

Tamworth Hill Swamp Reserve Revegetation Plan

(Revegetation plan to meet the requirements of the WA Limestone EPBC Approval for sand and limestone extraction at Millar Road Baldivis)



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1.0 INTRODUCTION

1.1 Background

Tamworth Hill Swamp is a reserve that is vested in the Western Australian Planning Commission (WAPC) and managed by the City of Rockingham. The vesting of the reserve will be passed to the City of Rockingham in the 2013/2014 financial year under a land swap agreement with the WAPC as outlined in the Rockingham Lakes Regional Park Management Plan.

The reserve is located approximately 44 km south of the Perth Central Business District, and lies adjacent to the Baldivis Town Centre (Figure 1).



Figure 1: Site Locality

The wetland is bounded by Eighty Road to the west, reserved bushland and Tamworth Hill Reservoir to the north (over Eighty Road), Nairn Drive to the east and Safety Bay Road to the south (Figure 2). It covers an area of approximately 39 ha.



Figure 2: Site Boundary

1.2 Tamworth Hill Swamp

Tamworth Hill Swamp is a freshwater sumpland situated in the Stakehill suite of wetlands. The wetland is subject to a number of protection mechanisms, including:

- Inclusion in the Rockingham Lakes Regional Park management boundary;
- Bush Forever (Bush Forever Site 356);
- Parks and Recreation zoning under the Metropolitan Region Scheme (MRS).
- A Conservation Category Wetland (CCW) classification by the Department of Environment and Conservation (DEC); and
- Identification as an EPP Lake, as outlined in the EPA's *Environmental Protection (Swan Coastal Lakes) Policy* (EPA, 1992).

Tamworth Hill Swamp is also part of Regional Ecological Linkage – R122. Regional ecological linkages (also known as green corridors) comprise of regionally significant vegetation that is to be protected for the purpose of reducing habitat fragmentation caused by clearing for development.

1.3 Plan Objectives

This revegetation plan has been prepared to meet the requirements of the WA Limestone EPBC Approval for sand and limestone extraction on a site in Millar Road Baldivis. The approval notice for this proposal requires the preparation of a 'Tamworth Hill Swamp Reserve Revegetation Plan' (THSRRP) for the Minister's approval that identifies measures to minimise the impacts of the action on Black Cockatoos.

Specifically, the THSRRP must detail the following:

- Measures to establish the equivalent of at least 12ha of habitat known to be primary feeding plants for Black Cockatoos within the Tamworth Hill Swamp, through landscape planting;
- The revegetation methods to be undertaken within revegetation zones;
- Measures to ensure that seedlings being planted are free of dieback, (*pytophthora cinnamoni*);
- Timeframes and survival targets proposed for plantings;
- Feral animal and weed controls to be implemented;
- Fencing to be undertaken;
- Contingency measures if targets are not met;
- The monitoring and survey measures to be utilised, including timing schedules and reporting requirements;
- Roles and responsibilities of contractors, staff and the person taking the action, prior to, during and following the rehabilitation and revegetation works, and;
- How the WA DEC, CoR, or other conservation organisations, have been consulted in the preparation of the THSRRP.

The following strategy outlines how these requirements of the EPBC approval will be achieved.

2.0 EXISTING ENVIRONMENT

2.1 Biogeographic Region

The subject area is located within the Swan Coastal Plain biogeographic region, under the Interim Biogeographic Regions of Australia (IBRA) (Thackway & Cresswell, 1995). These bioregions are classified due to geographic distinctions in the common climate, geology, landform, native vegetation and local species information of the area.

2.2 Climate

The climate of the region within which the subject area occurs is Mediterranean, experiencing the majority of its rainfall over the winter months, with hot, dry summer months. The nearest meteorological station is Medina Research Centre (Station No: 9194), which records an annual rainfall of 759.7 mm, and an average daily maximum temperature of 24.3°C (BOM, 2013). Winter rainfall in 2012 was relatively low, with July experiencing the lowest rainfall in 30 years at this location (39.4 mm compared to 163 mm in 2011) (BOM, 2013).

2.3 Landform, Geomorphology and Soils

Tamworth Hill Swamp is relatively flat and low-lying, occurring for its majority at 5mAHD. In comparison, Tamworth Hill, located immediately north-west of the swamp reaches a maximum height of 75mAHD. Tamworth Hill Swamp occurs within the Spearwood Dune System, where it has formed within an interdunal depression. The geomorphological classification of the wetland site (Gozzard, 1983) is Lm – marsh in interbarrier depression, low-level. The wetland overlies the following soil-landscape phases (DAFWA, 2007):

- Spearwood Wet Swamp Phase (211SpW_Swamp) - Swamp; sand over limestone;
- Spearwood S2a Phase (211Sp_S2a) - Lower slopes (1 - 5%) of dune ridge with moderately deep to deep siliceous yellow-brown sands or pale sands with yellow-brown subsoils and minor limestone outcrop;
- Spearwood S4a Phase (211Sp_S4a) - Flat to gently undulating sandplain with deep, pale and sometimes bleached, sands with yellow-brown subsoils;
- Spearwood S4c Phase (211Sp_S4c) - Flat to gently undulating sandplain with deep, yellow-brown or dark brown siliceous sands that are seasonally inundated.

2.4 Hydrology and Wetlands

Tamworth Hill Swamp is a large sumpland, surrounded by residential and commercial development. It is protected under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* and has been assigned a Conservation management

category by the DEC. The wetland forms part of the Stakehill wetland suite (Hill et al, 1996) and is also included in the Rockingham Lakes Regional Park, for which a Management Plan has been developed. The groundwater beneath the site lies within the Stakehill Groundwater Area. Groundwater flow (of the superficial aquifer) is west into Lake Cooloongup and into the ocean, or may filter down through the sandy substrate into the Rockingham Sand Aquifer. Groundwater salinity lies between 1000 and 2000 mg/L Total Dissolved Solids (TDS) (DoW, 2008).

Water quality within the wetland, when testing was undertaken in 1993/1994, indicated high water quality with low salinity and nutrient levels, and high concentrations on dissolved oxygen (EPA, 1994). It was determined to be relatively unpolluted compared to other wetlands in the metropolitan area.

2.5 Vegetation and Flora

Vegetation and flora has been assessed based on regional desktop information, and from a detailed on-site botanical assessment of the vegetation and flora community types and condition.

2.5.1 Regional Context

Tamworth Hill Swamp occurs in the Cottesloe Complex – Central and South in the north-western portion of the site and the Karrakatta Complex – Central and South in the south-eastern area (Heddle et al, 1980). These vegetation complexes are described as follows:

- Cottesloe Complex – Central and South: Mosaic consisting of a Woodland of *Eucalyptus gomphocephala*; an Open Forest of *Eucalyptus gomphocephala* – *Eucalyptus marginata* subsp. *marginata* – *Corymbia calophylla*; and a Closed Heath on the limestone outcrops.
- Karrakatta Complex – Central and South: Open forest of *Eucalyptus gomphocephala*, *E. marginata*, *Corymbia calophylla* and woodland of *E. marginata* and *Banksia* species.

2.5.2 Bush Forever

The entirety of the wetland is encompassed by Bush Forever Site No. 356 – Lake Cooloongup, Lake Walyungup and Adjacent Bushland, Hillman to Port Kennedy (DEP, 2000)

2.5.3 Vegetation Types

The vegetation types across the subject area largely consisted of Forest / Woodland and Sedgeland. Hill et al (1996) describes the wetland vegetation as concentric form, which is defined as complete or almost complete vegetation cover with vegetation types occurring in concentric zones. Vegetation types are described below:

- Er - Forest of *Eucalyptus rudis* subsp. *rudis* in sandy loam, with understorey varying between the following:
 - Scrub of *Melaleuca teretifolia* over Dense Tall Sedges of *Baumea juncea* and *Gahnia trifida*;
 - **Ficus carica* and **Cenchrus clandestinus*; and
 - Tall Sedges of *Baumea juncea*.
- Mr - Low Forest A of *Melaleuca raphiophylla* in sandy loam. Marked differences in the understorey were observed in this vegetation unit:
 - Dense understorey of grass weeds;
 - Tall Sedges of *Baumea articulata*, *Baumea juncea*, *Gahnia trifida*;
 - Tall trees of *Melaleuca teretifolia*;
 - Tall Sedges of *Baumea articulata*;
 - Understorey dominated by Herbs of *Centella asiatica* and *Lobelia anceps*; and
 - Scrub of *Myoporum caprarioides* over Open Herbs of *Centella asiatica* over Tall Sedges of *Baumea juncea* and *Gahnia trifida*.
- Ba - Dense Tall Sedges of *Baumea articulata* in wet black sandy mud.
- Bj - Dense Tall Sedges of *Baumea juncea* in black sandy clay.

