SOUTH EAST QUEENSLAND ECOLOGICAL RESTORATION FRAMEWORK:

MANUAL

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This work may be cited as:

Chenoweth EPLA and Bushland Restoration Services (2012) South East Queensland Ecological Restoration Framework: Manual. Prepared on behalf of SEQ Catchments and South East Queensland Local Governments, Brisbane.

The South East Queensland Ecological Restoration Framework consists of three documents being the:

1. Code of Practice 2. Guideline 3. Manual

The Framework will be subject to periodic review. If you have any suggestions for improvement we invite your feedback.
Please provide feedback to SEQ Catchments, PO Box 13204, Brisbane, Qld, 4003.

ISBN-978-0-9807088-8-2

DISCLAIMER:

PREPARED BY:

Cardno Chenoweth

Bushland Restoration Services

ON BEHALF OF:

Brisbane City — Dedicated to a better Brisbane

Gold Coast City Council

Redland City Council

Somerset Regional Council

SEQ Catchments — Healthy Land – Healthy Water

Logan City Council

Sunshine Coast Council

Moreton Bay Regional Council

Scenic Rim Regional Council

Lockyer Valley Regional Council

City of Ipswich

Toowoomba Regional Council

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APPENDICES

1 INTRODUCTION

"Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."

1.1 PURPOSE OF THE SEQ ECOLOGICAL RESTORATION FRAMEWORK

The South East Queensland (SEQ) Ecological Restoration Framework Project was originally proposed by the Environmental Managers Technical Reference Group (EMTRG), a group of environmental managers representing SEQ Councils. The EMTRG recognised that the high growth experienced in SEQ, combined with the diversity of stakeholders undertaking ecological restoration, required the development of a standard to ensure consistent ecological restoration delivery. In April 2011, the Council of Mayors (SEQ) subsequently endorsed the Framework as a regional standard for undertaking restoration projects. Ultimately, ecological restoration projects delivered under the Framework will:

- Conserve and enhance biodiversity through increasing the extent and improving the condition of native vegetation;
- Ensure long-term environmental and economic sustainability; and
- Ensure ongoing improvement and maintenance of ecosystem services.

The SEQ region, as defined by the SEQ Regional Plan 2009 – 2031 is made up of 11 Local Government Areas, including:

- Brisbane City Council
- Gold Coast City Council
- Ipswich City Council
- Lockyer Valley Regional Council
- Logan City Council
- Moreton Bay Regional Council
- Redland City Council
- Scenic Rim Regional Council
- Somerset Regional Council
- Sunshine Coast Regional Council
- Toowoomba Regional Council

The Framework is comprised of three key documents to guide the delivery of vegetation/ecological restoration works in the SEQ region including:

- **Code of Practice** – a policy document providing a head of power for the subsequent Guideline and Manual. The code of practice reflects the SEQ policy environments where it is to be housed.
- **Guideline** – a decision making tool to guide users to the most appropriate course of action in their project. This document guides application of the policy and links to current best practice and examples demonstrated in the Manual element.
- **Manual** – a technical but easy to use guide to all aspects of ecological restoration. This document is reflective of current best practice, and provides the minimum acceptable solutions to ecological restoration.

1.2 THE MANUAL

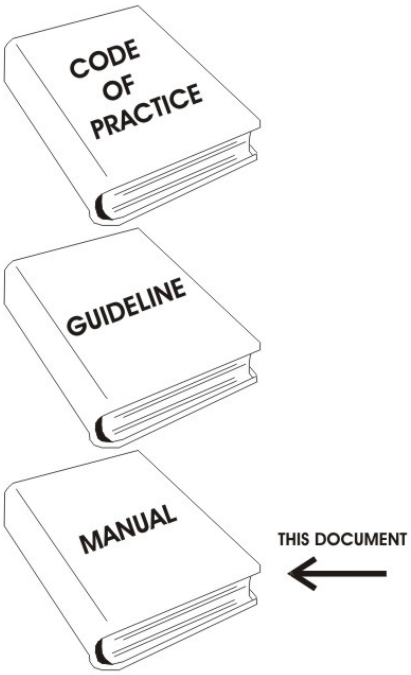
This document constitutes the Manual component of the SEQ Ecological Restoration Framework.

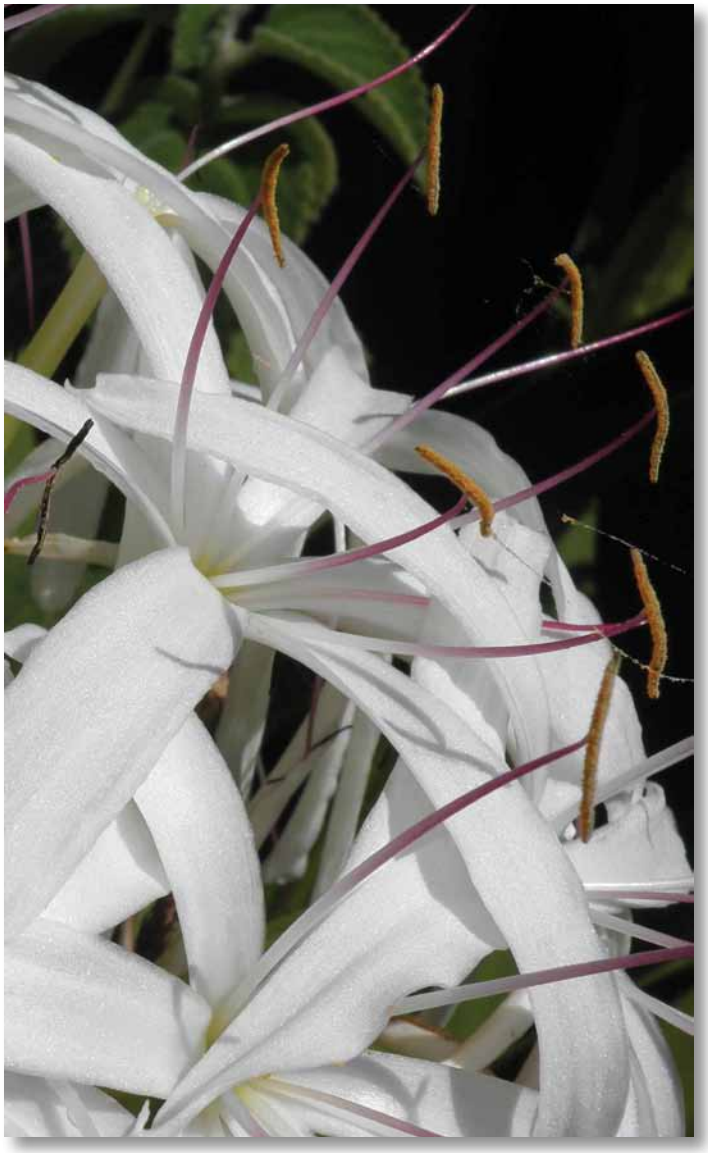
1.3 PURPOSE OF THE SEQ ECOLOGICAL RESTORATION MANUAL

The South East Queensland (SEQ) Ecological Restoration Manual has been prepared as a technical, easy to use guide to all aspects of ecological restoration in south east Queensland. It is intended that it be used in conjunction with the SEQ Ecological Restoration Guidelines and the Code of Practice. The Manual briefly explains what ecological restoration is and why it is practiced, before going on to discuss the four major ecological restoration approaches.

The Manual deals with ecological restoration techniques, providing detailed information about current best-practice in the restoration industry in South East Queensland.

SEQ ECOLOGICAL RESTORATION FRAMEWORK





A section on the importance of monitoring and evaluation, together with suggestions on how to incorporate monitoring into your project, is included at the end of the Manual. Case studies are incorporated throughout to show how the techniques described have been successfully applied in real-world situations in SEQ.

1.4 APPLICATION

This Manual applies to anyone undertaking ecological restoration works in SEQ, including but not limited to, contractors and employees of local councils, other government organisations and utility providers, as well as volunteers, community groups and private landholders. This document can be used to inform policies and strategies implemented by local government.

2 ECOLOGICAL RESTORATION

"Ecological restoration is an activity directed by humans that attempts to reinstate attributes of ecosystems that are considered to be of value."

2.1 WHAT IS ECOLOGICAL RESTORATION?

The Society for Ecological Restoration International (SERI) defines ecological restoration as:

> *"... the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."*

A key aspect of ecological restoration is that it returns structure and function to a site, which in turn improves habitat for fauna. Structure includes components such as vegetation height and density, canopy cover and appropriate species assemblages, as well as habitat features such as fallen logs. Function refers to the natural and self-sustaining processes which occur within the site, such as regeneration capacity, succession, and cycling of nutrients.

Without the return of structure and function to a site, the amount of ongoing maintenance which is required may never be reduced as the site is unable to develop to the stage where there is only a requirement for minimum maintenance. Although a highly degraded site may require many years of follow-up, the ultimate goal is for the level of human-directed activity to become less over time, as the site becomes self-sustaining. Natural processes must be restored if the site is to regain functionality.

2.2 WHY DO WE UNDERTAKE ECOLOGICAL RESTORATION?

Ecological restoration is an activity directed by humans that attempts to reinstate attributes of ecosystems that are considered to be of value. Activities that achieve these desired attributes are likely to include the control of environmental weeds, the re-establishment of wildlife corridors and/or the stabilisation of creek banks. As society's values change, so too will the priority placed on ecological restoration. Generally, however, the desire to maintain the integrity of our natural environment and improve the ecological function of areas previously subjected to disturbance remains constant.

To resolve the often competing objectives of preserving natural environments and development, the implementation of offsets has become an increasingly common solution. Ecological restoration can be used in the establishment of offset areas with the aim of maintaining (i.e. no net loss) or increasing (i.e. net gain) the level of biodiversity within a region.

2.3 WHAT IS THE DIFFERENCE BETWEEN RESTORATION AND REHABILITATION?

'Restoration' and 'rehabilitation' are two terms that are often used interchangeably but in this Manual they have quite distinct meanings. Restoration requires that the re-establishing plant community be similar to the original vegetation in structure, function and composition. On the other hand, rehabilitation involves the creation of structure and function, without the reinstatement of the original vegetation community. However, rehabilitation does require that the establishing planted community be similar to a naturally occurring plant community of the same type (e.g. a constructed freshwater wetland should resemble a natural system in terms of structure, composition and diversity). In essence, rehabilitation falls short of full restoration as it reinstates functioning of an ecosystem without preserving the pre-existing biotic integrity.

Of the four ecological restoration approaches described in the next section of this Manual, Natural Regeneration, Assisted Natural Regeneration and Reconstruction are classed as 'restoration' and Fabrication (or Type Conversion) is considered to be 'rehabilitation'.

But what about revegetation? 'Revegetation' is often used as a comprehensive term that covers all of the four restoration approaches. The thinking behind this is that each of these restoration approaches is concerned with returning vegetation communities to the site – hence, revegetation. Even when planting and direct seeding are not utilised, the specialised techniques employed (such as weed control or soil disturbance) are still encouraging the reinstatement of vegetation. However, in other sectors, revegetation is simply regarded as being about installing vegetation on a site, without consideration of any ecological restoration principles to re-establish natural functioning. For this reason, and to circumvent any potential confusion, the use of the term 'revegetation' has been avoided in this Manual.

3 APPROACHES TO ECOLOGICAL RESTORATION

"Regeneration capacity (commonly referred to as resilience) is a measure of the natural capacity for the re-establishment of vegetation that exists on a site."

3.1 BACKGROUND

The Guideline document introduces and describes the four approaches to ecological restoration. These are summarised in Table 1 below.

Table 1. Four common restoration approaches and their application.

NATURAL REGENERATION	
Applies:	• To relatively large, intact and weed-free areas of native vegetation. • Where native plants are healthy and capable of regenerating without human intervention. • When native plant seed is stored in the soil or will be able to reach the site from nearby natural areas, by birds or other animals, wind or water. • Where the plant community has a high potential for recovery after any short-lived disturbance, such as a fire or cyclonic winds. • When preventative action is all that is required to avert on-going disturbance e.g. erection of fencing to prevent intrusion by cattle.
Role of planting:	• Planting in such areas can work against the aims of restoration by interfering with natural regeneration.
Goal vegetation community:	• The re-establishing plant community will be similar in structure, composition and diversity to the original vegetation.
ASSISTED NATURAL REGENERATION	
Applies:	• To natural areas where the native plant community is largely healthy and functioning. • When native plant seed is still stored in the soil or will be able to reach the site from nearby natural areas, by birds or other animals, wind or water. • Where the natural regeneration processes (seedling germination, root suckering, etc.) are being inhibited by external factors, such as weed invasion, soil compaction, cattle grazing, mechanical slashing, etc. • When limited human intervention, such as weed control, minor amelioration of soil conditions, erection of fencing, cessation of slashing, etc. will be enough to trigger the recovery processes through natural regeneration. • When the main management issue is weed infestation and/or current land use practices.
Role of planting:	• Planting in such areas can work against the aims of restoration by interfering with natural regeneration except where species cannot return to site without direct intervention.
Goal vegetation community:	• The re-establishing plant community will be substantially similar in structure, composition and diversity to the original vegetation.

Table 1 cont'd

RECONSTRUCTION	
Applies:	• Where the site is highly degraded or altered. • When the degree of disturbance has been so great and long-standing that the pre-existing native plant community cannot recover by natural means. • To sites such as areas of fill, sites affected by stormwater flow, areas that have been drastically cleared, even though there may be a few remaining native trees or shrubs. • When a greater degree of human intervention is required, such as weed control, cessation of grazing and/or slashing, amelioration of soil conditions such as importation of soils, drainage works or re-shaping of the landscape
Role of planting:	• Importation of native species to the area is required, either through planting or direct seeding (in some situations). Natural regeneration and recruitment is insufficient to initially re-establish the original vegetation. Depending on the prevailing circumstances, the planting of a broad diversity of species from the target ecosystem may be unnecessary and the use of pioneers may be sufficient to re-establish ecological processes.
Goal vegetation community:	• The re-establishing planted community should be similar to the original vegetation in structure, composition and diversity.
FABRICATION (TYPE CONVERSION)	
Applies:	• Where site conditions have been irreversibly changed. • When it is not possible to restore the original native plant community. • Where a better-adapted local plant community can be planted that will function within the changed conditions. • In situations such as the construction of a wetland plant community to mitigate increased urban storm-water run-off.
Role of planting:	• Revegetation (planting) is the major component in a fabrication program.
Goal vegetation community:	• The re-establishing planted community should be similar to a naturally occurring plant community of the same type (e.g. a constructed freshwater wetland should resemble a natural system in terms of structure, composition and diversity)

(Table 1 adapted from a table in the Gold Coast City Council's "Guideline for the preparation of a Rehabilitation Plan")

Any one project is likely to require a combination of the above approaches, dependent on the particular site.

