

Banksia Woodland Restoration Project

Flora and Vegetation Completion Criteria



Mark Brundrett, Margaret Collins, Karen Clarke,
Vanda Longman and Anna Wisolith



Department of **Biodiversity,**
Conservation and Attractions



Department of Biodiversity, Conservation and Attractions
Locked Bag 104
Bentley Delivery Centre WA 6983
Phone: (08) 9219 9000
Fax: (08) 9334 0498

www.dpaw.wa.gov.au

© Department of Biodiversity, Conservation and Attractions on behalf of the State of Western Australia, November 2017

This work is copyright. You may download, display, print and reproduce this material in unaltered form (retaining this notice) for your personal, non-commercial use or use within your organisation. Apart from any use as permitted under the *Copyright Act 1968*, all other rights are reserved. Requests and enquiries concerning reproduction and rights should be addressed to the Department of Biodiversity, Conservation and Attractions.

This report was prepared by Mark Brundrett, Margaret Collins, Karen Clarke, Vanda Longman and Anna Wisoloth. Questions regarding the use of this material should be directed to:

Mark Brundrett or Karen Clarke

Swan Region

Department of Biodiversity, Conservation and Attractions

Locked Bag 104

Bentley Delivery Centre WA 6983

Phone: (08) 9442 0318, 9442 0300

Email: mark.brundrett@dpaw.wa.gov.au or karen.clarke@dpaw.wa.gov.au

The recommended reference for this publication is:

Brundrett M, Collins M, Clarke K, Longman V, Wisoloth A (2017) 'Flora and Vegetation Completion Criteria' (Department of Biodiversity, Conservation and Attractions: Perth)

This document is available in alternative formats on request.

Cover images: Left to right - Carnaby's cockatoos (*Calyptorhynchus latirostris*) on candle banksia (*Banksia attenuata*); the grand spider orchid (*Caladenia huegelii*). Photos by Mark Brundrett.

Abbreviations and Definitions

- **JA** – Jandakot Airport
- **β-diversity** – the difference in species diversity between samples in the landscape.
- **BWR** - Banksia Woodland Restoration project (this project)
- **CC** - Carnaby's cockatoo, Carnaby's black cockatoo, *Calyptorhynchus latirostris*
- **Completion criteria** – explicit goals that must be attained to call an element of a project "complete". These can be numeric or qualitative measures used to determine when the objectives of the restoration have been met. In some situations this means the current land manager can then be relinquished of responsibility for management of the site, this is not the case for the BWR project.
- **Disturbance opportunist** – plant species that germinates in response to a habitat disturbance such as fire or soil disturbance.
- **Diversity** – used in this document to refer to α-diversity i.e. species richness.
- **Environmental offset** - measures that are designed to compensate for the residual adverse impacts of an action on the environment.
- **FCT** – Floristic Community Type (used for vegetation classification at a regional scale).
- **Importance value** – the sum of the relative density, relative frequency and relative dominance of a given plant species. This index is used to determine the overall importance of each species in the floristic community. In this document it is determined according to method of Mueller-Dombois and Ellenberg (1974) using percentage foliage cover as a measure of dominance.
- **Quadrat size** – quadrats in Departmental reports are denoted by numbers indicating side length separated by a multiplication sign followed by a unit of distance e.g. 10x10m indicates a square 100m² quadrat.
- **Recalcitrant species** – plant species that produce little or no viable seed or that do not germinate readily. Many of these taxa are regarded as 'obligate resprouters', i.e. species that predominantly reproduce vegetatively by means of underground shoots, rhizomes or bulbs but rarely by seed germination. Some recalcitrant species can be reproduced by resource-intensive techniques such as cuttings, division, embryo rescue or tissue culture.
- **Rehabilitation** - where it is impossible to restore a site to its original condition, the establishment on a disturbed site of a plant and animal community that is similar to the original.
- **Restoration** - the establishment on a disturbed site of the plant and animal community that existed there prior to the disturbance, thus, ecosystem restoration is the "process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (SER 2004).
- **Sorenson's Coefficient (CC)** – is a measure of similarity between two plant communities.

$$= \frac{2C}{S1 + S2}$$

where C is the number of species in common, S1 = species richness at site 1 and S2 = species richness at site 2. Values range from 0 (complete dissimilarity) to 1 (complete overlap).

- **Transitional zone** – area between two plant communities, for example between upland and wetland vegetation or two Floristic Community Types, where the vegetation consists of a mixture of species from both communities.

Contents

1. Executive Summary	7
2. Introduction	9
3. Diversity, Density and Cover Targets	12
4. Vegetation Communities	15
5. Setting Completion Criteria.....	20
6. Conclusions	26
7. References	28
8. Appendices.	30

Figures

Figure 1. The location of Jandakot Airport in relation to Perth, the capital of Western Australia.	9
Figure 2. The categories of completion criteria used to determine the success of natural area restoration (EPA 2006).	10
Figure 3. Location of the topsoil source area at Jandakot Airport relative to the topsoil recipient areas in the Anketell Road, Forrestdale Lake and Ken Hurst Park restoration sites.	11
Figure 4. The density and ranked importance values of plant species detected in the topsoil source area at Jandakot Airport.	13
Figure 5. Diversity data showing the proportion of overlap in flora diversity between the topsoil source area and local reference sites adjacent to the recipient areas at Anketell Road and Forrestdale Lake.	14
Figure 6. Comparison of banksia woodland vegetation by Principal Coordinates Ordination (PCO) analysis.	15
Figure 7. Vegetation map of the Anketell Road restoration site showing upland, transitional zone and wetland areas.	17
Figure 8. Detailed vegetation map of the Anketell Road restoration site showing upland, transitional zone and wetland areas in relation to a 1953 aerial photograph.	18
Figure 9. Forrestdale Lake restoration site on the southwestern side of the central lake with soil sub-system mapping showing the wide range of soil types present where the Bassendean Dunes overlay the Pinjarra Plain.	19
Figure 10. Flow chart for development of the restoration completion criteria.....	20
Figure 11. Classification predicting the relative abundance of banksia woodland species in restoration sites based on reproductive potential determined from the presence of a viable soil seed bank, availability of seed, and potential for vegetative propagation.....	22
Figure 12. Predicted propagule source and propagation difficulty for the recruitment of plant species found in the topsoil source area at Jandakot Airport.....	22
Figure 13. Recovery of banksia species used as food sources by Carnaby's cockatoo at the Anketell Road restoration site over the period 2012 to 2016.....	27

Tables

Table 1. Data sources used to identify the Floristic Community Type/s at Jandakot Airport Precinct 5 and to prepare completion criteria.	14
Table 2. Additional Floristic Community Types (FCTs) with brief descriptions, found within the Bush Forever Sites containing the restoration areas.	18
Table 3. Completion criteria for plant diversity, density and cover in banksia woodland restoration sites at Anketell Road and Forrestdale Lake.	24
Table 4. Potential banksia food resources for Carnaby's cockatoos for two <i>Banksia</i> species at three sites.	25
Table 5. Carnaby's cockatoo food plants present in the topsoil source area at Jandakot Airport and method of establishment in the restoration sites.	25

Appendices

Appendix 1. List of plant species found in upland Banksia woodland of Floristic Community Type 23a at Jandakot Airport prior to clearing in 2012.	30
Appendix 2. Plant species found in upland Banksia woodland of Floristic Community Type 21c, the upland FCT determined to have occurred at the two restoration sites prior to disturbance.	32
Appendix 3. Plant species found in Floristic Community Types 4 or 12, the two FCTs determined to have occurred in the transition zones between upland and wetland prior to disturbance at the two restoration sites.	35
Appendix 4. Plant species introduced to the restoration sites by planting or direct seeding from 2012-2015, and the method of introduction.	38

1. Executive Summary

This report defines and explains the development of completion criteria used to measure the success of restoration work being undertaken by the Department of Biodiversity, Conservation and Attractions' Banksia Woodland Restoration Project (BWR project) and the progress towards those targets. The BWR project is funded by an offset required by the Commonwealth government under the Environment Protection and Conservation Act 1999 (EPBC Act) for further development of Jandakot Airport (Commonwealth of Australia 2010). Originally, funding for the project was limited to a five-year period and therefore, completion criteria targets have been set for the medium (five-year) term only.

One of the main objectives of the Banksia Woodland Restoration Project is to re-establish banksia woodland that is resilient, self-sustaining and requires minimal management in the long term in previously degraded areas. This banksia woodland should also maintain conservation values that existed prior to disturbance or land clearing. The completion criteria developed for the BWR project are site specific. They are based on data obtained from flora surveys of Jandakot Airport pre-clearing, reference sites in Banksia woodland near the two restoration sites and historic flora surveys. Data on diversity and density was also used to plan seed collection and nursery orders. The completion criteria targets are specific to the two restoration sites selected at Forrestdale Lake and Anketell Road and to the vegetation communities within each, which are upland Banksia woodland (Floristic Community Types (FCT) 23a and 21c) and transitional zone wetland vegetation (FCT 4 and 12). Both restoration sites, which total 50 hectares, occur within the conservation estate in the Perth metropolitan area. Therefore, there is no formal requirement for handover to new land managers on completion of restoration work. However, completion criteria are still required to ensure restored areas are self-sustaining and need minimal management in the long term.

In this report completion criteria were defined for major components of the vegetation structure; total diversity and average diversity, tree diversity, tree density, Carnaby's cockatoo (CC) food plant diversity and density, understorey diversity, native perennial plant density, native annual plant diversity, diversity and density of key understorey native species, and weed diversity, density and cover (see Table). Only three categories have specific density targets set as completion criteria; trees, CC food plants and native perennial plants. These are designed to ensure sufficient cover to stabilise the site, inhibit weed growth, establish over time similar CC food resources to Jandakot Airport prior to clearing, create Banksia woodland with structural similarity to undisturbed Banksia woodland, and create habitats for fauna and fungi.

One major challenge is that a significant proportion of Banksia woodland plants are recalcitrant - that is, very difficult or impossible to establish from seed. This means some species are likely to be very sparsely distributed or absent from restoration sites. Some species that are key components of intact Banksia woodland understorey such as *Hibbertia hypericoides* are included in this category. The BWR project aims to ensure these species are present, but density targets for individual species are unrealistic without further research into seed production and propagation.

To achieve the completion criteria the BWR project operates within an adaptive management framework with progress determined by annual monitoring. For example, low survival rates or difficulty establishing certain species, are corrected by interventions such as infill planting and seeding. Actions are also taken to control threats such as weeds, overgrazing, feral animals and disease and experimental trials used to compare the effectiveness of different restoration methods.

An example of how completion criteria are used to evaluate restoration success is provided by an analysis of the CC food plant density target. *Banksia* species are the primary CC food source in banksia woodlands, but their density fluctuates in restoration areas because seedlings suffer significant losses over summer through drought and heat stress. After four years of annual planting to replace summer losses, the

completion criteria target of at least 250 stems per ha of *Banksia* species was finally attained in spring 2016.

Table: Completion criteria for plant diversity, density and foliage cover in banksia woodland restoration sites at Anketell Road and Forrestdale Lake. Note: Diversity is α -diversity i.e. species richness.

Completion Criteria	Target
Total diversity	Maximise native species diversity across site based on Jandakot Airport pre-clearing (min. 80 species)
Average diversity (per 100m ²)	19 spp. (target: at least 60% of average native diversity at Jandakot Airport pre-clearing)
Tree diversity (overstorey)	Presence of all overstorey species: <i>Adenanthos cygnorum</i> , <i>Banksia attenuata</i> , <i>B. ilicifolia</i> , <i>B. menziesii</i> , <i>Eucalyptus marginata</i> , <i>E. tottiana</i> and <i>Nuytsia floribunda</i>
Tree density (overstorey)	At least 300 stems per ha
CC food plant diversity and density	At least 250 stems per ha of <i>Banksia</i> tree species. Presence of all CC food plants from Jandakot Airport pre-clearing: <i>Banksia attenuata</i> , <i>Banksia ilicifolia</i> , <i>Banksia menziesii</i> , <i>Eucalyptus marginata</i> , <i>Eucalyptus tottiana</i> , <i>Jacksonia furcellata</i> , <i>Xanthorrhoea preissii</i> , <i>Acacia saligna</i>
Average understorey diversity (per 100m ²)	17 spp. (target: 60% of average native understorey diversity at Jandakot Airport pre-clearing)
Native perennial plant density	At least 7,000 stems per ha
Native annual plant diversity and density	Ensure annual native species diversity and abundance matches or exceeds that at reference sites (Jandakot Airport pre-clearing and Anketell Road and Forrestdale Lake).
Key understorey native species diversity and density	Presence of all species appropriate to each restored plant community, especially those with high importance values in reference sites.
Weed diversity, density and cover	Effective control of weeds posing a serious threat to restoration success, especially perennials. Target for perennial grass weeds is <5% cover and other perennial weeds <1%.

2. Introduction

This report explains how completion criteria were chosen to measure the success of restoration work by the Department of Biodiversity, Conservation and Attractions' Banksia Woodland Restoration Project (BWR project) and provides some preliminary data on progress towards those targets. The BWR project is an offset required by the approval conditions set by the Commonwealth government under the Environment Protection and Conservation Act 1999 (EPBC Act) for the development of Jandakot Airport (Figure 1) (Commonwealth of Australia 2010). Details of the flora surveys on which these targets are based will be published separately. The methodology for calculating the completion criteria are discussed further in a separate report (Longman 2013). Targets for fauna are documented separately in a report by Moore and Barrett (2013).

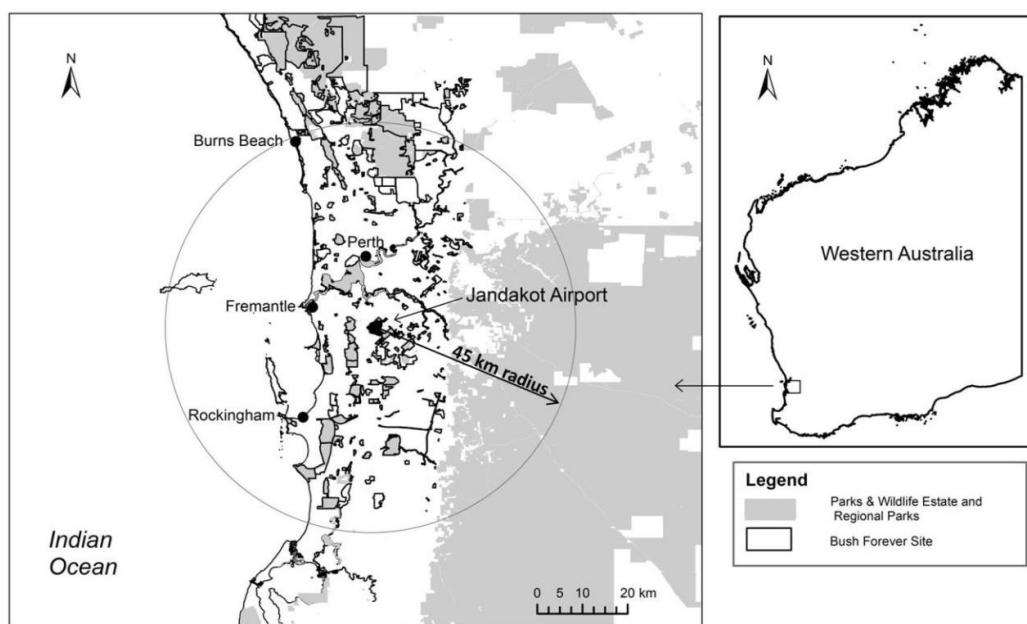


Figure 1. The location of Jandakot Airport in relation to Perth, the capital of Western Australia. The 45 km radius circle denotes the area specified for restoration activities by the Commonwealth government approval notice under the EPBC Act (Commonwealth of Australia 2010).

The objective of banksia woodland restoration is to re-establish a resilient and self-sustaining ecosystem that recreates the conservation values that existed prior to disturbance or land clearing and integrates into the surrounding landscape. Completion criteria are defined as “qualitative or quantitative standards of performance used to measure the success or otherwise of rehabilitation actions required for closure of a site” (Environmental Protection Authority (EPA) 2006). These criteria outline both physical and biotic factors for restoration sites; the former are less relevant where landforms have not been altered significantly, while biotic factors apply to all projects (EPA 2006). The most important biotic criteria required to achieve a self-sustaining and resilient ecosystem are; species diversity and abundance, genetic diversity, ecosystem diversity, establishment of canopy and important species (determined by IV ranking), and management of weeds, feral animals and disease (Figure 2, Completion Criteria No. 7-16, EPA 2006). Most major Western Australian restoration projects set criteria for plant diversity, abundance and cover, but are less likely to measure the structural complexity and resiliency of re-established vegetation, due to time and resource constraints. Likewise, plant genetic diversity and fauna diversity are rarely assessed unless included in supplementary research programs (EPA 2006). The BWR project developed completion

criteria to address the main biotic factors of importance in the restored areas, and particularly to document flora and vegetation recovery.