Reed / sedge wetlands are comparatively rare on the Swan Coastal Plain and are important habitats for shy and uncommon waterbird species. It is expected that these sedgelands survive during drier years by utilising the moisture retained by the peaty soils within the wetland.

2.5.4 Vegetation Condition

The vegetation condition of the swamp varied between Very Good and Good with some of the dampland in Excellent condition (Figure 3). Where the swamp was bordered by the cleared area around the perimeter and where the houses on the western side adjoined the remnant vegetation, the vegetation consisted of weed species and as such is classified as Completely Degraded (BEC, 2012).



Figure 3: Vegetation Units and Condition

2.5.5 Threatened Ecological Communities

One Threatened Ecological Community is recorded for Bush Forever Site No. 356 (DEP, 2000), within which Tamworth Hill Swamp occurs. It is Floristic Community Type 19 (Gibson et al., 1994). It is described as Sedgelands in Holocene dune swales of the southern Swan Coastal Plain. It is listed as critically endangered under the *Wildlife Conservation Act 1950* and Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The reason for its listing is its currently known limited distribution as there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes (BEC, 2012).

2.5.7 Weed Mapping

A total of 56 weeds have been identified within the subject area, all of which have been determined as weeds by the Western Australian Herbarium (2012) and DEC (2012c) (Figure 4).

A weed priority rating was applied to each weed species found within the subject area:

- High – weeds that have a rapid rate of invasiveness, widespread current or potential distribution and a high environmental impact;
- Moderate – weeds that have 2 of the characters listed above;
- Mild – weeds that have 1 of the characters listed above; and
- Low – weeds that have none of the above characters.

Twenty weeds recorded a priority weed rating of High, eighteen recorded a Moderate weed rating, eleven as a Mild weed rating and six as a Low weed rating.

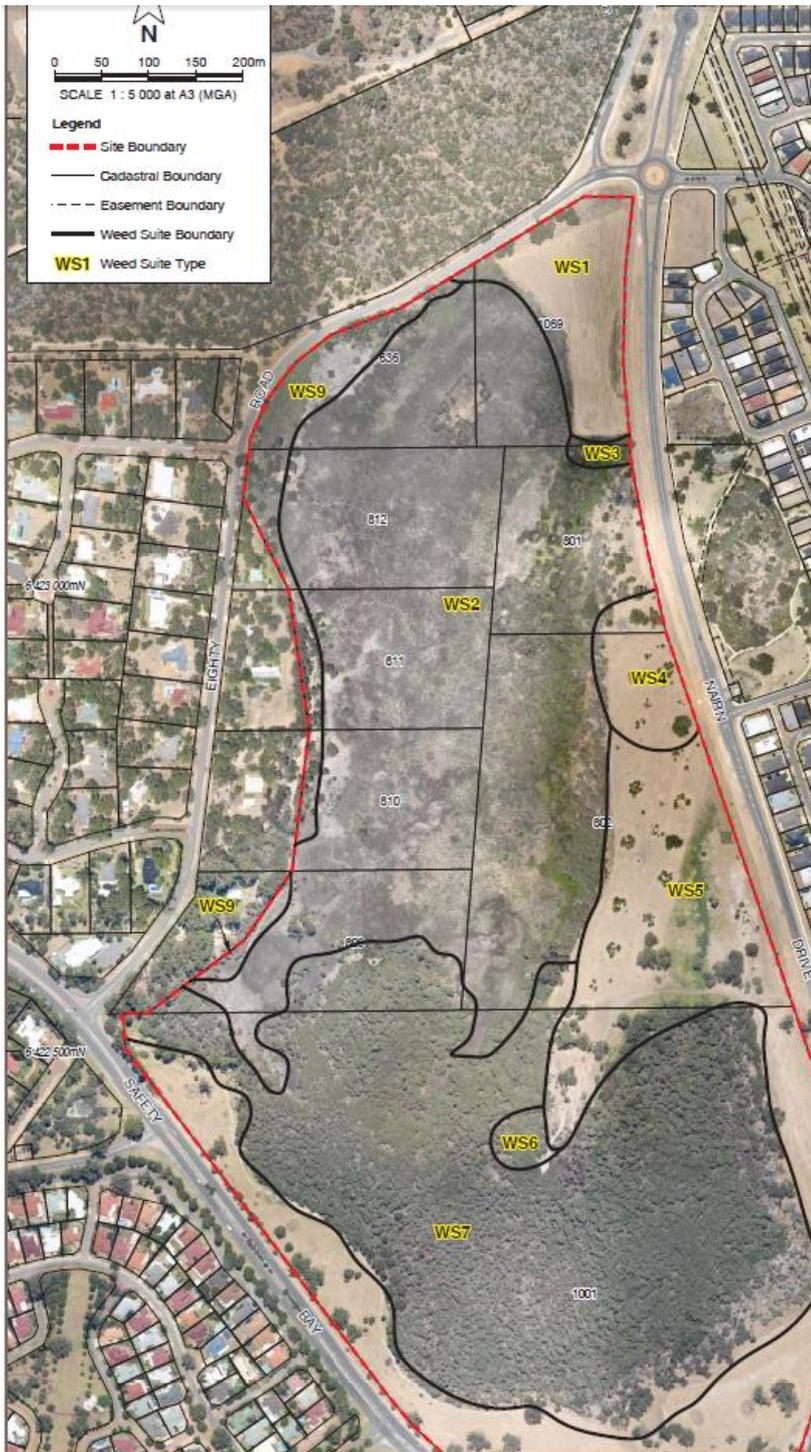
**Ficus carica*, although rated as moderate appears to be aggressive in the wetland and should be targeted for removal. It is common through the Woodland of *Melaleuca raphiophylla* and also both Sedgelands. Some of the **Ficus carica* were in immature fruit, but birds will be a disperser of their seeds, meaning that control will be an ongoing concern for some time.

**Gomphocarpus fruticosus* and **Cortaderia selloana* were also common in the Sedgeland of *Baumea juncea*. **Cortaderia selloana* also occurred in some areas of the Woodland of *Melaleuca raphiophylla*. Both of these have a high rating but care will need to be taken with their removal.

The following are Declared plants under the *Agriculture and Related Resources Protection Act 1976*. Removal of these should occur to ensure there is no further spread:

- **Solanum linnaeanum* - Apple of Sodom
- **Gomphocarpus fruticosus* - Swan Plant

Figure 4: Weed Mapping



Weed Suite 1: Cleared area at the northern end of the site beside Naim Road. The whole area is cleared. At the very northern road edge there were a few *Corymbia calophylla* and *Banksia grandis* trees and beside the swamp there were a few *Melaleuca raphiophylla* trees.

The dominant weeds were **Ehrharta calycina* 75%; **Bromus diandrus* 25%; **Lolium rigidum* 15%; **Hypochaeris glabra* and **Acetosella vulgaris* both 5%; and **Lupinus cosentinii*, and **Tritolium hirtum* both 3%.

Weed Suite 2: In Sedges of *Baumea juncea*. Dominant weed species include; **Ficus carica*;* *Gomphocarpus fruticosus*, **Conyza sumatrensis*, **Cortaderia selloana* and **Bromus diandrus*.

Weed Suite 3: Small section of **Typha orientalis* on the swamp boundary. This was a small area only in a very damp section on the perimeter of the swamp. A drain ran through this area.

Dominant weed species include; **Avena barbata*, **Bromus diandrus*, **Cenchrus clandestinus*, **Conyza sumatrensis*, **Ehrharta calycina*, **Euphorbia terracina*, **Gomphocarpus fruticosus*, **Solanum linnaeanum*, **Typha orientalis*.

Weed Suite 4: Degraded area on the east side of the swamp, extends up to Naim Road. Area includes scattered trees of *Eucalyptus gomphocephala* and *Eucalyptus rudis* subsp. *rudis* and shrubs of *Acacia saligna* and *Acacia pulchella* var. *pulchella*.

Dominant weed species include; **Acetosella vulgaris*, **Euphorbia terracina*, **Lupinus luteus*, **Bromus diandrus*, **Lagurus ovatus*, **Orobancha minor*, **Cenchrus clandestinus*, **Lolium rigidum*, **Solanum linnaeanum*, **Ehrharta calycina*, **Lupinus angustifolius*, **Tritolium campestre*, **Erodium botrys*, **Lupinus cosentinii*.

Weed Suite 5: Continuation of above but large areas of **Euphorbia terracina* and continues further south as a dominant. The area included scattered trees of *Eucalyptus rudis* subsp. *rudis*, plants of the sedge *Gahnia trifida* and herb *Centella asiatica*.

Dominant weed species include; **Arctotheca calendula*, **Euphorbia terracina*, **Lysimachia anvensis*, **Avena barbata*, **Hypochaeris glabra*, **Romulea rosea*, **Bromus diandrus*, **Lagurus ovatus*, **Sonchus oleraceus*, **Carduus pycnocephalus*, **Lotus subbiflorus*, **Tritolium campestre*, **Ehrharta longiflora*, **Vulpia bromoides*.

