SOUTH EAST QUEENSLAND ECOLOGICAL RESTORATION FRAMEWORK:

MANUAL

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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.

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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

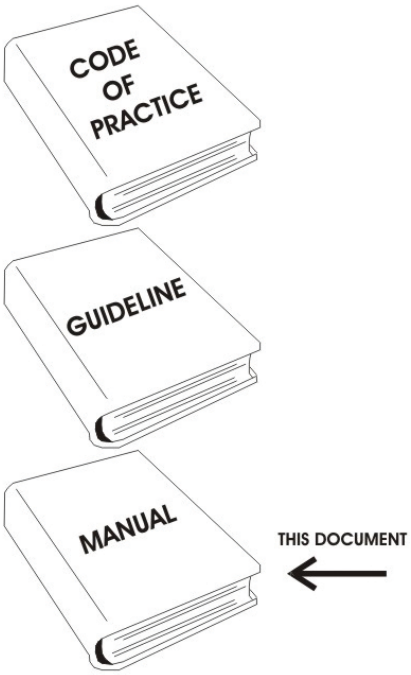
This document constitutes the Manual component of the SEQ Ecological Restoration Framework.

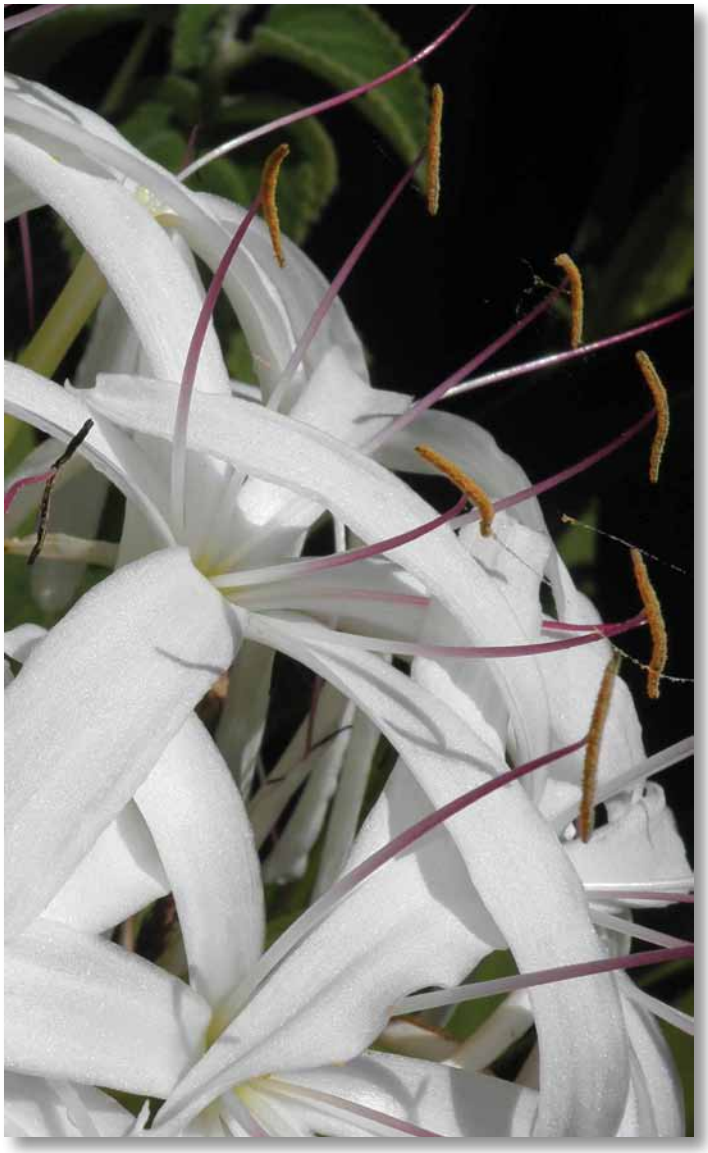
1.3 PURPOSE OF THE SEQ ECOLOGICAL RESTORATION MANUAL

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.

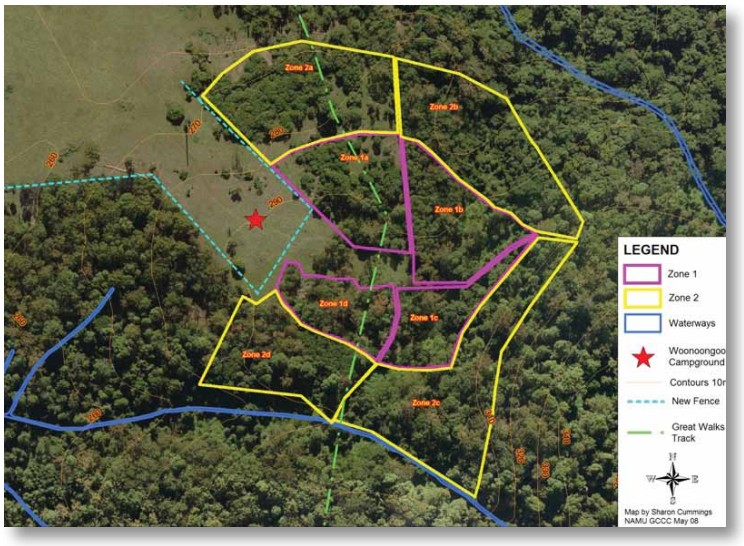


Figure 1 – Site showing management zones

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.

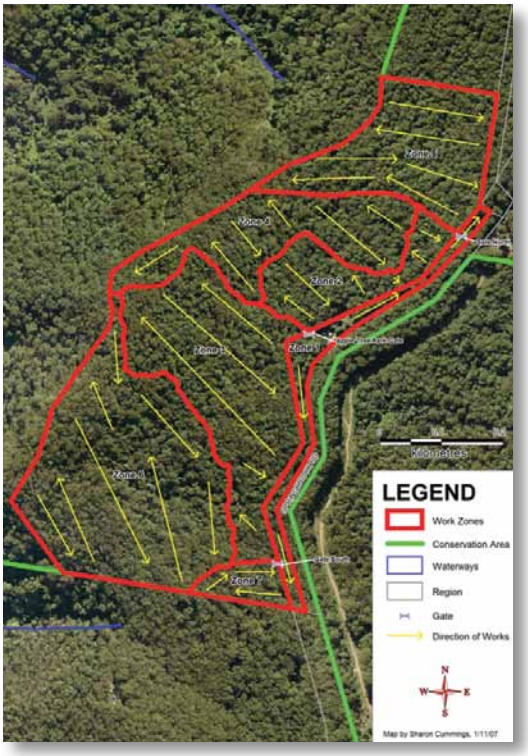


Figure 2 – Direction of work

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.

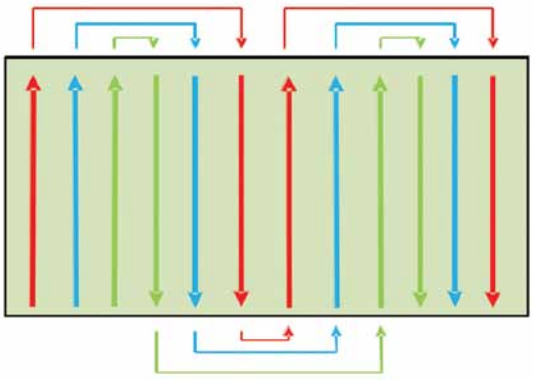


Figure 3 - Team working in lines

- 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.

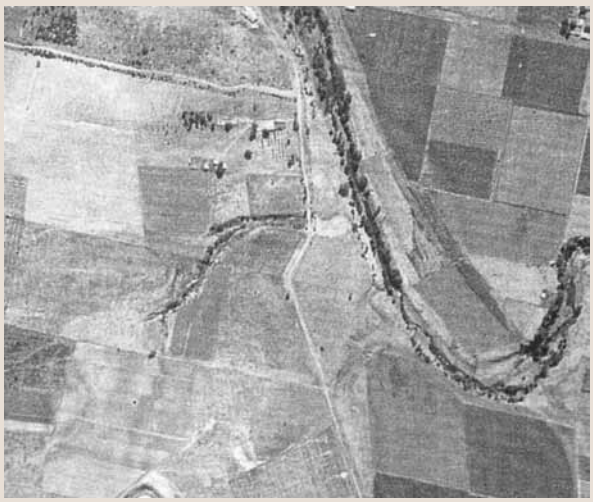
The introduction of soil bearing propagule material (seeds and/or living plants) is discussed further in section 5.9.6.

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;

- Local extinction or reduction of animal species responsible for pollen and seed dispersal; and/or
- High degree of degradation of the site e.g. loss of topsoil due to erosion.

In these circumstances, it may become necessary to introduce propagules (seed, spores and vegetative material) to a site, in order to obtain the necessary vegetation composition to restore a vegetation community or to establish a new, functional vegetation community.

There are several means of reintroducing plant material to a site, and choosing which technique to use is dependent on many factors, including:

- Availability of locally sourced seed and vegetative material;
- Accessibility to the site, and its topography;
- Availability of a water source;
- Degree of degradation of the site;
- Level of soil fertility;
- Necessity to quickly stabilise erodible soils;
- Budget; and
- Resources and time available for follow-up work.

Quick result?

Often planting is suggested as a means of obtaining quick, highly visible results – especially where the site is easily viewed by members of the local community. The introduction of good condition tubestock, tree guards and mulch to a site clearly suggests that work is underway. However, bear in mind that planting can actually hold back the reinstatement of natural processes on a site, particularly where there is adequate regeneration of native species already occurring or likely to occur. If you are uncertain about whether it really is necessary to plant on your site, refer to the flowchart in the SEQ Ecological Restoration Guideline to help you determine which of the four ecological restoration techniques is best to adopt. When choosing the best approach, keep in mind that some sites may need a long period of weed control before the native seed bank becomes apparent. If you are unsure about the recovery potential of the site, adopt a precautionary approach, using Assisted Natural Regeneration for at least 2-3 years before making a decision to plant. Although using Assisted Natural Regeneration techniques may not have instantaneous results, the long-term outcomes, when used on an appropriate site, can outweigh those obtained through planting.

5.9.1 PLANTING PROPAGATED MATERIAL

Planting is generally undertaken as part of Reconstruction or Fabrication.

5.9.1.1 SPECIES SELECTION

Determining which plant species should be selected for re-introduction to your site requires consideration of the following issues:

- Examine the reference site to determine which species might have been expected to have historically occurred at the planting site;
- Access RE information, historical records, and anecdotal information to gain ideas about the vegetation previously occurring on the site;
- Consider weather conditions at the site – susceptibility to frost, salt-spray from the ocean, heat, drought and wind. Plants vary in their tolerances to these conditions, so choose those which are suited to your site. Less tolerant plants can be planted in sheltered niches if they exist or be introduced during a secondary planting after vegetative structure has been created;
- Pioneer and early secondary species (those that grow quickly and are adapted to colonising disturbed areas) are ideally suited for a planting. These plants have the characteristics of:
    - Quick formation of canopy e.g. Mmacaranga (*Macaranga tanarius*), brown kurrajong (*Commersonia bartramia*) in rainforests; wattle, eucalypts and casuarina (*Allocasuarina*) species in sclerophyll communities;
    - Fixing of atmospheric nitrogen in the soil e.g. *acacia* species;
    - Rapid growth, resulting in early 'capture' of the site; and
    - Early senescence, making way for other species (late secondary and mature phase) to establish and eventually dominate;

- Mature-phase species (representative of the climax vegetation) in some circumstances may be introduced during the initial planting. However, these plants are slower-growing and may not exhibit rapid bursts of growth until changing site conditions (e.g. senescence of pioneers) become right for them;
- Choose early flowering and fruiting species to attract birds and bats to the site, resulting in the introduction of seeds that will promote natural regeneration;
- Choose species in all vegetative layers e.g. ground covers, shrub layer, and trees. However, ground covers can be difficult to maintain and often establish naturally on a site. Consider whether it may be better to rely on natural regeneration of ground covers; and
- Availability of stock – lead-in to a planting must be planned carefully to ensure good condition plants grown from locally collected seed are available.

The planting species list may not necessarily reflect the expected composition of the climax community. Using ecological restoration techniques ensures that birds, bats, insects and other animals will assist in the re-introduction of seeds to the site over time.

For Fabrication, species selection will not have a historical basis. The goal here (as with Assisted Natural Regeneration and Reconstruction) is to create a functioning system; however, this system will not necessarily have a connection with the vegetation that previously existed at the site. There are two ways of achieving the required functionality:

1. Copy an existing vegetation community if conditions are suitable; and
2. Create a vegetation community, formed around vegetative elements and conditions that could be expected to interact together to produce a self-sustaining system.

