CHAPTER 3

Identifying management options through site assessment

Framework for ecological restoration

The practice of restoring damaged ecological communities is a relatively new activity within Australia and internationally (McDonald 1996). In the Sydney urban context, the process of assisted natural regeneration in urban conservation reserves began only in the 1970s, and was restricted mainly to the Hawkesbury sandstone areas of Sydney.

Restoration of bushland communities on the shale soils of the Cumberland Plain is more recent, with work only commencing in the last 15 years. Thus our understanding of restoration processes on the Cumberland Plain is more limited than for the adjacent sandstone areas.

While it is a relatively simple matter to provide an aesthetically pleasing bushland 'garden' in either previously cleared or landscaped bushland, it is much more difficult to ensure that the outcome of restoration activities is a true restoration of the ecosystem, and that the genetic integrity of both the newly restored site and adjacent bushland has not been compromised in the process (Burgin 1996).

This publication was written to help those land managers wishing to restore Cumberland Plain ecosystems find information based on current, best practice techniques. These guidelines are not rigid, in that there is often no one right way, but rather a variety of techniques which can be applied to a restoration site depending on its circumstances (Department of Infrastructure, Planning and Natural Resources 2003b).

Implementation of ecological restoration processes

Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has to some extent been degraded, damaged or destroyed (Society for Ecological Restoration International Science & Policy Working Group 2004). As much, if not all, of the vegetation on the Cumberland Plain is in such a state, the need for ecological restoration is clear.

Restoration is the process of assisting recovery. It does not necessarily imply total intervention. Current restoration practices in eucalypt woodland involve a number of approaches arranged along a continuum from minimal to extensive intervention (Davies & Christie 2001):

- **natural regeneration**, where recovery occurs purely through natural processes on the site
- **assisted regeneration**, where the natural processes that lead to the re-establishment of native plant species are 'triggered' by management
- **reconstruction**, where more active steps of planting out stocks of native seedlings and/or reseeding are undertaken to start the process of native plant restoration
- **fabrication**, where the entire woodland is built from scratch.

Assessment of site resilience, combined with the goals of ecological restoration, will enable the appropriate approach to be identified. The hierarchy of action discussed below will guide the choice of the appropriate approach.

The 3Rs of restoration

The long-term goal of ecological restoration is ultimately the self-perpetuation of a plant community. The principle of minimal intervention or 'less is more' should be adopted when considering restoration activities. In other words, intervention should only be necessary to deal with the degree of damage on a site, and to achieve restoration goals (Department of Infrastructure, Planning and Natural Resources 2003b).

The 3Rs are the key approaches for ecological restoration, and like the above four processes, they are arranged in order of increasing intervention:

- ***Retain*** – Retain remnant indigenous vegetation on site. In many areas of western Sydney little bushland remains, so conserving existing natural areas should be the first priority.
- ***Regenerate*** – Where bushland remains but is degraded by weed invasion, grazing, etc., regeneration should be the primary goal. Even quite damaged bushland is valuable and capable of regenerating if given the right assistance.
- ***Revegetate*** – Where a site has failed to respond to natural and/or assisted regeneration techniques and there is no regeneration potential, reconstruction through revegetation is then an option.

Remember that increased intervention often means increased cost in both environmental and economic terms. The most cost-effective restoration approach is natural regeneration, where the ecological benefits are two-fold. First, the resilience of your site is assessed over a longer period, which is beneficial when establishing genetically diverse site-specific native vegetation. As a bonus, cost savings can also result.

Table 3 highlights the relationships between each process, approach and possible actions. The following sections of this chapter will address the benefits and limitations of each approach. It will become clear that an integrated strategy involving all three approaches may often be necessary to achieve ecological restoration on the Cumberland Plain.

Table 3: Actions used in ecological restoration

Process	Approach	Action
Natural regeneration	Retain	Remnant protection Fencing Stock removal
Assisted regeneration	Regenerate	Bush regeneration Use of 'triggers'
Reconstruction	Revegetate	Revegetation Direct seeding
Fabrication	Revegetate	Revegetation Direct seeding

Natural regeneration

Natural regeneration is the process in which any healthy ecosystem will recover following a disturbance such as fire. The damaged and fragmented nature of bushland on the Cumberland Plain means that there are few entirely healthy remnants left.

There are limitations to using natural regeneration as the sole ecological restoration approach. Environmental weeds such as African Boxthorn and African Olive are widespread on the Cumberland Plain. Fencing of remnants (and the removal of grazing) may result in the proliferation of these weeds. This proliferation can negate or reverse natural regeneration. Do not, however, let this discourage you from fencing remnants. It may just mean that some early-intervention bush regeneration is necessary.

Additionally, the level of degradation of the site limits the rate of natural regeneration. A mixed native/exotic pasture with some canopy overstorey may allow natural regeneration of eucalypts but the process can be slow and results cannot be predicted with accuracy.

If landscape-scale restoration is an aim, retention cannot be used as the sole approach. High-quality remnants only make up a small proportion of the Cumberland Plain. Poorer remnants with high weed levels cannot be restored by natural regeneration alone. Thus, limiting a restoration program to fencing will restrict the area of Cumberland Plain that can be restored.

Finally, a key attribute of a restored ecosystem is that it is suitably integrated into a larger ecological matrix or landscape, with which it interacts through abiotic and biotic flows and exchanges (Society for Ecological Restoration International Science & Policy Working Group 2004). Therefore, a remnant cannot be considered restored unless it is connected to other areas of vegetation.

Assisted regeneration

Assisted regeneration involves active intervention to help an ecosystem recover to near-original conditions. This is mainly achieved through the treatment or removal of environmental weeds and known as 'bush regeneration'.

Environmental weeds are only one degrading influence on the Cumberland Plain. Feral animals (especially rabbits and hares), inappropriate fire regimes and high nutrient loads are all factors that affect ecosystem health. Active intervention to deal with these disturbances is a valid approach to assist regeneration.

There are several benefits to assisted regeneration. Through the removal of weed species, native vegetation can (and often does) recover to near-original condition. Additionally, bush regeneration is excellent as a preventive strategy to stop the likely decline of higher quality remnants through continuing weed invasion.

Bush regeneration is an intensive approach generally involving teams visiting sites over sustained periods of time. The benefits of weed removal can be lost quickly if works cease before the site is self-sustaining. Typically, this may involve maintaining a site for five to ten years.

Reconstruction and fabrication

Reconstruction is the most active intervention to facilitate the restoration of an ecosystem. It generally involves the reintroduction/augmentation of plant species to a site in a process known as revegetation. Importantly, reconstruction relies on some remaining attribute of the former ecosystem to speed recovery such as a partially intact seed bank (viable seeds retained in the soil), some remnant vegetation elements and an intact hydrological regime (the natural water flow across the site). Reconstruction is most successful where these factors are present. Fabrication is the process of rehabilitating a site that has been radically changed, usually through earthworks, salinity, cultivation, etc.

Techniques used in bush regeneration, such as weed removal and feral animal control, are essential site preparation techniques prior to planting. Additionally these techniques need to be applied for a sustained period post-planting to ensure continued ecological restoration. If best practice techniques are used, the maintenance requirements can be lower than that of a bush regeneration program.

Revegetation, with our current techniques and level of understanding, cannot fully recreate the biological complexity of a healthy Cumberland Plain ecosystem. Although we are currently able to reintroduce almost all shrub and tree species, this is less so for the wide variety of groundcovers. The means exist to propagate a range of groundcover species, but the cost involved in planting them out at appropriate densities tends to be prohibitive. Nevertheless, revegetation has been shown to assist the reintroduction of a number of groundcovers (Nichols 2005).

Despite not being able to fully create the former vegetation community in the short term, revegetation can restore a range of important ecosystem functions. Revegetation areas can act as habitat and resources for animals and help restore former hydrological regimes.

Furthermore, reconstruction can be implemented in areas and over scales where assisted regeneration is not appropriate. It is the primary tool for linking areas of remnant vegetation and can also act as a buffer to minimise 'edge' effects such as weed invasion of remnants.

Revegetation is a useful tool to link areas of remnant vegetation and protect remnants from 'edge' effects. (Greening Australia (NSW))

Site assessment: determine the most appropriate restoration approach

The assessment of a restoration site is the process through which we determine the resilience of the vegetation on that site, so an appropriate management plan can be determined. Thus, prior to the commencement of any restoration activities, an assessment of the site and its potential to regenerate naturally is required (Buchanan 1989). The more that is known about the structure and function of the community you wish to restore, the greater the chance of success for your restoration project.

All the assessment models seek to analyse the resilience of the site and follow a similar approach.

1. Investigate past and present degradation sources and the potential for mitigation.
2. Predict the site's potential to recover.
3. Determine the most appropriate restoration approach and within that approach determine the appropriate restoration treatments or interventions.

Investigate past and present degradation sources

There are two main ways to determine the previous land use of an area. Either find documented evidence, or 'read' the land. Some of the questions below may help you find the land-use history of your site:

- Is the stand of trees even-aged or is there a range of ages? An even-aged stand indicates that there has been clearing or harvesting of trees.
- Is there evidence of tree stumps that have been cut? This can indicate past logging.
- Is there evidence of fire scars on trees? An indication of fire history.
- What are the plant types in the understorey? Herbs, especially broad-leaved ones (forbs), and shrubs indicate little disturbance. Grasses, lilies and daisies are often eaten out in areas that have been grazed, leaving mainly the less palatable shrubs.
- What is the percentage weed cover and what weed species are involved? The more weeds in an area the more degraded it is and the less likely it will support native animals.

Due to its ability to disperse long distances, Themeda australis *is a common native grass that occurs across the Cumberland Plain. (P. Watson)*

- Is there a 'browse line' on shrubs? A browse line indicates that the site has been grazed in recent times.
- Is there evidence of herbivore faeces? Their presence can indicate past grazing even if the grazer is no longer present.
- Is there a decline in tree health or dieback? Trees in a rural landscape may have canopies with many dead branches at the tips, or high mistletoe loads. This may indicate an imbalance in the landscape. Past land use such as clearing, grazing or fertiliser application may be responsible for poor tree health.
- Is there evidence of seedling regeneration? Seedlings beneath mature trees indicate that grazing pressure is light enough to allow regeneration. In heavily grazed sites there is little regeneration.
- Is there evidence of soil and rock removal, dumping of rubbish or garden clippings, or vehicle tracks?
- Are there signs of pest animals? Apart from direct sightings, identifying pest animals involves looking for signs of their presence, such as scats (droppings or faeces), rabbit scratchings and warrens, pig rooting or footprints.

Disturbances or other changes encourage invasion by exotic plants. These exotic plants are often 'weedy' disturbance specialists that can quickly colonise bare areas. Succession is the progression of changes in a community's composition, and this process is driven by competition between species for available resources (Bayley & Brouwer 2004). Understanding these successional changes over time and managing these areas to ensure that the balance is tipped to favour native species will be the key factors in establishing full ecological function to your community.

Predict the site's potential to recover

Currently our ability to scientifically predict the boundary between regeneration and reconstruction (revegetation) is limited due to a lack of formal research on the Cumberland Plain. The extent of the migratory zone (the area in which natural regeneration is possible) varies for each species. The distance a plant can disperse its seed correlates with the extent of its migratory zone. Practitioners are encouraged to collect seed only within a plant's dispersal range. The ranges for seed collection identified in Table 5 of Chapter 5 can therefore also be interpreted to indicate a plant's potential migratory zone.

You should avoid planting in areas where natural regeneration is expected to occur. It is a waste of resources and may artificially block niches that may be occupied by regenerating species.

Various factors need to be considered prior to choosing a restoration approach for your site (Department of Infrastructure, Planning and Natural Resources 2003b). These include:

- the nature and quality of existing native vegetation on-site will identify potential sources of seed
- the extent, nature, condition and diversity of structural elements present (canopy, shrub layer and groundcover) indicate whether representatives from these elements are likely to regenerate
- the individual native species present indicate the minimum range of biodiversity to be expected on-site
- the reproductive habit and dispersal mechanisms of individual species on-site indicates their persistence and ease of spread
- observed regeneration occurring
- the size of the remnant and its connectivity with other bushland areas
- past land-use and disturbance history, including fire history, may indicate the size and viability of seed in the soil
- soil conditions, including whether the soil has been altered or fill imported to the site, will influence the potential for a store of native seeds in the soil (known as the seed bank)
- nature of current and ongoing levels of disturbance, including adjacent land use and whether this can be controlled or not
- type of weed infestation and its extent and density will identify the type and extent of weed management required.

Encouraging natural regeneration is the preferred and recommended way to rehabilitate natural and semi-natural areas, as it retains the local native genetic component. In some cases this may simply be a matter of fencing areas adjacent to native trees and allowing natural seed fall to provide new seedling growth, while in other areas a more active approach may have to be implemented.

Canopy species

Most native tree species such as eucalypts, melaleucas, angophoras and casuarinas, do not have very effective long-distance seed dispersal mechanisms, and most seed is deposited within a zone one to two crown diameters wide (Benson & Howell 1993). Therefore, sites within this zone from a healthy parent tree might be considered a regeneration zone, where an unassisted and/or assisted regeneration strategy is the recommended option. If regeneration of native species is not occurring naturally over time, a more active management approach may be required, such as using triggers or introducing seed and/or seedlings.

Brunoniella australis *is a common herb found in Cumberland Plain Woodland. (P. Watson)*

Shrub understorey

It can be assumed that sites that have been cultivated, continually burnt or grazed for many decades will have little, if any, resilience and will therefore need to be reconstructed. The absence of a parent plant of a shrub species within dispersal distances (see Table 5 in Chapter 5) may indicate a reconstruction zone for those species. Using triggers (see Chapter 4) to assess the soil seed bank should also be trialled in those areas expected to have moderate resilience.

Grassy herbaceous understorey

Grasslands and herbs can be successfully regenerated through the management of fire and grazing regimes. The high dispersability of many native grasses means that the regeneration zone can extend well into what might be considered a reconstruction zone. However as exotic weeds can generally out-compete indigenous vegetation, a carefully considered weed-control strategy is essential.

Tip:

Native groundcover species, including less common and slower-growing native grasses and herbs, are a strong indicator of resilience. Examples include *Dianella* spp., *Aristida* spp. and *Lomandra filiformis* (Department of Infrastructure, Planning and Natural Resources 2003b).

Determine the most appropriate restoration approach

A plan of management for a site is important. Such a plan will clarify the goals and objectives for restoration of the site and clearly set out the proposed actions required. An accompanying work or action plan is also necessary. The work or action plan differs from a plan of management in that it provides specific restoration actions and techniques to be used in your restoration program. A site assessment will guide the works program and denote the type of restoration works required.

When assessing sites on the Cumberland Plain, you should err on the side of optimism, as vegetation in this area in the past has displayed surprising resilience. Underestimating this resilience can result in inappropriate and unnecessary intervention that may compromise recovery.

Knowing which patches of remnant bush are good and which are degraded is important. If funds and resources are limited, you then know which remnants to protect and manage first. Generally, it is better to start with 'healthy' remnants because they need fewer resources to look after and repair than more degraded remnants. An assessment sheet (see Table 4) has been developed specifically to help landholders assess the quality of their own patches of vegetation.