The techniques in the Manual focus on weed control primarily because exotic species are one of the greatest threats to biodiversity and a common thread between most or all restoration approaches. However, planting remains an important approach in ecological restoration. There are many instances where planting is warranted including sites where there is a rapid need to stabilise eroding soils or where important floristic elements cannot return to the site due to ecological barriers.

CASE STUDY 1

NUMINBAH CONSERVATION AREA (CA) ASSISTED REGENERATION - GOLD COAST CITY COUNCIL

BACKGROUND

The 560ha Numinbah CA ranges from degraded open areas to riparian zones (cleared and remnant), vegetated gullies, large areas of dry and wet sclerophyll vegetation types as well as dry and sub-tropical rainforest. The site varies in its level of degradation from open pasture to native vegetation that is a mixture of regrowth and remnant. The resilience of the site is estimated to be high due to existing vegetation, diversity of flora and fauna and where the site sits in the landscape. There are however large open areas including a section of creek that will require planting due to previous disturbance, a lack of forest structure in some areas and the lack of an intact soil profile in other areas.

After a desktop analysis where Regional Ecosystem mapping, flora and fauna records and fire mapping were interrogated, a number of site visits were conducted and a restoration plan was developed. The site was divided into precincts, zones and sub-zones to assist workers and managers with the direction of works. Once primary and follow-up works stabilise in one zone, works continue into the next zone after ensuring previous works are consolidated. Due to the size of the site coupled with competing priorities, works have simultaneously commenced in four different precincts designed to join up significant areas in the most ecologically and cost effective way possible while ensuring workers are provided with psychological boosts by seeing whole areas complete.

Most of the site will be restored via the 'assisted regeneration' approach where key areas are encouraged to regenerate with native species from the seedbank or surrounding biomass. Weeds are controlled in such a way that soil, habitat and water quality is protected and methods used continue to encourage the succession of native species. One section of creek will be planted in the next couple of years to assist with stabilisation, water quality and connectivity to other forested areas. The remaining open areas will be encouraged to reduce over time (maximising resilience while minimising costs) and any large gaps still remaining by year 8-10 of the project may be planted using locally collected seed.

IMPLEMENTATION

Primary works involved cutting and painting lantana (*Lantana camara*) from around natives (starting in zone 1) and to assist with creating access, as well as other primary weed control such as cutting glycine (*Neonotonia wightii*) and other exotic vines off native plants, spray preparation (hand weeding around seedlings or on immediate toe of bank) or isolating lantana for subsequent over-spraying activities. Secondary works included spot-spraying ground weeds such as mistflower (*Ageratina riparia*), broad-leaved paspalum (*Paspalum mandiocanum*), blue billy-goat weed (*Ageratum houstonianum*), crofton weed (*Ageratina adenophora*) and re-shooting lantana as well as over-spraying dense lantana. Maintenance has consisted of ensuring exotic and vigorous native vines do not take advantage of the trellis of dead lantana, following up on weed growth while ensuring the timing of maintenance activities is not left too long nor carried out so frequently that further ground is hard to gain. Monitoring the success of the zone is essential to expanding works. The weed control techniques included:

- Cut-Scrape-Paint (CSP) – used in the control of lantana when it is mixed with native vegetation. Loppers were used for accuracy, durability and safety and the plant is chopped up into approximately 50cm pieces and left on the ground to break down over time. The base is then treated and painted with glyphosate at a rate of 1:1 glyphosate:water. This is also used for exotic vines such as glycine. Anything above the head is left to breakdown and fall over time i.e. pulling it from the mid-storey or canopy will damage the native host.
- Spot-spraying – used for controlling ground weeds and weeds that have re-shot. Care was taken to prepare sensitive areas by hand-pulling or pushing down weeds from around native seedlings and ferns. An adjustable nozzle that allows the practitioner to delicately spot-spray weeds amongst native plants is required. This technique is also the most efficient way to maintain whole areas which is a necessary part of the restoration process especially on a large site like this.
- Over-spraying – used for over-spraying large sections of lantana that had been previously prepared by cutting it away from natives and creating tracks so all clumps could be reached and maintained.

Case Study 1 cont'd

- Stem Injection – used on larger tobacco bush once natives are present and are able to take their place.
- Manual removal – used for weeding mistflower from the immediate creek zone and near sensitive plants. Care needs to be taken so as to retain vegetation on the creek bank for stabilisation and habitat i.e. removal must be done over time or be guided by the level of native vegetation present. Steep and erosive areas were also considered when hand pulling lantana.

As of July 2010 after only 3 years effort of restoration, 55ha is under active management i.e. at maintenance level. This has been achieved by utilising a number of professional bush regeneration teams that work as a 3-4 person crew 1 day per week for two of the areas and one day a fortnight for the campground and high altitude forest. It is estimated that at this rate, all forested areas will be under a level of management within 10 years and the more open areas will be under reconstruction.

2008 - prior to work starting

2008

2010

(Case study courtesy of Jen Ford. Images supplied)

3.2 ECOLOGICAL RESTORATION PRINCIPLES

3.2.1 ECOLOGICAL RESTORATION AS A PROCESS

The primary goal of restoration work is to implement techniques on a site that will assist with creating or re-establishing natural processes. The role that the restoration worker plays is a preliminary trigger to the natural activity that will subsequently eventuate. The key to understanding the role that humans play is to emphasise that ecological restoration interventions are designed to eventually be phased out when the ecosystem has once again become self-sustaining. Comprehension of this concept is assisted by a sound understanding of succession and ecological processes.

3.2.2 SUCCESSION

As restoration work progresses on a site, ongoing changes to the structure and diversity of the vegetation will become apparent. These changes tend to occur in a cyclical manner, with the initial disturbance to the vegetation (either natural or man-made) being the trigger for changes. Even though our goal as restoration workers is to assist with the formation of a mature, fully-functioning community, it is important to recognise that the vegetation will have to pass through a variety of stages of succession first, over a period of many years.

Although initially triggered by disturbance, the lack of disturbance events in the long-term also contributes to succession. As an example, Kerosene bush *(Pultenaea villosa*) will dominate a site immediately following fire, but if fire is excluded over a period of years, its presence will decline as other species succeed it.

Note that, even on sites where plant re-introductions are considered necessary (the Reconstruction and Fabrication approaches to ecological restoration) the process of succession will still occur. Over time planted sites show changes in the overall composition. Some of the plants mature and reproduce as they fulfil their role as colonisers, and other plants are inhibited until conditions are created meeting their requirements for growth.

Additionally, introduction of seeds by birds, bats and other animals will result in further changes to vegetation composition over time. Therefore, a planted vegetation community does not necessarily mean a static, unchanging ecosystem – a planting, too, is subject to the natural processes that promote succession.

Patience is an important attribute for the restoration worker to possess. We cannot force the restoration processes to occur, but can take the actions that prompt its initiation.

There are project aims that may require more direct action. For instance, if the goal of the project is to restore koala habitat, then the need to rapidly establish a feeding resource for an at risk species may require intervention in the natural succession process.

3.2.3 DISTURBANCE AND DEGRADATION

Disturbance, often has negative connotations, however is an integral part of the functioning of a vegetation community. In the absence of degradation, such as the loss of biotic or abiotic components, an ecosystem is able to cope with disturbances such as the fall of a large tree or a flood event. Disturbance can be an essential part of the functioning of the ecosystem, without which further recruitment of native plants may not occur. Disturbance such as fire can be an integral part of the ecology of many native species and is a requirement to release seed or trigger germination. Disturbance, even on a very small scale (e.g. a brush turkey scratching leaf mulch away from the topsoil), creates the niches that allow seeds to germinate and establish. Certain species are reliant on some level of disturbance for their existence, such as the nationally endangered native jute (*Corchorus cunninghamii*) (Saunders, 2001).

As restoration workers, our role is to utilise techniques that reduce degradation on sites (such as controlling environmental weeds), while creating disturbances that mimic natural disturbances the vegetation community is adapted to.

Disturbance can be useful as a restoration or management tool, but must be implemented with great care.

Native jute (*Corchorus cunninghamii*) is a herbaceous plant species occurring in the narrow ecotone between subtropical rainforest and open eucalypt forest. It has a restricted distribution and is known from only four locations in South East Queensland.

3.2.4 HOW DO WE MIMIC NATURAL DISTURBANCE?

Regeneration of native plant species is stimulated by mimicking natural disturbances. The techniques used will depend on the individual species and vegetation community, as they have evolved to respond to disturbances in different ways. Some examples of these techniques are:

- Control of competing vegetation, especially environmental weeds;
- Controlled burns or burn piles in vegetation communities adapted to fire;
- Soil disturbances such as ripping or raking; and/or
- Alterations to hydrology in wetlands to reinstate natural movement.

More details on these techniques can be found in Section 5 of the Manual.

3.2.5 REGENERATION CAPACITY

Regeneration capacity (commonly referred to as resilience) is a measure of the natural capacity for the re-establishment of vegetation that exists on a site. It can be difficult to predict and often only becomes apparent once disturbance techniques have been applied. Generally, the less degraded a site is, the more likely it is to have high regeneration capacity. Regeneration capacity is also influenced by the type of disturbance and the length of time the disturbance has been occurring.

The potential for regeneration is often "hidden", in that it may consist of seed that is stored in the soil seed bank, or of seed that migrates to a site via the movement of wind, water, gravity, birds, mammals or insects. The close proximity of remnant vegetation will make the migration of seed and other vegetative material to the site more likely.

Assessing the resilience of a site helps us to determine which restoration approach is appropriate. Do not assume that a site has low regeneration capacity until you have assessed the site and carried out some restoration activity. Even a largely cleared paddock that has been grazed for years could possess some regeneration capacity. The presence of just one or two paddock trees, producing seed and attracting birds and bats, will increase regeneration capacity, and may form the core of restoration works using the Assisted Natural Regeneration approach or a combination of approaches.

Assisted natural revegetation after control of Lantana

Prior to control April 2007

June 2008

June 2009

3.2.6 NEED FOR CONSISTENT FOLLOW-UP

It is essential for consistent follow-up to be applied to a site once primary work has commenced, so as gains are not lost e.g. native species germinating from the seed bank are not out competed by weeds. Many weed species in the soil seed bank will be exhausted within a year or two, but some weed seeds (e.g. Easter cassia (*Senna pendula* var. *glabrata*) may have longevity of at least ten years. Particularly difficult weeds to treat such as madeira vine (*Anredera cordifolia*) and glory lily (*Gloriosa superba*) require a long-term commitment (of ten or more years) of constant attention. The take-home message here, is that it is ineffectual to do a little work on a site, simply walk away, and then expect that good results will be obtained. Follow-up and maintenance will always be necessary, and these elements should be considered right at the start of the planning process, before any physical work has even commenced.

3.2.7 PERMANENT CHANGES TO THE VEGETATION COMMUNITY

It may be necessary to accept permanent changes to the vegetation community that you are working in. For example, the exclusion of fire from urban remnants of sclerophyll forest may see a shift toward more rainforest species, such as tuckeroo (*Cupaniopsis anacardioides*) and pink euodia (*Melicope elleryana*). If this successional change is acceptable, the aims of the restoration project may need to be reviewed and updated. There is a case for arguing that these particular plants, although native, are invasive species and that they should be controlled, as they are not part of the original plant assemblage.

It is extremely unlikely that planned ecological burns would be permitted in urban-interface sites. In the absence of fire a shift toward higher prevalence of rainforest species will be permanent and in this case it may be pointless continuing to control these 'out-of-place' plants.

As long as the vegetation community maintains strong historical links with that which existed there previously (e.g. remnant canopy of sclerophyll species), the work being carried out can still be considered ecological restoration.

CASE STUDY 2

TENERIFFE PARK - BRISBANE CITY COUNCIL

BACKGROUND

In 1990 a group of bush carers in the inner city suburb of Teneriffe started work in Teneriffe Park. The site would have originally been covered by tall open forest with grey gum (*Eucalyptus propinqua*) and grey ironbark (*E. siderophloia*) (RE 12.11.3) and still supported several large remnant trees, with the ridges also supporting lower storey sclerophyll species.

IMPLEMENTATION

The presence of a very large crows ash (*Flindersia australis*) may or may not indicate that rainforest once occurred on the site. The central gully had been significantly disturbed through clearing and dumping of fill over many years and now supported a dense stand of Chinese elm (*Celtis sinensis*), camphor laurel (*Cinnamomum camphora*) and madeira vine. Historic disturbance, altered hydrology, increased fertility and exclusion of fire meant that restoration to a sclerophyll community was not feasible and a fabrication approach to restoration was adopted whereby weeds were progressively replaced by a rainforest community. (It was subsequently noted in Sattler and Williams 1999, that this type of forest develops a dense understorey of Araucarian rainforest species in the absence of fire, which further confirms the original decision to fabricate such a rainforest community.)

LESSON LEARNT

After twenty years the restored community resembles rainforest gullies that occur in nearby locations such as Mt Coot-tha. The site is displaying greater resilience to weed invasion and is providing habitat for local wildlife.

3.2.8 CRYPTIC SPECIES

The flora of a site is made up of a diversity of organisms – trees, shrubs, forbs, grasses, fungi, lichens, mosses, and micro-organisms. It is natural for attention to be caught by the larger, more eye-catching species on site, such as trees and shrubs. But don't undervalue the importance of the smaller, cryptic species. They fulfill a role that is just as important as that of the more charismatic species, despite their seeming insignificance. They have huge biomass, and without their presence, ecosystems would simply fail to function. Although they are often overlooked, take the time to appreciate the role that cryptic species play on the sites that are being worked. The value of fungi in ecological restoration is currently being studied and promoted by CSIRO (2010).

There are also cryptic organisms that threaten the success of restoration projects, such as die-back fungus that causes root-rot (*Phytophthora cinnamonii*) and amphibian Chytrid fungus that has led to a decline of frog species worldwide. These organisms can have devastating impacts on native tree and frog populations respectively. Sites known or suspected to be at risk from these pathogens must be managed with a strong emphasis on site hygiene, to minimise the transfer of disease from footwear, equipment and vehicles.