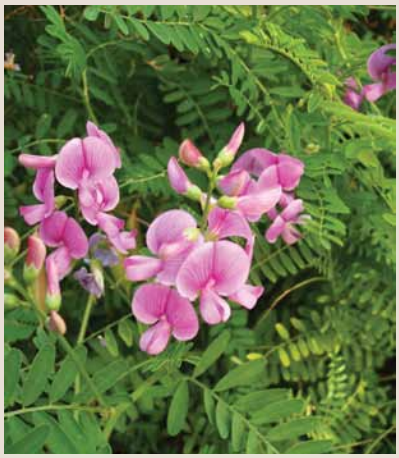
5.9.1.2 SOURCING PLANT MATERIAL

Limiting resources such as time, finances and available skill-base will determine if you choose to propagate your own plants, or purchase them commercially. In all but the largest organisations, purchasing plants from a commercial native plant nursery is the commonly-chosen option. This has the advantage of allowing you to draw on the seed-collecting, propagating and plant raising skills of a reputable native plant nursery.

Using a specialist native plant nursery has the following benefits:

- Awareness of genetic considerations when collecting seed and vegetative material;
- Experience with breaking dormancy mechanisms in hard-to-germinate seeds;
- Highly successful propagation techniques;

In sclerophyll communities a greater diversity of species occurs in the understorey and ground covers than in the canopy. Despite this, relatively few ground layer species are commercially propagated. Further work is needed in the propagation of ground layer, and some shrub species, so that a greater level of diversity can be introduced to Reconstruction and Fabrication projects where there is little likelihood of these diverse layers returning by natural means.



- Ability to provide high-quality stock to order when it is required;
- Provide a wide range of stock for purchase; and
- Draw on the resources of Greening Australia's Florabank, for best practice native species seed management.

However, it is advisable for you to check the quality of the plants you are purchasing. For example:

- Provenance of the plants – was seed or vegetative material for propagation collected from within the same catchment as the planting site, and generally within a 10km radius? (See Section 5.9.9 for more guidelines on genetic considerations.) ;
- Health of the plants – are plants in good condition and vigorous without having overgrown their pots, and do they have a well-developed root system without being pot-bound? Are plants free from pest and disease?; and
- Sun-hardening – have plants come straight from a shade-house? If so, sun-hardening for a minimum two weeks prior to planting is necessary in order to minimise transplant shock.

Plants are available in a variety of sizes of tubes and pots. The table below compares the advantages and disadvantages of each.

Table 5. Advantages and disadvantages of various plant sizes.

TYPE OF CONTAINER	ADVANTAGES	DISADVANTAGES
Seedling trays (i.e. trays containing multiple small containerised seedlings)	✓ Cheap ✓ Lightweight ✓ Easy to plant ✓ Rapid establishment	× Easily 'lost' during follow-up maintenance × Difficult to mulch around × Only suitable if large numbers of just a few species are being planted
Small tubes (approx 250mL capacity)	✓ Relatively cheap ✓ Fairly lightweight ✓ Easy to plant ✓ Suitable for most fast-growing species ✓ High rates of establishment	× May be overlooked during follow-up maintenance × Can dry out quickly on planting day – several wettings required if not planted immediately
Large tubes (approx 500mL capacity)	✓ Suitable for slower-growing species	× More expensive × Heavy to carry around a large or steeply-sloping site × Require a large hole to be dug – can be a problem on rocky sites
Pots/bags	✓ Creates an 'instant forest' – useful for creating a good show in high visibility areas	× Very expensive × Heavy to carry × Difficult to transport (take up a lot of space) × Require a large hole × Large bags may not transplant successfully

5.9.1.3 TIMING OF PLANTING

Planting should be timed to coincide with the wet season in South East Queensland. Planting conducted in summer and autumn will have reduced need for manual watering. If possible, planting should be done from February to May to avoid the worst of the heat while still having the likelihood of receiving good rainfall. Late spring plantings will be likely to require additional watering.

5.9.1.4 SITE PREPARATION

Frequently, actions will need to be taken in order to prepare the site ready for planting. These may include:

- Fencing to exclude grazing animals and people;
- Pre-spraying of exotic grasses and other weeds e.g. if planting into a previously grazed paddock;
- Providing an adequate source of water for planting, initial planting and maintenance if required;
- Arranging delivery of mulch and tree guards to the site (if required – see Section 5.9.1.5);
- Pre-treatment of heavy or compacted soils by deep ripping and/or application of gypsum. Care with erosive or dispersive soils, (be careful to 'Dial Before You Dig' on 1100 before undertaking ripping); and
- Inoculation of soil with micro-organisms (if necessary) – usually micro-organisms are introduced to the soil with the potting mix from the plant containers.

5.9.1.5 PRE-PLANTING PLANNING

Many decisions need to be made prior to planting day:

- What materials will be needed? e.g. plants, water crystals, fertilizer;
- What equipment will be needed? e.g. pumps, hoses, water tanks, buckets;
- What tools will be needed? e.g. auger, mattocks, shovels;
- How will the holes be dug? Mattocks, shovels, powered auger, tractor-mounted auger? A rocky site can really only be dug by hand (mattock or shovel). A steeply-sloping site will be inaccessible by tractor;
- How will water be provided to the site? On-site dam or creek, truck-mounted tank?;
- Will mulch be spread over the site before or after the planting? If so what type of mulch? Will the mulch affect a waterway?;
- How large is the area to be planted? At what density? How many plants will be required?; and
- Has a supervisor/team leader been selected to assign tasks, check quality control, and make sure nothing is overlooked?

Fertiliser can assist in giving planted stock a head start. However, it can have a negative affect on some species such as the non-rainforest Proteaceae species. Use of fertiliser in wetland plantings is not always desirable. Water crystals are useful on very dry sites (e.g. sandy soil with little organic matter) and should be utilised strictly according to the manufacturer's instructions.

5.9.1.6 PLANTING DENSITY

The density at which plants are spaced will be dependant on the aim of the project. However, when starting with an area devoid of native vegetation cover, the plantings should be established at a density that will result in rapid canopy closure so that exotic species are excluded. Experience has shown that planting trees and shrubs spaced at 1.5m centres achieves this aim. Wider tree spacings often mean there is a longer time before canopy closure and therefore a prolonged period of weed control.

The same principle applies to the establishment of ground layer and open wetland vegetation where there is an absence of overstorey elements. In this instance, to achieve the closure of vegetation and reduction of weeds it is necessary to plant at much tighter centres of at least 2-5 plants/m^2 (approx. 0.7 - 0.4m centres).

Higher density planting is also desirable at the edges of revegetation areas to reduce edge effects.

The sites illustrated below are adjacent to one another and were planted at the same time at different densities.

Ground cover under the densely planted site

Same location looking upward

Ground layer under the area that was not planted as densely (note abundance of weeds)

Same location looking upward

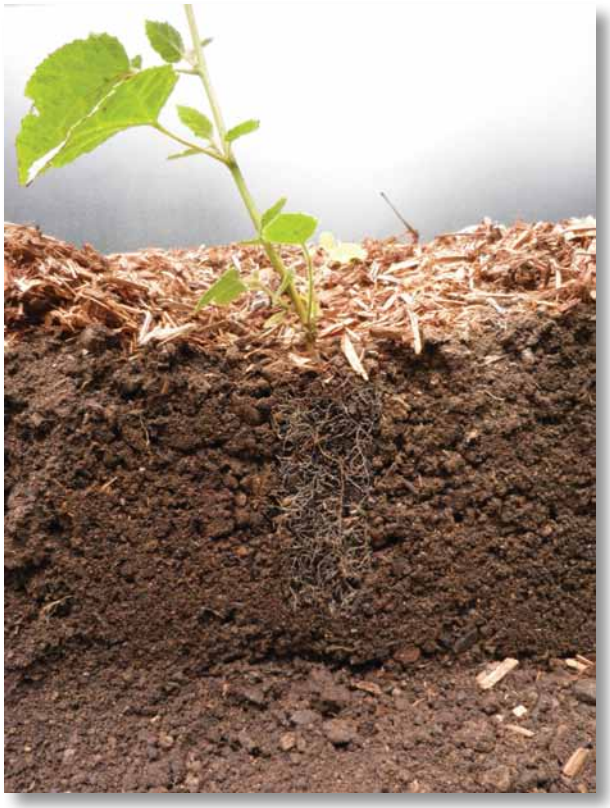
5.9.1.7 PLANT INSTALLATION

Here are some pointers on things to be aware of on planting day:

- Have all materials/plants/equipment ready on the day;
- Pre-sort the trees prior to commencement of planting.
    - Group plants according to the section of the site that they are to be planted in. E.g. sedges, rushes and lomandras along creek lines, and sclerophyllous plants in drier, rocky areas. This will make movement and laying out of plants easier.
    - Have a representative mix of species in each tray – this too will help with easy laying out of plants;
- Assign a specific task to each person – perhaps a few people digging holes, a few laying out plants, one person filling the holes with water, and yet another adding fertiliser. Make sure tasks are rotated periodically to avoid fatigue. Once each hole is ready, planting can commence;
- Holes dug should be slightly larger than the plant container size. In clay soils, check that the edges of the hole are not glazed – this often occurs when augers are used and will prevent the roots of the plant from spreading. Roughen the edges of the hole if this occurs or use a different tool;
- Moisture control is of paramount importance to the success of a planting – pre-water plants; fill dug holes with water before planting and allow water to soak in; on hot and/or dry days small tubes will dry out quickly and will require watering throughout the day; water plants in well after they have been planted;
- If using fertiliser and water crystals, place in the bottom of the hole and mix with soil prior to planting the tree. Do not allow the fertiliser to directly contact the plant roots;

- Slow release fertiliser is often used in restoration plantings. Note that some native species do not require fertilizer;
- When removing the plant from its container, handle the roots carefully to avoid dislodging the potting mix;
- Trees should be planted so that the top of the potting mix is just covered over by the back-filled soil from the hole. This will prevent the plant from drying out. Firm the plant gently into the soil using pressure from your hands, but be careful to avoid over-compaction of the soil;
- Creating a shallow dish using soil around the plant will help to retain water close to the plant's roots;
- Commercially available deterrents may protect the plants from native animals. Due to the use of fertilisers during propagation, the leaves of the newly planted trees are highly nutritious and very attractive to browsing animals; and
- Plants can be protected from sudden change, e.g. heat or frost, by adding an anti-transpirant.

Cross section of planted tubestock



Scattered plantings or trees in rows?

Most ecological restoration plantings space trees such that they are scattered. This is done in an attempt to mimic the distribution of vegetation within a natural community. But, do planting plants in rows affect the ecological outcomes? There has not been a great deal of research in this area. However studies in native monoculture and mixed native plantations (i.e. plantings in rows) have found that native flora and fauna are recruited in such plantings over time, particularly at the boundary of mixed plantations and natural systems (Kanowski *et al.*, 2005).

5.9.1.8 TREE GUARDS

Tree guards are useful for a variety of reasons, including:

- Protecting plants from browsers such as wallabies and hares;
- Protecting plants from desiccation, due to exposure from wind and sun;
- Protecting plants from frost;
- Creating a micro-climate that conserves moisture around the plant;
- Preventing off-target damage through follow-up herbicide applications during maintenance;
- Minimising flood damage providing they are secured correctly (e.g. secure hard wood stakes); and
- Easy identifiable location of plants.

Types of tree guards available, and the stakes required to support them, range from low-cost homemade creations to more expensive, commercially available guards. Examples include:

- Wire or plastic netting (small mesh) looped into a cylinder and secured with two wooden stakes;
- Corflute sleeve and single stake (variety of sizes available);
- Plastic sleeves stretched into a triangular formation using three bamboo stakes; and
- Cardboard cartons (such as from an empty 2L juice container) held in place with a single stake.

Which type of tree guard you select will depend on the purpose for which you require it. For example, a 1.5m high guard of wire netting, secured by two long wooden stakes would be required if your site is frequented by grazing macropods, but would be much less useful on an exposed, sandy coastal site. In this situation, a plastic guard to conserve moisture may be more appropriate.

Tree guards in use

Keep in mind that using tree guards will add greatly to your planting costs, as well as requiring additional labour to install. Make sure that guards are essential before undertaking this extra expense. There are sometimes negatives associated with their use, such as high humidity potentially increasing the risk of fungal infections or damage to trees in flood if inadequately installed or not removed.

Don't forget to budget for the removal of the tree guards, once the protection provided by them is no longer required. Gathering, transportation, storage and disposal of the guard components all add significantly to planting costs. Some degradable materials (such as wooden stakes) may be left on the site indefinitely, but it is never acceptable to leave plastic sleeves behind, as they can eventually become unsecured and create a litter problem.