Natural regeneration following the reduction of stocking rates at the EMAI demonstration site at Menangle. (DEC/R. Burton)

Table 4: Assessment sheet for Cumberland Plain remnant vegetation (bushland, grassland and paddocks with scattered trees)

Assessment questions (answer 'Yes' or 'No')	Site number or name			
Is the area fenced to control stock access?				
Is there regeneration of native trees and shrubs or, if in grassland, regular (annual) germination of native herbs?				
Is a diverse range of native tree and shrub species present, i.e. more than 10?				
If grassland, is a diverse range of grasses and broad-leaved herbs present?				
Is the ground covered with litter such as leaves, bark and twigs?				
Are there mosses, lichens or liverworts on rocks, fallen branches or the ground surface?				
Are weeds uncommon, sparsely scattered, absent or mainly found around edges of the area?				
Is there a very low incidence of pest animals, e.g. foxes and rabbits?				
Is the remnant or paddock shape a block rather than a strip?				
Is the area greater than two hectares?				
Is the remnant or paddock linked to other remnants by corridors, e.g. roadside vegetation or scattered trees no more than 50 metres apart?				
Is there a mix of tree ages present, i.e. saplings through to old-growth with hollows?				
If trees are present, is there also an understorey?				
Is the understorey mostly comprised of native shrubs and/or grasses and broad-leaved herbs?				
Are there standing trees (alive or dead) with hollows in the remnant?				
Are trees mainly healthy, with little or no dieback?				
Are less than 20 per cent of trees affected by mistletoe?				
Are there logs and fallen timber on the ground?				
If scattered paddock trees are unfenced, are stock camps absent?				
If scattered paddock trees are unfenced, is evidence of stock ringbarking or rubbing absent?				
Is the area free of herbicide, insecticide or fertiliser overspray from adjoining areas?				
Is the area free from the threat of salinity and/or high watertables in the next 10 years?				
Total number of Yes answers				

Key

Number of Yes answers			Vegetation remnant condition rating	Need for management attention
Remnant bushland	Remnant grassland	Scattered paddock trees		
14+	9+	12+	Healthy	Maintain current management
9–13	6–8	8–11	Good	Needs some management attention
5–8	3–5	5–7	Fair	Needs a significant level of management attention
0–4	0–2	0–4	Poor	Urgent management required

Prepared by McMahan S. & Brickhill J. NSW NPWS, adapted from Disappearing Islands Group (1993) and Goldney & Wakefield (1997)

Assessing and planning for habitat

Site assessment and strategies for restoration projects should take into account the existence and needs of native animal populations. It may turn out that your site was providing an important island of food or shelter in an otherwise inhospitable area, and that the restoration process has unintentionally disrupted this. Sometimes the transitional period during a restoration program can be devastating for the resident wildlife. Therefore maintenance and enhancement of fauna habitat must be an integral part of restoration aims and actions (Department of Infrastructure, Planning and Natural Resources 2003b).

Native fauna is dependent on vegetation for survival and this may include exotic vegetation. In turn the role that fauna plays in the pollination and dispersal of native vegetation may be crucial to the long-term regeneration and recovery of indigenous plant communities. The extent and nature of animal populations and the current habitat uses of a site therefore need to be assessed prior to undertaking restoration.

Site assessment and work plans should include actions that maintain and increase habitat. A site's habitat importance can be assessed by the existence of remnant vegetation, mature trees (the presence of hollows), dense understorey (particularly indigenous species), native fauna, exposed rock, logs, leaf litter and clean water. Actions to be considered include:

- Identify potential wildlife sanctuary areas on your site.
- Before removal, consider the habitat potential of weeds, unwanted trees and shrubs, and rubbish such as old pipes, car bodies, etc. and work towards their slow replacement by more natural components.
- Avoid removing weeds in areas providing important habitat for existing wildlife until nearby substitute habitat is provided.
- Retain and where possible reintroduce logs, bark and natural debris.
- For intensive weeding over large areas, adopt a mosaic pattern of weed removal (see Figure 4).
- Remove areas of dense weed infestation only outside peak breeding times (usually spring and early summer) or when they are not providing a major food source.
- Protect mature trees through the removal of weed vines smothering the canopy, and weed competition from around their bases.

This possum is nesting in an African Olive tree, a problematic weed species on the Cumberland Plain. Careful consideration is necessary to account for the habitat value of all vegetation on your restoration site. (Greening Australia (NSW)/R.Wood)

- Selectively retain mature weed trees in the absence of mature native trees until mature-sized native canopy trees are established.
- Remove weed trees gradually and consider poisoning in autumn to mimic the natural cycles of some exotic trees.
- Leave dead trees (including exotics) in place, where feasible, as they will provide habitat in the form of hollows and perches.
- Consider re-introducing artificial nesting boxes, although they need to be monitored to ensure they are not used by exotic animals.
- Consider the potential impacts of herbicide on amphibians.
- Try to repeat the density and species mix in revegetation sites that occur naturally in local remnants (remember to mimic aspect) thus ensuring a diversity of habitats is retained.
- Try to link habitat areas with a vegetated corridor and where possible regenerate/revegetate waterways to maintain bank stability, and provide important corridors and aquatic habitat.

Figure 4: Mosaic weeding pattern

1	2	1	2	1	2	1	2	1	2	Upslope
3	4	3	4	3	4	3	4	3	4	Downslope

Choose upslope sites to begin weeding; weed in number 1 areas and allow for regeneration/revegetation to develop in these areas to a height of no less than 1 to 2 metres, or a density similar to the previous weed cover, before commencing on number 2 areas and so on.

CHAPTER 4

Bush regeneration and the use of 'triggers'

Restoration through bush regeneration

In the vegetation communities on the Cumberland Plain, plants in the ground layer are highly important in contributing to plant diversity. Perennial herbs and grasses together account for more species than the shrub layer (Hill & French 2003). This is in contrast to the mix of species growing on Hawkesbury Sandstone, where the vegetation communities have a well-developed shrub layer (Thomas 1994).

Past land-use history, combined with the more open structure of woodland communities, has led to a proliferation of weed species in the ground layer. Cumberland Plain restoration projects often need to deal with large areas of semi-degraded bush containing major weed expanses in the understorey.

Despite these problems, Cumberland Plain communities exhibit much natural resilience in their tolerance to a dramatic range of environmental conditions (Department of Infrastructure, Planning and Natural Resources 2003b). Because of these wide tolerances, many Cumberland Plain remnants respond with surprising success to the regeneration techniques employed to restore them.

Preparing a bush regeneration program

Bush regeneration centres on the removal of competitive weeds. These are usually exotic plants, although native plants from other areas are also regarded as weeds.

Specific restoration and regeneration works must take account of the processes affecting weed spread. The cause of the weed infestation (stormwater, nutrient enrichment, etc.) is often overlooked and only the symptoms, that is the weeds, are dealt with. Any bush regeneration program should incorporate strategies and actions which prevent or reduce the degrading influences causing weed spread. Commonly occurring degrading influences include:

- urban runoff
- flooding and siltation in urban watercourses
- creekbank slumping and soil erosion
- overuse (recreational and grazing pressure) and damage to vegetation
- pollution of water, soils and air
- inappropriate fire regimes (burning too frequently or total suppression of fire)
- invasive plantings in local parks, private gardens and agricultural properties
- activities such as dumping, collecting timber or vandalism.

Regeneration of the native plant community from existing seed sources cannot occur where the potential for regeneration (site resilience) is absent. During regeneration, the on-site conditions are adjusted to encourage and favour the native plant community (National Trust of Australia NSW 1991).

It is important to remember that each site is unique. Local environmental conditions, as well as the threats to the area, will determine the best course of action. Three steps are recommended when setting up a bush regeneration program:

- define the aims
- collect information
- prepare an action or work plan.

Aims

An aim is a statement about the project which says what you are trying to achieve in terms of regeneration, your desired outcomes or general intention. It should be a short and clear statement that is realistic and credible.

Collecting information

An information base is an important part of the regeneration process. Gather information about the history of the site, as this often reveals how it became degraded in the first place. Information on the site's history and present condition will allow you to plan a work program and help you avoid costly mistakes later on (National Trust of Australia NSW 1991).

- **Prepare a detailed map –** The map should indicate the boundaries of your site, any major features of the area, e.g. creeks, rivers, drainage patterns, large rock outcrops, outstanding or unusual trees. Also mark constructed features such as drains, walls, paths or sheds.
- **Identify and map the plant communities** on your property. The NSW National Parks and Wildlife Service (now part of the Department of Environment and Conservation) mapped all the remnant vegetation communities found on the Cumberland Plain and a report, *Native Vegetation of the Cumberland Plain: Final Edition*, was released in October 2002. The report and maps can be found on the website www.environment.nsw.gov.au under 'Cumberland Plain Vegetation Mapping Project'.
- **Prepare a plant list –** This should include local native species, weeds and natives introduced from elsewhere. Take note of any species that are locally rare or endangered. The National Herbarium at the Royal Botanic Gardens in Sydney can help identify any unfamiliar plants (see Appendix 6 for contact details).
- **Record any wildlife** you see, e.g. birds, mammals, reptiles.

- **Photograph the site** before work starts. Use fixed photograph points. Continue to photograph regularly during the course of the project (every six to 12 months). Record the date, site and photographer on the back of every photograph.
- **Consider the resources available** – money, people, time, materials, etc.
- **Liaise with local residents** where applicable. Use open days, letter-drops etc. and take the opportunity to explain what your project hopes to achieve before you start work.

Assessing the site

Now that you have gathered your information, prepare a detailed assessment of the site (National Trust of Australia NSW 1991). This should include:

- a colour-coded vegetation map showing the condition of existing plant communities – use a simple grading system for weed density (e.g. almost weed-free bush, light weed infestation, severe infestation, total domination by weeds). Mapping weed density may reveal the source of the weeds and the maps can then beused to develop a weed management program in your action or work plan (Bayley & Brouwer 2004).
- sites which might require planting and the source of the required plants (see section on planting in Chapter 5)
- disturbed areas, both natural and those caused by people – assess whether the problem will continue, and whether it can be eliminated or modified.

Determining weed density

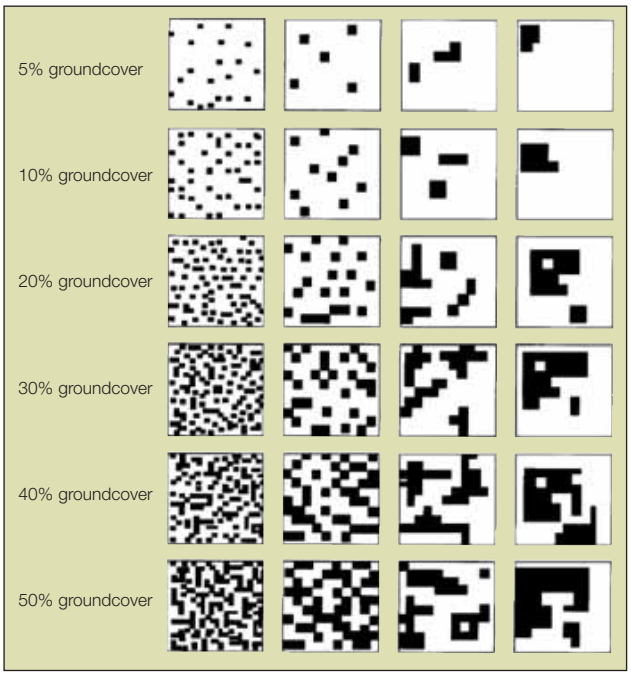
Knowing the density of weeds on your site can help you develop your vegetation map, which in turn will help you decide where to direct your weed-control efforts, and allow you to assess how well those controls have worked over time. By density we mean the proportion of the area covered by each weed species. This is usually expressed as a percentage of the area of infestation. Visual assessment is the simplest way to determine weed density. Figure 5 gives you an idea of how different weed densities, as a percentage of groundcover, may look. Note how dense a cover of 50 per cent appears. The CRC for Australian Weed Management has produced a document titled *Developing and implementing a weed management plan (Module 1)*. For more information on implementing a weed management plan, this document can be viewed at www.weeds.crc.org.au/documents/manual

Prepare an action plan

Although the information you have gathered will help to determine the priority areas and the order in which the work should be done, an action plan is necessary before work can begin. When preparing an action plan you should:

- **consider your priorities** – What are the major long-term threats to the native plants on-site, specific weeds, other disturbing factors such as drainage, fill, grazing? Can the threats be controlled or removed?
- prepare a **rough map of the site** by dividing it into logical zones (work zones) which will reflect the condition of the vegetation and the function of the zone, e.g. creek, boundary, stormwater discharge

Figure 5: A guide for the visual assessment of weed infestation as a percentage of groundcover



Source: Bayley (2001)

- decide on a **sequence of work** – Is the site best treated zone by zone, or is it better to treat the site as a whole and target particular weeds progressively?

Prepare a short-term plan of action. Which areas or weeds will be treated over the next couple of months? This plan should be flexible. Although you may not stick to it, it will give you direction. You need to be prepared to revise the plan if circumstances change (National Trust of Australia NSW 1991).

Tip:

Depending on the age of the vegetation on your site, resources such as tree hollows for native wildlife may not be available until a long time after rehabilitation, and you should consider importing habitat material such as logs or nesting boxes of appropriate sizes to attract the desired target species back to the area. Don't forget to plan for fauna in your action or work plan.

Identifying weeds

Knowing which plants are weeds and which are natives is an integral part of your bush regeneration program. If you have the resources, employing professional bush regenerators is a good way in which to ensure professional advice and techniques are used on your property. If funding is an issue and you plan to undertake the work yourself, but need help and training in weed identification and/or bush regeneration techniques, there are many resources available to help you with this endeavour.

For more information on identifying weeds, see Appendix 6 (contacts) and Appendix 7 (recommended reading).

Weed control techniques

The first step in any regeneration program is to identify the weeds on-site and, based on the priorities in your action plan, start to selectively remove them.

Primary weed clearance: This is the first step. It may involve herbicide or hand removal. Areas receiving primary treatment have varying degrees of weed infestation.

Secondary treatment or follow-up: Secondary treatment is intensive weeding in areas which have already received primary work. Areas which have been badly degraded (e.g. prone to runoff or next to roads and paths) may need intensive weeding for a longer time, while sites in good condition will need little follow-up.

Maintenance weeding: The amount of weed seed stored in the soil is incredibly large, even in our best remnants. Animals and wind are continually carrying in weed seed. Although competition from native plants will reduce the ability for these weeds to establish, a range of weed species is still able to establish even in the most pristine systems. These weeds need to be controlled regularly as they arrive in the remnant.

All areas should be monitored at least twice a year, particularly in spring and early summer (when herbaceous weed growth is at its most rapid), so that weeds can be detected and removed. Edges of roads and tracks will need to be targeted to keep the weeds at bay, but healthy bushland should only require infrequent weeding (National Trust of Australia NSW 1991).

Weed management aims to free up the resources, such as the availability of light, soil moisture and nutrients required by native plants, so that they can regenerate. Under the *Noxious Weeds Act 1993*, there are requirements relating to certain weed species that must be met by land owners and managers. A copy of the noxious weeds in each local government area is also available from your local council or through the NSW Department of Primary Industries website www.agric.nsw.gov.au/noxweed (see also the list of noxious weeds in Appendix 3).

It should be noted that not all environmental weeds that pose a problem in bushland areas are on the noxious weeds schedule. A list of the environmental weeds common on the Cumberland Plain and their treatment techniques can be found in Appendices 3 and 4. The Australian Association of Bush Regenerators (AABR) also has a comprehensive list of the environmental weeds in NSW on their website at www.aabr.org.au

Tip:

Do not attempt to clear more weeds than your resources will allow you to control. If weed control maintenance is not undertaken throughout the entire process of seedling germination and establishment, your strategies to control weeds may be at best ineffective and at worst may lead to increased weed proliferation and a decrease in the site's native seed bank and its future resilience.

Weed management on the Cumberland Plain requires an ability to identify weed and native species, particularly grasses and native groundcovers. Weed management also requires the resources and commitment to long-term follow-up weed control.

Long-term control is essential because, if you provide the resources (increases in light, moisture, nutrients, etc.) for native seedling germination by initial weed removal but do not continue weed control, the weeds will almost undoubtedly re-establish, out-compete and kill off the native seedlings. You will then have depleted the valuable native seed bank stored in the soil for no result, and the seed bank may even be exhausted in this unsuccessful attempt.

When setting weed management priorities, the following factors should be considered:

- size of the site
- level of threat to native species posed by particular weeds
- level of weed control needed to achieve the site's objectives
- stage of the reproductive cycle of the weeds involved and whether they are annuals or perennials
- ease or difficulty of controlling specific weed species, which is influenced by external constraints such as the weed's biology, uncontrollable upstream weed sources, the soil and weather conditions
- resources available and time constraints
- ecological function of the weeds – the habitat value of weeds should not be underestimated, and weed control measures may need to be staggered in time and space to accommodate the needs of wildlife.