3.2.9 RECOGNISING OUR 'IGNORANCE' IN RESTORATION

Ecological restoration is a complicated and developing field, and it is often the case that the more we learn, the more we realise how much there is to learn. Ecological restoration requires that we consider carefully, the multiple aspects involved in an ecosystem, and the complex, unpredictable and often unseen interactions that exist between components. We cannot assume that we have a thorough knowledge of everything that is occurring in an ecosystem.

With this awareness of our 'ignorance', it obviously becomes necessary to remain flexible, and to be prepared to change the approach as restoration progresses on the site. By implementing monitoring techniques, in order to gather data that is not always obtainable from informal observations, you may gain a better understanding of some of the more complex processes that are occurring on the site.

See Section 7 on how to incorporate monitoring into a project.

4 SITE ASSESSMENT

"Detailed site assessments are essential for all successful ecological restoration projects as this will inform all decisions made throughout the life of the project, including that of which restoration approach to utilise."

As part of the site assessment process, it is important that the aims and objectives for the site are clearly identified prior to commencement as they direct the collection of information and the restoration activities. The establishment of aims and objectives are described in the Guidelines. Refer to the Guidelines for additional information on site assessment.

A map of the restoration site, preferably with an aerial photograph background, will be required prior to assessing the site. The map will be used on site to mark features such as areas of vegetation, native and weed, access tracks, management issues and proposed work zones.

4.1 ASSESSMENT OF TARGET SITE

It is essential to undertake a detailed site assessment, prior to the preparation of an Ecological Restoration Plan. The following information is intended to assist this process.

Describe the history and background of the site

E.g. was the area previously grazed, when was the area cleared, is it an old house site, was the area ever used as a dump for industrial waste, was the area logged, what is the fire history? Knowledge of past uses will help to identify risk factors that are likely to influence the existing native vegetation and the success of restoration efforts. Understanding site history will help to determine realistic outcomes for the site.

Briefly describe the soils, drainage, topography and aspect

Include any issues that may impact on existing native vegetation or its restoration e.g. re-planting on an exposed north-facing site may have a detrimental effect on the survival of the plants. The choice of species for planting may need to be initially restricted to hardy species followed by the inclusion of more sensitive species at a later date. A soil assessment is necessary to determine the stability of the site and sensitivity to erosion, and will also influence the selection of plants.

Describe the native vegetation on the site

Describe existing plant community(ies) in terms of broad type and structure e.g. rainforest, tall sclerophyll forest and, where possible, by its Regional Ecosystem (RE) classification. If minimal native vegetation remains, describe the pre-existing plant community. (This may be determined by identifying nearby natural areas and/or by utilising the Queensland Herbarium Pre-clearing Regional Ecosystem mapping as a guide). Identify any threatened species listed under the *Nature Conservation Act 1992* or the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*. Identify the presence and location of otherwise significant plants such as locally uncommon species, hollow bearing trees and important feed resources, such as confirmed glossy black-cockatoo feed trees. Provide a species list and where needed an accurate tree survey.

The following should be considered when assessing existing vegetation communities:

a. Is the structure of the existing native vegetation on the site typical of its forest type? For instance, does subtropical rainforest remnant on the site have a dense and thick canopy with trees closely spaced? Does it have native plants in the understorey, a mid-layer, lower canopy and upper canopy? Is there evidence of regenerating plants and seedlings at ground level?

b. Describe the overall health of the native vegetation. Do the native plants appear healthy, maybe with flowers and fruits or is there evidence of die-back in the branches? Is the canopy damaged or sparse?
c. Are there indications of any age-classes under-represented e.g. few or no seedlings at ground level? Is the shrub layer or canopy layer absent or sparse?
d. Is there evidence of a healthy soil micro-climate, such as leaf litter, fallen branches, logs and rocks or is the ground relatively bare and/or compacted? Do you think that native seeds may be stored in the soil?
e. Is there a healthy and intact native plant community close or adjacent to the site?

Describe the weeds on the site

What weed species occur on site? Where do they occur?

- In the canopy?
- In the mid-layer?
- On the ground layer?

How do these weeds threaten native plants e.g. vine weeds such as madeira vine, can smother supporting trees, preventing flowering and fruiting. The weight of weed vines also causes branches to break. Dense groundcover weeds, such as trad aka wandering jew (*Tradescantia albiflora*), inhibit the germination of native seeds.

How will the structure be affected if you remove all the weeds at once? For instance, wholesale removal of all canopy woody weeds may damage smaller native plants by sudden exposure to sun, wind and light. Wholesale removal of all weeds at the ground layer may cause soil erosion.

What are the probable causes and sources of the main weed problems e.g. edge effect, birds, animals, stormwater run-off, nearby houses and gardens.

- Do native fauna rely on specific weeds on the site?
- What measures will be taken to protect the fauna?
- Are there more weeds than natives or vice versa?

Identify any other problems and constraints and indicate how they impact on the native vegetation and/or native regeneration

For example, is the area isolated from other native plant communities? If so, it will be more difficult for native seeds to migrate onto the site. What is the context of the site? For example, if there are weeds immediately upstream of a site then there will be a source of reinvasion. Are native species reproducing (e.g. male and female plants present)?

Describe the fauna that use the site

Provide a fauna species list. Are there fauna that will aid in the dispersal of native seeds (and weeds!)? Does the site fall within a continuous vegetated corridor or a stepping-stone corridor?

What is your estimate of the potential for natural regeneration of the native plant community on site?

Based on all of the above, from seeds stored in the soil or via seeds migrating onto the site by birds, flying foxes, wind, water and recovery from existing biomass, such as trees re-sprouting after being covered in vines, or plants re-sprouting from root stock.

Will the native plants return to the site?

- If only preventative measures were undertaken, such as fencing?
- If weed removal, minor soil disturbance, use of fire and/or fencing was undertaken?
- Only if native species were introduced through planting?

- Only if native species suited to permanently changed site conditions, were introduced through planting?
- If yes, have you considered germination periods of local species, inhibitors of germination (such as drought or cold winters), and time taken for weedy biomass controlled to break down.

What approach will you rely on:

a. Natural Regeneration?
b. Assisted NaturalRegeneration?
c. Reconstruction?
d. Fabrication?
e. Combination?

The information collected will provide the basis for the Ecological Restoration Plan which will guide the project.

4.2 PREPARING A BUDGET

Preparing a budget for a restoration project during the planning phase will help to prioritise works. The cost of restoration is highly variable. For example, fencing a small patch of vine forest is vastly different from Fabrication of 2 hectares of wetland in an urban area. The Landscape Queensland Industries Costing Guide provides some guidance on the cost of fencing, mulch and plant supply, but it is best to cost jobs on an individual basis based on the requirements of the Ecological Restoration Plan.

4.3 ASSESSMENT OF REFERENCE ECOSYSTEM

As noted in the Guidelines, a reference ecosystem should be located in close proximity to the restoration site, have similar abiotic features and preferably be in good condition with low levels of disturbance. Once one or more suitable reference sites are chosen, information should then be collected pertaining to the floristic make up of the community and its structure. This will generally include at a minimum, the dominant species and their relative abundance within the community. The amount of information required will depend on the condition of the restoration site.

A useful means of attaining this data is by following the methodology described by Neldner *et al.*, (2005) for undertaking 'secondary' site transects and by documenting site information using the 'Corveg' pro forma provided in the document. The full methodology is available at www.derm.qld.gov.au/register/p01418aa.pdf

4.4 FAUNA CONSIDERATIONS

Sections 4.6 and 5.4.9 of the Guidelines discuss the importance of integrating specific measures for fauna into ecological restoration projects. Refer to section 5.1.6 of the Manual for information regarding timing of works. Many fauna species have specific habitat requirements, including specific tree hollow requirements, niches on ground such as logs and branches or particular feed trees. Measures that can be undertaken to meet habitat requirements for fauna should be included in the ecological restoration project.

At a minimum the following should be considered with regard to fauna:

- Has provision been made for fauna movement opportunities across easements, tracks, utility corridors or major linear infrastructure such as roads and rail?;
- Has provision been given to the installation and maintenance of nest boxes, and the range of fauna likely to use the site?;
- Has the timing of on ground works in the vicinity of significant fauna habitat (raptor nests, flying fox camps) to avoid disturbance to breeding, been considered?;

- Are there particular species for which special consideration must be made in terms of provision of specialised food resources (e.g. koala food trees, butterfly host species) or cover (e.g. lomandra at water edges to limit accessibility by toads)?;
- Do native bee hives require translocation or does the site represent a suitable location into which hives can be introduced?;
- Is there a need to introduce complicated ground layer habitat (e.g. hollow logs, branches) for fauna such as reptiles?; and
- Is there a need to stage weed removal or alter the weed control techniques if weeds are currently forming a significant portion of fauna habitat?

5 ECOLOGICAL RESTORATION TECHNIQUES

"The key to comprehensive weed control work on a site is to work systematically."

5.1 STARTING WORK ON THE SITE

Even with the simplest of ecological restoration projects there are numerous decisions and tasks to consider. Checklists are a useful way of making sure important steps are not forgotten. Similarly safety is paramount on all projects and it is required to undertake risk assessments for individual sites. Examples of project checklists and site risk assessments are provided in Appendix A.

5.1.1 GETTING TO KNOW THE SITE

If possible, visit the site during all weather conditions, at different times of the year, and different times of the day to gain a thorough knowledge of the site, the weeds present and fauna utilising the habitat. It is ideal to do this before commencing implementation of work but multiple visits are not always practicable. Recognise that the site may change considerably as a response to actions taken during restoration works and that this will require a flexible approach to ongoing management.

5.1.2 MANAGEMENT ZONES

When work commences on a site, you will be required to follow the directions of the Ecological Restoration Plan. Mapping of the site will have divided the work area into suggested management zones (see Figure 1). The zones are based on topographical features, such as tracks, fences, ridges, creeks and/or drainage lines and other considerations such as the aims of the project, access, type and extent of weeds. These management zones will be the first point of reference in determining where to commence work and how work will progress.

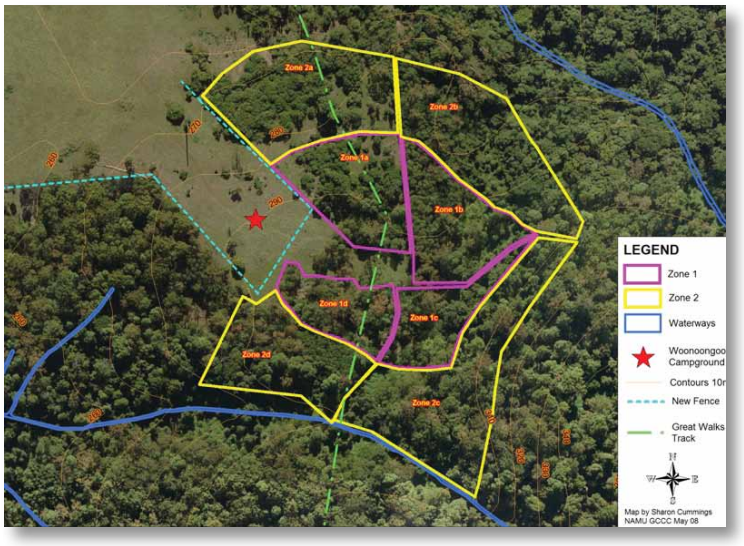


Figure 1 – Site showing management zones

As the bush regeneration team will be regularly at the site, the observations made will contribute greatly to decisions that are made as the project progresses.

5.1.3 WHERE TO BEGIN ON A NATURAL REGENERATION/ASSISTED REGENERATION SITES?

There has been much debate over whether it is better to commence work in the most intact section or the most highly degraded section of the site. The arguments for and against each of these positions are briefly presented as follows:

Work from area of intact native vegetation towards highly-degraded area

Reduces the risk of opening up the work site too quickly to additional weed invasion and ensures that follow-up requirements will be minimal because the established vegetation is fairly robust. However, this technique may not result in substantial improvements being made to the function and structure of the site overall, as the initial work focuses on maintenance-type activities, rather than the disturbance-creating primary work which can quickly kick-start the regeneration process.

Work from highly degraded area towards area of intact native vegetation

Invasive weed species are controlled immediately, preventing the risk of spread into the more established areas of vegetation. The approach can address impacts that may be increasing that which would otherwise become more costly if not addressed. This can lead to fast changes in the vegetation composition of a site, as weeds are controlled and native plants regenerate. Well timed follow-up is required. Large amounts of disturbance may adversely affect some fauna species, and on steeply sloping sites there is a risk that erosion problems may be created. On a site with good *regeneration capacity* and skilled bush regenerators, the native species will quickly establish, with little long-term negative effects.

Clearly, each individual site needs to be assessed and decisions made about how the work will be undertaken. The restoration worker will be required to make decisions about the practical techniques to be implemented at the worksite and be guided by the Ecological Restoration Plan. Although it may appear daunting, it is this requisite flexibility of approach to varying situations that makes ecological restoration a field of never-ending interest. Examples of different weed control techniques are provided in Section 5.3.

5.1.4 PRIORITISING WORK

The prioritisation of ecological restoration works and other activities such as fencing or rubbish removal will be identified during site assessment and detailed in the Ecological Restoration Plan. The prioritisation of works will also need to consider the budget and timeframe available, as well as the presence of declared pest species.

Prior to commencement of on-ground works the site must be secure from degrading impacts such as grazing and trampling by stock, unauthorised vehicle access, erosion and rubbish.

Some factors may require immediate attention due to the potential for adverse effects. These situations may include:

- The presence of highly invasive weeds in a position which may result in the weed dispersing further into natural areas e.g. madeira vine growing in the upper section of the site.;
- The presence of weeds that have a long-term effect on ecological communities such as vines;
- Flammable vegetative material accumulating in an area where fire is not desirable e.g. lantana (*Lantana camara*), molasses grass (*Melinis minutiflora*) or dead vine thickets in an ecotone area between sclerophyll forest and rainforest or adjacent to housing;
- Dense exotic vines smothering canopy trees; and/or
- Easy access by 4WD vehicles, motorbikes and pedestrians into areas which are not suitable for public access due to the risk of damage to the vegetation may require the erection of fences, bollards and other physical barriers.

The management zones are then worked sequentially so that all weeds are controlled in a **systematic** and **comprehensive** manner.

5.1.5 PRIMARY WORK, FOLLOW-UP AND MAINTENANCE

The carrying out of effective and comprehensive restoration works in a natural area requires that the site be revisited regularly, preferably over a period of at least two to five years, to achieve the best possible ecological outcomes. The intervals between working on the site varies, depending on the site attributes, the species of weeds being treated, regeneration capacity and the seasons.

