limited to autumn when willows are changing colour Can be difficult to distinguish willows from other plants
Remote sensing technology ASTER imagery and Spot 5 are currently under investigation as a cost-effective alternative for mapping willows on broad scales *Useful for gaining broad-scale mapping information*	Two spectral images taken in summer and winter or summer and autumn will enable willows to be best distinguished from other plants	Remote sensing technology Skilled GIS professional A composite of summer and winter SPOT 5 imagery or summer and autumn ASTER imagery	Large areas mapped in short timeframes Quicker and cheaper than conventional aerial methods Up to 77% accuracy Not limited by access	Winter images limited by undergrowth exposure, shadowing, topography and boundary-mixed pixels Will not pick up isolated trees or seedlings Requires specialised technology and skills

2. Establishing realistic objectives

Why manage willows?

Before deciding where to manage willows, you first need to determine why you want to manage them, as this will form the reference point for your program.

Set realistic objectives that focus on long-term outcomes, rather than on weed control alone.

For example, long-term objectives may include wanting to:

- improve river health by replacing willows and other weeds with native species
- protect and restore native vegetation by eradicating a recent willow infestation
- protect a threatened plant or animal by controlling willows that threaten their habitat
- stop the spread of willows and gradually control existing infestations.

It is often useful to set short, medium and long term objectives that enable you to measure progress over time.

Consult with your local community, land managers and investors to determine what objectives they want to achieve, as they may have different objectives and you may need to find the middle ground.

Timeframe	Example Objectives
Short term (between 1-2 years)	Prevent further spread of a seedling willow infestation by controlling and removing all adult plants capable of producing seed Start site rehabilitation activities, including erosion prevention measures where needed
Medium term (within 5 years)	Control and remove remaining adult plants where needed Control any seedling willows that emerge Continue site rehabilitation activities, including maintaing erosion prevention measures, follow-up monitoring and controls and revegetating with native plants
Long term (over 10 years)	Eradicate all undesirable willows Rehabilitate the site with appropriate native vegetation Demonstrate improvements in water quality and riparian health

Managing willows as part of a broader river health program

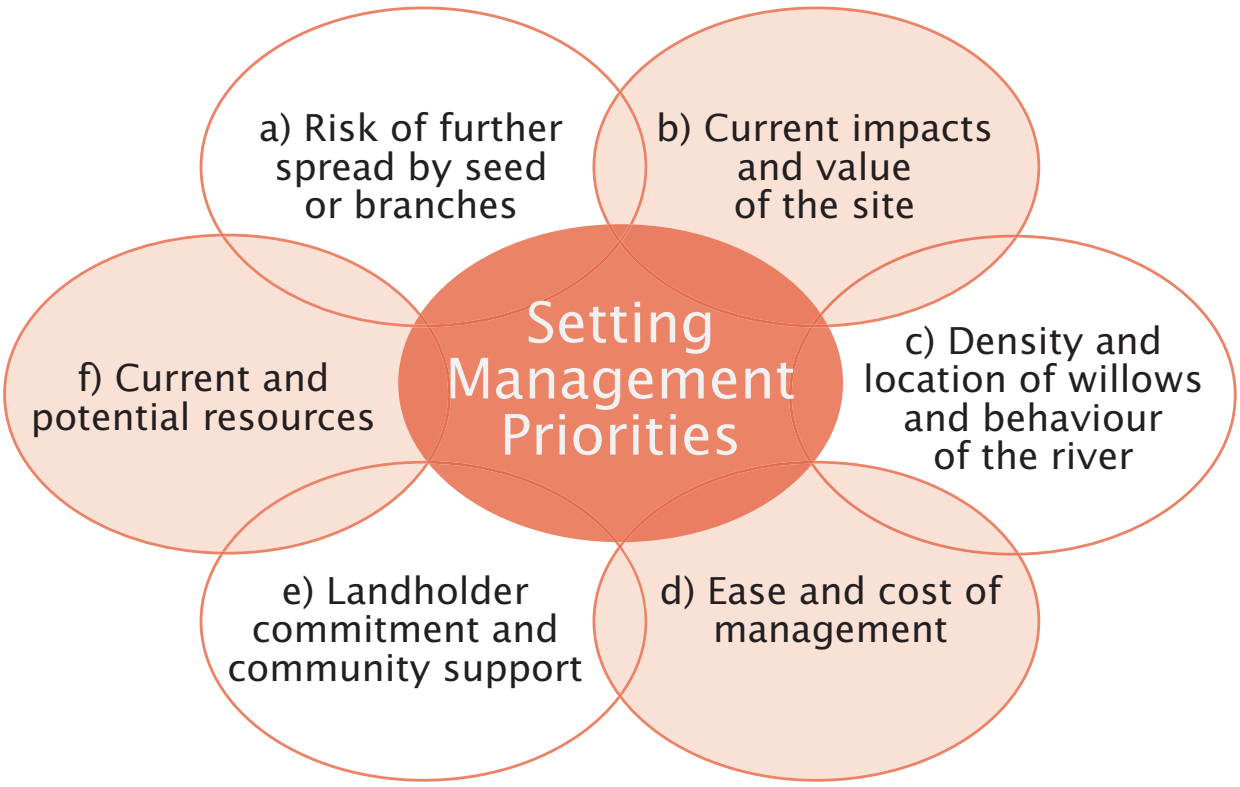
Many regional Catchment Management Authorities (CMA) or Natural Resource Management (NRM) bodies address the impacts of willows on river health through their regional river health strategies. This enables them to integrate willow management with the management of a range of other river health issues, such as bed and bank instability, livestock access, threatened assets, feral animals and other environmental weeds.

3. Setting priorities for management

Deciding which infestation has higher priority is not a simple process and will require you to assess a range of interlinking factors. Each situation will need to be judged on its particular mix of circumstances and may require compromises.

Remember, willows are not necessarily the only problem that needs management. It is also important to consider other current or potential problems in your area when setting priorities and allocating resources.

Some key factors to consider when setting priorities:
(note: you may need to add to this list for your particular area)



Each of these factors will have different levels of importance, depending on your specific situation and objectives. How you weight the importance of each, is up to you.

Always review and adapt your priorities over time, as new information becomes available.

Female *S. cinerea* catkins can shed lots of seed in spring. (Terry McCormack, North East CMA)

Bees collecting pollen from male *S. cinerea* catkins. (Sarah Holland Clift, DPI Victoria)

a) Risk of further spread by seed or branches

As with all weeds, it is much more cost effective to prevent future problems than to wait until the problem occurs.

Controlling spread by seed

Very high priority

The need to remove any willows that are producing viable seeds should be a very high priority for management, as these species have the potential to spread long distances into new areas and become a serious problem within a short time period (see Section 1 Understanding Willows, for further information). In some cases, such willows will need to be immediately controlled in areas where they do not currently cause significant impacts, to prevent them from spreading to other, more important, environments.

To determine the potential for spread by seed, you need to know:

- Is the present mix of willows able to produce viable seed?

  Pollination and seed production is most likely when fertile male and female plants from the same subgenus (tree or shrub willow) flower at the same time and are close enough for pollination to occur. Exactly how far willow pollen can travel is not yet known, but female plants growing 1 km from the nearest male have been observed producing viable seeds. It is therefore recommended that male plants are separated from females by at least 2 km and preferably more if possible.

- Are there potential seed sources outside the area covered by your plan?

  In some cases, willow seeds have been known to spread up to 50-100 km from their initial source, so seed may continue to spread in, from other catchments, regions or states.

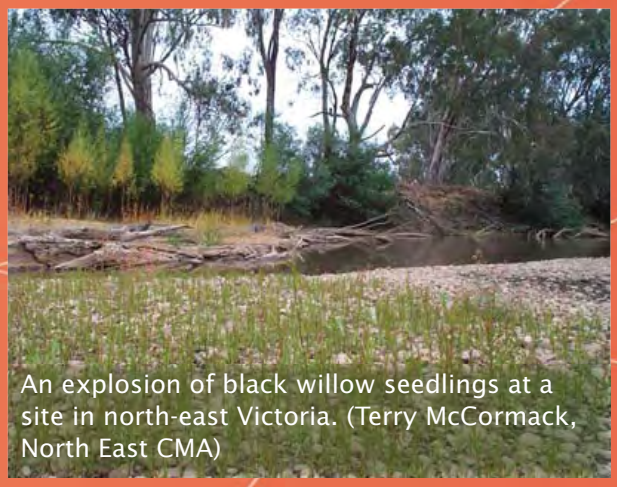
Early detection of, and rapid response to, seeding willows could save significant cost later on and may make the difference between complete eradication of the weed in the catchment and a long term, expensive control program.

Suggested actions:

- If you find female and male willows from the same subgenus ('tree' or 'shrub') within a few kilometres of each other, remove all female plants immediately (or males, if they are less common).
- If new seedlings are found, remove them immediately, preferably while they are still easy to pull up and before they flower and seed. Seek out and control all parent plants even if they are well away from the river (see inset box 'Selective control of female seeding willows').

Note: In some cases, parent plants may be a long way from the new seedling population, making them difficult to identify. If, however, hundreds to thousands of seedlings germinate in an area in the same season, it is likely that the parent plants are nearby.

The willows on this road cutting in Tasmania are not currently creating significant impacts but, if left unmanaged, they could spread into and threaten some of Tasmania's unique environments. (Sarah Holland Clift, DPI Victoria)



An explosion of black willow seedlings at a site in north-east Victoria. (Terry McCormack, North East CMA)

Selective control of female seeding willows

When resources are limited, rather than controlling all willows in an area, one sex can be targeted (whichever is in lowest abundance) to prevent spread by seed. A thorough survey is critical to this approach.

Thousands of viable seeds may still be produced in a short period if:

- Males are targeted for control, but a few are missed, as they may still pollinate the remaining female trees and enable them to produce viable seed, or
- Females are targeted for control, but a few are missed, as a single, female plant can produce thousands of seed each spring.

'X' marks the spot

Although control activities are possible year round, the sex of a willow can only be determined in spring when flowering occurs. A simple way to maintain a year-round record of the sex of willows, is to survey them in spring and mark all female trees in permanent paint or flagging tape. Female willows are then easily identifiable for selective control at a later date.

'X marks the spot': marking all female willows with an X is a simple way to identify the sex of a willow year round. (DPI Victoria)

To prevent permanent establishment, seeding grey sallow (*S. cinerea*, also known as 'wild pussy willows') are a high priority for eradication in Tasmania. (Sarah Holland Clift, DPI Victoria)

Preventing spread by twigs and branches

High priority

Willows that spread by twigs or branches are mainly of concern along waterways, where the twigs can break off, spread downstream, take root and establish new willow infestations.

To find out whether spread by twigs and branches is likely, you need to know:

- how easily the branches and twigs break off at the base
- the extent and density of the willow infestations, and
- the location of willows along the waterway.

Although managers tend to remove dense willow infestations first, it is actually more effective (and cost effective) to remove sparse populations first, as this is where population growth is most rapid.

Dense infestations can actually act as a 'choke' if the build up of sediment and debris around their roots traps twigs and branches and reduces their potential to spread further downstream. In contrast, sparse willow populations may not be sufficiently established to limit the spread of willows from upstream, but can act as a source of further spread downstream. There are also likely to be less negative consequences (for example, soil erosion) of removing sparse willows from a stream, compared with dense willows, since they have not yet started to cause significant changes to the stream (see Section 1 Understanding willows, for more information).

Suggested actions:

- If you find plants with brittle branches growing along waterways (for example, crack willow, *Salix fragilis,* and crack willow hybrids*, Salix x rubens*), first control sparse willow populations, then consider management of the dense infestations.
- Prioritise the management of dense infestations based on other key factors discussed in the following pages.

Spread by twigs and branches along a central Victorian stream

Extremely fragile branches make crack willow (*S. fragilis*) the most aggressive willow species to spread by twigs and branches. Aerial photographs clearly document the spread of crack willow along the Birch Creek, a small stream in central Victoria, in a study conducted from 1945 to 1991. This study found that:

- Willows spread downstream at a rate of 90-150 m per year.
- Willows are most likely to take root in shallow sections of a stream or silted backwater environments. In deep, free-flowing sections, where it is more difficult for willows to take hold in the middle of the channel, they tend only to lodge or grow on the banks. By trapping silt and debris, however, willows can eventually change the morphology of the river, creating shallow, braided streams that enable more rapid spread.
- Willow sticks of various sizes floated easily, over 50 m at a time, in reaches that were clear of obstructions under normal flow conditions, but stopped moving where channel obstructions (such as dense willow infestations) occurred.
- Dense clumps of willows act as 'chokes' that trap twigs and branches and thus hinder their ability to spread further downstream.
- The rate of willow spread is strongly related to the number of points of dispersal (i.e. how many willow clumps occur along the stream) and the amount of stream available for colonisation (i.e. the proportion of the stream without much canopy cover).

Management should focus on sparse rather than dense willow populations, as this is where population growth is most rapid.

'Which do I control first?': It's often tempting to control dense infestations (left), but control of sparse willows (right) first will help prevent spread by twigs and branches. (Sarah Holland Clift, DPI Victoria)

b) Current impacts and value of the site

Protect the best

Very high priority

It is much better to protect, preserve and / or rehabilitate high-value sites that are in good to excellent condition, rather than rehabilitate low-value sites in poor condition. High-value sites may include areas with threatened species or vegetation communities or sites otherwise identified as significant at international, state-wide or regional levels.

Sites with native vegetation in good to excellent condition:

- will generally require fewer resources to rehabilitate than sites in poor condition
- have a high chance of recovery, as native seed banks are more likely to exist, and
- are less prone to future willow invasion, due to reduced levels of disturbance and competition with other plants.

Isolated grey sallow plant growing on the Baw Baw Plateau in the Baw Baw National Park. The park is listed on the Register of the National Estate and forms part of the Australian Alps national parks system. (Parks Victoria)

Better value for money will be achieved by protecting, preserving and/or rehabilitating sites that are in good to excellent condition (above) rather than trying to rehabilitate sites in poor condition (below). (Terry McCormack, North East CMA)

Suggested actions:

- Identify and protect areas of high conservation significance that may be negatively impacted by willow invasion (for example, where willows may restrict the passage of a threatened fish species or out-compete significant native vegetation).
- Control willows in areas where there is a high likelihood of recovery, such as those in close proximity to native vegetation, or with downstream vegetation in good condition.

If you are unsure, consult your regional Catchment Management Authority or Natural Resource Management board for information on significant sites in your region.

c) Density and location of willows and behaviour of the river

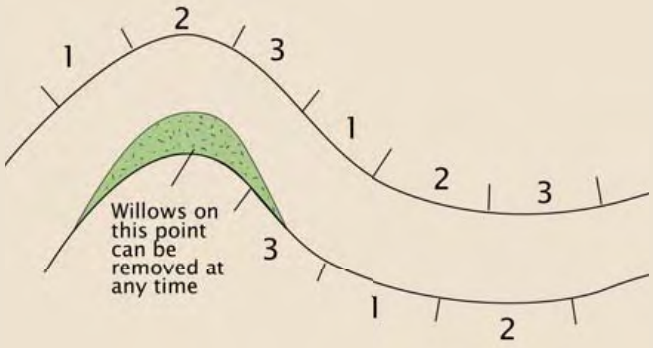
The potential impact of all willows is clear, but removal of willows can also have significant impact. The density and location of the willows and the behaviour of the river at the site are important factors to consider when contemplating management activities.

River behaviour is determined by understanding the geomorphology of the river and what was happening prior to willow invasion. If you are unable to recognise the indicators of flow energy level, equilibrium, aggradation and degradation, consult a specialist.

Manage willows first in locations where they have no benefit for erosion control.

Suggested actions:

- **In smaller streams,** willows can hold several metres of headcuts in their roots, extending over a few kilometres of stream. A headcut is an erosion feature that is a vertical or near-vertical drop or change in elevation of a stream channel or gully. There are several examples of major erosion occurring after willow removal as these headcuts migrate upstream. If you plan to remove these willows, you should plan for consequent bed erosion and how you will manage this.
- **In larger streams,** control willows wherever possible, so long as this does not trigger major erosion and willows are quickly replaced with native vegetation.
- **On channel beds and bars, and on bedrock banks,** remove willows if:
  - They are not preventing bed degradation. If they are preventing degradation, install bed control structures before removing willows.
  - There are other trees along the stream to provide shade. If there is not, plant native plants on adjacent land, and wait until they mature before removing the willows.
  - A significant amount of sediment has not accumulated around the willows. If significant amounts of sediment have accumulated, you should not remove more than 1 km at a time, as otherwise large amounts of sediment will be released, which may choke the river channel downstream.
- **On alluvial banks, on equilibrium or aggrading inside bends and straight reaches,** control willows in one operation, leaving at least the stump and roots behind. In locations where flow energies are too high for native plants to survive, structural erosion controls may be needed.
- **On alluvial banks, on outside bends and on straight, degrading reaches,** control willows in strips of three phases along the bank, with an interval of at least 5 years between, to allow the replacement vegetation to become well established and reduce the length of bank exposed to erosion. Where flow energies are too high for native plants to survive, consider the use of long-stem native tube stock or structural erosion control measures.



Phasing willows out of meander bends. The numbers represent the three phases of willow removal.

(David Outhet from Rutherfurd, I. D., Jerie, K. and Marsh, N. (2000) A Rehabilitation Manual for Australian Streams. Cooperative Research Centre for Catchment Hydrology and Land and Water Resources Research and Development Corporation.)

- **Where flow energies are too high for native plants to survive,** consider the use of long-stem native tube stock or structural erosion control measures (see Section 4 Site rehabilitation, for more information).
- **If willows cannot be removed from a site,** lop frequently to prevent them growing into large trees and layering into the stream, ensuring that even the smallest branches are removed from the area.

Willows growing in the river that are obstructing and diverting flows can have major negative impacts on watercourse structure and flood patterns. (Terry McCormack, North East CMA)

Should I always start from the top of the catchment and work down?

There has been a long-held belief that willow management should always start at the top of the catchment and work down, to prevent continued reinvasion by willows spreading from upstream. In fact, a range of important factors need to be considered when deciding where in the catchment you should control willows first.

Starting from the top of the river and working your way down can be very effective if:

- there are occasional or scattered willows that only occur on the banks and are not growing in stream, or
- all willows upstream have been controlled and you are now looking to progress further downstream.

With large, dense infestations and / or where willows encroach into the stream and are impeding flow, it may be better to create a mosaic along the river and then try to join the dots over time.

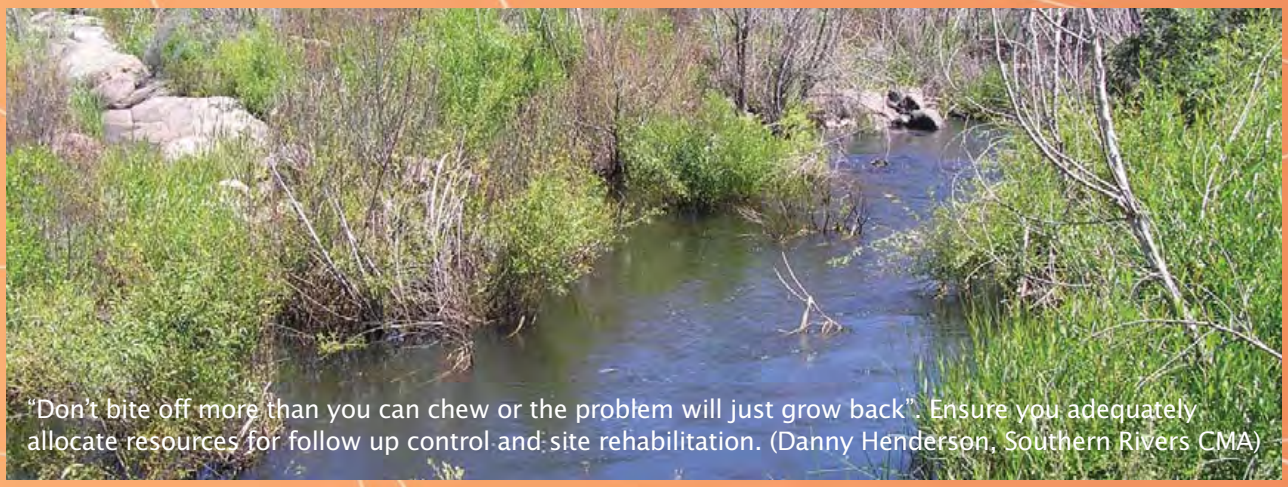
Creating a mosaic along the river and then joining the dots over time may be more effective than starting at the top and working down, in some instances.

If you start at the top and work down, you can increase the risk of flooding to properties at the willow face, as the water increases in momentum along the recently cleared part of the stream and is then impeded by dense willows constricting the channel downstream. The 'mosaic' method tends to reduce the effects of opening up large sections of waterways, thereby controlling potential increases in water velocity, and creates opportunities to establish native vegetation. This helps to maintain the bank integrity as the river is progressively opened up. Creating a mosaic may also result in vegetation of mixed age groups growing along the waterway, which aids in the recovery of biodiversity.

The type, extent and location of the willows and the behaviour of the river at the site are important factors to consider when deciding where to manage first.

Rather than working from the top down, willows should be managed according to the type, extent and location of the willows and the behaviour of the river. Risk assessment should be undertaken to address the potential for further willow spread and the potential hydraulic and geomorphological implications of controlling willows. Management activities based on risk assessment may, for example, need to take into account the following:

- Some seeding willows can spread seed up to 50 km in any direction on prevailing wind currents, including upstream and across catchments.
- When a recognised risk of propagation from twigs and branches exists, use of booms or other techniques to catch twigs and branches can help prevent them from spreading further downstream.
- Willows may need to be temporarily retained in some sections of river (for example, where flow energies are high and the bed or banks are in unstable soil types) until other structures are put in place and / or alternative vegetation is established.
- Willow control should only be conducted where site rehabilitation is possible and may depend on the willingness of landholders to become involved, as well as the source and type of funding available.



"Don't bite off more than you can chew or the problem will just grow back". Ensure you adequately allocate resources for follow up control and site rehabilitation. (Danny Henderson, Southern Rivers CMA)

d) Ease and cost of management

Having considered the potential for further spread, the site's current impacts and value, willow location and river behaviour, the next step is deciding how and when you will manage willows.

Willow management can be dangerous and expensive and what resources are available to you will be an important component when deciding which activities to undertake. Long-term outcomes are best achieved through careful assessment of the risks, effective allocation of resources and gradual adaptation of your program, over time, matched with available resources.

Note: There is a tendency for willow managers to focus on the easiest and most visible willows first, before considering management of more difficult plants. Other factors, such as potential for further spread and current impacts and value of the site, should also be considered when setting priorities for management.

Don't bite off more than you can chew – assess the risk, allocate resources effectively and adapt your program gradually over time!

Suggested actions:

- **Identify risks and assets:** Working with willows often involves considerable risk. Before deciding on a management strategy, it is critical to identify and assess all potential and likely risks in the project area and propose measures that might reduce them. What you discover in the process may determine the control and removal methods you eventually choose to employ.

  For examples of risks associated with willow management and how to reduce these risks, refer to Appendix 1. For control and removal methods, refer to Section 3.