5.9.1.9 MULCHING

Mulching of the planting site fulfils two main requirements:

- It suppresses weeds around the plants, reducing competition for resources such as light, moisture and nutrients; and
- It assists in water retention, keeping plant roots cool and moist.

Depending on the type of mulch used, mulching may also help improve soil structure by increasing the organic content. Types of mulch available include:

- Organic materials, such as hay, sugarcane waste bark, wood chips, cardboard, newspaper, and natural woven cloths such as jute or hessian; and
- Inorganic materials, such as polyethylene woven cloth and geotextiles.

The relative benefit of the various types of mulch will depend on the circumstances at each site.

The use of mulch may reduce the need for follow-up herbicide spraying by suppressing weeds, but keep in mind that mulch could also prevent the seeds of native plants from germinating.

Apply mulches such as hay and wood chips to a depth of approximately 75-100mm, as this will prevent light penetration while still allowing movement of air and moisture to the soil and plant roots. Be aware that mulch applied too thickly will prevent water (from rainfall or irrigation) from saturating the soil.

You may choose to simply mulch around individual plants (say to a radius of 50cm) or blanket mulch the entire site. With most native species it is important to prevent the mulch from touching the stems of the plants as this may lead to decay, this will depend on the type of mulch and the species planted.

As with tree guarding, mulching can be an expensive addition to your planting budget. Consider if it is really necessary. For example, a planting of pioneering rainforest species in productive soils will rapidly create a canopy shading out competing weeds, thus reducing the need for mulch. In this situation, scheduling maintenance sprays to control weeds while the plants are establishing may be all that is required. This approach also allows for natural recruitment to occur.

5.9.1.10 MAINTENANCE OF THE PLANTING

Maintenance, as with all ecological restoration work is fundamental in ensuring project success. Maintenance of the planting includes tasks such as:

- Herbicide spraying to control competing weeds;
- Watering while plants are establishing. This is often highly variable and depends on the suite of species planted, weather conditions and time of year when planted. A watering schedule may consist of watering every day for week 1, twice per week for weeks 2-6 and then weekly from weeks 6-12;
- Repair of tree guards if they become damaged;
- Replenishment of mulch;
- Maintaining exclusion fencing; and
- Additional planting if required.

Additional planting may be required to replace plants that do not survive (e.g. to meet survival rate requirements, or to fill gaps), but it may also be necessary to introduce new species at different stages of vegetation succession. For example, in a rainforest planting, mature-phase species that do not tolerate frost, sun or wind exposure are best introduced after a canopy of pioneer species has formed. Use an adaptive management approach, if one plant species consistently dies on a site, you should consider using in its place a species that is performing well.

Take time to visit your planting site regularly to observe how it is progressing and to ensure timely scheduling of required tasks. Maintenance will be required for several years following installation of the plants, although if maintenance is regular and thorough during the first 1-2 years, maintenance requirements are likely to taper off significantly in the following years. Getting the plants in the ground is just the first step. Only ongoing maintenance will determine if the planting will ultimately be successful.

5.9.1.11 CONCLUSION

It is important to bear in mind that reintroducing plant material to a site simply kick-starts the restoration process. The planting itself is not the end-product. Despite the warm feeling of satisfaction that we experience when we stand back and survey a planting that we have contributed to, it is vital to remember that the end result we hope to achieve is a well-structured, complex, functioning vegetation community. Planting the trees is merely the starting point.

As time passes, the plantings mature and natural regeneration begins to occur, and changes will be observed. At some point along the way, the site will change from a purely human-created construct to one which naturally includes elements which are not introduced deliberately to the site.

Events such as those listed below, will all help create a dynamic natural system:

- Competition between planted and regenerating plants will constantly change the mix of species present;
- Flowering and fruiting of both planted and regenerating plants, once they have reached maturity;
- Succession, resulting in changes to the structure and complexity of the vegetation;
- Increased numbers and diversity of animals using the site, as leaf litter and fallen branches accumulate, and tree hollows form; and
- Mature trees senescing, dying, and eventually contributing to the soil organic content.

This is the desired end-product – a fully-functioning system that can support itself in perpetuity, with minimal maintenance and input required. Take the time to think about the big-picture aspects of your planting when establishing the aims of the project; and the long-term results that are possible.

5.9.2 DIRECT SEEDING

Unfortunately direct seeding has had a chequered history in SEQ. Although widely accepted as a viable method of establishing vegetation, there have been mixed results in SEQ and as such many land managers have disregarded it.

Direct seeding can be a cost effective method of establishing vegetation costing around $0.40-0.60/m^2$ (Kraatz *et al.*, 2009).

There are a number of factors that determine the success of direct seeding and these are best considered well in advance of undertaking a project. The major considerations are:

- **Weeds**. Competition with weeds is one of the major determining factors of success. Once weeds have gained dominance over the sown natives it is difficult to regain control. Therefore good site preparation is required followed by vigilant maintenance by operators skilled in differentiating between germinating native and exotic species.
- **Soil/seed contact**. Many seeds of native species, particularly those in the Myrtaceae, are small and unless adequate contact is made with the soil will not germinate. Conversely, such seeds planted at depth will also struggle to germinate. Site preparation is therefore very important.
- **Fertility**. The greater the fertility the greater the likelihood that weeds will gain dominance over sown natives. It has been observed that less fertile sites are more successful than highly fertile sites. This said, direct seeding has been shown to be a viable technique for establishing some rainforest species in basaltic krasnozem (red podsolic) soils of the Atherton Tablelands (Doust et al., 2006).
- **Viability**. Care must be taken to ensure the seed utilised is viable. Attaining a certificate of viability from the seed merchant is a prudent step or if you have collected seed yourself undertake your own viability tests. Florabank provides details on how to conduct seed viability tests (ATSC and Mortlock, 1999) (see http://www.florabank.org.au)
- **Watering**. Watering is not advised. Provided there is good site preparation and sowing is undertaken at the correct time of year then watering is unnecessary and may compromise the project.
- **Time of year**. In SEQ the most appropriate time of year to sow is autumn. The gentle autumn rains followed by the cooler months of winter results in better establishment of the small seeded natives than the pounding summer rains that are often followed by hot days.
- **Harvesting**. Large numbers of seeds can be lost to foraging ants and other fauna. It is best to treat the seed with insecticide prior to sowing to deter harvesting.
- **Monocot/dicot**. Mixing monocotyledon species with dicotyledon species is not advised. Young native grass seeds are difficult to distinguish from exotics and as such will be difficult to manage. This said, seeding of pure monocotyledonous mixes is likely to be easier to manage. Although some work has been undertaken in the establishment of native grasses in the context of agronomy (Waters et al. 2000) and rangelands (Scholz, 1996) there appears to be little literature on establishing grasses in the sclerophyll ground layer and should be the subject of further investigations. Cole *et al.*, (2000) and Chivers (2006) provide some good information (see http://www.florabank.org.au/ and http://ga.yourasp.com.au)

There are a number of different approaches to direct seeding. Direct seeding machines are frequently utilised in the southern states.

Many projects in SEQ have used machines to create broad seed beds. The approach has often included the following steps:

- Spray the area with a non-residual herbicide. If necessary, slash the area prior to spraying in order to remove bulk. Wait for resprouting to occur and then spray. In an endeavor to reduce the weed seed bank, it is sometimes advisable to await the germination of a second generation of weeds and treat these again;

- Rip the area. It is preferable to cross rip the area to generate a seed bed with clods the size of golf ball to tennis balls;
- Sow immediately. Sowing into the active soil surface will enable seeds to fall into niches in the active soil surface. The seed mix is discussed below;
- Fence the area to prevent grazing or trampling; and
- Regularly monitor and treat weeds. At least for the first 6-12 months, treatment of weeds in direct seeding beds should be more frequent than in planting beds.

A freshly prepared seedbed with an 'active' surface

The seed mix should consider the following:

- The seed mix should include a good mix of large seeded and small seeded species. A mix dominated by wattle species is likely to achieve good site coverage for a number of years, but may not have adequate secondary species to allow the persistence of canopy cover following wattle senescence;
- Heat-treat or scarify all hard coated seeds (e.g. Acacia and Dodonaea species and most species in the Fabaceae). Do not boil the seeds;
- An ant deterrent should be added to the seed mix (e.g. a Permethrin powder). A slurry of 5gms of powder mixed with 20ml of water is sufficient to cover around 1kg of seed (Dalton, 1993);
- Immediately prior to sowing, bulk the seed mix with dry sand or saw dust. This enables easy sowing of the mix; and
- Hand sow the mix evenly across the active soil surface to achieve an even rate.

The left plot was direct seeded at the same time as the right was planted as part of a trial in Redlands. The photo represents a little over 2yrs of growth.

The appropriate volume of seed to use is variable depending on prevailing circumstances. In high rainfall areas of southern states, a rate of 150-250gms/km is applied in seeding machines, which equates to 300–1,000gms/ha (= 0.03-0.1gm/m^2) (Bonney, 1998). Good results have been achieved at high rates (up to 0.8gm/m^2), but it is likely that some of these sites are too dense and now require thinning. Kraatz *et al*., (2009) recommends 0.5gm/m^2 as a 'rule of thumb' in northern Australia.

8 yr old direct seeding in Slacks Creek. Sown approx. 0.3gm/m^2

Direct seeding can also be undertaken by placing only a pinch of seed (0.2-0.4gms) (Dalton, 1993) into a niche created by a tool such as a rake-hoe which can be used to both expose and cultivate the soil prior to seeding.

5.9.3 BRUSH-MATTING

Brush-matting requires that a supply of seed-bearing stems and branches be available which will provide the source of propagules to stimulate regeneration. The stems may be stockpiled briefly, or transferred immediately to the reintroduction site. Care must be taken to harvest the stems at a stage when they hold viable seed, and to monitor storage to ensure seed does not drop prior to use.

The harvested stems are laid over the area to be restored. Preparation of the site prior to brush-matting may be necessary e.g. ensure soil micro-organisms are present. Eventually the seed from the branches will drop to the ground, be covered over with soil by the movement of wind and wildlife, and germinate. Of course, follow-up maintenance, including weed control, will be required while the plants are becoming established.

This technique is frequently used in extractive industry such as sand mining in coastal heath. Vegetative material bearing seed, together with the retained topsoil layer are returned to the re-contoured site during post-mining restoration.

However, brush-matting is not restricted to this situation. For example, it may be possible to collect and broadcast the seed-bearing heads of native grasses such as kangaroo grass (*Themeda triandra*) as a quick and easy means of stimulating regeneration at a restoration site.

The following should be considered in relation to attaining brush-matting:

1. Don't collect from threatened Regional Ecosystems or from sites where threatened species are present; and
2. Don't cause damage to the donor site by over-harvesting. Ideally, harvest only from sites which are going to be cleared anyway e.g. for development.

Brush-matting is particularly useful in situations that are prone to wind erosion, as the vegetative material acts as a stabiliser, as well as delivering the seed to the required location. Brush-matting also helps to provide habitat, as well as increasing the texture of a site by creating micro-niches.

5.9.4 HYDROSEEDING AND HYDROMULCHING

Hydromulching and hydroseeding (often referred to as one and the same) are effective methods of surface stabilisation and/or seed application for landscapes (such as large or inaccessible areas), where more traditional means of mulching or planting would be costly and/or difficult.

Hydromulching entails combining cellulose, tackifiers and water in a hydromulching machine (JB Hydroseed, 2010). This resulting slurry, transported in a tank on a truck or trailer is then sprayed over prepared ground in a uniform layer for the purpose that it is intended. Sometimes a dye is added to assist in identifying areas that have been covered.

When seed and fertilisers are included in the hydromulch mix, the process can be defined as 'hydroseeding'. Because the mix is applied to the ground surface, the cellulose can separate seed from direct soil/seed contact. As such, the germination of small seeded species (e.g. Myrtaceae) is often prohibited, and therefore the technique is primarily suited to large seeded species (e.g. Mimosaceae).

5.9.5 TRANSPLANTING

Transplanting, also termed translocation, involves moving established plants from one site (donor site) to another (receiving site). Plants may be either transferred directly to the receiving site, or placed in pots in order to be cared for in a plant nursery prior to planting. Plants that spend an intermediate period of time in pots are more likely to be successfully transplanted.

Transplanting is best suited to grasses and soft herbaceous plants such as rushes, sedges, groundcovers, ferns and lilies. Trees and shrubs are more difficult to transplant due to the need to keep the roots relatively intact. Clumping plants that can be broken up into a number of smaller clumps for transplantation are ideal. Case Studies 7 and 10 describe situations where translocation of suitable plants were undertaken. Note that permits under the *Nature Conservation Act 1992* and possibly also under the *Environment Protection and Biodiversity Conservation Act 1999* must be obtained prior to translocation of native plants.