The BWR project restoration sites are located at Anketell Road and Forrestdale Lake on land managed by the Department of Biodiversity, Conservation and Attractions (Figure 3). The long term objective of restoration works is to allow the sustainable future management of the sites without major additional expenses. Ken Hurst Park is included in Figure 3 because topsoil from Jandakot Airport Precinct 5 was also transferred to this site to assist restoration activities undertaken by the Friends of Ken Hurst Park and the land manager, the City of Melville.

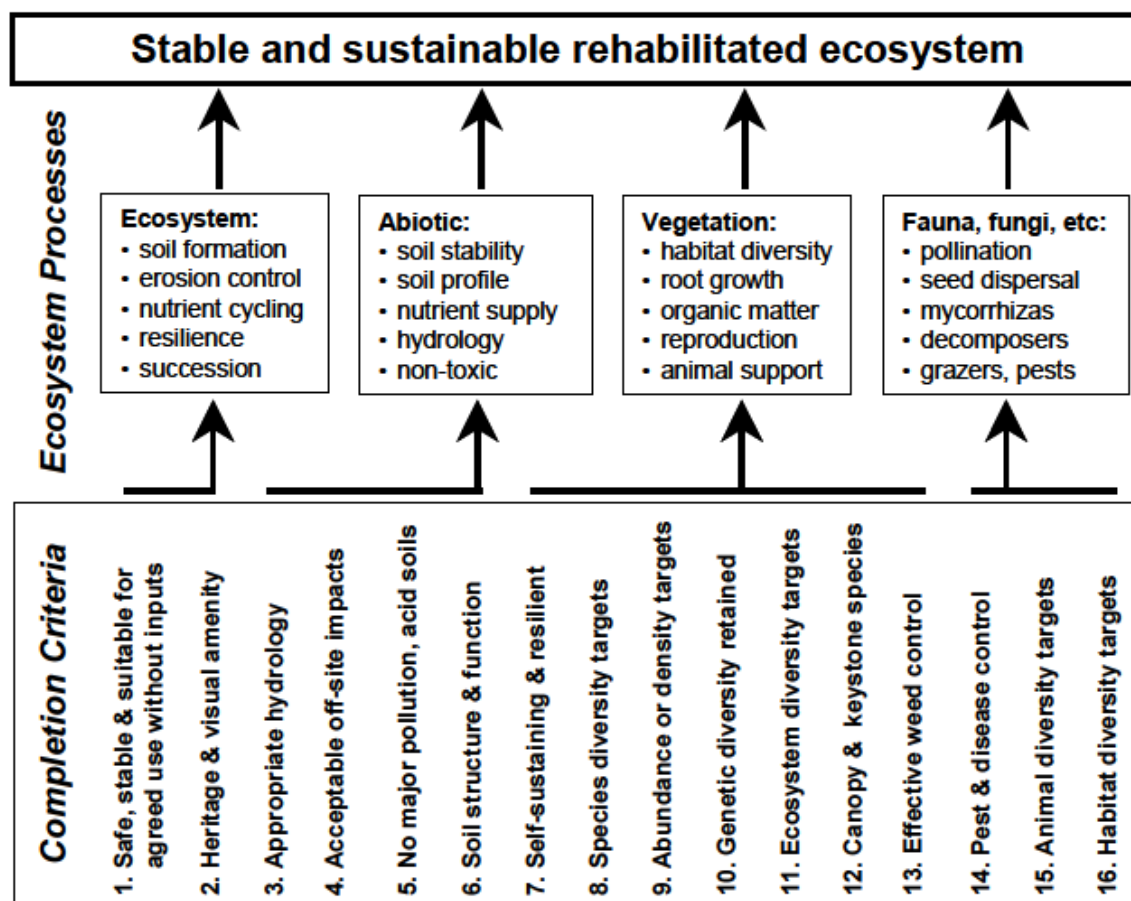


Figure 2. The categories of completion criteria used to determine the success of natural area restoration (EPA 2006).

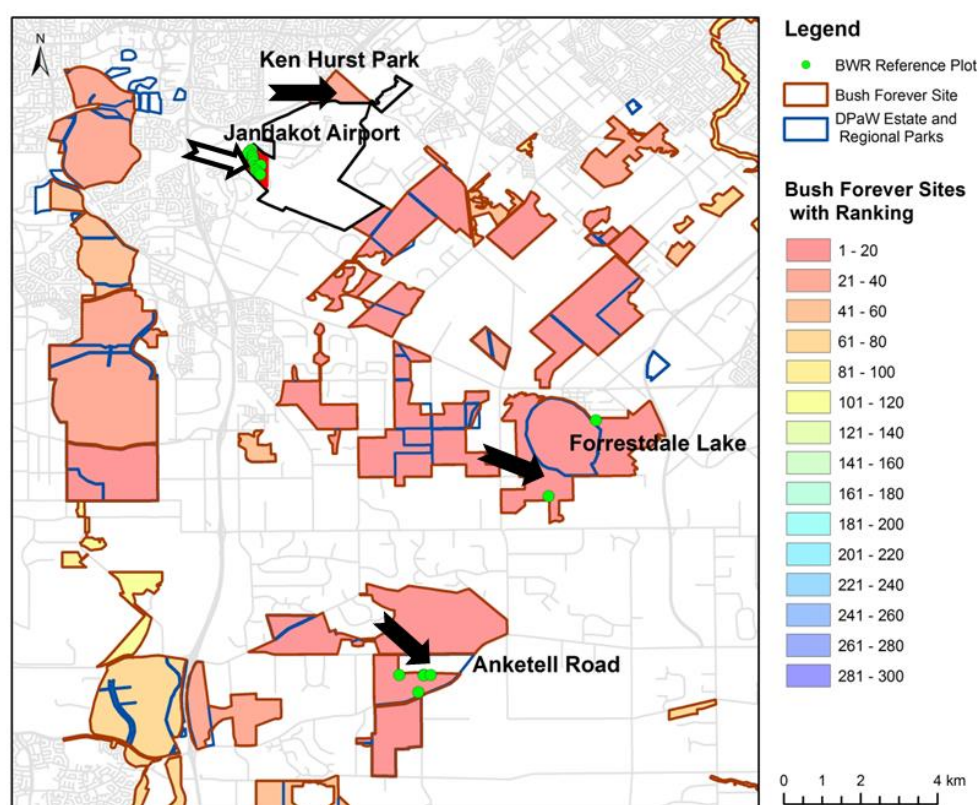


Figure 3. Location of the topsoil source area at Jandakot Airport relative to the topsoil recipient areas in the Anketell Road, Forrestdale Lake and Ken Hurst Park restoration sites. The location of the topsoil source area at Jandakot Airport Precinct 5 is indicated by a bright red colour and outlined black arrow. The topsoil recipient restoration sites at Anketell Road, Forrestdale Lake and Ken Hurst Park are shown by filled black arrows. The location of reference site quadrats used to inform completion criteria for the restoration sites are indicated by green dots. The boundaries of Jandakot and Beeliar Regional Parks and reserves in the Department of Biodiversity, Conservation and Attractions' estate near Jandakot Airport are indicated by a blue border. Site rankings for Bush Forever sites focused on biodiversity conservation values and similarity to the Jandakot Airport banksia woodland (Clarke *et al.* 2016). Rankings are indicated by colour coding (Clarke *et al.* 2016); the highest ranked (lowest numbers) are red and orange.

For the purposes of this project, completion criteria refer to specific restoration targets to be achieved by the end of the BWR project. These targets are specific to each of the vegetation communities within each restoration site (upland vegetation or transition zone vegetation adjacent to wetlands). The targets are defined separately for major components of the vegetation such as canopy species, key understorey species and CC food plants. Originally, offset funding for this project was limited to a five year time frame (Jandakot Airport Holdings Pty Ltd 2010). Therefore, completion criteria targets are set for the short to medium term only. For example, the limited time-frame made it necessary to set targets for plant density rather than overall cover.

Previous surveys measuring plant diversity on the Swan Coastal Plain (SCP) provided a substantial dataset on the presence or absence of species in plant communities known as Floristic Community Types (FCTs) (Keighery *et al.* 2012), but did not provide data on the relative density, cover and frequency of individual species. To fill this knowledge gap, flora and vegetation surveys were undertaken between late 2011 and early 2012 at the main reference site at Jandakot Airport prior to the clearing of Precinct 5 (Figure 3). This area was to be used as a topsoil source for restoration at Anketell Road and Forrestdale Lake (Figure 3). Flora surveys by the BWR project also focused on several habitats closer to the restoration sites, in order to

determine the relative importance of species in the plant communities believed to be most similar to the pre-clearing native vegetation at the proposed restoration areas (Figure 3). Flora data from all these sources were required to:

1. Anticipate and monitor plant recruitment from transferred topsoil in restoration sites.
2. Produce species target lists with prioritization of species for seed collection.
3. Provide species lists and quantities, based on density targets (stems/ha), for ordering seedlings from nurseries.
4. Determine the appropriate composition of seed batches for direct seeding.
5. Determine targets for native vegetation establishment.

3. Diversity, Density and Cover Targets

Diversity (species richness), density (stems/ha), foliage cover and frequency of native plant species at Jandakot Airport Precinct 5 were determined prior to clearing through flora surveys undertaken by the Department of Biodiversity, Conservation and Attractions (Appendix 1). An overall diversity of 80 native species was recorded in a survey of 12 quadrats at the site during the baseline survey (Appendix 1). Unfortunately, the survey was undertaken during the dry season when many annual species were senescing or dormant, and identification of many taxa was difficult due to the absence of fruits and flowers, as a result it is likely that the diversity of this site is an underestimate. Sampling effort by the BWR project was also limited by the short timeframe before clearing at Jandakot Airport Precinct 5, so was only sufficient to sample common plant species and may not have included all of the uncommon species.

Species importance values were calculated from BWR survey data as the sum of relative density, relative dominance (measured as % foliage cover) and relative frequency using the method of Mueller-Dombois and Ellenberg (1974). Importance value is a measure of the overall importance of a species within a floristic community with a high importance value indicating that a particular species is an important component of the floristic structure of a plant community. Importance values (IV) were then used to rank species found in Banksia woodland at JA Precinct 5 (a list of all taxa found at JA Precinct 5 with importance value rank is given in Appendix 1). About 40 of the species identified were relatively common at Jandakot Airport; these common species are represented in Figure 4 by species with importance values ranks of one to 40. The ranked species list provided vital information for the development of completion criteria, seed collection, composition of direct seeding mixes, and species lists for nursery orders (see Figure 10). Annual monitoring of progress provided additional information for intervention activities, refining the on-going seed collection, nursery orders and direct seeding mixes.

Further surveys were then undertaken in banksia woodland adjacent to the restoration sites at Anketell Road and Forrestdale Lake to provide additional data for development of completion targets for restoration. These local reference sites included many additional species not found at Jandakot Airport (JA), while JA vegetation included many species not found in the reference sites (Figure 5). Floristic similarity, calculated as Sorenson's Coefficient of community similarity (CC), was 0.47 indicating a relatively low similarity between topsoil donor (JA) and recipient sites. The Jandakot Airport vegetation was long unburnt and heavily grazed by the macropod population that had become trapped within the perimeter fencing as the area became isolated by surrounding urban development. In addition, examination of aerial photographs of the site showed that Precinct 5 had been subject to scrub rolling and heavy grazing by agricultural stock in the past, both of which would have affected vegetation structure and diversity (historical aerial photography, 1953 through to 2012). The degree of floristic similarity between sampling areas may have increased with additional sampling during spring. However, the difference could also be

due to the naturally high spatial variability in plant diversity within banksia woodlands (β diversity) (Keighery and Keighery 2016).

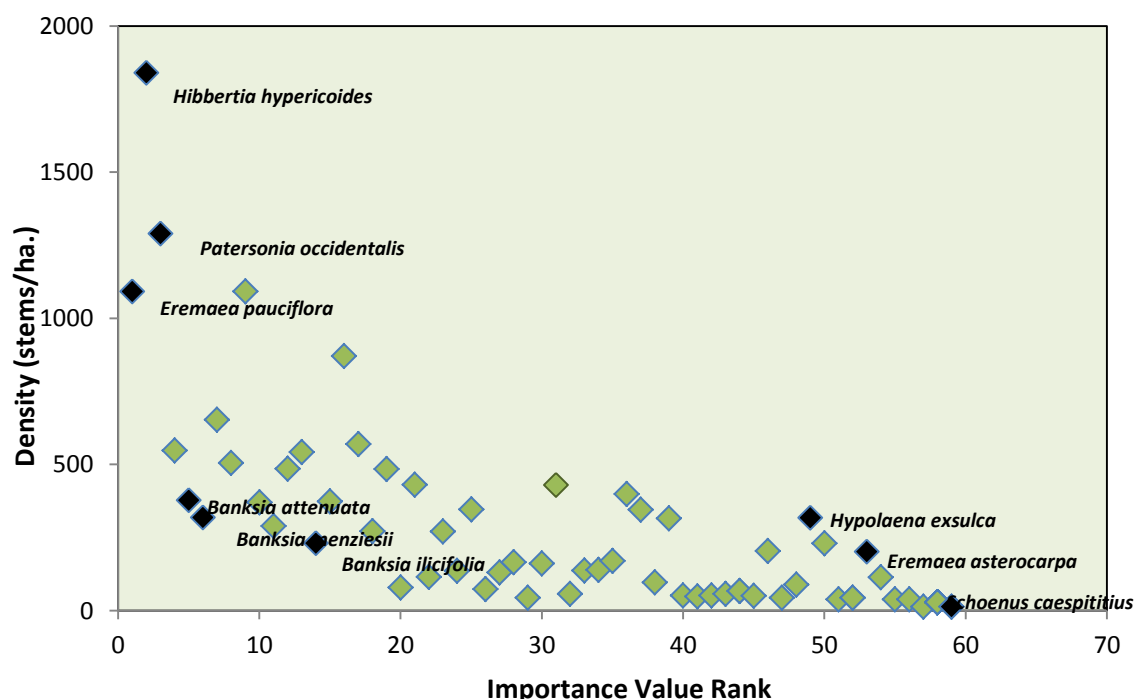


Figure 4. The density and ranked importance values of plant species detected in the topsoil source area at Jandakot Airport. Note: species with high importance values have a low rank. *Banksia attenuata*, *B. menziesii* (the dominant *Banksia* species for Floristic Community Types 21c and 23a), *B. ilicifolia* and several understorey species at either end of the ranking scale are labelled as illustrations of placement of taxa within the ranking system.

Statistical analysis by Principal Coordinates Ordination (PCO) was undertaken to compare local reference sites, Jandakot Airport Precinct 5 and earlier flora surveys of the Swan Coastal Plain (Keighery et al. 2012). Species presence/absence data from existing banksia woodland flora surveys was incorporated into the dataset to be analysed to provide a comprehensive examination of sites across the Swan Coastal Plain (Table 1). It is evident that very few sites closely matched the floristic characteristics of the Banksia woodland in JA Precinct 5 (Figure 5). The low overlap in plant species present (Figure 6) supports this surprisingly low floristic similarity between banksia woodland at JA Precinct 5 and local reference sites in similar FCTs. It has not been determined whether this is due to the effects of sampling time, localised disturbance, environmental factors, or if JA P5 represents a Floristic Community Type poorly represented in the conservation estate. Diversity of this site may have been underestimated because Jandakot Airport was surveyed during the dry season when many annual species were dormant or senescent. However, other factors such as heavy grazing by kangaroos and wallabies and the long-unburnt status of the site would also have impacted the diversity of small plants and annuals.

Table 1. Data sources used to identify the Floristic Community Type/s at Jandakot Airport Precinct 5 and to prepare completion criteria. Data from these flora surveys of Jandakot Airport and the Swan Coastal Plain were also used to compile a comprehensive flora list for Banksia woodlands in the project area. FCT = Floristic Community Type, 100m² quadrat = 10m×10m and 625m² = 25m x 25m.

