APPENDIX F

Analysis to Investigate TEC SCP20a Presence

Perth–Darwin National Highway (Swan Valley Section)– Supplementary Biological Studies 2015

Assessment of the Presence of the TEC SCP20a at Ioppolo Rd, Chittering

COFFEY

NOVEMBER 2015

WOODMAN ENVIRONMENTAL

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Perth–Darwin National Highway (Swan Valley Section) – Supplementary Biological Studies 2015: Assessment of the presence of the TEC SCP20a at Ioppolo Rd, Chittering

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0	Final report	BL	GW	26/11/2015		

DISCLAIMER

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DEFINITIONS

Term	Definition
ALOC	A module within PATN that is a non-hierarchal classification which includes an option of matching new sites to existing classifications
DPaW	Department of Parks and Wildlife
FCT	Floristic Community Type
GDA	Geocentric Datum of Australia
GIS	Geographical Information System
GPS	Global Positioning System
IBRA	Interim Biogeographic Regionalisation for Australia
INDVAL	A system of indicator taxon analysis
Ltd	Limited
MRWA	Main Roads Western Australia
m	Metre
MS-DOS	Microsoft Disk Operating System
NNB	A module within PATN that determines the nearest neighbour of a site (that it is most similar to)
PATN	Software package for pattern analysis of complex multivariate data
PC-ORD	Software package for multivariate statistical analysis of ecological communities
PEC	Priority Ecological Community
Pty	Proprietary
SCP	Swan Coastal Plain
TEC	Threatened Ecological Community

1 INTRODUCTION

Coffey Environments Australia Pty Ltd (Coffey) conducted a Level 2 assessment of flora and vegetation of Main Roads Western Australia's (MRWA) Perth–Darwin National Highway (Swan Valley Section) (the project) during spring 2014. The survey identified potential areas of the Threatened Ecological Community (TEC) SCP20a within the project's development envelope (Coffey 2015a). SCP20a (*Banksia attenuata* woodland over species rich dense shrublands) is currently listed by the Department of Parks and Wildlife (DPaW) as Endangered (EN) in accordance with criterion B ii of DEC (2010), due to a current limited known distribution, with a total area being very small with most occurrences being small and/or isolated and very vulnerable to threatening processes. This TEC is not listed under the Commonwealth legislation (*Environmental Protection and Biodiversity Protection Act 1999*).

MRWA is also investigating the suitability of a portion of land located on Ioppolo Road, Chittering (the proposed offset site) as an offset for ecological values potentially impacted by the project, including SCP20a. The DPaW have previously mapped two areas of SCP20a within this site. Coffey undertook a Level 1 assessment in winter 2014, of the proposed offset site, which inferred the potential for this TEC to be present based on relevee data collected out of the spring flowering period, however the areas mapped by Coffey were incongruous with the boundaries mapped by DPaW (Coffey Environments 2015b).

Woodman Environmental Pty Ltd (Woodman Environmental) was commissioned by Coffey to undertake a supplementary spring quadrat based survey and investigate the presence and extent of SCP20a within the proposed offset site

1.1 Aim and Objectives

The aim of the study was to confirm the presence and extent of SCP20a within the proposed offset site.

The objectives required to achieve this encompassed the following:

- Establish and assess quadrats within vegetation of the proposed offset site with species composition similar to that recorded for SCP20a (Gibson et al. 1994) (minimum of 3 quadrats depending on extent to be verified). Quadrat locations chosen in the field utilising previous mapping and data from Coffey and also DPaW, and assessing species composition on the ground.
- Combine the data with the existing DPaW data for the Swan Coastal Plain (SCP) and analyse utilising PATN and selecting multiple analysis pathways including the ALOC function within PATN.
- Interpret the analysis outputs to determine which quadrats may represent SCP20a.
- Where SCP20a confirmed to be present, map potential boundary/extent using field notes, DPaW inferred boundary information, aerial photo interpretation and GIS (Geographic Information System).

2 METHODS

2.1 Desktop/GIS Assessment

Prior to the field assessment, a number of Coffey's vegetation association polygons (Coffey 2015b) were identified to target for the SCP20a assessment. Areas which were targeted for assessment were based on:

- Limited descriptions and photographs of SCP20a provided by DPaW (DPaW 2014, Gibson *et al.* 1994).
- Communications with Jill Pryde, DPaW (pers. comm. 2015).
- Areas within Ioppolo Road which were previously mapped as SCP20a (DPaW).
- Areas identified by Coffey to be potentially representative of SCP20a on the proposed offset site (Coffey Environments 2015b).
- Review of Coffey's vegetation associations and their species composition (Coffey Environments 2015b).
- Similar areas of vegetation (to that mapped as SCP20a by DPaW and Coffey Environments) within the proposed offset site based on aerial photography interpretation.

2.2 Field Assessment

The field assessment was undertaken on the 15 – 16 of September 2015 by experienced botanists David Coultas and Alison Saligari. Table 1 lists the personnel involved in both fieldwork and plant identifications for the field survey. All personnel have had previous field experience in the Swan Coastal Plain region, with personnel involved in plant identifications having taxonomic experience with the flora of Swan Coastal Plain region. All plant material was collected under the scientific licences (pursuant to the *Wildlife Conservation Act 1950* Section 23C and Section 23F) as listed in Table 1.