- **Ensure that resources are available for planning, follow-up control, site rehabilitation and monitoring:** The biggest and most immediate cost of a willow project is the control and removal work. Long-term success, however, relies on good planning, follow-up control, site rehabilitation and monitoring. Allocating sufficient resources to a long-term willow management and rehabilitation project can be difficult with short funding cycles, but is absolutely essential for success. It is better to bite off small bits at a time and do them well than to conduct large-scale projects quickly.

- **Remember that people are the most important resource:** Assess how many 'people hours' will be required to complete the planned management program and consider what skills, training and experience are needed (including herbicide application, willow removal, willow disposal, monitoring and site rehabilitation).

Some useful tips:

- Using the right personnel for the job will save time and money in the long term. Consider the use of trained professionals, such as contractors, as they are experienced in identifying and minimising risks and skilled in the use of different management techniques.
- Financial assistance is often available for willow management programs. Check with local contacts in your area (such as Natural Resource Management bodies or Catchment Management Authorities) to see if there are any financial incentives.
- Machinery hire rates can be two or three times the cost of manual labour. Plan works carefully so that hired machinery is kept in operation all the time, to avoid having to stop and wait for manual tasks (such as felling trees or raking up debris) to be completed.

e) Landholder commitment and community support

Willows can be an extremely divisive issue within a community and the relationships you build can make or break a willow management program.

Landholder commitment

Willow management is a long-term process that often requires long-term support and commitment from adjacent landholders in order to be successful.

Engaging the community throughout all phases of a willow management program, from planning through to rehabilitation, monitoring and evaluation, is key to gaining long-term commitment from landholders in maintaining sites.

Some helpful ways of gaining landholder commitment:

- **Try to avoid making willow management compulsory** unless absolutely necessary, as landholder support is needed for effective long-term management of the site.

  In Tasmania, at least 85% of landholders must be on board before legislation is enforced. If the landholder will not support your project in the short term, this may change over time once they see the outcome of your work on neighbouring properties.

- **Be clear about which landholders you will provide assistance to and why.** It can become a challenge if you start to get too many requests from landholders who want you to work on their properties.

  If you are unsure about why you are targeting works in particular locations, then what are you doing there in the first place?

- **Take landholders to a demonstration site.** Show them 'before' and 'immediately after' photos and what it looks like now, to prepare them for what to expect.

  Most negative feedback about willow management is received immediately following control, when the visual impact is greatest. Be honest about this and let the landholder know that there will be an initial scar left on the landscape until the site has had time to rehabilitate. Over time, people will easily forget what the site looked like before the willows were removed, and even that the willows were ever there. It is much easier to visually demonstrate the long-term benefits of willow removal than to try to explain it with words.

- **Gain co-investment from the landholder in the management of the site** (for example, in fencing and revegetation of the site).

  Along the Bass River in West Gippsland, Victoria, the West Gippsland Catchment Management Authority (CMA) funded the cost of willow removal, site clean up, planting work and fencing material, while the landholders funded the construction of the fence and the tube stock required for planting. Once the works were completed, the landholders became responsible for the site, but the CMA assisted with any necessary follow-up control and monitoring. This long-term commitment from both the CMA and landholders has helped to ensure that the ultimate goal of improving river health is achieved.

- **Provide incentives to improve your chances of getting the best job done,** but be careful not to provide too many incentives as this may result in a lack of ownership by the landholder.

  A small incentive, such as providing native tube stock at 10c / tube less than what the landholders can source them at, may help to ensure that good tube stock is being planted.

- **Ensure everyone's responsibilities are clarified** and that everything is agreed and signed off on before the project starts.

Community support

Attempts to remove willows from along waterways are often still met with strong community opposition, but there is also growing opposition to leaving them unchecked. Strong community support will help to ensure that enduring outcomes are achieved. It is important, therefore, to understand community perceptions and to try to gain as much support as possible before starting works in an area.

For common community concerns and suggested responses to these, see 'Understanding your community' in Section 1 Understanding willows.

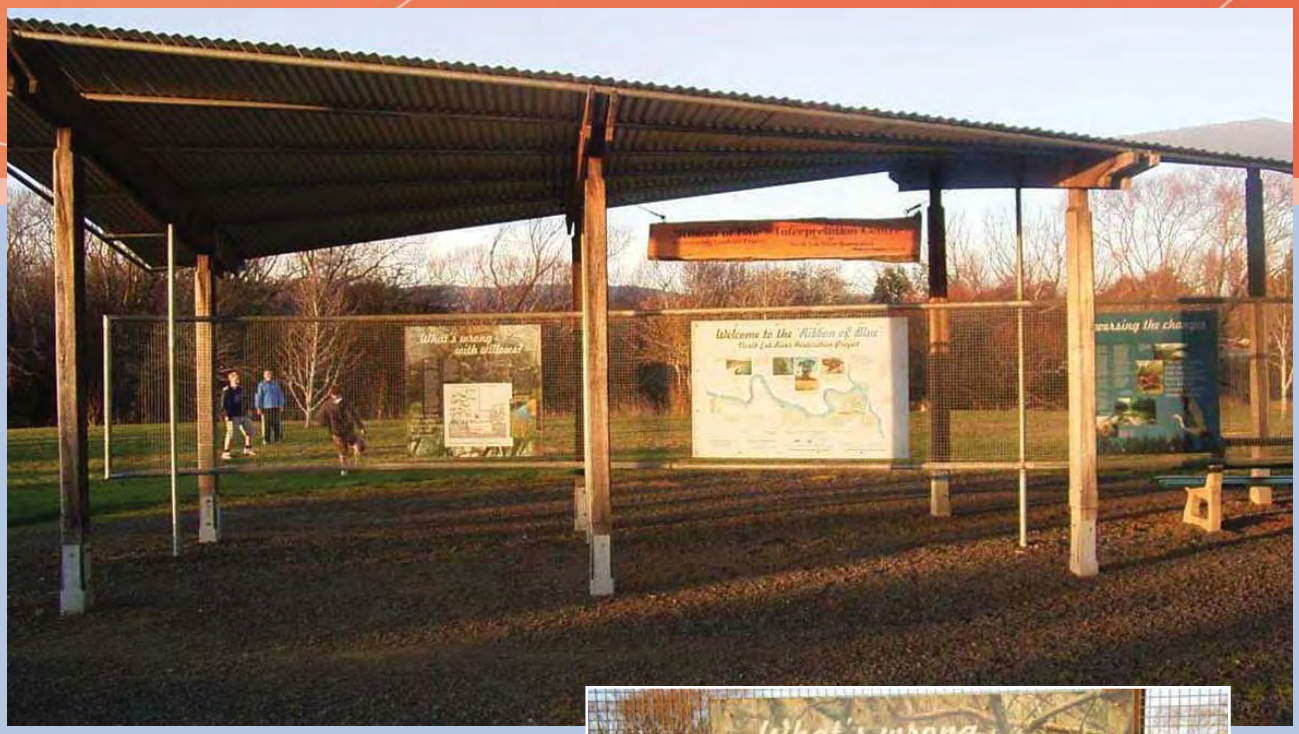
Some helpful ways of engaging the broader community:

- ☑ Provide resource material that explains the problem with willows and why they need to be managed.
- ☑ Explain management priorities and objectives (i.e. which sites are being targeted and why and what long-term improvements are planned).
- ☑ Give the community an opportunity to provide input through public meetings, workshops or field days.
- ☑ Listen to concerns and try to incorporate their suggestions into management planning.
- ☑ Set up interpretation signs and demonstration sites at frequently visited locations that provide a 'before and after' picture for visitors (see inset box, 'Interpretation signs: Lest we forget').
- ☑ Use the media to raise awareness and engender community support.
- ☑ Door knock and have face-to-face conversations with residents about what you are planning to do and why, and to give them an opportunity to provide comment.

Suggested actions:

- Establish and maintain good relationships and communication with land managers, the community and your investors throughout the entire management program, from site assessment and planning through to monitoring and evaluation.
- Clearly define the roles of all people involved in management so that everyone's responsibilities are known well in advance of management works starting.
- Proactively deal with community concerns by developing a communications strategy that incorporates landholder engagement and broader community education and awareness.
- Develop clear and measurable objectives, carefully set priorities for management and implement a sound, long-term management program.

It can take a long time to gain community support, but that support can be lost very quickly. Doing a good job that demonstrates clear environmental and social benefits is one of the best ways of gaining ongoing community support for your program.



Interpretation signs: Lest we forget

Interpretation signs can effectively communicate the benefits of willow management to the community.

The 'Ribbon of Blue' project involved the removal and rehabilitation of heavy crack willow infestations along the North Esk River in Launceston, Tasmania.

These signs at the 'Ribbon of Blue' interpretation centre are a permanent reminder of the problems willows once created and the benefits of managing them. Over time, without this reminder, it is easy for people to forget or not to be aware of what the site once looked like, before the willows were removed.

The signs were developed by the North Esk and Corra Linn Landcare groups as a key part of the project.

Signs are an invaluable education tool that will continue to promote the benefits of willow management for years to come.

f) Current and potential resources

A final consideration when setting priorities for willow management is the source of current and potential resources. When developing a management plan, it is important to consider where funding will come from, the investors' areas of interest and their likely level of investment. It is also worthwhile to maintain good relationships with your investors and to clearly demonstrate to them the outcomes of your program, to increase your chances of receiving funding in future.

Regularly review and adapt priorities

Setting priorities is an ongoing process that will require review and adaptation over time, as new information becomes available. No matter how well you plan your willow management program, unexpected situations will emerge. For example, urgent preventative work or a quick response should be sparked if:

- a new infestation of seedling willows is discovered, or
- there is an immediate risk of asset damage or loss of access to the river that was previously undetected.

4. Developing a plan for investment

Funding bodies are becoming increasingly wary of investing in programs that are not well planned and that are unable to demonstrate clear benefits for the environment and the community.

When developing a plan for investment you should always consider:

Context, scope and objectives

What is the project area, why has it been selected, what is the basis of this decision and what do we aim to achieve at the site?

Key risks/threats

What factors may hinder or enable success and how will we manage these?

Options for management

What approaches and techniques are available, which are preferred and why?

Information needed

What further information is needed to develop the detail for analysis and design, key assumptions and data?

Implementation strategy

What short-term actions are needed to achieve our long-term objectives? What are the assumptions or gaps that will get us from these actions to the desired long-term outcomes, and how will we know that we are on track to achieving this?

Communications strategy

Who do we need to communicate with, how and when?

Monitoring, review and adaptive management

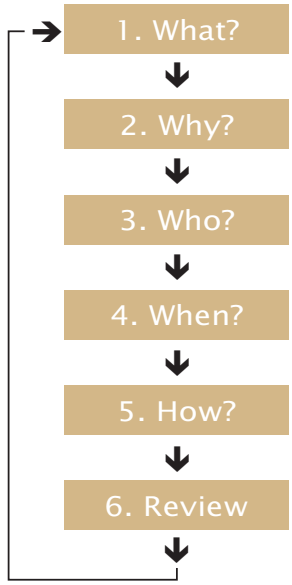
What, when and how will we demonstrate that the project objectives are being achieved?

Site-specific planning

Now that you have selected which sites to manage, the next step is to plan how you will conduct management at your site.

There is no golden rule to management that covers all situations. Planning, therefore, needs to take place on a site-by-site basis just before on-ground activities start.

Although the scale of the works will inevitably influence the complexity of the process, there are at least six basic steps that must be considered for all projects:



These steps are broken down into more detail in the pages that follow, each including the questions you need to answer and the activities you need to consider. Although this might sound complex, in reality many of these elements are basic common sense.

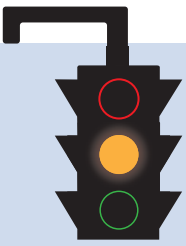
1. WHAT to do?

Before starting willow control works, you need to be clear about exactly *what* you intend to do. For example:

- ☑ What is your vision for the final project?
- ☑ What will success look like?
- ☑ What is the broader context?

  For example, does your regional Catchment Management Authority or Natural Resource Management board have a broad willow management policy or strategic priorities for waterway management?
- ☑ What other programs does your project fit into?
- ☑ What factors may hinder or enable success?
- ☑ What are the indicators you will apply to measure success?
- ☑ What is your monitoring strategy to enable you to learn and adapt management over time? (see Section 4 Site rehabilitation, for more information)

Have you considered?



- Land Tenure – Who actually owns or manages the land you propose to work on?
- Cultural heritage requirements?
- Any permits required/legal restraints (for example, works on waterways, fire management, local planning authority)?
- Revegetation and fencing programs?
- Occupational health and safety requirements?

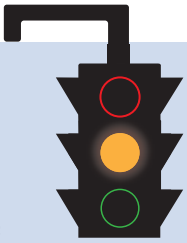
2. WHY manage willows?

This may seem an obvious question, but take time to ask yourself, '***Why*** am I embarking on a willow management project? How do I justify this project?' For example:

- ☑ Is the project based on ***fact*** (addressing a known, specific threat to a waterway) or ***opinion/emotions*** (addressing the broader desire for eradicating weeds and restoring waterways for 'pure' environmental purposes)?

  These are both legitimate reasons. Each, however, will impact on how you plan, implement and evaluate your project and the final outcome that is achieved, particularly communicating your purpose to stakeholders and generating support.

- ☑ Is the project part of a wider strategy for whole-of-waterway management (for example, for fish passage, water quality, fencing for stock exclusion)?



Have you considered?

- What is your capacity for maintaining your site for the next 3 years, 5 years, 10 years and onwards, following initial control works?

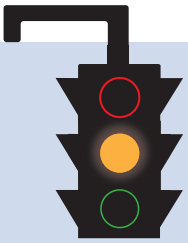
'The purpose of all river management actions is to improve riparian and river health, while safeguarding the environmental, economic and social assets associated with the river environment.'

Goulburn Broken Catchment,
Willow Management Strategy, 2005

3. WHO to involve?

Waterways are often the thread that binds together multiple agencies, community and other interest groups. Willow management works are often controversial and it is therefore vital that you are aware of who these stakeholders are and have a plan for engaging/advising them of your project. Note, for example, that:

- ☑ Landholders, fishing clubs, local government and other government agencies can all assist in the development of your project, by providing advice, resources and positive promotion.
- ☑ A communication strategy is a vital tool for engendering support, promoting your activity and even as a defensive mechanism in the event of negative feedback.



Have you considered?

- Have you developed and initiated your communications strategy?
- Have you got people with the skills to conduct works and maintain the site?
- Do you understand the perspectives of your community, landholders, contractors and investors?

  Be aware: willow removal can result in massive change to the landscape, both physically and aesthetically. It is often very messy in the short-term. This can shock people, even those who might support the project. Do not try to hide this fact, as people will be less surprised in their reactions if they understand that this is a normal part of the process.

'Consistency is crucial – it is important to maintain a set standard when dealing with landholders – everyone should get the same deal and never waiver from that'.

Mal Gibson, West Gippsland CMA

"If you can't be there next year, what are you doing there, now?"

Andrew Ford, Mersey NRM, Tasmania

4. WHEN to conduct the works?

Working on waterways can be highly seasonal. The extended period of a willow management project, from inception to completion, combined with arbitrary administrative guidelines (for example, funding timelines), means that the timing of works needs serious consideration. In particular, consider the following:

☑ Seasonal constraints (too wet, too dry).

For example, access to the site may be restricted during periods of wet weather and different control methods may be effective in different seasons.

☑ Advanced ordering of revegetation supplies.

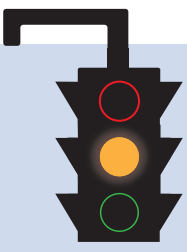
☑ Funding/budget guidelines.

This often conflicts with revegetation activities, as revegetation is often conducted in the spring following the end of the financial year. You may need to talk to your investors about how you can 'carry forward' funding for this activity. Funding, while important, is just one of the tools you will need to get the job done. Be creative and look for other opportunities that can help you achieve the same result, such as getting a Work for the Dole team or volunteer group involved, or gaining funding through carbon offsetting or Drought Assistance.

☑ Timing of farming and landholder operations.

☑ Timing of other neighbouring activities and projects.

It may be cost effective to adjust your timing to match other neighbouring activities.



Have you considered?

- Adjoining land use and tenure may change suddenly. For example, previously cropped land may suddenly be converted to grazing land. This may have a major impact on your project objectives, timing of works or budget (for example, unforseen fencing costs). Maintain regular dialogue with the adjoining land managers to help manage for these changes.

5. HOW to conduct the works?

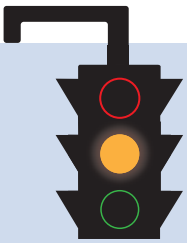
By now, you should be very familiar with the site and the various physical, social and financial constraints that apply. All these factors will combine to help you choose the most successful operational technique. Consider the following:

☑ Contractors?

Many agencies and groups employ contractors to do the willow control works, including tree felling, applying herbicides and removing debris. As there is often little room for error, clear communication and a good relationship with contractors is an important factor in the success of a willow management program. Ensure that contractors fully understand the requirements of the work and have appropriate training and insurance before any quotes are accepted.

Every site is different and may require a variety of control and disposal methods to achieve the most effective results.

See Section 3 Controlling and removing willows and Section 4 Site rehabilitation, for more detail.



Have you considered?

- Bed and bank instability and other potential changes to stream morphology.
- If lopping willows, do not underestimate the size of debris piles and how to dispose of them. this can be time consuming and costly, depending on the location and scale of the site.
- Match the technique to your budget.
- Willow management can be dangerous work, so ensure you have an occupational health and safety plan for each site.

6. Monitoring, evaluation and REVIEW!

Reviewing your project is a fluid process and should be undertaken at regular intervals during the life of the project. It will help to remind you of where you have been, and can help to avoid potential issues in the future. Most importantly, once the works are completed, take a breath and review what you have done, in detail. For example:

- ☑ Have the vision or expectations been met?
- ☑ What changes did you make during the process?
- ☑ What mistakes were made?
- ☑ Can you adapt the technique to better suit your specific purpose?
- ☑ What maintenance schedules will you now put in place, and how many years will you continue to conduct them?
- ☑ Have you considered exactly why you want to control willows and what you aim to achieve in the long term?

See 'Monitoring, evaluation and reporting' in Section 4 Site rehabilitation, for more information.

Additional resources

McNaught, I., Thackway, R., Brown, L. and Parsons, M. (2006) *A field manual for surveying and mapping nationally significant weeds.* Bureau of Rural Sciences, Canberra. (Available free of charge from http://www.affashop.gov.au)

Noonan, M.J. and Chafer, C.C. (2007) A method for mapping the distribution of willow at a catchment-scale using bi-seasonal SPOT5 imagery, *Weed Research,* being published.

Noonan, M.J. and Chafer, C.C. (2006) Comparison of ASTER, SPOT5 and aerial photography for mapping the distribution of willow at a catchment-scale, *Proceedings of the 13th Australasian Remote Sensing and Photogrammetry Conference,* Canberra.

Available for download at www.weeds.org.au/WoNS/Willows:

Holland Clift, S., Ede, F.J. and Wadley, S. (2006) *National Willows Program Resource Kit: Resource Sheets 2, 4* and *5.* Department of Primary Industries, Victoria.

- Willow Resource Sheet 2: Willow Identification, an essential skill for effective willow management
- Willow Resource Sheet 4: Willow and willow sawfly assessment form
- Willow Resource Sheet 5: Willow infestation classes

Section 3

Controlling and removing willows

Controlling and removing willows

Effective control of willows requires planning, resources, skills and appropriate equipment. Before deciding how to control willows, ask yourself again, 'Why am I controlling the willows in the first place?'

Planning, site preparation and rehabilitation

Have you conducted the appropriate planning and site preparation?

Controlling willows can be a very dangerous activity and, if done poorly, may result in more damage than good. Appropriate planning and site preparation is absolutely critical before starting any control activities. See Section 2 Managing willows, for help to plan works and prepare your site.

Before starting any control works, have you determined the appropriate rehabilitation methods?

If you are not planning to rehabilitate your site, why are you controlling the willows in the first place? See Section 4 Site rehabilitation, for more information.

Choosing a control technique

Weigh up the pros and cons

This section outlines a range of techniques to control and remove willows, recommended by a group of experienced practitioners in willow management from across Australia. To determine which of these best match your specific situation, it is important to weigh up the pros and cons of each method, taking into account factors such as site conditions, scale of the project, willow taxa and resources.

Consider your specific situation

To help you to make decisions about management we have provided as much detail as possible on each technique. Even so, how each is applied will be the subject of considerable variation between people and there are many specific situations where you may need to adopt an alternative technique or vary these methods.

Trial and refine new approaches, but don't reinvent the wheel.

This information is by no means prescriptive. It is intended as a guide to help determine the best method for each situation based on current evidence. We need to continue to trial and refine new approaches and promote these to others working on willows across Australia.

There is no, one best method for controlling willows – it all depends on your situation.

Important considerations

When choosing a technique and method of application:

- Choose the method that is appropriate for your situation and level of skills.

  Some of the methods in the following pages are extremely efficient and cost effective, but rely on well-trained and experienced operators to get a good result. The skill level of the operator may be the difference between success and disappointment.

- Carefully consider the advantages, disadvantages and cautions given for each method.

  On-ground practitioners are constantly learning the downsides of methods that were considered 'best practice' in the past. In some cases, these downsides can be difficult to predict and are not seen until many years after control (for example, after severe weather events, such as floods or storms). It is important to keep an open mind and recognise that if it hasn't happened to you, then that doesn't mean it won't.

- Be extremely cautious when applying these techniques to any situation.

  Willow control is a difficult, dangerous and expensive process. Like all waterway management activities, it is best to start small and gradually learn from and adapt your management over time.

- Carefully check relevant policies and regulations in your state or local government area and ensure that you have the necessary permits for operation, such as permits for working on waterways, access to private land, cultural heritage, boat operation, burning, occupational health and safety and chemical use.

  Before starting any willow control operations, you should ALWAYS check and follow any relevant policies and regulations in your state or local government area.

Which method should I use?

When choosing a control method, it is important to weigh up the pros and cons of each method, taking into account factors such as the type, density and size of willows, the site conditions and the conditions downstream.

A detailed check list that will help you to choose the most appropriate control technique is included as Appendix 2. This will also help to provide a sound basis for justifying your decision with landholders, the community and your investors.

Once you have identified potential control techniques from the check list, you will also need to consider:

- negotiations with the community, landholders and investors
- availability of resources, including funding, labour and equipment
- timing of control works
- skill level of operators, and
- potential external inputs to the site, such as seeding willows or willows growing upstream of the site.

Using chemicals

Before using herbicides on willows:

☑ **Ensure the product is registered for the purpose.**

When using herbicides, always read and adhere to the label instructions or appropriate off-label permits. The Australian Pesticides and Veterinary Medicines Authority (APVMA) regulates the registration of herbicides in Australia. The APVMA website (www.apvma.gov.au) has a searchable database of registered chemicals and current off-label permits.

☑ **Consider the proximity to water and the risk of contaminating waterways.**

Herbicides should be used in a way that does not contaminate waterways. See 'Using herbicides near water' in this section, for further information.

☑ **Manage for off-target impacts.**

When poisoning willows, other nearby plants may be affected and the risks of this must be considered and managed where necessary. Even cut-and-paint methods may have off-target impacts, as some nearby trees may have their roots grafted to the willows. When working near rare or threatened species, contact the appropriate flora and fauna officer in your area to confirm whether your chosen treatment techniques are appropriate.