Survey Site	Survey Area	Data Source
Jandakot Airport Precinct 5	Two 100m ² quadrats	Keighery <i>et al.</i> (2012)
Jandakot Airport Precinct 5	Twelve 100m ² quadrats	BWR project
Jandakot Airport Precinct 5	Twelve 625m ² quadrats	BWR project
Jandakot Airport Precinct 5	Four 10m wide belt transects (150m to 200m long)	BWR project
Banksia woodland adjacent to Restoration Sites	Six 100m ² quadrats	BWR project
Banksia woodland FCT 21c*, (same FCT as Restoration Sites)	Twenty-three 100m ² quadrats from Swan Coastal Plain flora survey	Keighery <i>et al.</i> (2012)
Banksia woodland FCT 23a ** (same FCT as JA Precinct 5)	Fifty-one 100m ² quadrats from Swan Coastal Plain flora survey	Keighery <i>et al.</i> (2012)

Notes: * Banksia woodland most similar to that originally present in the restoration areas is deduced as FCT 21c, based on adjacent quadrats assessed by Keighery *et al.* (2012). ** Jandakot Airport Precinct 5 is known to be FCT 23a (Keighery *et al.* 2012).

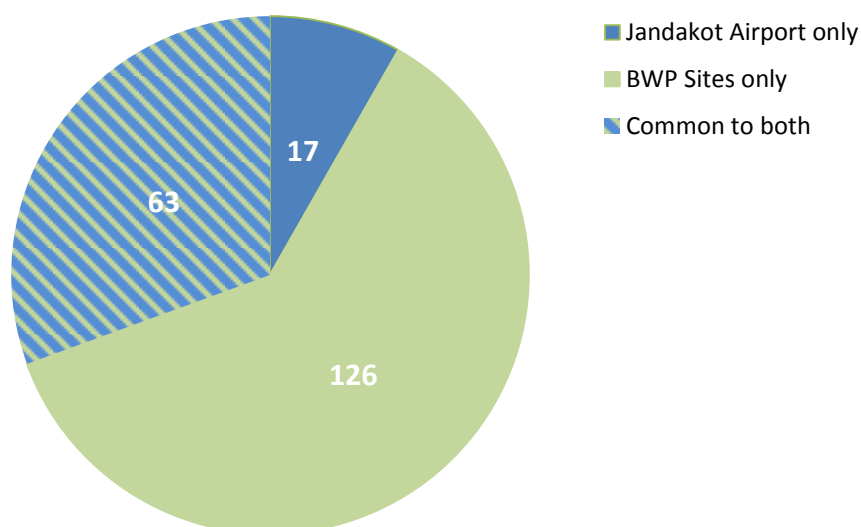


Figure 5. Diversity data showing the proportion of overlap in flora diversity between the topsoil source area (Jandakot Airport Precinct 5) and local reference sites adjacent to the topsoil recipient areas at Anketell Road and Forrestdale Lake. (Sorenson's Coefficient (CC) = 0.47)

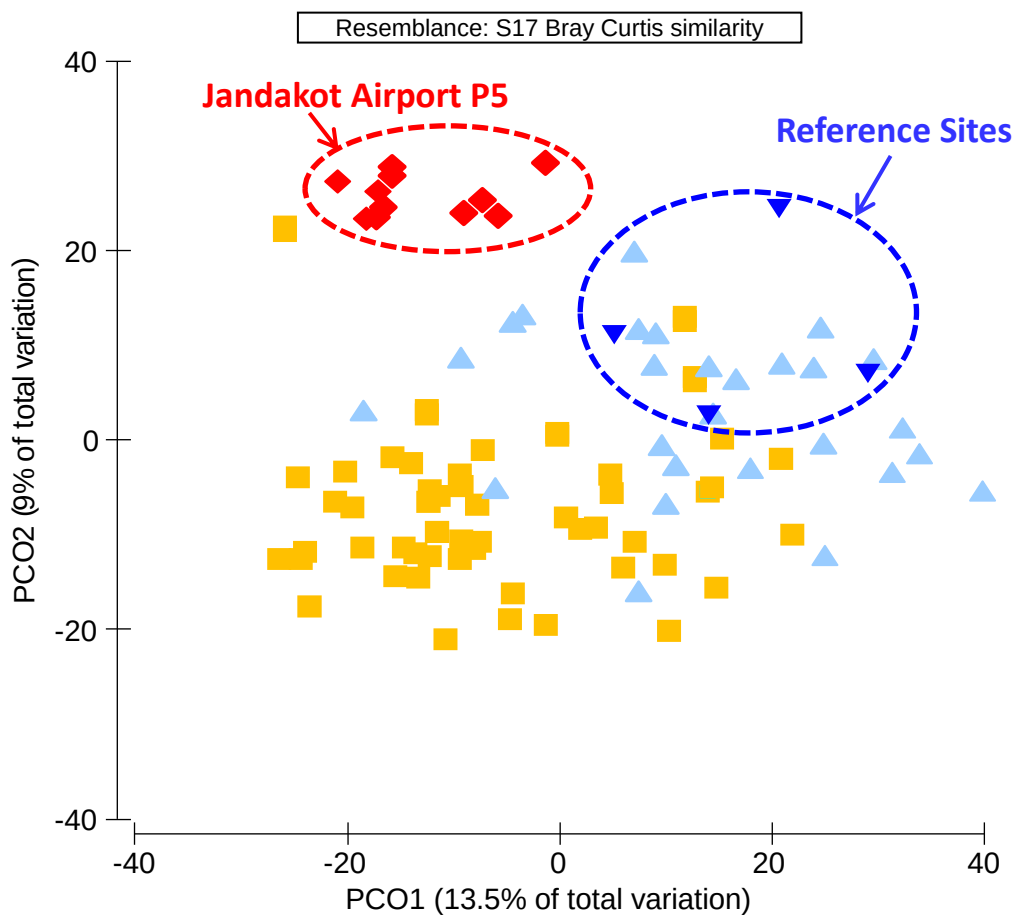


Figure 6. Comparison of banksia woodland vegetation by Principal Coordinates Ordination (PCO) analysis. Compares local reference sites for Floristic Community Type (FCT) 21c (dark blue triangles) with quadrats in Jandakot Airport Precinct 5 (red diamonds) and data from earlier flora surveys of the southern Swan Coastal Plain (Keighery et al. 2012) for the two FCTs 21c and 23a (orange squares and light blue triangles respectively). Analysis was undertaken using species presence/absence data in e-Primer v6 (Clarke and Gorley 2006). Note: Local reference sites were established in banksia woodland adjacent to topsoil recipient sites. FCT 21c = Low lying *Banksia attenuata* woodlands or shrublands and FCT23a = Central *Banksia attenuata* – *Banksia menziesii* woodlands.

4. Vegetation Communities

During the site selection process, topography, landforms, soils, wetland boundaries, vegetation complexes and predicted Floristic Community Types were used to choose restoration sites based on the information in Government of Western Australia (2000) and relevant GIS datasets (Clarke *et al.* 2016). This was to ensure that species were returned to areas with compatible characteristics. This was particularly important at the larger of the two restoration sites, Anketell Road, where a gradient between upland and wetland habitats occurs. *Banksia* woodlands consist of a complex group of Floristic Community Types, 38 FCTs contain banksia species of which 11 are named as types of ‘banksia woodland’ (Keighery and Keighery 2016). These banksia woodlands vary geographically with changes in rainfall, landform, soil type and hydrology (Keighery and Keighery 2016). Soil types on the Swan Coastal Plain are broadly organised into zones of increasing age with increasing distance from the coast (Government of Western Australia 2000) with banksia woodlands

generally occurring on the tops and slopes of dunes. Two major geological systems are associated with the restoration sites, Bassendean Sand at Anketell Road, and both Bassendean Sand and Guildford Formation at Forrestdale Lake (Playford *et al.* 1976). The Anketell Road restoration site is on the deep, infertile sands of the Bassendean Dunes where the banksia woodlands are part of the Bassendean Central and South Vegetation Complex (Government of Western Australia 2000). The Forrestdale Lake restoration site also lies on the Bassendean Dunes but further to the east, here the banksia woodlands grow on older low-lying dunes blown inland over the alluvial clay-based soils of the Pinjarra Plain (Government of Western Australia 2000). These banksia woodlands are part of the Southern River Vegetation Complex (Government of Western Australia 2000). At Forrestdale Lake the Bassendean sands vary in depth and drainage to create a range of soil subtypes.

The upland banksia woodland areas adjacent to the two restoration sites are either FCT 23a (Central *Banksia attenuata* and *Banksia menziesii* woodlands) and/or FCT 21c (Low-lying *Banksia attenuata* woodlands or shrublands). This was determined from BWR surveys of local reference sites (using the same methodology as at Jandakot Airport Precinct 5) and nearby sites previously sampled in Southern Swan Coastal Plain studies (Keighery *et al.* 2012 and Government of Western Australia 2000). It was determined that FCT 23a would have occurred only at the top of the slope at Anketell Road but that most of the upland areas would have been FCT 21c. The topsoil source area at Jandakot Airport is FCT 23a (Keighery *et al.* 2012 and Government of Western Australia 2000). However, the wetland and transitional zone vegetation (upland to wetland) within the two restoration areas are wetland Floristic Community Types (Table 2) (Government of Western Australia 2000). From BWR surveys and nearby sites sampled in regional studies (Keighery *et al.* 2012), it was predicted that the wetland and transitional zone vegetation at Anketell Road was primarily FCT 4 (*Melaleuca preissiana* damplands) and at Forrestdale Lake both FCT 4 and FCT 12 (*Melaleuca teretifolia* and/or *Astartea* aff. *fascicularis* shrublands).

The Anketell Road restoration site occurs on the slopes of a large Bassendean Dune with a deep sand profile. At Anketell Road three broad habitat types were identified and mapped prior to commencing works; upland, transitional zone (upland to wetland) and wetland (Figures 7 and 8). These habitat types were based on previous vegetation mapping in adjacent areas (Bowman Bishaw Gorham 1990), historical aerial photography pre-dating land clearing (Figure 8) and the Department's GIS datasets for soils, environmental geology and wetlands. Some areas of the Anketell Road restoration site were suitable for a mixture of upland and wetland species (Figures 7 and 8).

The Forrestdale Lake restoration site occurs in a different major landform element where low Bassendean Dunes overlay the clay-based Pinjarra Plain (Government of Western Australia 2000). No detailed vegetation mapping was available for the Forrestdale Lake restoration area, therefore we used detailed soil sub-type mapping, topography, wetland mapping and historical aerial photography to determine where upland banksia woodland would previously have occurred (Figure 9). In the Forrestdale Lake restoration area the transitional upland to wetland zones were very narrow and so are not shown at the scale of Figure 9.

It should be noted that it was not possible to get a perfect match of banksia woodland communities between Jandakot Airport and suitable cleared areas within the conservation estate. Consequently, restoration sites were selected with the most similar Floristic Community Types (Clarke *et al.* 2016). The site selection process identified a key shortcoming of the offset process; finding sites that are suitable for restoration of banksia woodland and protected for conservation is difficult in an urban landscape.

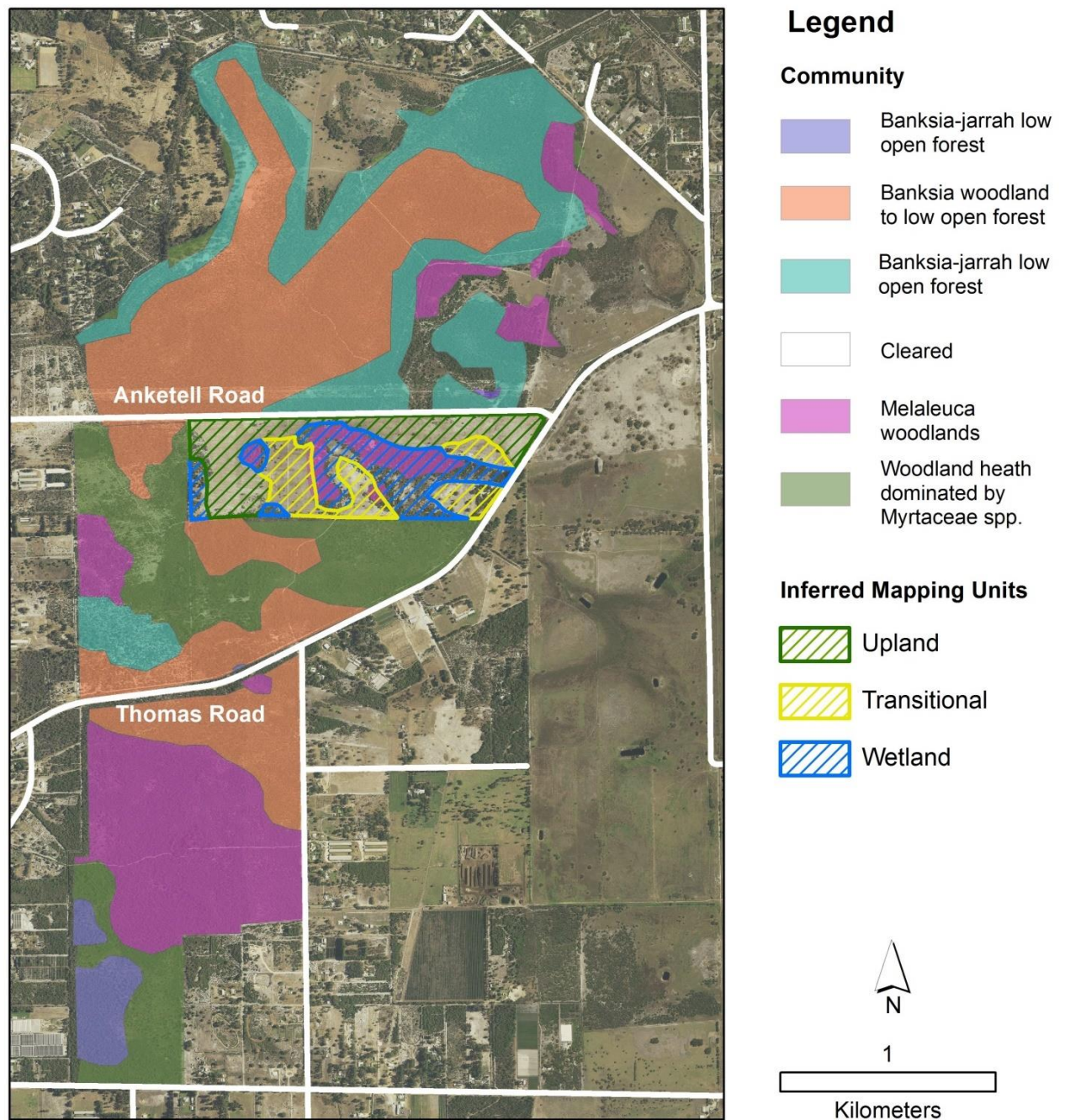


Figure 7. Vegetation map of the Anketell Road restoration site showing upland, transitional zone and wetland areas. This map is based on previous vegetation mapping by Bowman Bishaw Gorham (1990) (shown by solid colour shading) and historical aerial photographs. Note: Vegetation mapping above has been overlaid on a recent aerial photograph.