Tip:

The extent and diversity of weed problems on the Cumberland Plain are generally high and many sites are large. To tip the balance to greater native diversity will require the progressive targeting of weeds over time. It is essential that the long-term resources to maintain and control weeds are factored into any bush regeneration program.

An effective approach involves monitoring changes as work proceeds, with the flexibility to revise priorities as site conditions change.

The aim should always be to use a combination of techniques that achieve the agreed objectives with the least intervention practicable (Department of Infrastructure, Planning and Natural Resources 2003b).

The various best practice methods used to control noxious and environmental weeds common on the Cumberland Plain can be found in Appendixes 3 and 4. See also Appendix 6 for sources of more information on identifying and controlling weeds.

Tip:

Two exotic species, *Olea europaea* subsp. *africana* (African Olive) and *Myrsiphyllum asparagoides* (Bridal Creeper), have been identified as a major threat to conservation of native flora on the Cumberland Plain due to their wide distribution and ability to out-compete native species (Tozer 2003). It has been found that, compared with surrounding areas, the litter under African Olive trees is deeper and the soil has higher pH and phosphorus levels. This combination may be bad for the regeneration potential of native species (Cooke 2005). Control of these weeds should be a high priority in any weed management program (Tozer 2003).

The most commonly used methods and techniques applied in the management of weed infestations on the Cumberland Plain include:

- hand removal
- application of herbicides
- slashing, mowing, cutting back or fire to reduce the mass of large weed infestations
- weed matting and mulching
- mechanical clearing
- biological control.

An integrated approach involving combinations of the above is usually necessary. Appendix 4 describes the various methods used to control and remove weeds.

Hand removal

Because of the risk of damage to adjacent vegetation, removing weeds by hand in areas where they grow close to native or desirable plants is always preferable to using machinery, fire or spraying herbicides.

The frequent hard, dry and compacted nature of soils means, however, that digging and removing weeds can be time-consuming and lead to unacceptable levels of disturbance. Timing is important and wherever possible you should take advantage of favourable seasonal factors, such as moist soil conditions after rain (Department of Infrastructure, Planning and Natural Resources 2003b).

Basic hand-weeding techniques can be applied to particular groups of plants. For example, plants with tap root systems are removed using methods different from those for layered woody plants, or vines or scramblers that root at the nodes. Appendix 4 discusses the various methods of removing weed by hand. Always try and use the most efficient and labour-saving techniques.

Herbicides

The use of herbicides to control weeds is increasing, especially with the availability of biodegradable chemicals such as glyphosate (marketed as Zero, Roundup Biactive® or Glyphosate 340).

Given the scale, nature and extent of weed infestations across many Cumberland Plain sites and the limitations associated with hand removal, herbicides are important tools in a restoration project. A range of selective and non-selective herbicides are constantly being trialled to address weed problems across the Cumberland Plain.

A targeted bush regeneration program at Camden Town Farm demonstration site will allow land managers to selectively control weeds over time, thereby reducing competition between native plants for resources, such as light, moisture and nutrients. (DEC/R. Burton)

Roundup® is a herbicide commonly used in bush regeneration, whereas **Garlon®** is sometimes used to control weeds such as blackberry, prickly pear, lantana and privet. Other herbicides include **metsulfuron (Brush-off), fluroxypyr (Starane),** and **triclopyr and picloram (Access** and **Grazon).**

When choosing a range of herbicides for bushland rehabilitation work, care should be taken not only to choose the most effective chemical for the job, but to check the chemical's persistence in soil and water, its toxicity and the different effects it might have on individual weed species.

Use herbicide strictly in accordance with the labelling and ensure that any permits, orders or other 'off-label' use requirements are obtained and complied with. Permits for off-label uses should be sought from the Department of Primary Industries (phone (02) 6391 3100 or visit www.agric.nsw.gov.au).

Application techniques

While herbicides are valuable aids in weed management, they will also destroy native vegetation if used indiscriminately. There are many ways you can apply herbicides. Decide on which parts of your site you are going to use it and what method of application would be suitable. Appendix 4 has detailed information on the various techniques used for the application of herbicides, given the weed's form and habit.

You should limit the use of non-selective herbicides in native grassy woodland. Herbicide application here should be confined to carefully targeted spot-spraying by experienced operators. Further, avoid spraying to such an extent that the soil is left bare and susceptible to erosion.

When to apply herbicides

Time the application of herbicides to achieve maximum effectiveness. The right time to apply systemic poisons is when water and sugars are being rapidly moved (translocated) around the plant (usually spring and summer). Herbicides are likely to be less effective on plants which are not growing due to the season (winter) or which are stressed by drought, cold, frost and waterlogging (Buchanan 1989).

Plants which sucker easily from the roots, and plants with underground reproductive organs must be treated just after flowering when sugars (and hence herbicide) are moving down into the bulb or tuber. Treatment when sugars are moving upward from the underground organs to form the new season's shoot will be useless (Buchanan 1989). While this is the general rule there are always exceptions, so check the CRC for Australian Weed Management website at www.weeds.crc.org.au for more details.

Reducing weeds by slashing or mowing

Reducing weed bulk (biomass) by the selective use of slashing or mowing may be useful as an interim measure to provide access and allow more targeted and effective weed control. This is especially so in native grassy woodlands, where herbaceous weed growth can be difficult to selectively control.

Slashing or mowing can also be used in bushland areas (grassy native understorey) as an initial or holding treatment to reduce weed mass. It allows for more efficient follow-up as fast-growing re-shooting weeds can be spot-sprayed with herbicide among areas of native grasses and herbs.

Mowing and slashing provides an effective means of weed control in non-bushland areas, such as agricultural land, in clearings, along tracks and firebreaks, or where bushland adjoins suburban housing and protection from fire is an issue.

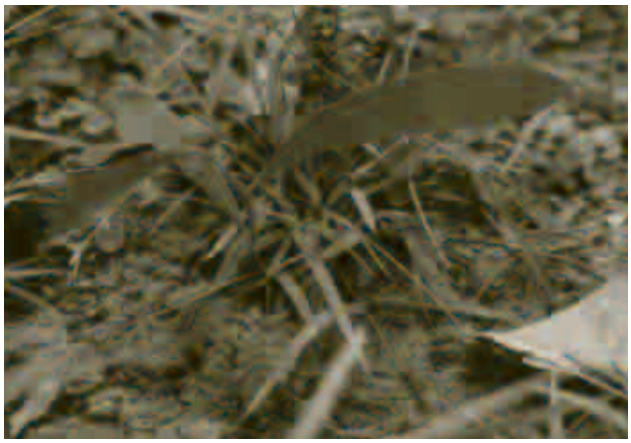
Mowing or slashing will reduce the weed biomass and, if carried out regularly over the growing season, can prevent the weeds from flowering and fruiting thereby reducing weed numbers in the following season. However, if mowing/slashing is irregular or is carried out after seeding has commenced, long-term weed control will not be achieved.

To effectively control exotic annual herbs and grasses, mowing or slashing must be done at least monthly in summer (possibly more frequently if conditions are warm and wet and weed growth is accelerated). For perennial weeds which mature in mid- to late summer, mowing or slashing may be reduced to two to three times each season, with the final treatment being applied late in the season as the fruit ripens and seed becomes viable.

The timing and height of cut also needs to be considered, as it may be possible to allow some native grasses to run to seed despite the mowing (Department of Infrastructure, Planning and Natural Resources 2003b). Slashing or mowing should not be used where endangered or vulnerable species may be present.

Reducing weeds with fire

In bushland, burning stimulates native plant seeds in the soil canopy. As weeds are also stimulated by fire and respond with regeneration, fire can be an incredibly useful tool in an integrated weed control program, and implementing an appropriate fire regime can help ensure certain weed species are kept in check. However, the deliberate use of fire to reduce weed biomass is not a technique to be used too regularly, because frequent burning in the same area will reduce structural diversity and abundance of native species. Planned and careful weed treatment is needed both before and after burning (Department of Infrastructure, Planning and Natural Resources 2003b). Fire should be an important component of any bushland management plan for the Cumberland Plain. For detailed information on the use of fire as a management tool, see the section on triggers later in this chapter.



Natural regeneration of native seedlings after fire. (P. Watson)

Mulching and matting to suppress weeds

These are generally inappropriate treatments in areas where native regeneration is predicted although matting may be considered in areas where erosion is a significant issue. Mulching can be useful on the edges of reserves to delineate the limits to mowing zones, and to suppress the encroachment of exotic lawn grasses. Only mulch if you are sure that the mulch is good-quality native leaf litter without seeds or bulbs.

Mechanical weed removal

Heavy machinery is frequently used to remove dense weed growth on roadsides, in wasteland or in areas where no desirable vegetation remains. In some situations, particularly where the soil is underlaid by weedy fill, 'scalping' the top ten centimetres of soil is a very effective means of removing both the weeds and a large part of the weed seed bank. However, machine clearance provides the very conditions which favour weed re-infestation, namely soft bare soil and high light levels.

When weeds are cleared by machine, large areas of bare soil are created. In erosion-prone areas it is essential that some form of cover is quickly established to prevent soil erosion and suppress new weed growth. Two techniques used to control erosion are:

- weed mats (discussed above)
- introducing new vegetation such as fast-growing colonising grasses.

Fast-growing native species like *Chloris ventricosa* and *Capillipedium spicigerum* can establish quickly. Once the area has been stabilised, both short- and long-lived trees, shrubs and groundcovers can be incorporated into the planting program.

In addition to sowing grasses (preferably native or sterile exotics), an ongoing weed control program must be initiated. In the short term, the use of mulch, weed mat or sowing a cover crop to stabilise the bare soil is recommended. Remember that mulch, plantings and weed matting on any large scale are generally considered inappropriate treatments in areas where native regeneration is predicted.

Patterns and sequence of regeneration

Bush regeneration in resilient sites

In sites that exhibit signs of resilience, the use of natural regeneration techniques only, or in combination with both natural and assisted regeneration, may be all that is required to stimulate regeneration of native species.

On agricultural properties where stock have been excluded from the restoration site, the area may experience some flux. Vigilant weed control will probably be required to ensure any germinating native seedlings are not out-competed by weeds. Strategic target weeding and comprehensive follow-up will lead to a gradual but significant improvement in the condition of the native vegetation (Davies & Christie 2001).

Weed control in areas with a native understorey

Controlling weeds in areas with a native understorey is more difficult. Hand removal is too time-consuming on large sites and problematic in hard, dry, compacted soils. Herbicide control is also problematic, because of the dangers to adjacent natives, and hand application is again too time-consuming.

The following practices demonstrate how a combination of methods can achieve maximum weed control and survival of native species in situations where a native understorey is present:

- Where annual weeds are tall, apply herbicide using a 'wick wiper' (see Method 9 in Appendix 4 for a description of this technique).
- Where it is required to control small privets, *Sida* (Paddy's Lucerne) and other small woody species in native grasslands use Garlon® at low concentrations.
- In areas of no or few native grasses, the use of the selective herbicide Fusilade® to control exotic grasses will allow native herbs to survive.
- Bulbs such as Watsonia in grassy native areas can be effectively controlled by a process of first whipper-snipping back the grass and bulbs. Subsequent regrowth in the bulbs is at a faster rate than the native grasses, allowing discrete herbicide treatment of bulb leaves during times of active bulb growth.
- To prevent seed drop from grasses and herbaceous weeds in areas of native understorey, target the aerial parts using a hand-held flame thrower to consume the plant and scorch seed.
- Reducing weed levels by slashing or mowing (as outlined above) may be a useful interim measure.

Tip:

A study by Semple & Koen (2003) found that regeneration in grazed native pastures is more likely than in grazed areas dominated by exotic plants. The results suggest that competition from annual and perennial exotics is a major limitation to the survival of eucalypt seedlings in their first two years.

CASE STUDY

Large-scale bush regeneration in Sydney Coastal River-flat Forest

As part of the Greening Western Sydney Project, Greening Australia has responsibility for restoring the remnants along 40 kilometres of Ropes, South and Eastern Creeks. Over 12 years Greening Australia has gained experience in applying efficient and effective strategies and techniques suited to this scale of work.

Before restoration most of the sites contained a scattered *Eucalyptus amplifolia* and *Casuarina glauca* canopy with occasional patches of shrubs, such as *Bursaria spinosa* and *Acacia parramattensis.* Native groundcovers were present but limited in extent. The sites were dominated by a dense mid-storey of African Olive and privets.

Primary works

Cut and paint woody weeds using chainsaws for large weeds and hand saws or loppers for smaller weeds.

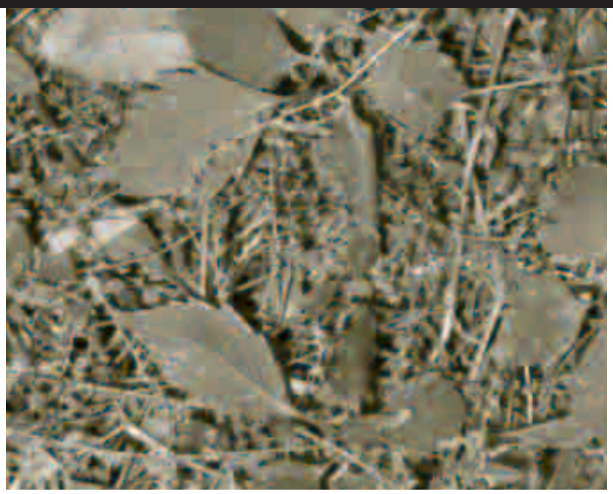
Brush-cut large areas of young growth to ground level and spray regrowth (before it exceeds 30 to 50 centimetres) with appropriate herbicides.

Create long and thin piles of woody debris for ecological 'pile burns'. The ecological value of pile burns in highly degraded areas where there is a lot of woody weed growth may be limited. However pile burns will allow the testing of the site's soil seed bank while also being an effective and cheap means of removing woody debris. Use the following method:

- remove large woody debris and pile or scatter separately for habitat
- spray water on piles to regulate temperature while burning
- on sites where it has been established that the soil seed bank has been exhausted, scatter locally collected native seed of hard-seeded species such as acacias onto cooling pile burn embers, and other herbs and grasses days later when the embers have completely cooled
- fence ash area with 'silt' fence to keep rabbits from grazing native regrowth (a 'silt' fence is a cloth fence used primarily to trap sediment but also works well to exclude grazers).

Rake up Wandering Jew, *Tradescantia fluminensis*, in the following way:

- rake and pile on weed mat or tarpaulin to allow for relocation
- pile in sunny location above high water level of nearby waterways where possible (larger taller piles leave less edge for regrowth)
- monitor piles for regrowth and spray edges with appropriate herbicide where necessary.



Employing best practice bush regeneration techniques will see a gradual return to 100% native groundcovers. (Greening Australia (NSW))

Follow-up works

Monitor continually straight after primary works and treat weed seedlings as they germinate.

Weeds generally come back first so:

- spot-spray privet/olive seedlings
- spot-spray any weedy herb seedlings, e.g. *Sida rhombifolia*, *Solanum pseudocapsicum* and *Cirsium vulgare* seedlings
- monitor the weeds' progress and allow a month or two for annual weed growth to reach about 50 centimetres or prior to seeding, then spot-spray.

Where annual weeds have not been treated as seedlings and have reached approximately one-metre high:

- brush-cut areas of tall annual weeds prior to seeding
- rake and pile weedy debris that has been brush-cut, which concentrates any debris that might set seed after cutting and allows you to monitor the germination of any seeds which can be treated more easily when piled rather than scattered around – treat as for Wandering Jew above
- return approximately two weeks to a month later (sooner if necessary) and spot-spray any reshooting annual weeds
- continue to monitor and spot-spray to keep annuals at bay
- monitor and repeat any time that tall annuals begin to dominate the site (although careful monitoring and follow-up should make this unnecessary)
- hand treat any persistent or woody weeds, e.g. *Cestrum parqui*, *Phytolacca octandra* and small woody weeds.

It should be remembered that repeated brush-cutting is not a long-term management option.