☑ **Ensure that users have appropriate training and safety equipment.**

Anyone using chemicals should have an appropriate training certification for the use of chemicals in your state or territory and should be wearing appropriate safety equipment for the chemical being used, including shirt and trousers (or overalls), rubber boots and gloves. Permits can be obtained following the satisfactory completion of a ChemCert Australia Inc. accredited Farm Chemical Users Course. Contact your local TAFE or other Registered Training Organisation for further details.

☑ **Ensure that you comply with state and/or local government legislation, particularly chemical use, pollution and native vegetation laws.**

Using herbicides near water

Herbicides are to be used in a manner that does not contaminate waterways. Some herbicide formulations are specifically registered for use in aquatic areas. It can sometimes be difficult to distinguish between an aquatic and riparian environment when willows may be growing in both.

If in doubt, use a herbicide registered for use in an aquatic area.

For guidelines on the use of herbicides in and around waterways, refer to:

Ainsworth, N. and Bowcher, A. (2005) *Herbicides: guidelines for use in and around water.* CRC for Australian Weed Management

This fact sheet aims to assist people responsible for riparian and aquatic weed management by providing information and specific recommendations. It is available for download from *www.weeds.crc.org.au/documents/gl01_herbicides_water.pdf*

Always seek site-specific advice if you are unsure of herbicide impacts.

Which chemicals to use?

There are several chemicals specifically registered for controlling willows.

When using herbicides, always read the label

Chemicals are not to be used for any purpose or in any manner contrary to the label unless authorised under appropriate legislation. Before using a herbicide for the control of willows, or any other weed, read and adhere to the instructions and conditions for use on the label. By law, you must read the label (or have it read to you) before using any herbicide product. The same applies for off-label permits. Always follow the label and permit directions.

Further information

For further information on chemicals registered for use on willows, the APVMA website (www.apvma.gov.au) has a searchable database of registered chemicals and current off-label permits.

Seek advice from your local chemicals supplier and always read the label.

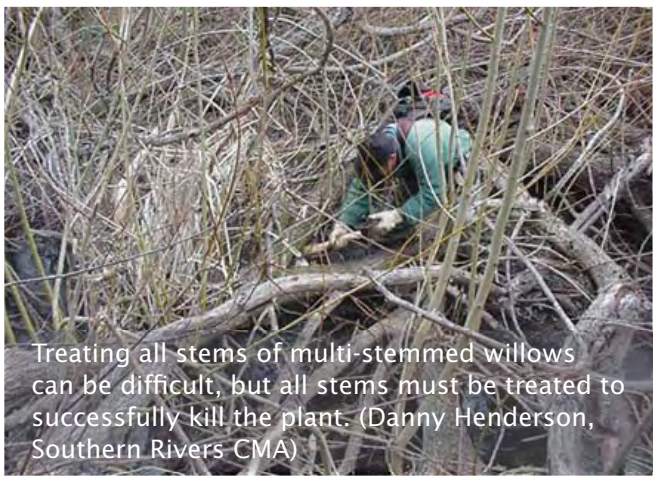
Herbicides currently registered for use on willows

Active Ingredient	States and territories where products are registered for use on willows	Formulation(s)	Application method	Comments
Glyphosate	All states and territories	Aqueous concentrate, soluble concentrate, liquid, suspension concentrate	Foliar application, stem injection, cut stump	Foliar spraying registered for trees < 2m high Some, but not all, glyphosate products are registered for use in aquatic areas
Picloram	All states and territories	Gel	Cut stump only	Not registered for use in aquatic areas
Picloram / Triclopyr	All states and territories	Non-aqueous concentrate (requires mixing with diesel)	Cut stump only	No products registered for use in aquatic areas

What can affect the success of chemical control?

Some potential causes of chemical control failure are:

- ☒ **Time of year** – generally the cut and paint and stem injection methods are effective throughout the year, however, in some areas, people have found the results to be unpredictable in spring.
- ☒ **Timing of application** – if the chemical is not applied immediately (within < 30 seconds) following cutting, the cut may seal up and the chemical will not be effectively absorbed.
- ☒ **Dirty willow leaves** – if leaves are dirty (for example, covered in silt from flood waters), foliar-applied herbicides can be less effective.
- ☒ **Cuts too deep or shallow or too far apart when stem injecting** – when cuts are too deep or shallow or too far apart, the chemical uptake may not be sufficient to kill the trees. The chemical will only be transported through the sapwood, which is just beneath the bark. This can be particularly challenging when working on horizontal limbs or inside the limbs at the base of multi-stemmed willows.
- ☒ **Rainfall or rising floodwaters** – herbicides can be washed off cut stumps or foliage if there are rains or rising floodwaters soon after application.
- ☒ **Not all stems were treated** – although often difficult, all stems in multi-stemmed willows must be treated to completely kill the plant.
- ☒ **Degree of stress** – willows may be under stress due to seasonal conditions and, therefore, not actively transporting fluids (including chemicals) through the trunk.
- ☒ **Clay soil in the cut** – the clay particles may bond with and neutralise the chemical.



Treating all stems of multi-stemmed willows can be difficult, but all stems must be treated to successfully kill the plant. (Danny Henderson, Southern Rivers CMA)

When can I control willows?

Willows can be effectively killed at any time of year, but other site-specific factors should be carefully considered when determining the timing of control works.

The best timing for control works will vary depending on a number of site-specific factors. These may include:

- **The climate** – for example, working in drier conditions and outside fire restriction periods.
- **What you are trying to protect at the site** – for example, conducting control works at times when they will have least impact on vulnerable plants or animals in the area.
- **Other activities being undertaken in your area** – for example, control of other weeds, planting or erosion control works.
- **Risks of soil disturbance, bank damage in wet conditions and risks of floods occurring during works.**

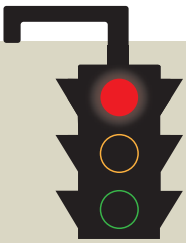
For a long time, people have believed that willow control can only be conducted during spring and summer, when the plants are in full leaf. Experienced willow managers, however, have gradually learned that willows can be effectively controlled at any time of the year if other site-specific factors allow.

West Gippsland Catchment Management Authority has been controlling willows for over 10 years. When they started, they believed that the chemical would only transfer through the plant when it was in full leaf, so they only controlled willows at that time of year. As the demand for control works increased, they started to push the boundary and conduct works further into autumn and winter.

They found that chemical control was just as effective at killing willows during autumn and winter, when the plants were apparently dormant, as they were in spring and summer, when the plants were in full leaf.

Detailed review of control methods

Machinery options



Stop and think!

Before choosing this method, consider:

- Occupational health and safety and WorkCover responsibilities or insurance.
- Potential damage to the river bank and adjacent vegetation by machinery, such as excavators, and how you will manage this.
- Matching the size of excavator to the size and scope of the works, considering the length of reach and lift required and the machine's impact on the river bank.
- The experience of your operators. All tree felling and chainsaw operators should be licensed and experienced with working with willows. Even operators who are very experienced with felling other tree species may need to adjust their techniques with the help of an experienced willow feller.
- How many people you will need for the operation.
- Fire restrictions, as this may mean that you need to defer your operation.
- Where the willows will be felled and moved to (see 'Waste management methods' towards the end of this section). You will need to find and decide on appropriate site/s for your chosen waste management method and prepare these areas appropriately.

Suitable for: Willows greater than 150 mm in stem diameter.

Advantages and Disadvantages: Refer to the table, 'Suitability, advantages and disadvantages of mechanical options', below.

How: There are several variations on these methods depending on your resources, skills and accessibility.

The advantages and disadvantages of each of these methods should be carefully weighed up against each other. Thorough planning is required to ensure a safe and effective job is conducted, with minimal impact to the river bank.

The main mechanical options include:

a. Excavator plus tree feller with chainsaw

- A qualified tree feller cuts the trees in situ using a chainsaw and immediately paints or sprays the sapwood layer of the stump with chemical.
- An excavator lifts the willows and stacks them into tightly woven piles above the flood level.
- In some cases, mesh litter fences / booms are erected across the waterway to catch twigs and branches floating away from the site.
- Material out of reach of the excavator (for example, mid-stream willows) may need to be dragged into reach, before lifting onto the stock pile.
- The banks are raked with a stick rake mounted on the excavator and then hand raked to remove all remaining willow material.

b. Excavator with a built-in grabber, chainsaw attachment and poison applicator

- An excavator prunes the trees in a top-down fashion and places the material on a heap behind the machine for processing or burning.
- Once pruned, a final cut is made to the main trunk and the poison is immediately applied, preferably with the spray nozzle visible from the operator's cabin.
- In some cases, mesh litter fences or booms are erected across the waterway to intercept downstream movement of twigs and branches.
- The banks are raked with a stick rake or environ comb attached to the excavator grab, before moving to the next tree.

c. Tree feller with a chainsaw and team to manually cut up and stack material

- Works are planned so that there is a significant distance between the feller/s and people clearing up and feeding fires.

  Note: *Burning is often the only waste management technique available for this method, as other techniques require machinery to move the material. See 'Waste management methods' towards the end of this section.*
- A qualified feller cuts the trees in situ using a chainsaw and paints the sapwood layer of the stump with chemical.
- Chainsaw operators cut the material into small pieces that can be moved manually.
- Other workers collect the material (starting with the smallest branches first), pile it into heaps and burn immediately.
- The site is raked and all pieces are picked up and placed on piles for burning.

  Note: *If you are unable to burn immediately, you may need to consider using a different control method.*

d. As per a) – c) but plants are first poisoned, via stem injection, 2-3 months before their removal

- Trees are stem injected (see 'Stem injection and leave standing' later in this section, for possible techniques).
- Within 2-3 months after stem injection, machinery is used, as per a) – c) above, to remove and manage the material.

Caution: Method d) must only be used where you are able to return to the site within 2-3 months following treatment. There have been many situations where works have been delayed (for example, due to seasonal conditions or funding issues) and willows have been left standing for too long. If willows are left too long following stem injection, they can become brittle and dangerous and pose a hazard to operators or others passing by. In particular, old trees with a hollow or rotten centre (which may not be obvious when looking at it) can be very prone to falling over or breaking.

An excavator working with 2 fallers with chainsaws is generally the preferred method for mechanically cutting, painting and removing willows. (Sarah Holland Clift, DPI Victoria)

Suitability, advantages and disadvantages of mechanical options

These should be carefully weighed up before selecting a control method.

An excavator working with 2 fallers with chainsaws is generally the preferred method for mechanically cutting, painting and removing willows. (Sarah Holland Clift, DPI Victoria)

Specialised excavator heads can cut and apply herbicide in one action. (DPI Victoria)

Occupational health and safety is a major issue when felling willows. (DPI Victoria)

If poisoning prior to removal, trees must be cut down within 2-3 months following treatment. (DPI Victoria)

Method	Suitable for
a) Excavator plus tree feller with chainsaw	Sites with access for machinery. Areas where there is significant risk to infrastructure or people if willows are left standing.
b) Excavator with a built-in grabber, chainsaw attachment **or** **grapple (forestry) shear and poison applicator**	Sites with access for machinery. Areas where there is significant risk to infrastructure or people if willows are left standing.
c) Feller with a chainsaw and team to manually cut up and stack material	Situations where there is little or no money for the work, but substantial, free labour available (for example, Landcare groups, Work for the Dole). Working in sensitive environments where there is no access for heavy machinery.
d) Poison prior to removal	Areas where there is a significant risk of damage to downstream infrastructure or risk to people and property. Sites you are confident you can return to within 2-3 months of poisoning, to remove trees.

Advantages	Disadvantages
Allows you to cover large areas and handle large weights, thus reducing labour and manual handling. Less impact on the bank, as the excavator (if it is large enough) can lift branches, rather than dragging them. Useful for problem trees that would otherwise be dangerous to fell, as it can manage willows on uneven or sloping ground or terrain.	High cost and requires licensed operators. Machine hire will be expensive compared to the chainsaw operator and other staff, so to get the best value for your dollar, you should balance your resources to keep the excavator working continually. Weight and vibration can cause soil disturbance on the river bank. Requires access for heavy machinery (for example, gates, bridges, cattle grids). Can be very messy. Risk of twigs or pieces being pressed (planted) into ground by machinery. Risk of downstream colonisation from fallen twigs or pieces. Occupational health and safety needs to be given high consideration with machinery and on-ground operators working on the same site. As the percentage of native vegetation increases, the machine has to work slower to preserve the surrounding native vegetation.
For suitable willows, the excavator can complete the entire operation without the need for additional fellers or poison applicators. Reduces the risk to people on site, as no one is required to stand under the willows or near machinery. Some machines have a poison system with the spray nozzle visible from the operator's cabin for application immediately after cutting. Some machines have a grab and cutter bar that rotates through 360 degrees, enabling them to harvest willows of all sizes and shapes.	High cost and requires licensed operators. Generally slower than method a), as multiple cuts are required. Lacks a degree of flexibility as, without a rotating head, it can be difficult to adjust the grab to deal with whole willows (for example, multi-stemmed trees and shrubs). May only be effective at removing the upper branches, with a chainsaw feller still needed to fell the main trunk. Requires access for heavy machinery (for example, gates, bridges, cattle grids). In some regions, the machinery required is not commonly available. If a machine-based poison applicator is used, it can be difficult to see if the chemical has been sprayed effectively onto the trunk. A chainsaw operator may still be required to fell trees out of reach of the excavator. A second excavator may be needed to help clean up the site.
Cutting willows into smaller-sized pieces and dealing with smaller areas at a time makes it easier to clean up sites. Removes the risk of twigs or pieces being pressed (planted) into ground by machinery.	Slow and very labour intensive; more on-site planning and preparation will be needed before felling. Much more precise felling techniques are required, compared with machinery. Some willow trees cannot be safely felled without machine assistance and it is not feasible to operate chainsaws on difficult terrain. It is difficult to judge the tension in willows; saws will become jammed, even by very experienced operators. Waste material has to be dealt with almost immediately, as it is often too difficult to manually move it out of the potential flood zone. The wood piles created are more prone to dispersal during floods than large, tight piles created by machinery. Manual handling means that occupational health and safety becomes a major issue. Access to the amount of labour required is not always possible or cost effective.
Reduced risk of regeneration from stem fragments left behind after operation. Wood hardens in first 3 months, making it easier to cut down. Dead timber can be burned immediately as it is piled, if not prevented by fire restrictions.	The overall cost of control (stem injection then felling later) can be greater than cutting the tree down green. Not appropriate for shrub willows, such as grey sallow (*S. cinerea*), due to their many stems – consider stem injection and leave standing. Site must be revisited within 3 months following stem injection to remove the material. If the project is delayed and trees are left standing too long, trees can become very brittle, hard and unpredictable, posing a problem to operators and chainsaws when felling. Dead trees may cause log jams in flood events, posing a significant infrastructure risk (for example, to bridges and fences). If stem injecting does not completely kill the tree, it may become extremely difficult to kill later. Timing of revegetation, fencing and follow-up control works may be more disrupted than if cutting the tree down green. Need to monitor and evaluate any changes in the risk to the public or infrastructure.

Left: An excavator making light work of willow removal. (DPI Victoria) Right: A long-reach excavator is useful where access is difficult. (Melbourne Water)

Types of machinery

"Newer machinery is often much faster than old machinery, which can help to speed up operations and reduce costs. Good machine operators lift material whenever possible to minimise drag."

Mal Gibson, West Gippsland CMA, Victoria

Using machinery to remove willow branches and stems can speed up willow control where there is suitable access. Machinery used in willow removal operations includes:

Excavators

Excavators are often the preferred machinery for use, as they can lift and therefore minimise the need to drag material. Dragging willows can cause significant damage to banks and result in many branches breaking off that will need to be picked off the site.

When choosing an excavator it is important to consider:

- the length of reach needed for the job (i.e. length of boom)
- the pressure of the excavator on the river bank (i.e. the weight of the machine and the width of tracks), and
- the type of head on the excavator.

An excavator with a log grab or claw that closes from 2 sides (commonly used in forestry) is generally the preferred option for removing willows. Other variations include a bucket and thumb (an ordinary grab bucket with a hydraulic attachment) and a 4 in 1 (commonly used on front-end loaders and back hoes).

"Use excavators around 20 tonnes or more. The long reach is important as less movement is required, which helps to reduce soil compaction in the riparian zone."

Andrew Ford, Mersey NRM, Tasmania

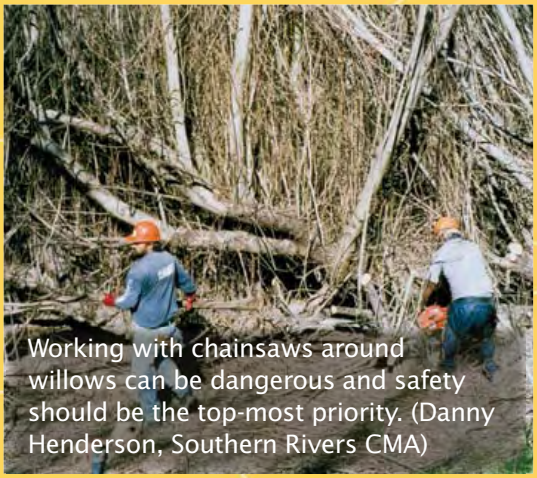
This excavator has a specialised head so that cutting, herbicide application and removal can be done in one operation. (DPI Victoria)

Chainsaws

"A professional and experienced chainsaw crew is vital for safe and effective felling of willows."

Tim Cox, Consultant / Project Manager, Central New South Wales

Willow trees should only be felled by professionals. If using chainsaws, an 18-inch bar is normally required. Chainsaw operators require a chainsaw operator's licence (contact your local



Working with chainsaws around willows can be dangerous and safety should be the top-most priority. (Danny Henderson, Southern Rivers CMA)

Willows should only be felled by professional and experienced chainsaw operators. (Danny Henderson, Southern Rivers CMA)

TAFE or other registered training organisation for further details). Working with chainsaws around willows can be particularly challenging because of the multi-stemmed habit and brittle nature of many willows and the unsafe site conditions in many situations.

"Crack willows have unusual timber pressures and can be extremely dangerous and unpredictable. It is critical that correct felling techniques are used. Always have several chainsaws and multiple people on site for safety as, even with the correct technique, saws can be jammed."

Andrew Ford, Mersey NRM, Tasmania

Rubber-tyred skidder/front-end loader

Since excavators have become more advanced (with the inclusion of hydraulic systems), rubber-tyred skidders have become a less-preferred option for willow management. Rubber-tyred skidders are primarily used for winching and are most efficient when there is an excavator working with them to rake and prepare the material. Skidders are mainly useful when controlling willows in areas where an excavator cannot reach (for example, in the middle of a channel), or where the distance to the stockpile is long (for example, more than 100 m). They are less stable than excavators and are not appropriate for use on multi-stemmed trees or shrubs, such as crack willow or grey sallow.

Tractors

Tractors with suitable attachments such as a front-end loader, 4-in-1 bucket, root rake and winch and chains can be used for manoeuvring logs and trash into stockpiles. This may help speed clean-up operations. Excavators, however, are generally preferred for clean-up operations, as they can lift the material and therefore minimise impacts caused by dragging material, such as damage to river banks and branches breaking off.

Tractors can speed up clean-up operations. (Melbourne Water)

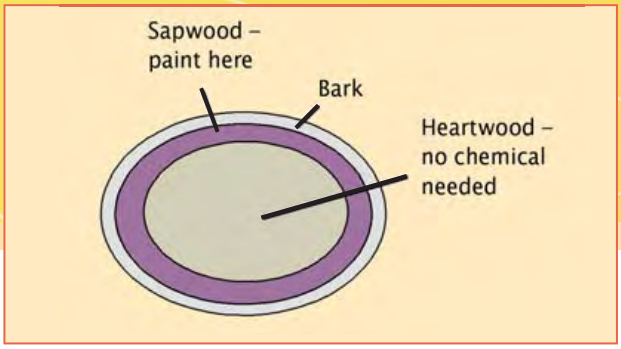
Skidders are primarily for winching and may be useful if the distance to the heap is long (for example, more than 100 m). (DPI Victoria)

Chippers and grinders

Chippers and grinders can be used for mulching willow material, but this can be expensive and the amount of material that will be produced should never be underestimated. See 'Waste management methods' towards the end of this section, for more information on mulching.

Caution! Care should always be taken when using machinery along river banks, as significant damage may be caused.

Cut and Paint: Paint the sapwood only



Non-machinery: Cut, paint and remove

Stop and think!

Before choosing this method, consider:

- Occupational health and safety issues. For safety, people should work outside the arc of the tool being used. This can be easy to forget in this type of small operation, but it is particularly important if using a brush cutter with a chainsaw disc.
- Where to apply the chemical. For plants with a stem diameter greater than 10 mm, chemicals need only be applied to the sapwood (just beneath the bark).
- How will you capture and remove any smaller branches that may break off in the process of removing a larger branch?
- What will you do with the material once it has been removed? (See 'Waste management methods' later in this section for more information). Before cutting limbs and seedlings, be sure you have somewhere to place the debris where it can dry out over the next six to eight weeks and not be swept away in the next rise in the river or take root and grow.


A range of equipment (Willow Warriors Inc.)

Suitable for:

- use on plants up to 200 mm in stem diameter.

  Note: *The methods included here are not all strictly 'non-mechanical', as they also include the use of brush cutters and limbing chainsaws.*

Advantages:

☑ By cutting the stems, it is easier to identify any stems that have not been treated.

Debris can be removed from the flood-prone area, thus preventing the risk of damage to downstream infrastructure caused by large amounts of smaller debris.

Disadvantages:

☒ Requires easy access to a location where offcuts can be placed outside the flood-prone area to dry out for at least 6-8 weeks. This may mean carrying offcuts some distance from the site, which can significantly slow down control works.

How:

1. Limbs and seedlings are cut as close to the ground as possible with a horizontal cut, to avoid spikes or tripping hazards.
2. Chemical is applied to both the trunk and cut stem to reduce the risk of re-sprouting.

   Note: *For stems less than 10 mm, chemical is applied to the whole cut. For stems greater than 10 mm, chemical is applied just to the sapwood layer (just beneath the bark).*

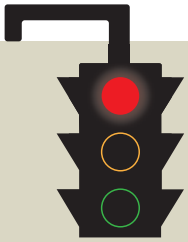
If working near water, a method is needed to capture and remove smaller debris that may break off larger branches.

The equipment that you choose will generally depend on the stem diameter of the willow.

Stem diameter	Recommended materials
10 mm	Secateurs
Between 10 and 20 mm	Loppers
Between 20 mm and 50 mm	Bush saw, folding saw, brush cutters or long-handled forestry loppers (preferably the hooked by-pass style, rather than the anvil type).
Between 50 and 100 mm	Heavy duty brush cutter using a circular blade with chainsaw teeth riveted to it – this has the advantage of operators being able to stand rather kneel when working.
Up to 200 mm	Small limbing chainsaw with a 300-400 mm bar.

Stem injection: Cut to the correct depth
(Water Wise No. 3: Exotic trees along waterways. Mount Lofty Ranges Catchment Program and Environment Protection Agency, Department for Environment, Heritage and Aboriginal Affairs, Government of South Australia)

Stem inject and leave standing



Stop and think!