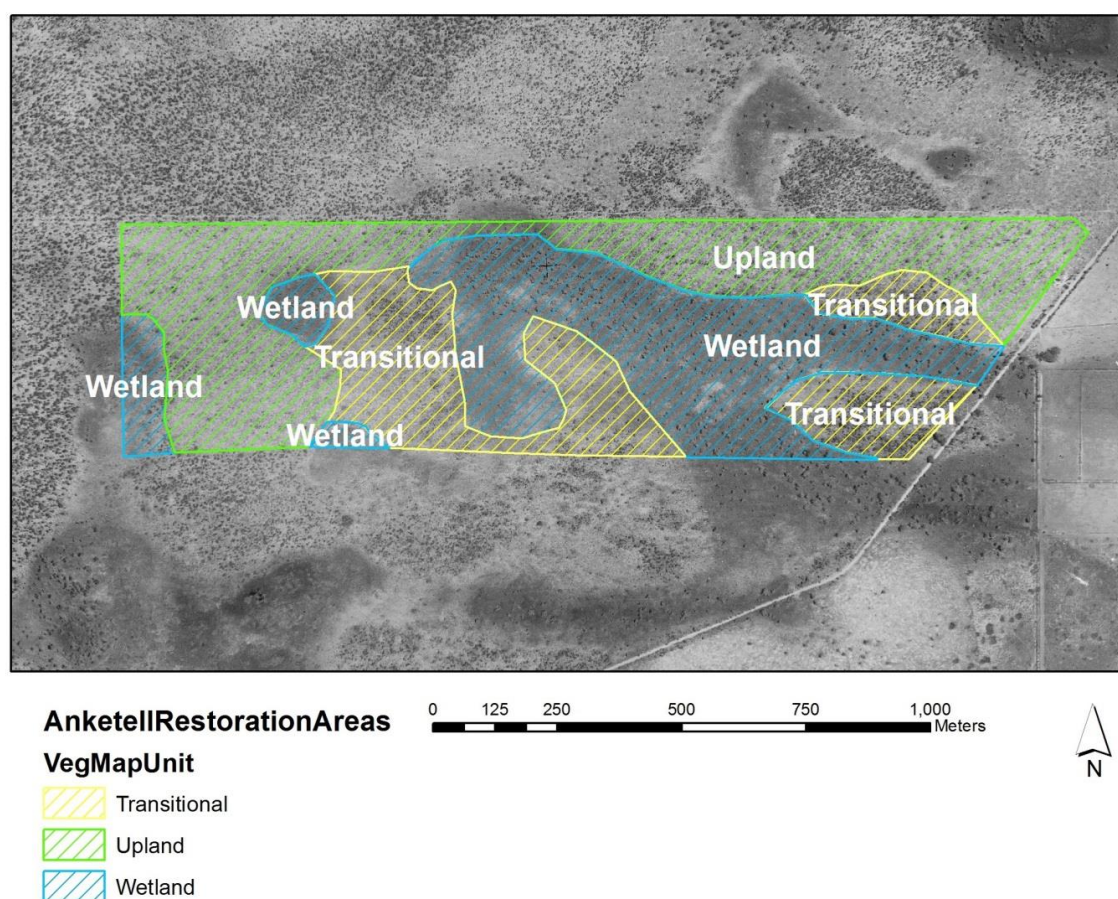


Figure 8. Detailed vegetation map of the Anketell Road restoration site showing upland, transitional zone and wetland areas in relation to a 1953 aerial photograph. The mapping is also based on a survey by Bowman Bishaw Gorham (1990). The upland vegetation is deduced to be FCT 21c (low-lying *Banksia attenuata* woodlands or shrublands) and the wetland vegetation to be primarily FCT 4 (*Melaleuca preissiana* damplands).

Table 2. Additional Floristic Community Types (FCTs) with brief descriptions, found within the Bush Forever Sites containing the restoration areas i.e. BFS 345 and BFS 347 (BFS = Bush Forever Site, numerical codes refer to Forrestdale Road and Anketell Road respectively) (Government of Western Australia 2000). Note: Only FCT 4 and 12 are predicted to occur in the BWR project's restoration areas.

FCT	Description	Bush Forever Site/s
4	<i>Melaleuca preissiana</i> damplands	- Wandi Nature Reserve and Anketell Road Bushland, Wandi/Oakford (BFS 347) - Forrestdale Lake and Adjacent Bushland, Forrestdale (BFS 345)
5	Mixed shrub damplands	Wandi Nature Reserve and Anketell Road Bushland, Wandi/Oakford (BFS 347)
8	Herb-rich shrublands in claypans	Forrestdale Lake and Adjacent Bushland, Forrestdale (BFS 345) (eastern side only)
10a	Shrublands on dry claypans	Forrestdale Lake and Adjacent Bushland, Forrestdale (BFS 345) (eastern side only)
12	<i>Melaleuca teretifolia</i> and/or <i>Astartea</i> aff. <i>fascicularis</i> shrublands	- Wandi Nature Reserve and Anketell Road Bushland, Wandi/Oakford (BFS 347) - Forrestdale Lake and Adjacent Bushland, Forrestdale (BFS 345)

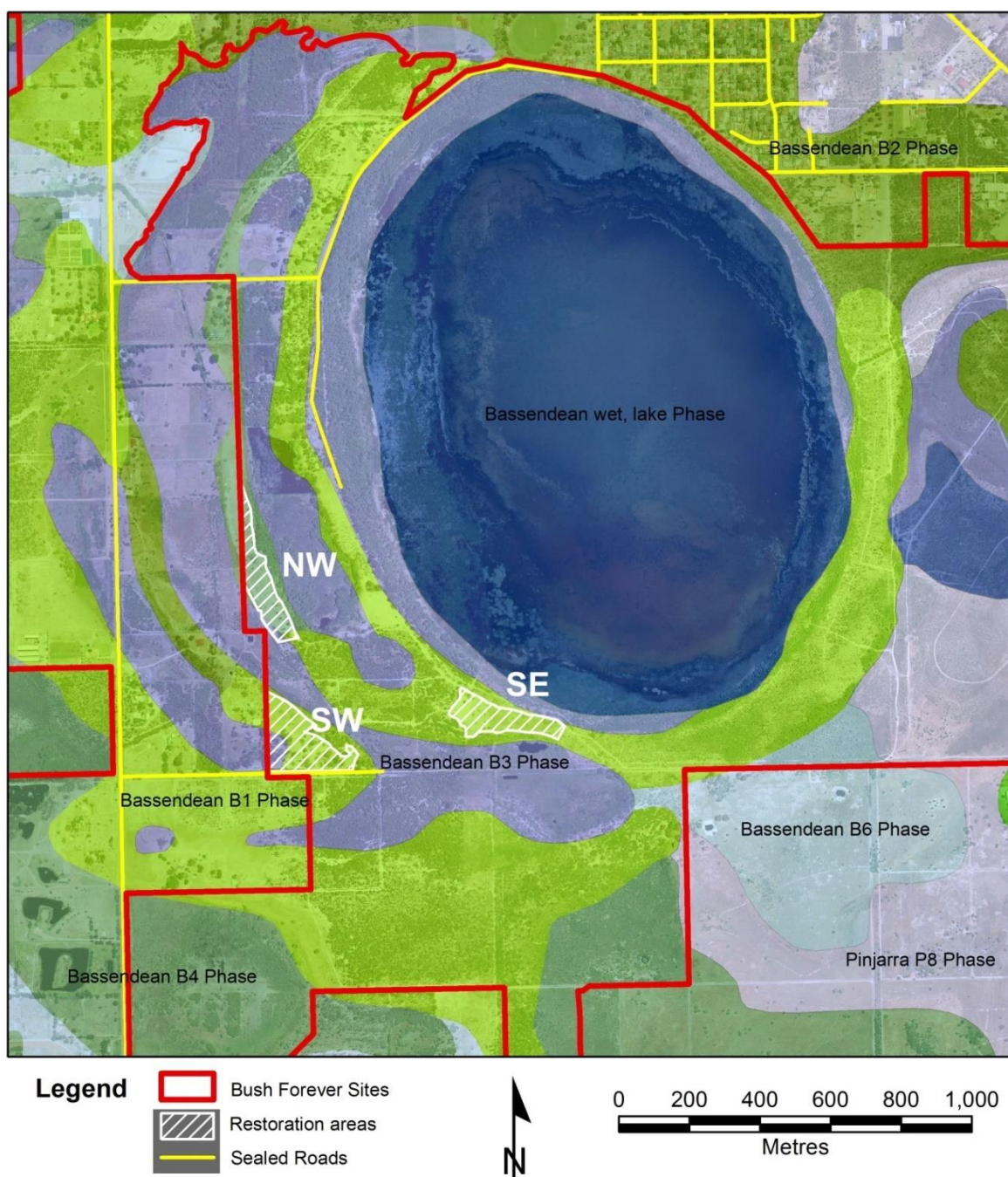


Figure 9. Forrestdale Lake restoration site on the southwestern side of the central lake with soil sub-system mapping showing the wide range of soil types present where the Bassendean Dunes overlay the Pinjarra Plain. The location of the three sections of this restoration site are shown outlined in white and labelled NW, SW and SE. Upland banksia woodlands previously occurred on the soil subtypes shaded green and wetland vegetation either remains or previously occurred on the soil subtypes shaded blue or purple (Department of Agriculture 2005). The delineation of the vegetation boundaries was based on soil subtypes, wetland mapping (Department of Biodiversity, Conservation and Attractions 2015) and historic aerial photography. The upland vegetation was deduced to be FCT 21c (low-lying *Banksia attenuata* woodlands or shrublands) and the wetland vegetation to be FCT 4 (*Melaleuca preissiana* damplands) and FCT 12 (*Melaleuca teretifolia* and/or *Astartea aff. fascicularis* shrublands).

5. Setting Completion Criteria

This report contains an outline of the initial investigations explaining why particular completion criteria listed in Table 3 were chosen. Annual reports for the BWR project may contain updated values for some criteria that may have changed due to operational constraints. The data sources and processes used to set completion criteria, as well as their role in managing restoration projects, are summarised in Figure 10.

The initial step in setting completion criteria was to create species lists for the types of banksia woodland at Jandakot Airport and the restoration sites using data from previous surveys and the BWR project surveys (see Section 3). These data (provided in Appendices 1, 2 and 3) were used to make preliminary species lists for seed collection, nursery orders and direct seeding mixes. Species lists were revised as monitoring data become available from the BWR project. A review of the literature on Western Australian seed ecology was also undertaken enabling each species to be assigned to a putative ecological category based on seed production, seed viability and/or germination in the laboratory or nursery (Bell *et al.* 1990, Bell *et al.* 1993, Meney *et al.* 1997, Roche *et al.* 1997, Bell 1999, Turner *et al.* 2006, Rokich and Dixon 2007, Turner *et al.* 2013). Data on seed availability and germination categories were then used to predict the availability and suitability of species for use in restoration sites (Figure 11).

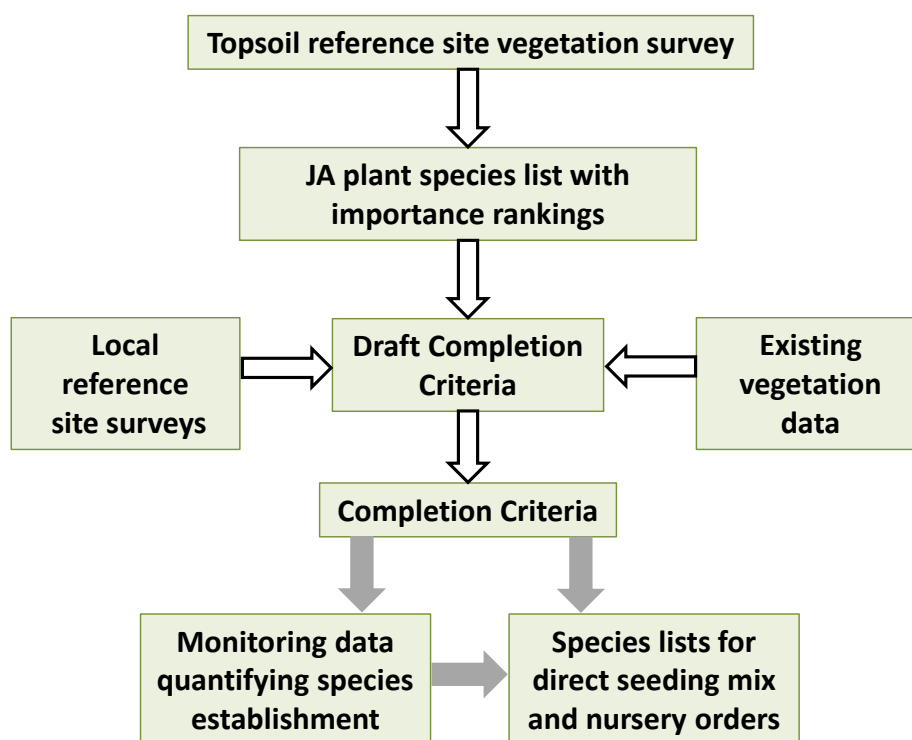


Figure 10. Flow chart for development of the restoration completion criteria. Completion criteria were based on species diversity, density, cover and frequency at Jandakot Airport Precinct 5 but revised to reflect local vegetation characteristics adjacent to the restoration sites. A complete list of data sources used in the preparation of the revised completion criteria is provided in Table 1. Note: grey arrows denote the use of the completion criteria in monitoring species establishment. Feedback from monitoring surveys was used to inform the preparation of species lists for seed collection and nursery orders, and the composition of direct seeding mixes.

The pre-clearing survey of Jandakot Airport Precinct 5, summarised in Appendix 1, revealed that of the 80 species detected, 35 (approx.. 43%) were expected to be recalcitrant i.e. species that produce little or no viable seed, or that do not germinate readily and therefore are likely to be sparsely distributed or absent from the restoration sites (Figure 12). Sub-classification of these putative recalcitrant species into taxonomic categories revealed that approximately 53% were monocots and over a quarter of these fell into the 'sedge' category, i.e. plants in Anarthriaceae, Cyperaceae or Restionaceae. For species expected to be recalcitrant vegetative material was collected (where possible) and sent to a specialist nursery for propagation.

Different species lists based on local reference sites were developed for the different vegetation communities at the restoration sites, i.e. upland areas without respread topsoil and transitional zone (upland to wetland) areas (Appendices 2 and 3 respectively). Species present only in local reference sites were also included in the overall species list for the restoration areas where topsoil was spread, because they can reasonably be presumed to have once been present at these sites, and some may be able to recolonise from adjacent bushland. Common species that occur in transitional vegetation were included in the lists of species for seed collecting, planting or direct seeding in the transitional areas between upland and wetland communities.

Using our detailed floristic dataset from reference sites, it was possible to set separate targets for the diversity and density of individual plant species as well as different plant growth forms (i.e. trees, shrubs, herbs, sedges and grasses), to ensure all major components of vegetation structure were re-established (Longman 2013). However, targets for individual species and some plant growth forms were impractical to attain due to limitations of the soil seed bank, seed availability, or nursery propagation (Figures 11 and 12). Consequently, targets were simplified to include separate targets for trees, understorey plants, annuals and weeds (Table 3). Representatives of all plant growth forms including grasses, sedges and annual species were included in seeding mixes or planting lists if available. Some annual species such as *Podotrochea gnaphalioides* and *Austrostipa compressa* were already present in large numbers at the sites prior to initiation of restoration.