Weed Suite 6: In Woodland of *Melaleuca raphiophylla*. A very weedy area surrounded by very good condition vegetation. It included about 20 Pampas Grass plants. Dominant weed species include; **Carduus pycnocephalus*, **Heliophila pusilla*, **Cortaderia selloana*, **Phytolacca octandra*, **Ehrharta longiflora*, **Solanum americanum*, **Ficus carica*, **Sonchus oleraceus*.

Weed Suite 7: In Woodland of *Melaleuca raphiophylla*. Dominant weed species include; **Carduus pycnocephalus*, **Heliophila pusilla*, **Cortaderia selloana*, **Phytolacca octandra*, **Ficus carica*, **Schinus terebinthifolius*.

Weed Suite 8: Frontage on Safety Bay Road. Occasional trees of *Eucalyptus gomphocephala*, *Eucalyptus rudis* subsp. *rudis* and *Melaleuca raphiophylla* and shrubs of *Acacia saligna*.

Dominant weed species include; **Bromus diandrus*, **Euphorbia terracina*, **Cenchrus clandestinus*, **Hypochaeris glabra*, **Ehrharta calycina*, **Lupinus luteus*, **Ehrharta longiflora*.

Weed Suite 9: Along the western boundary in front of the houses. Dominant weed species include; **Briza minor*, **Fumaria capreolata*, **Raphanus raphanistrum*, **Carduus pycnocephalus*, **Hypochaeris glabra*, **Silene gallica*, **Cenchrus clandestinus*, **Lactuca serriola*, **Solanum nigrum*, **Conyza sumatrensis*, **Lolium rigidum*, **Sonchus oleraceus*, **Ehrharta longiflora*, **Lysimachia anvensis*, **Stellaria media*, **Euphorbia terracina*, **Pelargonium capitatum*, **Stenotaphrum secundatum*, **Ficus carica*, **Polypogon maritimus*, **Vicia sativa*.

Along the verge of Eighty Road to the north of the houses the understorey consists of dense **Stenotaphrum secundatum* and **Cenchrus clandestinus*.

3.0 MANAGEMENT AND IMPLEMENTATION STRATEGY

The overall management strategy of Tamworth Hill Swamp has been designed based on the management requirements of each management zone within the site boundary (refer to Figure 5). Each of these zones has been mapped based on their current condition, predominant weed species or suites and the vegetation communities found in each zone. These physical characteristics will guide the management and rehabilitation response for each zone to ensure treatment is targeted and effective.



Figure 5: Management Zones

The focus of management for the reserve is to protect and maintain areas of the site that are in better condition, and then work towards improving and rehabilitating degraded areas.

The priority management zones for the purpose of implementing the THSRRP as a requirement of the EPBC Approval for the sand and limestone extraction are zones 1- 5 & 7 see (priority rehabilitation mapping below).

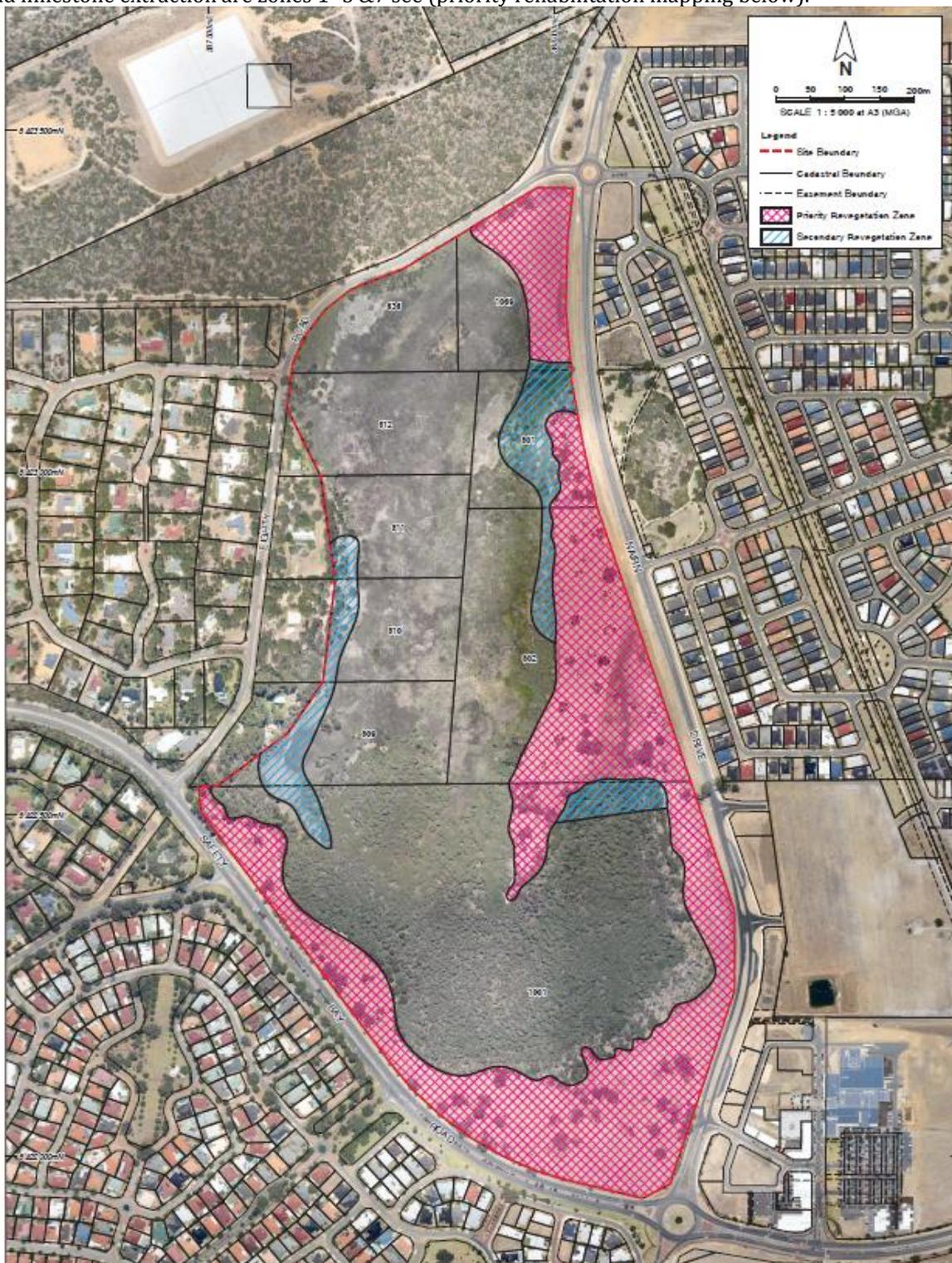


Figure 6: Priority Rehabilitation Areas

3.1 Management Strategies for all Zones 1-5 & 7

While each zone will require a different approach based on current condition, type and weed species, some of the management requirements are applicable to the wider site. A proposed revegetation species list for the whole site is provided in Appendix A. and weed control measures for all the high priority weeds identified across the site are outlined in Appendix B. Additional actions that are applicable across all zones are detailed below.

3.1.1 Fencing and Access

Unauthorised vehicle access is not permitted within the site, and will be prevented by inspecting and repairing the current boundary fence to a standard that prevents all types of vehicle access (including 4wd's and motorbikes). Locked emergency access gates should be installed (if not already) in strategic locations to allow access into the site for emergency vehicles. The indicative location for these gates is shown on the following infrastructure plan (Figure 7).



Figure 7: Infrastructure Plan

In addition a few pedestrian access gates will be installed at strategic openings into the site, to encourage controlled pedestrian access. Pedestrian gates will be constructed so as to permit only people and prams/push-bikes. In order to ensure pedestrian access is managed and controlled, and to ensure emergency vehicle access is maintained, an upgrade of the existing track is recommended. This can be achieved through the installation of crushed limestone over the existing fire access track, at 200mm depth, and 4m across to allow emergency vehicles to comfortably navigate.

3.1.2 Feral Animal Control

Surveying for the development of this plan also included a specific search for evidence of introduced fauna. There was little evidence within the reserve of feral fauna occurring. To ensure that this remains the case, the following recommendations for all zones are made:

- Minimise the construction of additional tracks and pathways throughout and leading into the reserve, as this provides exotic fauna easy access to the area;
- Install physical barriers to exotic fauna, such as updated fencing that excludes fauna such as foxes, cats and rabbits; and
- If introduced fauna colonise the area and negatively impact the native fauna presiding in the reserve, a control program may have to be implemented.

3.1.3 Seed Collection

Seed collection will be one of the methods utilised to gain stock for use in the revegetation program. Seeds will be collected from suitable species included on the revegetation species list by qualified revegetation personnel and stored in a seed bank system for later usage onsite.