Sustained follow-up has led to the restoration of a dense native groundcover, including *Dichondra repens*, *Centella asiatica*, *Einadia* spp., *Solanum prinophyllum*, *Hydrocotyle* spp., *Veronica plebia*, *Pratia purpurascens* and *Microlaena stipoides.*

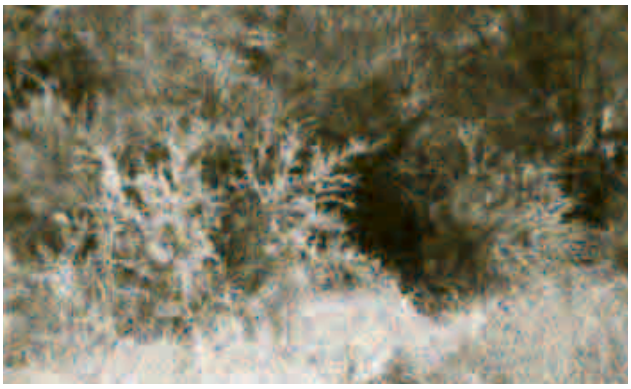
Continuing site assessment and maintenance

Rehabilitated areas need to be monitored and managed after rehabilitation. Rehabilitation success is often compromised by the invasion of weeds, stock, feral animals and human activities. Self-sustaining conditions may take many years to reach.

Maintenance of remnant areas may include:

- repairing any erosion problems
- fire management
- pest and weed control
- fencing maintenance
- assessing the site's resilience and introducing seed or seedlings from a known provenance if required.

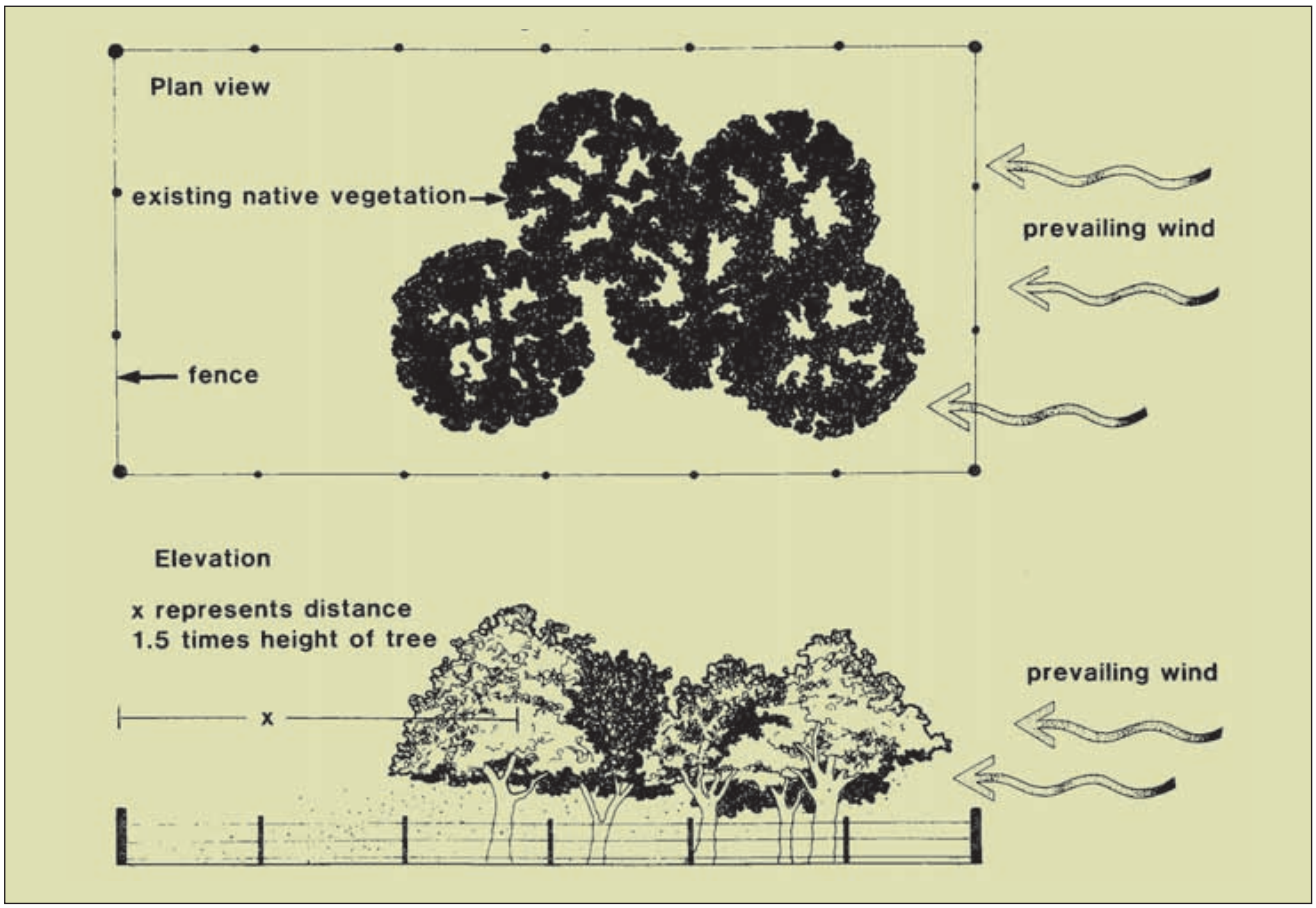
Once an area of remnant vegetation has been fenced to protect from stock or other uses which damage native vegetation (see Figure 6), and vermin and weeds controlled, the bush may grow back from stored seed, coppices and underground organs. Remember it may take one to two years before seedlings germinate. However, if no *regeneration* is taking place and the remnant is not responding to regeneration techniques (including both natural regeneration and/or assisted regeneration, including the use of 'triggers'), *revegetation* activities such as direct seeding or planting may need to be considered (see Chapter 5).



The Eastern Creek demonstration site at Doonside before bush regeneration techniques were employed. (Greening Australia (NSW))

Nine months after bush regeneration techniques began at the Eastern Creek site. (Greening Australia (NSW))

Figure 6: Fencing of remnant eucalypts to encourage natural regeneration



Source: Venning (1988)

The use of regeneration 'triggers'

In the past, disturbance to an ecosystem has generally been perceived negatively: as an event involving damage or destruction. However it is now understood that disturbance is a natural process integral to community and ecosystem dynamics (Thomas 1994; Pickett *et al.* 1992).

In areas like the Cumberland Plain that are integrated with urban and farming communities, natural disturbance regimes either no longer exist or have been extensively modified, and sometimes environmental disturbance 'triggers' may be needed to aid regeneration and maintain the ecological health of the bushland.

Fire as a management tool

In the grassy Cumberland Plain woodlands, fire was traditionally used to stimulate underground food resources and grass for game (Benson & Howell 1990b; Kohen & Downing 1992). Fire is an important part of the Australian landscape, and much of the country's flora and fauna have evolved in its presence. Inappropriate fire regimes may significantly reduce the biodiversity of Cumberland Plain communities.

Numerous studies indicate that many of Australia's plant species require fire, or some other form of disturbance, to regenerate from seed. Fire may induce seed germination through breaking the seed's dormancy in some way allowing seed release from canopy stores, or by altering the environment to provide better conditions for germination. These better conditions include the temporary improvement in seedbeds or making scarce resources more available (Hobbs 2002).

Many species have evolved in fire-prone habitats and have adaptations that allow individuals to survive fire (Gill *et al.* 1981). Such adaptations include epicormic buds (formed under the bark), the ability to resprout from underground organs called lignotubers (these plants are referred to as 'resprouters'), and the establishment of soil-stored seed and canopy seed banks (referred to as 'obligate seeders').

Bordered on three sides by national parks, Sydney has a sprawling urban area also containing significant bushland reserves. Prescribed (fuel reduction) burning is a major tool used in managing the threat of wildfire to suburbs and outlying rural areas adjacent to bushland. However low-intensity prescribed fires for fuel reduction may be detrimental to the conservation of native plants because the heat derived is insufficient to stimulate the germination of buried, dormant seed (Bradstock & Auld 1995).

The use of fire for ecological purposes is not as common as its use for the reduction of fuel loads, despite the evidence of numerous ecological benefits such as the promotion of species diversity.

Fire exerts a powerful influence on the native vegetation found on the Cumberland Plain. If we want to conserve western Sydney's vegetation communities, we must consciously manage fire. The components of a fire regime include season, intensity and frequency.

Seasonal timing of fire

The early European settlers found that from 1788 to 1845 the pattern of fire around Sydney was markedly seasonal with 87 per cent of fires occurring from August to January, i.e. in spring and early summer. Although incomplete, written records of fires in the Sydney area in this period provide some indication of pre-settlement fire regimes and possible Aboriginal land management practices. In the earliest years, local Aborigines were described as frequently 'setting fire to the country' (Phillip 1791; Hunter 1793; Tench 1789) particularly in the summer, or when it was dry or windy (Hunter 1793). Writers commented on the Aboriginal practice of burning the previous season's grasses to encourage new growth (Atkinson 1826 and Bennett 1834, as cited in McLoughlin 1998).

In contrast with this earlier 'natural' or historical fire season, current prescribed burning practices follow a distinctly different seasonal pattern. More than 60 per cent of prescribed burning for asset protection in Sydney between 1980 and 1995 was conducted in autumn and winter (McLoughlin 1998).

A fire regime between August and January has been identified as the optimal seasonal range for many of Sydney's plant communities. It may be unsuitable to consider prescribed burning in the hottest part of this season (November to January), and the occasional burn in winter or autumn would not be too detrimental. However, the ecological implications of the seasonal timing of fire in the remainder of this period merits consideration in fire management plans and prescribed burning programs, along with frequency and intensity, as changes to the fire regime over time may result in altered vegetation composition (McLoughlin 1998; Whelan 1995).

Intensity of fire

Work to date on the seed banks of eucalypt woodlands suggests that while many species germinate in the absence of fire, the fullest range of species is obtained when fire is present. Work by Hill (2000) suggests that there is a substantial soil seed bank (1000 seeds/m^2) under Cumberland Plain Woodland. More heat-responding species than smoke-responding species were identified in research by Thomas *et al.* (2003).

Although smoke and ash can stimulate seed germination, for many species with hard seed coats the breaking of seed dormancy occurs with heat (Auld & O'Connell 1991). Legume species are an important component of the shrub species found in many of the vegetation communities on the Cumberland Plain. Studies of legume species have concluded that the highest germination for most species occurred at 80°C, while little germination occurred at temperatures below 40°C (Hill & French 2003).

Tip:

Experimental studies show that grazing can reduce the survival of seedlings that germinate following fire (Leigh & Holgate 1979). Grazing should be excluded from burnt areas for the first one to two years after fire, and while perennial species are setting seed.

Low-intensity fires often provide a competitive advantage for resprouting species over 'seeder' species. This is due to the fact that most obligate seeders are fire-sensitive and adult plants are generally killed outright, whereas vegetative resprouters often survive such fires. If low-intensity fires are not hot enough to induce germination of seed stored in the soil or canopy, the result is relatively little seed regeneration. In contrast, high-intensity fires will favour the seeders in any vegetation community (Thomas 1994).

Fuel loads in Cumberland Plain vegetation are markedly lower than those of vegetation communities found on the Hawkesbury Sandstone areas of Sydney. On the shale soils of Cumberland Plain Woodland, for example, the accumulation curve for fuel load builds up to around 9.5 tonnes/hectare then flattens out, while for sandstone woodland it reaches over 30 tonnes/hectare (Watson, forthcoming). Lower fuel loads will directly influence fire intensity. So although property protection is still a priority when managing Cumberland Plain vegetation, there is not the same degree of conflict between burning for ecological purposes and for asset protection as occurs in the sandstone areas of Sydney.

Fire frequency

Fire frequency can be defined as the number of fires occurring in a given time. Fire frequency has a major effect on communities through its interaction with plant species characteristics, and can affect both community structure and composition.

The understorey of most vegetation communities on the Cumberland Plain is dominated by herbaceous plants, with only patchy shrub representation. This contrasts markedly with the shrub-dominated Hawkesbury Sandstone communities. Herbaceous species tend to have shorter life spans than larger woody plants. This could be a significant advantage in a community that is subject to frequent fire events, suggesting that this vegetation type may be reflecting a long-term adaptation to frequent fires (Thomas 1994).

Fire regimes that encourage a balance between trees and shrubs, and open patches dominated by forbs and grasses may hold the key to maintaining species diversity in many of the Cumberland Plain vegetation communities. A study by Watson (forthcoming) suggests that an open grassy woodland with obligate seeder shrubs is best maintained using variable intervals between fires of between four and 12 years. Inter-fire intervals need to be long enough to allow regeneration of obligate seeder shrubs. Almost all Cumberland Plain Woodland shrub species will be producing seed three years after a fire. On the other hand, fire needs to occur before short-lived fire-dependent species and their seed banks lose their viability (senesce).

Kangaroo Grass (*Themeda*) is potentially vulnerable to this viability problem. Recent research suggests this species may play a key role in ecosystem function in grassy woodlands, regulating nitrogen to the advantage of native perennials over annual weeds (Prober *et al.* 2004). In Victorian grasslands, *Themeda* declines due to self-shading between six and 11 years after fire, and does not recover to any great extent if burnt after 11 years (Lunt & Morgan 1999). Although *Themeda* in Cumberland Plain Woodland may be slower-growing due to poorer soils, it has been suggested that inter-fire intervals in *Themeda*-dominated remnants on the plain should not exceed 12 years to ensure the vigour and persistence of this species is maintained (Watson, forthcoming).

A related issue may exist with Native Blackthorn (*Bursaria spinosa*). Research suggests that frequency and dominance of this species increases as fire frequency decreases. Shrubs other than *Bursaria* may be more abundant in areas where fire is moderately frequent than in areas burnt often or rarely. Although *Bursaria* has a tendency to dominate Cumberland Plain bushland landscape under particular circumstances, this does not imply that it is a problem plant in itself. *Bursaria* is a natural and important component of all Cumberland Plain remnants. Its thorny nature and tendency to form thickets make it important habitat for many birds (Watson, forthcoming).

Bursaria spinosa *dominates in a long unburnt site, Scheyville National Park. (P. Watson)*

In contrast Themeda australis *is dominant with small patches of* Bursaria spinosa*. This site at Holsworthy has shorter inter-fire intervals. This picture was taken 12 months post-fire. (P. Watson)*

However its management may be a consideration when planning for species diversity.

The relatively low abundance of other shrubs in long-unburnt areas may reflect competitive interactions with *Bursaria*. Some ground species favour open patches, and will therefore decrease in abundance if these patchy areas are lost from the landscape (Watson, forthcoming).

Given uncertainties around minimum intervals for maintaining obligate seeder shrubs, and maximum intervals for limiting *Bursaria* expansion and maintaining *Themeda*, it is suggested that managers monitor sites for:

- **Flowering of obligate seeder shrubs** – Fire should normally be excluded until these species have had a couple of good flowering years.
- ***Bursaria* expansion** – Managers may want to apply fire more frequently if *Bursaria* is encroaching into previously open areas.
- ***Themeda* health and density** – Burning should revitalise *Themeda* and open up the grass sward so herbs can regenerate.

These simple monitoring measures will assist in tailoring fire regimes to particular sites and growth rates, which will vary with differences in rainfall and topography.

The understorey in Shale Gravel Transition Forest has a higher shrub component than the grassy Cumberland Plain Woodland. Shrub species such as Dillwynia tenuifolia, Pultenaea parviflor *and* Ozothamnus diosmifolius *are in abundance. (P. Watson)*

In contrast, grasses such as Microlaena *and* Themeda *dominate the understorey at this moderately burnt Cumberland Plain Woodland site at Ropes Creek. (P. Watson)*

In some remnants, *Themeda* will be uncommon and/or *Bursaria* dominant, possibly indicating a low exposure to fire. These remnants may have woody weeds. An experimental approach to the use of fire is suggested on these sites. Introduction of *Themeda* through seeding, using seed from a known source, could be considered. Short inter-fire intervals could be trialled in parts of the landscape using mosaic burns to assess possibilities for weed control, and to create open patches. If *Themeda* patches exist, experimental fires could perhaps focus on these areas.