As the project progresses, the specific types of activities that are required to be carried out will change. These activities fall into three broad areas which differ according to the type of work which is carried out, the time since commencing works and the progress of the restoration process.

Primary work

The initial works within the site or a section of the site will commonly involve a sequence of activities such as the control of all groundcover weeds, woody weeds in the understorey and exotic vines prior to the control of weed trees. Primary work has the effect of creating a large degree of disturbance which will stimulate the germination of native and exotic species. Therefore, continuing works should be scheduled shortly after the initial visit to allow for timely control of the newly regenerating weeds. Highly invasive weeds such as madeira vine should be treated as a priority during primary work in order to avoid invasion of newly disturbed areas. Techniques used during primary work commonly involve spot spray, cut-scrape-paint, cut-paint, scrape-paint, roll-hang and over spraying. Refer to section 5.3.3 for herbicide control techniques.

Some weeds will need to be treated in steps e.g. where areas of weed is being used by nesting birds or where the staged removal of canopy weed trees is required. At the end of primary work, the zone will have been comprehensively and systematically worked.

Note that on a larger site which is broken up into a number of management zones, work will progress at differing stages in each zone. Therefore, a visit by the restoration team to the site may involve some primary work (e.g. using the cut-scrape-paint technique on mature cat's claw creeper (*Macfadyena unguis-cati*) in the canopy) in one zone, while follow-up (e.g. spot-spraying cat's claw creeper seedlings and resprouts) will need to continue in previously worked zones.

Follow-up

At intervals, which will vary according to the type of weed impacting the site and growing conditions, follow-up work will be necessary. This generally involves the spot-spraying of newly germinating weeds and resprouting sections of woody weeds and vines. It is at this stage that observational visits should be made to the site to determine what progress the vegetation is making, and decide when to implement further follow-up work. A site that receives badly-timed, too frequent or too little follow-up will rapidly experience setbacks, as weed propagules will quickly become established in the newly disturbed areas. Germinating native seedlings may be swamped by weeds or damaged by inexperienced operators thereby exhausting the seedbank. Unless adequate follow-up can be ensured when planning restoration works, there is little point in commencing primary work, as time and resources are consumed with no substantial gain achieved.

Maintenance

By the maintenance stage, the vegetation community is at a point where native plant species are germinating and establishing, and canopy formation is occurring. By this stage, weed density is starting to decrease as the native plants which have been encouraged during the previous restoration works are able to out-compete the weeds. One of the fundamental principles of ecological restoration is that it attempts to create or re-establish an ecosystem that is self-sustaining. Therefore, it is the underlying goal that maintenance will eventually be decreased to a minimum. While this is not always possible, due to factors such as the continual reintroduction of weed propagules to the site from nearby residential areas; unfavourable seasons or weather event; persistent weed species; or global influences such as the enhanced greenhouse effect, it should always be strived for.

Where possible at the planning stage, arrange the management zones in a sequence that requires restoration workers to walk past previously worked areas approaching the next zone to undertake primary work. This is an ideal technique for keeping track of changes that are occurring on the site, but not always feasible. Extra time does not need to be allowed for site inspection, as large amounts of the worked area will be observed as workers move towards the next primary work area. Avoid making the most remote corner of your site the first zone to be worked (unless there is a priority situation such as a highly invasive or declared weed), as chances are, you will not get back there for many months, by which time the opportunity to carry out timely follow-up works may have passed.

Although it is recommended to complete primary work in one zone before commencing work in a second zone, there may be site constraints or weather conditions which require more than one zone to be worked at the same time. As the management zones move through to maintenance and the time required in each zone is significantly reduced, the adjacent zones can be consolidated into a larger work area.

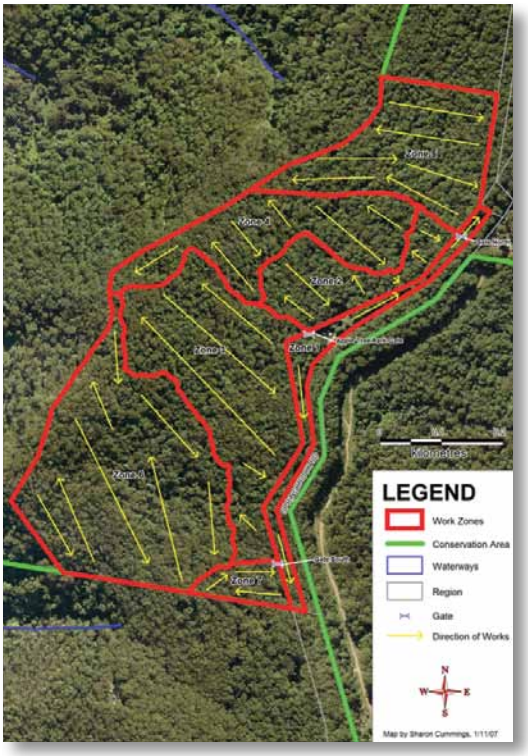


Figure 2 – Direction of work

Systematic and comprehensive

The key to comprehensive weed-control work on a site is to work systematically (see Figure 2). It is of vital importance to cover every square metre of the work site (conditions allowing). Failure to cover the ground comprehensively means that weeds are missed which, as a worst case scenario, results in further flowering and fruiting of the weed, slowing down the site's progress. At the very least, it will mean that the same ground will have to be covered again to treat the missed weeds, wasting time and resources. The two key words to remember – **systematic** and **comprehensive**!

5.1.6 TIMING OF WORKS

External factors such as weather conditions (drought, frost and flooding) and seasonal growth habits of plants can greatly influence timing of restoration works. These factors must be taken into consideration when planning how to approach a site. Some examples include:

- Glory lily can only be spot-sprayed during the summer or early autumn as it dies back to an underground tuber over the winter;
- Planting should be undertaken in the wet season (summer and autumn in SEQ) to allow the best chance for the tubestock to establish successfully without requiring frequent watering;

- Following fire germination of weed seedlings in some vegetation communities is likely to be stimulated, necessitating a spot-spray within one to two months;
- Drought conditions may slow the growth of both native and weed species, resulting in fewer visits being required to a site in order to keep it maintained;
- Weeds that are in a stressed condition due to drought are less susceptible to herbicide uptake and it may not be possible to obtain a good result if they are treated at such times; and
- Warm weather or a rainy spell will trigger weed germination and growth, requiring more frequent visits to a site.

5.1.7 WORKING AS A TEAM

Usually restoration work is undertaken by a group of people working together. As such, a description is given here on how a team undertaking restoration work can operate effectively together.

Work usually commences at an easily identifiable landmark e.g. a track, road-edge or simply at the edge of the vegetation remnant. The direction of work will depend on factors such as the size of the management zone and the terrain. A key aspect in working together effectively to cover the entire work site systematically and comprehensively, is working in lines (see Figure 3). Using this technique ensures that every square metre of the site is treated for weeds. It should be employed during all phases of work, from primary work such as cut-scrape-painting woody weeds in the understorey or follow-up work and maintenance such as spot-spraying. It works as follows:

- The first team member commences work using an edge as a guide, moving from one end of the work site or zone to the other, with the width of the worked area depending on the density of the vegetation being worked, and the density and type of weed. An individual's worked area will vary depending on these factors.
- The second team member positions themselves so that they are slightly behind and to the side of the first team member, approximately 1-3m from the edge of the line. This allows them to observe the area that has already been worked, and carry out their weed control so that the two worked areas meet. Again, the width of the second team member's worked area will vary according to the vegetation, but they should ensure that they do not fall more than 5-10m behind the leader, so that the cohesiveness of the team is maintained.
- Any remaining members of the team arrange themselves in a similar fashion, always ensuring that the line remains staggered and that all team members remain in verbal contact with each other. Teams of three or four people usually function best, however larger teams can also work effectively together, providing that good communication is emphasised. The team member who is on the outside edge of the run (red in the Figure 3 diagram) may find it useful to tag their line (using coloured flagging tape) as they work through the site, as it will be their responsibility to follow the line back once the far edge of the zone has been reached, and the team has turned in order to continue working through the site systematically.

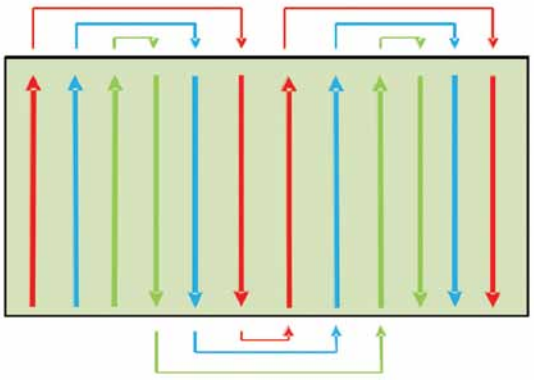


Figure 3 - Team working in lines

- Because the line of workers is staggered, each individual only has to concern their self with making sure that one edge of their worked area meets up with that of their co-workers, as the worker to their other side is required to maintain the staggered formation, thus ensuring that no gaps in the worked area are left.

Walking the line

- It can be beneficial to try to keep the lines fairly straight, if the terrain allows, in order to facilitate the movement of workers through the site without becoming disoriented, and to avoid confusion. This may mean that in a relatively weed-free area it will be necessary for workers to walk straight through a section of the site. It is important to avoid the temptation to zig-zag from side to side in an attempt to "chase weeds", as this will make the line crooked which is difficult for other workers to follow.

Clearly, communication skills are an essential aspect of working effectively as a team. Examples of good communication that facilitates the smooth operation of the team are:

> *"I have to veer off my line to get around this fallen tree, but you'll be right to maintain your line as I will soon move back to mine."*

It may also be necessary, especially when workers are new to the idea of working systematically in lines, to prompt them to stay in formation. For example:

> *"You're starting to move in front of me. You need to drop back behind me a bit."*
> (in order to maintain staggered line)

Working as a team in lines is an acquired skill and it will take time and practice in order to learn how to carry it out proficiently. However, do persist! The advantages of working in lines include:

- Covering the site systematically and comprehensively, to enable the most efficient implementation of restoration works;
- Building up observations of site as different team members will observe different aspects;
- Effective use of the time and resources that have been allocated to the site; and
- Building team strength and cohesiveness.

Safety Caution:

When working on a steeply sloping site it is advisable to work across the contour rather than up and down the slope, as this is physically less demanding. However, it is especially important for the restoration workers to stay markedly staggered in this case, due to the high risk of rocks being dislodged.

5.1.8 SITE HYGIENE

Where there are known or suspected diseases such as Phytophthora, Myrtle Rust or Chrytid fungus, protocols must be put in place to prevent spread on or off site. These may include wash down areas, shoe disinfectant trays, tool disinfectant and adherence to clearly defined access tracks. These measures are only effective if team leaders and members have a consistent commitment to following protocols that sometimes seem onerous at the end of a long days work. The most recent information regarding disease control, including declarations and quarantine zones, must be made available to all workers. The Australian Government invasive species webpage provides information about invasive diseases, fungi and parasites in Australia that affect native species, available at http://www.environment.gov.au/biodiversity

5.2 SOME PRACTICAL TIPS

5.2.1 TARGET WEEDING

A general principle of ecological restoration is to comprehensively and systematically control all weeds. This systematic approach reduces the risk of weed recolonisation, potentially by a more invasive or difficult to control weed. However, in some circumstances it may be necessary to undertake targeted weed control, i.e. concentrate on one weed species.

Targeted weeding is the control of an identified weed in a certain area (as identified in site assessment and detailed in the Plan).

Examples of circumstances where target weeding is undertaken are:

- The presence of Class 1 or 2 declared plants or an isolated patch of a highly invasive, dominating or difficult to control weed such as madeira vine or cat's claw creeper;
- The presence of weeds that have potential to transform the vegetation community rapidly, such as aggressive vines in the canopy;
- Weeds with seasonal susceptibility must be treated while they're actively growing e.g. Glory Lily; or
- There are limited funds for the work.

Note that no herbicides are registered for use on all weeds, therefore you may need to group weeds according to the herbicide and target these together.

5.2.2 MANAGEMENT OF NATIVE VINES

Native vines can be a natural part in all communities. Where disturbance has occurred, plants including both weeds and natives, may rapidly colonise the area of disturbance. Native vines may grow vigorously in disturbed areas or along a remnant edge, where light and nutrients are freely available. The vines may out-compete and smother regenerating native trees and shrubs or smother and break canopy trees eventually causing damage to the forest structure.

These native vines also provide habitat (shelter and food source) for native fauna or protect the forest edge from damaging winds or excessive exposure to light.

In situations where native vines are damaging canopy trees or smothering natural regeneration control should be considered. It is advisable to consult an experienced bush regenerator for advice prior to commencing control.

Control includes the selective cutting back of the more vigorous vines that are damaging the canopy (cut at head height and at the ground and leave in tree to die) or cutting vines away from the plant where they are smothering smaller trees and shrubs. Avoid cutting vines when flowering or fruiting.

Vine thickets may require pruning to facilitate the easy movement of restoration workers through the site. This is especially important when the site will continue to be worked over several years, requiring access to all areas with knapsacks for efficient follow-up and maintenance work.

5.2.3 WEEDS AS HABITAT FOR FAUNA

In the absence of native vegetation, many species of weeds are utilised by birds, reptiles, mammals and insects for shelter, nesting sites, food and roosting. For example:

- Both the flowers and fruit of lantana are attractive to many birds and butterflies;
- Thickets of lantana provide good shelter for nesting and protection from predators;
- Camphor laurel is an important alternative food source for birds and bats in areas where sub-tropical rainforest has diminished; and
- Thick exotic grasses such as South African pigeon grass (*Setaria sphacelata*) are utilized by wren and finches for feeding and nesting.

These weeds are best contolled incrementally, allowing time for the creation of new habitat to occur following restoration activities, so that adverse effects on fauna are minimised.

Large woody weeds such as camphor laurel should be treated by stem injection (once understorey weeds have been controlled and the area stabilised) and allowed to die *in situ*, provided there is no risk to humans or infrastructure from falling limbs. The dead stags are ideal perches for birds that prefer to observe their surroundings from an elevated position.

Fallen trees and vegetative litter such as decaying weed material all create habitat. Dead stags often contain hollows used by wildlife. Ecological restoration is all about how an ecosystem works, and it is irrelevant if the site appears untidy to the uninformed observer. A complicated structure can be beneficial, as a range of micro-niches are created which promotes the establishment of vegetation and the presence of fauna.