Table 1: Personnel Licensing Information

Personnel	Role	Flora Collecting Permit / Permit to take T-DRF
David Coultas	Fieldwork	SL011384 / 147-1415
Bethea Loudon	Plant identifications	SL011382 / 149-1415
Alison Saligari	Fieldwork	SL011380 / 148-1415

A total of seven permanent flora survey quadrats were established within areas suspected to be representative of SCP20a, and both within and outside of polygons mapped by Coffey Environments and DPaW (Figure 1). All quadrats measured 10 m by 10 m and were marked with a fence-dropper within the north-west corner. All vascular flora taxa that were visually identifiable within each quadrat were recorded.

The following information was recorded at each quadrat:

- Personnel;
- Unique quadrat number;
- Date of survey;
- GPS (Global Positioning System) coordinates (Geocentric Datum of Australia (GDA)94);
- Site photograph;
- Topography (including landform type and aspect);
- Soil colour and type (including the presence of any rock outcropping and surface stones);
- Vegetation condition - South West Botanical Province (Keighery 1994);

- Approximate time since fire;
- Presence of disturbance (if any);
- Percentage foliage cover (for each taxon); and
- Height (metre (m)) (for each taxon, excluding climbers/aerial shrubs).

The field assessment targeted areas that had the potential to represent SCP20a (discussed in Section 2.1), by traversing areas on foot and utilising existing tracks by vehicle. Polygons which were not identified as having potential to be representative of SCP20a were not assessed. Vegetation mapping and boundaries were verified, and assessed for their potential to represent SCP20a vegetation. Ground-truthing involved the recording of waypoints and tracks using a hand-held GPS (Global Positioning System). Photographs were taken of the vegetation of areas investigated along with field notes detailing the observations at each point.

2.3 Plant Collection and Identification

Specimens of unknown taxa were collected and pressed for later identification at the Western Australian Herbarium. Identifications were undertaken by experienced senior botanist Bethea Loudon.

Taxon nomenclature generally follows *FloraBase* (DPaW 2015a) with all names checked against the current DPaW Max database to ensure their validity. However, in cases where names of plant taxa have been published recently in scientific literature but have not been adopted on *FloraBase* (DPaW 2015a), nomenclature in the published literature is followed. The conservation status of each taxon was checked against *FloraBase*, which provides the most up-to-date information regarding the conservation status of flora taxa in Western Australia. Specimens are kept in-house for reference for a period of one year after finalisation of the project.

2.4 Statistical Analysis

Classification analysis of quadrat data from the proposed offset site was conducted using seven quadrats established at the Study Area (IR-01 – IR-07), with 1098 quadrats from the updated version of the SCP dataset (Keighery *et al.* 2012).

The updated version of the SCP dataset, sourced through *NatureMap* (DPaW 2015b), contains weed and native flora quadrat data compiled between 1990 and 1996 for the southern SCP. This dataset is derived from a database that has been compiled and maintained over many years, combining the results of a number of floristic studies conducted on plant communities of the IBRA (Interim Biogeographic Regionalisation for Australia) SCP Bioregion, south of the Moore River. It includes sampling site details, the native and introduced (weed) flora collected at these sampling sites and the floristic community type (FCT) assigned to these sampling sites. The taxonomy of the flora in the database has been updated regularly as determined by Greg and Bronwen Keighery. This dataset lists the taxonomy (including family names) which was current in this database on 23 June 2005 when the dataset was compiled (DPaW 2015b).

The combined analysis consisted of 1815 vascular taxa entities. Taxa belonging to several categories were removed or altered prior to analysis, as listed below:

- Taxa that are now considered to not occur in Western Australia by the Western Australian Herbarium – such taxa were removed from the analysis due to the inability to determine their current name.

- Taxa where the recorded name is not listed on the census of Western Australian flora and a current name could not be determined.
- Taxa that are not known from the South West land division.
- Supplementary names where the genus is a known weed species were changed to reflect this status (so as not to be assessed as a native taxon).

Some taxa and infra-taxa were amalgamated where taxonomy was unclear or could not be determined in all cases. In addition, genus/species entities were combined with entities that went to subspecies or varietal level. All taxa removed and amalgamated from the classification analysis are presented in Appendix A.

Initially, the ALOC function of PATN was proposed to be used in order to “lock” the original groupings of the SCP dataset, as it has the option of "no-reallocation" of the existing classification. ALOC is a non-hierarchal classification that includes an option of matching new sites to existing classifications, and creating new classes when the new sites do not "fit". However, as there are many issues with using ALOC, including having to use MS-DOS (Microsoft Disk Operating System) to run it and difficulties in detecting real differences between existing classes and new ones (Ted Griffin pers. comm. 2015), this analysis pathway was not pursued.

With ALOC discounted as an analysis pathway, the use of OptimClass (Tichý et al. 2010) analysis was considered in order to determine the most suitable approach to classification based on the available data. OptimClass evaluates the quality of a set of different partitions of the same dataset, based on the number of taxa that are faithful to clusters of that partition. Faithful taxa are identified using the Fisher’s exact test for the right-tailed hypothesis, which is a suitable measure of statistical fidelity of taxa to clusters of quadrats (Sokal & Rohlf 1995; Chytrý *et al*. 2002). However as OptimClass runs off percent foliage cover data, this analysis was unable to be undertaken as the SCP dataset only contains presence/absence data.