Before choosing this method, consider:

- Public liability issues or the potential risk of damage to downstream infrastructure in floods. A thorough risk assessment should be conducted before considering this method, to determine if it is safe to leave the willows standing, once dead, to rot down over time.
- Appropriate personal protective equipment (PPE), including gloves to protect the hands from chemical and glasses to protect the eyes from accidental splashes or being poked by twigs or branches.
- Mixing a dye with the chemical so you can easily see where it has been applied or spilt.
- The number of people required. Low-skilled operators can work in pairs, with one person chiselling and the other injecting the chemical and then rotating tasks to reduce the risk of repetitive strain injury (RSI).

Suitable for:

- Isolated trees and scattered stands in difficult-to-access areas where there is low risk to people, property and downstream infrastructure.
- Grey sallow (*S. cinerea*) and other taxa in swamps, spring soaks, wetlands or billabongs, or in areas where willows are spreading through remnant vegetation and where there is no appropriate access to machinery.
- Willows with less than 100 mm diameter trunks in difficult-to-access locations.
- Areas where use of machinery or mechanical removal may cause damage to surrounding remnant native vegetation.

Advantages:

☑ Lower cost than other methods, as willows are treated in one operation and no waste removal is required.

☑ Reduced risk of regeneration from stem fragments left behind after operation.

☑ Can be used by low-skilled operators, as the tools are simple to operate, easy to maintain and are associated with lower risk of injury.

Disadvantages:

☒ Can be unsightly to see dead willows left standing.

☒ Risk of damage to people, property or downstream infrastructure.

☒ Larger trees with thick bark can be difficult to treat with this method.

☒ Can be difficult to stem inject horizontally growing limbs.

It is often easier to cut, paint and remove the limb, rather than stem inject. If you choose to stem inject, ensure that you make cuts in the bottom of the limb, and be aware that you will be cutting with the grain and thus a longer split will be made.

How:

Trees are stem injected and dead trees are left standing to eventually break down and decay. There are various methods of doing this, depending on the equipment that is used. These are outlined in further detail in the table, 'Application of stem injection methods using different types of equipment'.

For all methods a) – d) (outlined in the table, 'Application of stem injection methods using different types of equipment' on the following page):

1. Trees are stem injected around the entire stem or trunk and underneath the lowest shoot or branch, ensuring that cuts or drill holes are:
   - **a maximum of 2-3 cm apart** – if a wider gap is left, the plant can survive on this sap stream
   - **horizontal** – to avoid the chemical from pouring out one side of the cut
   - **at an angle of 45 degrees down into the white sapwood** – if the notch is too deep or too shallow the chemical may not be absorbed into the sap flows (see 'Using chemicals' on earlier in this section, for more information) and
   - **clean of mud or soil** – as clay particles can bond with the glyphosate and neutralise it.
2. Chemical is applied within 30 seconds (and within 10 seconds, where possible) to improve the chances of successfully killing the tree.
3. Where there are forks in the limb close to the ground, the inside of each fork is treated.
4. The site is monitored 6-8 weeks later to re-treat any surviving limbs – if parts of the plant have survived, the sapwood will still be white.
5. Dead trees are left standing to fall and break down naturally, unless regular monitoring and review indicates that further action is required to manage the debris.

Application of stem injection methods using different types of equipment

Method	When to use	Limitations	How
a) Chisel and mallet	Easy for low-skilled operators, as tools are low-tech and low maintenance. Note: for low-skilled operators, a 250 ml applicator bottle is often better than an injection pack. If you have large numbers of willows on one site, however, a well-maintained injector pack is more efficient.	There is a risk of applying too much chemical and spilling it over the applicator bottle or gloves – to avoid this, ensure that the hole in the applicator nozzle is no more than 2 mm in diameter.	Holding a 25 mm wide chisel at 45 degrees to the stem, use the mallet to cut a horizontal notch downwards into the white cambium layer of the trunk or stem. Push the chisel down to open the cut and then pull it out. It is important the notch is made downwards and horizontal to hold the chemical in. Inject 2 ml of undiluted chemical into the cut, from either an injector pack or a 250 ml applicator bottle.
b) Axe and injector pack ***Note:*** *For multi-stemmed willows, where you need to get in tight between limbs, use a chainsaw instead of the axe.*	Allows the operator to work independently, with the axe or tomahawk in one hand and injector gun in the other. When used by trained operators, can be much faster than the chisel and mallet method. The injector pack allows the operator to set the amount of chemical to be applied.	There is more risk associated with swinging an axe or tomahawk than using a chisel and mallet. The main risk is of the axe deflecting off the limb and hitting someone, particularly with an inexperienced operator. Injector pack requires daily cleaning and oiling of seals and injectors to prevent leaks. Injectors with glass cylinders need to be protected from breakage.	Use the axe or tomahawk to cut a notch at 45 degrees to the stem and apply 2-5 ml of undiluted chemical (as the cuts are larger than if using the mallet and chisel).
c) Cordless drill and injector pack	Most effective for large trees with thick bark, horizontal limbs and limbs growing close together.	Only practical where batteries can be recharged each night and 5 or 6 spare batteries can be carried with the operator, as batteries only last for about 90 minutes each. Small drills are ineffective.	Drill a hole across the cambium layer rather than into it, to reduce the number of drill holes and chemical needed.
d) Scrap and paint	On small, scattered seedlings where it would be difficult to avoid off-target damage from foliar spraying. To follow up small areas of regrowth at stem injection sites. On seedlings up to 2 cm in diameter that cannot be hand pulled and where it is difficult to find a dry place to leave cut stems (for example, willows growing in the bed of a river with steep or muddy banks). On willows with branches growing up out of the water (including wetlands).	Labour intensive; area needs to be checked thoroughly, as stems are small and may be difficult to detect until a follow-up visit.	Using the edge of any tool (chisel, secateurs or axe), scrape 20 mm off the green bark down to the white cambium layer and smear chemical along the scrape. For stems over 1 cm in diameter, apply to two sides of the stem.

"To reduce any potential risks to people from leaving willows standing, we place signs near access points to the river, warning people that willows have been treated and may fall at any time."

Jeff Cottrell, Friends of the Colo Inc., New South Wales

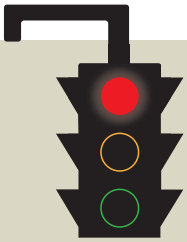
Can large willows be controlled without using chemicals?

Most willows will coppice profusely after they are cut down. A small amount of chemical applied to the stump will help prevent this. If, however, you are determined to control willows without using any chemicals:

1. Lop as close to the ground as possible.
2. Split trunks with an axe to let decay organisms in.
3. Follow up in 6-8 weeks to remove any new shoots.
4. Split trunks with an axe again.
5. Follow up again, by removing any new shoots.
6. Repeat steps 4-5 again and again and again, until no new shoots emerge.

Any attempt to control willows without using chemicals needs to be done with the recognition that a very large labour input over a long time period will be needed to achieve successful results.

Foliar spray and leave (seedlings up to 2 m)



Stop and think!

Before choosing this method, consider:

- The potential for spray to drift and cause non-target damage. This may be reduced by reducing the pressure on spray units to produce a bigger droplet size.
- The information outlined in 'Using chemicals' earlier in this section.

Hand pulling a willow seedling along the Queanbeyan River. (Sarah Holland Clift, DPI Victoria)

Suitable for:

- Willow seedlings under 2 m high, particularly in areas with numerous seedlings, where hand pulling is not possible and debris control and aesthetics is not an issue.
- Regrowth from cut stump method.

Advantages:

☑ Low cost, as large numbers of willows can be treated in a short period of time.

Disadvantages:

☒ Risk of non-target damage.

☒ Generally restricted to spring and summer, when foliage is dense.

☒ Silt on leaves from recent floods may affect the uptake of the chemical.

Caution: Do not spray directly over the water body.

How:

1. Registered herbicide is sprayed onto foliage to run off, using a backpack sprayer or handgun applicator.
2. May be conducted with the assistance of a helicopter, 4 wheel drive vehicle, quad bike, boat or amphibious vehicle, each with a spray unit attached.

Hand pulling

Suitable for:

- The control of small seedlings and rooted fragments (up to 2 years old).

☑ Hand pulling is a simple and effective approach for controlling small willow seedlings and rooted fragments while they are still small.

It is generally only possible to hand pull seedlings in their first one to two years of growth, so early detection and control of new willow growth is essential.

Willows often encroach into or overhang the water so it may be necessary to use a herbicide registered for use in an aquatic area. (Sarah Holland Clift, DPI Victoria)

Controlling willows growing in water

Trees growing in water are notoriously difficult to kill, however effective treatment is possible.

Willows in the water can be treated using stem injection, by applying chemical to the base of the tree (where possible) and to the limbs where they emerge from the water.

Where branches are growing through the water and have grown root masses:

1. Lift the branch out of the water.
2. Cut off the root mass and apply chemical to the branch still attached to the main tree (note: the chemical must be registered for use in aquatic areas).
3. Hold the branch out of the water for 30 seconds after applying the chemical and then let it fall back into the water.

Always use a chemical registered for use in aquatic areas

To ensure success, you should return to the site within six to eight weeks to re-treat any surviving limbs. Leaves on branches that are less than 2 m high may also be foliar sprayed after the taller limbs have been treated by stem injection. These branches may also require re-treatment.

Where the water or mud is deep, the use of boats is recommended to get around and treat waterside limbs. Inflatable boats with heavy-duty plastic, to reduce the chance of punctures, are preferred, as operators can slide comfortably on the ends or sides of the boat rather than having to work out of the solid hull of a canoe or kayak and risk over balancing. Waders may also be used, but are more dangerous and require more effort than working from a boat.

Note: *Waders can cause drowning if the operator falls over in deep water and the waders fill with water. If choosing to use waders, ensure that all people wearing waders receive adequate safety training and that there are people on shore watching and ready at all times to respond to any emergencies.*

Other control methods

Removal of whole tree 'roots and all'

When willow control works were first begun, removal of the entire tree, roots and all, was common practice. In many cases, this has caused significantly more damage than it alleviated by destabilising banks and leaving them prone to erosion. It has also turned landholders and the broader community against willow removal in some areas. In some cases, removal of the entire willow may still be warranted, for example, where the willow stump or root mat will continue to cause a mid-stream obstruction, flow deflection or channel shallowing.

Removal of the whole tree is not recommended unless you plan to completely change the structure of the water course.

As the roots take time to decay, they may provide a degree of erosion protection until the site can be rehabilitated.

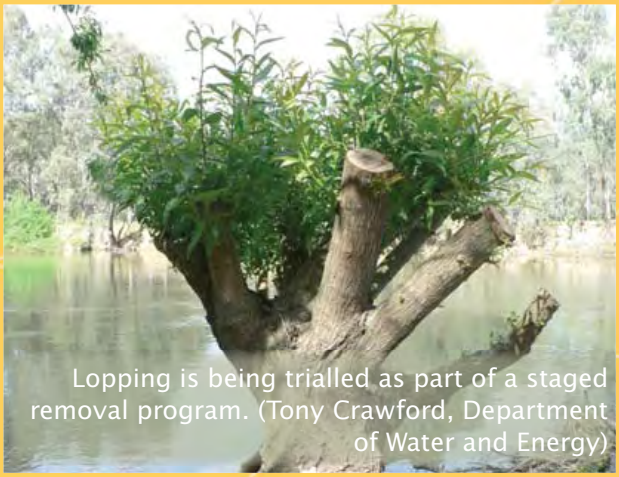
Developing new techniques

The staged replacement of willows

A large-scale riparian native revegetation program has started along the upper reaches of the Murray River around Albury-Wodonga, but is being impacted in places by the presence of dense stands of willows.

There is a major concern that, if the willows are totally removed and replaced with native seedlings, further bank erosion will occur and the native seedlings will be lost before they reach maturity.

This has led to a staged replacement program of willows to natives. This involves keeping the willows alive so that they can still perform some function of erosion control, until the native plants have matured. Removal and maintenance of parts of the willow canopy is important to allow better light conditions for the emerging native seedlings.



Lopping is being trialled as part of a staged removal program. (Tony Crawford, Department of Water and Energy)

As the rate of willow canopy regrowth is rapid, compared to native seedling growth rates, a maintenance lopping program is required. This may be needed every second year at each site, until the native vegetation has matured.

To determine the best ways of retarding the rate of regrowth of willows following lopping, trials are currently being undertaken by the Murray River Works Unit of the NSW Department of Water and Energy. These trials are investigating ways of lopping just the landside branches and treating these lopped branches to minimise coppicing.

Once the native vegetation has established well enough to assist in the control of stream bank erosion to an acceptable rate, the willows are then killed by stem injection. Only small lengths of stream bank (less than 200 m) will be done this way, so as to minimise potential willow debris issues.

It is hoped that this method will allow willows to help control erosion until native vegetation has established, while requiring low maintenance in terms of lopping and having minimal impact on the establishment of the native seedlings.

For further information or to discuss your ideas, contact River Works Unit, NSW Department of Water and Energy, Albury, Ph 02 6024 8880.

Biological management of willows

Willows have not yet been declared a target for biological control and no biological control agents have been deliberately introduced for willows in Australia. Overseas research, however, indicates that biological control has great potential as a willow management tool. To help protect the current investment being made in willow management, biological control is currently being investigated (Adair *et al.* 2006). Further investment in biological control, however, still needs to be secured to enable this work to progress further.

It is important to remember that biological control will never eradicate willows and will always need to be integrated with the above control methods.

Willow sawfly

The recent arrival of the willow sawfly (*Nematus oligospilus*) into Australia has sparked much interest from both willow managers and the community. It is unclear how willow sawfly arrived in Australia, but it was not deliberately introduced. The larval stage feeds on willow leaves and large populations of larvae can defoliate adult willow trees.

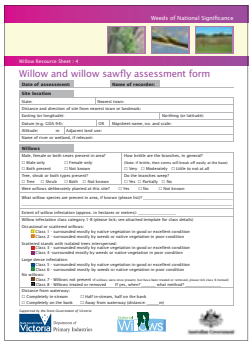
The sawfly is now widespread across New South Wales, Victoria and eastern South Australia. It is not yet known how sawfly will affect willows in Australia. It is possible that a mixture of outcomes will occur across Australia, with some areas experiencing significant impacts from willow sawfly, and other areas not impacted to any significant extent.

Do not become complacent about management just because sawfly is present.

It is important to still continue using other control techniques to manage willows in areas where sawfly exists, as it may not have any significant impact on willows in many areas.

Research is currently under way to understand the potential impacts of sawfly and to help develop a broader range of willow management options than is now available.

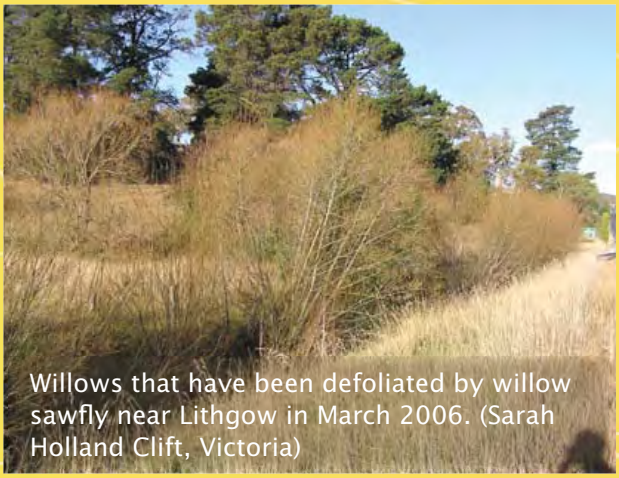
For further information on the willow sawfly, refer to the: *National Willows Program Resource Kit, Willow Resource Sheet 3: Willow sawfly (Nematus oligospilus).* This is available for download at www.weeds.org.au/WoNS/willows.


Weeds of National Significance

Willow Resource Sheet – 4

Willow and willow sawfly assessment form

Willow sawfly larvae. (Sarah Holland Clift, DPI Victoria)



Willows that have been defoliated by willow sawfly near Lithgow in March 2006. (Sarah Holland Clift, Victoria)

Waste management methods

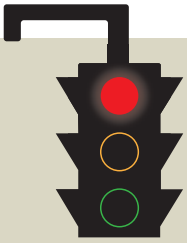
Do not underestimate the scale of the waste produced

Willow removal activities produce an enormous amount of material that needs to be managed. Responsible management of debris is critical to avoid re-growth from fallen branches and potential debris issues in flood events. Further research is required to come up with new waste management methods that can deal with large amounts of willow material.

Currently, there are only a few waste management methods available, which include:

1. **Piling and burning**: The most widely used method of removal.
2. **Mulching**: More expensive than burning and generally limited to urban areas and the removal of small infestations.
3. **Feed to stock, furniture and firewood**: Of limited use for very small amounts of willow material.

Piling and burning



Stop and think!

Before choosing this method, consider:

- Burning control measures and fire restriction periods. You should strictly adhere to 'burning' control measures specified by the relevant local government or state authority, particularly during fire restriction periods and on 'smog alert days'.
- The policies and regulations for burning in your state and local government area. In particular, advise your local government fire officer and CFA of your proposed activity, time of operation and location.
- The potential for smoke and ash pollution to affect nearby population centres.
- The risk of debris becoming a hazard to boating and infrastructure if moved in flood waters.
- The risk of fire spreading and threatening houses, infrastructure and nearby vegetation.
- Access to adequate fire-fighting equipment (for example, a water pump and hose, knapsack, bucket and rake hoe), in case of spot fires caused by sparks.

Advantages and Disadvantages of Piling and Burning

Advantages	Disadvantages
Reduced costs, as disposal is conducted on site.	Pollution
Reduced risk of regeneration from debris.	Risk of debris becoming a hazard to boating and infrastructure if moved in flood waters.
	Risk of fire spreading and threatening houses, infrastructure and nearby vegetation.
	Limited time period available, due to fire restrictions in many areas.
	Suitable machinery is required on site to stoke the burning piles.

Using an excavator to stack willow material, ready to burn, in West Gippsland, Victoria. (Sarah Holland Clift, DPI Victoria)

Working in remote environments: *S. cinerea* (grey sallow) on the Wingecarribee Swamp cannot be burned, so cut stems are painted with chemical, to prevent regrowth, and piled to gradually break down naturally. (Sarah Holland Clift, DPI Victoria)

Piling and burning is generally the preferred waste management method for willow material, because:

- It is cheap and simple, compared with mulching.
- It creates space for revegetation and fencing activities.
- The risk of regeneration from willow debris is reduced.
- It leaves a clean site, clear of debris that looks more aesthetically pleasing.

How to pile and burn?

1. Stack the material in tight piles on high ground, preferably outside the flood zone.
   a. If it is not possible to stack piles outside the flood zone (in some cases, the flood zone can be over 6 km from the river), use common sense and ensure that the material is stacked out of the creek bed and outside revegetation and fence lines.
   b. Stack piles tightly by intertwining branches into the heaps to resist break up in flood waters. Smaller heaps are more efficient and reduce travel times for excavators. Build the heaps by first placing small, dead and dry timber at the bottom and then larger logs on top.
   c. Stacking piles tightly is critical to help prevent material from breaking up and causing significant debris issues during flood events.
   d. With logs over 600 mm in diameter, run a chainsaw cut one third of the way through the log, at metre intervals along the log. This allows the heat to drive out any remaining moisture and allows fire to rapidly penetrate into the log.
2. Allow the piles to dry (for up to 6 months if possible, depending on climate and site conditions).
3. Burn on site.

   Note: *Burning material before it has completely dried can create significant amounts of ash and smoke pollution. Unburnt piles within the flood zone, however, can create significant debris issues in flood events, particularly if they are not stacked tightly enough.*

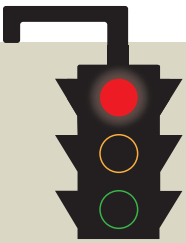
Work for the Dole crew stacking willow material by hand, ready to burn, near Blessington, Tasmania. (Sarah Holland Clift, DPI Victoria)

Working near towns or in urban areas

Smoke pollution and the risk of fire to nearby houses, infrastructure or vegetation, means that burning is often not an option in highly populated areas. An alternative is to truck the material off site and out of town to burn it. If cost is the major factor, it is still often cheaper to carry the material out of town to burn, than to chip the material on site.

If burning is not an option, consider mulching as an alternative, particularly if works are small scale and there is a use for the mulch on or near the site (for example, in a caravan park).

Mulching



Stop and think!

Before choosing this method, consider:

- Mulching creates a huge amount of material that needs to be managed. The material needs to be placed somewhere and often this is at a significant cost.
- Is there a local use for the mulch?
- At larger scales, the mulching process is extremely resource and plant intensive.
- In urban areas, it is generally still cheaper to truck the material off site and out of the town to burn, than to mulch.
- Good access to the site is required.
- Compost heaps have been known to spontaneously combust, on occasion.
- Mulch from willows has been known to regenerate if not chipped small enough, so regular follow up is essential.
- The risk of rogue willow chips flying from the chipper and hitting people nearby.

Willow wood can be chipped on site and reused as mulch. It can be expensive however, and must be chipped finely (<15 mm diameter) to minimise the chance of pieces re-shooting.

The wood should be chipped to the smallest size possible (<15 mm diameter) to prevent the chips from regenerating.

How to mulch?

Large-scale operations require:

- A truck with a tub grinder on the back.
- An excavator fitted with a grab attachment for feeding the tub grinder.
- If leaving the mulch on site, a wheel loader to move the chips.
- If transporting the mulch off site, truck tippers to carry away the material – you will be surprised at how much material is created and, therefore, how many truck tippers you will need!

Some contractors with large tub grinder set ups may provide their own excavator and operator to conduct both the willow control and disposal activities. Before engaging a tub operator, ask for the tub grinder specifications (for example, the maximum log diameter and length it will process) and ensure that they meet your needs.

Small-scale operations require:

- A trailer-type chipping unit (these can be hired from many municipal shires) towed by the truck that receives the chips.
- People to feed the unit by hand, for willow limbs smaller than 100 mm diameter.

Advantages and Disadvantages of Mulching

Advantages	Disadvantages
Reduced transport costs (compared to removal of trees) and reduced costs of buying mulch if used on site. Mulch will help in site rehabilitation – a good 10 cm-thick layer will help to reduce weed invasion and therefore reduce the cost and effort required in revegetation. Less pollution than burning.	The cost of mulching operations can be substantial. Good access to the site is required. Mulch could wash into rivers after a flood and cause pollution. Compost heaps have been known to spontaneously combust, on occasion. Mulch from willows has been known to regenerate – this must be monitored!

Other waste management methods

Feed to stock

Willow material left after removal operations may be fed to stock or other animals. Research from New Zealand suggests that the feed value of willows is 65-70% dry matter digestible, which is about the same as lucerne hay. Willow leaves are also high in protein, zinc and magnesium, which are important elements for animal health. Sodium (salt) levels can be low, however, so if little or no pasture is available, a salt block may be also needed.