Seed collection is generally undertaken in between October and February. Seed collection will be restricted to a maximum of 20% from any one plant. Seeds collected from the site will be utilised in the revegetation (either through direct seeding or propagation and planting), direct seeding will also be supplemented with purchased tubestock. This will ensure adequate numbers of revegetation stock are available and will allow for purchase of plant which have proved difficult to grow from onsite seeds, or which are propagated by other methods. The seed collection program is proposed to be undertaken for two years to develop the seed bank for future use at the site.

3.1.4 Site Preparation Works

Prior to planting the areas proposed for revegetation, all sites should be adequately prepared to maximise the survival success of all planted vegetation. The following must be undertaken, as a minimum, to prepare the site:

- Temporary fencing must be constructed around planting areas.
- The degraded and cleared planting areas must be ploughed and ripped, with ripping to one metre undertaken during late summer to early autumn. Ripping within this soil type (largely sand with some clay) is unlikely to require heavy machinery; a multi-tynd ripper will be suitable (White and Mullan, 2010). This approach is not considered necessary in better condition bushland areas, where the focus is more on natural regeneration as opposed to revegetation.
- Where necessary (in low lying areas), planting areas should be mounded to avoid waterlogging of soil. This should be undertaken in mid-winter to ensure sufficient mounding. Erosion control should be introduced where mounding has occurred. Mounds are sufficient between 5 to 10 cm above ground level (White and Mullan, 2010).
- A sufficient settling interval of one month should be enforced prior to planting.
- Weed control must be undertaken in planting areas / rip lines, using a residual and knockdown herbicide (eg. Round-up) to target couch grass, sorrel and dock in particular. This should be undertaken twice (i.e. in May/June and then approximately two weeks prior to planting) (White and Mullan, 2010).
- Appropriate withholding periods (usually two weeks) must be observed following application of herbicides.
- If soil is required to be imported onto the site it must be sourced from a certified dieback free source.
- All workers will be made aware of the potential spread of dieback and the requirement to keep machinery and vehicles entering the site to be free of any soil or vegetative matter, particularly if they have been working on another site from which the dieback status is unknown.

3.1.5 Planting and Planting Density

Plants will be installed at a density on 1 plant/m². Where existing vegetation is present within each zone, the target will be to achieve this density across the whole zone. Therefore if the existing bushland is in poor condition, then plants will be installed in the bushland to increase the density of native vegetation within that section of bushland, to an average of 1 plant/m². This is meant to be used as a rough guide, and some on-site interpretation will be necessary, however as a general rule, where enough open space or weed affected areas exists to undertake revegetation, plantings should occur.

Revegetation areas within low lying edges of the wetland that receive inundation will be planted predominantly with rushes and sedges, and scattered trees suitable for establishment in a wetland zone (such as *Melaleuca rhaphiophylla*).

Planting will also not be undertaken in designated firebreak areas. Tubestock planting may be reduced if direct seeding is used, but the density targets for each zone will still be used to assess success of the program once the seed stock has germinated. All tubestock will be planted with a fertiliser tablet and rabbit guards to prevent foraging by rabbits and kangaroos. All tubestock must be certified dieback free before planting.

The individual management requirements for each relevant zone (Zones 1- 7) are outlined below.

3.2 Zone 1

3.2.1 Description

This zone has been historically cleared of understorey and heavily impacted by unauthorised human access and use, and weed invasion. Occasional trees of *Eucalyptus gomphocephala*, *Eucalyptus rudis* subsp. *rudis* and *Melaleuca raphiophylla* and shrubs of *Acacia saligna* exist in Zone 1. The vegetation condition in this zone was identified as 'Degraded'.

3.2.2 Weed Control Strategy

Weed control should be undertaken as a priority to allow control over weeds as much as practicable prior to undertaking revegetation works.

Therefore it is recommended that intensive weed control be undertaken in the first year, in accordance with the management requirements for each of the high priority weeds identified in this zone outlined in the table below. The management, control measures and optimal timing for control of all high priority weed species can be found in Appendix B of this document.

Table 1: High priority weed species in Zone 1

Weed Species (Common Name)
* <i>Bromus diandrus</i> (Great Brome)
* <i>Ehrharta calycina</i> (Perennial Veldt Grass)
* <i>Ehrharta longiflora</i> (Annual Veldt Grass)
* <i>Euphorbia terracina</i> (Geraldton Carnation Weed)
* <i>Hypochaeris glabra</i> (Flat Weed)

Refer to Appendix B for descriptions of control methods of high rating.

3.2.3 Revegetation Strategy

Revegetation will be undertaken across the cleared areas, which is the majority of this zone. Revegetation will include a mixture of direct seeding and tubestock planting (depending on resourcing at the time). Monitoring will be undertaken annually following planting to monitor the success of the program, and identify where additional management should be concentrated.

Area requiring revegetation and clearing in Zone 1 is approximately 9ha (90,000m²). Plantings will consist of the following approximate structure for this zone:

- 20% overstorey species
- 50% middle storey species
- 30% understorey species

Refer to Appendix A for the planting species list and what is appropriate for planting in each zone.

3.3 Zone 2

3.3.1 Description

This zone has been historically cleared of understorey and heavily impacted by unauthorised human access and use, and weed invasion. The area includes scattered trees of *Eucalyptus rudis* subsp. *rudis*, plants of the sedge *Gahnia trifida* and herb *Centella asiatica*. The vegetation condition in this zone was identified as 'Degraded'.

3.3.2 Weed Control Strategy

Weed control should be undertaken as a priority to allow control over weeds as much as practicable within this zone.

It is recommended that intensive weed control be undertaken in the first year, in accordance with the management requirements for each of the high priority weeds identified in this zone outlined in the table below. The management, control measures and optimal timing for control of all high priority weed species can be found in Appendix B of this document.

The botanical assessment in this zone determined that large areas of **Euphorbia terracina*, are widespread across this zone. All high priority weeds located in Zone 2 are outlined in the table below.

Table 2: High priority weed species in Zone 2

Weed Species (Common Name)
<i>*Arctotheca calendula</i> (Cape Weed) - Not high priority, but common in Zone 2
<i>*Avena barbata</i> (Bearded Oats)
<i>*Bromus diandrus</i> (Great Brome)
<i>*Carduus pycnocephalus</i> (Slender Thistle)
<i>*Ehrharta longiflora</i> (Annual Veldt Grass)
<i>*Euphorbia terracina</i> (Geraldton Carnation Weed)
<i>*Hypochaeris glabra</i> (Flat weed)
<i>*Lagurus ovatus</i> (Hare's Tail Grass)
<i>*Romulea rosea</i> (Guildford Grass) - Not high priority, but common in Zone 2
<i>*Vulpia bromoides</i> (Squirrel Tail Fescue)

Refer to Appendix B for descriptions of weed control methods

3.3.3 Revegetation Strategy

Revegetation for zone two will include a mixture of direct seeding and tubestock planting (depending on resourcing at the time). Monitoring will be undertaken annually following planting to monitor the success of the program (refer Section 6.0), and identify where additional management should be concentrated.

Area requiring revegetation and clearing in Zone 2 is approximately 9.6 ha (96,000m²). Plantings will consist of the following approximate structure for this zone:

- 20% overstorey species
- 50% middle storey species
- 30% understorey species

Refer to Appendix A for the planting species list and what is appropriate for planting in each zone.

3.4 Zone 3

3.4.1 Description

Mixture of forest of *Eucalyptus rudis* subsp. *rudis*, and *Melaleuca raphiophylla* over Low Woodland of **Ficus carica* and open low grass of **Cenchrus clandestinus*. The vegetation condition in this zone was identified as 'Degraded'.

3.4.2 Weed Control Strategy

Weed control should be undertaken as a priority to allow control over weeds as much as practicable within this zone. It is recommended that intensive weed control be undertaken in the first year, in accordance with the management requirements for each of the high priority weeds identified in this zone outlined in the table below. The management, control measures and optimal timing for control of all high priority weed species can be found in Appendix B of this document.

Table 3: High priority weed species in Zone 3

Weed Species (Common Name)
<i>*Arctotheca calendula</i> (Cape Weed) - Not high priority but common in Zone 3
<i>*Avena barbata</i> (Bearded Oats)
<i>*Bromus diandrus</i> (Great Brome)
<i>*Carduus pycnocephalus</i> (Slender Thistle)
<i>*Ehrharta longiflora</i> (Annual Veldt Grass)
<i>*Euphorbia terracina</i> (Geraldton Carnation Weed)
<i>*Hypochaeris glabra</i> (Flat weed)
<i>*Lagurus ovatus</i> (Hare's Tail Grass)
<i>*Romulea rosea</i> (Guildford Grass) - Not high priority but common in Zone 3
<i>*Vulpia bromoides</i> (Squirrel Tail Fescue)

3.4.3 Revegetation Strategy

Zone 3 is within the second priority area for revegetation works, and therefore will be prioritised for planting works, however not in advance of the priority zones (1, 2 and 5). Therefore revegetation will include a mixture of direct seeding and tubestock planting (depending on resourcing at the time). Monitoring will be undertaken annually following planting to monitor the success of the program, and identify where additional management should be concentrated.