5.2.4 WEEDS AS NATIVE NURSERIES

The presence of weeds can be helpful to the reinstatement of natural processes to the site. Here are some of the ways that this can occur:

- Lantana thickets attract birds and small mammals to feed on the fruit and to seek protection from predators. In doing so, they deposit the seeds of many other species in their droppings, which germinate freely once the lantana has been controlled, either by over-spraying or through manual removal. In ecological restoration, the richest germination of native seedlings is often seen in areas once dominated by lantana; and
- Wild tobacco (*Solanum mauritianum*) is a small tree which bears fruit that is attractive to birds, drawing them to a site in much the same way as lantana. In addition to this, the large, broad leaves of wild tobacco can help to create a temporary canopy or protective edge on a highly disturbed site. It may be beneficial to initially retain the wild tobacco in a regenerating rainforest, to encourage the reintroduction of native plant species, provide structure and to assist with the formation of canopy. Once the native species are regenerating the wild tobacco should be controlled as it will be competing with the native plants for resources.

5.2.5 SITE EXPANSION

On many sites, the native vegetation is often an isolated patch or patches, surrounded by exotic species such as pasture grasses. In these situations where space exists for expansion of the remnant, there is a simple technique that can be used to gradually increase the extent of the stand of restored vegetation. This technique can be used in most forest types. During the maintenance phase, regularly (depending on growing conditions) spray out a narrow strip of the weedy section beyond the boundary of the remnant. For example, when working in a rainforest remnant, spray one to two metres beyond the canopy dripline. The newly disturbed area will be receptive to dispersed seed and should regenerate readily. The expanding edge should be included as part of the maintenance program. By regularly repeating this procedure, expansion of the remnant can be achieved with minimal resources, often with the potential to eventually link up remnant vegetation.

5.2.6 AVOIDING DAMAGE TO NATIVE PLANTS

Ecological restoration is, to a large degree, about assisting the return of structure and function to an ecosystem by reducing impacts such as weeds and encouraging the establishment of native vegetation. However in the course of weed control work, it is possible that a small number of native plants, especially small recently germinated seedlings, could be impacted. For example, while spot-spraying weeds, it may be difficult to avoid herbicide affecting a few of the native seedlings. To avoid of-target damage where native seedlings are present, the site should be prepared prior to spraying by pulling back the weeds around the native seedlings. The selection of herbicide can also avoid damage to native seedlings e.g. avoid herbicides that are residual in the soil. Other precautions include, use of marker dye and correct spray nozzle, only spraying in calm dry weather and good plant identification skills. Ecological restoration attempts to reinstate a process, and if the weed control is done correctly many more native plants will germinate, survive and thrive during the restoration process. It is also important to state that haphazard spot-spraying by inexperienced operators is unacceptable.

Camphor laurel conversion

Restoration workers on the Far North Coast of NSW, faced with the daunting problem of large stands of camphor laurel forest replacing the original sub-tropical rainforest, have found that the weed is not as limiting to the goals of ecological restoration as first believed. In fact, when handled correctly, camphor laurel forest can be converted to sub-tropical rainforest within a surprisingly short period of time.

The key to this is the fact that camphor laurel mimics the structure of a native forest, encouraging birds and mammals to continue using the forest as habitat and as a food source, dispersing seeds of many plant species as they do so. Once the camphorlaurel has been treated, abundant regeneration of native plants, coupled with timely follow-up work to control camphor seedlings, results in the prompt re-establishment of a rainforest canopy. There is still debate over whether the staged removal of the camphor laurel (controlling a proportion of the trees at a site every year over a period of years) or patch removal (treating all trees at a site simultaneously) is the better method to use. However, as with any restoration work, the control technique chosen will depend on a myriad of factors, including density of the weed, time and resources available, scope for follow-up work, topography of the site, and the potential regeneration capacity of the native vegetation. To read further on camphor conversion, access John Kanowski and Carla P. Catterall's research at http://www.griffith.edu.au

5.2.7 SKILLS OF THE BUSH REGENERATOR

Identification skills – of both native and weed species

Take time to learn which species are present on your site. A good technique is to collect one unknown plant specimen each day in order to identify it that evening at home. There are many excellent plant references and field guides available. One of the most useful field guides is "Mangroves to Mountains" (Leiper *et al*., 2008) as it is very comprehensive containing photographs and brief descriptions of most of the commonly found native plant species in SEQ. Other simple plant identification keys available are:

- Interactive lucid keys such as Euclid, Environmental Weeds of Australia and Wattles: Acacias of Australia, Australian Tropical Rain Forest Plants;
- The [Online] Field guide to Common Saltmarsh Plants of Queensland;
- Rainforest Trees and Shrubs: A field guide to their identification (Harden, *et al*., 2006);
- Rainforest Climbing Plants: A field guide to their identification (Harden, *et al*., 2006); and
- Plants of the Forest Floor - a guide to small native plants of subtropical eastern Australia (Watsford, 2008).

If unsure of the correct identification, check against a site species list, consult with a competent botanist, or send the specimen to the Queensland Herbarium. You may also find it useful to create your own personal herbarium, by pressing and drying the specimens you collect, labeling them correctly, and storing them for future reference. It is important to have the ability to identify both native and exotic species at differing growth stages, from early seedling to mature plants.

Knowledge of different techniques and when to use them

These skills, in addition to others required by bush regenerators are summarised below (adapted from Byron Shire Council, 2010):

- Understanding of ecological processes as the community moves from a disturbed to a more stable state;
- The importance of vegetation for fauna habitat;
- The capacity to consider a site's ecosystem resilience and expected response to weed control (negative or positive) and of the steps that are required to sustain, improve or protect the ecological values of a site;
- Ability to determine which techniques are best used to undertake weed control or to mitigate other degrading processes that are threatening the value of a site;
- Understanding how remnant vegetation fits a broader landscape context and whether the site is a potentially useful stepping stone or corridor for mobile fauna such as birds or bats;
- Recognise and manage fauna habitat features including the potential short to medium term role of weeds as habitat;
- Ability to identify and manage, where possible, other factors affecting restoration, e.g. garden dumping, vandalism, stormwater, proximity to source of further weed invasion, informal track-making and lack of diverse native seed source;
- Observation, communication, navigation and First Aid skills;
- Ability to take account of seasonal variations on weed control outcomes and maintenance requirements or seasonal usage of habitat;
- Understanding that there must be a balance between primary and follow-up work, such that there are sufficient resources made available to follow up all primary work, before expanding the work area;
- Understanding optimum timing of follow-up weed control so as to maximise resources and minimise off-target damage;
- Understand the role of fire in managing the vegetation types at the site; and
- Chemical users certificate (ACDC Licence).

Knowledge of relevant legislation

This will include Occupational Health and Safety laws as well as environmental and heritage protection legislation. Bush regenerators must comply with the requirements of the *Workplace Health and Safety Act 2011* or, when working on Commonwealth lands, the Commonwealth's *Occupational Health and Safety (Commonwealth Employment) Act 1991*. Bush regeneration contractors should also obtain all relevant permits required under State and Commonwealth legislation (e.g. *Nature Conservation Act 1992, Fisheries Act 1994*, *Vegetation Management Act 1999*, *Land Protection (Pest and Stock Route Management) Act 2002)*. Contractors must also be aware of and adhere to cultural heritage protection obligations under the *Aboriginal Cultural Heritage Act 2003* and where chemicals are in use, the *Agricultural Chemicals Distribution Control Act 1966*.

To assist operators in demonstrating these matters have been considered as part of a project it is useful to document decisions. Example pro formas are provided in Appendix B.

5.3 WEED CONTROL TECHNIQUES

The next nine sections contain detailed information about various weed control techniques, including use of herbicide, manual, mechanical, and biological weed control. The technique chosen will depend on factors such as the nature of the weed to be treated, existing native vegetation, skills of the operator, budget available, accessibility of the site and difficulty of the terrain.

When selecting which technique to use, keep in mind that generally a combination of weed control methods will be required to effectively treat the weeds in a given situation. For example, when treating lantana it may be necessary to manually treat those plants which are growing into the canopy of trees by cutting the climbing branches off with loppers and treating the roots of the plants by cut-scrape-paint. Then, the large thickets of lantana that remain can be over-sprayed or large stems cut-scrape-paint with herbicide. Usually, the least labour intensive method will be the most cost-effective. It would be ineffectual to hand-pull large areas of lantana that are growing in a gap in a rainforest remnant when it can be easily and quickly over-sprayed. An integrated approach to weed control is recommended using a range of techniques.

5.3.1 MANUAL WEED CONTROL

Manual weed control involves either hand-removal or chipping/grubbing of weeds using a hand tool such as a hoe or knife.

Hand-removal of weeds is only suitable in limited situations, such as:

- It is appropriate to hand-pull weeds, including soft annuals, when they are growing closely around a threatened plant species, if there is a risk that the use of herbicide might adversely affect the threatened species;
- Riparian areas, where vulnerable aquatic fauna may be present, or where the water is used for human consumption, may not permit the use of herbicide spray;
- If there is only very sparse weed present (e.g. a few scattered grasses in a eucalypt forest) then it is just as efficient to hand-pull or crown these weeds as to spray them;
- In sandy or loose soils, smaller specimens of woody weeds may be easily hand-pulled with the root intact; and/or
- Following primary work, where disturbance of the ground has resulted in a rich germination of both weeds and native species growing closely together, it may be necessary to hand-weed around the juvenile native plants prior to spot-spraying.

Apart from these circumstances, the use of herbicide is preferable to hand-removal of weeds, as it is the most effective use of time and resources , reduces soil disturbance, and achieves equally good results. In addition to this, there are many circumstances in which the manual control of weeds is unsuccessful e.g. roots may be snapped off and left in the ground to reshoot; and madeira vine, when cut and left untreated in the canopy is likely to drop its tubers over a prolonged time, with detrimental results.

Another aspect of manual weed control is the bagging of weed seed heads and madeira vine tuberlings for removal from the restoration site. When doing this it is necessary to assess the advantages and disadvantages of this action. Is the time taken to gather up the seeds and tubers, bag them, remove them from the site and dispose of them going to outweigh the time that will be necessary to control the weeds if they are allowed to remain on site to germinate? Your decision will depend on factors such as:

- The quantities of seed or tubers that are present; and
- The longevity of the weed seed e.g. Easter cassia seeds can remain viable in the soil for at least a decade. If you suspect that maintenance of the restoration site will not extend for that period of time, removal of the pods containing seeds is recommended.

Crowning is a particular method of manual removal suitable for species such as ground asparagus (*Asparagus aethiopicus*) and grasses (isolated plants or small patches), and other weeds that have their growing points below the surface of the ground. Grasp the leaves or stems and hold them tightly so that the base of the plant is visible. Plants with long stems (such as ground asparagus) should be cut back first. Insert a sturdy knife close to the base of the plant at a slight angle, with the tip well under the root system. Cut through the roots close to the base. Depending on the size of the plant, two or more cuts may be needed to sever all of the roots. Lift the plant from the ground and check that the base of the plant, where the roots begin, is completely removed. Suspend the plant above the ground (e.g. in a nearby tree) to ensure that resprouting does not occur.

Figure 4 - Crowning

5.3.2 SELECTING A HERBICIDE

5.3.2.1 LEGAL CONSIDERATIONS

Herbicides are registered for use on specific weeds, within specific circumstances and must be used as per the directions on the label. In SEQ there is also an off-label permit which allows the herbicides listed to be used in the manner prescribed on the permit. If an operator is unsure of the best product to use or the current registration status of a given product ,information sources such as the Public Chemical Registration Information System available at http://services.apvma.gov.au/PubcrisWebClient/welcome.do and the DEEDI weeds website at http://www.dpi.qld.gov.au/ provide the most reliable and up to date information regarding herbicide use.

Material Safety Data Sheets (MSDS) also provide important information about individual chemicals.

5.3.2.2 OTHER CONSIDERATIONS

Herbicide control of weeds provides an effective and efficient method if used correctly. Herbicide selection needs to be carefully considered in light of the individual site characteristics, including weed species present and objectives of the Ecological Restoration Plan.

Because ecological restoration is undertaken in natural and sometimes sensitive environments, it is desirable to use chemicals with minimal adverse environmental impacts. Frequently ecological practitioners utilise glyphosate and metsulfuron methyl, although several other herbicides are utilised for controlling weeds. Whilst some of these herbicides can have additional impacts (e.g. impacts on aquatic organisms) there are occasions where their effectiveness warrants their use. Consideration must also be given to whether herbicide application is undertaken for the purposes of weed control of declared or highly invasive species (i.e. the specific purpose is the removal of the weed) which differs from ecological restoration, whereby the aim is to replace exotic species with native species. Some other chemicals utilised for weed control include Fluroxypyr, 2,4-D amine and 2,2-DPA.

Herbicides can be broadly categorised as:

- Selective - for example dicot-selective herbicides that target broadleaf weeds or monocot-selective herbicides that target grasses;
- Non-selective - which treat a broad range of weeds;
- Systemic herbicides - that are translocated through the tissues of the plant;

- **Contact herbicides** - where the damage occurs rapidly at the point of application;
- **Pre-emergent herbicides** - aimed at preventing weed succession (for obvious reasons these do not feature highly in ecological restoration);
- **Post-emergent** - aimed at destroying seedlings or mature weeds;
- **Persistent herbicides** - that can ensure an extended suppression; or
- **Short-term herbicide**s - are rapidly degraded and as such have a very short-lived effect.

Herbicides are also classified by their mode of action e.g. metsulfuron is a Group B herbicide which inhibits amino acid synthesis within target weeds. This is important to know for management of weed resistance as weeds are prone to develop resistance to Group B herbicides, and it is recommended that they be used in rotation with herbicides which are effective on the same weed species but have different modes of action.

When selecting a herbicide, points to consider are:

- Do you need to use a selective herbicide to avoid damage to native species?;
- Does the site occur within restricted areas such as waterways?; and
- Timing of year is important for treatment of some weeds. Plants need to be actively growing for some herbicides to be effective.

To facilitate the effectiveness of herbicide application, various additives may be considered. Commonly used additives include:

- **Marker dye** – generally a red or blue dye used to indicate which areas of weed have already been sprayed therefore improving efficiency and safety. Use non rhodamine based marker dyes;
- **Surfactant** – ensures maximum contact between chemical droplet and the leaf;
- **Penetrant** – improves penetration from the outside to the inside of the leaf, so that herbicide is able to translocate better to other parts of the plant;
- **Oils** – improve the rain fastness, reduce spray drift, increase herbicide cover and reduce run off; and
- **pH buffer** – to prevent pH alteration to waterways.