An additional category was set for total plant density for all species that provide food for Carnaby's cockatoo (abbreviated as CC), and specifically for the density of banksia trees. In banksia woodland, *Banksia attenuata* and *B. menziesii* are the most important natural food sources for cockatoos with other food plants of much lower importance due to either low abundance or infrequent fruiting. Estimates of available food resources for Carnaby's cockatoos (Tables 4, 5) were calculated using data from 2012 banksia seed collections for the BWR project from three sites (Jandakot Airport, Melaleuca Park and Ridges), and published Carnaby's cockatoo energetics (Cooper *et al.* 2002; Valentine and Stock 2008). At the time of assessment all sites were severely affected by drought and data are therefore likely to be underestimates of normal resource potential. It is evident that there is high variability in seed production per tree, both between sites and banksia species (Table 4). It should be noted that the number of seeds in Table 5 relates to annual production per tree. Based on this data the estimated number of trees required to support a single bird for one year ranges from 6,205 to 19,345 for *B. menziesii* and 730 to 4,015 for *B. attenuata*. However, seed production is seasonal and in the early stages of restoration, before banksia trees are capable of providing seed set similar to that of mature plants, other plant species may be more important as food sources, e.g. *Jacksonia* species (Table 5). A more comprehensive list of plants used by Carnaby's cockatoos can be found at: https://www.dpaw.wa.gov.au/images/documents/plants-animals/animals/p4c_plantlist_20110415.pdf

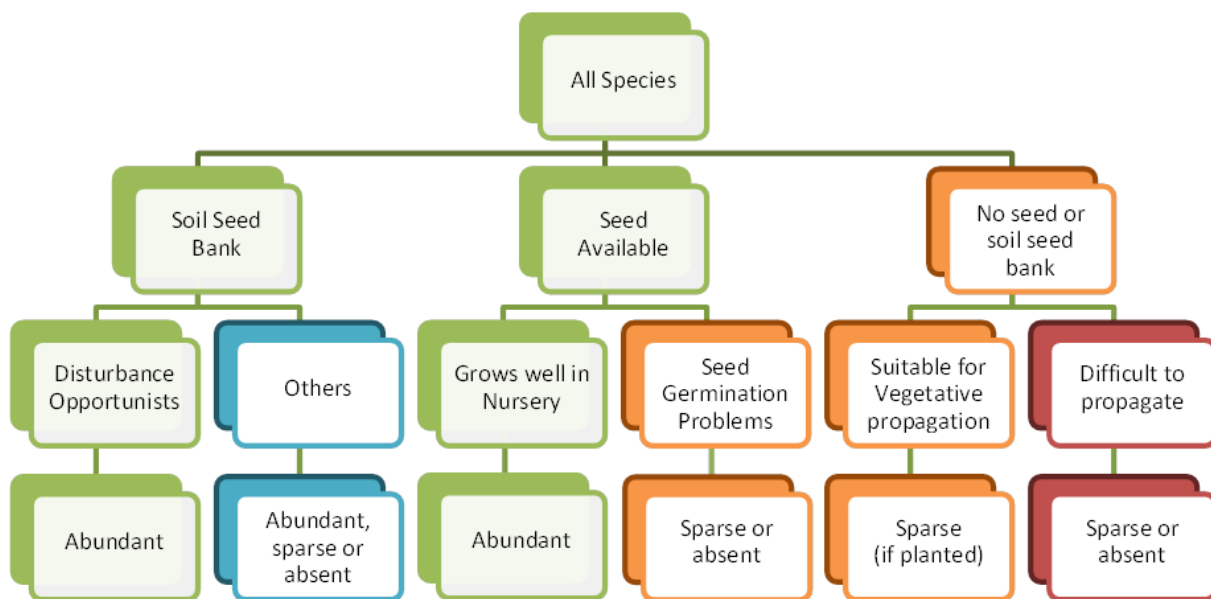


Figure 11. Classification predicting the relative abundance of banksia woodland species in restoration sites based on reproductive potential determined from the presence of a viable soil seed bank, availability of seed, and potential for vegetative propagation. Note: recalcitrant species are those that produce little or no viable seed, or that do not germinate readily. These species may be able to be propagated from cuttings or by using *in vitro* techniques but this makes seedlings expensive to produce and therefore planting of these species is likely to be sparse (EPA 2006).

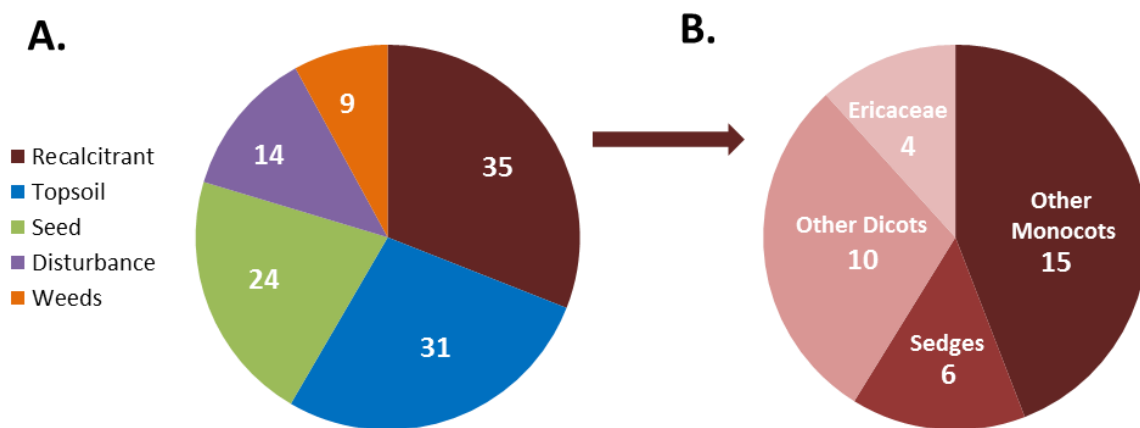


Figure 12. A. Predicted propagule source and propagation difficulty for the recruitment of plant species found in the topsoil source area at Jandakot Airport (Note: some species occur in more than one category). “Recalcitrant” species are those that produce little or no viable seed, or that do not germinate readily. “Topsoil” indicates species that are expected to be recruited from the soil seed bank. “Seed” indicates seed is available for the propagation of seedlings. “Disturbance” refers to disturbance opportunist species likely to colonize the restoration sites without assistance because disturbance of the topsoil is likely to trigger germination of dormant seed. “Weeds” is the proportion of weed species present in the topsoil source area. B. Sub-classification of the putative recalcitrant species into taxonomic categories.

To reach completion criteria targets, lists of species were produced for seed collecting, nursery orders and preparation of seed mixes for direct seeding. These were subsets based on the full species lists from Appendices 1 and 2 for upland vegetation, or Appendix 3 for transitional zone wetland vegetation. These subset lists take into account the relative importance values of species at the topsoil source area (JA Precinct 5), as well as local reference sites to prioritise species for seed collecting, nursery orders and seed mixes for direct seeding. Seed availability, germinability and the feasibility of using cuttings or divisions was also taken into account (Figure 11). Appendix 4 provides a detailed list of the species introduced to the restoration sites by planting or direct seeding, including methods of introduction. At least four of the ten most important understorey species from JA Precinct 5 are known recalcitrants; *Hibbertia hypericoides*, *Lyginia barbata*, *Phlebocarya ciliata* and *Dasypogon bromeliifolius*. These four species were established at the restoration sites by planting tube stock, but only in low numbers. Density data for canopy trees from the 10x10m quadrats at Jandakot Airport (0.12ha total) was not adequate to determine accurate canopy densities. Consequently, canopy tree density targets were based on transects and larger plots with a cumulative sampling area of 1.5ha. Adequate sampling of shrubs, herbs, grasses and sedges was achieved using the 10x10m quadrats.

Initially, completion criteria included density targets for a wide range of species based on JA Precinct 5 and local reference site surveys, with additional species added from nearby quadrats of the relevant Floristic Community Type, from previous regional surveys (Longman 2013). However, monitoring over time revealed these targets were unrealistic for many species for a number of reasons:

1. The magnitude of monitoring required to detect uncommon species.
2. The short-term nature of the project. Ecological restoration is a long-term process and some species take decades to establish the density and cover characteristics of intact banksia woodland.
3. The need for expensive, specialised propagation techniques and/or further research beyond the scope of the BWR project.

In addition, the species lists in the appendices are based on quadrat-based surveys that provide a limited record of the diversity at any given site (Government of Western Australia 2000). Larger numbers of replicates within each vegetation type can provide lists that are more detailed. However, many species in banksia woodlands are uncommon (Keighery and Keighery 2016) and are unlikely to be recorded in a quadrat-based survey. A more comprehensive and fully revised upland banksia woodland species list for Jandakot Airport is being compiled by the BWR project.

Table 3. Completion criteria for plant diversity, density and cover in banksia woodland restoration sites at Anketell Road and Forrestdale Lake. Data Source codes indicate sources of reference data at Jandakot Airport Precinct 5 prior to clearing; JA1 = survey of 10x10m quadrats and JA2 = survey of 10 x (140-200m) transects by the BWR project. Diversity refers to α -diversity (species richness). Species names in bold are known to be recalcitrant.

Completion Criteria*	Target	Data Source for Target
Total diversity	Maximise native species diversity across site based on Jandakot Airport pre-clearing (min. 80 species)	JA1: Total of 80 native spp. in 12 quadrats
Average diversity per 100 m²	19 spp. (target: at least 60% of average native diversity pre-clearing)	JA1: Average native diversity is 31 spp., range: 27-39 per quadrat
Tree diversity (overstorey)	Presence of all overstorey species	JA1: <i>Adenanthos cygnorum</i> , <i>Banksia attenuata</i> , <i>B. ilicifolia</i> , <i>B. menziesii</i> , <i>Eucalyptus marginata</i> , <i>E. todtiana</i> and <i>Nuytsia floribunda</i>
Tree density (overstorey)	At least 300 stems per ha	JA2: 300 stems per ha
CC food plant diversity and density	At least 250 stems per ha of <i>Banksia</i> spp. Presence of all CC food plants from Jandakot Airport pre-clearing	JA2: 250 stems per ha of banksia spp. CC food plants at Jandakot Airport pre-clearing: <i>Banksia attenuata</i> , <i>Banksia ilicifolia</i> , <i>Banksia menziesii</i> , <i>Eucalyptus marginata</i> , <i>Eucalyptus todtiana</i> , <i>Jacksonia furcellata</i> , <i>Xanthorrhoea preissii</i> , <i>Acacia saligna</i>
Average understorey diversity per 100 m²	17 spp. (target: 60% of average native understorey diversity pre-clearing)	JA1: Average native understorey diversity: 29 spp., range: 25-36
Native perennial plant density	At least 7,000 stems per ha	JA1: Set at about 50% of reference site stem density (~13,000 stems per ha)
Native annual plant diversity and density*	Ensure annual native species diversity and abundance matches or exceeds that at reference sites.	Jandakot Airport pre-clearing (JA1) and Anketell Road and Forrestdale Lake reference sites.
Key understorey native species diversity and density**	Presence of all species appropriate to each restored plant community, especially those with high importance values in reference sites.	e.g. Species with highest importance values at JA1: <i>Eremaea pauciflora</i> , <i>Hibbertia hypericoides</i> , <i>Patersonia occidentalis</i> , <i>Lyginia barbata</i> , <i>Banksia attenuata</i> , <i>Banksia menziesii</i> , <i>Amphipogon turbinatus</i> , <i>Scholtzia involucrata</i> , <i>Phlebocarya ciliata</i> , <i>Dasypogon bromeliifolius</i> , <i>Desmodcladus flexuosus</i> , <i>Dampiera linearis</i>
Weed diversity, density and cover***	Effective control of weeds posing a serious threat to restoration success, especially perennials. Target for perennial grass weeds is <5% cover and other perennial weeds <1%.	Prior knowledge of the effect of weeds on native species diversity, density and cover in weedy versus non-weedy quadrats.

* Annual species were included in seed mixes when available. In some instances these species had invaded the disturbed areas from adjacent uncleared woodland prior to initiation of restoration activities or had germinated in response to soil disturbance during restoration activities.

** Regular monitoring of densities and survival with intervention to increase diversity and density where practicable.

*** Monitoring of weed invasion, and density and cover of extant weed species is done twice a year and remedial action taken on an annual basis.

Table 4. Potential banksia food resources for Carnaby's cockatoos for two *Banksia* species at three sites. Estimates are given for the minimum number of trees required to feed a single cockatoo each day for *Banksia attenuata* and *B. menziesii* at three sites and assume consumption of all seeds. The estimates are based on observations of unopened follicles on cones at Jandakot Airport and two seed collection sites (Melaleuca Park and Ridges) in the northern Perth Metropolitan Region. The Field Metabolic Rate (FMR) represents the minimum daily energy requirement of a Carnaby's cockatoo. Carnaby's cockatoo FMR is 726 kJ/day, and seed energy content of banksia seed 22.0 kJ/g (Cooper *et al.* 2002). Mean seed weights for *B. attenuata* and *B. menziesii* were 0.75g and 0.50g respectively. Note: *Banksias* flower once a year and retain seed in cones until the next flowering season therefore seeds/tree represents the total annual seed production.

Location	Banksia Species	Seeds/ Tree*	Energy (kJ/tree)	%FMR/ Tree	Minimum No. Trees/ Cockatoo/ Day
Jandakot Airport	<i>Banksia attenuata</i>	181	332	45.7	2
Jandakot Airport	<i>Banksia menziesii</i>	23	43	5.9	17
Melaleuca Park	<i>Banksia attenuata</i>	54	100	13.8	7
Melaleuca Park	<i>Banksia menziesii</i>	8	14	1.9	53
Ridges	<i>Banksia attenuata</i>	36	66	9.1	11

Table 5. Carnaby's cockatoo food plants present in the topsoil source area at Jandakot Airport and method of establishment in the restoration sites. 'Seedlings' listed under 'Propagule Source' indicates that these were grown in a nursery and planted in the restoration areas rather than germinating from seed *in situ*. Note: *Jacksonia furcellata* and *Acacia saligna* are disturbance opportunist species and seed stored in topsoil is likely to germinate in response to disturbances such as topsoil respreading.

Species Name	Priority for Cockatoos*	Growth Form	Propagule Source in Restoration Sites
<i>Banksia attenuata</i>	High	Tree	Seedlings & direct seeding
<i>Banksia ilicifolia</i>	High	Tree	Seedlings & direct seeding
<i>Banksia menziesii</i>	High	Tree	Seedlings & direct seeding
<i>Eucalyptus marginata</i>	Medium	Tree	Seedlings & direct seeding
<i>Eucalyptus tottiana</i>	Medium	Tree	Seedlings & direct seeding
<i>Jacksonia furcellata</i>	Medium	Shrub	Topsoil seedbank
<i>Xanthorrhoea preissii</i>	Medium	Shrub	Seedlings & direct seeding
<i>Acacia saligna</i>	Low	Shrub	Seedlings & direct seeding

* https://www.dpaw.wa.gov.au/images/documents/plants-animals/animals/p4c_plantlist_20110415.pdf

6. Conclusions

The classical view of secondary ecological succession is that, provided environmental conditions remain the same, vegetation will develop through a series of floristic communities towards a single 'climax' vegetation type, a process described as "Relay Floristics" (Egler 1954). However, previous studies of mine site rehabilitation have found that while vegetation structure appears to progress readily towards a pre-mining state, the floristic community composition is highly influenced by the species that establish first and that this composition is difficult to alter after it has established (Norman *et al.* 2006, Koch 2007). The short-term nature of the Banksia Woodland Restoration project makes establishment of cover values similar to those of undisturbed banksia woodland unachievable, but it is expected that similar plant densities and diversity are achievable. Difficulty in adjusting plant species composition after establishment means that it is important to ensure the initial species diversity is similar to that required in the final restored banksia woodland. Not all banksia woodland plants are likely to be present in the topsoil seed bank, thus direct seeding and planting are required to complement the recruitment of seedlings derived from respread topsoil. Completion criteria were developed to direct the management and activities of the restoration project towards achieving these objectives.

The completion criterion for diversity was set at 60% of that found at Jandakot Airport Precinct 5 for individual monitoring quadrats. Similar short-term targets have been set previously for diversity in mine site rehabilitation areas, e.g. Alcoa World Alumina Australia sets a target of 60% of the diversity of adjacent forest for 15 month-old rehabilitation (Grant and Koch 2007). Diversity criteria were set to maximise similarity of the restoration sites to the topsoil source (JA Precinct 5) and surrounding banksia woodlands. A minimum target of 80 species was set for total diversity at the site level, based on the data recorded in the twelve 10x10m survey quadrats in the topsoil source area.

There were no short-term completion criteria for total cover as it will take many years or decades for individual species to reach values that are typical in mature banksia woodland. Only the completion criteria categories; tree density, CC food plants, and native perennial plants density had specific numerical densities (stems/ha) set as completion criteria. These were designed to ensure sufficient cover to stabilise the site, inhibit weed growth, ensure similar CC food resources to JA Precinct 5, and create banksia woodland with structural similarity to undisturbed banksia woodland.

Progress towards reaching each completion criteria has been published in BWR project annual reports for 2013 – 2016. The changing density for CC food trees at the Anketell Road restoration site is provided below as an example to illustrate the success of the restoration process (Figure 13). The fluctuation in banksia densities between spring and autumn are due to annual seeding and planting in autumn, and losses of seedlings over the summer drought period. Provided plants survive the summer drought, insect and animal grazing, and grow to maturity (i.e. produce flowers and fruit) they will provide additional propagules for ongoing recruitment so that supplementary seeding becomes unnecessary. *Banksia menziesii* first began flowering in autumn 2015 and set seed successfully, releasing seed onto the restoration site in 2016. The calculated regression line shows that the completion criteria target for CC food plants will be met in spring 2016 provided the annual planting effort to replace summer losses is maintained as in previous years (Figure 13).

Most restoration projects are not long enough to undertake the monitoring and subsequent management actions required to ensure that species are returning to density, cover and frequency values found in undisturbed habitats. Components such as litter, fallen woody debris and habitat for fauna and fungi can take many years to recover. However, monitoring reproduction (via flowering, set seed and recruitment, or by asexual vegetative means (such as clonal division) gives an interim measure of regenerative potential and indicates whether vegetation structure will gradually return to values more typical of intact banksia

woodland. There is a need for long-term monitoring of restored banksia woodland in the Perth metropolitan area to establish the time required for plant diversity, as well as vegetation structure and function to recover.