As the shrub complement of Cumberland Plain vegetation increases, appropriate fire frequencies are also likely to increase. As explained above, to maintain grassy Cumberland Plain remnants, fires should probably be a minimum of four years and a maximum of 12 years apart. Castlereagh Woodland contains more shrub species, including the slow-growing obligate seeder *Petrophile pulchella*. Thus minimum intervals need to be somewhat higher than in Cumberland Plain Woodland; approximately six years is suggested with a maximum interval around 20 years (Watson, forthcoming).

Across the plain, the gradient in fire frequency thresholds can be expected to match the gradient in grass/shrub dominance, ranging from Cumberland Plain Woodland (4 to 12 years), through Shale Gravel Transition Forest (5 to 15 years), Castlereagh Ironbark Forest (6 to 20 years), Castlereagh Scribbly Gum Woodland (6 to 20 years), and Agnes Banks Woodland (7 to 25 years).

In all vegetation types, greatest species diversity is likely to be maintained by ensuring variation in the length of inter-fire intervals within these thresholds (Keith & Bradstock 1994; Morrison *et al.* 1995). In all cases, careful observation of regeneration methods, flowering times and senescence will help refine these estimates.

As with all thresholds, the occasional violation is not likely to cause major problems. Patchiness in time and space may, in fact, lead to some parts of landscapes being burnt very frequently and others very rarely, and this may even benefit biodiversity if the extent of these areas is limited. However repeated frequent fire across a landscape will most likely result in loss of species diversity, as will long-term fire exclusion (Watson, forthcoming; Worboys *et al.* 1998). To allow for seed production and building of seed bank reserves, a period of three reproductive years should be added to the minimum fire interval for sites that have recently experienced an inter-fire interval below the relevant minimum threshold (Keith *et al.* 2002).

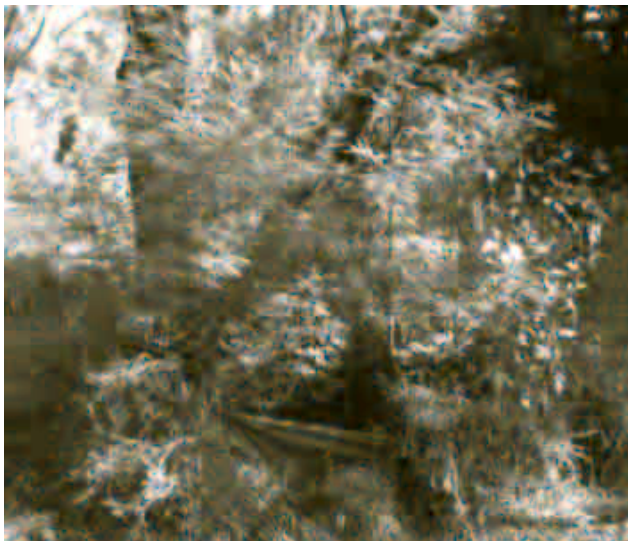
Research also suggests there are considerably fewer weeds in frequently burnt Cumberland Plain Woodland sites than in those with moderate or long inter-fire intervals, suggesting that frequent burning along the edges of larger remnants may actually be a good way to control weeds, manage fire hazards and control some edge effects (Watson, forthcoming). However it should be noted that a single fire should not be used to control weeds, as many weeds are also stimulated by fire and fire as such should be just one technique in a well developed management program (Howell 1992).

Integrated and mosaic fire patterns

The deliberate use of strategically placed pile burns has been very successful in stimulating the regeneration of native vegetation on restoration sites. The pile should be kept below one metre high and not cover more than ten square metres to ensure the fire is controllable and does not sterilise the soil by producing too hot a burn for soil-stored seed. Using weed debris from the site can result in both labour and cost savings (Department of Infrastructure, Planning and Natural Resources 2003b). Hand broadcasting of native seed in the ashen area has led to successful germination of natives.

Broader patch burns have also been successfully used on the Cumberland Plain. This technique is often integrated with prior weed management. For example, herbicide spray or wiping of weeds has occurred to control standing populations of weeds such as patches of *Pennisetum clandestinum* (Kikuyu) or *Eragrostis curvula* (African Lovegrass), with the dead weeds providing fuel for the fire (Department of Infrastructure, Planning and Natural Resources 2003b). The months after a fire may also offer good opportunities for weed control, as some resprouting weeds or weed seedlings may be targeted more easily without damaging native species.

Results of a successful pile burn at the South Creek demonstration site, Erskine Park. (Greening Australia (NSW))



In all Cumberland Plain vegetation communities fire is best used in a mosaic pattern. This will ensure a variety of post-fire age classes of vegetation, which in turn will provide habitat for a full range of animal species and maximise the chances of plant diversity. When planning for the use of fire, one consideration should be coordination of your program with that of your neighbours so a variety of post-fire vegetation classes is achieved in a mosaic pattern across the landscape.

Tip:

Greatest species diversity is maintained by using fire regimes that encourage variation. Variation in the length of inter-fire intervals (within thresholds), variation in fire intensity and a variable season of burn (between August and January) are likely to provide the best results for the native biodiversity of your bushland.

Planning the use of fire

When planning to use fire in a restoration project, land managers will need to consult the NSW Rural Fire Service (RFS) and the Department of Environment and Conservation (DEC). Approvals and permits are sometimes required for conducting hazard reduction burns.

The RFS provides environmental approvals for hazard reduction works only. If the planned fire is for ecological reasons rather than for hazard reduction, approval may be required from DEC. The RFS or NSW Fire Brigades will still need to be contacted about conducting a safe and legal burn.

Local bushfire risk management plans are prepared by the local bushfire management committee and these should be first considered when planning a hazard reduction or bush regeneration burn. Contact your local RFS fire control centre or NSW Fire Brigades for more detailed advice.

Landholders also have responsibilities under the *Rural Fires Act 1997* to prevent bushfires on their land and to minimise the danger of a fire spreading onto other land. As such, it may be inappropriate for a large property to encourage the regeneration of vegetation along the boundary with adjoining properties, particularly where assets on adjoining land may be at risk from bushfire. Depending on the size of the property and possible risks, it may be appropriate to leave a break or conduct burns aimed at hazard reduction along this boundary area. It is therefore important to plan any regeneration burns and revegetation works carefully. The local RFS fire control centre can provide advice on these matters.

Smoke water and smoked mulch

More Cumberland Plain Woodland species respond to heat than smoke (Morris & Wood 2001) and the heat signal from fire is important for maintaining community composition in this vegetation community. Other studies have shown that for some native species it is the elements in smoke that trigger regeneration, rather than fire itself (Department of Infrastructure, Planning and Natural Resources 2003b). The limited use of smoke water may then be used as a potential tool to 'trigger' regeneration in some areas where burning is considered improbable.

Soil disturbance

Deliberate soil disturbance can be used to relieve the often severe compaction problems arising from past management regimes on the Cumberland Plain, releasing soil-stored seed banks and creating niches for regeneration. Bare, compacted areas, such as former car parks and old tracks, provide good targets for this technique (Department of Infrastructure, Planning and Natural Resources 2003b). Please note that deep disturbance (ripping) is not generally recommended for Cumberland Plain sites and should never be undertaken in saline or waterlogged areas.

Reduction in plant mass

Greening Australia has observed that slashing seems to favour native grasses. This is because it removes the bulk of grass shoots, preventing exotics from achieving dominance in the grassland (D. Williams, Greening Australia (NSW), pers. comm., 2004). However slashing is more suited to grassy agricultural lands and should not be used in good quality remnants.

At the Greening Western Sydney Hoxton Park site, managed by Greening Australia (NSW), a fire in January 2001 led to large-scale germination of *Acacia* seedlings. An alternative approach to controlling plant mass could be to let the *Acacia* seedlings grow on and out-shade the exotic grasses. The introduction of native shrubs and trees may be a means of favouring native species on the ground (Davies & Christie 2001; D. Williams, Greening Australia (NSW), pers. comm., 2004).

Herbicide and scarification in introduced pastures

In remnants where introduced pasture vegetation is prevalent, natural regeneration is not likely to occur due mainly to the intense competition from introduced species and the density of the groundcover. Techniques that can encourage regeneration include using a knockdown herbicide combined with scarification to reduce weed competition and soil compaction.

When many desirable native species are already present in the understorey, natural regeneration is likely to occur with minimal physical intervention. In these situations, some small-scale trigger disturbance, such as scarification of the soil or the use of fire, can be beneficial.

Reducing stocking rates and careful management of grazing regimes will allow natural regeneration to occur on pasture land. (DEC/K. Wale)

Grazing management

Timed pressure ('crash') grazing or managed selective grazing may also provide the disturbances required for a sustainable and healthy remnant community. Fencing out remnants allows the landholder to appropriately manage the area as a separate land unit.

Grazing can also be used as a tool for controlling weeds and reducing fire hazards. However, care should be taken that grazing regimes are appropriate: ensure that at least twelve months to two years has passed after the initial exclusion of livestock. During this period, any natural regeneration can be observed and the appropriate management options addressed (Department of Infrastructure, Planning and Natural Resources 2003a).

Crash grazing involves the use of many hungry animals for a short period, as the most damage is usually caused when animals become full and bored. Also, keep in mind where the animals have previously been grazing and the possibility of weed seeds being introduced to the area through faeces or attached to wool or fur.

Other triggers

Some species may sucker from their root system when they have been disturbed, and bushland restoration managers may deliberately disturb plant roots to trigger natural regeneration. This has often been most successful in relation to *Casuarina glauca* regeneration where suckering from the root system has been achieved by mechanical disturbance. Some suckering of wattle species, such as *Acacia parramattensis* and *A. implexa*, has also been observed in the course of hand digging to remove weeds (Department of Infrastructure, Planning and Natural Resources 2003b).

Another method to stimulate natural regeneration is to water or irrigate. This method induces a trigger response from vegetation resulting in seedling germination when artificially simulating favourable conditions after flood (Department of Infrastructure, Planning and Natural Resources 2003b).

CHAPTER 5

Restoration through revegetation

Revegetation versus natural regeneration

Revegetation is an excellent tool for linking areas of remnant native vegetation. However its ecological and genetic value is limited in restoring areas which have the potential to regenerate naturally.

The more that is known about the structure and function of the community you wish to restore, the greater the chance of success. Resilience on any Cumberland Plain site can be surprisingly strong and persistent in or adjacent to remnants, even in extremely degraded and altered areas not likely to be formally classified as woodland (Department of Infrastructure, Planning and Natural Resources 2003b). Many Cumberland Plain remnant and regrowth areas have endangered ecological status and revegetation in or immediately adjacent to them requires approval from the Department of Environment and Conservation (DEC). Licensing queries should be directed to DEC's Wildlife Management Unit on (02) 9585 6540.

Revegetation measures should only be considered when:

- the regeneration potential of a site has been wholly or severely depleted
- attempts to trigger regeneration of soil-stored seed by a range of techniques have failed
- key missing species can not be naturally recruited to an area.

In revegetation programs the aim is to use the minimum intervention necessary to re-establish natural regeneration processes. This is a sound philosophy from both a resource and ecological perspective. In relation to the vegetation communities on the Cumberland Plain it means that we need to be aware of the potential to oversimplify ecosystems through revegetation.

There is very little documentation on the past distribution of native vegetation on the Cumberland Plain and it is important that the full range of species variation is retained (Benson & Howell 1993). We are only beginning to understand the subtle complexities in biological diversity, and in many areas small remnants provide the only records of the pre-European vegetation (see Appendix 1 for a list of reference sites). Thus it is easy for us, often unintentionally, to distort the natural community by introducing non-local plant material through our revegetation projects. As a result, the valuable genetic resources of an area can be irrevocably lost.

Species selection

'Best practice' in species selection has changed markedly over the past few decades from the simple use of Australian native species, through using only locally indigenous species, to propagating material from the particular bushland area to be planted. The use of indigenous species grown from local seed is essential for revegetation projects. These local species are adapted to the local climate and soil conditions and provide natural resources for the local wildlife.

The aim of restoration projects should be to repair and enhance. They should not impair the site's ecological values in order to simplify the restoration process. The increasing use of propagated and planted material, the pressure for quick results and the pressure for increased planting variety at the local level raise questions about maintaining genetic integrity in restoration programs.

It is generally the more easily obtained, collected and propagated species that tend to be used in revegetation projects, and these are typically canopy trees such as eucalypts and certain pioneer shrubs (often species of the family Fabaceae such as peas and wattles). Groundcovers, particularly in any quantity or diversity, are less often used, if at all (Department of Infrastructure, Planning and Natural Resources 2003b).

Historically there has been a lack of detailed knowledge about the structure and diversity of Cumberland Plain communities. Recent studies by Tozer (2003) and NSW National Parks and Wildlife Service (2002) now provide valuable information on the species and diversity found in the plain's endangered ecological communities.

These documents should be consulted for comprehensive information and species lists about the endangered ecological communities on the Cumberland Plain. The report *Native Vegetation of the Cumberland Plain: Final Edition* (2002) can be found on the DEC website www.environment.nsw.gov.au under 'Cumberland Plain Vegetation Mapping Project'.

When planning the distribution and abundance of the vegetation community you wish to emulate, you should also be guided by your observations of existing nearby remnants. A good way to tell if a plant is local to your area is to look at vegetation along the roadsides or in conservation reserves. Appendix 1 provides a list of reference sites. Another good source of information is Greenweb. A list of species for each local government area can be found on their website www.greenwebsydney.net.au

Seed collection

Genetic integrity and diversity

Material for propagation is best found on-site or close to it. This is known as 'local provenance'. The use of site-adapted local seed for propagation is best for restoring pre-existing plant communities and conserving local biodiversity. It is also more likely to lead to a successful self-perpetuating plant community, as local provenant seed is adapted to local soils, climatic conditions and ecological processes.

The rate of change in Cumberland Plain endangered ecological communities is considered very slow, with many species (particularly understorey species) remaining highly localised and dispersal very limited. Table 5 provides guidelines on seed collection ranges based on estimated dispersal distances for various plant categories.

Table 5: Guidelines for seed collection ranges

Plant categories	Collection range	Pollination by	Seed dispersal	Life span	Population density
Forbs and herbs	1	Wind Insects	Birds Insects Mammals Gravity	Short	Low-high
Wattles	1	Insects Birds Mammals	Insects Gravity	Short-medium	Low-high
Peas	1	Self Birds Insects	Insects Gravity	Short-medium	Low-high
Orchids and lilies	1	Insects	Wind	Short-medium	Low-medium
Ferns and allies*	1	Spores: no pollination	Wind	Short-long	Low-medium
Heaths and understorey shrubs	2	Insects Wind Birds Possibly self	Insects Gravity	Short	Low-high
Daisies	2	Insects	Wind	Short-medium	Low-high
Grasses	2	Wind	Wind	Short	High
Fleshy fruit plants (not trees), e.g. *Dianella*, *Exocarpus*	2	Birds Bats Other mammals Insects	Birds Bats Other mammals	Medium	Low-high
Banksias	2	Birds Mammals Insects	Wind Gravity	Medium-long	Low-medium
Casuarinas and conifers	2	Wind	Wind Birds Gravity	Long	Low-high
Eucalyptus, Angophora, Syncarpia, Callistemon	2	Birds Bats Other mammals Insects	Wind Gravity	Medium-long	Low-high
Trees with fleshy fruits	3	Birds Bats Other mammals Insects	Birds Bats Other mammals	Long	Low-medium

* Ferns and allies are a special case because of their reproductive physiology. You may need to check how each species interchanges genetic material.

Key

Collection ranges	Guideline for seed collection
1	Crucial to collect as locally as possible from remnant or adjacent (same vegetation and microclimate).
2	Collect locally but can extend to nearby remnants that were formerly contiguous. For small plant populations, use general principles.
3	Can collect widely, but preferably not beyond subivisions of the state.