5.9.6 TRANSLOCATION OF TOPSOIL

Stripping and stockpiling the top 50 to 100mm of topsoil from mining sites is a well-accepted means of carrying out post-mining restoration. This topsoil layer contains seeds, rootstock, rhizomes, tubers and soil micro-organisms. Stripped soil can only be stored for a limited time period due to the loss of viability of soil organisms and propagules, and the risk of decomposition.

Case Study 8 describes a situation where translocation of sections of intact topsoil was used to move an entire vegetation community.

CASE STUDY 7

TRANSLOCATION OF SHINY PLECTRANTHUS

Raising the height of the wall of the Hinze Dam in the Gold Coast hinterland is due to result in the inundation of hundreds of hectares of vegetation. As part of the rehabilitation works associated with this project, transplanting of threatened species was undertaken in order to conserve genetic diversity. One species, the endangered shiny plectranthus (*Plectranthus nitidus*), was particularly suitable for translocation, as it is a small, soft herbaceous plant that occurs in the ground layer of riparian areas, moist rainforests and rocky outcrops. The plants were collected from the inundation zone and transplanted to receiving sites higher up in the catchment area of the dam. Ongoing monitoring of the transplanted shiny plectranthus is being undertaken to ensure success and to date, the initial population size transplanted has doubled.

5.9.7 LONG-STEM PLANTS

A technique which is becoming more widely used is the planting of long-stem plants. These trees are propagated in small tubes in the nursery for 10-18 months, after which they have developed long woody stems more than 1m high. Careful use of slow-release fertilisers ensures plants do not become pot-bound. The long-stem trees are then planted to a depth of 1m, and an extensive network of roots develop from the buried stem. This technique has the advantage of:

- No post-planting watering required;
- Increased growth rates;
- Higher survival rates; and
- Reduces plant losses, as plants are less likely to be ripped out by flood.

Experimentation has shown that this technique can be used successfully in riparian areas and sand-dunes (where long-stem plants are able to resist erosion, access reliable soil moisture, have less root competition, and a stable soil temperature) but long-stem plants are now also used on rainforest and saline sites. The main reason for its success appears to be that it encourages development of a robust root-network. It is suitable for most hard-tissue plants.

There is reduced use of resources because site preparation is lessened, tree guards are not necessary, post-planting maintenance is minimal, and use of fertiliser and water is restricted. However, more time is required to allow plants to grow to a suitable height in the nursery, and more time and energy are expended digging 1m deep holes.

A guide on how to grow long-stem seedlings and the planting technique can be found at: http://www.australianplants.org

CASE STUDY 8

SIPPY DOWNS HEATH TRANSLOCATION

BACKGROUND

The development site "Brightwater Estate" at Bundilla on the Sunshine Coast, Queensland in part supported broad areas of heath habitat for several at risk species including *Blandiflora grandiflora, Acacia baueri*, *Schoenus scabripes, Boronia rivularis* and *Acacia attenuata*.

The developer, Stockland, worked in conjunction with the University of the Sunshine Coast to undertake a large scale translocation of the heath that was otherwise at risk of being lost to development.

IMPLEMENTATION

A total area of 12.2 hectares of heath was translocated to a 15 hectare plot located at the University. 'Biscuits' or 'turves' of soil from the heath were moved in 2m square pieces of 300-400mm deep. This included plants, seed stock, animals and trees (trees were pruned to 1.5m tall prior to transport). An excavator was used to lift turves intact and load them on to trucks to carry them to the University site.

The 15 hectare plot at the University was prepared to receive the translocated turves by removing soil to ensure the water table was maintained and by monitoring nutrient levels.

The project cost approximately $5 million to implement.

The University of Sunshine Coast has been undertaking monitoring of the plots and is the subject of a number of PhDs.

Visual assessment during the author's site inspection indicated that there were little differences between the diversity and structure expected in the undisturbed community.

LESSON LEARNT

The method appears to be an effective approach to establishing heath, however, the situation is unique in that large areas of heath are rarely available for removal and the cost is highly prohibitive. Nonetheless, the project demonstrates that with good planning and an understanding of ecosystem processes that soil can be transferred from one site to another for the purpose of establishing vegetation.

Receiving site prior to translocation in 2007

Receiving site following translocation in 2008

On ground image of the translocated heath in 2010

5.9.8 LAYERING

Layering is a useful technique to apply when planting to stabilise coastal dunes. Simply dig a 20cm deep trench, drop in a 50cm length of stolon taken from beach spinifex (*Spinifex sericeus*), yellow beach bean (*Vigna marina*) or goat's foot morning glory vine (*Ipomoea pes-caprae* subsp. *brasiliensis*), and back-fill the trench. No watering is necessary, and the rapid colonisation ability of these species will quickly stabilise newly formed or disturbed dunes.

5.9.9 GUIDELINES FOR COLLECTING SEED AND VEGETATIVE MATERIAL

Guidelines for collecting seed and vegetative material for planting in restoration projects in or near natural areas are detailed below. Make sure that the appropriate permits have been obtained if collecting seed from plants listed under the *Nature Conservation Act 1992* or collecting from a National Park. Collecting from council owned land is also likely to need prior approval from the relevant council.

5.9.9.1 SEED COLLECTION

It is important to consider the issue of genetics in the selection of seeds and seedlings. The following Guidelines have been developed to provide practical assistance when collecting seeds for use in restoration projects (Playford, 1998; Gold Coast City Council, 2007):

- Collect in an area within the local catchment, preferably with the same aspect, generally no further than a 10 kilometre radius. The extent of the collection area will vary depending on the method of seed dispersal (which influences the ease of gene flow). For example, fig seed can be more widely dispersed by flying fox than seed from a lomandra that drops straight from the parent plant;
- Collect from as many 'wild' growing plants as possible to ensure variation. Seeds should not always be gathered from a favourite or easy-to-access site, nor should they be picked only from well-laden or easy-to-reach specimens (all of which ensure lack of variation);
- Collect seed from several (at least 10) well-spaced plants to reduce the possibility of them being related. Mix together equal amounts of seed from each plant before sowing. This is particularly important if planting uncommon or rare species;
- If the planting program is to be ongoing, identify each seed collection plant so that different plants can be used in the following years;
- Do not collect only from "good looking" specimens. Such plants may be in this condition because they are responding to certain favourable environmental conditions present at the time. If these conditions change in any way so may their ability to survive;
- Try not to collect from isolated plants, as self-pollination and/or inbreeding may have occurred and this can often yield low quality seed;
- Seed collection from plantations and other planted specimens requires caution. A plantation will be a poor source of seed if it was derived from the seeds of a single plant, or from seeds of unsuitable provenance;
- Seed collected from woodlands or forests where only a few trees have flowered well will also tend to be more inbred than seed collected after a heavy flowering year when it is likely that greater rates of out-crossing have occurred; and
- Be careful not to strip plants of their seeds as they may be important food for wildlife. Over-harvesting may also negatively impact on the local seed bank available for natural regeneration in the area of collection.

5.9.9.2 COLLECTION OF VEGETATIVE MATERIAL

The use of vegetatively propagated plants in restoration projects may be necessary if insufficient local viable seed is available or if germination of seeds is prolonged, erratic or difficult. Vegetative propagation can be a useful tool, especially when propagating ground layer plants that spread by bulbs, corms, rhizomes or stolons, such as native grasses, matrush (*Lomandra* spp.), flax lilies (*Dianella* spp.), and native ginger (*Alpinea* spp.).

Vegetative propagation includes the use of stem or root cuttings, aerial layering or division, and plants produced through these methods are genetically identical to parent plants. There is a lack of genetic variability within a planting and thus the possibility of increased susceptibility to disease and insect attack.

Guidelines for collection of vegetative material are similar to those for collection of seed.

6 MAINTAINING SITE RECORDS

"It is important to bear in mind that reintroducing plant material to a site simply kick-starts the restoration process."

6.1 DAILY RECORD SHEET

A record of the work undertaken at a site each day when visited should be maintained. This Daily Record Sheet includes details such as:

- Date and staff who worked that day;
- The work done, area covered, weeds controlled and the methods used to do it;
- Weather conditions, including temperature, wind speed and direction and humidity;
- Growing conditions;
- Fauna observed at the site;
- Flowering and fruiting of native plants;
- Observation of results of previous works; and
- Any other observation of interest and relevance to the restoration of the site.

The purpose of keeping a Daily Record Sheet is predominantly to allow a long-term, accurate record of actions taken and changes in conditions at a site over the time that it is being restored. This information can be used to determine the costs of restoration at a site. Daily Record Sheets are a valuable tool for learning, as techniques which have shown to have been successful can be further refined and used on other sites. (see *Appendix B*)

6.2 CHEMICAL USAGE

In addition to the daily record, legislation requirements under the *Agricultural Chemicals Distribution Control Act 1966* specify that a record must be kept of herbicides applied – such as the name of the herbicide, quantity used, dilution rate, method of application and weather conditions. This record can be incorporated into the Daily Record Sheet in order to reduce time required to record the day's works and keep all relevant information together.

7 MONITORING AND EVALUATION

"Evaluation helps determine if project goals and objectives have been met, and provides the opportunity to analyse what has worked really well, and what may have gone wrong.."

7.1 INFORMAL MONITORING

For most ecological restorationists concerned primarily with hands-on restoration work, informal techniques will be sufficient to meet monitoring needs. One of the best ways to do this is with photopoints. A permanent photopoint can be set up using a star picket marked with fluorescent yellow safety cap, so that a photograph may be taken of the site at regular intervals as it is being restored. A time series of photographs, from a degraded state prior to the commencement of restoration, through the transition stages, to the minimum maintenance stage, can be a powerful reminder of the changes that have been achieved by restoration. Photos can also inspire others by showing what can be achieved at one site is certainly possible at another.

Daily Record Sheets (as described in section 6.1) are another means of informal monitoring (see *Appendix B*).

7.2 FORMAL MONITORING

Formal monitoring, using carefully collected quantitative data from plots (quadrates and transects) is time-consuming, and the data may require painstaking analysis. As such, this may be better undertaken by restoration ecologists, independent from the project. However, formal monitoring is able to provide additional information that informal observations cannot. This is likely to be important when determining whether Performance Indicators have been achieved and whether the project is heading in the right direction to achieve project goals.

One potential approach is to measure the progress of the site utilising the BioCondition tool. BioCondition is a terrestrial vegetation condition assessment tool for biodiversity in Queensland. This method involves assessing, scoring and weighting various vegetative attributes (such as native plant species richness, tree canopy cover and fallen woody material) and landscape attributes (such as size of patch, context and connection) in order to obtain a final BioCondition score. The score ranges from a rating of 1 (for 'good' biodiversity condition) to 4 (for 'poor' biodiversity condition). BioCondition was designed to allow comparisons to be made of biodiversity between sites, and to enable rigorous decision-making at State, regional, and local levels, but it could also be adopted as a way of assessing the progression of restoration on a site over time. Measurements may also be compared against benchmarks determined from reference sites and/or the base condition of the subject site prior to commencement of ecological restoration works. More details are available at: http://www.derm.qld.gov.au

Other detailed methods can be utilised such as fauna survey/trapping to ascertain whether the fauna assemblage is tending toward that expected in an undisturbed community, although this is an expensive option and needs to be undertaken by specialists in possession of relevant licenses.

Whatever approach is adopted, it is important that it serves the purpose of determining whether Performance Indicators and aims of the project have been or will be achieved.

7.3 EVALUATION

Evaluation helps determine if project goals and objectives have been met, and provides the opportunity to analyse what has worked really well, and what may have gone wrong. Carrying out restoration works without taking the time to assess on a regular basis, the progress that has been made may result in costly mistakes being made both ecologically and financially.

7.4 ADAPTIVE MANAGEMENT

Adaptive management involves learning from previous management actions in order to improve future management. There are two types of adaptive management:

- **Passive adaptive management**. The responses of the system are monitored and used to improve management e.g. an unplanned fire triggers a flush of germinating seeds, resulting in the decision to send a team of restoration workers to spot-spray herbicide to control new weed growth.
- **Active adaptive management**. Management actions are taken partially to improve learning about the system e.g. a decision is made to conduct a planned burn in a section of a restoration site, in order to observe the germination response of both native and non-native plants in this particular vegetation community to fire. This results in a massive establishment of weeds and hence is not pursued as a viable technique.

7.5 REPORTING

Practically every funded restoration project will have a requirement for regular reporting. Stakeholders will want details about the work undertaken, funds expended, and whether the objectives of the project are being met. There is usually a standard format for such reports.