Classification analysis using PATN (V3.1.2) (Belbin & Collins 2009) as used in the previous analysis by Gibson *et al.* (1994) was undertaken to analyse the dataset. Classification results of the analysis were produced as a dendrogram. The placement of the proposed offset site quadrats within the dendrogram were then reviewed, along with their relationship to quadrats from the SCP dataset that represent the TEC SCP020a. Two separate analyses were run, one containing weed species and one with weeds excluded, to see how the absence of weeds affected the placement of quadrats within the dendrogram.

Nearest neighbour analysis (NNB) was also undertaken using PATN, to determine which SCP quadrats the proposed offset site quadrats were most similar to, based on the number of species they have in common. Indicator taxon analysis (INDVAL) was then conducted using PC-Ord (McCune & Mefford 2011) using the method of Dufrene & Legendre (1997), to determine the indicator taxa for the FCT(s) of the proposed offset site quadrats and SCP20a. A Monte Carlo permutation test was used to test for the significance of the indicator taxa. Indicator taxon analysis identifies faithful taxa i.e. those species that consistently represent the FCT.

3 RESULTS

A full list of taxa recorded in quadrats from the proposed offset site is presented in Appendix B, with raw quadrat and detailed site data presented in Appendix C. A total of 194 taxa were recorded, including 13 weed species. Average species richness per quadrat was 49.6. The vegetation of the proposed offset site was in Excellent to Pristine condition (Appendix C).

The Study Area quadrats consist of the following vegetation:

- IR-01 – Low open woodland of *Corymbia calophylla*, *Banksia attenuata* and *B. grandis* over mid open shrubland of *Allocasuarina humilis* and *Xanthorrhoea preissii* over low open shrubland of *Calothamnus sanguineus*, *Eremaea pauciflora* and *Hibbertia hypericoides* over low open rushland of *Mesomelaena pseudostygia.*
- IR-02 – Low woodland of *C. calophylla* and *Eucalyptus marginata* over tall isolated clumps of shrubs of *Adenanthos cygnorum* subsp. *cygnorum* over mid isolated clumps of shrubs of *Stirlingia latifolia* over low open shrubland of *Astroloma xerophyllum*, *H. hypericoides* and *Leucopogon conostephiodies* over low open rushland of *M. pseudostygia.*
- IR-03 – Low woodland of *E. marginata* over mid sparse shrubland *Macrozamia fraseri* and *X. preisii* over low open shrubland of *Conostephium pendulum*, *H. hypericoides* and *L. conostephiodies.*
- IR-04 – Tall shrubland of *Jacksonia sternbergiana* and *X. preisii* over mid open shrubland of *A. humilis* and *Chamelaucium* sp. Gingin (N.G. Marchant 6).
- IR-05 – Low woodland of *E. marginata* over mid isolated clumps of shrubs of *X. preisii* over low open shrubland of *Banksia dallanneyi* subsp. *dallanneyi* and *H. hypericoides* over low open rushland of *M. pseudostygia*.
- IR-06 – Low woodland of *E. marginata* over mid sparse shrubland of *X. preisii* over low open shrubland of *A. xerophyllum* and *H. hypericoides* over low isolated clumps of herbs of *Patersonia occidentalis* over low isolated clumps of rushes of *M. pseudostygia.*
- IR-07 – Low open woodland of *Eucalyptus todtiana*, *B. attenuata* and *B. menziesii* over mid sparse shrubland of *A. humilis* and *X. preissii* over low open shrubland of *E. pauciflora*, *H. hypericoides* and *Melaleuca trichophylla* over low open rushland of *M. pseudostygia*.

The section of the dendrogram (analysis with weeds included) in which the SCP20a and proposed offset site quadrats occurred is presented in Appendix D. Examination of the classification dendrogram found that the proposed offset site quadrats grouped in close association with quadrats representing SCP28; quadrats from SCP20a (and 20b and 20c) were represented on adjacent arms of the dendrogram, indicating a lower level of similarity between these quadrats and those within the proposed offset site. The results of nearest neighbour analysis found that the individual quadrats of the proposed offset site had the most species in common with quadrats representing various SCP FCTs, including SCP20a (quadrats IR-01, IR-05), SCP21a (quadrat IR-03), SCP23a (quadrat IR-04), SCP23b (quadrats IR-02, IR-07) and SCP28 (quadrat IR-06) of the SCP dataset (Keighery *et al.* 2012) (Appendix E). However this analysis is less conclusive as it does not take into account indicator taxa for each group.

Descriptions of these various FCTS are as follows (Gibson *et al.* 1994):

SCP20a: *Banksia attenuata* woodlands over species rich dense shrublands (originally documented as having a mean species richness of 67.4);
SCP21a: Central *Banksia attenuata-Eucalyptus marginata* woodlands (54.6);
SCP23a: Central *Banksia attenuata-B. menziesii* woodlands (62.8);
SCP23b: Northern *Banksia attenuata-B. menziesii* woodlands (53.8); and

SCP28: Spearwood *Banksia attenuata* or *Banksia attenuata-Eucalyptus* woodlands (55.2)

SCP20a is a TEC, and SCP23b is a Priority Ecological Community (PEC), as listed by DPaW. The remaining communities are not considered to be threatened (DPaW 2015c; 2015d).