Prior to using additives check the label and off-label permits (if relevant). Note that there are herbicide products that contain all these additives already, and may present a more cost-effective and kill-effective option.

Always wear the appropriate Personal Protective Equipment (PPE) in accordance with the herbicide label, such as safety glasses, impervious gloves and boots. Also, great care must be taken when spraying weeds to avoid spray drift. Spraying in still conditions limits the risk of drift, as does ensuring spray nozzles are frequently checked to maintain a large enough droplet size.

5.3.3 HERBICIDE CONTROL TECHNIQUES

A weed may be simply defined as a plant growing where it is not wanted. A weed does not necessarily have to be a plant that originates outside Australia. There are a number of Australian species that are weeds in SEQ such as the umbrella tree (*Schefflera actinophylla*) which is native to north Queensland, but is a significant environmental weed in South East Queensland. In this Manual we are primarily concerned with environmental weeds – those that readily invade and colonise bushland. Many declared plants (which tend to be weeds of agricultural or commercial importance) will also be found on restoration sites.

Classes of declared plants in Queensland, and the measures that are required to control them, are described in Table 2 (over page).

The Pest Management Plans prepared by local government will also identify weeds of significance within the relevant local government area.

Table 2. Classes of declared plants of Queensland Land Protection (Pest and Stock Route Management) Act 2002

CLASS	DESCRIPTION
1	A Class 1 pest is one that has the potential to become a very serious pest in Queensland in the future. We need to prevent the import, possession and sale of these species so that they can't escape to become pests. All landholders are required by law to keep their land free of Class 1 pests. It is a serious offence to introduce, keep or sell Class 1 pests without a permit.
2	A Class 2 pest is one that has already spread over substantial areas of Queensland, but its impact is so serious that we need to try and control it and avoid further spread onto properties that are still free of the pest. By law, all landholders must try to keep their land free of Class 2 pests and it is an offence to keep or sell these plants without a permit.
3	A Class 3 pest is one that is very common in Queensland but is having a serious impact on native bushland. Landholders can be required to control these pests if they live next to 'environmentally sensitive areas', such as national parks or reserves, but only if the reserve is still free of the pest. Class 3 pests cannot be sold.

The herbicide weed control techniques described below provide a range of proven methods that can be used on a restoration site. Details of which technique should be used for a particular plant or in a particular situation may be found in Appendix C.

5.3.3.1 CUT-SCRAPE-PAINT

Cut-scrape-paint is a modification of the cut-paint technique. Cut the stem of the plant close to the ground (approximately 1-2cm) ensuring that soil does not come in contact with the cut surface. The cut can be made at a slight angle in order to increase the surface area that is exposed to the chemical. Apply herbicide immediately to the cut stump using poison pot and brush or dripper bottle. Using a knife, scrape the sides of the stump thoroughly to expose the green tissue. Apply herbicide to the scraped stump. The chemical must be applied within 10 seconds of the cut or scrape being made in order for it to be fully effective. The depth of the scrape depends on the depth and thickness of the bark of the plant. For example, ochna (*Ochna serrulata*) and cherry guava (*Psidium cattleianum*) have a thin cambium layer a short distance under the surface and should only be scraped very lightly. Other plants such as umbrella trees and wild tobacco can be scraped more deeply. Note that, if when using this technique the stem of the plant is too thick to cut easily with loppers or hand saw, the plant is probably better suited to stem-injection.

Figure 5 – Cut-Scrape-Paint

5.3.3.2 CUT-PAINT

Cut the stem of the plant close to ground level. Apply herbicide to the cut stump using poison pot and brush or dripper bottle. This method is best suited to easy-to-treat weeds such as small-leaved privet (*Ligustrum sinense*), provided that the diameter of the stem at ground level is less than approximately three centimetres. If a glyphosate-/ metsulfuron methyl herbicide mix is being used in the poison pot, a greater range of weeds can be controlled using this method e.g. Easter cassia.

5.3.3.3 SCRAPE-PAINT

Figure 6 – Scrape-Paint

Scrape as much of the stem as possible (one side of the stem) using a knife and apply herbicide to the scrape. Leave a small section of the vine unscraped, and then twist the vine so that the next scrape is made on the opposite side of the stem to the preceding scrape. Continue along the length of the vine, scraping and painting as much of the stem as possible, with scraping to be concentrated along the thicker stems close to the root of the plant. This is the best method to use for madeira vine, as it allows the chemical to translocate to the underground storage organs and aerial tubers which may be hanging in large clusters above head height. This avoids the potential problem of tubers from cut stems left hanging in the trees from dropping to the ground and sprouting. When scraping madeira vine stems a deep scrape is advisable – scrape right through to the fibrous, stringy section of the stem, taking care not to sever the vine. This method is also suitable for treatment of ochna. Case Study 3 describes how this method was used successfully to control cat's claw creeper (*Macfadyena unguis-cati*).

5.3.3.4 OVER-SPRAYING

Figure 7 – Over-spraying

Over-spraying involves the use of knapsacks or power sprayers to treat large expanses of weed such as lantana thickets. The foliage must be covered with herbicide but not to the point of running off the plant. The dead plants remain in place and can be cut down at a later stage or left *in situ* to provide protection for emerging seedlings. Prior to over-spraying, any weeds that are growing closely around established native plants must be hand removed or treated by cut-scrape-paint. It may be necessary to cut access tracks so that all sections of the expanse of weed are easily reached by the operator. Tracks that are cut must take into account the distance that the chemical can be projected, which will depend on the equipment that is being used. Generally, power sprayers can project the chemical further than is possible with a knapsack, though power spraying is often not suitable on sites where native plants are present due to the likelihood of off-target damage. Native and exotic vines may take advantage of the dead frames and timely follow-up is necessary.

Over-spraying is advantageous as it leaves the dead plants intact to prevent erosion and over-exposure of large areas, protects native seedlings from herbivores such as wallabies, retains the structure and avoids trampling by humans. Leave the sprayed plants intact for as long as possible so that native seedlings can establish under the shelter provided.

Boom spraying is of limited application for most ecological restoration work, however, it may occasionally be useful when preparing large areas for planting (either Reconstruction or Fabrication).

5.3.3.5 SPLATTER GUN

This small gas-powered injector kit is fitted into a knapsack for easy carrying and delivers large droplets in a stream over the weed. The gun is used to deliver a concentrated herbicide (glyphosate or metsulfuron methyl) across large dense expanses of weed. The method is used for species such as lantana (ratio of 1:9 of glyphosate:water). Splatter gun involves spraying strips at one to two metre intervals over the thicket. The herbicide is then translocated throughout the entire plant. Because it is gas-powered, the splatter gun can project the herbicide long distances, reducing the number of access tracks that need to be cut prior to spraying in large or difficult to access sites. The method does not require the whole plant to be covered as in over-spray.

5.3.3.6 SPOT-SPRAYING

Figure 8 – Spot-spraying

A knapsack filled with an appropriate herbicide mix is used by the operator to selectively control environmental weeds. A keen eye and an ability to distinguish between the native and weed species likely to be present, especially at seedling stage, is essential. Marker dye is added to the chemical mix to allow the operator to see what has already been sprayed, thus covering the ground weeds comprehensively and thoroughly. Glyphosate and metsulfuron methyl are the main herbicides used for spot-spraying in ecological restoration, together with the addition of a penetrant and/or surfactant and marker dye. Dilution rates of chemical used in the knapsack will vary depending on the weed species present. See Appendix C for application rates for some of the more commonly found weeds.

5.3.3.7 ROLL-HANG

Vines such as mile-a-minute (*Ipomoea cairica*) which produce long stolons extending many metres along the surface of the ground, are suited to the roll-hang method. Locate the base of the plant and carefully pull up the runners and roll them up. The resulting roll of vine is then hung in the fork of a tree to dry out as if it is left on the ground it is likely to re-shoot. Where runners are climbing up into a tree they are cut off at head height prior to the runner being rolled up – there is no need to pull cut vines down from trees as this action is likely to damage the tree. The base of the vine is treated using the cut-scrape-paint method.

5.3.3.8 GOUGE-PAINT

This method applies to plant species that have a fleshy underground storage organ, such as the large tuber that is often found at the base of madeira vine. It is also particularly appropriate for the treatment of climbing asparagus (*Protasparagus plumosus*). If using this technique on climbing asparagus, first cut the stems that are growing into the canopy at head height and also at the base. The fleshy rhizome can then be gouged, or alternatively in the case of climbing asparagus, it may be struck several times firmly with the head of a pair of loppers, allowing the brown outer covering of the crown to peel away exposing the white fleshy inner section of the rhizome for application of herbicide. Gouge out sections of the fleshy base with a knife and apply herbicide using a paint pot and brush or dripper bottle within 10 seconds.

5.3.3.9 BASAL BARKING

This method involves mixing an oil-soluble herbicide in diesel/kerosene and painting or spraying the full circumference of the trunk or stem of the plant from ground level to a height of approximately 45cm. Basal bark application is suitable for thin-barked woody weeds including saplings, regrowth and multi-stemmed shrubs. The method will usually result in the mortality of difficult-to-control woody weeds at any time of the year, provided the bark is not wet or too thick to enable the herbicide to penetrate. The method should not be used in wet weather, adjacent to waterways or in areas where native trees and shrubs are located. The use should be restricted to situations where a weed is particularly difficult to control e.g. cherry guava and where other methods have been unsuccessful.

5.3.3.10 WICK WIPING

Wick wipers can be manually used with a sponge or wick applicator, attached to a container filled with herbicide or as an attachment towed by a tractor. The manual method can be used to selectively apply herbicide to the leaves of weeds growing in sensitive situations. The hand held container can leak and generally spot spraying would be recommended. The use of a tractor drawn wick wiper is used to control taller growing species such as introduced grasses and to encourage the growth of lower growing species. This method could be used in preparation for planting.

5.3.3.11 STEM-INJECTION

Large woody weeds such as camphor laurel, coral trees (*Erythrina* spp, Privet *Ligustrum* spp) and umbrella trees are generally treated by stem-injection. Holes are drilled at regular intervals around the base of the tree and exposed roots using a drill powered by either batteries or a generator. A tree injection syringe attached to a small capacity knapsack is used to fill the holes with the herbicide. Stem-injection of trees can also be undertaken using a hatchet to create cuts in a 'brickwork pattern' in trunks of trees for the application of herbicide (known as tree frilling). Frilling is more labour-intensive than drilling, especially where trees are multi-stemmed or where there is limited room to swing a hatchet. Whichever method is used, the greatest benefit of stem-injection is that the trees can be left standing *in situ* as they die, provided there is no risk to humans or infrastructure from falling limbs. This creates convenient roosts for birds and other animals, and prevents the formation of large amounts of debris on the ground and damage to understorey plants which would result if the trees were to be cut down using a chainsaw.

Figure 9 – Stem-injection

CASE STUDY 3

RESTORING RIPARIAN VEGETATION IMPACTED BY SEVERE CAT'S CLAW CREEPER - HURST FAMILY PARK, NERANG - GOLD COAST CITY COUNCIL

THE SITE

Hurst Family Park is a riparian zone 3.9km long with vegetation occurring on both sides of the creek and is approx. 17.2ha in size. Native vegetation is made up of five Regional Ecosystems including 12.3.1, endangered vine forest on alluvial plains; 12.3.7 (*Eucalyptus tereticornis*, *Melaleuca viminalis* and *Casuarina cunninghamiana*) along water courses and 12.3.11, which is listed as an 'of concern' tall woodland to tall open forest.

THE PROBLEM

Cat's claw creeper (*Macfadyena unguis-cati*) present at all layers of the forest with heavy vines starting to collapse mature river oak and vines severely impacting on many native plants in the mid and lower storeys. The thick carpets on the ground smothered populations of plants, altering habitat and preventing native plant regeneration. Numerous other weeds occurred at the site including madeira vine, Dutchman's pipe, camphor laurel, devil's fig, tobacco bush, Singapore daisy, trad and exotic grasses such as setaria. Cat's claw posed the biggest threat of all the weeds present.

Before

ACTIONS

Some primary works had been done by the Nerang River Keepers, the local community group, but it was decided they move sites to ensure their viability as psychological advances in the initial years are difficult on such a weed infested site. The group however assisted the restoration process by controlling some of the more mature cat's claw vines, freeing up the canopy and planting trees at the entrance of the park to assist with gaining more community support for the river.

Case Study 3 cont'd

Preparation of a restoration plan for the lower fresh water reaches of the Nerang River prior to an aerial survey for cat's claw creeper and madeira vine. Some zones were ear-marked for particular works identified by the community group but mostly work zones were designed to impact on the cat's claw and clumps of madeira vine while maximising the regeneration capacity of the site.

Works commenced in the upper reaches of the site and concentrated on the control of mature cats claw vines i.e. those impacting the canopy and mid-stratum. Where vines were climbing up trees into the canopy, they were cut at waist height, peeled off the tree and treated low to the ground using the CSP technique. The vine above the top cut is left to die over time.

Cat's claw was also cut off from existing native plants in the mid-storey at head height and then low to the ground using CSP to allow for easier maintenance and good visibility. It also reduced the ladder affect while maximising the regenerative capacity of each clump of vegetation i.e. birds and flying foxes are using these clumps for roosting and for food and at the same time deposit seed. Smaller vines were either cut off close to the ground or pulled away from smaller native plants (seedlings, ferns and some clumps of native ground cover) in preparation for spot-spraying.

Areas of native vegetation and areas with forest structure are joined up over time by workers continuing to spray out exotic groundcovers and seedlings to approximately 1m past the drip lines of plants and clumps of vegetation.

More open areas dominated by exotic grasses (mainly setaria) and less dense in cat's claw were considered to have a sound seed bank but to date have been retained as grass. In areas of good vegetation all weeds are controlled as part of the systematic approach and in this case were threatened first.

With each maintenance run the areas of native species are expanded and where the buffer of exotic vegetation is thin, are joined up. This approach is termed as assisted regeneration.

Other considerations such as not compromising the stability of the creek bank, retaining habitat, herbicide application (rates, variety of weeds, sensitive areas and safety) and the experience of workers has also influenced the approach.

RESULTS

To date 9.5 ha are under maintenance, all mature vines have been controlled and 180 contractor team days have been worked. Of the lower reaches of the Nerang River approximately 80% of the area owned by council is now under maintenance. It is anticipated that all areas i.e. more than 4km of vegetation on both sides of the river will be consolidated in the next 3-5 years.