Another important aspect of reporting is to share an account of a project (successful or not) with other practitioners. This could be published in a journal (e.g. Ecological Management and Restoration), newsletter (e.g. Land for Wildlife) or a presentation can be made at a relevant conference or meeting. Either way, the vital point is that knowledge gained, through both successes and failures, is of great value to restoration workers, in helping them to refine techniques and gain new understandings of how to influence ecological processes to bring about restoration.

8 PRACTICES FOR PARTICULAR ECOSYSTEMS

"In most instances at least 2-5 years are required to ensure the success of a project."

Whilst the techniques outlined in this Manual are applicable to a range of ecosystems, it is worthwhile considering some of the practices that should be considered when undertaking ecological restoration in particular ecosystems.

8.1 FRESHWATER WETLANDS AND RIPARIAN CORRIDORS

Although freshwater wetlands and riparian corridors cover a broad range of ecosystems there are a number of considerations common to all including:

- These environments frequently provide habitat for frogs. Globally there has been a decline in frog numbers which has been attributed to the spread of Chytrid fungus. To minimise the likelihood of further spreading this disease, equipment and boots should be sanitised prior to commencing work in wetland and riparian/waterway environments;
- Given impacts of herbicides on aquatic life there should be restricted use of herbicides in these environments with preference given to aquatic fauna 'friendly' products; and
- Weeds are difficult to address in wetlands and waterways. Frequently native and exotic species look similar and as such great care must be paid to their management. In some circumstances native species will act like weeds such as *Phragmites australis* or *Typha orientalis*, and depending on the goal of your restoration project, may require management. Manual control is often required in the first instance so as to avoid eutrophication of waters particularly in the instance of floating aquatic weeds. That is, the use of chemicals to overspray a large mass of weeds results in the material sinking to the bottom resulting in massive and rapid input of nutrients into the system.

There are some issues particularly relevant to riparian corridors/waterways. Although erosion is a natural process in waterways we are frequently faced with rapidly eroding banks due to the historic clearing of vegetation and altered hydrological patterns. 'Scour' of banks is one of the most common forms of erosion targeted for treatment.

Some considerations when dealing with erosion include:

- Frequently geotextiles (e.g. jute) are used in favour of mulch in waterways because they are less likely to wash away in flooding events. These are often used where the bank has been re-contoured;
- In many instances the re-contouring of banks is either difficult and/or cost prohibitive. Planting directly into the bank is a solution, but the key to most bank erosion problems is the actively eroding toe and as such this area must also be addressed (Price and Lovett, 1999). Planting in this zone is difficult and to maximise success it has been recommended that the roots of species are matched with the size of the slump; and
- The use of long-stem plants are useful in creek bank restoration as they are less likely to wash away during floods.

Case Study 9 demonstrates use of the Fabrication approach, where erosion control was achieved using a combination of re-contouring and jute matting while planted seedlings became established.

With regard to artificial wetlands the guide "Planting Wetlands and Dams" by Nick Romanowski (2009) provides many useful tips. Some of these include:

- Only using a limited range of plants in the initial planting followed by introducing additional species overtime through staggered plantings; and
- Care must be given in wetland environments to protect plantings from grazing during establishment.

CASE STUDY9

HOMESTEAD PARK, LOGAN WATERWAY PLANTING

BACKGROUND

A tributary of Slacks Creek within Homestead Park, Shailer Park, was rehabilitated as part of Logan City Council's Waterway Rehabilitation Action Plan.

The tributary was deeply incised with banks very steep to cliffed and undercut. Due to the urbanisation of surrounds and modification to the waterway, a pre-European vegetation community was not likely to be attained and hence a fabrication approach to restoration was adopted.

IMPLEMENTATION

A 432 square metre section of the north bank was selected for rehabilitation.

The stream bank was graded to a 45° angle and weeds controlled. Immediately following stream bank remodelling, thick jute mat was laid to prevent soil erosion and control weed growth.

Seedlings were planted along the bank through the jute matting by cutting X-shaped slits.

LESSON LEARNT

The technique of controlling weeds, applying jute and subsequent planting with a mix of riparian species proved effective at bank stabilisation, preventing weed re-establishment and establishing a fabricated habitat.

Above - Project implementation in 2004

Below - The site in 2010

CASE STUDY10

SALTWATER CREEK RECONSTRUCTION OF SALTMARSH

BACKGROUND

This project was undertaken by the Department of Transport and Main Roads in conjunction with FRC Environmental to offset the impacts of the Houghton Highway duplication on saltmarsh. Four species of the saltmarsh community (*Sporobolus virginicus*, *Sesuvium portulacastrum*, *Suaeda australia* and *Sarcocornia quinqueflora*) were transplanted to a degraded site on Brenner Road, Rothwell using a number of experimental treatments, including the use of 'plugs'.

IMPLEMENTATION

In March 2008 the plugs of saltmarsh were attained using a shovel from the donor site. Plugs were individually transplanted into two transects with or without geotextile matting. Two years following transplantation, saltmarsh survival was compared between the two transects. It was found that only 33% of the plugs without geotextile matting survived compared to 80% of those planted with geotextile matting, which had begun to spread.

Monitoring of epifauna (crabs, gastropods) showed an increase in use of rehabilitated areas compared to bare patches.

LESSON LEARNT

FRC Environmental made the following recommendations at the end of the trial in relation to transplanting plugs of saltmarsh:

- Future transplanting of saltmarsh should be undertaken on geotextile material; and
- Saltmarsh plants should be planted as close together as possible to aid in coalescence.

Installing the plugs. With geotextile on the left and without on the right.

Same area in 2010. Without geotextile on the left and with on the right.

Results and implementation photograph courtesy of the Department of Transport and Main Roads in conjunction with FRC Environmental.

8.2 SALTMARSH AND MANGROVE

Any work in saltmarsh and mangrove communities is likely to require a permit under the *Fisheries Act 1994*.

Laegdsgaard (2006) undertook a review of ecology, disturbance and restoration of coastal saltmarsh in Australia. In the review made several key points that are pertinent to saltmarsh restoration:

- *"Actions such as fencing to remove cattle from saltmarsh areas, diversion of stormwater away from saltmarsh and weed removal are the most common rehabilitation methods for saltmarsh.";*
- *"Zonation of saltmarsh plants requires a specific combination of land gradients (to ensure inundation) and soil salinity.";*
- *"The best results from restoration are generally achieved where the environment has been prepared for the natural recolonisation or regeneration of saltmarsh plants.";*
- *"In transplantation from natural sites, it is important to consider the impacts to the donor sites and that the effects of harvesting may take some time to recover."; and*
- *"Saltmarsh areas that are restored using transplants from donor sites may establish a compliment of fauna faster as some may be transported in with the transplant. This is effectively inoculating the site with fauna."*

Many of the approaches and techniques outlined in the NSW Saltwater Wetlands Rehabilitation Manual (DEEC, 2008) are applicable in SEQ (see http://www.environment.nsw.gov.au)

Case Study 10 (on previous page) describes restoration of a degraded saltmarsh site by transplanting 'plugs' of suitable species.

8.3 HEATH

Heath is a community occurring in diverse locations including mountains and in wet and dry areas of the coastal plain. Most montane heath in SEQ occurs in protected estate (e.g. Glass House Mountains, Mt Coolum, Lamington) and because of its location has not been subject to significant levels of disturbance, although impacts from recreational use of these areas can be severe.

Lowland heath of the mainland has been all but lost from the Gold Coast and is frequently impacted where it occurs near urbanised areas on the Sunshine Coast. Heath can be significantly impacted by changed hydrological and nutrient regimes. Given this, before any work is undertaken in these systems these abiotic impacts must be addressed prior to biotic impacts such as weeds. Site assessment is critical in this community to identify the source of the abiotic impact such as nutrient sources from urban runoff, inappropriate fire regimes etc.

8.4 SCLEROPHYLL FORESTS

The most common vegetation communities in SEQ are sclerophyll forest. Sclerophyll can be broadly grouped into three sub categories in the region:

- Swamp sclerophyll forest (e.g. melaleuca forests);
- Wet sclerophyll forest (e.g. flooded gum forest with rainforest understorey); and
- Dry sclerophyll forest (e.g. spotted gum forests).

Significantly, the desired fire interval in each of these communities is quite different and as such influences how fire should, or shouldn't, be used in each as a restoration tool. Protection from fire may be necessary while saplings are establishing.

Carr *et al*., (2010) outline a number of considerations for eucalypt woodland plantings, most of which have been discussed in this Manual. Of note however is the recommendation to deplete soil nutrients (particularly nitrogen and phosphorus) before planting to resist re-invasion by exotic weeds through:

- Weed harvest, scalping, sugar (or organic carbon) application;
- 'Mining' of nutrients using unfertilised crops; and
- Subsequent establishment of dense kangaroo grass (*Themeda triandra*) swards to continue 'locking up' nutrients.

Although these recommendations apply to woodlands as opposed to open forest, there are likely to be situations in the SEQ region where similar approaches may prove beneficial.

8.5 RAINFOREST

There are numerous rainforest associations in the region including:

- Coastal or littoral rainforest (notophyll vine forest);
- Warm temperate rainforest (simple notophyll vine forest);
- Dry rainforest (araucarian notophyll vine forest or araucarian microphyll vine forest);
- Subtropical rainforests; and
- Cool temperate rainforest (microphyll vine/fern forest).

As the latter occurs at altitude, it is largely protected in national parks and is infrequently the subject of ecological restoration in SEQ.

The Manual emphasizes a preference for the use of Natural Regeneration or Assisted Regeneration where regeneration capacity exists. There are instances where this capacity has been lost and it is necessary to undertake planting. Kooyman (1996) identifies a number of considerations when undertaking rainforest reconstruction work including:

- When planting is required, the preferred size is 200mm/1 litre bags or similar. Plants should be 60-70cm tall;
- Frost hardy species can be used as a nurse crop where necessary. Known frost hardy species include black wood (*Acacia melanoxylon*), brown kurrajong (*Commersonia bartramia*), native quince (*Guioa semiglauca*, *Mallotus* spp.), sweet pittosporum (*Pittosporum undulatum*) and corduroy tree (*Sarcopteryx stipata*);
- Wind breaks and edge plantings are useful; and
- Vine species should not be planted until canopy species have grown sufficiently so that they can be supported.

8.6 BEACH FOREDUNE

The beach foredune is a harsh environment in which to establish plants being subject to salt spray, onshore winds and a sandy substrate. At times there may be a need to stabilize sand through a variety of methods including matting.

Where planting is required it may be necessary to commence with ground cover species such as beach spinifex (*Spinifex sericeus*), yellow beach bean (*Vigna marina*) or goat's foot morning glory vine *(Ipomoea pes-caprae* subsp. *brasiliensis*) to assist in stabilising the site. Trees and shrubs may require protection from wind and sand blasting through the use of tree guards.

Where moisture retention is poor consider using water retention crystals and/or regular watering.

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WEBSITES

AABR website:
www.aabr.org.au

Australian Plants website:
www.australianplants.org

DERM Website:
www.derm.qld.gov.au

DPI Website:
www.dpi.qld.gov.au

DSEWPC Website:
www.environment.gov.au/biodiversity

Florabank:
www.florabank.org.au

NSW Department of Environment and Climate Change:
www.environment.nsw.gov.au

Sunshine Coast Council:
www.sunshinecoast.qld.gov.au

Wildlife Friendly Fencing Project:
www.wildlifefriendlyfencing.com

GLOSSARY

Abiotic: Non biological influences such as light, wind, modified hydrological regimes and changed soil conditions.

Biodiversity: The variety of life and its processes, including diversity of organisms, genetic diversity, and the communities and ecosystems in which they occur.

Biotic: Biological influences such as pests (weeds and animals) and 'rogue' native plant species.

Ecological restoration: The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Compare with Rehabilitation.

Ecologically sustainable development (ESD): Development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends. The targets of the South East Queensland Natural Resource Management Plan 2009–2031 represent the outcomes of ESD.

Ecosystem services: The goods and services provided by ecosystems that benefit, sustain and support the wellbeing of people. They include production of food and medicines, regulation of climate and disease, provision of productive soils, clean water and air, opportunities for recreation and spiritual benefits. (from SEQRP)

Ecosystem: Consists of the biota (plants, animals, microorganisms) within a given area, the environment that sustains it, and their interactions.

Environmental Weeds: All weeds impacting the environment including those listed under the *Land Protection (and Stock Route Management) Act 2002* and local council ordinances.

Function: The dynamic attributes of an ecosystem, including interactions among organisms and interactions between organisms and their environment.

Indigenous species: The biota that occur in a particular location such as in a reference ecosystem (see also *Local provenance*).