Note: *Given the negative impacts and highly invasive nature of willows, it is not recommended, or legal in most cases, to grow willows as feed for stock.*

Furniture

The use of willows for making furniture is very specific and will not remove much material. People who want to make furniture from willow wood are highly selective and generally only choose specific pieces of good, straight timber, leaving you with a lot of material still to dispose of. In Tasmania, this method has been successfully combined with mulching or burning techniques, where large, straight trunks are milled for furniture, while the smaller branches are burned or chipped for use as mulch.

Much of the willow material cut down during control activities will not be useful for making furniture, so you will always still need an alternative waste management method for the remaining material.

Firewood

Willow wood is not recommended for use as firewood for the purpose of home heating. In Australia, slow combustion wood heaters are not designed to burn softwood, as they are built to an Australian Standard to burn hardwood only. While willow wood could be used in an open fireplace, it burns quickly, creates substantial amounts of smoke, leaves virtually no coals and provides limited heat. Alternative and better performing fuel woods are preferred by fireplace users. If, however, willows are going to be burnt anyway, using it for firewood provides an additional use and reduces the need to use native timbers for fuel.

Mulching is generally limited to small-scale jobs where there is a specific need for the resultant mulch. (left: Melbourne Water, right: DPI Victoria)

Additional resources

Weed management

CRC for Australian Weed Management (2004) *Introductory weed management manual.* Department of Environment and Heritage, Canberra. (Available on www.weeds.crc.org.au/documents/manual.pdf)

Using herbicides in and around water:

Ainsworth, N. and Bowcher, A. (2005) *Herbicides: guidelines for use in and around water.* CRC for Australian Weed Management. (Available on www.weeds.crc.org.au).

Biological control of willows:

Adair, R., Sagliocco, J. and Bruzzese, E. (2006). Strategies for the biological control of invasive willows (Salix spp.) in Australia. *Australian Journal of Entomology*, 45, 259-267.

Willow sawfly:

(All available on www.weeds.org.au/WoNS/willows)

Ede, F. (2006) *National Willows Resource Kit: Resource Sheet 3 – Willow Sawfly (*Nematus oligospilus*)*, edited by S. Holland Clift, Department of Primary Industries, Victoria.

Ede, F. (2006) *Willow sawfly (*Nematus oligospilus*) in Victoria: Status report, July 2006*. Department of Primary Industries, Victoria.

Ede, F. (2006) *Willow sawfly activity in Victoria: the 2006 / 2007 season*. Department of Primary Industries, Victoria.

Section 4

Site rehabilitation

Treated willow regrowth (DPI Victoria)

Site rehabilitation

Having gone to the effort and expense of removing the willows, it is important to make sure that long-term improvements to the site are achieved and that the site does not revert back to a willow-infested or other degraded condition.

Site rehabilitation must be part of every willow management program. If you don't plan to rehabilitate your site, why are you removing the willows, in the first place?

Site rehabilitation includes:

1. Follow-up monitoring and control of willows and other weeds.
2. Managing for erosion and other structural changes.
3. Fencing and stock access.
4. Re-establishing suitable vegetation.
5. Monitoring, evaluation and reporting of program outcomes.

Site rehabilitation should be considered as part of your initial project planning, as it is a long-term process that requires both funding and commitment.

This section outlines the principles involved in rehabilitating a site following willow removal and some of the options available. It is not an exhaustive set of guidelines and further assistance may be needed. For a more detailed guide on site rehabilitation, refer to:

Rutherfurd, I. D., Jerie, K. and Marsh, N. (2000) *A Rehabilitation Manual for Australian Streams.* Cooperative Research Centre for Catchment Hydrology and Land and Water Resources Research and Development Corporation.

This document is available for free download from www.rivers.gov.au.

During site rehabilitation works, you will start to see all of your hard work paying off and your vision starting to become a reality. It is the ideal time to promote the outcomes of your work to the local community, land managers and investors.

1. Follow-up monitoring and control

"If you can't be there next year what are you doing there, now?"

Andrew Ford, Mersey NRM, Tasmania.

The site must be monitored and treated for any regrowth, or reinvasion of willows or other weeds, for several years after initial control is conducted, until you are certain that the site will remain willow free. The amount of follow-up control and the number of years that monitoring will need to continue will vary depending on the:

- size and location of the initial infestation
- success of the initial treatments and rehabilitation efforts
- suitability of the site for reinvasion, and
- seed source in the catchment and adjoining catchments.

What makes my site susceptible to reinvasion?

Reinfestation can occur from on-site regrowth or re-colonisation, with fragments from upstream willow sources or from seed spread in by wind or water. The most likely source of reinfestation will be regrowth from cut stumps or rooted fragments left on site following control works.

Help prevent new willow seedlings reinvading your site by quickly establishing a fast-growing ground cover and a diverse range of locally native species.

As willow seeds live for just 1-2 weeks, there is little chance of seeds germinating on site, unless they have been carried in from elsewhere. Willow seeds require bare, wet ground to germinate. Quickly establishing a fast-growing ground cover and diverse range of plant species should, therefore, help to prevent invasion by new seedlings. Invasion by seeds cannot always be mitigated by revegetation works, however, as mid-stream sand or gravel banks may still remain exposed. In addition, in areas where remnant vegetation remains, it can be easy to miss detecting young willows, as it may take them 2-3 years to grow into view above the remnant grasses or shrubs, at which point they may also start to set seed.

If seedlings do appear at your site, look for any potential seed sources in your surrounding area and control them immediately. In some cases, seed can spread up to 50-100 km from its parent plant, so identifying the source of new seedlings at a site may be difficult.

If rehabilitation activities have been conducted effectively, this will help minimise, but will not negate, the risk of willows reinvading from other areas. Follow-up monitoring over several years needs to be conducted in all situations.

Controlling regrowth and reinvasion by seed or fragments

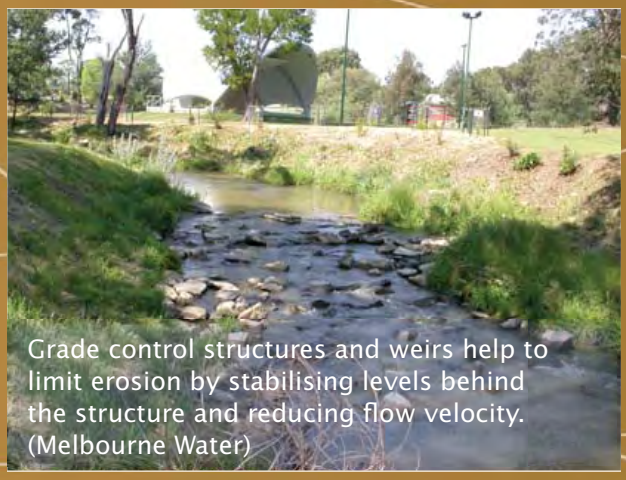
To effectively control regrowth:

- If possible, visit the site approximately 6-8 weeks after treatment to monitor and control for regrowth.
- Inspect the sites no later than 12-18 months after initial control, and then every 1-2 years, until you are certain that the site will remain willow free. If there is little chance of seed or branch fragments reinvading the site, monitoring may only need to be conducted for up to 2-3 years. If there are obvious sources of seed or fragments from the neighbouring area, however (for example, willows occurring upstream or male and female plants in the surrounding region), ***you may need to continue monitoring for up to 10 years, or longer, until the source populations have been controlled.***
- During each visit, look carefully for regrowth from cut stumps or rooted fragments and pay close attention to areas where seed or branch fragments may settle and grow, such as bare banks or mid-stream islands.

If you can find and control any new willows within their first 2 years, they are easy to treat and there are no issues with debris.

- Hand pull, foliar spray or cut and paint the stems as soon as possible with a registered herbicide (See Section 3 Controlling and removing willows, for guidelines on these methods).
- Where possible, encourage the landholder to undertake follow-up control – you might consider including this in any Works Agreements, as part of the landholder's responsibilities, and establish a system for reminding them to do this each year (for example, via post or the media).
- Even if the landholder does agree to control the regrowth, continue to visit the site every 1-2 years to inspect for new infestations or regrowth, until no new plants are found at the site.
- Inspect for regrowth following any high-flow events, even if the site has been clean of willows for many years, as silt and willow material will be transported and deposited and in-stream islands may be exposed to colonisation.

Two to three weeks after a major flood can be an opportune time to monitor for willows, as they may easily be detected by their bright green foliage amidst the native seedlings in the area. (Ian Turnbull)



Grade control structures and weirs help to limit erosion by stabilising levels behind the structure and reducing flow velocity. (Melbourne Water)

Controlling other weeds

If other weeds occur at or near the site, these should be controlled both before and following willow removal. Otherwise, the reduced competition and increased light levels may allow other weeds to quickly infest the site. This includes aquatic weeds, such as sagittaria, and riparian weeds, such as blackberry.

2. Managing for erosion and other structural changes

Erosion caused by willow removal

When willows are removed from streams, some level of bed and bank erosion may temporarily occur, as the roots rot down and sediment is

Monitoring and follow-up control: Keys to successful management

Friends of the Colo Inc., a volunteer group dedicated to eradicating black willow from the World Heritage-listed Wollemi National Park, treated black willows along 60 km of river in the Wollemi National Park from 2000 to 2002. From 2003 to 2007, they treated black willows along an additional 40 km of river downstream of the Wollemi National Park and in the associated wetlands. Ongoing black willow control projects are also being conducted in the adjoining Macdonald, Grose and Hawkesbury-Nepean Rivers, thereby helping to prevent new seed blowing into and germinating in the Colo River catchment.

The 60 km of river in the Wollemi National Park was first monitored 12 months after control treatment, when approximately 200 seedlings and trees were discovered and controlled. The second monitoring trip was conducted 2 years later, in 2005, and about 100 seedlings and 5 trees were controlled. Bush walkers have reported the discovery of 12 seedlings in 2007, but detailed monitoring still needs to be conducted, as two of

Volunteers controlling willows along the Colo River. (Willow Warriors Inc.)

these were growing near each other and one had started to produce female catkins. Friends of the Colo plan to conduct monitoring and follow-up control every 2 years, for at least 10 years, until all potential seeding willows in the surrounding region have been controlled.

Such commitment means that eradication of black willow from the Wollemi National Park may actually be achieved!

Rock beaching on a recently cleared bank. (DPI Victoria)

Rockwork on the Molonglo river, ACT. (DPI Victoria)

released into the stream. These effects are likely to last at least five years.

Stock exclusion and revegetation may be sufficient to control such erosion. In some situations, however, further works are required. This may include sites along high-stress parts of a river, such as:

- along gravel bars
- on the outside bends of streams, and
- in gully erosion sites.

Managing for erosion and other potential structural changes along a river needs to be considered when planning willow management, particularly if conducting extensive willow removal operations.

Available options

Options for managing potential structural instability during and following willow removal include:

- Stock exclusion and revegetation or natural regeneration (see 'Fencing and stock access' and 'Re-establishing suitable vegetation' in the pages that follow).
- Seeking expert advice from river engineers, particularly if you are not sure what role the willows are playing in bank stabilisation.
- Leaving the willows in areas where they play a vital role in bank stabilisation, until a suitable alternative has been established, for example, through a staged removal or replacement program (see 'Other control methods' on page X in Section 3 Controlling and removing willows).
- Planting fast-growing, sterile, annual grasses (such as sterile rye corn, *Secale cereale*) as a temporary measure to stabilise the soil until native plants have had time to establish.

  Note: *This grass can be later treated with herbicide to help the native vegetation establish.*

- Use of erosion control matting to stabilise soil while native plants establish.

  Note: *Care should be taken when selecting which matting to use, as some degrade too quickly. All matting is designed to breakdown, however it is vital that the matting chosen stays viable long enough for the planted vegetation to mature and become self-mulching.*

- Constructing appropriate engineering structures, such as grade control structures, rock armouring (also called 'rip rap', or 'rock beaching'), groynes, retards, pile fields, sediment traps or artificial riffles.

  Note: *Engineering structures, alone, provide only short to medium-term solutions. To achieve long-term improvement in river health, these should be used in combination with options such as natural regeneration, revegetation and fencing. Before deciding on which structure to construct:*

  - Carefully consider the pros and cons of each structure and what you aim to achieve with it.
  - Minimise any potential effects on important ecological processes, such as fish passage.
  - Ensure that you have consulted the appropriate authorities in your state / territory and have gained any relevant permits for these works.
  - Consult an expert river engineer, if you have any uncertainties.

Remember, erosion is a natural process occurring at all times in rivers and should not always be viewed as a negative process.

Caution! Before starting on any of the above works, you should be aware of and adhere to all relevant policies and legislation in your state/ territory and obtain any necessary permits.

Rockwork has been used to stabilise this tree. (Melbourne Water)

3. Fencing and stock access

Using fencing to exclude stock from the site

Allowing stock access to waterways hinders regeneration and can lead to issues of bank instability and poor water quality. In most cases, therefore, fencing is needed to exclude stock from the site.

How wide should my buffer strip be?

The width of land that you fence off will depend on your objectives, location and adjacent landholder, and the regulatory framework that governs the area.

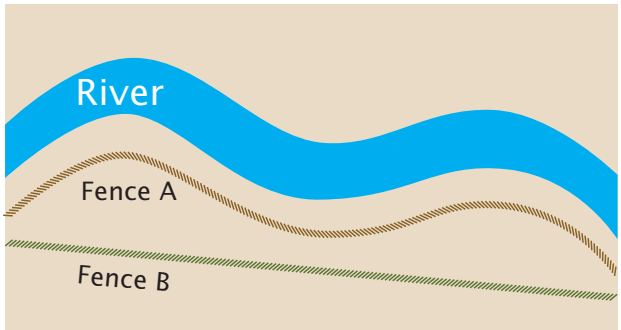
As a general rule, wider is better.

Fences are ideally located at least 20-30 m from the top of the bank. This allows better access for vehicles for follow-up monitoring and control, reduces the chance of fence damage from debris and floodwater and provides an important habitat for fish and terrestrial animals. At an absolute minimum, landholders should fence off at least 5 m of land from the top of the bank.

Riparian vegetation helps banks to resist erosion. (DPI Victoria)

Some potential ways of persuading landholders to fence off a wider buffer strip are:

- Providing additional incentives to landholders who fence off wider buffer strips (see 'Establishing off-stream watering points and/or stock crossings' over the page).
- Explaining that it will cost the landholder less to fence off a greater distance from the top of the bank, as the fencing can be constructed in straighter lines, which requires less fencing materials and labour. For example, Fence A, below (with a buffer width of 5 m), will require significantly more fencing materials and labour costs to erect than Fence B (with a buffer width ranging from 7-20 m).



- Explaining the need for continued access to the site, by foot or vehicle, for planting, weed control and other site-maintenance activities. For example, if the fence is constructed too close to the bank or revegetation area, it can become extremely difficult to access the site to spray serrated tussock, blackberry or other weeds invading the area.

Herbicide was applied to the grassed area to help natives establish. (DPI Victoria)

You may help increase the width of land to be fenced off, by setting up different landholder agreements, with different incentives, based on how wide a buffer they are prepared to give.

When to exclude stock?

Stock should be excluded from the site at least until plants have had time to establish. This could take many years, depending on the climate, soil type and flow regime at your site.

In some cases, once the site has had time to regenerate, grazing can be used for short periods in fenced areas to control weeds and reduce grass levels. If you must allow stock access to your site:

- Do this in autumn, as banks are more likely to be dry, water levels are low and native grasses will have set seed.
- Fence off a wide section of land from the river (for example, 30-40 m), rather than a narrow strip (for example, 6-10 m).
- Monitor the site closely and remove the stock if they are damaging revegetated areas.

Establishing off-stream watering points and/or stock crossings

To compensate landholders for the loss of access of stock to the river, many regions establish off-stream watering points and / or stock crossings. This provides an incentive for landholders to fence off more land adjacent to the river and improves your chances of rehabilitating the site.

4. Re-establishing suitable vegetation

Natural regeneration

The aim of natural regeneration is to encourage native plants to regenerate from the existing seedbank. Allowing the native riparian vegetation to re-establish through natural regeneration is preferable to revegetation, as:

- native plants establish that are adapted specifically to the site (these are known as 'local provenance' species)
- local biodiversity is conserved, and
- natural regeneration is far more cost effective than revegetation.

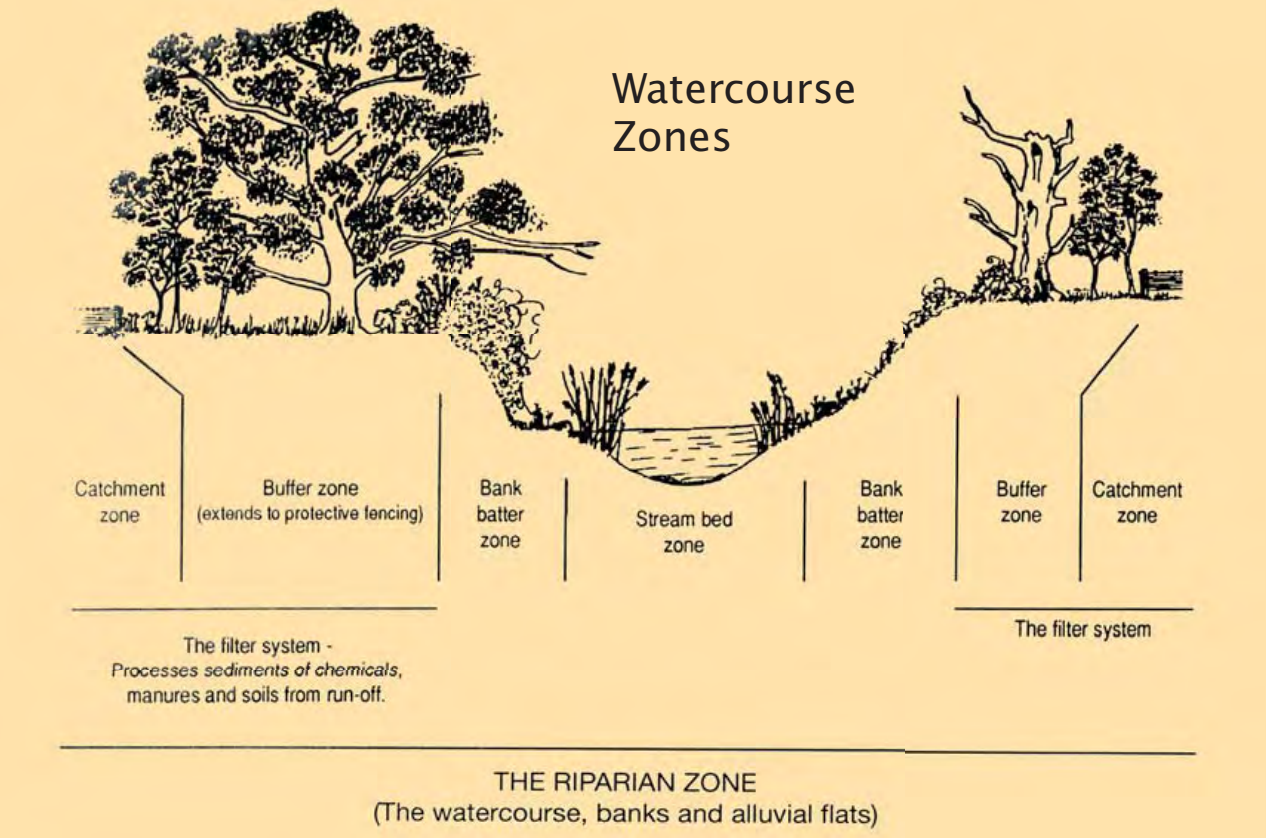
Removing mature willows can promote substantial regeneration of native seedlings, provided a native seedbank still exists. Natural regeneration will be more successful where native vegetation is intact and the willow infestation is recent.

Revegetation

Revegetation is required when a site:

- has limited or no potential for natural regeneration
- has key species missing that cannot be naturally recruited to an area
- is at risk of erosion, when natural regeneration may not occur quickly enough to stabilise the soil before the next high flows or flood event.

Natural riparian plant communities are often complex, with a mix of plant types. These include trees, understorey and water-edge



(Watercourse Management – A field guide for the Mount Lofty Ranges Upper River Torrens Landcare Group Inc. Third edition 2003.)

species. Willow management programs often aim to rehabilitate to a 'natural' riparian environment. Depending on the initial condition of the site, this may not always be achievable. All revegetation activities, however, should aim to establish a suitable blend of locally native plant species. Planting locally native plants along the river bank will enhance the quality of the water flowing into and down the waterway and removes the risk of planting other potential weeds.

"Ideally, a rehabilitated site should have a mix of tree species, understorey and water- edge flora such as sedges and rushes."

Mal Gibson, West Gippsland CMA, Victoria

How to plant?

The three main methods available for conducting revegetation are:

- direct seeding
- regular tube stock or hyco cells, and
- long-stem native tube stock (see inset box, 'Long-stem native tube stock – an alternative for streambank erosion control', later in this section).

Each planting method has advantages and disadvantages, so consider which is best for your situation and seek advice if you are uncertain.

When revegetating a site:

- Preferably, use locally native species propagated from material collected from your local area, as this ensures that the plants being established are appropriate for the habitat of the local area (see www.florabank.org.au for further information).
- Disturbed areas should be resewn to grass as soon as possible on exposed banks, to immediately bind and stabilise the soils.
- Focus initial revegetation activities on establishing 'disturbance response' species (such as *Acacia, Cassinia* and some *Eucalyptus* species), in order to provide a sound structure on which to build successive revegetation efforts or to enhance the site's ability to more naturally recover.
- Try to schedule your weed-control activities just before starting revegetation activities, to prevent competition from weeds.

For a detailed guide on revegetation techniques, refer to:

Corr, Katherine (2003) Revegetation techniques: *A guide for establishing native vegetation in Victoria.* Greening Australia Victoria.

This guide is available for free download from: http://live.greeningaustralia.org.au/GA/VIC/TipsAndTools/revegetationguide.htm

Caution! Due to the likelihood of flooding on most riparian revegetation sites, plastic tree guards should be avoided in favour of more biodegradable options (for example, cardboard 'milk carton' guards).

Long-stem native tube stock: An alternative for streambank erosion control

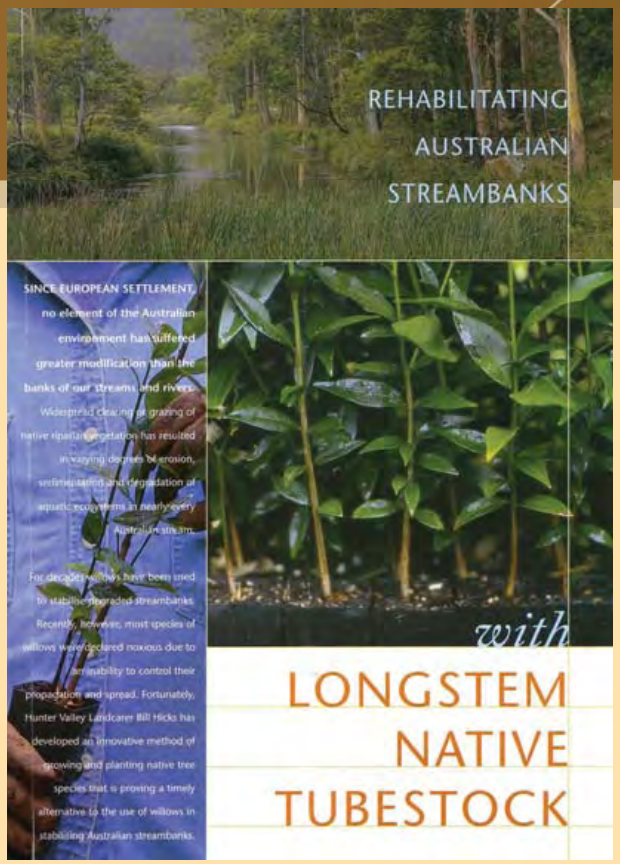
The re-establishment of locally native plant species is the best alternative to planting willows, as they provide many environmental and social benefits, such as increasing stream flow and health and provide quality habitats for animals.