After

(Case study and images courtesy of Jen Ford)

5.3.4 COMMERCIAL OPERATOR'S LICENCE

Employees and contractors applying pesticides in Queensland are obliged to have a Commercial Operator's Licence, (ACDC licence) issued under the *Agricultural Chemicals Distribution Control Act 1966*. In acquiring this licence, restoration workers will gain an understanding of issues relating to the use of chemicals in the following categories:

- Prepare and apply chemicals; and
- Transport, handle and store chemicals.

Whilst an ACDC Licence is not required by non-commercial operators, they are still bound by the Act.

5.3.5 CHEMICAL MIXING RATES

Herbicides and additives are generally mixed with water and the rate the herbicide is mixed is expressed as a ratio of herbicide to water – e.g. 1:100 would mean one part herbicide to 100 parts water. The higher the number used to describe the water component, the weaker the dilution. So 1:50 is a much stronger mix than 1:200. A mix of 1:1 (as used for cut-scrape-paint) would be equal parts of herbicide and water.

The advantage of using ratios means that calculations can be made for the correct dilution for any size spray unit (from a knapsack through to a power sprayer) to obtain the rate that you require.

When mixing a 10L knapsack for over-spraying or spot-spraying, the following quantities of herbicide would be added in order to obtain the correct dilution:

Table 3. Guide to equate herbicide volumes with ratios.

RATIO	QUANTITY OF HERBICIDE IN 10L WATER
1:50	200mL
1:100	100mL
1:200	50mL

Note, for products such as metsulfuron methyl that are granular substances, these dilution rates do not apply. Instead, they must be weighed (usually 1g to 1.5g is required for a 10L pack) and dissolved in water before adding to the knapsack.

The chemical application rates for some of the more commonly encountered environmental weeds are presented in Appendix C.

5.3.6 WEED CONTROL EQUIPMENT

Care must be taken to avoid transporting weed seeds and plant diseases from one restoration site to another via vehicles, tools, equipment and boots.

A vehicle washdown area, located at the works depot provides an adequate facility for hosing down vehicles to remove mud and sand (and the seeds that adhere).

To reduce the possibility of introducing plant diseases and weeds from one site to another the following measures should be applied between sites:

- Secateurs to be sharp and cleaned with methylated spirits; and
- Footwear to be cleaned of loose soil and preferably treated with bleach using a spray bottle or foot bath.

Take some time to consider this issue – you certainly don't want to be responsible for inadvertently introducing a serious environmental weed or disease into an area where it will cause a great deal of damage.

5.3.7 TOOLS USED IN ECOLOGICAL RESTORATION

Personal Protective Equipment (PPE)

Appropriate PPE should be worn during ecological restoration activities. The MSDS includes information about the most appropriate PPE when using specific herbicides.

Knapsack

A 15 litre knapsack spray unit is used for spot-spraying weeds close to the ground or over-spraying large expanses of weeds such as lantana. Usually an adjustable nozzle will need to be purchased separately as the fan-shaped nozzle that is supplied with the knapsack is not appropriate for spot-spraying in areas of natural vegetation. The nozzle can be adjusted to widen the flow of herbicide (to allow good coverage over soft annual weeds close to the ground) or narrow the flow of herbicide under high pressure (to project long distances over a large patch of lantana). When working in steep, slippery or otherwise hazardous terrain it is advisable to only-fill the knapsack to 10 litres.

Power sprayer

A power sprayer is a large volume spray tank (anywhere from 100L to 1500L), with a hose and spray nozzle attached and mounted on the tray of a work vehicle. Suitable for accomplishing large areas of over-spraying, the power sprayer is driven by a pump that either runs off the vehicle's battery or is petrol-fuelled. While use of the power sprayer is restricted to areas with vehicle access, the length of the hose (up to 200m) allows the operator to cover a large area of ground. Chemical mixing rates are the same as when using knapsacks. Only mix enough chemical for the task, as it is not advisable to store mixed chemical in the tank.

Splatter gun

A small, gas-powered knapsack is filled with a more concentrated herbicide mix than is used for spot-spraying and over-spraying.

Loppers

Used for cutting down small woody weeds and large vines, as well as to improve accessibility to all areas of a site by cutting tracks through weed thickets or through dense areas of smothering vines. Good quality, strong, light loppers are recommended.

Handsaw

A small folding saw which is used on trunks which are too large to cut with loppers.

Secateurs

Useful for cutting small woody stems and vines.

Figure 10 – Basic equipment needed for ecological restoration works

Knife

Used for scraping vines and the sides of cut stumps, as well as for crowning out. Ensure knife has a sturdy blade.

Poison pot and brush

A small chemical-resistant plastic container held in a metal frame with a carrying handle and a spike to allow it to be pushed into the ground. The poison pot is placed conveniently close to the weed that is being treated to reduce risk of chemical spillage. A paint brush (approximately 1.5cm wide) is dipped into the poison pot in order to apply herbicide to a freshly-made cut, gouge or scrape. Label the poison pot clearly as containing herbicide. Ensure that pot has a lid when not in use and for transportation.

Dripper bottle

A small bottle with a drip applicator tip can be adapted for herbicide application. Dripper bottles are convenient to carry in areas where minimal herbicide is required due to the sparseness of weed, or where steep and rocky terrain makes the carrying and placement of a poison pot difficult. The advantage of the dripper bottle is that it can be carried in a pouch on the tool belt and so does away with the need to constantly place and pick up a poison pot as you move through the site. A disadvantage is that the bottles can leak or drip causing off-target damage. Ensure the dripper bottle is labelled as containing herbicide.

Drill and tree injection syringe

Either a battery-operated cordless drill or a generator-powered drill are the most effective means of treating larger woody weeds. If using a battery-operated drill, at least four batteries will be required in order to allow a reasonable time for drilling. The lithium-ion batteries have a long useable life and are generally quick to recharge. When drilling, a tree injection syringe attached to a small capacity knapsack (2 or 5 litres) is used to apply herbicide to the drilled holes.

Tool belt

A series of leather or canvas pouches, attached to a belt and tied around the waist, is a convenient hands-free safe means of carrying tools through the work site. As well as holding a folding saw, knife, secateurs and dripper bottle, the tool belt can also be adapted to carry additional items such as a snake bandage or drinking water.

Purchase **good quality** equipment (See figure 10). Although the initial expense may seem prohibitive, these quality tools will help make the job easier, and will last for many years. In addition, replacement parts are more easily obtainable for reputable brands. Clean and service equipment regularly, lubricate any moving parts, and keep cutting edges sharp. A small outlay of time and money will ensure that tools are reliable and in good working order, allowing efficient performance of your task.

5.3.8 MECHANICAL WEED CONTROL

Mechanical weed control involves the use of powered equipment such as brushcutters, chainsaws, slashers or tritters. These methods are best used in situations where there is a large, uninterrupted stand of weeds, but it is feasible that equally good results can be obtained using less expensive techniques such as over-spraying and stem-injection. In addition, mechanical methods can only be used where the site is accessible by vehicles or machinery which require that the terrain be relatively flat. The use of bulldozers is generally not recommended in ecological restoration projects, particularly where they will result in soil compaction or inadvertent soil erosion.

Mechanical techniques include slashing, ripping, using powered tools and machinery. For example, it may be possible to slash lantana or thick exotic grasses prior to spraying the regrowth with an appropriate herbicide before planting. An example of a project that utilised mechanical control is described in Case Study 4.

No matter which machine is used on a site, the operator must be well informed about the task they are to perform. Preferably, operators would have had experience working on ecological restoration projects and understand the 'tread lightly' approach. If machine operators are not experienced in ecological restoration they must be informed of the optimum method and given sufficient guidance until they can operate the machinery in a way that minimises damage to the non-target plants.

Sensitive areas should be clearly protected through the use of fencing or flagging tape. Care must be taken not to spread weed seeds on machinery. Facilities should be available to allow the machinery to be washed down prior to it being moved to another natural area.

CASE STUDY 4

MECHANICAL CONTROL - WILSON'S SCRUB, D'AGUILAR NATIONAL PARK

BACKGROUND

Wilson's Scrub is a 20ha patch of rainforest within D'Aguilar National Park (DNP), formerly Brisbane Forest Park. Historical disturbance by logging and fire opened up gaps in the rainforest canopy, allowing the establishment of broad weedy patches dominated by lantana (*Lantana camara*). As the first in a series of restoration trials in DNP, stick-raking was implemented at Wilson's Scrub in 1997. This method involves physically removing lantana by means of a stick-rake mounted on the blade of a bulldozer.

IMPLEMENTATION

A 5ha gap choked with lantana was stick-raked using a D-65 Komatsu bulldozer in February 1997.

Following mechanical clearing, 100hrs of hand removal of lantana and other weeds by DNP staff, resource members and Brisbane Rainforest Action and Information Network (BRAIN) members was performed. The process of natural regeneration was monitored closely by BFP staff.

Large scale germination of pioneer species (including *Trema tomentosa, Homalanthus nutans*, *Solanum aviculare, Hibiscus heterophyllus* and *Rubus* sp.) and exotics (mainly Asteraceae species and lantana) was observed. A total of 42 species, consisting of 70% native species were recorded in 1998.

Most pioneer species were found to be native and natural regeneration was strongest near the gap edge. (The photo of dense *Trema tomentosa* to the right was taken in July 1999).

After 30 months, further sampling indicated that some pioneers (particularly *Sigesbeckia orientalis* and *Solanum aviculare*) had died off and been replaced by other pioneers and some secondary species (including *Acacia melanoxylon* and *Mallotus philippensis*). The growing canopy was providing means for recruitment of later secondary species such as *Cryptocarya triplinervis*.

In July 2010, 13 years after stick-raking and 10 years since any maintenance had been performed at the site, the site was revisited. Despite the return of lantana over much of the treated area, many of the secondary species previously observed were standing proud of the lantana shrub layer.

LESSON LEARNT

This mechanical method was shown to be an efficient and cost effective means of triggering successional regeneration in a large area of disturbed rainforest dominated by lantana. Initial monitoring indicated high recruitment and dominance by a diversity of native species. However, in the absence of ongoing maintenance dense lantana cover returned to the patch which has no doubt slowed the recovery of the area. Despite this, the method has enabled the establishment of a number of secondary species that are likely to inhibit the lantana and aid in ongoing succession.

(Images courtesy of Bruce Noble)

Case study compiled in conjunction with Department of Environment and Resource Management

5.3.9 BIOLOGICAL CONTROL OF WEEDS

Biological control (biocontrol) of weeds is generally used in conjunction with other weed control techniques because biocontrols on their own are insufficient to treat the weed adequately. The objective is to stress the plants, reduce their competitiveness, and prevent them from reproducing. Biocontrol should be used as part of Integrated Weed Management (IWM).

Biocontrols may be insects or pathogens, and in Queensland, Primary Industries and Fisheries (part of the Department of Employment, Economic Development and Innovation), is undertaking biological weed control for a number of weeds, including cat's claw creeper, lantana, mother of millions and madeira vine. Examples of Biological agents currently in use are listed below:

- Cat's claw creeper - a leaf-sucking tingid *Carvalhotingis visenda* and a leaf-tying moth *Hypocosmia pyrochroma* are currently used. A new leaf-mining buprestid beetle *Hylaeogena jurecki*, has been approved to be used in trials;
- Lantana – there are about 18 species that have been released including bugs, beetles, flies, moths and a fungus;
- Mother of millions – weevils *Osphilia tenuipes* and *Alcidodes sedi* have been studied in detail in the quarantine facility at the Alan Fletcher Research Station, while preliminary studies of a further two agents have been undertaken in South Africa. None of these insect species have yet been released;
- Madeira vine - testing of two agents, the leaf beetles *Plectonycha correntina* and *Phenrica* sp., has been undertaken in South Africa and Argentina respectively. Neither of these has yet been released in Queensland; and
- Water hyacinth - the water hyacinth Wweevil, *Neochetina bruchi* was first released in South East Queensland in 1990. Field testing of this weevil is still ongoing and it appears that *N.bruchi* is effective.

Biological control agents are chosen to selectively target just one host weed. The biocontrol is released at strategic infestation sites, which then spread to other infestations of the host weed.

As biological controls are required to be released to a selection of sites at once, the implementation of a biocontrol regime should be overseen by a experienced individual or authority.

More information on biological controls can be found at the Queensland Primary Industries and Fisheries website: http://www.dpi.qld.gov.au

Trial and error?

Listed are a wide variety of weed control techniques in this manual, including the use of herbicides, mechanical removal and biological control. The control methods described here are current best-practice, knowledge of which has been gained through many years of trial and observation by experienced restoration workers. However, experimentation may reveal new techniques. The best approach to controlling a weed or tackling a particular situation may not yet exist! Ecological restoration is a new industry and requires a flexible approach. Try out a new method or adapt an existing technique, based on your observations about the site that you are working on, your experiences with a particular weed or emerging knowledge from ecological research. Always ensure you are working within the limits of relevant legislation. Make careful note of what you trial and the outcome of your experiment. And make sure you share what you have found with others – we need you to contribute to the pool of knowledge that exists about ecological restoration so that we can all continue to make it better!

5.4 EROSION AND SEDIMENT CONTROL

Although erosion control is more frequently applied when using the Reconstruction or Fabrication approaches to ecological restoration, it also has a place in Assisted Natural Regeneration, for example stabilisation of old tracks by brush matting or placement of logs or rocks to slow or divert surface water.

Soil erosion and subsequent sediment transport and deposition can severely impact the environmental values of waterways. Uncontrolled erosion over a restoration site can ruin weeks of hard work, destroy plants and cost thousands of dollars in rectification works. Under the *Environmental Protection Act 1994* release of contaminants, including soil and mulch, is an offence. As such, controlling erosion and sedimentation should be considered throughout the planning and implementation of restoration projects. For large high-risk projects engaging an erosion and sediment control specialist should be considered.

It is important to be aware that restoration projects themselves can result in erosion and there are basic concepts that need to be implemented throughout a project such as minimising clearing, covering exposed soils and diversion of flows around exposed areas. Access tracks to and from a site often require robust erosion and sediment control.

Risk assessment

As a general concept, the risk of erosion increases with:

- Increased slope;
- Dispersive soils;
- Exposure of large areas of soil; and
- Concentrated flow paths.