Local provenance: Indigenous species established form the seed sourced from natural populations within a particular site or area (see also *Indigenous species*).

Niche: The part of the environment into which a species fits (i.e. its specific habitat), and to which it is adapted.

Performance Indicators: Provide very clear goals and are used to establish if the aims and objectives of the ecological restoration plan are being met.

Precautionary principle: Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Reference ecosystem (or reference community): An ecosystem that serves as the model for planning an ecological restoration project and as a reference against which the success of the project can be evaluated. The reference ecosystem has not been subject to extensive past disturbance.

Regional Ecosystems (REs): Communities of vegetation that is consistently associated with a particular combination of geology, land form and soil in a bioregion. The Queensland Herbarium has mapped the remnant extent of regional ecosystems for much of the state using a combination of satellite imagery, aerial photography and on-ground studies.

Rehabilitation: Emphasises the reparation of ecosystem processes, productivity and services, without necessarily re-establishing the pre-existing biotic integrity.

Resilience: The ability of an ecosystem to regain structural and functional attributes that have suffered harm from stress or disturbance.

Self-sustaining: A restored ecosystem which is resilient to disturbance and requires minimal long-term management input.

Structure: All vegetative elements within an ecosystem either dead or alive including, but not limited to, trees, shrubs, ground covers, lianes, logs and leaf litter.

Succession: The directional non-seasonal cumulative change in the types of plant species occupying an area through time. It involves the processes of colonization, establishment, and extinction. Most successions contain a number of stages, each of which are characterised a particular dominant species assemblage.

Threatened species: Plants or animals which have been listed as extinct, extinct in the wild, critically endangered, endangered, vulnerable, rare or conservation dependant under either federal or state legislation.

Vegetation community: An assemblage of particular populations of different plant species within a specified location in space and time.

ACRONYMS

ACDC: Agricultural Chemicals Distribution Control

BFP: Brisbane Forest Park

BRAIN: Brisbane Rainforest Action and Information Network

CSP: Cut-Scrape-Paint

DEEDI: Department of Employment, Economic Development and Innovation

GCCC: Gold Coast City Council

IWM: Integrated Weed Management

MSDS: Material Safety Data Sheet

PPE: Personal Protective Equipment

RE: Regional Ecosystem

SEQ: South East Queensland

SEQFBC: South East Queensland Fire and Biodiversity Consortium

SERI: Society for Ecological Restoration International

APPENDIX **A**

EXAMPLES OF PROJECT CHECK LISTS AND SITE RISK ASSESSMENT /INDUCTION RECORD

- Project Checklist modified from Sunshine Coast Regional Council Natural Areas Project Checklist
- Site Risk Assessment courtesy of Sunshine Coast Regional Council

Natural Areas Project/Activity Checklist

1. PROJECT DESCRIPTION

Project/Activity Title	

Officer undertaking Project/Activity	

Planned commencement and end date for Project/Activity	
Provide an overview of Project/Activity	

Risks (Identify the risks associated with this project/activity

Officer undertaking this check	
Same as above	**Date**

Is this activity to occur on Council managed land	

Note for a project to be undertaken on property not managed by Council. Approval from the Manager is required.

Is this project identified in your current annual plan?	

Has this activity been budgeted for?	

(If the project has not been included within the annual work plan or does not have an identified budget this project cannot proceed).

What is the identified budget for this project/activity	$

What is the job number for this project/activity	

2. COUNCIL MANAGEMENT

Property Number	
Owner	
Legal Description (as per Proclaim)	
Property Type (as per Proclaim)	

Check Emap

What is the property shown within Councils Mapping System – Open Space Layer
Gazetted

Is this activity to occur on Amenity Reserve Undeveloped	

FOLLOW <u>ADDITIONAL STEPS</u> BELOW SECTION 8

Will this project/activity require Public Consultation?	

3. STAKEHOLDERS

Identify who might have an interest in this project/activity of site

Community Group*		Strategic Planning	
Parks Field Leader Hinterland		Environment Policy Waterways	
Parks Field Leader Coastal		Environment Policy Biodiversity	
Arboricultural Services		Development Assessment	
Parks Foreman Area		Road Management Services Construction	
Asset Manager Environmental Operations		Marketing and Media	
Councillor			
*Community Group name			

4. ENVIRONMENTAL & CULTURAL CONSIDERATIONS

Environmental
Does this project require a permit or legislative approval?
Have you checked that your activity does not trigger the following Act(s) which may require a permit? Check with Development Assessment to see if an application maybe required to be submitted for the works.
Permits maybe required under the following Commonwealth and State Acts
ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999 NATURE CONSERVATION ACT 1992
WATER ACT 2000
VEGETATION MANAGEMENT (REGROWTH CLEARING MORATORIUM) ACT 2009
VEGETATION MANAGEMENT ACT 1999
ENVIRONMENTAL PROTECTION ACT 1994
ABORIGINAL CULTURAL HERITAGE ACT 2003
FISHERIES ACT 1994
COASTAL PROTECTION AND MANAGEMENT ACT 1995
Wetlands Assessable
Check Emap Fauna Wetlands Impact Assessable layer
Coastal zone assessable
Check EPA website for requirements
Koala Management Area
Check Emap Fauna – Koala Mngt Area
Fish Management Area
Check Emap Fauna – Fish Management Area

Are Acid Sulphate soils present		Will these be disturbed	

Any EVR species present onsite

If Yes what considerations will be required to ensure that EVR's are not impacted or appropriate management considerations have been included within project implementation.

What are the proposed working hours.

Cultural
Heritage Significance

Does a recognised site of significance exist within the work area or adjacent to it.

5. SAFETY CONSIDERATIONS

Will a Minor Work Safety Plan be required (If no got to next Q)	

Has the Minor Work Safety Plan be prepared (a minor works safety plan is required to be prepared and sited before works can commence)	

Will a Job Safety Analysis be required for this activity?	

All current Safety information can be accessed from this link

Dial Before You Dig (DBYD)

Does a Dial Before You Dig check need to be undertaken for this Project?	

Site Hazards Present
(Other than Services)
Confined Space Asbestos

Other (list)

Services
Telecommunications Gas Water

Sewerage Survey Energex

Roadway Bikeway

Other

6. COMMUNICATIONS

Will there be any promotion of this activity	
Will you need to advise anyone of this project	

Who should be advised of the project/activity?
Customer Services Media and Marketing
Local Councillor Residents
Community Group(s) Police, Fire, Ambulance
Public transport companies

How will these groups be advised?

Group	How * **(see descriptors below)**	When	Confirmed (Insert date)

Other Identify:

7. ONGOING MAINTENANCE

Who will be undertaking maintenance once this project/activity is finished?
Have funds been identified to undertake ongoing maintenance
Yes

8. ASSET MANAGEMENT UPDATE

Will Asset Management Systems need to be advised to update data held against this asset?

Yes	(If yes provide confirmation of who will be contacted and when)

Contact Person:	Date Contacted

Additional Checks

Do you require to undertake additional checks	

Check with the Strategic Planning Team to see if this site has been identified for a future use
Provide details of contact with Strategic Planning

Check with Development Assessment (Development Assessment Duty Officer) to confirm that no approval has been given for operational works to occur on this site
Provide details of contact with DA

Check with relevant section within Council to confirm any future plans associated with this site
Provide details of contact with relevant section within Council

Supervisor undertaking check	Project/Activity Approved

Reasons for not approving Activity

# #	Communication Type:	To Whom	Format	How Often	Responsibility

The following set of questions provides a guide to assist in determining whether some form of public participation should be considered for your project, plan or strategy.

- Is there a legislative trigger that requires public participation e.g. Local Government Act & IPA?
- Does the Corporate Plan require there to be public participation?
- Has the Council asked for community input on this decision or similar ones in the past?
- Has the community asked the Council to talk to them about an issue associated with a pending decision?
- Does the Council need to understand community values and priorities to inform policies, planning and service delivery (eg what the community sees as sustainable outcomes from development)?
- Will the decision have significant social, environmental and/or economic sustainability impacts for one or more stakeholders?
- Would the Council decision be significantly improved by input from community stakeholders?
- Is there already – or will there be – media and/or community concerns/expectations (eg. from past experiences) about the issues?
- Is this a complex or difficult case with widely divergent alternatives and views to consider?
- Is there an opportunity to build community capacity and improve the understanding between Council and the community?
- Is there an opportunity to establish partnerships (eg. Private sector/government agency/community organisations) to collaboratively address issues?
- Is there an opportunity to build community capacity and improve the understanding between Council and the community?
- Does the community need to be informed about a Council decision, or pending process?

Sunshine Coast Regional Council

Site Risk Assessment and Site Induction Record – Environmental Operations

SAFE PLAN

Property Name		Site Supervisor	
Property Address		Date	
☐ Communications available on site?	☐ Mobile	☐ Two Way Radio	☐ Other ……

IDENTIFIED HAZARDS	SCORE BCM	SCORE ACM	CONTROL MEASURES IMPLEMENTED	CONTROL MEASURES IMPLEMENTED
CLIMATIC HAZARDS				
☐ Lighting/Glare			☐ Mobile Phone ☐ Communication options ☐ Emergency evacuation plan ☐ Check weather forecast ☐ PPE, rest, water, sunscreen ☐ Work in pairs/groups ☐ Work method statements	☐ Appropriate & Protective Clothing ☐ First aid response/Kit ☐ Training & competency Other control measures:…….... …… ……
☐ Extreme Temperatures				
☐ Hail/Severe Storm/Lightning				
☐ Rainfall/Flooding				
☐ Dehydration				
☐ UV				
☐ Fire				
PHYSICAL HAZARDS				
☐ Working In Public Areas			☐ Mobile Phone ☐ Other communication devices ☐ Navigation device ☐ Minimal level of supervision ☐ Moderate level of supervision ☐ High level of supervision ☐ Void fall protection system ☐ Reconnaissance ☐ Work in pairs/groups ☐ Emergency evacuation plan ☐ Use warning signs/barricades ☐ Adequate drinking water ☐ Temporary Guarding ☐ Maintained/checked (plant and equipment ☐ Hearing protection ☐ Licenses ☐ Dial before you dig ☐ Work in pairs/groups ☐ PPE ☐ Traffic control ☐ Silt trap/erosion sediment ☐ Site assessment ☐ Emergency evacuation plan ☐ Work method statements	☐ Additional resources ☐ Training & competency ☐ Emergency details ☐ First aid response/Kit ☐ Adhere to exclusion zones ☐ Protective footwear ☐ Safety Harness and davit ☐ Dust mask/respirator/SCBA ☐ Spill kit ☐ Sharps kit and training ☐ Training & competency ☐ First aid response/Kit Other control measures:…….... …… …… …… …… …… …… …… …… ……
☐ River Or Stream Crossing				
☐ Heights > 2 Metres				
☐ Cliffs Or Crevices				
☐ Concealed Holes				
☐ Slippery Surfaces				
☐ Plant And Equipment				
☐ Loss Of Communications				
☐ Soft Sediments (Mud, Quick Sand)				
☐ Falling Objects (Trees, Rocks)				
☐ Depths Over 1.5m				
☐ Unstable Slopes				
☐ Working Over Or Near Water				
☐ Dust				
☐ Uneven ground				
☐ Confined Spaces				
☐ Contaminated Environment				
☐ Unexploded Ordinances				
☐ Working On Or Near Roadways				
☐ Inadequate Amenities (Water…)				
☐ Over Head /High Voltage				
☐ Noise				
☐ Underground Services				
☐ Driving				
FLORA AND FAUNA				
☐ Bites (Ticks, Leeches, Ants)			☐ Emergency/medical details ☐ Training & competency ☐ First aid response/Kit ☐ Protective Clothing ☐ Insect repellent	☐ Emergency evacuation plan ☐ Site assessment ☐ Communication device Other control measures:…….... ……
☐ Allergies – Plant/Animal				
☐ Stinging Plants				
☐ Animal Attacks (Dogs, Snakes)				
☐ Plants With Spikes, Thorns Etc				

Overall Risk Assessment

☐ Insignificant risk

☐ Significant risks but can be effectively controlled using control measures outlined above

☐ Risks are significant and not easily controlled. Seek further help on control measures. Do not proceed with activity until risks are adequately controlled including change of proposed venue for activity. Repeat assessment with new information.