Indicator species analysis showed that the following species are faithful taxa to each of the FCTs listed above (Appendix F) (with p <0.001):

- SCP20a – *Alexgeorgea nitens*; *Bossiaea eriocarpa*; *Burchardia congesta*; *Conospermum undulatum*; *Hibbertia huegelii*; *Hibbertia hypericoides*; *Mesomelaena pseudostygia*; *Stirlingia latifolia;*
- SCP21a – No indicator taxa recognised;
- SCP23a – *Banksia menziesii*; *Gompholobium tomentosum*; *Lomandra hermaphrodita*; *Patersonia occidentalis*;
- SCP23b – *Banksia attenuata*; *Eremaea pauciflora*; and
- SCP28 – No indicator taxa recognised.

Typical species of these FCTs include (Gibson *et al.* 1994):

- SCP20a – *B. attenuata*, *Bossiaea eriocarpa*, *Conostephium pendulum, Hibbertia huegelii, H. hypericoides, Petrophile linearis, Scaevola repens* subsp. *repens, S. latifolia*.
- SCP21a – *B. attenuata*, *B. eriocarpa*, *Gompholobium tomentosum, H. hypericoides, P. linearis*.
- SCP23a – *B. attenuata*, *B. menziesii*, *B. eriocarpa*, *G. tomentosum, P. linearis, Scholtzia involucrata*.
- SCP23b – *B. attenuata*, *B. menziesii*, *B. eriocarpa*, *Calytrix flavescens, E. pauciflora, Philotheca spicata, Hibbertia subvaginata, Jacksonia floribunda, P. linearis, S. involucrata.*
- SCP28 – *B. attenuata*, *H. hypericoides*, *Desmocladus flexuosus*, *M. pseudostygia*.

Removal of weed species from the analysis (second analysis dendrogram not presented) had the effect of grouping the proposed offset site quadrats with quadrats representing SCP23c and SCP28, with no variation in the placement of these quadrats and their proximity to SCP20a quadrats. SCP23c is a supplementary FCT that was created following a revised analysis of the updated SCP dataset with data from surveys subsequent to the original SCP dataset of Gibson *et al.* (1994). Any quadrats that did not fit within the descriptions of the original FCTs were added as Supplementary Types. SCP23c is described as North-eastern *Banksia attenuata-B. menziesii* woodlands and is not considered to be threatened. No published documentation exists for SCP23c (Val English, pers. comm. 2015).

4 DISCUSSION

The results of the analysis of the proposed offset site quadrats indicates that understorey species strongly influence the outcomes, almost to the exclusion of the dominant tree layer. This is evident particularly in quadrat IR-05 where *B. attenuata* is absent and the community is dominated by *E. marginata*.

Analysis of the Study Area quadrats with the SCP data was conducted with weeds retained in the dataset in order to replicate the original SCP analysis parameter and provide an initial indication of relationship between the Study Area quadrats and the larger regional dataset. This analysis was then repeated with the weeds removed to minimise any effects of gradients in weed invasion patterns on the SCP and provide clarification of relationships between quadrats based solely on native species composition. These gradients, related to surrounding landuses climatic factors and

available vectors of weed invasion have the potential to affect grouping of quadrats based on vegetation condition and weed presence rather than native species composition.

The vegetation of the proposed offset site was found to be most closely related to FCT SCP28 in both analyses, a common vegetation community of the SCP. The second analysis excluding weeds identified a close relationship between the proposed offset site quadrats and both SCP 28 and also SCP23c. The grouping with SCP23c in the second analysis (in the absence of weeds), would indicate that the original quadrats assessed as SCP23a (Gibson et al. 1994) were potentially located in areas of elevated weed presence.

The quadrats from the proposed offset site occurred in the same supergroup as SCP20a within both analyses however were situated on separate branches within the same subgroup, with reasonable separation between these branches. The average species richness of the proposed offset site quadrats (49.6) was reasonably lower than the SCP20a quadrats (67.4) indicating that the proposed offset site quadrats are unlikely to represent FCT SCP 20a (*Banksia attenuata* woodland over **species rich** dense shrublands).

Although SCP20a was previously indicated as occurring within the proposed offset site by DPaW, the current analysis indicates that the vegetation within the proposed offset site has a closer relationship with SCP28 and a less close relationship with existing SCP20a quadrats in the SCP dataset. Although the use of near neighbour analysis, which does not take into account any assessment of faithful taxa, indicates that quadrats IR-01 (which correlates to the indicative SCP20a polygon mapped by DPaW) and IR-05 show some affiliation with SCP20a, the dendrogram result from the PATN analysis show they are most closely related to SCP28 which is considered to be well reserved and not of any conservation significance.

The historical quadrats at Ioppolo Road, used by DPaW to originally indicate the presence of SCP20a are not contained in the updated SCP dataset (Keighery *et al.* 2012) and were not used in the Bushforever analysis used to determine supplementary FCTs to those originally published for the Swan Coastal Plain by Gibson *et al.* (1994). Although there are similarities between vegetation of the proposed offset site and SCP20a based on the nearest neighbour results, when all the current data is utilised, the vegetation of the proposed offset site is demonstrated to not be closely related to SCP20a and is most likely to represent SCP28. As a result of this analysis it is recommended that the potential presence of SCP20a at Ioppolo Road be reviewed by DPaW.