Where native plants are difficult to establish, long-stem native tube stock is a viable alternative. 'Long stems' are an innovative method of growing and planting native trees that, just like willows, establish easily, grow rapidly, produce extensive roots and require little attention.

How do they differ from regular tube stock?

Long stems differ from regular tube stock in the way they are grown and planted. They have increased growth and survival rates, as they are planted 0.5-1.5 m deep in the soil, where they have better access to subsurface soil moisture. Trials have demonstrated that long stems can withstand flooding and achieve rapid erosion control.

Long stems are more expensive and labour intensive to grow and plant, as they take 18 months to grow and need to be planted deep in the soil. They are therefore most suited to areas where regular tube stock will not survive, such as drought or flood-prone areas or on in-stream gravel bars and islands. It may be necessary to pay part of the cost of the tube stock upfront to encourage your local nursery to grow them.



Which species can be used?

A large range of native species have been grown and planted as long stems. Most species that naturally occur along streams are considered to be suitable for long-stem development, due to their tolerance to sediment build up around the stem. It is always a good idea, however, to trial any untested species before trying to mass produce them.

How was it developed?

This innovative method was developed by Hunter Valley Landcarer Bill Hicks, who was concerned about the use of willows for stream bank erosion, long before many willows were declared noxious. Bill set about developing a method of producing long-growing mature plants in a small tube with well-developed, non-distorted root systems.

Bill reasoned that, when this tube stock was planted, it would not only have a well-developed root ball, but would simulate a willow cutting by sprouting roots along the length of the stem. He was right!

Where can I get further information and instructions?

For further information and instructions on how to grow and plant long-stem native tube stock, refer to the brochure 'Rehabilitating Australian streambanks with longstem native tubestock', which can be downloaded from www.weeds.org.au/WoNS/willows (scroll down to 'Alternatives to Willows').

5. Monitoring, evaluation and reporting

Have your original objectives been met? What changes were made during the process? What mistakes were made and what was learnt? How can we adapt the program to better achieve objectives?

Monitoring, evaluating and reporting are vital elements in a willow management program, in order to:

- establish comprehensive baseline data
- evaluate the effectiveness of on-ground management actions at achieving the short and long-term objectives of the program
- adapt to changes at the site throughout the life of the program
- influence future management actions and improve best practice guidelines for management
- report on progress against management targets and demonstrate clear outcomes to your investors and community, and
- further involve the community in willow management programs and persuade them of the value of willow management.

It is important to monitor your site to demonstrate that your management efforts are achieving what they were intended to do and for early detection of any unforseen negative impacts that need to be remedied.

When should I monitor my site?

Monitor your site at regular intervals throughout the life of the project (for example, every 6-12 months). To make valid comparisons, monitoring must be conducted at similar times of year, each year, in a consistent manner.

Review your plan annually, to assess the effectiveness and efficiency of the implemented management strategies and adapt future management efforts accordingly. The data obtained from regular monitoring is an essential part of this process.

Incorporate monitoring into your yearly activity timetable.

What should I monitor?

Monitoring should focus on both:

- short-term management targets, such as checking for regrowth, vegetation establishment and other weed invasion, and
- long-term outcomes, such as demonstrated improvements in river health.

While short-term outcomes, such as successful control and revegetation, can provide a good indication that your project will lead to improvements in river health, long-term monitoring will provide a stronger basis for persuading the community and investors that your program is achieving what it intended. Such long-term studies are desperately needed to demonstrate the importance of willow removal in river health management.

When planning your monitoring program, consult your regional Catchment Management Authority or Natural Resource Management organisation.

Revisit your original objectives and develop your monitoring program to demonstrate that these objectives are being achieved.

Examples of monitoring actions to achieve program objectives

Question, based on original objective	Proposed monitoring action
How effective were your control measures?	Check for regrowth to assess the effectiveness of your control measures.
Is reinvasion occurring?	Identify new willow infestations by checking for seedlings or new plants. Monitor and control any new weed infestations at the site.
How are your efforts at site rehabilitation going?	Assess the rate of establishment of desirable vegetation by monitoring the growth of native plants; assess potential problems such as bank instability; monitor for impacts and movement of willow debris where willows are left standing; identify any new issues that will affect your management program and adapt your activities accordingly.
Is the health of your river improving, over time, as a result of willow removal?	Monitor indicators of river health such as: ▪ water quality (including turbidity, nutrient levels, dissolved oxygen, water temperature, salinity and toxicants) ▪ riparian and aquatic organisms (including macroinvertebrates, fish and plants), and diversity, health and habitat value of the riparian vegetation. Monitoring can be conducted at the site before, during and for many years after willow management, to assess the impact of management activities on river health. Where possible, identify and take advantage of any existing monitoring programs being conducted in your area, such as Waterwatch, Index of Stream Condition assessment or university research projects. **Long-term monitoring studies are desperately needed to demonstrate the long-term outcomes of willow management programs in improving river health.**
Are your investors and the community happy?	Continually establish and maintain relationships with your local community, land managers and investors throughout the life of the project. Involve the community and land managers in monitoring the site, as this will enable them to see the improvements being made and promote this to others in the community. Take photos before, during and after control works and develop information brochures or signs to demonstrate visually what has been achieved, over time. Report your monitoring results to your investors, to effectively demonstrate your progress and outcomes. **Clearly demonstrating the outcomes being achieved, make it more likely that funding will continue and that the site will be improved for the long term.**

Improving management, over time

Willow management is an evolving process and rivers are dynamic environments, so the best options for management will depend on your specific situation.

Review your program regularly and make gradual improvements, over time.

By recording the information that has been collected during the monitoring process, a picture of what is happening on the site, over time, will develop. This will provide information on progress to date and enable you to continually improve management, over time.

To effectively track progress, you could use a site diary to document information such as:

- activities undertaken
- observations about seasonal conditions or other factors that may influence the results of your control program
- the cost of control (both in labour and dollars) to evaluate the cost effectiveness of different methods and to ensure you stay within budget, and
- monitoring results.

Willow management is an evolving process and rivers are dynamic environments, so it is often best to start out small and gradually learn from, and adapt, your program to your specific situation, over time.

Additional resources

Rutherfurd, I. D., Jerie, K. and Marsh, N. (2000) *A Rehabilitation Manual for Australian Streams.* Cooperative Research Centre for Catchment Hydrology and Land and Water Resources Research and Development Corporation. (Available on www.rivers.gov.au)

Price, P., Lovett, S. & Lovett, J. (2004) *Managing riparian widths, Fact Sheet 13*, Land & Water Australia, Canberra. (Available on www.rivers.gov.au)

Upper River Torrens Landcare Group Inc. (2003) *Watercourse Management – A field guide for the Mt Lofty Ranges*. Third edition.

Corr, Katherine (2003) *Revegetation techniques: A guide for establishing native vegetation in Victoria*. Greening Australia Victoria. (Available on http://live.greeningaustralia.org.au/GA/VIC/TipsAndTools/revegetationguide.htm)

Brochure, *Rehabilitating Australian streams with long stem native tubestock*. (Available at www.weeds.org.au/WoNS/willows; scroll down to 'Alternatives to Willows')

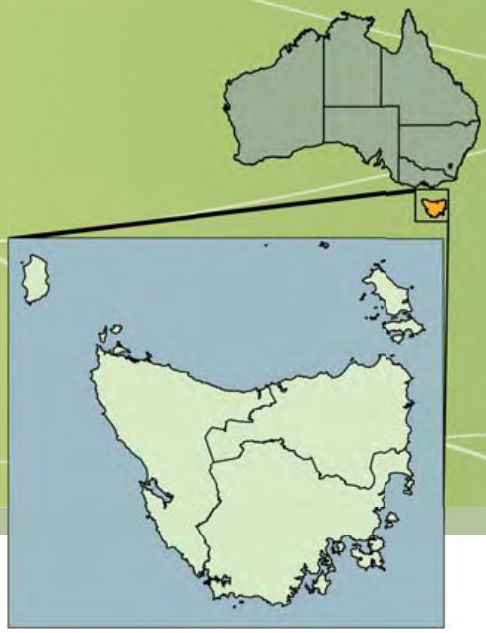
Florabank website, www.florabank.org.au. This website recognises and shares the best available knowledge from research and practice in native species seed management.

Section 5

Case studies

Case Study 1

State-wide eradication of seeding willows in Tasmania



Sam Smee, Tasmanian Land and Water Professionals

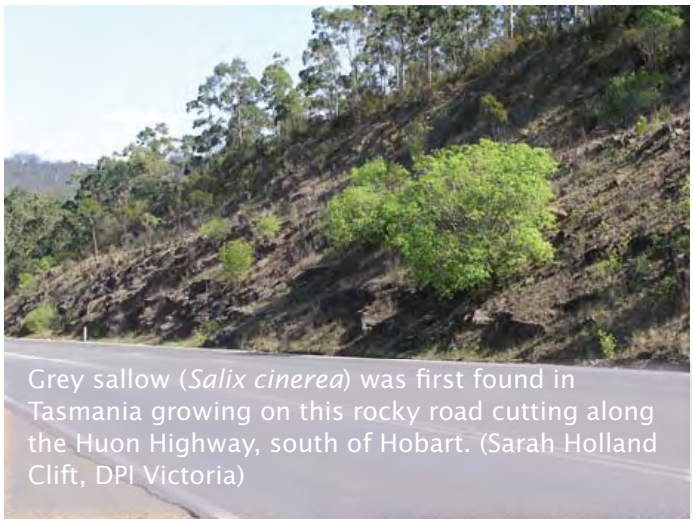
What and where?

Grey sallow (*Salix cinerea*) was first noticed in Tasmania on a rocky road cutting on a main highway south of Hobart in 2000. Its discovery led to many other infestations being found in the surrounding area, where the seed had been carried by wind or water.

As soon as grey sallow was discovered growing in Tasmania, it wasn't long before it was identified at other sites around the state. A large infestation was found growing along a railway line at Queenstown on Tasmania's west coast, for example, and another was found infesting a boggy area alongside a highway at Penguin on the north-west coast. Grey sallow was also sighted growing in a paddock at Edith Creek in north-west Tasmania.

Why manage willows?

Grey sallow's ability to produce prolific amounts of seed make it one of the most invasive willow species in Australia and, when conditions are suitable, can lead to massive outbreaks of seedlings. Such events have already been observed in Victoria and New South Wales, following disturbances that have exposed moist soil, such as fire, floods or land clearing (see 'Seeding willows: It may not happen overnight, but it will happen' in Section 1 Understanding willows).



Grey sallow (*Salix cinerea*) was first found in Tasmania growing on this rocky road cutting along the Huon Highway, south of Hobart. (Sarah Holland Clift, DPI Victoria)

The discovery of grey sallow in Tasmania has prompted fears about its potential threat to the unique ecology of the Tasmanian wilderness, including the nearby World Heritage Areas, should it ever gain a strong foothold. Hopefully its early discovery, however, has created an opportunity to potentially eradicate grey sallow in Tasmania before it becomes firmly established.

"Seeing Tasmania's first significant population of seeding grey sallow is like going back in time and seeing Australia's first introduced blackberries. We have a chance to do something to protect Tasmania from even greater willow invasion."

Andrew Crane, Weed management Officer, DPIW, Tasmania

Who to involve?

Following the initial discovery of grey sallow in southern Tasmania, Kingborough Council, in conjunction with the Tasmanian Herbarium and the Department of Primary Industries and Water (DPIW), sourced funds and started control works. It soon became obvious, however, that a much larger, state-wide program was needed.

In response to this challenge, the DPIW teamed up with Tasmanian Land & Water Professionals Pty Ltd. to develop an action plan to combat the threat of grey sallow. With funding from the Australian government's *Defeating the Weed Menace* programme, the Tasmanian Seeding Willows Project began in July 2006.

Local landowners learn about grey sallow at a field day at Leslie Vale, south of Hobart. (Sam Smee, Tasmanian Land and Water Professionals)

Volunteers from West Coast Wilderness Railway help control grey sallow in Queenstown, using the cut, paint and remove method. (Sam Smee, Tasmanian Land and Water Professionals)

With infestations spread out across the state, it was vital to engage public support to identify and report other infestations. A public awareness campaign was launched across all media and many new sightings were reported as a result. On inspection, all of these new sightings turned out to be *Salix x reichardtii*, a hybrid form of grey sallow that looks very similar.

"We have that all-important community support that is vital for success; a network of eyes right across the state, observing and reporting any suspect willows. That sort of thing is priceless."

Sam Smee, Tasmanian Land & Water Professionals

When and how to conduct the works?

With the clear aim of eradicating grey sallow from Tasmania, the state-wide project has embarked on a campaign with three areas of activity as its focus:

Investigate...Educate...Eradicate

In July 2006, investigations began straight away with on-ground surveys to determine the extent and density of known infestations, followed by mapping of surrounding areas to unearth any additional, outlying plants. In particular, wet areas downstream and downwind of known infestations were targeted. All plants found were recorded with a GPS (Global Positioning System), following national weed mapping standards, and downloaded into GIS (Geographic Information System) software to generate accurate maps.

Once positively identified, all infestations of grey sallow were controlled, from November through to April. A combination of techniques was used to maximise control of the willows, while minimising environmental damage.

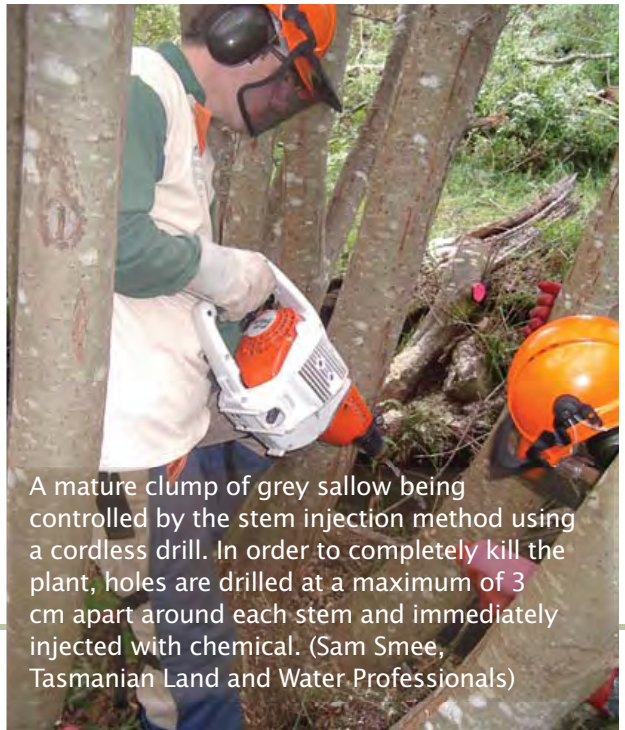
Monitoring, evaluation and review

After one and a half years of the three-year project, many more infestations of grey sallow have been found. The goal of state-wide eradication, however, is still feasible. An important biological trait in the project's favour is that, unlike many other weeds, grey sallow seed is short lived, surviving only up to six to seven weeks.

The project is scheduled to continue until June 2009. Meanwhile, any new plants positively identified as grey sallow will be immediately controlled. Review is an ongoing process and all sites will be revisited for at least two years following control to assess and control any regrowth.

"We may be stuck with blackberries, but grey sallow is one weed that won't be allowed to become another blight on our landscape."

Sam Smee, Tasmanian Land & Water Professionals



A mature clump of grey sallow being controlled by the stem injection method using a cordless drill. In order to completely kill the plant, holes are drilled at a maximum of 3 cm apart around each stem and immediately injected with chemical. (Sam Smee, Tasmanian Land and Water Professionals)

Case Study 2

Turning a degraded urban waterway into an enhanced riparian corridor in Victoria

Damian Magner, Melbourne Water

What and where?

Once a typical example of urban waterway degradation, the willow and weed landscape of a small urban tributary of Back Creek in eastern metropolitan Melbourne has been transformed into an enhanced riparian corridor, appreciated by the local community. The 500-metre section of creek is located in South Surrey Park.

Why manage willows?

In 1997, prompted by community and local council interest in improving the park and creek, a master plan was drawn up with significant input from local residents. With the support of Melbourne Water, the responsible authority for the area along the creek, a rehabilitation program began that involved the removal of willows and other weeds, as well as channel stability and revegetation activities.

Who to involve?

The project was managed by Melbourne Water's capital works program, which is funded through a drainage rate contribution paid by Melbourne households. Contractors conducted the initial works and the Friends of South Surrey Park and local council completed the revegetation works with funding from Melbourne Water's river health grants program.

As with many urban areas, the local community's views about the value of willow trees included some park users who objected to their removal. There was also the potential negative impact of construction noise and visual disturbance to private properties that backed on to sections of the creek. To reduce the impact of noise on local residents, rock delivery (for grade control structures) was timed to take place when most residents were away from home. To reduce the visual impact, works were staged over several years, to enable native vegetation to establish.

An information leaflet, which included the proposed plan, was distributed to all properties adjoining the site to give them an opportunity to comment and ask questions. Information signs, including the contact details of the relevant project officer, were also placed on site.

"People said they used to be hesitant to go down along the creek, due to the dark and seedy atmosphere that the willows created. Since the willows were removed, we have had very positive feedback from park users and the surrounding community."

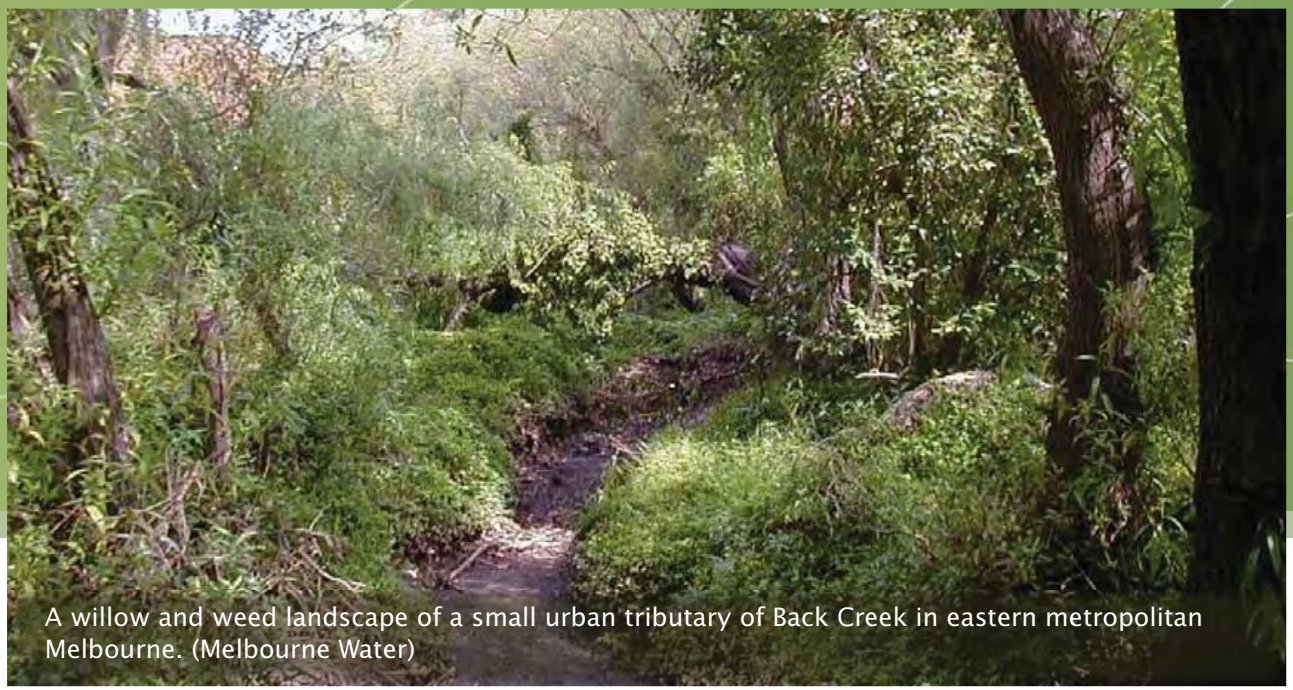
Damian Magner, Melbourne Water

When and how to conduct the works?

Rehabilitation works were undertaken in four separate stages over a number of years, to reduce the visual impact of tree removal. The first stage, for example, was already revegetated and growing before stage two was begun.

Before starting willow removal works, other weeds at the site were controlled, such as blue morning glory (*Ipomoea indica*), English ivy (*Hedera felix*) and tradescantia (*Tradescantia fluminensis*). In some locations, willow and oak trees were retained to provide screening and to keep a partly treed character to the riparian zone. These trees will be removed in the future, once revegetation growth has advanced.

Because the willows were small and the creek was ephemeral at the upstream end, the willows were cut down green, removed and the remaining stumps painted with herbicide. In later stages, willows and other woody weeds



A willow and weed landscape of a small urban tributary of Back Creek in eastern metropolitan Melbourne. (Melbourne Water)

were stem injected, felled soon after and the remaining stumps also painted with herbicide. All stumps were left in the ground. Where there were major stability issues, a detailed survey and design was undertaken and grade control structures installed.

Because of a lack of remnant vegetation in the area, the site was actively revegetated after each stage of works. A dense ground layer of native species was established to out-compete weeds that otherwise continually reinfest such urban areas. Shrub and tree species were planted more sparsely to give a more open view of the river.

Monitoring, evaluation and review

The revegetation contracts include a three-year maintenance program, which also covers the removal and control of any willow regrowth. After these contracts are completed, the site will be monitored and maintained as part of Melbourne Water's recurrent maintenance program.

The urbanised nature of the catchment, as well as the existence of upstream willows and other woody weeds (for example, desert ash) which may continue to reinfest the site, will make constant monitoring necessary. Melbourne Water is committed to ensuring that the site is maintained over the long term.

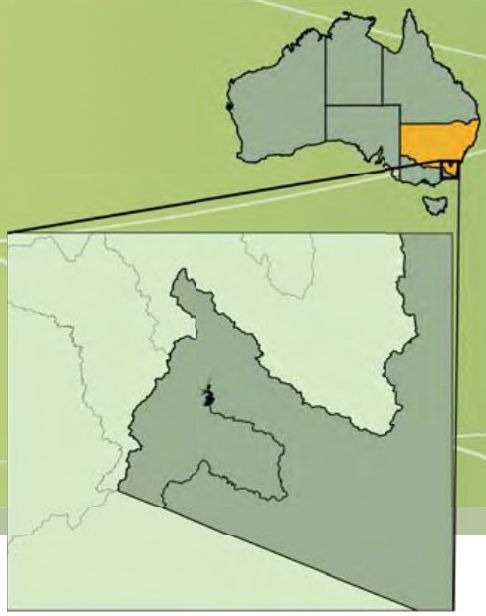
"This has resulted in a positive result for both the community and the environment. The area now feels safer, looks more pleasant, water quality has improved, flows have increased and there is now more suitable habitat for native species along the river."