Sunshine Coast Regional Council

WH&S RISK CALCULATOR

Consequences

Likelihood	Insignificant None or very minimal injuries	Minor First aid treatment only	Moderate Medical treatment required	Major - Major medical treatment required	Catastrophic Life threatening injuries or death
Almost Certain: Expected to occur at most times (eg, 3 per year)	M-28	M-40	H-60	E-88	E-100
Likely: Will probably occur at most times (eg, 1 per year)	L-16	M-36	H - 56	E-84	E-96
Possible: Might occur at some time (eg, 1 per 5 years)	L-12	M-32	M-52	H-72	E-92
Unlikely: Could occur at some time (eg, 1 per 5 to 15 years)	L-8	L-24	M-48	H-68	H-80
Rare: May occur in rare conditions (eg, unlikely during next 15 years)	L-4	L-20	M-44	H-64	H-76

Sunshine Coast Regional Council

WH&S RISK CALCULATOR

Risk Process	
Identify	Identify the hazards/risks of the work
Assess	Assess the likelihood and consequence of the hazards/risks
Control	Control the hazards/risks using control measures considering the hierarchy of control
Monitor	Monitor the effectiveness and use of implemented control measures

Risk Score Legend		Hierarchy of Control	
E	Extreme risk – immediate action required	ELIMINATION	*Eliminate* the process, material or substance completely
H	High risk – prioritised action required	SUBSTITUTION	*Replace* the process, material or substance with a safer one
M	Moderate risk – planned action required	ISOLATION	*Isolate* the person(s) from the process, material or substance
L	Low risk – actioned by routine procedure	ENGINEERING	*Design or re-design* the process, material or substance
SCRC – 04/2009		ADMINISTRATION	*Limit exposure* to the risk by job rotation, work procedure and/or providing adequate training
		PPE	Use of *personal protective equipment*

Comments: (attach additional pages if required) ……
……
……
……
……
……

Sunshine Coast Regional Council

Site Risk Assessment and Site Induction Record – Environmental Operations

Site Induction Record - The undersigned have participated in the risk assessment process for the particular site and agree to abide by all instructions given for this location.

All staff must possess and show evidence of a blue/white card safety induction

NAME	SIGNATURE	DATE

APPENDIX **B**

EXAMPLES DAILY RECORD SHEET

- Daily Record Sheet courtesy of Gold Coast City Council

Corresponding Invoice #:

Daily Record Sheet

for Ecological Restoration Works on Gold Coast City Council Land

Location:		**Date:**	
Work zones:		**Total hours:** (workers x hours on site)	
Contractor name:			
Personnel:			
Work completed: (description of work done)	**Primary work (inc. initial spray run)** Area worked: m2, Hours spent: hrs		
	Follow-up work Area worked: m2, Hours spent: hrs		
Comments on previous works & reminder for follow-up works			
Native fauna notes (sightings, behaviour)			
Flora notes (e.g. flowering, fruiting, germinating, threatened species)			

	Reportable incidents	**Details**
☐	**Environmental Issues** (significant erosion, fires etc.)	
☐	**Animal Management** (cattle, pigs, foxes, dogs etc.)	
☐	**Illegal Dumping** (Garden waste, cars, rubbish etc.)	
☐	**Illegal Access** (motorbikes, cars, mtn bikes, camping)	
☐	**WH&S** (accidents, near misses, safety issues)	
☐	**Other** (Public comments,	

Name:_____ Signature:_____

Corresponding Invoice #:

Herbicide Distribution Sheet

Environmental Conditions			
☐ Clear	☐ Dry	Wind speed (*km/hr*):	
☐ Overcast	☐ Mild	Wind direction (*N,E,S,W*):	
☐ Showers	☐ Humid	Temperature (^{O}C):	
Zone Vegetation Type	☐ Rainforest	☐ Coastal	
☐ Dry Eucalypt	☐ Riparian	☐ Dune system	
☐ Wet Eucalypt	☐ Wetlands	☐ Other:	

Location:		**Time start:**	
Date:		**Time finish:**	
Personnel using herbicide			

Equipment Used	Chemicals Used (trade name)	Total quantity applied on site	Rate:	Plants treated	Method
☐ Knapsack	☐ Glyphosate:	→ amount used ? *ml.*			
☐ Power spray	☐ Metsulf. methyl:	→ amount used ? *g.*			
☐ ATV unit	☐ Surfactant:	→ amount used ? *ml.*			
☐ Poison Pot	☐ Penetrant:	→ amount used ? *ml.*			
☐ Injector Kit	☐ Dye:	→ amount used ? *ml.*			
☐ Applicator Bottle	☐ Other:	Tot. volume of mixture: Litres			
☐ Other		Total area treated: m^2			

Equipment Used	Chemicals Used (trade name)	Total quantity applied on site	Rate:	Plants treated	Method
☐ Knapsack	☐ Glyphosate:	→ amount used ? *ml.*			
☐ Power spray	☐ Metsulf. methyl:	→ amount used ? *g.*			
☐ ATV unit	☐ Surfactant:	→ amount used ? *ml.*			
☐ Poison Pot	☐ Penetrant:	→ amount used ? *ml.*			
☐ Injector Kit	☐ Dye:	→ amount used ? *ml.*			
☐ Applicator Bottle	☐ Other:	Tot. volume of mixture: Litres			
☐ Other		Total area treated: m^2			

Equipment Used	Chemicals Used (trade name)	Total quantity applied on site	Rate:	Plants treated	Method
☐ Knapsack	☐ Glyphosate:	→ amount used ? *ml.*			
☐ Power spray	☐ Metsulf. methyl:	→ amount used ? *g.*			
☐ ATV unit	☐ Surfactant:	→ amount used ? *ml.*			
☐ Poison Pot	☐ Penetrant:	→ amount used ? *ml.*			
☐ Injector Kit	☐ Dye:	→ amount used ? *ml.*			
☐ Applicator Bottle	☐ Other:	Tot. volume of mixture: Litres			
☐ Other		Total area treated: m^2			

Name:__________________________ Signature:________________________

APPENDIX **C**

CONTROL TECHNIQUES AND HERBICIDE APPLICATION RATES FOR PARTICULAR WEED SPECIES

DISCLOSURE

At the time of publication the following chemicals and techniques are registered for use and are commonly utilised. Other chemicals and techniques are used in the ecological restoration industry. Laws and best practice techniques change over time and as such it is best to check with your local government as to the current preferred approach.

Under label or off-label permits 11463 and 9868. Permit 9868 requires that persons who can use the product under the permit are "All persons who are trained in the use and handling of agricultural chemicals and who are performing weed control as part of a bush regeneration/restoration project". Operators are legally obliged to read the label before using any herbicides. If the species you wish to treat is not on the label it will be necessary to read the off label permit. Always consult the ecological restoration plan for the projects.

Additional useful references include the Weeds of Southern Queensland (Dight et al., 2011) and PUBCRIS (http://services.apvma.gov.au/PubcrisWebClient/welcome.do).

HERBICIDE (+ E.G. TRADE NAME)	PRINCIPLE USES	ECOTOXICOLOGY	GROUP	SCHEDULE	UPTAKE AND RESIDUAL AFFECT
Glyphosate 360gl (Weedmaster® or Roundup Biactive®)	Non- selective weed control	Full Aquatic registration (in **most formulations**),	M	5	Absorbed through the leaf via spraying and through the cambium when applying techniques such as stem injection and cut, scrape and paint. Extremely short-lived and rapidly immobilised (both in soil and water). Degraded within hours in most environments
2,4-D 625 gl amine (Amicide 625)	Selective of broad-leaved weeds in native grasses (limited effect on deep rooted dicots, legumes etc.)	Aquatically registered formulations **available**	I	5	Mainly absorbed through leaves and stems. Fairly immobile and reltively short-lived in the soil. (degraded within days in most environments)
Fluroxypyr 333gl (Starane advance)	Selective broad-leaf control (particularly effective on undersown legumes weeds)	N (demonstrated toxicity to aquatic organisms)	I	NS	Absorbed through the leaves. Relatively short-lived in the soil though highly persistent in water
Metsulfuron Methyl (Brush-off, Ally, Associate)®	Selective of broad-leaved weeds but also able to control a variety of monocots when applied at higher rates especially Liliaceae and Commilinacea. Lower rates do affect monocots.	N (demonstrated toxicity to aquatic organisms)	B (potential resistance rotate with other herbicicdes)	NS	Mainly leaf absorbed. May persist for 3-6 months in the soil profile.
Metsulfuron + Glyphosate	Non-selective weed control and used with particular weeds or combination of weeds.	N (demonstrated toxicity to aquatic organisms)	MB (potential resistance rotate with other herbicicdes)	5	Mainly leaf absorbed, may persist for 3-6 months in the soil profile.
2,2-DPA	Grass (monocot) selective herbicide suitable for targeting dense weedy grass infestations amongst desirable native vegetation.	Yes (limited)	J	NS	Leaf and root absorbed

***Aquatic reg indicates that formulations of this herbicide may carry and aquatice registration, some formulations do not and individuals should check PUBRCRIS prior to assuming they have an aquatically regitered formulation. Addition of non-aquatically re...**

Gly	Glyphosate	eg. Weedmaster Duo®, Roundup Biactive®					
MM	Metsulfuron methyl	eg. Brushoff ®, Brushkiller®, Associate®					
S	Surfactant	eg. LI700®, Prosil®, Pulse®					
A	Spray Adjuvant	eg. Agral®, Protec®, Codacide®,					
D	Colour Marking Dye	eg. Herbi (red or blue) Liquid Dye®					

COMMON NAME	SCIENTIFIC NAME	APPLICATION METHOD	CHEMICAL	RATE	ADJUVENT	SURFACTANT	COMMENTS
TREES							
Cinese Celtis	*Celtis sinensis*	Stem Inject	Glyphosate	1:1.5 Gly:water			
		Cut, Scrape and Paint	Glyphosate	1:1.5 Gly:water			
		Basal Bark (saplings)	Fluroxypyr	210ml:10L diesel			
		spot-spray	Glyphosate	200ml:10L water + A + D			
			Glyphosate + Metsulfuron Methyl	200mL Gly + 1.5g MM in 10L water + S + A			
Camphor Laurel	*Cinnamomum camphora*	Stem Inject	Glyphosate	1:1.5 Gly:water			
		Cut, Scrape and Paint	Glyphosate	1:1.5 Gly:water			
		Basal Bark (saplings)	Fluroxypyr	210ml:10L diesel			
		Spot spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + S + D			
			Glyphosate	200ml:10l water + A + D			
Cadaghi	*Corymbia torelliana*	Cut, Scrape and Paint	Glyphosate	1:1.5 Gly:water			
		Stem Inject	Glyphosate	1:1.5 Gly:water			
		Basal Bark (saplings)	Fluroxypyr	210ml:10L diesel			
		Spot spray	Glyphosate	100ml Gly: 10L water + A + D			
Loquat	*Eriobotrya japonica*	Basal Bark(sapling)	Fluroxypyr	210ml:10L diesel			
		Spot spray	Glyphosate	200ml Gly:10L water +			
		Cut Scrape and Paint	Glyphosate	1:1.5 Gly:water			
		Stem Inject	Glyphosate	1:1.5 Gly:water			
Cockscomb Coral Tree and Coral Tree	*Erythrina crista-galli and E. x sykesii*	Spot spray	Glyphosate	200ml Gly:10L water + S+ A			
		Basal Bark (sapling)	Fluroxypyr	210ml/10L diesel			
		Cut Scrape and Paint	Glyphosate	1:1.5 Gly:water			
		Stem Inject	Glyphosate	1:1.5 Gly:water			
Brazilian cherry	*Eugenia uniflora*	Cut Scrape and Paint	Glyphosate	neat (undiluted)			
		Stem Inject	Glyphosate + Metsulfuron Methyl	1g MM added to 1 Gly:1.5 water			
		Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + S + D			
Golden Rain Tree	*Koelreuteria elegans; paniculata*	Cut Scrape and Paint	Glyphosate	1:1.5 Gly:water			
		Stem Inject	Glyphosate	1:1.5 Gly:water			
		Basal Bark (sapling)	Fluroxypyr	210ml:10L diesel			
		Spot spray	Glyphosate	100ml Gly:10L water + A + D			
Privet (Large and Small leaved)	*Ligustrum lucidum and L.sinense*	Spot Spray	Glyphosate	200ml Gly:10L water + S+ D			
			Metsulfuron methyl	1.5g MM:10L water + A + D			
			Fluroxypyr	30ml:10L water +			
		Cut Scrape and Paint	Glyphosate	1:1.5 Gly:water			
		Stem Inject	Glyphosate	1:1.5 Gly:water			
		Basal Bark (sapling)	Fluroxypyr	210ml:10L diesel			