In conclusion, the vegetation of the proposed offset site (the vegetation of Ioppolo Road sampled during this study) that were considered to be SCP20a based on the 2014 survey (Coffey Environments 2015a), is not representative of SCP20a as indicated by this study. Confusion or uncertainty around allocating new quadrats to existing FCTs from the original Swan Coastal Plain analysis (Gibson *et al.* 1994) arises from the requirement by DPaW to maintain results of historical floristic analyses (and FCTs) which may be inappropriate in the context of more recent data and analysis findings.

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403000 404000 405000 406000

6518000 6517000 6516000 6515000 6514000 6513000

IR-04 IR-03 IR-02 IR-07 IR-01 IR-06 IR-05

BaBmNf BaBm2 BaBmNf Em2 EmCc1 Em2 Em3 CcEm Et BaBm1 Em BaBmNf Em4 Cc2 Et EtNf Et Em BaBmNf Em4 EtNf Cc3 EmCc2 Em3 Em3 BaBmNf CcEm Cc1 Et EtNf Cc1 EmCc1 Ba

Legend

- WEC Quadrat Locations
- Property Boundary
- Coffey Environments Vegetation Associations
- Coffey Environments SCP20a Boundary
- Dept of Parks & Wildlife SCP20a Boundary

403000 404000 405000 406000

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This map should only be used in conjunction with WEC report Coffey15-28-03

Perth-Darwin National Highway (Swan Valley Section) Assessment of the Presence of TEC SCP20a at Ioppolo Road, Chittering

Revision: 0 - 25 November 2015

Author: Bethea Loudon

WEC Ref: Coffey15-28

Filename: Coffey15-28-Scope-3.mxd

Scale: 1:16,000 (A3) Grid: MGA Zone 50

Figure

1

403000 404000 405000 406000

6518000 6517000 6516000 6515000 6514000 6513000

IR-04 IR-03 IR-02 IR-01 IR-05 IR-06 IR-07

BaBmNf BaBm2 BaBmNf Em2 EmCc1 Em2 Em3 CcEm Et Em3 BaBm1 Em IR-07 BaBmNf Cc2 Em4 IR-06 Et EtNf Et Em BaBmNf Em4 EtNf Cc3 EmCc2 Em3 Em3 BaBmNf CcEm Cc1 Et EtNf Cc1 Ba EmCc1

403000 404000 405000 406000

Legend

- WEC Quadrat Locations
- Property Boundary
- Coffey Environments Vegetation Associations
- Dept of Parks & Wildlife SCP20a Boundary
- Potential Additional Area of SCP20a

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This map should only be used in conjunction with WEC report Coffey15-28-03

Perth-Darwin National Highway (Swan Valley Section) Assessment of the Presence of TEC SCP20a at Ioppolo Road, Chittering

Revision: 0 - 25 November 2015

Author: Bethea Loudon

WEC Ref: Coffey15-28

Filename: Coffey15-28-Scope-3.mxd

Scale: 1:16,000 (A3) Grid: MGA Zone 50

Figure

2

Appendix A: Vascular Plant Taxa Amalgamated and Omitted During Statistical Analysis

Taxon	Amalgamation/Deletion
Acacia lasiocarpa	Amalgamated
Acacia lasiocarpa var. *bracteolata* long peduncle variant (G.J. Keighery 5026) (P1)	
Acacia lasiocarpa var. *lasiocarpa*	
Acacia lasiocarpa (Pinjarra form) (BJ Keighery 2230)	
Acacia pulchella	Amalgamated
Acacia pulchella var. *glaberrima*	
Acacia pulchella var. *glaberrima* (Variant 2) (GJ Keighery 9188)	
Acacia pulchella var. *pulchella*	
Acacia pulchella var. *reflexa*	
Anigozanthos manglesii	Amalgamated
Anigozanthos manglesii subsp. *manglesii*	
Austrodanthonia acerosa	Amalgamated
Rytidosperma acerosum	
Banksia dallanneyi var. *dallanneyi*	Amalgamated
Dryandra lindleyana	
Billardiera ?*fraseri*	Amalgamated
Pronaya fraseri	
Boronia ramosa	Amalgamated
Boronia ramosa subsp. *anethifolia*	
Boronia ramosa subsp. *ramosa*	
Caladenia flava	Amalgamated
Caladenia flava subsp. *flava*	
Conostylis aculeata	Amalgamated
Conostylis aculeata subsp. *aculeata*	
Conostylis aculeata subsp. *breviflora*	
Conostylis aculeata subsp. *bromelioides*	
Conostylis aculeata subsp. *cygnorum*	
Conostylis aculeata subsp. *preissii*	
Conostylis crassinervia subsp. *crassinervia*	
Drosera erythrorhiza	Amalgamated
Drosera erythrorhiza subsp. *erythrorhiza*	
Drosera erythrorhiza subsp. *magna*	
Drosera erythrorhiza subsp. *squamosa*	
Drosera menziesii	Amalgamated
Drosera menziesii subsp. *menziesii*	
Drosera menziesii subsp. *penicillaris*	
Epilobium billardiereanum	Amalgamated