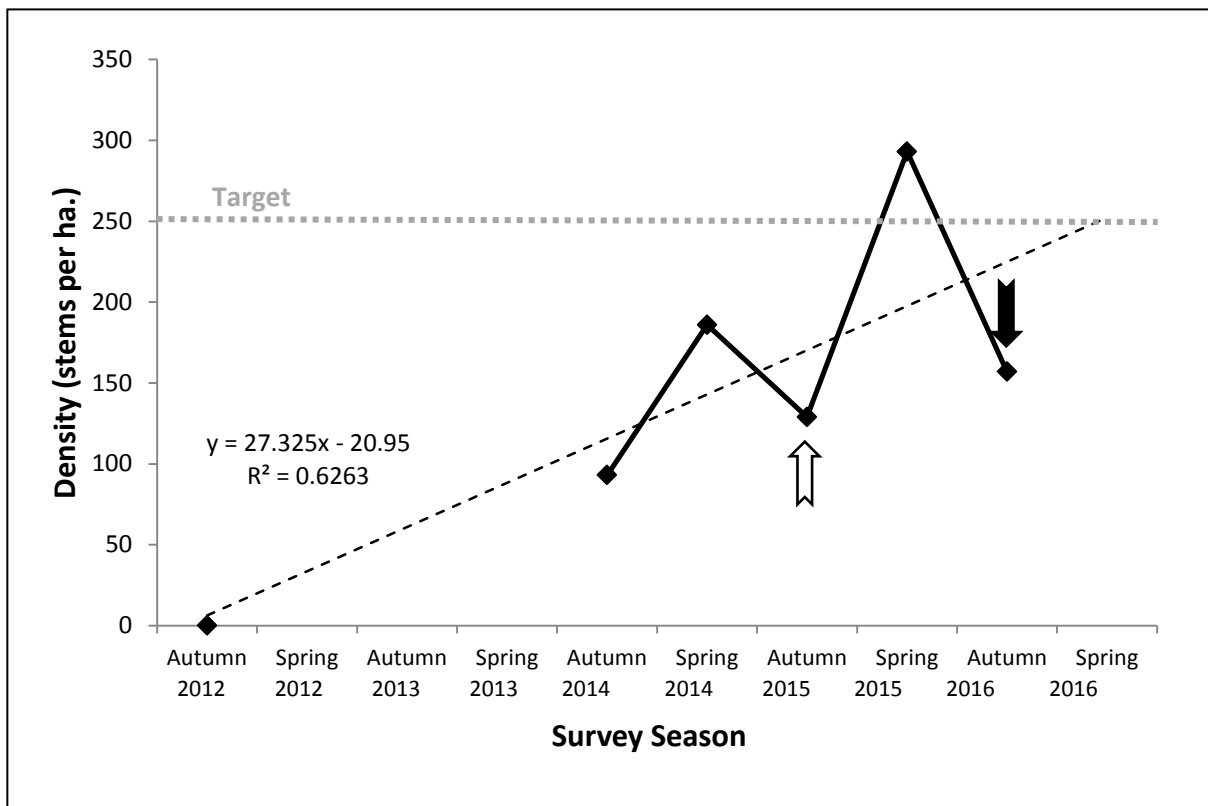


Figure 13. Recovery of banksia species used as food sources by Carnaby's cockatoo at the Anketell Road restoration site over the period 2012 to 2016. Seedlings of both *B. attenuata* and *B. menziesii* were planted during autumn of 2014 and 2015, and seed of both taxa was sown in autumn 2016 to enhance recovery. The grey dotted line is the Completion Criteria target set for CC food plants of "At least 250 stems/ha of *Banksia* spp.". Data are calculated from means of stems per 5x5m quadrat. Restoration was initiated in autumn 2012 and monitoring of tree density commenced in autumn 2014. Outlined and filled arrows indicate respectively the timing of first flowering and first seed release from follicles for *B. menziesii*.

7. References

- Bell DT, Plummer JA and Taylor SA (1993) Seed germination ecology in Southwestern Western Australia. *The Botanical Review* 59 24-73
- Bell DT (1999) Turner Review No. 1 The process of germination in Australian Species. *Australian Journal of Botany* 47 475-517
- Bowman Bishaw Gorham (1990) 'Overview of Vegetation and Environmental Values of the Jandakot Area.' (Unpublished report prepared for the Department of Planning and Urban Development, Perth, Western Australia)
- Clarke KR, Gorley RN (2006) 'PRIMER v6: User Manual/Tutorial' (PRIMER-E Ltd: Plymouth)
- Clarke K, Glossop B, Brundrett M and Collins M (2016) 'Banksia Woodland Restoration Project: Site Selection for Topsoil Transfer and Management Actions.' (Department of Parks and Wildlife: Kensington, Western Australia)
- Commonwealth of Australia (2014) 'Environmental offsets. June 2014.' (The Senate. Environment and Communications References Committee) Available at http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Environmental_Offsets/Report/index [Verified 4 November 2016]
- Commonwealth of Australia (2010) 'Jandakot Airport Expansion, Commercial Development and Clearance of Native Vegetation, WA - EPBC 2009/4796.' (Department of the Environment and Energy: Canberra) Available at <https://www.environment.gov.au/2Fepbc%2Fnotices%2Fassessments%2F2009%2F4796%2F2009-4796-variation-to-condition.pdf&usg=AFQjCNE-g56Hyqu3HvelucdljBd5YYV-jw> [Verified 7 November 2016]
- Cooper CE, Withers PC, Mawson PR, Bradshaw SD, Prince J and Robertson H (2002) Metabolic ecology of cockatoos in the south-west of Western Australia. *Australian Journal of Zoology* 50, 67-76.
- Department of Agriculture (2005) 'Soil-landscape mapping South-Western Australia [Shapefile geospatial data].' (Department of Agriculture: Perth, Western Australia)
- Department of Parks and Wildlife (2015) 'Geomorphic Wetlands Swan Coastal Plain [Shapefile geospatial data].' (Department of Parks and Wildlife: Kensington, Western Australia)
- Egler FE (1954) Vegetation Science Concepts I. Initial Floristic Composition, a Factor in Old-Field Vegetation Development. *Vegetatio* 4, 412-417.
- Environmental Protection Authority (2006) Guidance Statement No. 6. Rehabilitation of Terrestrial Ecosystems. (Environmental Protection Authority: Perth, Western Australia) Available at <http://www.epa.wa.gov.au/policies-guidance/rehabilitation-terrestrial-ecosystems-gs-6> [Verified 27 January 2017]
- Government of Western Australia (2000) 'Bush Forever. Volume Two – Directory of Bush Forever Sites.' (Department of Environmental Protection: Perth, Western Australia)
- Grant CD, Koch JM (2007) Decommissioning Western Australia's first bauxite mine: co-evolving vegetation restoration techniques and targets. *Ecological Management and Restoration*. 8, 92-105.
- Jandakot Airport Holdings Pty Ltd (2010) 'Jandakot Airport Offset Plan. March 2010.' (Jandakot Airport Holdings, Jandakot, Western Australia)
- Keighery GJ, Keighery BJ (2016) Floristics of the *Banksia* woodlands of the Swan Coastal Plain. In 'Banksia Woodlands. A Restoration Guide for the Swan Coastal Plain.' (Eds JC Stevens, DP Rockich, VJ Newton VJ, RL Barrett, KW Dixon) pp. 7-30 (UWA Publishing: Crawley, Western Australia)

- Keighery BJ, Keighery GJ, Longman VL, Clarke KA (2012) 'Weed and Native Flora Data for the Swan Coastal Plain.' (Department of Parks and Wildlife: Kensington, Western Australia) Available at <https://naturemap.dpaw.wa.gov.au/> [Verified 27 January 2017]
- Koch, JM (2007) Restoring a jarrah forest understorey vegetation after bauxite mining in Western Australia. *Restoration Ecology Supplement*. 15, S26-S39.
- Longman, VL (2013) 'Completion Criteria Data for the Anketell Road and Forrestdale Lake Restoration Sites. Banksia Woodland Restoration Project.' (Department of Environment and Conservation, Perth, Western Australia)
- Meney, KA, Dixon, KW, Pate, JS (1997) Reproductive potential of obligate seeder and resprouter herbaceous perennial monocots (Restionaceae, Anarthriaceae, Ecdeicoleaceae) from South-western Western Australia. *Australian Journal of Botany* 45, 771-782.
- Moore T, Barrett G (2013) 'Banksia Woodland Restoration Project: Fauna Monitoring and Milestones.' (Department of Parks and Wildlife: Kensington, Western Australia)
- Mueller-Dombois D, Ellenberg H (1974) 'Aims and Methods of Vegetation Ecology.' (Wiley; New York)
- Muir Environmental (1993) 'Evaluation of Proposed Conservation Areas Jandakot Airport.' Report for the Federal Airports Corporation. (Muir Environmental: Perth, Western Australia)
- Norman MA, Koch JM, Grant CD, Morald TK, Ward SC (2006). Vegetation succession after bauxite mining in Western Australia. *Restoration Ecology* 14, 278-288.
- Playford PE, Cockbain AE, Low GH (1976) 'Geology of the Perth Basin, Western Australia.' (Department of Mines: Perth, Western Australia)
- Rokich DP, Dixon KW (2007) Recent advances in restoration ecology, with a focus on *Banksia* woodland and the smoke germination tool. *Australian Journal of Botany* 55, 375–389.
- Roche S, Dixon KW, Pate JS (1997) Seed aging and smoke: Partner cues in the amelioration of seed dormancy in selected Australian native species. *Australian Journal of Botany* 45, 783-815.
- Society for Ecological Restoration International Science & Policy Working Group (2004) 'The SER International Primer on Ecological Restoration. Version 2: October 2004' (Society for Ecological Restoration International: Tucson) Available at <http://www.ser.org/page/SERDocuments> [Verified 31 January 2017]
- Turner SR, Steadman KJ, Vlahos S, Koch JM, Dixon KW (2006) Seed treatment optimizes benefits of seed bank storage for restoration-ready seeds: The feasibility of prestorage dormancy alleviation for mine-site revegetation. *Restoration Ecology* 21, 186-192.
- Valentine LE, Stock W (2008) 'Food Resources of Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*) in the Gnaralpa Sustainability Strategy study area.' (Department of Environment and Conservation: Kensington, Western Australia) Available at <http://ro.ecu.edu.au/ecuworks/6147/> [Verified 27 January 2017]

8. Appendices.

Appendix 1. List of plant species found in upland Banksia woodland of Floristic Community Type 23a at Jandakot Airport prior to clearing in 2012.

Species listed in bold are potential food sources for Carnaby's cockatoo. IV Rank = Importance Value Rank. A species of high Importance Value has a low IV Rank. Codes for Main Propagule Source: T = topsoil, S = collected seed (used for both nursery-raised seedlings for planting and/or direct seeding), V = vegetative material used for cuttings or divisions for planting, I = invasion over time, blank space = unknown. A "yes" in the Recalcitrant column indicates a potential recalcitrant species. The growth form category "Sedge" includes plant species with sedge-like growth habits in Anarthriaceae, Cyperaceae or Restionaceae.

Species	IV Rank	Growth Form	Main Propagule Source	Density (stems/ha $\pm$ SD)	Potential Recalcitrant
<i>Acacia pulchella</i>	40	Shrub	T	50 $\pm$ 52	
<i>Acacia saligna</i> subsp. <i>saligna</i>	57	Shrub	T,S	8 $\pm$ 29	
<i>Adenanthos cygnorum</i> subsp. <i>cygnorum</i>	33	Shrub	T	17 $\pm$ 58	
<i>Allocasuarina humilis</i>	20	Shrub	S	275 $\pm$ 431	
<i>Amphipogon turbinatus</i>	7	Grass	T,S	792 $\pm$ 653	
<i>Arnocrinum preissii</i>	57	Geophyte		8 $\pm$ 29	yes
<i>Austrostipa compressa</i>	26	Grass	T,S	100 $\pm$ 74	
<i>Banksia attenuata</i>	5	Tree	T,S	258 $\pm$ 378	
<i>Banksia ilicifolia</i>	15	Tree	S	92 $\pm$ 231	
<i>Banksia menziesii</i>	6	Tree	S	275 $\pm$ 319	
<i>Beaufortia elegans</i>	48	Shrub	S	67 $\pm$ 231	
<i>Bossiaea eriocarpa</i>	14	Shrub	T	467 $\pm$ 543	
<i>Burchardia congesta</i>	29	Geophyte	T,S	75 $\pm$ 45	
<i>Caladenia flava</i>	57	Geophyte	I	8 $\pm$ 29	
<i>Calectasia narragara</i>	57	Herb		8 $\pm$ 29	yes
<i>Calytrix flavescens</i>	17	Shrub	S	483 $\pm$ 570	yes
<i>Chamaescilla corymbosa</i> var. <i>corymbosa</i>	57	Geophyte	T,S	8 $\pm$ 29	
<i>Conostephium pendulum</i>	39	Shrub		117 $\pm$ 316	yes
<i>Conostephium preissii</i>	25	Shrub		233 $\pm$ 347	yes
<i>Conostylis aculeata</i>	19	Herb	S	350 $\pm$ 485	
<i>Conostylis juncea</i>	57	Herb	S,V	8 $\pm$ 29	
<i>Conostylis setigera</i> subsp. <i>setigera</i>	45	Herb	S	42 $\pm$ 51	
<i>Croninia kingiana</i>	53	Shrub	S	33 $\pm$ 115	yes
<i>Dampiera linearis</i>	13	Herb	V	417 $\pm$ 486	yes
<i>Dasypogon bromeliifolius</i>	10	Herb	T,S,V	350 $\pm$ 371	yes
<i>Daviesia triflora</i>	34	Shrub	T,S	83 $\pm$ 140	
<i>Desmocladius fasciculatus</i>	47	Sedge		25 $\pm$ 45	yes
<i>Desmocladius flexuosus</i>	11	Sedge	T,V	233 $\pm$ 290	yes
<i>Eremaea asterocarpa</i> subsp. <i>asterocarpa</i>	52	Shrub	S	58 $\pm$ 202	
<i>Eremaea pauciflora</i>	1	Shrub	S	975 $\pm$ 1092	
<i>Eucalyptus marginata</i> subsp. <i>marginata</i>	21	Tree	S	42 $\pm$ 79	
<i>Eucalyptus tottdiana</i>	44	Tree	S	17 $\pm$ 58	
<i>Gompholobium tomentosum</i>	37	Shrub	T,S	75 $\pm$ 97	
<i>Haemodorum spicatum</i>	57	Geophyte	S	8 $\pm$ 29	yes
<i>Hemiandra pungens</i>	57	Shrub		8 $\pm$ 29	
<i>Hensmania turbinata</i>	41	Herb		50 $\pm$ 52	yes