Life span		Population densities
Short (Years, including annuals)	Low	< 10 plants per/ha
Medium (Decades)	Medium	10–50 plants per/ha
Long Centuries)	High	> 50 plants per/ha

Source: Hawkesbury–Nepean Catchment Management Trust Draft Provenance Protocols

The collection of suitable material is more difficult when small, isolated remnants are involved, and where the plant community is restricted in occurrence. The limited availability of source material creates pressures that could lead to over-collection of seed or even place remnant plant populations at risk. Only ten per cent of a species' total annual seed crop should be collected from an area. It is important to leave seed on-site as it can play an important role in natural regeneration of the plant community, as well as providing valuable food resources for fauna.

For best results, it is recommended that you collect seed only from naturally occurring areas of native vegetation and where there are relatively large numbers of individuals. This will ensure that local genetic diversity is maintained, seed is viable and good establishment of plants is achieved.

Tip:

Most bushland communities on the Cumberland Plain are listed as endangered under the *Threatened Species Conservation Act 1995* and a licence from the Department of Environment and Conservation is required to collect seed from species and communities listed under this Act. Contact the Wildlife Licensing Unit on (02) 9585 6540.

Hardenbergia violacea *in a seed orchard in the Western Sydney Parklands, Hoxton Park. (Greening Australia (NSW))*

A consistent supply of quality seed is essential for the success of revegetation projects. For large-scale revegetation, or projects that will be undertaken over a number of years, it might be worthwhile establishing a seed orchard of native provenance species. This will protect the genetic integrity of the restored bushland site while also producing significant time and cost savings for your project.
Where only very small amounts of propagating material is available because of the rarity of the species or the small size of the natural populations, stocks of such material for revegetation work may be built up over time by cultivation (Howell *et al*. 1995).

A licence to collect seed

Under the *Threatened Species Conservation Act 1995*, a licence is required when undertaking an action that is likely to 'harm' an endangered ecological community. This definition includes collecting seed from such a community, and licensing provides a mechanism for addressing the dangers of over-collection. In licensing seed collection, DEC also gives consideration to the issue of provenance and maintaining genetic integrity. For the purposes of these guidelines, DEC's position on seed collection and provenance is guided by the FloraBank guidelines available at www.florabank.org.au

There is an issue about how local the stock should be and how far afield appropriate collection might be. Currently 'local' is interpreted to mean as close as possible to a site. However, the DEC-issued licence to collect seed will indicate collection distances on a case-by-case basis. You should closely match conditions present at the collected location to those of the planting site. Of course the plant community, geology and soil type should be the same but aspect should also be considered.

When buying or ordering stock from a nursery, it is advisable to specify from which provenance you wish the seed collected. If purchasing seed from seed merchants, ask for seed that was collected from the same area where you intend to plant. You should also ask in which year the seed was collected, especially for eucalypt seed that can lose viability quickly if stored inappropriately. Other seeds such as hard-coated Acacia seeds have long storage lives and the year of collection is less critical. Alternatively, you could engage a seed collector to collect from your required provenance and then provide this seed to the nursery, or engage a grower who will collect from your site and grow the seedlings for your project.

Table 6 details the approximate collection times on the Cumberland Plain of seed from the species described in this guide. This timetable can be used for planning your seed collection year. Be sure to monitor trees and shrubs for more specific details of when individual species' seed is ripe. Please note that seeding times of species described in this table can vary from year to year and even across the region depending on local conditions and seasonal variation.

Table 6: Collection times for Cumberland Plain species

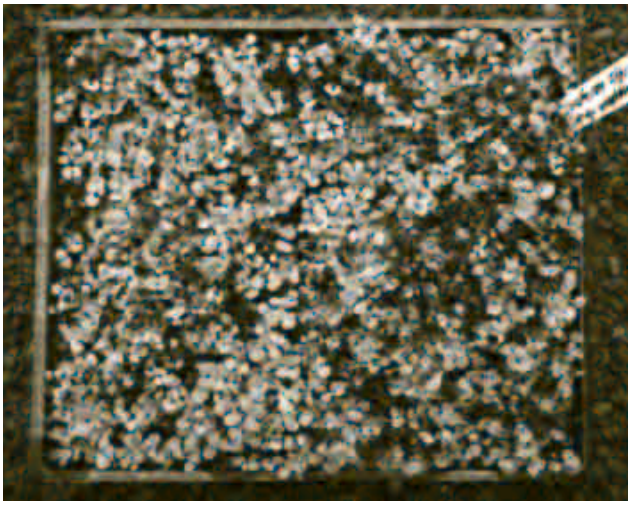
Species	Collection window
Acacia binervia	November–December
Acacia decurrens	Early to mid-December
Acacia elongata	November
Acacia falcata	Late November–early December
Acacia floribunda	Late November–early December
Acacia parramattensis	Late November–early December
Acacia ulicifolia	October–January
Acmena smithii	May–September
Ajuga australis	Late December–end January
Allocasuarina littoralis	All year round
Angophora bakeri	April–July
Angophora subvelutina	February–June
Backhousia myrtifolia	December–January
Banksia spinulosa	All year
Billardiera scandens	December–March
Bulbine bulbosa	November–early January
Bursaria spinosa	April–May
Callistemon salignus	All year
Carex appressa	December–January
Casuarina cunninghamiana	All year
Casuarina glauca	All year
Clematis glycinoides	November–early December
Danthonia tenuior	December–May
Daviesia genistifolia	November–January
Daviesia ulicifolia	November–January
Dianella caerula	November–February
Dichelachne micrantha	December–January
Dillwynia juniperina/sieberi	November–early January
Dodonaea falcata	November–December
Dodonaea viscosa	October–February
Echinopogon caespitosus	December–early March
Eleocharis spp.	December–January
Eucalyptus amplifolia	Late July–early March
Eucalyptus crebra	December–May
Eucalyptus eugenioides	June–September
Eucalyptus fibrosa	April–October
Eucalyptus globoidea	March–June
Eucalyptus maculata	January–May
Eucalyptus moluccana	January–March
Eucalyptus parramattensis	November–February
Eucalyptus punctata	October–February
Eucalyptus sideroxylon	August–February
Eucalyptus tereticornis	January–March
Geranium solanderi	December–February
Glycine tabacina	October–June
Hakea sericea	All year
Hardenbergia violacea	November–December
Indigofera australis	November–February
Juncus spp.	December–March
Kunzea ambigua	December–March
Leptospermum spp.	All year
Lomandra longifolia	December–March
Melaleuca decora	All year
Melaleuca linariifolia	All year
Melaleuca styphelioides	All year
Microlaena stipoides	November–February
Ozothamnus diosmifolius	November–January
Poa labillardieri	December–March
Pultenaea microphylla	October–February
Solanum spp.	December–March
Sorghum leiocladum	Beginning of January
Stipa spp.	November–February
Themeda australis	Late December–early January
Wahlenbergia gracilis	December–February
Wahlenbergia stricta	November–February

Source: Greening Australia (NSW)

Checklist: Planning for seed collection

- A self-perpetuating plant community is promoted by the use of site-adapted endemic propagation material.
- Seed collection should be carried out within the framework of a formal seed collection policy or code of practice. *The Model Code of Practice for Community Based Collectors and Suppliers of Native Plant Seed* (1999) by FloraBank is the most recent and can be found on the FloraBank website at www.florabank.org.au
- Collectors need to meet requirements under the *Threatened Species Conservation Act 1995* including a section 91 licence from DEC when seed is collected from a plant community that is listed under the Act. Most plant communities on the Cumberland Plain have been listed.
- Seed should be collected on a project-by-project basis with the amounts collected based on the requirements of that project. Do not aim to stockpile seed.
- The proportion of seed taken from any one site should only be 10 per cent of a species' total annual seed crop from that site.
- Collectors require a clear understanding of the provenance range and vegetation communities involved.
- Collectors need to be aware that some species are protected under Schedule 13 of the *National Parks and Wildlife Act 1974* and that it is an offence to pick these plants.

Germination of Angophora floribunda *seed. (Greening Australia (NSW))*



Site preparation and planning

Revegetation work needs clear goals and objectives and a realistically long planning horizon. Planning should identify the ideal or preferred range of species to be included. As much time as possible – 12 months would be a good minimum – should be allowed so that local provenance seed collection and propagation can be carried out and planting staged, allowing as many species as practicable to be included from the range identified. This is particularly important in relation to the key component species of the community.

Sufficient resources to implement the revegetation work, for prior weed control and for ongoing maintenance also need to be allocated if efforts are not to be wasted (Department of Infrastructure, Planning and Natural Resources 2003b).

Tip:

One lesson that can be drawn from Cumberland Plain restoration projects is that good ground preparation and pre-planting weed control were the most important factors for ensuring the survival of planted tubestock and seeding operations.

Like any other restoration approach, revegetation requires the mitigation or treatment of any degrading influences. Thus environmental weeds and problems such as erosion need to be addressed. Additionally, any efforts that can be put into site preparation will greatly benefit the restoration results.

Erosion control

Before deciding to clear vegetation, you should first consider if stabilisation will be an issue. If the soil or soil/slope/climate combinations are prone to erosion, you will need to act quickly after clearing the site.

The methods for clearing unwanted vegetation are limitless. They range from pulling up individual weeds, to large-scale herbicide application, to using bulldozers. All techniques are legitimate in certain situations.

When selecting some form of physical soil stabiliser (in contrast to plantings) a number of factors should be considered. The most important will be the erosion risk, then the size of the site, and of course the resources available. Other factors will include the effect of the stabiliser on soil aeration, water penetration and soil

Managing badly eroded sites will need to incorporate erosion control techniques. (DEC)

temperature, any weed suppressant properties, germination conditions for desired plants as well as the longevity of the stabiliser. There are many effective weed and erosion-control mattings available on the market.

Depending on the scale of the operation and the erosion risk, a few logs thrown across the slope or, if necessary, pegged into place can also be a useful erosion-control technique.

In areas of moderate to low erosion risk, fast-growing native colonising species can be used to stabilise the soil. Some native grasses, such as *Chloris ventricosa*, *Austrodanthonia racemosa* or *Capillipedium spicigerum* will grow and establish cover quickly (Berryman 2005). Once the area has been stabilised using a fast-growing cover crop, both short-lived and long-lived trees, shrubs and groundcovers can be incorporated into the planting program.

Soil compaction

Ripping is a method used to relieve soil compaction and improve moisture retention. Ripping is not generally recommended on the Cumberland Plain except for severe compaction problems such as on old roads or carparks. A rip line should be no deeper than 20 to 50 centimetres, and where slopes are involved the rip line should follow the contour of the land. Deep ripping is not recommended in saline or waterlogged soils as it can create further problems.

Ripping should be undertaken early in the planting season or several months before. For saline areas, mounding of the soil may be required. See Chapter 2 and later in this chapter for specific information on planting in saline areas.

Mulching

Mulching of areas or around individual plants will both conserve moisture and delineate revegetated areas clearly. This is especially useful for sites that are bounded by mown areas. Undoubtedly the best mulch is the original leaf litter but on many sites it is unavailable in large quantities. An alternative is to approach the local council for mulched tree loppings, but be careful of material which contains seeds from unwanted plants. Some companies sell leaf litter and eucalyptus mulch.

Cypress pine woodchips are also available, as is a wide range of pine products. Recycled material, such as layers of newspaper, cardboard and the felt underlay of carpets, can be good weed suppressants. Dead weeds themselves are also handy suppressants and mulches. However, remember that if the mulch is deep enough to suppress weed growth, it will also suppress any native plant regrowth (Buchanan 1989), so for areas where native plant regrowth is an objective other weed control techniques should be used.

Weed and feral animal control

Weed control should be undertaken prior to planting, preferably two to six or more months before to deplete as much weed seed bank as possible. The section on weed control in Chapter 4 discusses many weed control strategies in detail. For the various treatment methods used on individual weed species, see Appendix 4.

Rabbit control is an ongoing issue on the Cumberland Plain. In some situations rabbit control should be done during the site-preparation phase, but seedling loss from herbivorous feral animals can generally be minimised by using tree guards.

The use of tree guards in combination with weed mats has been very effective on the Cumberland Plain. This technique protects the seedlings from rabbits, weed competition and the extremes of weather while also retaining valuable moisture (Department of Infrastructure, Planning and Natural Resources 2003c).

Watering

Pre-watering of holes and plants prior to planting is beneficial. Newly planted seedlings should be watered in. Watering following planting is usually beneficial depending on site characteristics, resources and weather conditions, but is not always possible.

Fencing

Protective fencing or other barriers may be used to restrict access, and protect and delineate planting areas. When fencing to exclude stock from your rehabilitation area, it is important to consider the following:

- make sure animals cannot reach over the fence to graze the vegetation (electric fencing is a cheap way to exclude stock)
- exclude stock from the rehabilitation areas for at least one to two years after revegetation and during the flowering and seeding periods of the new plantings.

Rabbits will eat young seedlings and rural revegetation projects on the Cumberland Plain may need to consider protecting them from these pests. (DEC)

Direct seeding

Direct seeding has many advantages. It is quick, there is little labour involved, the cost per plant is low, plants grow quickly because their roots have not been disturbed, and the random placement looks more natural. There is some evidence to suggest that directly seeded trees, once established, are more resistant to drought and better able to recover from insect defoliation. Total failure can also result if the seed is not viable, the ground not moist enough and the temperature is wrong for germination. Drought can also be disastrous and heavy storms can wash away the seed if the site is poorly prepared.

Various methods of seed harvesting. (Greening Australia (NSW))

The advantage of direct seeding is that it is a much cheaper method for revegetation than tree planting. Costs as low as 5–20 cents per tree are possible, although realistically a final cost of about 50 cents per tree could be expected. In comparison, contractors can charge up to $3.50 per tree for the total cost of tubestock establishment.

Historically, the technique of direct seeding has often been limited to the use of a small range of suitable species such as large-seeded plants like acacias. Recent improvements in direct seeding techniques have meant that a greater diversity in species establishment is now possible. Direct seeding is often successfully carried out in combination with other planting activities.

One of the benefits of collecting local seed is its cost-effectiveness. However, seed collection can be time-consuming and should be factored into your planning program. The collection of seed is an art in itself requiring specialised skills and knowledge, especially if the seed drops as soon as it is ripe or if it is high in the canopy. Some species have dormancy mechanisms which inhibit immediate seed germination. Table 6 details the best times to collect seed from some Cumberland Plain species.

Refer to the organisations and books in FloraBank for more detailed information on how to collect, handle and store native seed, available by visiting www.florabank.org.au

Site preparation

Site preparation and the climatic conditions experienced after seeding are the two major factors in determining how successful your seedling establishment will be. While there is little you can do to control the weather, good site preparation is one area in which land managers can maximise the chances of a successful project.

Good site preparation aims to provide ideal conditions for seed germination and seed establishment. The basic requirements are:

- soft soil (not compacted) so that air, water and roots can penetrate
- bare soil, free of leaf litter and, more importantly, free of weeds, as weeds will compete with your native plants for water and nutrients (Buchanan 1989).

Methods of achieving soft and bare soil depend on the scale of the problem, the size of the site and cost. Bare soil can be achieved by:

- scraping off the debris and leaf litter
- fire alone or in combination with prior weed control using herbicides
- spraying weeds with herbicides three times in the 12 months before seeding (either knockdown and residual control such as Vorox AA® or knockdown only such as Roundup®)

- scraping off the topsoil to remove weed seeds – in paddocks and roadsides the top 2–10 centimetres, depending on soil type, has the highest concentration of these
- spot preparation, where small spots (one-metre diameter) can be prepared by removing weed and grass cover with a mattock or rakehoe and scarified, before being hand-sown (Buchanan 1989).

In bushland areas nothing may need to be done to create soft soil. However in areas compacted by heavy machinery, ripping to a depth of 20–50 centimetres is recommended. For severely affected areas deep ripping may be appropriate, but it is not recommended to rip deeper than 80 centimetres. After this deep ripping, the soil can be scarified by a conventional plough to depths of approximately 20 centimetres.

Ripping and ploughing must be done along the contours. The combination of ripping and ploughing should produce a coarse, rough seedbed which creates furrows for moisture retention and minimises overland water flow.