Mulberry	*Morus spp.*	Spot Spray	Glyphosate	200ml Gly:10L water + S + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
		Basal Bark (Juvenile)	Fluroxypyr	210ml:10L diesel			
Canary Island Date Palm	*Phoenix canariensis*	Spot Spray	Glyphosate	200ml Gly:10L water + S + D			
		Stem Inject	Glyphosate + Metsulfuron Methyl	1g MM added to 1 Gly:1.5 water			
Guava	*Psidium guajava*	Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + S + D			
		Cut Scrape and Paint	Glyphosate + Metsulfuron Methyl	1g MM added to 1 Gly:1.5 water			
		Stem Inject	Glyphosate + Metsulfuron Methyl	1g MM added to 1 Gly:1.5 water			
Umbrella Tree	*Schefflera actinophylla*	Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate	1 Gly:1.5 water (do not stem inject when in flower)			
Broad-leaf Pepper Tree	*Schinus terebinthifolius*	Spot Spray	Glyphosate	200ml:10L water + S + A			
			Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + S + A			
			Fluroxypyr	30ml:10L water			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Basal Bark (sapling)	Fluroxypyr	210ml:10L diesel			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
Giant Devils Fig and Wild Tobacco	*Solanum chrysotrichum and S. mauritianum*	Spot Spray	Glyphosate	150ml Gly:10L water + A + D			
			Fluroxypyr	30ml/10L water			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Basal Bark (Juvenile/ Mature)	Fluroxypyr	210ml/10L diesel			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
African tulip tree	*Spathodea campanulata*	Spot Spray	Glyphosate	200ml Gly + 1.5g MM in 10L water + A + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
Cocos palm	*Syagrus romanzoffiana*	Stem Inject	Glyphosate + Metsulfuron Methyl	1g MM added to 1 Gly:1.5 water			
		Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
Yellow Bells	*Tecoma stans*	Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Basal Bark	Fluroxypyr	210ml/10L diesel			
		Spot Spray	Glyphosate	150ml Gly: 10L water + A + D			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
Tipuana	*Tipuana tipu*	Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate	1 Gly:1.5 water			

GRASSES							
Creeping Bamboo/ Clumping Bamboo	*Arundinaria spp./ Bambusa spp.*	Cut and spray (re-growth/seedling)	Glyphosate	100ml Gly: 10L water + D			
			2,2-DPA	150g:10L water			
		Cut stump and fill segment	Glyphosate	1 Gly:1.5 water			
Broad-leaved carpet grass, Narrow-leaved carpet grass, Para grass, Mosman River grass , Pangola grass, Guinea grass, Rhodes grass, Molasses grass, Sour grass, Paspalum, Bahia grass, Vasey grass, Broad-leaf paspalum, Kikuyu grass, Bana grass, Elephant grass	*Axonopus compressus, A. fissifolius, Brachiaria mutica, Cenchrus echinatus, Chloris gayana, Digitaria eriantha, Megathyrsus maximus, Melinis minutiflora, Paspalum conjugatum , P. dilatatum , P. notatum , P. urvillei , P. wettsteinii , Pennisetum clandesti*	Spot Spray	Glyphosate	100ml Gly:10L water + D			
Herbs							
Agave/Century plant	*Agave americana*	Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate	1g MM added to 1 Gly:1.5 water			
Crofton weed	*Ageratina adenophora*	Spot Spray	Glyphosate	100ml Gly:10L water + D			
			Metsulfuron methyl	1/2 - 1g MM: 10L water + D			
Mistflower	*Ageratina riparia*	Spot Spray	Glyphosate	100ml Gly:10L water + D			
			Metsulfuron methyl	1/2 - 1g MM: 10L water + D			
Blue billy-goat weed	*Ageratum houstonianum*	Spot Spray	Glyphosate	100ml Gly:10L water + D			
			Metsulfuron methyl	1g MM: 10L water + D			
			Fluroxypyr	30ml/10L water			
			2-4,D	30ml/10L water			
Ragweed	*Ambrosia artemisifolia*	Spot Spray	Glyphosate	100ml gly:10L water + A + D			
			Metsulfuron methyl	1.5g MM: 10L water + A + D			
Cobblers pegs	*Bidens pilosa var. pilosa*	Spot Spray	Fluroxypyr	30ml/10L water			
			2, 4-D	30ml/10L water			
			Glyphosate	100ml Gly: 10L water + A + D			
			Metsulfuron methyl	1g MM: 10L water + A + D			
Mother of Millions; Live Leaf Plant; Resurrection Plant	*Bryophyllum delagoense; Pinnatum*	Spot Spray	2, 4-D	50ml/10L water			
	Bryophyllum delagoense		Metsulfuron methyl	1.5g MM:10L water + S + D			
Purple/Green Succulent, Inch Plant	*Callisia fragran; repens*	Spot Spray	Fluroxypyr	90ml/10L water			
			Metsulfuron methyl	1.5g MM:10L water + S + D			
			Glyphosate	200ml Gly:10L water + A + D			
			Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			

Hairy Commelina; Trad (wandering Jew); Purple Succulent; Striped Trad	*Commelina benghalensis; Tradescantia fluminensis/ albiflora;Tradescantia pillida; Zebrina pendula syn Tradescantia zebrina*	Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
			Glyphosate	200ml Gly:10L water + A + D			
			Metsulfuron methyl	1.5g MM: 10L water + S + D			
			Fluroxypyr	90ml/10L water			
Glory lilly	*Gloriosa superba*	Foliar Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
Polka dot plant	*Hypoestes phyllostachya*	Spot Spray	Metsulfuron methyl	1.5g MM:10L water + S + D			
			Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
Fish bone fern	*Nephrolepis cordifolia*	Spot Spray	Metsulfuron methyl	1g MM: 10L + A/S + D			
			Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
Coral berry	*Rivinia humilis*	Spot Spray	Glyphosate	100ml Gly: 10L water + A + D			
			Glyphosate + Metsulfuron Methyl	100ml Gly + 1.5g MM in 10L water + A + D			
Mother-in-law's tongue	*Sansevieria trifasciata*	Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
Flannel Weed	*Sida cordifolia*	Spot Spray	Fluroxypyr	60ml/10L water			
Ground Asparagus	*Asparagus aethiopicus*	Spot Spray	Metsulfuron Methyl	1.5g MM : 10L water + A + D			
			Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A/S + D			
Singapore Daisy	*Sphagneticola trilobata*	Spot Spray	Metsulfuron methyl	1.5g MM in 10L water + A + D			
			Glyphosate + Metsulfuron Methyl	100ml Gly + 1g MM in 10L water + A + D			
SHRUBS							
Groundsel bush	*Baccharis halimifolia*	Spot Spray	2,4-D	40ml/10L water			
		Spot Spray	Glyphosate	200ml Gly:10L water + A + D			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
Green cestrum	*Cestrum parqui*	Spot Spray	Glyphosate	200ml Gly:10L water + A + D			
			Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
Duranta	*Duranta erecta*	Overall Spray (re-growth/seedling)	Glyphosate	200ml Gly:10L water + A + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
Lantana	*Lantana camara*	Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Spot Spray	Fluroxypyr	40ml/10L (spring, summer)-60ml/10L water (Autumn, Winter)			
		Spray (spot spray and overspray)	Glyphosate	100ml Gly:10L water + D			
		Spray Red Flowering species	Glyphosate	200ml Gly:10L water + A + D			
		Splatter Gun	Glyphosate	1 Gly:9 water			

Leucaena	*Leucaena leucocephela*	Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Spot Spray	Fluroxypyr	30ml/10L water			
HERBS							
Murraya	*Murraya paniculata*	Spot Spray	Glyphosate	200ml Gly:10L water + A + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
Mickey mouse bush	*Ochna serrulata*	Basal Bark	Fluroxypyr	210ml/10L diesel			
		Spot Spray	Fluroxypyr	30ml/10L water			
		Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A/S + D			
		Scrape (lightly) and Paint - juvenile	Glyphosate	neat (undiluted)			
		Cut Drill and Fill - mature	Glyphosate + Metsulfuron Methyl	1g MM added to 1 Gly:1.5 water			
Prickly pear	*Opuntia Spp.*	Spot Spray	Glyphosate + Metsulfuron Methyl	100ml Gly + 1.5g MM in 10L water + A + D			
		Cut Scrape and Paint in horizontal cuts across flat stems	Glyphosate + Metsulfuron Methyl	1g MM added to 1 Gly:1.5 water			
Castor Oil Plant	*Ricinus communis*	Spot Spray	2, 4-D	45ml/10L water			
			Glyphosate	100ml/ 10L water			
		Cut Scrape and Paint	Glyphosate	1g MM added to 1 Gly:1.5 water			
		Stem Inject	Glyphosate	1g MM added to 1 Gly:1.5 water			
Easter Cassia/ Winter Senna	*Senna pendula var. glabrata*	Spot Spray	Glyphosate	200ml Gly:10L water + A + D			
		Cut and Paint		1 Gly:1.5 water			
		Stem Inject (Mature)	Glyphosate	1 Gly:1.5 water			
Smooth senna	*Senna septemtrionalis*	Spot Spray	Glyphosate	200ml Gly:10L water + A + D			
		Cut and Paint	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
Yellow Oleander	*Thevetia peruviana*	Basal Bark	Fluroxypyr	210ml/10L Diesel			
		Spot Spray	Glyphosate	200ml Gly:10L water + A + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate	1 Gly:1.5 water			
VINES							
Madeira Vine	*Anredera cordifolia*	Spot Spray	Fluroxypyr	30ml/10L water			
		Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A/S + D			
		Scrape and Paint (mature vines)	Glyphosate	Scrape as much stem as possible in 1m lengths on alternate sides. Gouge and paint ground tubers. Scrape and paint roots			
Moth vine	*Araujia sericiflora*	Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
		Cut Scrape and Paint	Glyphosate (aerial)	1 Gly:1.5 water			

Dutchman's pipe	*Aristolochia elegans*	Spot Spray	Glyphosate + Metsulfuron Methyl	200ml Gly + 1.5g MM in 10L water + A + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
Climbing Asparagus	*Asparagus africanus; plumosus*	Basal Bark	Fluroxypyr	210ml/ 10L diesel			
		Spot Spray	Glyphosate	200ml Gly:10L water + A+ + D			
Balloon Vine	*Cardiospermum grandiflorum*	Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
		Spot Spray	Glyphosate	100ml Gly:10L water + D			
Green/ Silver-leaf desmodium; Siratro; Horesgram; Glycine	*Desmodium intortum; Macroptilium atropurpureum; Macrotyloma uniflorum; Neonotonia wightii*	Spot Spray	Glyphosate	200ml Gly:10L water + A+ + D			
			2,4-D	40ml/10L water			
			Glyphosate + Metsulfuron Methyl	100ml Gly + 1.5g MM in 10L water + A + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
Moon flower; Mile-a-minute; Morning Glory; Blue Morning Glory	*Ipomoea alba; I. cairica; I. indica and I.purpurea*	Spot Spray	Glyphosate + Metsulfuron Methyl	100ml Gly + 1.5g MM in 10L water + A + D			
			2, 4-D	30ml/10L water			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
Creeping Lantana	*Lantana montevidensis*	Spot Spray	2,4-D	40ml/10L water			
			Glyphosate + Metsulfuron Methyl	100ml Gly + 1.5g MM in 10L water + A + D			
			Metsulfuron methyl	1.5g MM : 10L water + A + D			
Cat's Claw Creeper	*Macfadyena unguis-cati*	Spot Spray	Glyphosate	100ml Gly : 10L water + S + D			
			Glyphosate + Metsulfuron Methyl	100ml Gly + 1g MM:10L water + A + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
Edible passionfruit; Stinking Passionflower; Corky Passionfruit; White Passionfruit	*Passiflora edulis; foetida; suberosa; subpeltata*	Spot Spray	Glyphosate + Metsulfuron Methyl	100ml Gly + 1g MM in 10L water + A + D			
			Glyphosate	200ml Gly:10L water + A + D			
			2,4-D	30ml/10L water			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
Kudzu	*Pueraria lobata*	Spot Spray	Glyphosate + Metsulfuron Methyl	100ml Gly + 1.5g MM in 10L water + A + D			
			Fluroxypyr	30ml/10L water			
		Gouge and Paint tubers	Glyphosate	1 Gly:1.5 water			
		Stem Inject	Glyphosate + Metsulfuron Methyl	1/1 (g) + 1g (MM) Per Litre of water			
Climbing nightshade	*Solanum seaforthianum*	Spot Spray	Fluroxypyr	30ml/10L water			
			Glyphosate	100ml Gly : 10L water + A + D			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			
Black eyed susan	*Thunbergia alata*	Spot Spray	2-4,D	30ml/10L water			
			Glyphosate	200mL in 10L water			
			Metsulfuron methyl	1.5g in 10L water			
		Basal Bark	Fluroxypyr	210ml/ 10L diesel			
		Cut Scrape and Paint	Glyphosate	1 Gly:1.5 water			