Species	IV Rank	Growth Form	Main Propagule Source	Density (stems/ha ± SD)	Potential Recalcitrant
<i>Hibbertia huegelii/sericosepala</i> ¹	43	Shrub	V	50 ± 67	
<i>Hibbertia hypericoides</i> subsp. <i>hypericoides</i>	2	Shrub	T	1225 ± 1840	yes
<i>Hibbertia subvaginata</i>	23	Shrub	T,V	158 ± 271	
<i>Hovea trisperma</i> var. <i>trisperma</i>	58	Shrub		4 ± 14	
<i>Hypocalymma robustum</i>	28	Shrub	S	125 ± 166	
<i>Hypolaena exsulca</i>	12	Sedge		608 ± 869	yes
<i>Jacksonia furcellata</i>	35	Shrub	T,S	83 ± 170	
<i>Laxmannia squarrosa</i>	57	Herb		8 ± 29	yes
<i>Lechenaultia floribunda</i>	57	Shrub	V	8 ± 29	
<i>Lepidosperma squamatum</i> s.l.	36	Sedge	V	150 ± 399	yes
<i>Leucopogon conostephioides</i>	18	Shrub		283 ± 272	yes
<i>Levenhookia stipitata</i>	57	Herb	T	8 ± 29	yes
<i>Lomandra caespitosa</i>	43	Herb	T,V	50 ± 67	yes
<i>Lomandra hermaphrodita</i>	27	Herb	T,V	108 ± 131	yes
<i>Lomandra micrantha</i> subsp. <i>micrantha</i>	57	Herb		8 ± 29	yes
<i>Lomandra preissii</i>	57	Herb		8 ± 29	yes
<i>Lomandra suaveolens</i>	57	Herb	V	8 ± 29	yes
<i>Lyginia barbata/imberbis</i> ²	4	Sedge	T,V	875 ± 548	yes
<i>Macrozamia fraseri</i>	56	Herb	S	4 ± 14	
<i>Melaleuca seriata</i>	31	Shrub	S	150 ± 430	
<i>Melaleuca thymoides</i>	30	Shrub	S	92 ± 162	
<i>Nuytsia floribunda</i>	42	Tree	S	33 ± 49	
<i>Patersonia occidentalis</i> var. <i>occidentalis</i>	3	Herb	T,S,V	1275 ± 1290	yes
<i>Persoonia saccata</i>	51	Shrub	T,S	17 ± 39	yes
<i>Petrophile linearis</i>	22	Shrub	S	158 ± 116	yes
<i>Phlebocarya ciliata</i>	9	Herb	V	692 ± 1092	yes
<i>Phlebocarya filifolia</i>	46	Herb	V	83 ± 204	yes
<i>Pimelea sulphurea</i>	57	Shrub		8 ± 29	
<i>Podolepis gracilis</i>	50	Herb	S	25 ± 45	
<i>Rytidosperma occidentale</i>	57	Grass	T,S	8 ± 29	
<i>Scaevola repens</i> var. <i>repens</i>	57	Shrub		8 ± 29	
<i>Schoenus caespititius</i>	58	Sedge		4 ± 14	
<i>Schoenus curvifolius</i>	32	Sedge	V	92 ± 138	yes
<i>Scholtzia involucreta</i>	8	Shrub	S,V	450 ± 505	
<i>Stirlingia latifolia</i>	16	Shrub	S	425 ± 374	yes
<i>Stylidium piliferum</i>	54	Herb		17 ± 39	yes
<i>Stylidium repens</i>	24	Herb		125 ± 136	yes
<i>Thysanotus thyrsoideus</i>	57	Geophyte		8 ± 29	yes
<i>Thysanotus triandrus</i>	49	Herb	V	25 ± 62	yes
<i>Trachymene pilosa</i>	50	Herb	T	25 ± 45	
<i>Wahlenbergia preissii</i>	57	Herb		8 ± 29	
<i>Xanthorrhoea preissii</i>	38	Herb	S	100 ± 346	
<i>Xanthosia huegelii</i>	55	Herb		17 ± 39	

1. Unidentified species in *Hibbertia huegelii/sericosepala* complex

2. Unidentified species in *Lyginia barbata/imberbis* complex

Appendix 2. Plant species found in upland Banksia woodland of Floristic Community Type 21c, the upland FCT determined to have occurred at the two restoration sites prior to disturbance.

Ticks in columns headed by site codes indicate presence in reference quadrats at a survey site. Data is compiled from BWR surveys and Keighery *et al.* (2012). Site Codes: FL = Forrestdale Lake, AR = Anketell Road, D = Denis De Young Reserve, J = Jandakot Airport (jand05, Keighery *et al.* 2012), M = Modong Nature Reserve. Codes for main propagule source: T = topsoil, S = collected seed (used for both nursery-raised seedlings for planting and/or direct seeding), V = vegetative material used for cuttings or divisions for planting, I = invasion over time, blank space = unknown. A “yes” in the Recalcitrant column indicates a potential recalcitrant species. The growth form category “Sedge” includes plant species with sedge-like growth habits in Anarthriaceae, Cyperaceae and Restionaceae.

Species	FL	AR	D	J	M	Growth Form	Main Propagule Source	Potential Recalcitrant
<i>Acacia huegelii</i>	✓	✓	✓			Shrub	S	
<i>Acacia pulchella</i>	✓			✓		Shrub	T	
<i>Adenanthos cygnorum</i> subsp. <i>cygnorum</i>	✓		✓	✓		Shrub	T	
<i>Amphipogon turbinatus</i>	✓		✓			Grass	T,S	
<i>Anigozanthos manglesii</i> subsp. <i>manglesii</i>	✓		✓			Geophyte	S	
<i>Aotus procumbens</i>			✓			Shrub	S	
<i>Arnocrinum preissii</i>			✓			Geophyte		yes
<i>Asteridea pulverulenta</i>			✓			Herb	S	
<i>Astroloma xerophyllum</i>				✓		Shrub		yes
<i>Austrostipa compressa</i>		✓		✓	✓	Grass	T,S	
<i>Austrostipa flavescens</i>			✓			Grass	S	
<i>Banksia attenuata</i>	✓	✓	✓	✓	✓	Tree	T,S	
<i>Banksia ilicifolia</i>	✓	✓		✓	✓	Tree	S	
<i>Banksia menziesii</i>	✓	✓	✓			Tree	S	
<i>Beaufortia elegans</i>				✓		Shrub	S	
<i>Bossiaea eriocarpa</i>	✓	✓	✓		✓	Shrub	T	
<i>Brachyloma preissii</i>	✓					Shrub		
<i>Burchardia congesta</i>	✓	✓				Geophyte	T,S	
<i>Caesia micrantha</i>		✓				Geophyte		
<i>Caladenia flava</i>	✓	✓			✓	Geophyte	I	
<i>Calytrix angulata</i>			✓			Shrub	S	yes
<i>Calytrix flavescens</i>			✓			Shrub	S	yes
<i>Calytrix fraseri</i>	✓					Shrub	S	yes
<i>Cartonema philydroides</i>	✓					Herb	S	
<i>Chamaescilla corymbosa</i> var. <i>corymbosa</i>	✓	✓				Geophyte	T,S	
<i>Conostephium pendulum</i>	✓	✓				Shrub		yes
<i>Conostylis aculeata</i>	✓		✓			Herb	S	
<i>Conostylis juncea</i>		✓			✓	Herb	S,V	
<i>Corynotheca micrantha</i>	✓					Geophyte		
<i>Crassula colorata</i>		✓	✓			Herb	S	
<i>Dampiera linearis</i>		✓	✓	✓		Herb	V	yes
<i>Dasypogon bromeliifolius</i>	✓	✓	✓			Herb	T,S,V	yes
<i>Desmocladus flexuosus</i>	✓	✓				Sedge	T,V	yes
<i>Dianella revoluta</i> var. <i>divaricata</i>	✓					Herb	S	
<i>Drosera erythrorhiza</i> subsp. <i>erythrorhiza</i>	✓	✓				Geophyte		yes
<i>Drosera macrantha</i> subsp. <i>macrantha</i>					✓	Geophyte		yes
<i>Drosera menziesii</i>	✓					Geophyte	V	yes
<i>Drosera paleacea</i> subsp. <i>paleacea</i>					✓	Herb		yes
<i>Drosera pallida</i>	✓	✓				Geophyte		yes
<i>Eriochilus dilatatus</i>	✓					Geophyte	I	yes

Species	FL	AR	D	J	M	Growth Form	Main Propagule Source	Potential Recalcitrant
<i>Eucalyptus tottiana</i>		✓				Tree	S	
<i>Euchilopsis linearis</i>					✓	Shrub	S	
<i>Euchiton sphaericus</i>		✓				Herb	S	
<i>Gompholobium tomentosum</i>	✓	✓	✓	✓	✓	Shrub	T,S	
<i>Gonocarpus pithyoides</i>		✓				Herb		
<i>Hemiandra</i> sp. Jurien (B.J. Conn & M.E. Tozer BJC 3885)	✓					Shrub	V	yes
<i>Hensmania turbinata</i>				✓		Herb		yes
<i>Hibbertia racemosa</i>	✓		✓			Shrub		yes
<i>Hibbertia subvaginata</i>	✓	✓		✓	✓	Shrub	T,V	
<i>Homalosciadium homalocarpum</i>		✓		✓	✓	Herb	T	
<i>Hovea trisperma</i> var. <i>trisperma</i>		✓				Shrub		
<i>Hypocalymma angustifolium</i> subsp. Swan Coastal Plain (G.J. Keighery 16777)					✓	Shrub	S	
<i>Hypolaena exsulca</i>		✓			✓	Sedge		yes
<i>Jacksonia furcellata</i>	✓		✓		✓	Shrub	T,S	
<i>Jacksonia gracillima</i>		✓			✓	Shrub	S	
<i>Kennedia prostrata</i>					✓	Shrub	S	
<i>Kunzea glabrescens</i>	✓	✓			✓	Shrub	S	
<i>Laxmannia sessiliflora</i> subsp. <i>australis</i>			✓			Herb	S	yes
<i>Lechenaultia expansa</i>				✓		Shrub	V	
<i>Lechenaultia floribunda</i>	✓		✓			Shrub	V	
<i>Lepidosperma squamatum</i> s.l.			✓			Sedge	V	yes
<i>Leucopogon conostephioides</i>	✓	✓	✓	✓	✓	Shrub		yes
<i>Leucopogon polymorphus</i>				✓		Shrub		yes
<i>Lomandra caespitosa</i>	✓	✓	✓			Herb	T,V	yes
<i>Lomandra hermaphrodita</i>	✓	✓				Herb	T,V	yes
<i>Lomandra micrantha</i> subsp. <i>micrantha</i>	✓					Herb		yes
<i>Lomandra nigricans</i>		✓				Herb		yes
<i>Lomandra sericea</i>		✓				Herb		yes
<i>Lyginia barbata/imberbis</i> ¹	✓	✓	✓	✓	✓	Sedge	T,V	yes
<i>Macarthuria apetala</i>			✓			Herb		
<i>Macarthuria australis</i>	✓					Herb		
<i>Macrozamia fraseri</i>	✓					Herb	S	
<i>Melaleuca preissiana</i>	✓	✓			✓	Tree	S	
<i>Melaleuca seriata</i>				✓		Shrub	S	
<i>Melaleuca thymoides</i>		✓	✓			Shrub	S	
<i>Microlaena stipoides</i>	✓	✓				Grass	S,V	
<i>Microtis media</i> subsp. <i>media</i>				✓		Herb	I	
<i>Millotia tenuifolia</i> var. <i>tenuifolia</i>	✓					Herb	I	
<i>Neurachne alopecuroides</i>	✓					Grass	S	
<i>Nuytsia floribunda</i>	✓	✓				Tree	S	
<i>Patersonia occidentalis</i> var. <i>occidentalis</i>	✓	✓	✓			Herb	T,S,V	yes
<i>Petrophile linearis</i>	✓	✓	✓			Shrub	S	yes
<i>Philothea spicata</i>	✓	✓	✓			Shrub	S	
<i>Phlebocarya ciliata</i>		✓	✓		✓	Herb	V	yes
<i>Pithocarpa pulchella</i> var. <i>pulchella</i>				✓		Herb	S	
<i>Podotheca chrysantha</i>	✓					Herb	I	
<i>Podotheca gnaphalioides</i>		✓				Herb	T,S	
<i>Poranthera microphylla/moorokatta</i> ²		✓			✓	Herb	S	

Species	FL	AR	D	J	M	Growth Form	Main Propagule Source	Potential Recalcitrant
<i>Pterostylis nana</i> s.l.		✓				Geophyte	I	yes
<i>Pterostylis sanguinea</i>	✓				✓	Geophyte	I	yes
<i>Pterostylis</i> sp. crinkled leaf ³					✓	Geophyte	I	yes
<i>Pyrorchis nigricans</i>					✓	Geophyte	I	yes
<i>Quinetia urvillei</i>	✓	✓				Herb	T	
<i>Regelia inops</i>				✓		Shrub	S	
<i>Rhodanthe citrina</i>		✓				Herb	T	
<i>Rytidosperma caespitosum</i>			✓			Grass	T,S	
<i>Rytidosperma occidentale</i>					✓	Grass	T,S	
<i>Schoenus curvifolius</i>	✓	✓		✓		Sedge	V	yes
<i>Schoenus efoliatus</i>		✓				Sedge	V	yes
<i>Schoenus grandiflorus</i>	✓					Sedge	V	
<i>Scholtzia involuocrata</i>	✓		✓			Shrub	S,V	
<i>Sowerbaea laxiflora</i>	✓					Geophyte		
<i>Stirlingia latifolia</i>	✓		✓			Shrub	S	yes
<i>Stylidium araeophyllum/neurophyllum</i> ⁴	✓	✓	✓	✓		Herb	S	yes
<i>Stylidium calcaratum</i>			✓			Herb	S	yes
<i>Stylidium piliferum</i>		✓			✓	Herb		yes
<i>Stylidium repens</i>	✓		✓	✓	✓	Herb		yes
<i>Thysanotus arbuscula</i>	✓	✓				Herb		yes
<i>Thysanotus manglesianus/patersonii</i> ⁵	✓					Geophyte	S	yes
<i>Thysanotus multiflorus</i>				✓		Herb	S	
<i>Thysanotus thyrsoideus</i>				✓		Geophyte		yes
<i>Trachymene pilosa</i>	✓	✓	✓			Herb	T	
<i>Tricoryne elatior</i>		✓				Herb		yes
<i>Wahlenbergia preissii</i>			✓			Herb		
<i>Xanthorrhoea preissii</i>		✓		✓	✓	Herb	S	

1. Unidentified species in *Lyginia barbata/imberbis* complex

2. Unidentified species in *Poranthera microphylla/moorokatta* complex

3. *Pterostylis* sp. crinkled leaf (G.J. Keighery 13426)

4. Originally identified as *Stylidium brunonianum*, and now has become either *Stylidium araeophyllum* or *S. neurophyllum*

5. Unidentified species in *Thysanotus manglesianus/patersonii* complex

Appendix 3. Plant species found in Floristic Community Types 4 or 12, the two FCTs determined to have occurred in the transition zones between upland and wetland prior to disturbance at the two restoration sites.

Ticks indicate presence in reference quadrats for each survey site. Data is compiled from our surveys and Keighery *et al.* (2012). Site Codes: FL = Forrestdale Lake, AR = Anketell Road, C = Casuarina Prison, G = City of Gosnells reserves, M = Modong Nature Reserve. Codes for Main Propagule Source: T = topsoil, S = collected seed (used for both nursery raised seedlings for planting and/or direct seeding), V = vegetative material used for cuttings or divisions for planting, I = invasion over time, blank space = unknown. A “yes” in the Recalcitrant column indicates a potential recalcitrant species. The growth form category “Sedge” includes plant species with sedge-like growth habits in Anarthriaceae, Cyperaceae or Restionaceae.