Damian Magner, Melbourne Water

Revegetation with native plants and channel stabilisation. Note the Oak tree at centre left is being temporarily retained to provide some tree cover until native vegetation establishes. (Melbourne Water)

Case Study 3

Willow control along the Snowy River in NSW



What and where?

The Snowy River in New South Wales runs through 105 km of privately held land, and 165 km of the Kosciusko National Park. In 1967, it was dammed at Jindabyne as its final diversion under the Snowy Mountains Scheme, which reduced flows at Jindabyne to 1% of the mean average natural flow. The Snowy River Rehabilitation Project, as implemented by the Southern Rivers CMA, primarily focuses on the Snowy River and tributaries below Jindabyne Dam to the Victorian border.

Why manage willows?

After 30 years of flow diversion, riparian weeds including willows and blackberry established extensively on the accumulated sand and silt within the wide, 'de-watered' river channel. The Snowy River had become an indistinct, braided channel, with poor water quality and a stream biota more typical of a lowland wetland than a mountain river. In anticipation of an environmental flow eventually being delivered, local catchment managers began to map and selectively remove seeding willows from the mid-1990s. In August 2002, an ideal opportunity presented itself to remove remaining willows to help rehabilitate the stream bed when the New South Wales, Victorian and Commonwealth governments announced the gradual return of environmental flows to the Snowy over the next ten years.

Who to involve?

The project called on the skills of many organisations and individuals including:

- Local and regional natural resource management staff (particularly the Southern Rivers Catchment Management Authority).
- The late Dr Kurt Cremer, a research scientist with excellent knowledge of willow biology and identification.
- Willow managers from other areas, who helped determine management and control techniques.
- Local contractors, who conducted on-ground works.
- Local community interest groups who sat on the initial steering Committees.

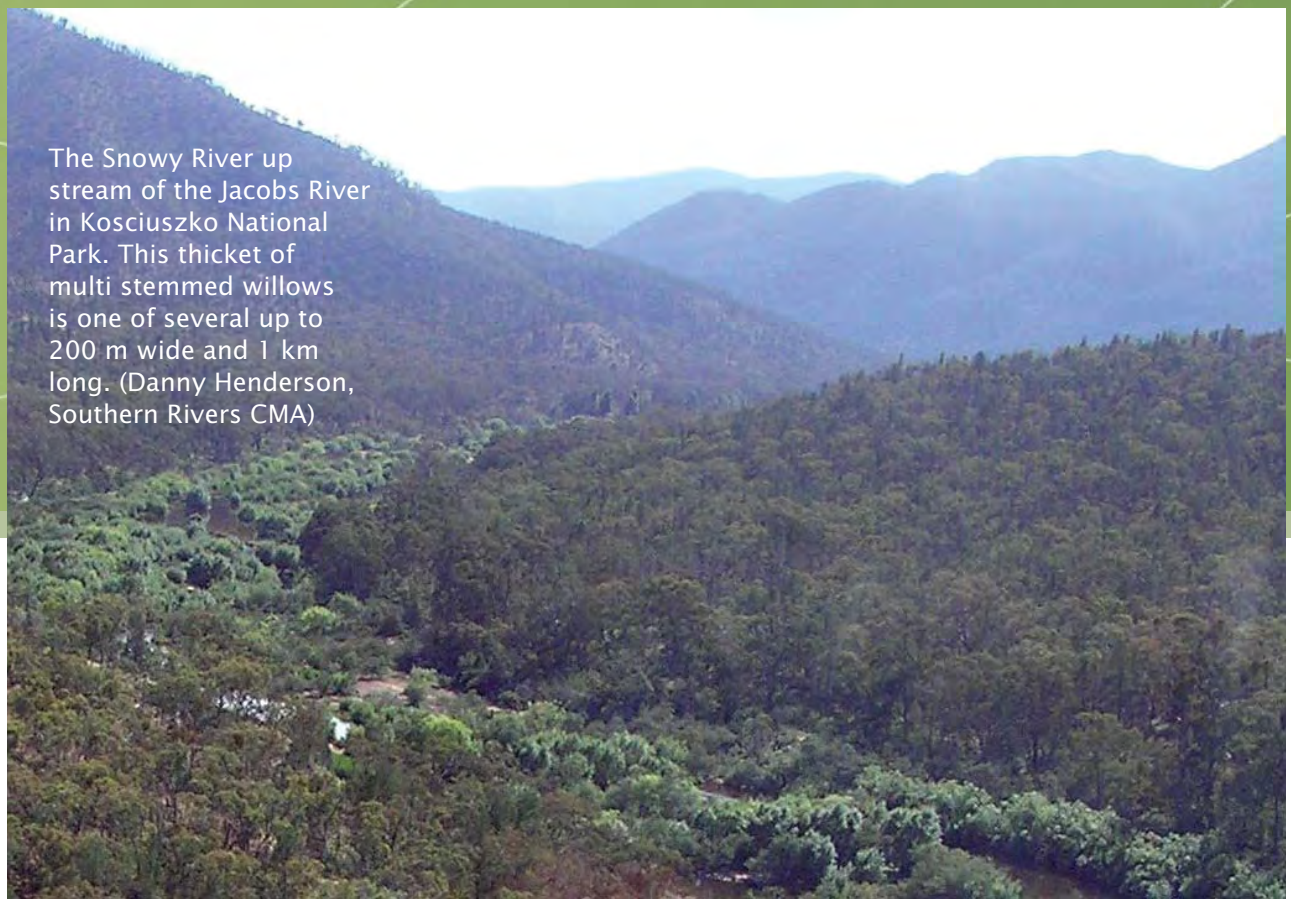
The entire program is coordinated by an agency-community reference group, which meets annually to review issues and outline future programs. The use of local contractors and plants sourced from local nurseries has added economic value to the region.

Riverfront landholders, whose tenure is typically to 'the high bank', were kept informed throughout the project and their consent formally sought before willow control took place on or adjacent to their lands. Project staff attended field days, shows and local events to explain the program and to gain feedback from the community.

There are now very few people who do not support willow removal along the Snowy. Those with initial objections changed their minds once they saw the results and the improvements in river health that followed increased flows.

"By involving adjacent landholders throughout the process, willows have now been managed along 98% of the river's length in New South Wales and there is a strong community acceptance of the program and its benefits for the river."

Danny Henderson, Southern Rivers CMA, New South Wales



The Snowy River up stream of the Jacobs River in Kosciuszko National Park. This thicket of multi stemmed willows is one of several up to 200 m wide and 1 km long. (Danny Henderson, Southern Rivers CMA)

When and how to conduct the works?

Mapping

A comprehensive survey of willows along the Snowy River in spring, when catkins had emerged, determined the sex of the trees and identified 17 different willow taxa. An aerial inspection along remote sections of the Snowy in autumn, when the trees were changing colour, was recorded on video to give managers and contractors a logistics planning tool.

Control

Following the initial survey, female trees were targeted to prevent future spread by seed. From 2002 onwards, the Australian and state governments jointly funded a full-scale operation to control problem willows from the Snowy River channel below Jindabyne Dam. The program targeted all willows, including crack willow (*S. fragilis*), purple osier (*S. purpurea*) and a range of hybrid species. Many weeping willows (*S. babylonica*) were retained in areas where they were identified as significant by the community or landholders.

Control techniques varied, according to the size and type of willow. Seedlings were foliar sprayed, purple osier and other 'shrub' willows were cut, painted and removed (over time this technique proved less successful than stem injection) and adult 'tree' willows were stem-injected using glyphosate and left standing to break down naturally. In areas where 'tree' willows posed a risk to people or were of concern to landholders if left standing, they were felled and burned.

Funding

Funding was achieved by building an early consensus on control targets and methods, maintaining both strong community support and priority for the program in core budget processes, and using this to leverage funds from a range of annual grant processes. Major investment was secured from the Australian Government Natural Heritage Trust, NSW Department of Premier and Cabinet, and the NSW Environmental Trust. Willow control cost as much as $18,000 per km in braided sections of the river (stem injection only, 2005) and up to $30,000 per km in areas where willows had to be cut, painted and removed (2002). Follow-up treatment, if done within two years of initial work, cost around $1,000 per km of river.

This particular section of river has up to five deep channels separated by rocky bars. Treatment cost was approximately $18,000 per km. (Danny Henderson, Southern Rivers CMA)

Monitoring, evaluation and review

Field inspections by project staff and a detailed reporting process by contractors provide measures of the program's success. Key lessons which have emerged so far include:

- Control was possible at all times of year, but success was less certain in spring.
- Some trees treated successfully during summer, autumn or winter still grew new leaves in spring, but soon after dropped these leaves and died.
- The success of stem injection treatment was reduced if flood waters inundated freshly treated axe cuts within 24 hours of treatment.
- The success of foliar spraying using glyphosate was reduced if seedlings were coated in silt from flood inundation.
- Control costs varied depending on the type, density and location of the willows. Large, dense infestations in easy-to-access areas, for example, were often cheaper to treat than sparse infestations of small, multi-stemmed or flood-damaged trees among blackberry or in difficult terrain.

Willow contractors preparing to commence remote operations on the Snowy River within Kosciuszko National Park. (Danny Henderson, Southern Rivers CMA)

Follow-up foliar spray work was not done soon enough at this site, making treatment of these multi-stemmed three year old willows a similar cost to the initial treatment. (Danny Henderson, Southern Rivers CMA)

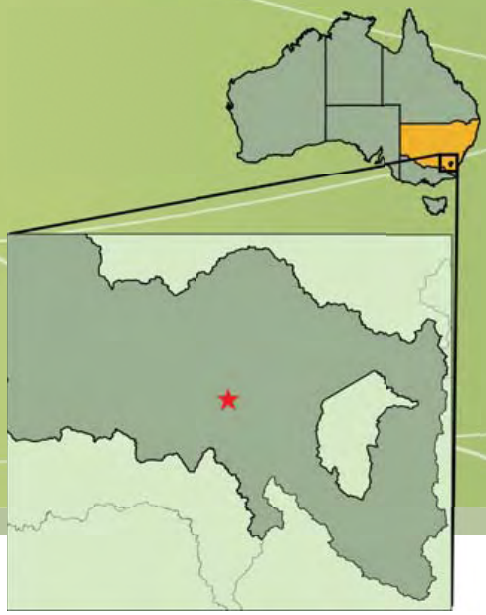
- Competition between contractors and repeated experience has led to more efficient control methods. Contractors discovered, for example, that 'shrub' willows (some with up to 250 stems ranging from 5-20 cm diameter) could be controlled more efficiently and effectively by selective removal of stems to allow operator access, and then injecting most of the remaining stems, rather than the full 'cut and paint' method.
- Dead willow break-down depended on site conditions and tree type. Many trees collapsed within two years of treatment, but some trees in elevated, dry sites or in water remained standing five years later. Mature crack willow (*Salix fragilis*) trees often remained intact, eight years post-treatment. Break down has been quicker in areas periodically inundated, compared to permanently wet or dry areas.
- Willow seed continues to spread into controlled areas. It is thought that this seed comes from trees planted for shelter or as ornaments on nearby properties or from the female weeping willows (*Salix babylonica*) not controlled along the river.
- Environmental flows released into the Snowy River in 2002 changed river levels, which in turn regularly wetted areas previously continually dry. Although this had obvious benefits for the river, it also led to willow regrowth and increased opportunities for establishment. Rapid expansion of reeds into these newly wetted areas hid willow seedlings until they were more than two metres high, making follow-up control more expensive.

Willows may still reinvade from upstream tributaries or from seed blowing in from elsewhere. Initial control on 185 km of river has taken 4 years and will require follow-up monitoring for a number of years to control new infestations. Willow removal has been the single, largest management intervention in the physical rehabilitation of the Snowy River, and will remain so until environmental flow levels are substantially increased. It is expected that benefits to river channel recovery and formation will be much greater level than if willow control had not been achieved.

A detailed monitoring and review program has meant that the project could be improved and adapted over time, as new information was gained.

Case Study 4

Black willow eradication in the Riverina region of NSW



What and where?

Black willow (*S. nigra*) was originally imported from North America and planted in the Tumut area of New South Wales between 1964 and 1977 for forestry purposes. In the intervening 37-year period, black willow spread over hundreds of kilometres throughout the region, with self-sufficient populations thriving. Other infestations also exist in Victoria and other parts of NSW.

Why manage willows?

Black willow is vigorous and produces massive amounts of seed, which are dispersed by wind and water. A number of plantation areas, scattered throughout the region, have been identified as the seed source for self-seeding black willow populations within a 100 km radius of Tumut. Although the original plantations have been destroyed, naturalised populations of black willow now exist throughout the region.

If left unchecked, black willow has the potential to infest and dominate rivers and streams throughout the region but, at present, it is still feasible to completely eradicate it. Other willows were also causing problems along the river, but black willows were specifically prioritised for control because of their increased risk of spread.

A coordinated control program in the nearby upper Murrumbidgee catchment had almost completely eradicated black willow from that region, and its success encouraged hope that the aim of eradication in the Riverina was achievable.

Who to involve?

The *Riverina Black Willow Management Plan* commenced in 2002 to protect waterways and the general environment from increasing black willow invasion. To ensure that this aim was met, the Black Willow Working Group and Tumut-Adelong Region Catchment Management Group were formed to oversee the management plan's objectives.

Central to the success of the plan was the education of land managers, including government agencies, and the general public about the problems posed by black willow, so that they could play a key role in its detection and control across the region.

The New South Wales Government also responded by declaring black willow as a Control Class 3 noxious weed in local government areas where it posed a serious threat and there was strong community support for its control. This level of declaration requires black willow to be '*fully and continuously suppressed and destroyed*'.

When and how to conduct the works?

By continually suppressing and destroying black willow, the long-term aim of the management plan was to totally eradicate it from the region within 10 years. To achieve this, the short-term objectives were to:

- Remove all dense infestations of seeding willows located along Blowering Dam and Adelong, Bombowlee, Goobarragandra and Batlow creeks.
- Remove all scattered or marginal infestations located along Tarcutta and Umbango creeks and the Murrumbidgee River at Gundagai.
- Locate and treat rare and isolated infestations.
- Identify and treat any new seedlings found.

Half a million seedlings and adult plants were removed along a 40 km stretch of the Murrumbidgee River between the Burrinjuck Dam in NSW and the ACT border in spring and autumn by private contractors in teams of 3 or 4.

Control methods varied depending on the size of the willow. Small seedlings were foliar sprayed

Black willows growing near Tumut, New South Wales. (Cherie White, Murrumbidgee CMA)

using backpack sprayers, 1-3 m high willows were cut, painted and removed and larger trees were stem injected and left standing, being careful to treat all stems. In all cases, the chemical used was Roundup Biactive™. Large trees were only removed where they posed significant risk to nearby downstream infrastructure.

Monitoring, evaluation and review

Following initial control works, it was discovered that some adult willows remained and new seedlings had emerged. During follow-up control conducted over the following 2 years, more than 100,000 seedlings were removed. Luckily, early detection meant that these emerging seedlings were easily controlled by hand pulling or cut and paint methods.

Had the black willow seedlings not been detected and controlled so quickly, these seedlings could have grown much larger and become much more difficult and costly to control later on.

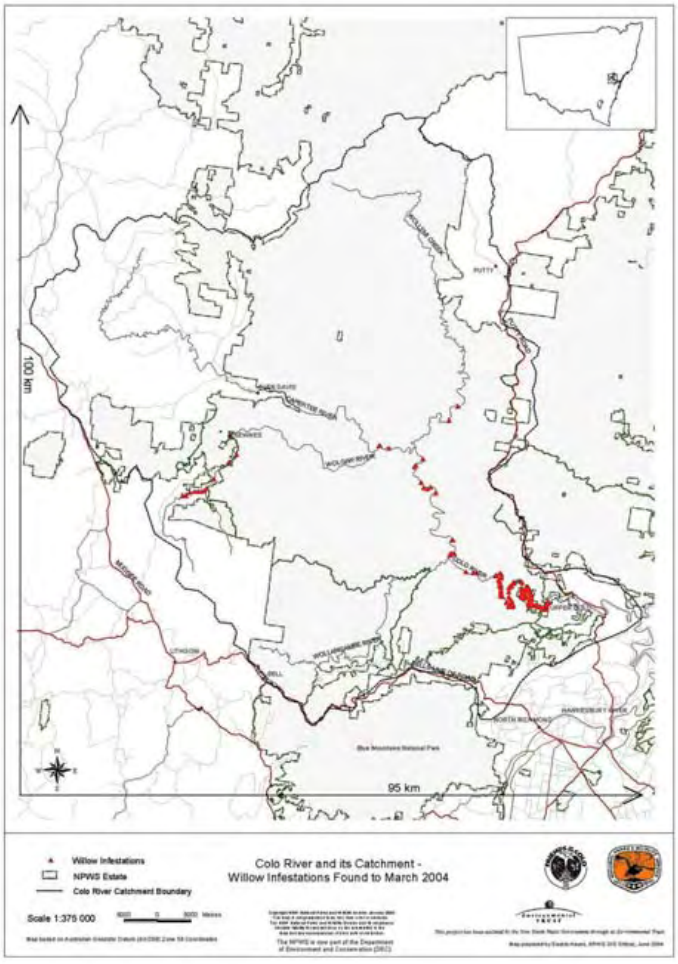
Thanks to the coordination and commitment of this program, black willow has now almost been completely eradicated from the area. Having educated local land managers and community groups, these people can now carry out the on-going monitoring, evaluation and control work needed to keep black willow at bay.

Black willow seedlings growing out of a road, near Tumut, New South Wales. (Cherie White, Murrumbidgee CMA)

Stem injection via fill and frill method. (Cherie White, Murrumbidgee CMA)

Case Study 5

Willow eradication in the rugged wilderness of Wollemi National Park, NSW



What and where?

The Wollemi National Park has been the scene of a vigorous campaign against invading willows, involving community volunteers and the New South Wales National Parks and Wildlife Service (NPWS). Black willows *(S. nigra)* were originally imported from the USA and planted along the lower reaches of the Colo River in the late 1960s. Although they were later removed by a flood, their offspring had already spread down along the river and upstream into the Wollemi National Park.

The problem was first brought to the attention of the NPWS in 1998 by a bushwalker alarmed at the number of willows along the river. In a subsequent survey, about 5000 trees were recorded along a 60-70 km section of river within Wollemi National Park. Later surveys downstream of the park, to the junction with the Hawkesbury River, found another 5000 trees as well as galleries of an estimated 7000 seedlings in the wetlands in the side creeks.

Why manage willows?

The Wollemi National Park and Wilderness Area, home of the Wollemi Pine, contains the largest remaining areas of wilderness in New South Wales and is part of the Greater Blue Mountains World Heritage Area. The spread of black willow into the park along the Colo River, the major river running through the park, posed a major threat to the integrity of the World Heriatge Area.

Considered one of the worst willows in Australia, black willow produces abundant amounts of seed and has been known to spread up to 100 km from its initial source. It was originally thought that willows were spreading in from areas upstream. Surveys along tributaries of the Colo, however, found that the infestations in the Wollemi National Park were initiated from seed blown up the river from large galleries of black willow growing downstream.

Once black willow was discovered in the Wollemi National Park, an eradication campaign was started to protect the park and surrounding areas from its impacts and further spread.

Bounded by 200-300 m cliffs, much of the Colo River is relatively inaccessible through normal means, but makes for some fun rafting trips. (Friends of the Colo)

Who to involve?

Bounded by 200-300 m cliffs, much of the Colo River is relatively inaccessible through normal means. There are few walking tracks, even fewer roads and it flows through a rugged wilderness area. Through the enthusiasm of the NPWS staff, local bushwalkers and canoeists, a community group, Friends of the Colo, was formed to help tackle the problem and make a long-term commitment to eradicating invasive willows from the Colo River catchment. Groups of volunteers and NPWS staff travelled down the Colo River in canoes and rafts, identifying and controlling willows as they went.

In 2005, the community group Willow Warriors Inc. was formed as an offshoot of Friends of the Colo, to expand their work to other remote rivers in south-eastern Australia. Willow Warriors Inc. is currently involved in willow management projects along the Goobarragandra, Grose, Murrumbidgee, Shoalhaven, Hawkesbury-Nepean, Wollondilly and Wingecarribee Rivers.

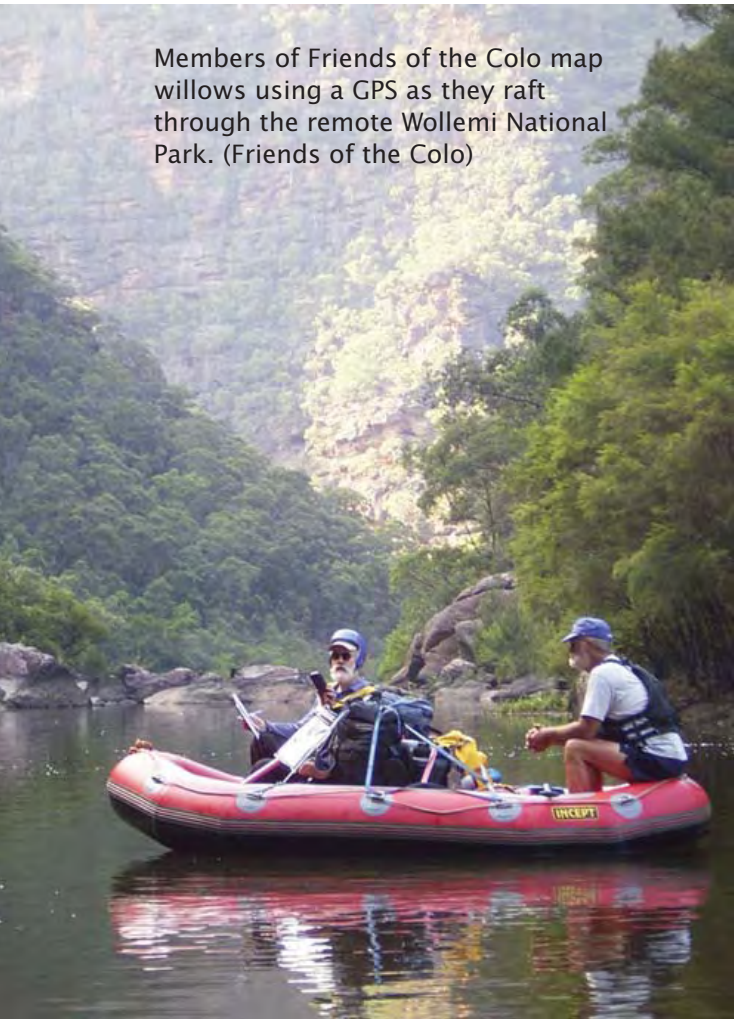
Both groups are strongly supported by the NSW National Parks and Wildlife Service, NSW Environment Trust, Australian Government Envirofund, Hawkesbury-Nepean Catchment Management Authority and local councils.

When and how to conduct the works?

Friends of the Colo used a variety of methods for surveying, recording and controlling willows. These included inflatable rafts or canoes, walking (carrying all equipment by backpack) and helicopter (to get volunteers into areas inaccessible by other means).