Area requiring revegetation and clearing in Zone 3 is approximately 425 m².

Plantings will consist of the following approximate structure for this zone:

- 10% overstorey species
- 50% middle storey species
- 30% understorey species

3.5 Zone 4

3.5.1 Description

This zone is described as a mixture of low forest of *Melaleuca raphiophylla* and dense tall sedges of *Baumea juncea*. The vegetation condition in this zone varies between 'Good to Degraded', to 'Degraded'.

3.5.2 Weed Control Strategy

Weed control should be undertaken as a priority to allow control over weeds as much as practicable within this zone. It is recommended that intensive weed control be undertaken in the first year, in accordance with the management requirements for each of the high priority weeds identified in this zone outlined in the table below. The management, control measures and optimal timing for control of all high priority weed species can be found in Appendix B of this document.

Table 3: High priority weed species in Zone 4

Weed Species (Common Name)
* <i>Avena barbata</i> (Bearded Oats)
* <i>Ehrharta calycina</i> (Perennial Veldt Grass)
* <i>Ehrharta longiflora</i> (Annual Veldt Grass)

3.5.3 Revegetation Strategy

Zone 4 is within the second priority area for revegetation works, and therefore will be prioritised for planting works, however not in advance of the priority zones (1, 2 and 5). Therefore, revegetation will include a mixture of direct seeding and tubestock planting (depending on resourcing at the time). Monitoring will be undertaken annually following planting to monitor the success of the program, and identify where additional management should be concentrated.

Area requiring revegetation and clearing in Zone 4 is approximately 0.54ha (5,400m²).

Plantings will consist of the following approximate structure for this zone:

- 5% overstorey species
- 40% middle storey species
- 55% understorey species (including sedges and rushes)

Refer to Appendix A for the planting species list and what is appropriate for planting in each zone.

3.6 Zone 5

3.6.1 Description

This zone consists of cleared open paddock with limited native vegetation remaining. The vegetation condition in this zone was assessed as 'Degraded'.

3.6.2 Weed Control Strategy

Weed control should be undertaken as a priority to allow control over weeds as much as practicable within this zone. It is recommended that intensive weed control be undertaken in the first year, in accordance with the management requirements for each of the high priority weeds identified in this zone outlined in the table below. The botanical assessment determined that the dominant weeds were **Ehrharta calycina* (75%); **Bromus diandrus* (25%); **Lolium rigidum* (15%); **Hypochaeris glabra* and **Acetosella vulgaris* both (5%).

Table 4: High priority weed species in Zone 5

Weed Species (Common Name)
<i>*Arctotheca calendula</i> (Cape Weed) - Not high priority but common in Zone 5
<i>*Avena barbata</i> (Bearded Oats)
<i>*Brassica tournefortii</i> (Mediterranean Turnip, Wild Turnip)
<i>*Bromus diandrus</i> (Great Brome)
<i>*Ehrharta calycina</i> (Perennial Veldt Grass)
<i>*Euphorbia terracina</i> (Geraldton Carnation Weed)
<i>*Hypochaeris glabra</i> (Flat Weed)

3.6.3 Revegetation Strategy

Zone 5 is one of the priority revegetation areas, as outlined in the EPBC approval notice. Therefore revegetation will be undertaken across the cleared areas, which is the majority of this zone. Revegetation will include a mixture of direct seeding and tubestock planting (depending on resourcing at the time). Monitoring will be undertaken annually following planting to monitor the success of the program and identify where additional management should be concentrated.

Area requiring revegetation and clearing in Zone 5 is approximately 2.1 ha (21,000m²).

Plantings will consist of the following approximate structure for this zone:

1. 20% overstorey species
2. 50% middle storey species
3. 30% understorey species

3.7 Zone 7

3.8.1 Description

This zone is described as a mixture of dense tall sedges of *Baumea juncea* and dense tall sedges of *Baumea articulate*, with parkland cleared trees adjacent to the private properties on the western side. The vegetation condition in this zone is mostly 'Good' to 'Degraded', with pockets of dense sedges in 'Excellent' condition.

3.8.2 Weed Control Strategy

Weed control should be undertaken as a priority to allow control over weeds as much as practicable within this zone. It is recommended that intensive weed control be undertaken in the first year, in accordance with the management requirements for each of the high priority weeds identified in this zone outlined in the table below.

Table 5: High priority weed species in Zone 7

Weed Species (Common Name)
<i>*Carduus pycnocephalus</i> (Slender Thistle)
<i>*Ehrharta longiflora</i> (Annual Veldt Grass)
<i>*Euphorbia terracina</i> (Geraldton Carnation Weed)
<i>*Hypochaeris glabra</i> (Flat Weed)
<i>*Lactuca serriola</i> (Prickly Lettuce)
<i>*Pelargonium capitatum</i> (Rose Pelargonium)

In addition to the high priority weeds identified above, the botanical assessment determined along the verge of Eighty Road to the north of the houses the understorey consists of dense **Stenotaphrum secundatum* and **Cenchrus clandestinus*. These areas should be targeted to avoid significant further weed spread.

3.8.3 Revegetation Strategy

Zone 7 is within the second priority area for revegetation works, and therefore will be prioritised for planting works, however not in advance of the priority zones (1, 2 and 5). Therefore revegetation will include a mixture of direct seeding and tubestock planting (depending on resourcing at the time). Areas in obviously good condition (i.e. areas of thick native sedges) will be avoided for revegetation works. Monitoring will be undertaken annually following planting to monitor the success of the program, and identify where additional management should be concentrated.

Area requiring revegetation and clearing in Zone 7 is approximately 0.44ha (4,400m²).

Plantings will consist of the following approximate structure for this zone:

- 5% overstorey species
- 40% middle storey species
- 55% understorey species (including sedges and rushes)

4.0 IMPLEMENTATION SCHEDULE

The schedule has been developed to provide optimal rehabilitation planning of the site over the first 3 years. Ultimately the best results will be achieved if all zones are managed in unison, however this isn't always feasible. This schedule should be considered past 3 years to ensure ongoing management of rehabilitated areas. It is important to continue weed control measures long term to enable the natural bushland to re-establish.

Table 6: Implementation Schedule

	Zone 1 (priority reveg zone)	Zone 2 (priority reveg zone)	Zone 3 (2 nd priority reveg zone)	Zone 4 (2 nd priority reveg zone)	Zone 5 (priority reveg zone)	Zone 7 (2 nd priority reveg zone)
Year 1	<ul style="list-style-type: none"> • Intensive broadscale weed spraying/control (refer to Appendix A) 	<ul style="list-style-type: none"> • Intensive broadscale weed spraying/control (refer to Appendix A) 	<ul style="list-style-type: none"> • Weed control (refer to Appendix A) 	<ul style="list-style-type: none"> • Weed control (refer to Appendix A) 	<ul style="list-style-type: none"> • Intensive broadscale weed spraying/control (refer to Appendix A) 	<ul style="list-style-type: none"> • Weed control (refer to Appendix A)
Year 2	<ul style="list-style-type: none"> • Intensive broadscale weed spraying/control. • Site preparation including soil ripping. • Tubestock planting and direct seeding (Refer to Appendix B) 	<ul style="list-style-type: none"> • Intensive broadscale weed spraying/control. • Site preparation including soil ripping. • Tubestock planting and direct seeding. (Refer to Appendix B) 	<ul style="list-style-type: none"> • Weed control. • Site preparation including soil ripping and temporary fencing. • Tubestock planting and direct seeding. (Refer to Appendix B) 	<ul style="list-style-type: none"> • Weed control. • Site preparation including soil ripping and temporary fencing. • Tubestock planting and direct seeding. (Refer to Appendix B) 	<ul style="list-style-type: none"> • Intensive broadscale weed spraying/control. • Site preparation including soil ripping. • Tubestock planting and direct seeding. (Refer to Appendix B) 	<ul style="list-style-type: none"> • Weed control. • Site preparation including soil ripping and temporary fencing. • Tubestock planting and direct seeding. (Refer to Appendix B)
Year 3 - onwards	<ul style="list-style-type: none"> • Ongoing weed control. • Monitor success against survival criteria. • Replace lost seedlings. 	<ul style="list-style-type: none"> • Ongoing weed control. • Monitor success against survival criteria. • Replace lost seedlings. 	<ul style="list-style-type: none"> • Ongoing weed control. • Monitor success against survival criteria. • Replace lost seedlings. 	<ul style="list-style-type: none"> • Ongoing weed control. • Monitor success against survival criteria. • Replace lost seedlings. 	<ul style="list-style-type: none"> • Ongoing weed control. • Monitor success against survival criteria. • Replace lost seedlings. 	<ul style="list-style-type: none"> • Ongoing weed control. • Monitor success against survival criteria. • Replace lost seedlings.