If your restoration site includes one of these risk factors you should consider undertaking a specific erosion risk assessment and plan erosion and sediment control activities. On restoration sites where large scale ripping of soils is intended, the need for ripping needs to be assessed against the risk of erosion.

Perhaps the most difficult erosion to manage as part of ecological restoration projects is that occurring on the banks of waterways or gully/tunnel erosion on sodic soils. The latter requires a variety of approaches and may necessitate mechanical intervention (Alt *et al.*, 2009) and/or chemical intervention. Chemical intervention involves reducing the Exchangeable Sodium Percentage (ESP) and increasing the Calcium:Magnesium ratio of soils by the mechanical addition of calcium products such as gypsum (DTMR, 2010). The treatment of eroding banks of waterways requires further detailed explanation as provided in Section 8.

Many areas in SEQ contain dispersive and/or sodic soils which are easily washed away. When washed into waterways the clay particles will stay in suspension, resulting in significant impacts on waterway health.

The "Best Practice Erosion and Sediment Control" published by the International Erosion Control Association (2008), although largely focused on the construction industry, is a useful reference guide for assessing the erosion risk on any particular site. Individual councils may also have local erosion and sediment control guides that are more specific to the restoration process (for example the Sunshine Coast Regional Council has an excellent guide available at http://www.sunshinecoast.qld.gov.au).

Erosion Control

Controlling erosion is the most effective way of protecting the site and reducing the chance of erosion and environmental damage. Consideration for erosion control should include:

- Timing of works / high intensity storms and large rain events are characteristic of summer weather in SEQ. Avoiding these times of year can significantly reduce the risk of erosion impacting the project;
- Diversion of water / diverting excess water around the site can reduce the quantity and velocity of water flowing though the site. This minimises the risk of erosion on the site and avoids mixing of 'clean' diverted water with potentially 'dirty' run-off from the site;

- Reducing soil exposure / minimising clearing and immediate progressive re-establishment of vegetation will limit soil exposure. Weed removal should be undertaken in patches (i.e. limited area) during low-risk periods. Mulch and other ground covers can be used to protect soils, however suitable products must be used to ensure the mulch is not washed away. Note that thick fibrous matting, if not installed correctly, can allow water to flow under the mat causing high level of erosion; and
- Reducing water velocities / long, steep slopes will allow higher water velocity, thus increasing the risk of sheet and rill erosion. The use of diversion drains, check dams and berms parallel to the contours lines will reduce the velocities.

Commercially available products such as sediment fences, geotextiles, rock-filled gabions and jute mesh need to be installed and positioned properly. It is also important to use the correct device in each situation. For example, if you are trying to stabilise an area with a combination of jute mat and seeding, you would use a very open-weave grade of jute to allow germination and growth of seedlings. Rock gabions may be more suitable for severely eroded stream beds where the water velocity cannot be controlled. Jute must be pinned securely to the ground, maximising contact between the mat and the soil. Do not use plastic meshes, as wildlife may become caught in their fibres.

However, controlling erosion may be as simple as:

- Placement of rocks or logs (gathered from the site) to divert or slow a flow of water that is contributing to erosion;
- Planting bank stabilising species such as matrush (*Lomandra hystrix*); and
- Using organic mulches to stabilise the soil. Note; loose mulch should not be used in locations where there is a risk of them entering waterways. Mulch is considered to be a water contaminant under the *Environmental Protection Regulation 2008* (Schedule 9).

Sediment capture

Capturing sediment before it leaves the site can be expensive and challenging. It is preferable to control erosion in the first place. Sediment capture relies on slowing water flow so that sediment particles can fall out of suspension. Note that if the site contains dispersive soils sediment, capture can only be achieved by using sediment basins and flocculants. Slowing of water velocities can be achieved through various methods including those mentioned above as well as the use of sediment fencing. It is important to maintain sediment capture devices by removing sediment build-up regularly.

5.5 FIRE PRACTICES

Protection of life and property always remains the priority in considering use of fire. The SEQ Fire and Biodiversity Consortium (SEQFBC) provide information about balancing fire safety with ecological goals in the Individual Property Fire Management Planning Kit: Balancing Fire Safety with Conservation of Bushland Plants and Animals. The SEQFBC has also compiled a suite of resources which provide practical advice, including the Fire Monitoring Manual, which explains the link between land management, biodiversity and fire, and the Operational Fire Manual, which provides operational guidelines to help plan and conduct prescribed burns for either hazard reduction or ecological purposes. You should always seek expert input if you are contemplating a prescribed burn from your local rural fire agency, local government authority, Queensland Parks and Wildlife Service, or DERM.

Planned burns may only be carried out with the written approval (Permit to Light Fire) and co-operation of the Queensland Fire and Rescue Service. In urban or peri-urban areas, local government may also impose additional restrictions or conditions on the utilisation of burning practices.

In ecological restoration, burning is used primarily as a means of stimulating the regeneration of certain native plants and communities, although it can serve as a weed control technique to a certain extent. Obviously, in fire-adapted communities, the incorporation of fire must be considered as part of the overall management of the site. Fire used in combination with chemical and mechanical methods can be effective when these are undertaken prior to ignition and at regular intervals in the post burn period.

It is always best to burn in a mosaic pattern, in order to retain unburned patches which animals can move into, and which will act as a source of seed for plant regeneration and facilitate a range of age classes.

The frequency, intensity and season of burning will depend on the particular vegetation community that you are working in. The SEQ Fire and Biodiversity Consortium, in their document "Fire in Bushland Conservation", suggest the following fire frequencies:

Table 4. SEQ Fire and Biodiversity Consortium recommended fire frequencies.

VEGETATION TYPE	RANGE OF INTERVALS BETWEEN FIRES
Rainforest and vine scrubs	Exclude fire
Creekside vegetation	Exclude fire
Tall eucalypt forests	20 – 100 years
Open eucalypt forests and woodlands with a shrubby understorey	7 – 25 years
Open eucalypt forests and woodlands with a grassy understorey	3 – 6 years
Melaleuca forests	15 – 30 years
Coastal heath	7 – 20 years
Heaths of rocky areas	15 – 50 years

The Regional Ecosystem Description Database (Queensland Herbarium, 2009) also contains recommendations regarding fire regimes for individual regional ecosystems. (See http://www.derm.qld.gov.au)

Mimicking the affects of fire can assist in determining the most appropriate approach to ecological restoration to utilise on a site. For example, burn piles are designed to stimulate the germination of native seed. If burning an area is impractical, the use of smoke water can also mimic the affect of fire.

This is achieved because smoke contains a compound that can break the dormancy of some seed, or increase the germination of seeds which have low levels of germination otherwise. Smoke water (both liquid and granulated forms) is commercially available which assists in the germination of some species of native plants.

Case Study 5, demonstrates some of the results that can occur from using fire as a restoration tool.

CASE STUDY 5

FIRE AND RESTORATION, TREES ROAD CONSERVATION AREA - GOLD COAST CITY COUNCIL

THE SITE

Trees Road Conservation Area - 53.4 hectares - steep Regional Ecosystems 12.11.5a (*Eucalyptus carnea*, *E. tindaliae* woodland to open forest on metasediments) and 12.11.5k (*Eucalyptus fibrosa, Corymbia henryi* or *E. seeana* woodland to open forest on metasediments).

THE ISSUES

Housing located at the top of the north-facing slope. Weed on the upper slopes is mainly lantana and molasses grass, while the gullies are impacted by lantana and mistflower. White passionflower is scattered throughout the site. Both molasses grass and lantana are well adapted to fire and are known to assist in carrying fire. Both species are also thought to increase fire intensity and assist in carrying fire into the canopy.

ACTIONS

Approvals and planning required prior to the burn. Liaison with all neighbours. Setting up transects so that the burn and its outcomes can be monitored. Preliminary weed control. Personnel - Queensland Fire and Rescue, Rural Bushfire Brigade and Natural Area Management Unit rangers all involved.

The burn was lit from the top of the slope in strategic locations so as to ensure a lower intensity fire that trickled down the slope. In areas where lantana was in the understorey, flame heights increased but as conditions on the day were optimal and good soil moisture was present, the fire was quick to reduce to lower levels, even where lantana persisted in the gullies.

RESULTS

Weeds such as lantana and molasses grass re-shot after the fire as did the native kangaroo grass. Professional bush regenerators systematically worked from the top of the slope in bands approx. 10m wide across the slope. The use of marker dye assisted the workers to cover all the site. Re-shooting lantana and molasses grass together with many germinating white passionflower were spot-sprayed.

The burn zone, gullies and neighbours boundaries have all been under maintenance since 2008. The burn area has recovered to be virtually weed-free, containing a healthy native canopy with a thick understorey of kangaroo grass. The gullies are recovering with wetter species which will assist in breaking up a run of fire, should one occur in the future.

The area currently under maintenance is approximately 12 ha with the burn area only requiring a minimum of maintenance. The ratio of weeds to natives is significantly altered via the burn and subsequent follow-up weed control.

Before burn, 2009

After burn, 2009

(Case study and images courtesy of Jen Ford)

5.6 SOIL DISTURBANCE

Disturbing the soil, either mechanically, or by using hand-tools such as a rake or manually hand pulling, can be a useful technique to trigger the regeneration of native plants. Seed which has become buried deeply in the soil is brought to the surface where it is exposed to light, water and nutrients. Soil disturbance does not need to be entirely over a site. Disturbing the soil in just a few key locations, such as ripping adjacent to remnant vegetation, can be enough to initiate natural processes. Note that soil disturbance, particularly ripping, may lead to a requirement to increase maintenance frequency, as weed seeds in the soil will also be stimulated to germinate.

5.7 FENCING

Fencing is utilised to exclude grazing animals or exclude site trampling by animals or pedestrians. It can be installed to protect any type of ecological restoration project. In sites adjacent to pedestrian or construction traffic, the use of signage on fences can assist in alerting people why there is no access. Fencing comes in a variety of types, including:

Poor fence design can lead to native animal mortalities

- Strand wire fencing on posts or star pickets. Although the aim is to exclude animals, this should not be at the cost of injuring or killing animals. Barbed wire entangles many native animals particularly those with soft membranes such as flying foxes and gliders. Poor fence design can also result in injury/mortality;
- Electric fences for stock exclusion. This may be preferable to barbed wire, however electric fences are dangerous to some wildlife as involuntary muscle contraction triggered by electric shocks causes some species of fauna to hang onto the fence, unable to withdraw; and
- Wire mesh fences, to exclude predation from smaller animals such as wallabies and hares.

The 'Wildlife Friendly Fencing Project' (see http://www.wildlifefriendlyfencing.com) provides guidance on wildlife friendly fencing solutions.

In a number of instances fencing can represent a low cost method of restoring the landscape where resilience is intact. Case Study 6 shows the technique of Natural Regeneration which can be implemented simply by using effective fencing to protect a site.

Other methods can be used to limit the effects of grazing on newly planted trees including tree guards and chemical deterrents (see also sections 5.9.1.7 and 5.9.1.8).

5.8 IMPORTATION OF SOIL

Severely disturbed sites requiring rehabilitation techniques such as Fabrication may require the importation of soil in an attempt to restore abiotic elements. Be aware that imported soil (and mulch) may contain weed seeds and/or soil-borne pathogens, and only obtain soil from a reputable supplier that has been certified free of weeds, fire ants and phytophthora. Imported soil should also be tested for acidity and treated, if necessary, before delivery to the site.

Soil can also be used to reintroduce biotic elements. This may include inoculating the target site with 'living' soil from nearby undisturbed sites to a degraded site to kick-start biotic processes in the new location. This should ideally be undertaken where the nearby undisturbed site is destined to be disturbed and may only require very small quantities.

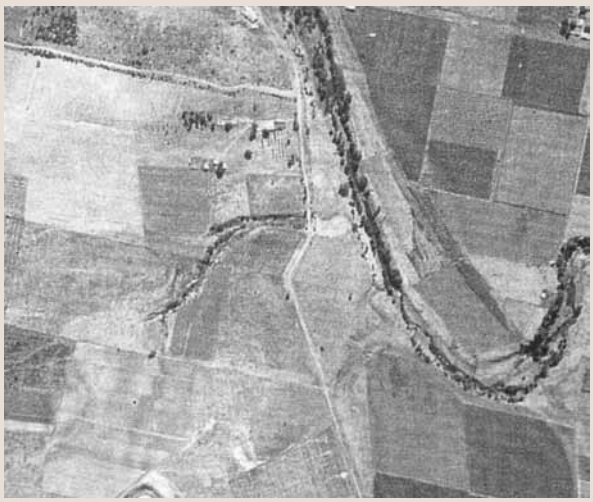
The introduction of soil bearing propagule material (seeds and/or living plants) is discussed further in section 5.9.6.

CASE STUDY 6

NATURAL REGENERATION, TENTHILL CREEK, LOCKYER VALLEY

BACKGROUND

Natural regeneration allows re-establishment of vegetation with little to no interference required. This change is evident in a number of areas in the Lockyer Valley where the exclusion of stock and fire has allowed for the natural recruitment of trees.



1933 – Section of Tenthill Creek illustrating limited vegetation cover, particularly in the side gully.

2010 – Section of Tenthill Creek illustrating evidence of natural regeneration.

Areas that once supported very little vegetation on Tenthill Creek 20 years ago now support mature specimens of *Corymbia tessellaris*, *Eucalyptus tereticornis*, *Callistemon viminalis* and *Acacia salicina*.

LESSON LEARNT

Heavy grazing pressure and regular spring burns can be sufficiently intense to kill even large trees over successive seasons. Exclusion of stock through fencing and fire can allow landscapes to recover, even at a broad scale. Fencing is a relatively cheap restoration option costing only around $8,000-$10,000/km.

Based on Case Studies prepared by David Allworth on behalf of SEQ Catchments for the Lockyer Valley. Paddock photo courtesy of David Allworth.

Natural recruitment of trees in a Lockyer paddock

5.9 RE-INTRODUCTION OF PLANT MATERIAL TO THE SITE

Previous sections of this Manual have dealt with the restoration of vegetation communities using the Assisted Natural Regeneration method of ecological restoration. During the course of restoration works, new plant stock will often migrate to the site via means such as dispersal of seed and vegetative material by birds, bats, insects, wind, water and gravity. However, often these natural means are insufficient to ensure the reinstatement of the previous vegetation community, or in the case of Fabrication, the creation of a new vegetation community. Reasons for this may include:

- Habitat fragmentation, leading to isolation of vegetation remnants, especially in an urban or peri-urban situation;
- Local extinction of particular plant species;