The following key activities outline the group's approach:

- ***Train volunteers*** – Volunteers were well trained in whitewater and wilderness safety at awareness days held at Penrith Whitewater Stadium and accompanied by experienced whitewater rafting guides on most trips. Volunteers were also trained in willow identification, weed mapping and treatment techniques.
- ***Determine the extent of the problem*** – The size, type and location of willows were recorded by site in the wilderness area, and then by 200 m transects along the river outside the park. The experience gained from this project led Willow Warriors to map willows by species in 200 m transects on their projects to ensure they could assess the



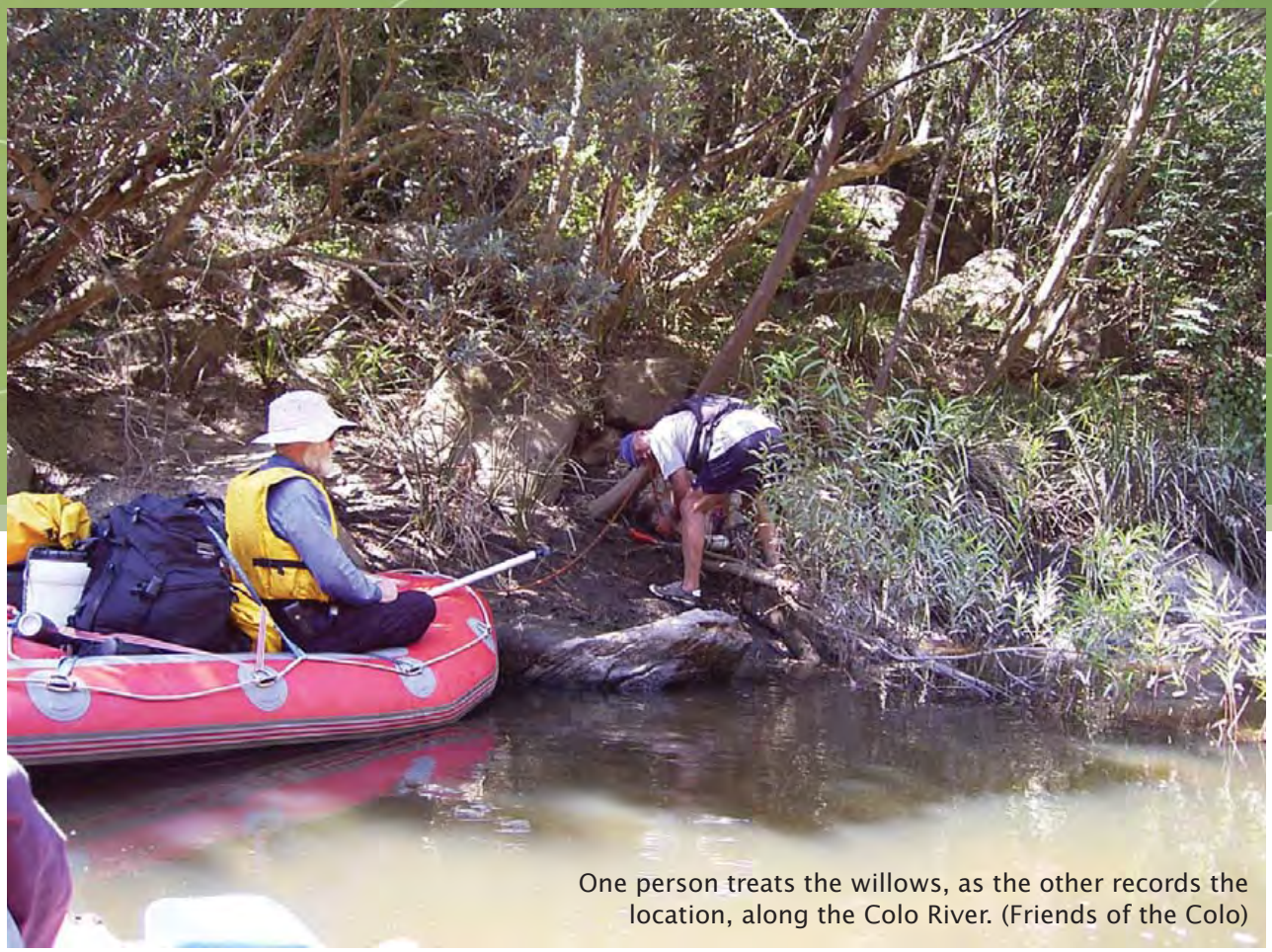
Members of Friends of the Colo map willows using a GPS as they raft through the remote Wollemi National Park. (Friends of the Colo)

amount of work involved in the catchment and prioritise the tasks required.

- ***Treat willows*** – Groups of volunteers travelled down the Colo River in canoes and rafts, stopping to apply glyphosate to willows by stem injection. A dye was used in the glyphosate to clearly mark the trees that had been treated and to indicate any spilt herbicide. Approximately 5000 willows were treated inside the Wollemi National Park from 2000 to 2003, and another 12000 treated outside the park from 2003 to 2006. The work off-park was split into sections and prioritised according to the risk re-infestation posed to areas already treated.
- ***Follow-up monitoring*** – Follow-up inspections confirmed that the willows were effectively killed and that other species had not been harmed. Many of the treated willows were left to naturally decay as they were not considered to be a significant risk to people or downstream infrastructure.
- ***Rehabilitation through natural regeneration or revegetation with native species*** – In most cases, treated areas were allowed to naturally regenerate from the remaining seed bank. At two sites, revegetation was required to ensure bank stability. Revegetation was conducted using long-stem native tube stock, grown from seed collected from the local area and propagated in a volunteer nursery run by Friends of the Colo.

Monitoring, evaluation and review

In December 2006, when the last mature female black willow trees were treated, members of Friends of the Colo toasted the end of primary willow control works with a bottle of champagne on the banks of the Colo. Monitoring trips are planned every two years to ensure that any seedlings missed can be treated before they get a chance to produce seed. In 2005, 100 seedlings and small trees were found and in 2007, 35 seedlings and small trees were found. The Friends of the Colo will continue to monitor the river for many years to come, to control any regrowth or reinvasion from other areas and to ensure that the willows are successfully



One person treats the willows, as the other records the location, along the Colo River. (Friends of the Colo)

replaced with native vegetation through natural regeneration or revegetation works.

A small stand of male trees remains on an unstable slope on private property. In consultation with the landholder, they will be gradually removed and replaced with appropriate native vegetation.

The Friends of the Colo continue to work on other significant weeds within the park, as well as willows.

Without the long-term commitment of these volunteers, willows could continue to invade and impact upon these precious environments.

To become involved with Friends of the Colo or Willow Warriors or for further information contact:

Willow Warriors Inc
10 Heather Close, Baulkham Hills NSW 2153

Phone: 0418 210 347

email: willowwarriors@optusnet.com.au

Internet: http://tech.groups.yahoo.com/group/willowwarriors/

Case Study 6

Partnerships and good management give a great result for the Bass River, Victoria

What and where?

The health of the Bass River in South Gippsland, Victoria, has been given a healthy boost thanks to a joint partnership between 14 committed landholders and the West Gippsland Catchment Management Authority (WGCMA). The WGCMA has been working to improve the health of waterways in the Bass Catchment since 1998. This project saw the removal of 14 km of willows, construction of 28 km of fencing and planting of 57,600 native tube stock along the river.

Why manage willows?

The Bass River drains the western end of the Strzelecki Ranges, forming a major tributary flowing into Western Port Bay. Extensive land clearance, agricultural development and infestation by willows have reduced in-stream habitat values and contributed to poor water quality.

Who to involve?

The project to remove willows was a joint partnership between 14 committed landholders and the West Gippsland Catchment Management Authority (WGCMA). The CMA funded the cost of the willow removal, site clean up, planting work and fencing material, while the landholders funded the construction of the fence and the tube stock required for planting. The CMA also helped to create an off-stream water source in cases where whole stream frontage was fenced off.

"The key to the success has been the strong project focus between all partners, including landholders, CMA and Landcare."

Malcolm Gibson, Operations Manager, West Gippsland CMA.

When and how to conduct the works?

A 20 tonne excavator and two qualified fellers worked together to remove dense willow stands at an average rate of 100 m per day. Trees were cut in situ, lifted from the river, stacked and then burnt. Stumps were poisoned using Roundup Biactive™.

The banks were raked with a stick rake mounted on the excavator and then hand raked to remove all remaining willow material. The site was then sown with a mix of rye grass and native tree tube stock. The grass was planted to help immediately stabilise the riparian zone until native plants established.

This project saw:

- 14 km of willows removed
- 28 km of fencing constructed, and
- 57,600 native tubestock planted along the river

BEFORE: Willow infestation along the Bass River

Monitoring, evaluation and review

West Gippsland CMA monitors each site twice annually in autumn and spring for two years following willow removal and covers the costs of any replanting, treatment of willow regrowth or other weed control required during this time. After this, the landholder is responsible for monitoring and maintaining their site.

In addition, WGCMA monitor the site for water quality and diversity of macro-invertebrates, before willow removal and for 8 years after, to ensure that the ultimate goal of improving the health of the waterway is being achieved.

After just one year of monitoring, they found that:

- 97% of native tubes planted had survived
- very little willow regrowth had occurred, and
- water quality and macroinvertebrate diversity in the river had markedly improved.

"Overall success is only achievable if all parties fully commit to the project, ensuring that maintenance targets are met and allowing time for the establishment of the vegetation in the riparian zone."

Malcolm Gibson, Operations Manager, West Gippsland CMA.

AFTER: willows removed from the Bass River

12 MONTHS LATER: fencing and revegetation completed, river health improved

(All photos: Mal Gibson, West Gippsland CMA)

Case Study 7

Community restoration of an urban creek in the ACT

What and where?

Restoration of a highly degraded creek has won the community around Yarralumla Creek a Keep Australia Beautiful Award and an improved area for all to enjoy. Yarralumla Creek is an urban stream in the ACT that drains the 35 square km Woden catchment. Since European settlement, the catchment has been impacted by land clearing and grazing but, over the past four decades, the effects of urbanisation have led to more extreme alterations, including changes to water flows, reduced water quality and less available habitat for native wildlife. A range of invasive pest plant species, including willows, have infested the river banks and are out-competing native vegetation.

Why manage willows?

The objective of this project was to improve the environmental and social values of Yarralumla Creek, including the public safety hazard and impact of willows, which had redirected flows, eroded the river banks and increased the transport of sediment downstream. As well as willows, a number of other issues needed to be managed, including limited creek access for recreation purposes, invasion by 'garden escapes', high velocity flows caused by concrete channels, pollutants from urban stormwater run-off and large amounts of human-created litter.

To succeed, the following key components would need to be addressed:

- Improve native habitat values by revegetating using a wide range of native species.
- Improve the watercourse structure and flows by undertaking revegetation and rock works.
- Raise community awareness about stormwater issues and the importance of riparian ecosystems.
- Improve water quality.
- Reduce gross pollutants from manufactured litter inputs.
- Improve safe access to the creek for passive recreation.

Who to involve?

The Molonglo Catchment Group and the Department of Urban Services worked jointly on the project with assistance from Canberra Urban Parks and Places, Conservation Volunteers Australia, the local community and the adjacent rural lessee.

To raise awareness of the creek's condition, the need to restore it and to encourage the community to take part in the project, a display was erected at a local workshop and media releases were distributed.

The campaign was embraced by the local community who joined in many activities, including pest plant control, revegetation, picking up litter, water quality monitoring and fencing. On Mothers Day, for example, about 320 people attended a planting day to commemorate their mothers, called 'Trees for Mum'.

Conservation Volunteers Australia teams became involved in planting, litter removal and woody weed control and additional weekend volunteer activities were carried out by the Molonglo Catchment Group.

Yarralumla Creek, before restoration May 2004 (Stefanie Straub, ACT Department of Territory and Municipal Services)

Yarralumla Creek, directly after restoration works June 2005. (Stefanie Straub, ACT Department of Territory and Municipal Services)

When and how to conduct the works?

The project's key activities included:

- ***Removal of woody weeds, including willows*** – All pest willows, selected poplars and other woody weeds were removed within and adjacent to the creek. The material that was cut down was mulched into wood chips and spread around the new plantings adjacent to the creek.
- ***Revegetation with a wide range of native species to improve habitat and water quality and help stabilise the creek banks*** – To date, over 15,000 plants have been planted, including macrophytes, grasses, shrubs and trees. While the very dry conditions enabled pest plants to be removed without damaging the creek banks, it made revegetation extremely difficult. At many planting sites, soil absorbents were needed to enable the water to penetrate the soil surface.
- ***Litter removal*** – In March 2005, 22 volunteers took part in Clean Up Australia Day in the area, where they collected 678 kg of rubbish. Ongoing litter collection is being carried out by the adjacent rural lessee.
- ***Water quality monitoring and fencing off hazardous, eroded sections of creek.***

"For many years, Yarralumla Creek was not utilised. It was neglected and ridden with litter and the many willows present blocked access to the creek and created an unsafe environment. Now there is creek access, a walking track and an open, pleasant outlook that families can safely enjoy."

Stefanie Straub, ACT

Monitoring, evaluation and review

Restoration of any natural landscape is a long-term activity and the Yarralumla Creek project will continue for a number of years. Active involvement of the community is helping to ensure the ongoing success of this project.

Revegetating the site with native species in 2005 has increased the available habitat for native animals, helped stabilise the banks and reduce erosion and improved the visual and recreational value of the area.

To further improve the area, future activities planned include:

- Continued follow-up weed control, litter collection, water quality monitoring and revegetation, including the re-establishment of pockets of native grasses where banks were left bare.
- Installation of erosion control structures, such as rock and Ecocells®, to stabilise the severely eroded sections of the creek.
- Developing formalised access points to specific areas along the creek for recreational purposes.
- Investigation of a proposal to install wetlands, bio-retention basins and litter traps up-stream of the creek to slow water flows and capture nutrients and litter.

In October 2005, the Yarralumla Creek Community Restoration Project won a Keep Australia Beautiful ACT Sustainable Cities Award in the Environmental Innovation category.

Section 6

Further information

Contacts

Region	Telephone number	Website
National	For current contact details visit website	www.weeds.org.au/WoNS/Willows/
Australian Capital Territory Parks, Conservation and Lands	13 22 81	www.tams.act.gov.au/live/environment
New South Wales Department of Primary Industries	(02) 6391 3100	www.dpi.nsw.gov.au/
Queensland Department of Primary Industries and Fisheries, incorporating Biosecurity Queensland	13 25 23	www.nrw.qld.gov.au/
South Australia Department of Water, Land and Biodiversity Conservation	(08) 8303 9620	www.dwlbc.sa.gov.au/
Tasmania Department of Primary Industries and Water	1300 368 550	www.dpiw.tas.gov.au/
Victoria Department of Primary Industries	13 61 86	www.dpi.vic.gov.au/

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Glossary

Term	Definition
ASTER	A high resolution imaging instrument flying on the satellite Terra. Advanced Spaceborne Thermal Emission and Reflection Radiometer.
Catkin	A stalk with many tiny, petalless flowers that are usually either all male or all female (although some willows can have male and female flowers on the same catkin). Catkins can be found on willows, birches, oaks, poplars and certain other trees.
Cultivar	A variety of a plant that has been created or selected intentionally and maintained through cultivation. For example, *Salix matsudana* 'Tortuosa' (tortured willow) is a cultivar created by the nursery trade from the species *Salix matsudana*.
Genus	A unit of taxonomic classification above the level of a species. All willows are in the genus *Salix*. The genus name is written as the first part of a scientific name. For example, *Salix fragilis* refers to the genus *Salix* and species *fragilis*. The genus can be shortened to the first letter, such as *S. fragilis*, so long as it is clear that this refers to genus *Salix*.
Hybrid	A cross bred plant or animal. Hybrids may be formed as a result of a male of one species pollinating a female of another. The hybrid has a mix of genetic material from both parents. For example, *S. alba* can hybridise with *S. fragilis*. The hybrid that results may be identified by its parents (*S. alba* x *S. fragilis*) or its own name (*S.* x *rubens*), where x indicates that it is a hybrid.
Species	A unit of taxonomic classification below the level of genus. The species name is the second part of a scientific name. For example, *Salix fragilis* refers to the genus *Salix* and the species *fragilis*.
SPOT5	Satellite images taken around the world with a SPOT5 satellite sensor.
Subgenus	Sub-category of a genus above the level of species. Individuals within a subgenus usually have certain characteristics that distinguish them from other members of the same genus. For example, the genus *Salix* has three subgenera: *Salix* ('tree willows'), *Vetrix* ('shrub willows') and *Chamaetia* ('alpine or dwarf willows'). These three subgenera can be easily distinguished from each other by certain characteristics.
Subspecies (ssp)	A sub-division of a species of organisms, usually based on geographic distribution. The subspecies name is written in lowercase italics following the species name. For example, *Salix cinerea spp. cinerea* and *Salix cinerea spp. oleifolia* are two subspecies of the species *Salix cinerea*.
Sucker	A shoot arising from roots or underground stems.
Taxa	The members of a particular taxonomic group, such as a genus, subspecies or species. For example, all willows are in the genus *Salix*, so willow taxa will include all subcategories (species, sub species, hybrids, varieties or cultivars) of the genus *Salix*.
Variety (var.)	A taxonomic subdivision of a species consisting of naturally occurring or selectively bred populations or individuals that differ from the remainder of the species in certain minor characteristics. For example, *Salix alba* var. *vitellina* (golden willow) and *Salix alba* var. *alba* (white willow) are two varieties of the species *Salix alba*.

Acronyms

Term	Definition
APVMA	Australian Pesticides and Veterinary Medicines Authority
CMA	Catchment Management Authority
NRM	Natural Resource Management
TAFE	Technical and Further Education
WoNS	Weed of National Significance

Appendix 1:
Examples of risks involved in willow management

Risks	Description of risk
Damage to downstream infrastructure	After willow control, there is a risk that debris can be moved downstream, where it can become a hazard to bridges, other infrastructure and boating.
Worker safety	Willow removal is dangerous, particularly where heavy machinery and chainsaws are involved. Works are often conducted in riparian environments where footing can be unstable and access limited. If willows are left standing after poisoning, there is a risk to worker safety from falling limbs and blockages to the river during follow-up maintenance.
Public safety	When leaving willows standing after poisoning by stem injection method, there is a risk to public safety from falling limbs.
Bank instability following willow removal	Willow removal can leave some riverbanks devoid of vegetation, which can temporarily lead to bank instability.
Impacts on remnant native vegetation	Using machinery can cause significant damage to native vegetation. Once willows are controlled, these plants will be important in helping control erosion and in recolonising areas where willows have been removed.
Reinvasion from willow regrowth or other weeds	Removing willows creates cleared areas that are prone to reinvasion by willows or invasion by other weeds (for example, blackberry or aquatic weeds). This may threaten significant environmental assets, such as areas of remnant native vegetation or habitats for rare/endangered aquatic or riparian fauna.
Reduced water quality from catchment inputs	There are many potential sources of input from the catchment that could impact on water quality in the river, such as high sediment and attached nutrient loss from hill slopes or contaminants carried in storm water runoff. Where dense willow infestations exist, there is often little to no ground cover under the willows to absorb excess nutrients and other runoff prior to it reaching the river.


(Melbourne Water)


(Danny Henderson, Southern Rivers CMA)


(Willow Warriors Inc.)

Suggestions to reduce risk
Dispose of debris as soon as possible by removing it from the site, piling and burning. Construct debris piles above flood line where possible.
Good training of personnel. Have well-established safe working procedures. Use well-maintained equipment.
Do not use this method in a public area. Fell willows before they die and become unstable. Put up signs to alert the public that works are being/have been undertaken.
Practice staged removal or use of appropriate engineering solutions. In some situations, it may be advisable to leave individual trees if they are playing a vital role in bank stability. Use waterway experts to provide advice.
Does machinery need to be used on site? If so, minimise impacts of machinery by carefully identifying access points and sites for piling and burning waste material and choose machinery that has least impact on the banks (for example, some excavators can carry, rather than drag, willow material, which reduces pressure on the banks).
Control other weeds before, during and after willow removal. Prior to control, look outside your site and manage any weeds that will likely invade your site following willow removal. Ensure willows are 100% killed by using correct herbicide application techniques, to prevent regrowth. Conduct thorough site clean ups and follow-up control. Revegetate the area as quickly as possible.
Establish a quick-growing ground cover to filter nutrient and storm water runoff before it reaches the waterway. Determine and manage for any potential threats to water quality from land use in the surrounding catchment.


(DPI Victoria)


(DPI Victoria)

Appendix 2:

Checklist of things to consider when determining an appropriate control technique

			Project site assessment	
			Tick which boxes are applicable to your site then look along the rows to determine which control methods (highlighted in green) best match your situation	✓
Assessment Factors	Willow target	Size	More than 150 mm stem diameter	
			Less than 150 mm diameter, more than 2 m in height	
			Small plants, less than 2 m in height	
		Type	Tree (subgenus *Salix*)	
			Shrub (subgenus Vetrix)	
		Density	Occasional or scattered willows	
			Scattered stands with isolated trees interspersed	
			Large dense infestation	
		Location	Bank	
			Instream	
		Form	Horizontal stems that need treating	
			Vertical stems that need treating	
	Potential environmental impacts on site	Machinery access to site	Easy to bring machinery on site	
			Difficult to bring machinery on site	
		Machinery access to willows without causing damage to bans	Easy for machinery to access willows without causing damage to banks	
			Difficult for machinery to access willows without causing damage to banks	
			Wet ground: Machinery tracks could cause significant damage to the site	
			Dry ground: Machinery tracks unlikely to cause significant damage to the site	
		Existing vegetation within willows (effect of falling limbs on vegetation)	Mostly native vegetation in good or excellent condition	
			Mostly weeds, grass or native vegetation in poor condition	
		Existing vegetation adjacent to willows (track issues caused by machinery)	Mostly native vegetation in good or excellent condition	
			Mostly weeds, grass or native vegetation in poor condition	
		Waste management	Area available for stockpiling willow material (either on or off-site)	
			No areas appropriate for stockpiling willow material	
			No fire restrictions prohibit stockpiling	
			Fire restrictions prohibit stockpiling	
	Potential social impacts	Public access	Public land or high recreational use along waterway (risk to people)	
			Private land (negotiate outcome with landholder/community)	
	Conditions downstream of site (distance to consider will depend on how far willows are likely to travel – for example, will travel less distrance along wide flood plain than along fast flowing gorge)	Infestation class (refer to Willows Resource Kit: Resource sheet 5)	Infrastructure considered at high risk from willow movement downstream	
			Active floodplain considered at high risk from willow movement downstream	
			Infestation classes: 1, 3, 5, 7, 8	
			Infestation classes: 2, 4, 6	
			Rank the available options for your site in order of preference / closest match to above assessment	

Control method options							
Mechanical options							
Excavator plus feller with chainsaw and cut stump treated with herbicide	Excavator with built in grabber, chainsaw attachment or grapple (forestry) shear and poison applicator	Feller with a chainsaw and team to manually cut up and stack material and cut stump treated with herbicide	Poison prior to removal	Non-machinery	Stem inject and leave standing	Foliar spray and leave standing	Hand pulling

✗ = not recommended

✓ = options available

Willows Management Guide