5.0 MONITORING AND ASSESSMENT

5.1 Monitoring

Each year following initial revegetation and planting, a report will be produced detailing the quantities of seedlings planted. This can then be used as the baseline data for future assessments. Assessments into planting success will be undertaken each spring during the establishment period, and for three years after this phase is complete for each zone.

The following indicators will be assessed:

- Range of species present in revegetation zones and health of planted vegetation
- Presence of weeds in the revegetation zone (including an estimated density / percentage cover)
- Comments on estimated mortality for planted vegetation to allow for survival rate to be estimated
- Collection of photography from designated locations to build up a photographic record of progress for the site.

The monitoring methodology will utilise establishment of permanent monitoring quadrats within each revegetation stage, as well as establishment of photo point monitoring locations.

A summary monitoring report will be produced annually by the City which outlines the findings of the above program.

5.2 Performance Targets

The following performance targets have been set for the revegetation program.

Table 7: Performance Targets

Characteristic	Minimum Target / KPI
Plant density	1 plant / m ²
Species composition	75% of revegetation species list
Weed cover	<20%

Adherence to these performance targets will be assessed during each annual monitoring event. Should the performance targets not be met in revegetation stages at the end of the first 12 months maintenance period after planting, remedial works which may be implemented include:

- Additional revegetation works to increase plant densities and species representation;
- Weed management;
- Rubbish removal; and
- Continuing/maintaining plant protection measures (e.g. tree guards) and removing when no longer required.

If remedial works are implemented, performance targets would be further assessed for these areas in next annual monitoring event.

5.3 Tamworth Hill Swamp Reserve Revegetation Plan – Summary of Matters

The matters which were required to be addressed through the requirement for the Tamworth Hill Swamp Reserve Revegetation Plan which was set as an EPBC Act approval condition for WA Limestone were outlined in Section 3.0. The table below identifies how these matters have all been addressed:

Table 8: Tamworth Hill Swamp Reserve Revegetation Plan Requirements Summary

Requirement	Outcome / Comment
Measures to establish the equivalent of at least 12ha of habitat known to be primary feeding plants for Black Cockatoos within the Tamworth Hill Swamp, through landscape planting	Revegetation in priority revegetation Zones 1,2 and 5 will result in establishment of over 20ha of plants, the majority of which are known feeding plants Black Cockatoos within the Tamworth Hill Swamp.
The revegetation methods to be undertaken within revegetation zones defined in Appendix A Figure 2 (of the EPBC approval notice)	These revegetation zones are reflected in the management zones outlined in this report. The priority revegetation zones, reflect the revegetation zones outlined in the EPBC Approval Notice.
Measures to ensure that seedlings being planted are free of dieback, (<i>Plytophora cinnamoni</i>)	All seedlings must be certified dieback free before plantings can occur. Any soil imported into the site must be dieback free, and contractors must be made aware of their obligations to reduce the risk of dieback spread.
Timeframes and survival targets proposed for plantings	The commencement for plantings are at the discretion of the City of Rockingham, but once commenced must accord with the implementation and monitoring schedules outlined above.
Feral animal and weed controls to be implemented	Rabbit guards will be installed around each seedling when planted, Further temporary fencing will be erected prior to plantings. Intensive weed control is critical to the success of the rehabilitation program and will be undertaken in accordance with the methodology outlined above.
Fencing to be undertaken	Fencing around the site will be inspected and repaired where required. Temporary fencing will be erected around revegetation areas.
Contingency measures if targets are not met	Monitoring and contingency measures have been outlined above.
The monitoring and survey measures to be utilised, including timing schedules and reporting requirements	Monitoring and contingency measures have been outlined above.
Roles and responsibilities of contractors, staff and the person taking the action, prior to, during and following and rehabilitation and revegetation works undertaken on the offset areas	The City is responsible for implementing these actions, and may utilise contractors or City staff to undertake the works. The City will manage the revegetation program.
How the WA DEC, CoR, or other conservation organisations, have been consulted in the preparation of the THSRP	The City of Rockingham have been heavily consulted in the preparation of this report, to ensure the outcomes are consistent with the long term management objectives of Tamworth Hill Swamp, while meeting the approval requirements of the EPBC approval.

Appendix B: Proposed Weed Control Methods for Tamworth Hill Swamp

Species	Common Name	Zone ¹							January	February	March	April	May	June	July	August	September	October	November	December	Treatment Summary (see 'Weed Des further information)	
		1	2	3	4	5	6	7														
<i>Arcotheca calendula*</i>	Cape Weed		✓	✓		✓															Ensure root is severed, selective or spraying.	
<i>Avena barbata</i>	Bearded Oat		✓	✓	✓	✓															Aim to prevent seed production	
<i>Brassica tournefortii</i>	Mediterranean Turnip, Wild Turnip					✓															Spot spray	
<i>Bromus diandrus</i>	Great Brome	✓	✓	✓		✓															Prevent seed set, hand pull plants and s	
<i>Carduus pycnocephalus</i>	Slender Thistle		✓	✓			✓	✓													Hand removal and spot spraying	
<i>Cortaderia selloana</i>	Pampas Grass																				Cut out small plants, remove uprooted resprouting. Spray treatment	
<i>Ehrharta calycina</i>	Perennial Veldt Grass	✓			✓	✓															Ensure removal of crown or spray treat	
<i>Ehrharta longiflora</i>	Annual Veldt Grass	✓	✓	✓	✓		✓	✓													Hand remove small infestations or spr	
<i>Euphorbia Terracina</i>	Geraldton Carnation Weed	✓	✓	✓		✓	✓	✓													Spot spray and hand removal	
<i>Ficus carica*</i>	Edible Fig, Common Fig			✓																	Hand remove seedlings. Stem inject and regrowth.	
<i>Hypochaeris glabra</i>	Flat Weed, Smooth Catsear	✓	✓	✓		✓	✓	✓													Hand removal to ensure the taproot is spray treatment	
<i>Lactuca serriola</i>	Prickly Lettuce					✓	✓														Hand removal to ensure the taproot is treatment	
<i>Lagurus ovatus</i>	Hare's Tail Grass		✓	✓																	Prevent seed set, hand remove small infestations. Selective spray treatment.	
<i>Pelargonium capitatum</i>	Rose Pelargonium					✓	✓														Remove entire stem and spot spray	
<i>Romulea Rosea*</i>	Guildford Grass, Onion Grass		✓	✓																	Manual control is difficult. Spray in win flowering.	
<i>Vulpia bromoides</i>	Squirrel Tail Fescue		✓	✓																	Prevent seed set. Hand pull plants or sp	
Optimal	Occasional	Manual Removal Treatment																				
Optimal	Occasional	Spray Treatment																				
		¹ Zones 8 and 9 - spot weed control on outer edges where appropriate																				
		* Not high priority weed species but common in that Zone																				

Addendum 1 (September 2019)

Background

The approved Tamworth Hill Swamp Reserve Revegetation Plan (THSRRP) identified the following performance targets for the revegetation program to establish 12 ha of habitat known to be primary feeding plants for Black Cockatoos within Tamworth Hill Swamp.

Characteristic	Minimum Target / KPI
Plant density	1 plant / m ²
Species composition	75% of revegetation species list
Weed cover	<20%

The THSRRP noted that should targets not be met, remedial works may be implemented including:

- Additional revegetation works to increase plant densities and species representation;
- Weed management;
- Rubbish removal; and
- Continuing/maintaining plant protection measures (e.g. tree guards) and removing when no longer required.

If remedial works are implemented, performance targets should be further assessed for these areas in next annual monitoring event.

In the six years since the THSRRP was approved, the City has undertaken revegetation works across 13.23ha of the reserve. The extent of works to date covers a larger area than the 12ha target set by the THSRRP and can be viewed as a significant financial and operational commitment by the City to successfully implement the actions listed in the THSRRP.

In September 2018, the City engaged environmental consultants, Emerge Associates, to undertake an assessment of revegetation performance since the implementation of the THSRRP in 2013. The methods and results of this assessment are explained in detail below.

Methods

Desktop and Field Assessment Methodology

As part of the Revegetation Performance Assessment, the Tamworth Hill Swamp Revegetation Project Report for 2017/2018 and a digital mapping file of the revegetation areas were reviewed to identify the boundaries and previous planting information for the seven revegetation areas.

A sampling frame comprising a grid of 10m x 10m sample units was placed over each of the seven revegetation areas (Figure 1). Three sample units were randomly selected within each revegetation area (21 in total).

The site was traversed on foot and vehicle and the 21 pre-determined sample units were surveyed and photographed. The position of sample unit was recorded using a hand-held GPS unit connected to a Samsung tablet displaying the sampling frame. The north-west corner of each sample was permanently marked with a metal post.

The boundaries of the seven revegetation areas were ground-truthed and any additional areas of revegetation within the site were mapped.