Weed control is essential for at least the minimum time needed to allow a build-up of soil moisture and to enable good establishment and growth of seedlings in the first year. There are four main options for a weed control strategy:

- controlling weeds for several months prior to seeding – useful for perennial or persistent weeds to deplete the weed seed bank
- controlling weeds only once (usually 30 days prior) before seeding operations
- controlling weeds throughout the first year as this is critical for long-term success, or
- controlling weeds throughout both the first and second years to help ensure survival, increased growth rates and reduced risk from unplanned burns.

The strategy you use will generally depend on the resources available and particular characteristics of your site.

Sowing techniques

Hydro-seeding

Hydro-seeding is provided by commercial companies in three forms: hydromulching, straw mulcher blows and 'glob' seeding.

Hydromulching is where seed, fertiliser and wood fibre or paper mulch are mixed in a tank on the back of a truck. The mix can be applied to steep slopes that are difficult to treat by other methods. The wood fibre provides initial surface erosion control, helps to retain moisture, and moderates ground temperature. On steep slopes or erosive areas, binders such as bitumen emulsion or polymer binder can also be added to the slurry (Buchanan 1989).

Straw mulcher blows is where a stream of chopped straw or hay is blown through a mist of polymer or bituminous binder. Seed and fertiliser can be applied at the same time. This method has greater moisture-retention properties than hydromulching and is therefore recommended for areas with erratic rainfall (Buchanan 1989).

Tip:

Favourable environmental conditions such as moist soil conditions and minimal weed competition are crucial to the success of direct seeding operations.

This mechanical seeder removes the top layer of grass, sprays herbicide, sows the seed and then covers the seed, all in one pass. (Greening Australia (NSW))

Glob seeding is where chopped fibreglass, seed, fertiliser and a coagulating agent are mixed then ejected through a high-pressure jet designed to soak up the slurry into 'globs' (Buchanan 1989).

Current thought is that native grasses fare poorly in hydromulching as the seed prefers to be covered by soil.

Mechanical seeding

For large areas more than a few hundred metres long, it can often be more efficient to use a machine. These machines are designed to either rip or create a raised furrow or a trench along which a predetermined quantity of seed is sown at specified intervals. Seed is often bulked with sawdust, bran, pollard, chick pellets or vermiculite. The seed is generally covered lightly in these specialised machines as the critical factor is to sow the seed at the right depth.

For small seeded species such as eucalypts, melaleucas and she-oaks the seed can be left uncovered or lightly covered by dragging wheat bags, a chain, brush or even a carpet behind the machine (Buchanan 1989). The NSW Department of Primary Industries, Greening Australia and Landcare are useful contacts for more information on seeding operations (see Appendix 6).

Hand sowing

Hand broadcasting seed is a suitable method for small areas or areas where access or slope are issues. Seeds can be sprinkled over the prepared site and covered lightly with soil by dragging a hessian bag half-filled with sand or the back of a rake.

Brush matting

The application of brush matting (cut stems) usually has two aims: to prevent erosion and spread seed. Species which retain seed on the plant but which shed it when the branch dries out (*Melaleuca*, *Eucalyptus*, *Hakea* and *Leptospermum)* are most suitable. If the site is steep or subject to erosion, the brush may need to be pegged down.

There are several disadvantages to this method. The material is usually scarce and its relocation may deplete the original area. Further, the amount of seed can vary enormously, as can its viability. For these reasons it is not always reliable but, combined with other methods, including planting, it can be very successful. It may be possible to obtain material from areas or trees about to be cleared. It is important to check that the seed on brush matting is ripe before cutting and laying.

Sowing depth

Protection is essential because germination is improved in all methods of seeding if the seed is covered, because this improves the availability of moisture to it and stops seeds being eaten. Optimum cover is generally considered to be between two to three times the smallest diameter of the seed. Conventional tyne harrows can bury seed too deeply. Dragging wheat bags and suchlike over the site, compacting seed into the soil using a roller or even tractor tyres, a chain dragged behind the machine or applying a thin layer of soil, coarse sand, fine gravel or vermiculite can all aid protection (Buchanan 1989).

Sowing time

Ideally the soil needs to be moist for several weeks prior to seeding operations to ensure germination and then for many weeks after seeding to successfully establish. As well as moisture, the soil temperature should favour growth and weeds should be at a minimum. In Sydney, early autumn is generally accepted as the best season (Buchanan 1989), as it gives time for the seedlings to establish before winter. Another good time to seed could be early spring, assuming that the seedlings will establish well enough to withstand dry summer conditions. It may be better to stick to an autumn seeding to avoid the risk of heaving to deal with seedling establishment over a particularly hot, dry summer.

Sowing rates

Seeding rates per hectare vary enormously. Common values in agriculture range from 100 grams to more than 4 kilograms per hectare, but rates can be as high as 12 kilograms per hectare. The weight of seed required can be roughly calculated using the following formula:

$$\text{Weight of seed required} = \frac{\text{Number of plants required per ha}}{\text{Number of viable seeds per kg} \times \text{\% establishment}}$$

If the viability is not known, the number of seeds per kilogram can be substituted for the number of viable seeds. Percentage establishment may be as low as one per cent for small seeded species such as eucalypts and five per cent for large-seeded species like acacias (Buchanan 1989).

Pre-treatment of seed

Seed pre-treatment is required for seed that has dormancy mechanisms that prevent germination. For example, *Acacia* species require pre-treatment with boiling water before they are direct seeded. *Acacia* seeds should be plunged in just-off-the-boil hot water for about one minute followed by a longer plunge in cold water (up to 24 hours). Other treatments include scarification, where sandpaper is used to scratch hard-coated seeds or the seedcoat is nicked using a scalpel. A cold treatment has been found to be useful for *Bursaria spinosa*, as seed from this species germinates successfully after it has been stored in the fridge for two weeks.

A technique of treating only half of the seed to be sown ensures that not all of the seed will be lost in the event of a fire, drought, heat wave, etc. This technique is particularly good in areas where arson may be a high risk. This method will ensure that not all the seed will be lost in the event of a fire, and germination of half the seed will still result.

Post-sowing weed control

This should not be a problem provided that site preparation is good. However if weeds do invade the site after sowing, they must be controlled. Keep a one-metre-square-radius area around the seedling totally weed-free, as this will substantially increase seedling growth rates.

Consider hand-weeding or selectively applying herbicides which kill grass but not broad-leaved species (Curtis 1991). Hand-weeding is expensive but can be effective for smaller areas. Herbicides can be applied selectively by a skilled operator and, where the weeds are much taller than the wanted species, a wick applicator may be used. Chapter 4 discusses in detail various weed control strategies used for particular site conditions.

Transplanting topsoil

The transfer or replacement of bush topsoil (A1 horizon) can be done on a small scale. A shovel, wheelbarrow and a load of soil from a weed-free area of bush can help regenerate a small, bare area faster than many other techniques.

In large-scale projects such as mining, the removal of the topsoil and its replacement is a well planned operation (Environment Protection Agency 1995). The topsoil is vital for later rehabilitation as it contains seeds, vegetative reproductive organs and most of the organic matter. It is best if the soil can be immediately transferred, as stockpiling reduces the quality of soil resources. Stockpiles become anaerobic, soil structure deteriorates, organic matter and nutrients maybe lost, seed and plant propagules die and beneficial soil micro-organisms are reduced. If topsoil has to be stockpiled, it should be for as short a time as possible. The stockpile should be less than two metres high with a large surface area and revegetated using native species to discourage weeds (Environment Protection Agency 1995).

Planting

Planting of seedling tubestock is the most common method used to reintroduce vegetation. Seedlings are better than seeds in many ways. They have already germinated and have roots to absorb moisture and anchor themselves. However, all the advantages of direct seeding are disadvantages for seedlings. Planting rather than sowing is a slow process, a lot of labour is involved and the cost per plant is higher. Many projects incorporate both direct seeding *and* planting methods. Some difficult-to-germinate species, species that produce little seed, and species required for specific locations are all probably best planted out, while the remainder can be directly seeded.

Plant selection is essential and local species from provenance stock should be used in your planting programs (see above section on species selection). Local species are adapted to the local climate and soil conditions, so they are more likely to survive. They are also more likely to provide the right resources for local wildlife. Local species are ideal except where conditions have significantly changed such as in areas affected by salinity or intense dieback.

There is not such a bewildering array of techniques involved in planting as there is in direct seeding, but there is still a long list of important considerations. Try to plant at the most opportune time of year, usually the wet season. On the Cumberland Plain the optimal season for planting is the same as for direct seeding: early autumn around March. Avoid planting in dry times or during drought periods.

Greening Australia (NSW) and the Department of Infrastructure, Planning and Natural Resources are running an extensive revegetation program at their Hoxton Park site. (Greening Australia (NSW))

Propagation

Propagation of plants for regeneration can be done many ways. Propagation from seed and cuttings is certainly the most common, but techniques such as division, layering and even tissue culture are also used (Buchanan 1989). The surest way to ensure that you are using the right technique for the right species is to talk with a local representative from the Department of Primary Industries. A list of useful references on propagation techniques can be found in Appendix 7.

The most important factors for successful planting include:

- the plants are actively growing
- surrounding soil is moist
- sufficient rain in the following few months
- the plants are free of weed competition.

Tubestock are the favoured-size container for many revegetation projects and achieve the best results. Tubestock are relatively cheap, easy to handle, and are the correct size and root-to-shoot ratio for rapid establishment in the field. Plants six to nine months old are generally used. In broad-scale revegetation projects with minimal weed control, tubestock will have caught up with more advanced plants after only one year.

Tubestock grown from locally collected seed may be available in local nurseries. To ensure that tubestock is grown from local material, ask about the source of seed. Another way of obtaining local provenance material is to ask your local nursery to grow your tubestock from seed that you have collected locally, or to collect and grow your seed for you. An alternative is to propagate your own tubestock from seed you have collected. For detailed information on propagating your own tubestock, see Appendix 7 for a list of appropriate publications.

Site preparation

Before planting, plan ahead and prepare the site. Good site preparation will increase the likelihood of successful planting and assist in good plant growth during the first few seasons. Activities to think about include:

- assessing the site to determine factors which may influence the type of plants that may grow there – is it currently grazed, on a steep slope, does it have saline soils, etc?
- propagating seeds yourself or having the seed you collect from your site propagated for you by your local nursery – remember to only collect 10 per cent of a species' total annual seed crop, and that a licence to collect seed from endangered species and communities is required from DEC, phone (02) 9585 6540

- obtaining good-quality planting stock propagated from material collected in your area from nurseries that specialise in growing local native species
- controlling feral grazing animals such as rabbits
- if the site is adjacent to grazing land, protecting the seedlings by fencing off the area from stock.

As with direct seeding, site preparation is essential. Weed control and soft soil are key factors for seedling establishment.

Weed control can be done mechanically, by pulling, digging, cultivation or by knockdown herbicides such as Roundup®. For a detailed account of appropriate weed control techniques based on specific site conditions see Chapter 4 and Appendices 3 and 4.

Soft soil can be provided by digging over the soil where the stock is going to be planted. If you only have hand tools, the best option is to dig to approximately the depth of the container and at least twice the width (Buchanan 1989).

If you are undertaking a large job where the ground has been compacted and native plants are not present, the use of farm equipment for ripping is ideal. Only rip along the contour and no deeper than 20 to 50 centimetres.

Planting techniques

Planting techniques need to be clarified before you start the project. The two major factors to consider are soil type and equipment.

You need to decide whether you are going to dig 30,000 holes in two weeks with your mattock and spade, or whether you are going to use a mechanical device such as 'Tree Planter' or other mechanical equipment. Two people can plant up to 5000 trees a day using a Tree Planter (Buchanan 1989). The use of mechanical equipment only becomes economical if you are going to plant over 5000 seedlings. Disadvantages are their difficulty of use in rocky soils or on sloping sites and only being able to plant in straight lines.

When planting tubestock:

- give all seedlings a thorough watering the day before planting
- plant at the same depth in the soil as it was in the container
- place the plant in the hole and gently firm the soil around the plant
- give the seedling a good soaking to remove any air pockets.

Whenever possible, tubestock should be watered in and tree-guards erected on the day of planting. Tree-guards provide the seedlings with some protection from drying winds, frosts and grazing by animals such as rabbits and hares. Where practical, individual weed mats or a layer of mulch can be placed around individual plants to help control weeds and conserve moisture.

Spacing of your seedlings will depend on:

- the species involved
- the purpose of the planting
- whether planting is the sole means of revegetation or is supplementing direct seeding.

In moister areas, stems two to five metres apart are common, or six to nine metres apart in drier areas supporting fewer trees. Remember, bush does not normally grow in straight lines. Where practical, try to plant in groups and clusters, especially for groundcover species (grasses, herbs, sedges, ferns). For these plants the best way to ensure establishment is to plant in single-species clumps. Most importantly, do not plant more seedlings than you can maintain.

Translocation and transplanting

A number of common species such as *Commelina cyanea* and *Dichondra repens* can be transplanted easily. The large-scale transfer of soil seed bank from sites about to be cleared is another method of translocation which has been used previously with some success.

However, the endangered status of many sites requires that any translocation planting or soil transfers should only be carried out as a last resort and in accordance with an approval or licence from the appropriate authority such as DEC or the local council. The *Guidelines for Translocation of Threatened Plants in Australia* (Vallee *et al.* 2004) should be consulted before considering any translocation. These guidelines are available via the website for the Australian Network for Plant Conservation at www.anbg.gov.au/anpc

Pattern and sequence of revegetation

To decide what species should be introduced and the timing of their introduction the following should be considered:

- the site's goals and objectives
- the desired (and achievable) plant community
- species availability
- practical management and maintenance issues
- the level of competition from weeds
- the best route to achieve a workable ecological succession.

Planting all layers at once

One approach to revegetation projects is to introduce all layers, including grasses, sedges and groundcovers, at the outset. This approach is very reliant on project resources, since weed control is essential in both the preparation and maintenance phases of the project. 'All-layer' planting is more appropriate where sites are small, and a sufficient quantity and diversity of plants are available. Introduction of all layers is especially useful in projects where there are erosion problems as this method will provide cover and ensure a diversity of root depth.

When using this approach, avoid the temptation to overuse those species that are readily obtainable (e.g. *Lomandra longifolia*) to avoid skewing the species balance of the community. One variation on the all-layers method is to initially plant a basic mix with a minimum group of native species that can be expanded later, for example three tree species (one short-lived, two long-lived), two shrub species (one short-lived, one long-lived), and groundcover species (vegetative spreaders, short- and long-lived perennials). Once these are established, interplantings with a greater variety of species can be made in the now protected environment (Benson & Howell 1993).

The role of short-lived plants, such as *Acacia* species and some colonising groundcovers, is to stabilise the ground surface and provide a protected growing environment for slower-growing, long-lived species. Ensure the short-lived tree and shrub species are planted at moderate densities to allow good light at ground level. For detailed information on the recommended species lists see the description of ecological communities in *Native Vegetation of the Cumberland Plain: Final Edition* (NSW National Parks and Wildlife Service 2002).

It will also be appropriate to change the species mix along longer corridors to suit local habitats, such as wetter depressions and changes in soil type or landscape position, that are encountered along the corridor.

Commelina cyanea *and* Dicondra repens *are hardy native groundcovers that are easily transplanted and respond well in most planting programs. (DEC/P. Rebuck)*

Planting groundcovers

Groundcovers are very important in the structure of most vegetation communities found on the Cumberland Plain. Diversity in the groundcover layer is not only vital for biodiversity, but essential for a functioning ecosystem. When introducing groundcovers in a planting program, it is important to plant them very densely in single-species clusters to achieve solid patches of cover quickly. This method will also help with weed management.

Greening Australia (NSW) has been trailing a technique that reintroduces native groundcovers in areas previously dominated by the exotic groundcover Wandering Jew (*Tradescantia fluminensis*). They have successfully trailed the introduction of two native groundcovers, *Microlaena stipoides* and *Commelina cyanea*. The technique involves cultivating seed onto jute matting and then laying the mat along prepared sections of creek bank. This technique has been used at the South Creek demonstration site at Erskine Park (Appendix 2).