Taxon	Amalgamation/Deletion
Eremaea asterocarpa	Amalgamated
Eremaea asterocarpa subsp. *asterocarpa*	
Eremaea pauciflora	Amalgamated
Eremaea pauciflora var. *pauciflora*	
Eremophila glabra	Amalgamated
Eremophila glabra subsp. *albicans*	
Isolepis cernua	Amalgamated
Isolepis setiformis	
Jacksonia decumbens	Amalgamated
Jacksonia floribunda	
Lepidobolus preissianus	Amalgamated
Lepidobolus preissianus subsp. *preissianus*	
Lomandra micrantha	Amalgamated
Lomandra micrantha subsp. *micrantha*	
Melaleuca incana subsp. *incana*	Amalgamated
Melaleuca polygaloides	
Melaleuca systena	Amalgamated
Melaleuca sp. Yanchep (G.J. Keighery 11242)	
Melaleuca thymoides	Amalgamated – *M. thyoides* not found in Perth
Melaleuca thyoides	
Myriocephalus isoetes	Amalgamated
Myriocephalus rhizocephalus	
Myriocephalus occidentalis	
Orobanche australiana	Amalgamated
Orobanche minor	
Patersonia occidentalis	Amalgamated
Patersonia occidentalis var. *occidentalis*	
Pericalymma ellipticum	Amalgamated
Pericalymma ellipticum var. *floridum*	
Platysace juncea	Amalgamated
Platysace teres	
Pterostylis nana	Amalgamated
Pterostylis pyramidalis	
Pterostylis vittata	Amalgamated
Pterostylis ?vittata	
Romulea rosea	Amalgamated
Romulea rosea var. *australis*	
**Silene gallica*	Amalgamated
**Silene gallica* var. *gallica*	
Stylidium araeophyllum	Amalgamated
Stylidium ?araeophyllum	

Taxon	Amalgamation/Deletion
Stylidium calcaratum	Amalgamated
Stylidium mimeticum	
Stylidium piliferum	Amalgamated
Stylidium piliferum subsp. *piliferum*	
Stylidium saxifragoides	
Stylidium rigidifolium	Amalgamated
Stylidium striatum	
Synaphea petiolaris	Amalgamated
Synaphea petiolaris subsp. *petiolaris*	
Tribonanthes longipetala	Amalgamated
Tribonanthes uniflora	
Triglochin muelleri subsp. *muelleri*	Amalgamated
Triglochin muelleri subsp. *recurvum*	
Verticordia plumosa var. *brachyphylla*	Amalgamated
Verticordia plumosa var. *pleiobotrya*	
Vicia sativa	Amalgamated
Vicia sativa subsp. *sativa*	
Xanthosia huegelii	Amalgamated
Xanthosia huegelii subsp. *huegelii*	
Xanthosia pusilla	
**Pseudognaphalium luteoalbum*	Name changed to *Helichrysum luteoalbum* in dataset
Mentha x spicata	Status changed from native to introduced
Verbascum sp.	Status changed from native to introduced
Vulpia sp.	Status changed from native to introduced
Cassytha sp.	Deleted – insufficient material for identification
Grevillea sp.	Deleted – insufficient material for identification
Haemodorum sp.	Deleted – insufficient material for identification
Lepidosperma sp.	Deleted – insufficient material for identification
Marianthus parviflora	Deleted – invalid name
Polymeria sericea	Deleted – invalid name
Prasophyllum sp.	Deleted – insufficient material for identification
Psoralea aff. *graveolens*	Deleted – invalid name
Schoenus brevifolius	Deleted – excluded name
Thelymitra pauciflora	Deleted – excluded name
?*Tricoryne elatior*	Deleted – insufficient material for identification
Triglochin incurva	Deleted – invalid name
Veronica sp.	Deleted – insufficient material for identification
Veronica stolonifera	Deleted – invalid name

Appendix B: Vascular Plant Taxa Recorded in the Proposed Offset Site

Anarthriaceae

Lyginia imberbis

Apiaceae

Xanthosia huegelii

Araliaceae

Trachymene pilosa

Asparagaceae

Laxmannia grandiflora subsp. *grandiflora*
Lomandra caespitosa
Lomandra hermaphrodita
Lomandra preissii
Lomandra sericea
Sowerbaea laxiflora
Thysanotus dichotomus
Thysanotus manglesianus
Thysanotus sparteus

Asteraceae

Brachyscome iberidifolia
**Hypochaeris glabra*
Millotia tenuifolia var. *laevis*
Podotheca gnaphalioides
**Ursinia anthemoides*

Casuarinaceae

Allocasuarina humilis

Celastraceae

Stackhousia monogyna
Tripterococcus brunonis

Colchicaceae

Burchardia congesta

Cyperaceae

Caustis dioica
Lepidosperma pubisquameum
Lepidosperma sp.
Lepidosperma squamatum
Mesomelaena pseudostygia
Tetraria octandra

Dasypogonaceae

Calectasia narragara

Dilleniaceae

Hibbertia hibbertioides var. *hibbertioides*
Hibbertia huegelii
Hibbertia hypericoides
Hibbertia sericosepala
Hibbertia subvaginata

Droseraceae

Drosera erythrorhiza
Drosera menziesii
Drosera pallida

Elaeocarpaceae

Tetratheca nuda

Ericaceae

Astroloma pallidum
Astroloma xerophyllum
Conostephium minus
Conostephium pendulum
Leucopogon conostephioides
Leucopogon sp. D Perth Flora (aff. polymorphus)
Leucopogon sp. Murdoch (M. Hislop 1037)

Fabaceae

Acacia applanata
Acacia pulchella
Acacia sessilis
Bossiaea eriocarpa
Daviesia incrassata subsp. *incrassata*
Gastrolobium capitatum
Gompholobium knightianum
Gompholobium marginatum

Fabaceae (cont.)