Figure 1: A 10m x 10m sample unit from within a revegetation area.

Data Analysis and Mapping Methodology

Sample data was used to demonstrate revegetation performance for each revegetation area. One of the three samples within Revegetation Area Two (RA2) was separated from the other two RA2 samples for some analyses due to differences in vegetation type (wetland versus dryland). The separated sample is mapped on Figure as RA2ii and the original samples are mapped as RA2i.

Analysis was undertaken using Microsoft Excel to determine plant density, plant survival, species richness, species diversity and weed cover. Results were assessed against revegetation 'performance targets' provided in the THSRP, as per the table above.

Mean values for plant density and species richness were calculated from the three samples surveyed in each revegetation area. A sample mean is a statistic that indicates the central tendency of a population. An upper and lower 95% confidence interval (CI) was calculated for each sample mean. A 95% CI is a statistic that provides indication of the spread of expected values within a sampled population.

Species diversity was presented graphically based on composition obtained across all three samples within each revegetation area. The species and number of plants installed in each revegetation area each year (CoR 2018) and the species recorded in samples within each revegetation area were compared directly to these lists.

Revegetation success was mapped using a categorical scale based on the three performance targets outlined in the THSRP. The performance categories adopted included 'no targets met', 'one target met', 'two targets met' and 'all targets met'.

Results

Plant Survival and Density

Of the seven revegetation areas, RA2 supported the highest number of living plants and RA1 the lowest, as shown in Figure 2. The number of dead plants was able to be determined for the revegetation areas planted during or after 2017 (RA5, RA6 and RA7) due to the presence of empty tree bags. The tree bags within the remaining revegetation areas (RA1-RA4) were removed prior to the site sampling being undertaken by Emerge. A comparison between the number of surviving plants and the number planted was used to determine the number of dead plants within these older revegetation areas. Evidence of ongoing infill planting was observed across multiple revegetation areas.

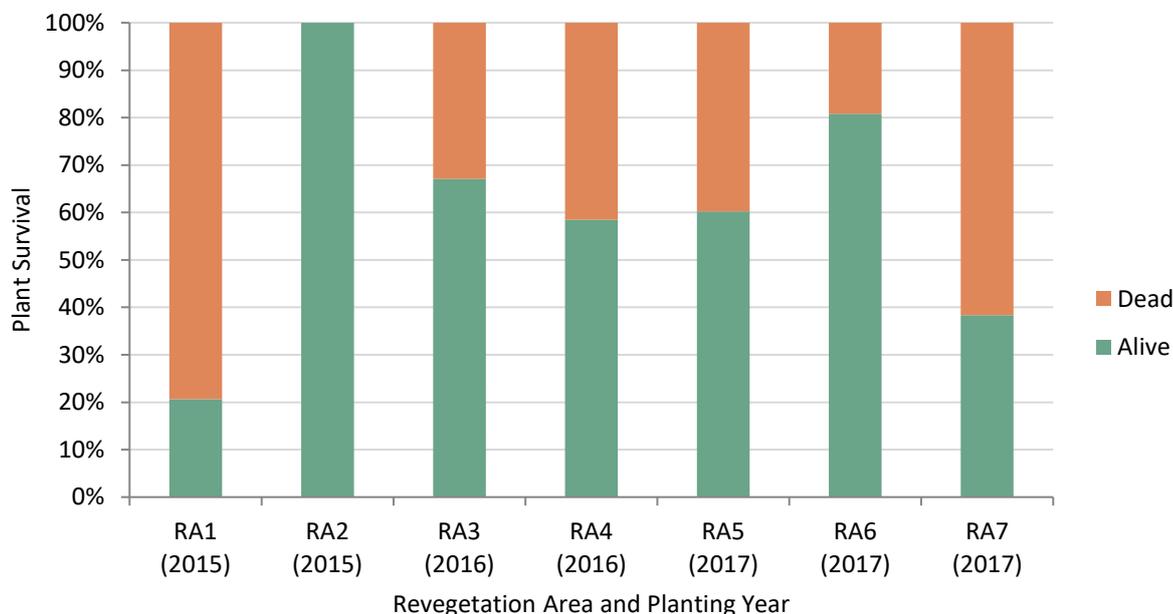


Figure 2: Plant survival across revegetation areas.

All revegetation areas, except for RA2ii supported a density of less than the target density of one living plant/m², as shown in Table.

Species Richness and Diversity

Species richness differed significantly between revegetation areas, ranging from four species in RA1 to 13 species in RA3. Five of the revegetation areas (RA2ii, RA4, RA5, RA6 and RA7) met the THSRRP performance target in that they supported equal or greater than 75% of the number of species planted. RA2i supported the lowest percentage of species with 30% of the species planted recorded. However, only two samples were located in this area, rather than three in all other revegetation areas, due to the abovementioned separation of RA2 into wet and dry areas. RA2ii supported more than 100% of the number of species planted which is likely due to natural recruitment from wetland vegetation within the site.

The composition of species varied considerably within and across revegetation areas and most areas lacked native groundcover species. RA2 had the most groundcover species (five) and the densest coverage of vegetation at the ground layer. This can be attributed to the presence of *Centella asiatica* in the low lying areas. A total of 16 native shrub species were recorded, with many species, such as *Hakea trifurcata*, recorded within all sampled revegetation areas. A total of 12 tree species were recorded in the site. It was difficult to distinguish between the multiple *Eucalyptus* species planted across the site due to the juvenile stage of the plants, these unidentified individuals were recorded as *Eucalyptus* sp.

Weed Cover

Weed cover was variable within revegetation areas and also varied across revegetation areas as shown in Figure 3. The highest weed cover was recorded in RA4 (mean 41.7% \pm CI), and the lowest weed cover was recorded in RA1 (7% \pm CI). The spread of 95% CI for sample means indicates that only RA1 can be expected to have weed cover consistently below the target of 20%.

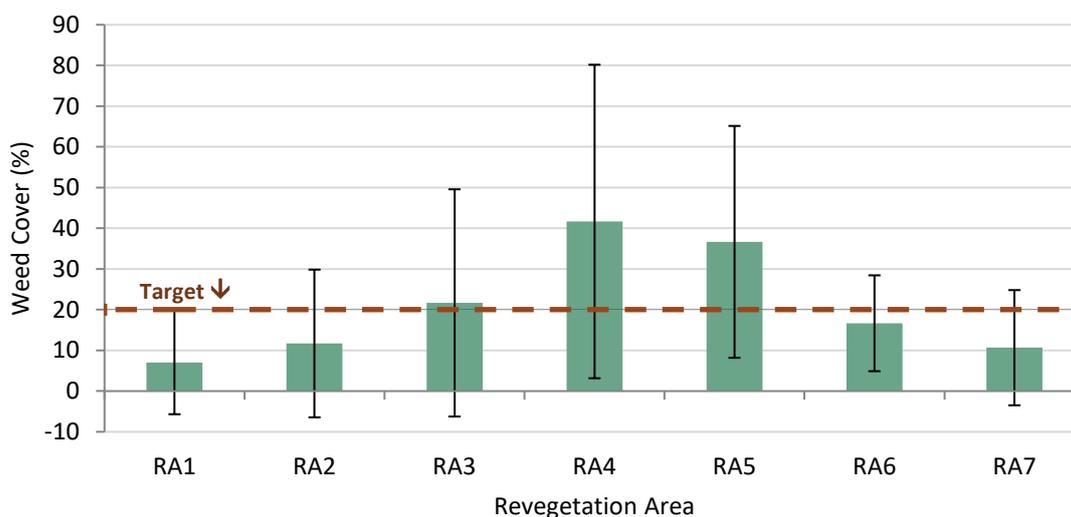


Figure 3: Weed cover within the revegetation areas

Revegetation Success

One revegetation area, RA2ii, successfully met two out of the three performance targets, and was the only revegetation area to meet the plant density target of ≥ 1 plant/m², as shown in Table 1. Five of the seven revegetation areas supported at least 75% of the species planted, and only one revegetation area, RA1, met the weed cover target. The performance of the revegetation areas against the target is shown in Figure 4. Revegetation areas 8-13 represent additional areas of planting that have been undertaken by the City, beyond the requirements of the THSRRP.

Table 1: Summary of performance targets within each environmental offset revegetation area.