Creating a woodland framework

In both Cumberland Plain Woodland and Sydney Coastal River-flat Forest communities, particularly where shade-loving weed groundcovers are likely, canopy species and fast-growing nitrogen-fixing pioneer shrubs can be planted first with the introduction of groundcovers, native grasses, herbs and climbers deferred for 12 months or longer if natural recruitment of these species has not already occurred.

This method relies upon the theory that once upper strata trees and shrubs are planted (using local provenance seed) and established, the resulting improved soil conditions and intermediate shading will increase spaces for native grasses and broad-leaved herbs (forbs) currently disadvantaged by exotic grass swards (Davies & Christie 2001).

The method assumes that revegetation activities will provide protection and create niche areas for the regeneration and recruitment of native groundcovers. It relies upon sustained intervention over time, tailored to manipulate competition using a weed control program and thereby harness the site's underlying potential for natural recovery.

This strategy aims to provide a woodland framework using selected species found in the site's association of pre-existing vegetation (Davies & Christie 2001). If natural regeneration is slow or non-existent, this method can be undertaken in combination with the introduction of various trigger methods (discussed in detail in Chapter 4) to encourage natural recruitment of native vegetation. The aim is to achieve species diversity over time and in stages. Long-term commitment in both time and resources is imperative.

Tip:

Grassy woodland communities do not naturally have a large shrub component and the planting of trees and shrubs in high densities can have detrimental effects on many native groundcover species. Maintaining patchiness is always a good idea no matter what active management you take.

Multi-species tubestock planting

Another possibility is tubestock planting as a multi-species introduction process. This is where a number of species, including colonisers, are planted in each tube so that planting results in an instant community (Department of Infrastructure, Planning and Natural Resources 2003b).

Adding shrubs later

Canopy trees and groundcovers are the focus of the initial planting process while shrubs can be added later when available. It is thought that shrubs are more incidental in woodland habitats and it is more important that the grassland component is not filled with shrubs (Department of Infrastructure, Planning and Natural Resources 2003b).

Species selection and revegetation in saline areas

There is considerable debate over species selection for salt-affected sites. There are many non-local natives and exotic species that have a high degree of salt tolerance and which may be useful for addressing salinity and non-biodiversity objectives such as agro-forestry. Fortunately many plants on the Cumberland Plain have a degree of salt tolerance. Two common techniques for species selection in saline areas include:

- using species previously found on the site, with propagules selected from as close as possible to the site – this is the recommended option, although the greater the change in salinity and water imbalance, the less likely it is to be effective
- using species that occur in naturally saline or waterlogged sites in the vicinity – there is far less risk with this technique and results often reflect natural succession on a landscape scale (Department of Infrastructure, Planning and Natural Resources 2003b).

Planting and site preparation should be carried out as described in the rest of this publication. However, deep ripping of waterlogged soils is generally not recommended.

Never just plant within the scalded area but in surrounding areas as well including, where possible, the recharge area. In severely affected areas it may be necessary to progressively plant from the surrounding areas towards the centre of the scald over many years.

Where waterlogging is a problem, mounding has proved a useful technique to establish seedlings. Salt tends to accumulate at the top of the mound due to evaporation of the rising watertable. Consequently seedlings should be placed in the dip at the top of the mound or on the sides of the mound (Department of Infrastructure, Planning and Natural Resources 2003b).

Management of edges

Many weeds on the Cumberland Plain are not just edge-related or edge-occupying but spread extensively across the whole of the bushland site. One way of countering this is to make buffer plantings of canopy or other elements to extend areas that compete with and shade-out encroaching weeds. It is a good practice to leave gaps, where possible, as an expansion zone (see Figure 6 in Chapter 4). It is anticipated that native recruitment will occur in the gaps between the remnant vegetation and the planted buffer zones. Note that planting as an edge treatment will require DEC approval under the *Threatened Species Conservation Act 1995* if adjacent to remnants which are classed as endangered or contain endangered species.

CASE STUDY

Creating a woodland framework in pastureland

Greening Australia (NSW) in association with Department of Infrastructure, Planning and Natural Resources has been involved in a major Cumberland Plain restoration project known as Greening Western Sydney. This project involves large-scale planting of native provenance tubestock across pastureland. The techniques honed by Greening Australia have been highly successful.

An extensive revegetation program undertaken by Greening Australia (NSW) and the Department of Infrastructure, Planning and Natural Resources at their Western Sydney Parklands site at Hoxton Park. (Greening Australia (NSW))

Site preparation

The site is prepared by slashing existing pasture along the contours on which the plantings will run. Contour planting minimises the risk of erosion problems. The slashed area is left long enough to allow significant pasture regrowth giving maximum results when herbicide is applied. Where pasture is green and not too high, slashing is removed from the program.

Narrow one-metre-wide herbicide lines are sprayed along the contour lines to be planted. This ensures that the young plants are free from competition when establishing. The site is left for one to two weeks until the herbicide has taken effect. In areas of severe weed infestation this technique may be repeated twice before any seedlings are planted.

Planting operation

The seedlings are planted using a Treeliner mechanical planter. The plants are placed approximately two metres apart within each row which are around 2.5 metres apart. This is necessary to provide vehicle access for later maintenance. At these distances some 1920 plants per hectare will be planted with all rows planted along the natural contours of the site. Steep sections are hand planted. Species are mixed and planted in a random fashion as this has been found to give the best results in re-establishing vegetation. All seedlings are planted with individual weed mats and tree guards.

Maintenance

Approximately three months after planting, a follow-up application of herbicide is applied. This will maintain an area free from competition around each plant. Future herbicide application will be applied as required (two to four times a year) for up to three years. An active weed control program targeting environmental weeds is also introduced.

Tip:

Expansion zones are an important aspect of current best-practice revegetation. They are areas at least 20 metres wide that have been left between the remnant bushland and the buffer planting. The aim is for the remnant to 'expand' and gradually fill the gap through natural regeneration. This technique will not only protect your remnant from encroaching weeds but also encourage the natural expansion of important Cumberland Plain remnants.

Installing physical barriers such as logs, bollards or the use of a planted mulched boundary is a useful and acceptable option where access is an issue or the edges of the remnant need to be defined for maintenance problems, e.g. invasive mowing practices. These activities again should be incorporated into a weed maintenance program to control weeds along the edge of remnants.

Other management techniques that can help control invasive weeds along the edges of remnants could be to slash or fire a buffer zone area. Frequent burning of the buffer zone will disadvantage weeds, while advantaging some native species. The buffer area will not have the species complexity and diversity of the remnant, but will act as a good weed buffer for the bushland area while still having a significant native component.

Corymbia maculata *seed. (Greening Australia (NSW))*

These options need to be flexibly deployed according to the specific impacts from adjacent areas. A combination of approaches is often more effective than a single one. What happens over time to the edge needs to be monitored, and management modified as necessary (Department of Infrastructure, Planning and Natural Resources 2003b).

Develop a yearly program

While you are working on your site, make a note of the flowering and fruiting times of all plants. This will help you work out your planting strategy.

In the spring, look at the areas where weeds will be removed. Decide if planting will be needed and which species will be suitable. Collect seeds from the site or from nearby areas. Begin propagating the seeds. Then begin to control weeds from the area to be planted.

Once the weather has cooled down in autumn, begin your planting program. This is also the time when the soil is still moist, so hand watering will not be as important.

Re-creating habitat components in a revegetation program

An essential ingredient in the rehabilitation of degraded landscapes and a sign of the project's success, is the return of native wildlife to new and viable habitat. The more diversity in your planting, such as dense shrub layers and areas of open grassy patches, the greater the value for wildlife habitat.

Lomov (2005) evaluated the success of large-scale restoration projects for the recovery of plant-insect interactions. The results show that, although restoration of Cumberland Plain Woodland may take decades, recovery of certain plant-insect interactions (pollination by bees, seed dispersal by ants) can occur in the early stages.

Birds and other animals, however, may be slower to return to young rehabilitation areas where resources such as tree hollows are not available. These may not be available for a very long time after rehabilitation, and land managers can use nesting boxes of appropriate sizes to attract the desired target species. Introducing habitat material, such as logs and fallen timber, can also add to the diversity of habitat. Plant around remnants so the plantings act as a buffer protecting the remnant. Connecting remnants using corridor plantings can further increase their ecological value.

Care and maintenance after planting

Greening Australia (NSW) has identified the importance of appropriate follow-up maintenance to high seedling survival rates. So remember it is important not to plant more seedlings than you can maintain.

Maintenance includes the application of appropriate herbicides to reduce competition from weeds, slashing, ensuring the quality of bagging and staking, and appropriate fire hazard reduction. This last factor is especially important in the first five years of seedling establishment (Department of Infrastructure, Planning and Natural Resources 2003c).

Watering

For any revegetation project you should aim for as little reliance on watering as possible but instead develop an ecosystem that can cope with local conditions. If you have been unlucky enough to plant just before the onset of a drought, certainly water your seedlings if the resources are available. If the soil is dry when planting, give each plant a good drenching, up to 20 litres each, and then you may not need to water again.

In the first year of establishment some watering may be needed, but aim for several good drenchings a year to encourage a deep root system and a plant capable of looking after itself. Frequent light watering, on the other hand, encourages a shallow root system and plants that die in subsequent dry periods.

The best way of watering seedlings is by conserving water which is naturally in the system: in other words, remove the competing weeds which are losing water by transpiration and provide tree guards, individual weed mats or mulch to keep the soil cool and thereby reduce evaporation (Buchanan 1989). The use of water-retaining granules has also proved successful in revegetation projects.

Fertilising

Fertiliser is not recommended for indigenous plants, as they are naturally adapted to local soil conditions. Fertiliser runoff can also be detrimental to waterways and encourage weed growth. If you do choose to fertilise, for example on soils mistreated during construction work, it is best to apply fertiliser that the tree roots and not the grass roots can reach. One or two slow-release fertiliser tablets placed in the hole beneath the tree roots are generally sufficient. Further fertilisation is not needed after this period (Buchanan 1989).

Weed control

The competition from grass and weeds for water during the first spring and summer is possibly the most important influence on seedling survival and growth. It is vital to reduce weed and grass growth as much as possible during this time.

The finely divided dense roots of many weeds, especially grasses, more than effectively compete with native tree and shrub roots for nutrients and, more importantly, water.

An area of approximately a metre diameter around each plant should be kept weed-free. Methods of weed control are numerous and include the application of residual herbicides to bare soil after planting to prevent weed germination; repeated applications of knockdown herbicides; thick application of mulches; and weed control mats (Buchanan 1989).

Maintenance at the Department of Infrastructure, Planning and Natural Resources, Greening Western Sydney's Hoxton Park site, involves the spraying of Roundup® approximately three months after planting to a small area around the base of new plantings to reduce competition for water and nutrients from surrounding noxious weeds and pasture. Seedlings were maintained using a regime that sprayed around the seedlings twice a year. In some cases where pasture growth was excessive, a third spray was required. This weed control regime is only used for the first 2–3 years of the plant's life after which the plants are self-sustaining. Over the last few years Greening Australia has found that plantings treated in this manner have achieved much higher survival and growth rates.

Within the project, two types of Roundup® maintenance spraying techniques were used depending on the type of planting and terrain. Backpacks were generally used for smaller community plantings or where vehicle access was limited (e.g. steep slopes). For larger plantings, such as the broad-acre mechanical planting at Hoxton Park, a spray arm mounted to a 4WD vehicle was employed. Where the planting lines are relatively uniform and the land surface relatively flat, this is a far more efficient method of maintenance spraying.

This method has also proved beneficial during small grass fires of low intensity. Some plants were noted to have survived these fires due to the lack of fuel in the area surrounding the tree as a result of previous spraying operations (NSW Department of Urban Affairs and Planning 2001).

An alternative to chemical weed control is to slash between the rows of planted tubestock and/or direct seeding lines.

Herbicide is being applied using a spray arm mounted to a 4WD vehicle. This technique is employed to effectively control weeds on broad-acre mechanically planted sites. (Greening Australia (NSW))

Slashing has the added advantage of not only reducing competition from weeds but also reducing potential fire hazards at the site while maintaining a good mulch layer. Care should be taken around rows of direct seeding, which may need to be marked out to prevent them from being slashed over.

If you are planning to graze your revegetation area as a method of weed control, ensure that it is not during the flowering and seeding times for native vegetation and do not introduce stock into revegetated areas within the first 12 months of seedling establishment (NSW Agriculture and Fisheries 1991). See Appendix 4 for detailed descriptions of the various methods used to remove weeds.

Weed matting and mulches

The use of mulch as a method of weed control around planted tubestock can be time-consuming and costly. However, mulches are a safe and effective method of controlling, or at least ameliorating, soil conditions. Mulching helps control soil water loss, soil temperature fluctuation and weed invasion.

Mulches can be expensive. More economical materials include sheets of newspaper, hay or straw mulch, even a mulch of dead weeds. Combinations can also be used; newspaper combined with dead weeds is cheap and effective. However, some organic mulches, on decomposing, create a flush of nitrogen-fixing bacteria which act on the decaying matter and make the soil very acidic. If young seedlings have been planted into the mulch, the decay action may harm them. For this reason, fine-grained mulches such as sawdust, which decompose very quickly, are not recommended.

Remember, if the mulch is deep enough to suppress weed growth, it is also deep enough to suppress any native plant regrowth. If there is any possibility that the site being treated has native plant seed remaining in the soil or recruitment of native plants is anticipated, then the use of a mulch should be re-considered or at least restricted to particularly weedy sites (Buchanan 1989).

Tree guards

Plant guards are essential in most rural projects, but before you spend a lot of money or time, think carefully about what you are protecting plants from. Rabbits, goats, domestic stock, native animals, children or frost might each require a different solution.

On the Cumberland Plain protecting young trees from rabbits is often a major concern. Commercial tree guards come in different shapes and sizes. The most popular variety is a plastic sleeve held in place with bamboo stakes. A low-cost alternative for keeping rabbits off is old milk cartons or homemade wire mesh tree guards.

Another issue is whether to guard each plant or fence the whole area. This is generally dependant on your resources and the presence of stock. The use of tree guards in combination with weed mats has been very effective on the Cumberland Plain. This technique protects the seedlings from rabbits, weed competition and the extremes of weather, while also retaining valuable moisture (Department of Infrastructure, Planning and Natural Resources 2003c).

In a recent survey undertaken at numerous restoration sites on the Cumberland Plain, Greening Australia (NSW) estimates the survival rate of bagged versus unbagged seedlings was 81 per cent to 16.5 per cent.

Staking and tying

On restoration projects, staking should be avoided wherever possible, as it is time-consuming, expensive and potentially damaging to the plant. Plants with individual guards should not need staking and tying. If you consider that tying is essential, you must prevent the tie or stake rubbing the plant stem as it will damage the bark and, in extreme cases, the wood as well. Such damage can lead to structural weakness and insect or fungal attack. Stems should be tied loosely to prevent ring-barking and to promote root growth (Buchanan 1989).

Insecticides

Large-scale control with insecticides may be tempting but it should only be done in the most extreme cases. Most native species are fairly hardy and can re-shoot after even severe defoliation.

Control of stock access and feral animals

Fencing out livestock and vermin is very important to protect young trees until they are at least two metres tall. Trees planted in groups and permanently fenced from livestock allow an undisturbed area for regeneration. The root zone does not become overly compacted as the livestock have a variety of shaded areas to gather in.

Where native pasture has been established through regeneration or revegetation activities, grazing management of the established pasture should aim to optimise the growth of the sown species. Grazing should not commence until the plants are firmly rooted and cannot be pulled from the ground. Delaying grazing until the year after sowing is essential to most establishing pastures (NSW Agriculture and Fisheries 1991).

Feral animal control, particularly of rabbits, may be required in some situations for approximately the first one to two years after seedling establishment. Fencing and/or individual tree guards are often the most cost-effective methods.

Fire

The best protection for your plants in the first few years is weed and grass control. A fire in the first five years of plant development will kill most of your plants. On the other hand fire will encourage native grasses. In later years your revegetation site should be subjected to a managed fire regime (see the section on the use of triggers in Chapter 4).

Replacing losses

Some seedlings may not survive the initial establishment period and it may be necessary to replace these seedlings.