Species	FL	AR	C	G	M	Growth Form	Main Propagule Source	Potential Recalcitrant
<i>Acacia pulchella</i>	✓	✓		✓		Shrub	T	
<i>Acacia saligna</i> subsp. <i>saligna</i>	✓					Shrub	T,S	
<i>Acacia stenoptera</i>		✓			✓	Shrub	S	
<i>Adenanthos cygnorum</i> subsp. <i>cygnorum</i>	✓					Shrub	T	
<i>Adenanthos obovatus</i>	✓	✓	✓	✓	✓	Shrub	S	
<i>Allocasuarina fraseriana</i>		✓				Tree	S	
<i>Amphipogon laguroides</i> subsp. <i>laguroides</i>			✓	✓		Grass		
<i>Aotus gracillima</i>	✓					Shrub		
<i>Aphelia cyperoides</i>	✓			✓	✓	Sedge	S	yes
<i>Astartea scoparia</i>	✓	✓		✓	✓	Shrub	S	
<i>Asteridea pulverulenta</i>				✓		Herb	S	
<i>Austrostipa compressa</i>		✓	✓	✓		Grass	T,S	
<i>Banksia attenuata</i>		✓				Tree	T,S	
<i>Banksia ilicifolia</i>			✓			Tree	S	
<i>Boronia crenulata</i> subsp. <i>viminea</i>	✓					Shrub	S	
<i>Boronia dichotoma</i>				✓		Shrub		
<i>Bossiaea eriocarpa</i>		✓				Shrub	T	
<i>Brachyloma preissii</i>	✓					Shrub		
<i>Burchardia bairdiae</i>	✓					Geophyte		
<i>Burchardia congesta</i>		✓				Geophyte	T,S	
<i>Burchardia multiflora</i>				✓		Geophyte		
<i>Caesia micrantha</i>			✓			Geophyte		
<i>Caladenia flava</i>		✓				Geophyte	I	
<i>Calothamnus lateralis</i> var. <i>lateralis</i>	✓				✓	Shrub	S	
<i>Calytrix flavescens</i>		✓				Shrub	S	yes
<i>Cassytha flava</i>				✓		Herb		
<i>Cassytha glabella</i>		✓		✓		Herb	I	
<i>Cassytha micrantha</i>					✓	Herb	I	
<i>Cassytha racemosa</i>	✓					Herb		
<i>Centrolepis aristata</i>	✓	✓	✓	✓	✓	Sedge	S	yes
<i>Centrolepis drummondiana</i>	✓	✓		✓		Sedge	S	yes
<i>Chamaescilla corymbosa</i> var. <i>corymbosa</i>		✓				Geophyte	T,S	
<i>Chordifex sinuosus</i>					✓	Sedge		
<i>Comesperma calymega</i>					✓	Herb		
<i>Conostylis juncea</i>		✓	✓	✓		Herb	S,V	
<i>Corymbia calophylla</i>		✓				Tree	S	
<i>Crassula colorata</i>		✓				Herb	S	
<i>Cyathochaeta avenacea</i>			✓	✓		Sedge		
<i>Cytogonidium leptocarpoides</i>				✓		Sedge		
<i>Dampiera linearis</i>	✓	✓	✓	✓	✓	Herb	V	yes

Species	FL	AR	C	G	M	Growth Form	Main Propagule Source	Potential Recalcitrant
<i>Dasypogon bromeliifolius</i>	✓	✓	✓	✓	✓	Herb	T,S,V	yes
<i>Desmocladus fasciculatus</i>		✓				Sedge		yes
<i>Desmocladus flexuosus</i>		✓				Sedge	T,V	yes
<i>Drosera erythrorhiza</i> subsp. <i>erythrorhiza</i>		✓				Geophyte		yes
<i>Drosera gigantea</i> subsp. <i>gigantea</i>					✓	Geophyte		
<i>Drosera glanduligera</i>			✓	✓	✓	Herb		yes
<i>Drosera macrantha/menziesii/pallida</i> ¹		✓				Geophyte		yes
<i>Drosera neesii</i> subsp. <i>neesii</i>	✓					Geophyte		
<i>Drosera paleacea</i> subsp. <i>paleacea</i>				✓		Herb		yes
<i>Drosera pulchella</i>	✓					Herb		
<i>Epilobium billardiareanum</i>	✓					Herb		
<i>Eragrostis elongata</i>	✓					Grass		
<i>Eucalyptus rudis</i> subsp. <i>rudis</i>	✓					Tree		
<i>Euchilopsis linearis</i>	✓			✓	✓	Shrub	S	
<i>Eutaxia virgata</i>	✓					Shrub	S	
<i>Evandra pauciflora</i>				✓	✓	Sedge		
<i>Gompholobium tomentosum</i>		✓		✓		Shrub	T,S	
<i>Goodenia micrantha</i>	✓					Herb		
<i>Hemiandra pungens</i>				✓		Shrub		
<i>Hibbertia vaginata</i>		✓				Shrub	S	
<i>Homaloscladium homalocarpum</i>		✓		✓	✓	Herb	T	
<i>Hyalosperma cotula</i>		✓		✓		Herb	S	
<i>Hydrocotyle callicarpa</i>		✓				Herb	S	
<i>Hypocalymma angustifolium</i> subsp. <i>Swan Coastal Plain</i> (G.J. Keighery 16777)	✓	✓	✓	✓	✓	Shrub	S	
<i>Hypolaena exsulca</i>	✓	✓	✓	✓	✓	Sedge		yes
<i>Isolepis stellata</i>					✓	Sedge		
<i>Isotropis cuneifolia</i> subsp. <i>cuneifolia</i>	✓					Shrub	S	yes
<i>Jacksonia furcellata</i>	✓					Shrub	T,S	
<i>Jacksonia gracillima</i>		✓				Shrub	S	
<i>Kennedia prostrata</i>	✓					Shrub	S	
<i>Kunzea glabrescens</i>	✓	✓		✓	✓	Shrub	S	
<i>Latrobea tenella</i>	✓					Shrub		
<i>Laxmannia ramosa</i> subsp. <i>ramosa</i>				✓		Herb		
<i>Lechenaultia expansa</i>			✓	✓		Shrub	V	
<i>Lechenaultia floribunda</i>		✓				Shrub	V	
<i>Lepidosperma longitudinale</i>	✓			✓		Sedge		
<i>Lepidosperma pubisquameum</i> ²		✓				Sedge	V	yes
<i>Lepidosperma squamatum</i> s.l.		✓		✓	✓	Sedge	V	yes
<i>Leptocarpus coangustatus</i>	✓					Sedge		
<i>Leptomeria pauciflora</i>					✓	Shrub		
<i>Leucopogon conostephioides</i>		✓				Shrub		yes
<i>Leucopogon gracillimus</i>				✓		Shrub		yes
<i>Levenhookia stipitata</i>		✓		✓		Herb	T	yes
<i>Liparophyllum violifolium</i>	✓					Herb		
<i>Lobelia tenuior</i>			✓	✓		Herb	S	
<i>Lomandra caespitosa</i>		✓				Herb	T,V	yes
<i>Lomandra hermaphrodita</i>		✓		✓		Herb	T,V	yes
<i>Lomandra sericea</i>		✓				Herb		yes
<i>Lomandra suaveolens</i>		✓		✓	✓	Herb	V	yes
<i>Lyginia barbata/imberbis</i> ³		✓		✓	✓	Sedge	T,V	yes
<i>Melaleuca preissiana</i>	✓	✓	✓	✓	✓	Tree	S	

Species	FL	AR	C	G	M	Growth Form	Main Propagule Source	Potential Recalcitrant
<i>Melaleuca raphiophylla</i>	✓					Tree		
<i>Melaleuca seriata</i>		✓		✓		Shrub	S	
<i>Melaleuca teretifolia</i>	✓					Shrub	S	
<i>Melaleuca thymoides</i>		✓				Shrub	S	
<i>Melaleuca viminea</i> subsp. <i>viminea</i>	✓					Shrub	S	
<i>Nuytsia floribunda</i>			✓			Tree	S	
<i>Opercularia vaginata</i>		✓				Herb		yes
<i>Patersonia occidentalis</i> var. <i>occidentalis</i>	✓	✓	✓	✓	✓	Herb	T,S,V	yes
<i>Pauridia occidentalis</i> var. <i>occidentalis</i>	✓					Herb		
<i>Pericalymma ellipticum</i>	✓	✓	✓	✓	✓	Shrub	S	
<i>Petrophile linearis</i>		✓				Shrub	S	yes
<i>Philothea spicata</i>		✓		✓	✓	Shrub	S	
<i>Phlebocarya ciliata</i>		✓	✓	✓	✓	Herb	V	yes
<i>Phyllangium paradoxum</i>		✓	✓	✓		Herb	S	
<i>Pimelea lanata</i>				✓		Shrub		
<i>Podotheca gnaphalioides</i>		✓				Herb	T,S	
<i>Poranthera microphylla</i> /moorokatta ⁴		✓		✓		Herb	S	
<i>Pultenaea reticulata</i>	✓					Shrub		
<i>Quinetia urvillei</i>		✓		✓		Herb	T	
<i>Regelia ciliata</i>	✓			✓		Shrub	S	
<i>Rhodanthe citrina</i>		✓				Herb	T	
<i>Schoenus efoliatus</i>	✓	✓	✓	✓	✓	Sedge	V	yes
<i>Schoenus odontocarpus</i>	✓			✓		Sedge	S	yes
<i>Schoenus rigens</i>				✓		Sedge		
<i>Schoenus subbulbosus</i>			✓		✓	Sedge		yes
<i>Scholtzia involucrata</i>	✓					Shrub	S,V	
<i>Selaginella gracillima</i>				✓		Herb		
<i>Siloxerus humifusus</i>	✓	✓	✓	✓	✓	Herb	S	
<i>Stylidium araeophyllum</i> /neurophyllum ⁵	✓	✓		✓	✓	Herb	S	yes
<i>Stylidium calcaratum</i>				✓	✓	Herb	S	yes
<i>Stylidium piliferum</i>		✓				Herb		yes
<i>Stylidium repens</i>	✓	✓	✓	✓	✓	Herb		yes
<i>Thysanotus multiflorus</i>			✓	✓	✓	Herb	S	
<i>Thysanotus patersonii</i>			✓			Geophyte	S	yes
<i>Thysanotus thyrsoides</i>	✓		✓	✓		Geophyte		yes
<i>Trachymene pilosa</i>		✓	✓	✓		Herb	T	
<i>Tremulina tremula</i>	✓					Sedge		
<i>Tricoryne elatior</i>		✓			✓	Herb		yes
<i>Verticordia densiflora</i>				✓		Shrub		
<i>Xanthorrhoea preissii</i>		✓	✓	✓	✓	Herb	S	
<i>Xanthosia huegelii</i>	✓	✓		✓	✓	Herb		

1. Indeterminate as not flowering. Will be one of these three species

2. *Lepidosperma pubisquameum* "flat form"

3. Unidentified species in *Lyginia barbata/imberbis* complex

4. Unidentified species in *Poranthera microphylla/moorokatta* complex

5. Originally identified as *Stylidium brunonianum*, and now has become either *Stylidium araeophyllum* or *S. neurophyllum*

Appendix 4. Plant species introduced to the restoration sites by planting or direct seeding from 2012-2015, and the method of introduction.

A wider range of species was initially considered for restoration but only those species for which seed or cuttings were successfully obtained are listed below. IV Rank = Importance Value Rank (from Appendix 1). Some of these species are regarded as recalcitrant. A “yes” in the Recalcitrant column indicates a potentially recalcitrant species. Ticks indicate incorporation into species lists for nursery orders either for seedlings or cuttings (Nursery Orders), or for direct seeding mixes (Direct Seeding).

Species	IV Rank	Nursery Orders	Direct Seeding	Potential Recalcitrant
<i>Acacia alata</i>			✓	
<i>Acacia huegelii</i>		✓	✓	
<i>Acacia pulchella</i>	40	✓	✓	
<i>Acacia saligna</i> subsp. <i>saligna</i>	57	✓	✓	
<i>Acacia stenoptera</i>			✓	
<i>Adenanthos obovatus</i>			✓	
<i>Allocasuarina fraseriana</i>		✓	✓	
<i>Allocasuarina humilis</i>	20	✓	✓	
<i>Amphipogon turbinatus</i>	7	✓	✓	
<i>Anigozanthos humilis</i> subsp. <i>humilis</i>			✓	
<i>Anigozanthos manglesii</i> subsp. <i>manglesii</i>		✓	✓	
<i>Arnocrinum preissii</i>	57		✓	yes
<i>Astartea scoparia</i>			✓	
<i>Austrocladia compressa</i>	26		✓	
<i>Babingtonia camphorosmae</i>			✓	
<i>Banksia attenuata</i>	5	✓	✓	
<i>Banksia ilicifolia</i>	15	✓	✓	
<i>Banksia menziesii</i>	6	✓	✓	
<i>Beaufortia elegans</i>	48	✓	✓	
<i>Bossiaea eriocarpa</i>	14	✓	✓	
<i>Brachyloma preissii</i>			✓	
<i>Burchardia congesta</i>	29	✓	✓	
<i>Calothamnus lateralis</i> var. <i>lateralis</i>		✓	✓	
<i>Calytrix flavescens</i>	17		✓	yes
<i>Calytrix fraseri</i>		✓	✓	yes
<i>Chamaescilla corymbosa</i> var. <i>corymbosa</i>	57		✓	
<i>Conostephium pendulum</i>	39		✓	yes
<i>Conostylis aculeata</i>	19	✓	✓	
<i>Conostylis juncea</i>	57		✓	
<i>Conostylis setigera</i> subsp. <i>setigera</i>	45	✓	✓	
<i>Corymbia calophylla</i>		✓	✓	
<i>Croninia kingiana</i>	53		✓	yes
<i>Dampiera linearis</i>	13	✓		yes
<i>Dasypogon bromeliifolius</i>	10	✓	✓	yes
<i>Desmocladus flexuosus</i>	11	✓		yes
<i>Dianella revoluta</i> var. <i>divaricata</i>		✓	✓	
<i>Dichopogon capillipes</i>		✓		
<i>Eremaea asterocarpa</i> subsp. <i>asterocarpa</i>	52	✓	✓	
<i>Eremaea pauciflora</i>	1	✓	✓	
<i>Eucalyptus marginata</i> subsp. <i>marginata</i>	21	✓	✓	
<i>Eucalyptus rudis</i> subsp. <i>rudis</i>		✓	✓	
<i>Eucalyptus tottiana</i>	44	✓	✓	

Species	IV Rank	Nursery Orders	Direct Seeding	Potential Recalcitrant
<i>Gastrolobium capitatum</i>			✓	
<i>Gompholobium tomentosum</i>	37	✓	✓	
<i>Haemodorum spicatum</i>	57		✓	yes
<i>Hakea prostrata</i>			✓	
<i>Hemiandra pungens</i>	57	✓	✓	
<i>Hensmania turbinata</i>	41	✓		yes
<i>Hibbertia huegelii</i>	43	✓	✓	
<i>Hibbertia hypericoides</i> subsp. <i>hypericoides</i>	2	✓		yes
<i>Hibbertia racemosa</i>		✓		yes
<i>Hibbertia subvaginata</i>	23	✓	✓	
<i>Hovea pungens</i>			✓	
<i>Hovea trisperma</i> var. <i>trisperma</i>	58		✓	
<i>Hypocalymma angustifolium</i> subsp. Swan Coastal Plain (G.J. Keighery 16777)		✓	✓	
<i>Hypolaena exsulca</i>	12	✓		yes
<i>Jacksonia furcellata</i>	35	✓	✓	
<i>Jacksonia sternbergiana</i>			✓	
<i>Kennedia prostrata</i>		✓	✓	
<i>Kunzea glabrescens</i>		✓	✓	
<i>Lechenaultia floribunda</i>	57	✓	✓	
<i>Lepidosperma squamatum</i> s.l.	36	✓		yes
<i>Leucopogon propinquus</i>			✓	yes
<i>Lomandra caespitosa</i>	43	✓	✓	yes
<i>Lomandra hermaphrodita</i>	27	✓	✓	yes
<i>Lomandra nigricans</i>		✓		yes
<i>Lomandra preissii</i>	57	✓		yes
<i>Lomandra suaveolens</i>	57	✓		yes
<i>Lyginia barbata</i>	4	✓	✓	yes
<i>Lyginia imberbis</i>	4	✓		yes
<i>Macarthuria australis</i>			✓	
<i>Macrozamia fraseri</i>	56		✓	
<i>Melaleuca preissiana</i>		✓	✓	
<i>Melaleuca raphiophylla</i>		✓	✓	
<i>Melaleuca seriata</i>	31	✓	✓	
<i>Melaleuca teretifolia</i>		✓		
<i>Melaleuca thymoides</i>	30	✓	✓	
<i>Melaleuca viminea</i> subsp. <i>viminea</i>		✓		
<i>Nuytsia floribunda</i>	42	✓	✓	
<i>Orthrosanthus laxus</i> var. <i>laxus</i>		✓		
<i>Patersonia occidentalis</i> var. <i>occidentalis</i>	3	✓	✓	yes
<i>Pericalymma ellipticum</i>		✓	✓	
<i>Persoonia saccata</i>	51		✓	yes
<i>Petrophile linearis</i>	22	✓	✓	yes
<i>Philothea spicata</i>			✓	
<i>Phlebocarya ciliata</i>	9	✓		yes
<i>Phlebocarya filifolia</i>	46	✓		yes
<i>Podothea chrysantha</i>			✓	
<i>Podothea gnaphalioides</i>			✓	
<i>Pultenaea reticulata</i>			✓	
<i>Regelia ciliata</i>		✓	✓	
<i>Regelia inops</i>		✓	✓	

Flora and Vegetation Completion Criteria for Banksia Woodland Restoration

Species	IV Rank	Nursery Orders	Direct Seeding	Potential Recalcitrant
<i>Schoenus caespititius</i>	58	✓		
<i>Schoenus curvifolius</i>	32	✓		
<i>Schoenus efoliatus</i>		✓		yes
<i>Scholtzia involucrata</i>	8	✓	✓	
<i>Stirlingia latifolia</i>	16	✓	✓	yes
<i>Stylidium brunonianum</i>			✓	yes
<i>Thysanotus patersonii</i>		✓	✓	yes
<i>Thysanotus triandrus</i>	49	✓		yes
<i>Xanthorrhoea preissii</i>	38	✓	✓	