Revegetation Area	Performance target (Coterra Environment 2013a)		
	≥1 plant/m ²	≥75% of Revegetation species list	<20% weed cover
RA1	✗	✗	✓
RA2i	✗	✗	✗
RA2ii	✓	✓	✗
RA3	✗	✓	✗
RA4	✗	✓	✗
RA5	✗	✓	✗
RA6	✗	✓	✗
RA7	✗	✓	✗

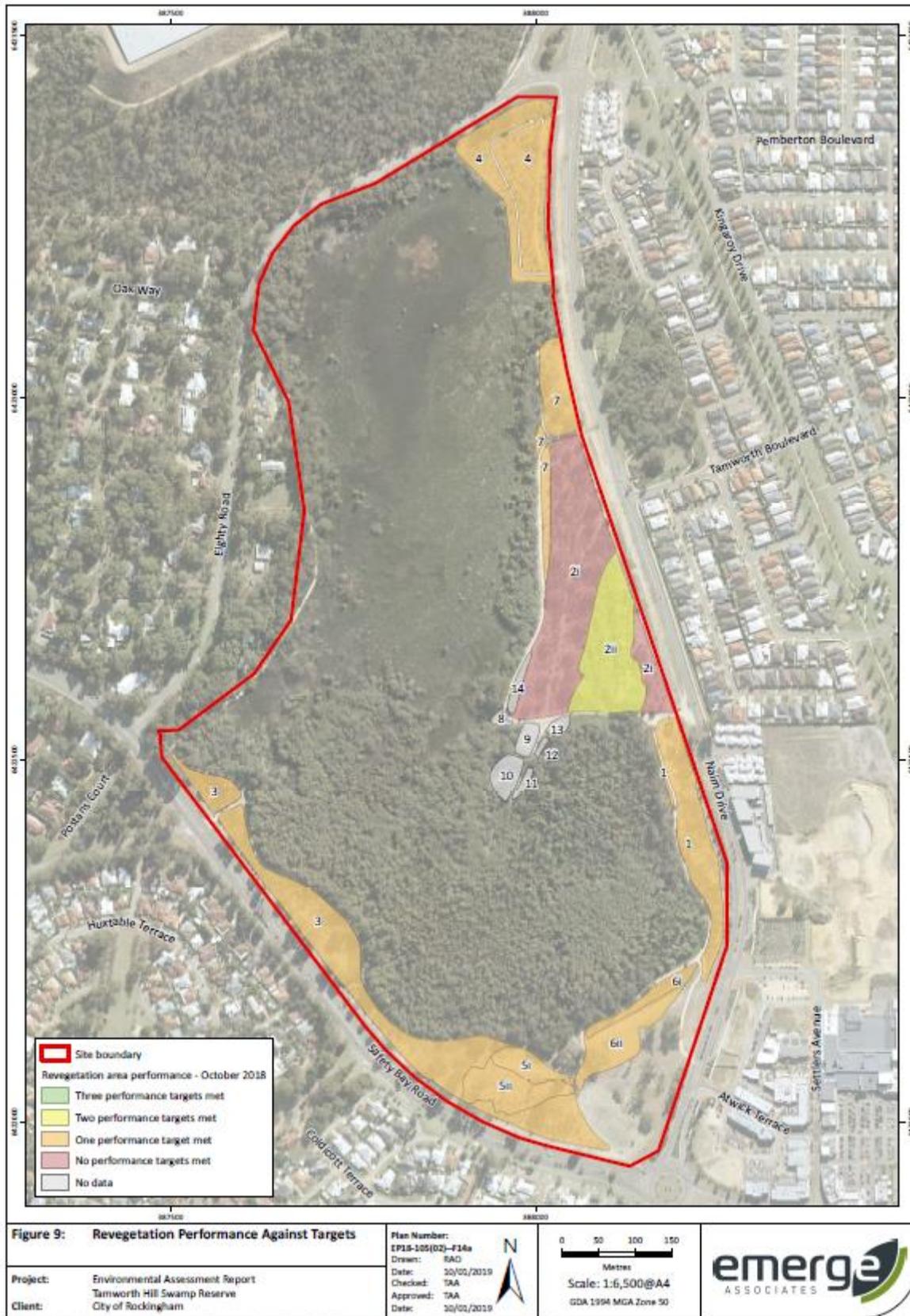


Figure 4: Revegetation Performance Against Targets (excerpt from the City's draft Tamworth Hill Swamp Management Plan 2019)

Despite the significant commitment to meet the THSRRP performance targets, the results of the revegetation performance assessment have identified a requirement for additional contingency planting. This requirement is attributable to plant mortality rates being higher than originally anticipated.

As identified in Epanchin Neill *et al.* 2009 and James *et al.* 2011, revegetation is an expensive practice that often fails. These studies have identified that the failures can be attributed to abiotic and biotic factors, rather than seasonal influences, being the primary cause of plant mortality in the first few years after the completion of revegetation works.

The results of the Revegetation Performance Assessment have been used to inform the preparation of a robust Infill Planting Strategy which will aim to meet the performance targets of the THSRRP through revegetation works to be undertaken over the next five years (2020-2024). It must be noted that the environmental offset revegetation works will continue beyond 2023, at which point the City's progress towards meeting the performance targets will be reviewed and the Infill Planting Strategy revised accordingly.

Infill Planting Strategy

The Infill Planting Strategy for the next five years and associated costings are presented in Table 2, below.

Table 2: Infill Planting Strategy and costings.

Revegetation Area	Average Bare Ground	Total area (m ²)	Bare ground area (m ²)	Recommended planting ratio (plants/m ²)	Number of plants required	Cost to plant bare ground area (\$4 per plant)
1	52%	11,434	5,946	1	5,946	\$23,600
2	32%	29,977	9,593	1	9,593	\$38,372
3	32%	37,902	12,129	1	12,129	\$48,516
4	32%	17,350	5,552	1	5,552	\$22,208
5	47%	9,165	4,308	1	4,308	\$17,232
6	25%	8,568	2,142	1	2,142	\$8,568
7	40%	7,655	3,062	1	3,062	\$12,248
TOTAL		122,051	42,732		42,732	\$170,744

Implementation

All revegetation is proposed to use tubestock sourced from local nurseries where possible. Prior to planting, weed control must be undertaken to increase the rate of revegetation success. Tree guards can prevent animals such as rabbits from grazing on tubestock. However, if tree guards are not removed, they can become litter resulting in negative impacts to the plants, native fauna and the wetland environment. The tree guards used will be made from compostable material and removed in the first winter following planting if the plants are well established. Alternative measure to prevent animal grazing will also be considered such as fencing off revegetation areas to prevent kangaroo and rabbit access.

Plant Densities

No additional planting is currently recommended for RA2ii as it meets the density and diversity targets. Future monitoring will be undertaken within RA2ii to determine whether additional planting is required at a later date.

Additional planting within all revegetation areas will be undertaken at a density of one plant per m² across the areas of bare ground. This planting density accounts for the coverage of existing plants. The plant densities within the revegetation areas will be reassessed as part of the 2024 update to the Tamworth Hill Swamp Management Plan to determine if additional planting is required to achieve the performance target of one plant per m².

Plant Species Selection

The revegetation areas that lack well established shrubs and trees suitable for black cockatoo foraging habitat should be planted with tubestock using the species identified in the previous planting lists for each revegetation area in the *Tamworth Hill Swamp Revegetation Project Report 2017/2018* (CoR 2018). Where revegetation areas have well established shrubs and trees suitable for black cockatoo foraging habitat, planting of tubestock using native ground cover species is will be undertaken to establish a more complete plant community. The recommended ground cover species for revegetation areas with established trees and shrubs has been derived from Gibson *et al.* (1994) FCT species lists 21a and 21c which reflect nearby banksia woodland vegetation and are a suitable target ecosystem for dryland areas within the reserve.

Weed Control

Weed control should be undertaken prior to revegetation to increase the plant survival rate and prevent further weed infestation. All City staff members and contractors will be trained in hygiene practices before undertaking works in the revegetation areas to reduce the potential for pathogen introduction.

Costings

The costs of the proposed revegetation will be paid for over the next five years in accordance with Table 3, below.

Year	Number of Plants	Cost
2020	8,546	\$34,186
2021	8,546	\$34,186
2022	8,546	\$34,186
2023	8,546	\$34,186
2024	8,546	\$34,186
	42,732	\$170,744

Monitoring

Permanent quadrats assessed by emerge will be monitored twice a year for five years in spring and in autumn, to ensure results are directly comparable to those collected during the Revegetation Performance Assessment.

Contingency

A detailed assessment of the environmental offset revegetation areas will be undertaken after five years, to assess whether the performance targets have been met. If the targets have not been met, a plan for any further infill planting required will be considered at that time.

References

City of Rockingham. (2018). *Tamworth Hill Swamp Revegetation Project Report 2017/2018*.

Epanchin-Niell, R., Englin, J. & Nalle, D. (2009) Investing in rangeland restoration in the Arid West, USA: countering the effects of an invasive weed on the long-term fire cycle. *Journal of Environmental Management*, **91**, 370–379.

Gibson, N., Keighery, B., Keighery, G., Burbidge, A. and Lyons, M. (1994). *A Floristic survey of the southern Swan Coastal Plain*, Department of Conservation and Land Management and the Conservation Council of Western Australia, Perth.

James, J.J., Svejcar, T.J. and Rinella, M.J., 2011. Demographic processes limiting seedling recruitment in arid grassland restoration. *Journal of Applied Ecology*, *48*(4), pp.961-969.