Gompholobium tomentosum
Hovea trisperma
Isotropis cuneifolia
Jacksonia floribunda
Jacksonia sternbergiana
Sphaerolobium medium

Goodeniaceae

Dampiera linearis
Scaevola canescens

Haemodoraceae

Anigozanthos humilis subsp. *humilis*
Anigozanthos manglesii
Conostylis aculeata subsp. *aculeata*
Conostylis aurea
Conostylis juncea
Conostylis setigera subsp. *setigera*
Conostylis teretifolia subsp. *teretifolia*
Haemodorum laxum
Haemodorum sp.

Hemerocallidaceae

Johnsonia pubescens subsp. *pubescens*
Tricoryne elatior
?*Tricoryne elatior*

Iridaceae

**Gladiolus caryophyllaceus*
Patersonia juncea
Patersonia occidentalis var. *occidentalis*

Lauraceae

Cassytha flava

Loganiaceae

Phyllangium divergens

Myrtaceae

Calothamnus sanguineus
Calytrix flavescens
Calytrix sylvana

Myrtaceae (cont.)

Chamelaucium sp. Gingin (N.G. Marchant 6)
Corymbia calophylla
Eremaea pauciflora
Eucalyptus marginata
Eucalyptus todtiana
Hypocalymma xanthopetalum
Melaleuca trichophylla

Orchidaceae

Caladenia flava
Elythranthera brunonis
Leporella fimbriata
Prasophyllum sp.
Pterostylis recurva
Pterostylis sp. short sepals (W. Jackson BJ259)
Pterostylis ?*vittata*

Phyllanthaceae

Phyllanthus calycinus

Poaceae

Amphipogon turbinatus
**Briza maxima*
Neurachne alopecuroidea

Proteaceae

Adenanthos cygnorum subsp. *cygnorum*
Banksia attenuata
Banksia dallanneyi var. *dallanneyi*
Banksia grandis
Banksia menziesii
Grevillea pilulifera
Hakea ruscifolia
Persoonia saccata
Petrophile linearis
Petrophile macrostachya
Stirlingia latifolia
Synaphea spinulosa subsp. *spinulosa*

Restionaceae

Alexgeorgea nitens
Desmocladus fasciculatus
Desmocladus flexuosus
Hypolaena exsulca
Lepidobolus preissianus subsp. *preissianus*

Rutaceae

Boronia ramosa
Philotheca spicata

Stylidiaceae

Stylidium albolilacinum
Stylidium ?*araeophyllum*
Stylidium cygnorum
Stylidium ?*diuroides*
Stylidium eriopodum
Stylidium neurophyllum ms
Stylidium piliferum
Stylidium repens
Stylidium schoenoides

Violaceae

Hybanthus calycinus
Hybanthus floribundus subsp. *floribundus*

Xanthorrhoeaceae

Xanthorrhoea preissii

Zamiaceae

Macrozamia fraseri

Total number of taxa: 128 (includes 124 native taxa)

Note: * indicates introduced (weed) taxa

Appendix C: Raw Data Recorded within Quadrats in the Proposed Offset Site

Site Name:	IR-01 (Woodman Environmental)
Site Type:	QUADRAT
Dimensions:	10m x 10m
Survey Date:	15/09/2015
GPS Location:	GDA94 Zone 50 404737E 6516405N
Landform Type:	Upper Slope
Slope Class:	Level (0 degrees)
Soil Type:	Sand
Soil Colour:	Yellow
Rock Outcrop:	No bedrock exposed
Vegetation Condition:	1 - Pristine
Disturbance:	Dieback
Fire:	>5 years

DOMINANT TAXA IN VEGETATION STRATA

SPECIES LIST

Taxon Name	Avg. Height	Cover Alive
Acacia applanata		0.1
Acacia sessilis		0.1
Alexgeorgea nitens		0.1
Allocasuarina humilis	1.6	2
Amphipogon turbinatus		0.1
Anigozanthos humilis subsp. *humilis*		0.1
Astroloma pallidum		0.1
Banksia attenuata	4	2
Banksia grandis	1	2
Billardiera ?fraseri		0.1
Bossiaea eriocarpa		0.1
Burchardia congesta		0.1
Calectasia narragara		0.1
Calothamnus sanguineus	0.4	8
Calytrix sylvana		0.1
Cassytha flava		0.1
Conostephium pendulum		0.1
Conostylis aculeata subsp. *aculeata*		0.1
Conostylis aurea		0.1

Conostylis setigera subsp. *setigera*		0.1
Corymbia calophylla	4	2
Desmocladus fasciculatus		0.1
Desmocladus flexuosus		0.1
Drosera erythrorhiza		0.1
Drosera menziesii		0.1
Elythranthera brunonis		0.1
Eremaea pauciflora	0.6	6
**Gladiolus caryophyllaceus*		0.1
Gompholobium knightianum		0.1
Haemodorum sp.		0.1
Hakea ruscifolia		0.1
Hibbertia huegelii		0.1
Hibbertia hypericoides	0.5	15
Hibbertia sericosepala		0.1
Hibbertia subvaginata		0.1
Hovea trisperma		0.1
**Hypochaeris glabra*		0.1
Hypolaena exsulca		0.1
Jacksonia floribunda		0.1
Lepidosperma sp.		0.1
Leucopogon sp. D Perth Flora (aff. *polymorphus*)		0.1
Lomandra hermaphrodita		0.1
Mesomelaena pseudostygia	0.4	15
Millotia tenuifolia var. *laevis*		0.1
Patersonia occidentalis var. *occidentalis*		0.1
Petrophile linearis		0.1
Philotheca spicata		0.1
Phyllangium divergens		0.1
Prasophyllum sp.		0.1
Pterostylis recurva		0.1
Scaevola canescens		0.1
Sphaerolobium medium		0.1
Stirlingia latifolia	0.4	1
Stylidium cygnorum		0.1
Stylidium ?diuroides		0.1
Synaphea spinulosa subsp. *spinulosa*		0.1
Tetraria octandra		0.1
Tetratheca nuda		0.1
Thysanotus sparteus		0.1
Trachymene pilosa		0.1
?Tricoryne elatior		0.1
Xanthorrhoea preissii	1.5	8

Xanthosia huegelii		0.1

PHOTO

Site Name:	IR-02 (Woodman Environmental)
Site Type:	QUADRAT
Dimensions:	10m x 10m
Survey Date:	15/09/2015
GPS Location:	GDA94 Zone 50 404824E 6517258N
Landform Type:	Upper Slope
Slope Class:	Gently Inclined (3 degrees)
Soil Type:	Sand
Soil Colour:	Yellow
Rock Outcrop:	No bedrock exposed
Vegetation Condition:	1 - Pristine
Disturbance:	Dieback
Fire:	>5 years

DOMINANT TAXA IN VEGETATION STRATA

SPECIES LIST

Taxon Name	Avg. Height	Cover Alive
Acacia applanata		0.1
Adenanthos cygnorum subsp. *cygnorum*	3	5
Alexgeorgea nitens		0.1
Anigozanthos humilis subsp. *humilis*		0.1
Astroloma pallidum		0.1
Astroloma xerophyllum	0.5	3
Boronia ramosa		0.1
Bossiaea eriocarpa		0.1
Burchardia congesta		0.1
Caladenia flava		0.1
Calothamnus sanguineus		0.1
Calytrix flavescens		0.1
Calytrix sylvana		0.1
Cassytha flava		0.1
Conostephium minus		0.1
Conostephium pendulum		0.1
Conostylis aurea		0.1
Conostylis juncea		0.1
Conostylis setigera subsp. *setigera*		0.1
Corymbia calophylla	6	1
Daviesia incrassata subsp. *incrassata*		0.1
Desmocladus fasciculatus		0.1

Desmocladus flexuosus		0.1
Drosera erythrorhiza		0.1
Drosera menziesii		0.1
Eucalyptus marginata	10	15
Gompholobium knightianum		0.1
Haemodorum sp.		0.1
Hibbertia huegelii		0.1
Hibbertia hypericoides	0.5	20
Hibbertia subvaginata		0.1
Hypocalymma xanthopetalum		0.1
Hypolaena exsulca		0.1
Isotropis cuneifolia		0.1
Jacksonia floribunda		0.1
Johnsonia pubescens subsp. *pubescens*		0.1
Lepidosperma sp.		0.1
Leporella fimbriata		0.1
Leucopogon conostephioides	0.5	3
Leucopogon sp. D Perth Flora (aff. *polymorphus*)		0.1
Lomandra hermaphrodita		0.1
Lomandra sericea		0.1
Lyginia imberbis		0.1
Mesomelaena pseudostygia	0.4	10
Millotia tenuifolia var. *laevis*		0.1
Neurachne alopecuroidea		0.1
Patersonia occidentalis var. *occidentalis*		0.1
Petrophile linearis		0.1
Philotheca spicata		0.1
Stirlingia latifolia	0.7	3
Stylidium ?araeophyllum		0.1
Stylidium cygnorum		0.1
Stylidium eriopodum		0.1
Stylidium piliferum		0.1
Stylidium repens		0.1
Synaphea spinulosa subsp. *spinulosa*		0.1
Tetraria octandra		0.1
Trachymene pilosa		0.1
**Ursinia anthemoides*		0.1
Xanthorrhoea preissii		0.1
Xanthosia huegelii		0.1

PHOTO

Site Name:	IR-03 (Woodman Environmental)
Site Type:	QUADRAT
Dimensions:	10m x 10m
Survey Date:	15/09/2015
GPS Location:	GDA94 Zone 50 403382E 6517157N
Landform Type:	Mid Slope
Slope Class:	Moderately Inclined (10 degrees)
Aspect:	NW
Soil Type:	Sand
Soil Colour:	Grey
Rock Outcrop:	No bedrock exposed
Vegetation Condition:	2 - Excellent
Disturbance:	Historical logging
Fire:	>5 years

DOMINANT TAXA IN VEGETATION STRATA

SPECIES LIST

Taxon Name	Avg. Height	Cover Alive
Alexgeorgea nitens		0.1
Bossiaea eriocarpa		0.1
Brachyscome iberidifolia		0.1
Caladenia flava		0.1
Calytrix flavescens		0.1
Conostephium minus		0.1
Conostephium pendulum	0.5	2
Conostylis aculeata subsp. *aculeata*		0.1
Desmocladus flexuosus		0.1
Drosera pallida		0.1
Eucalyptus marginata	8	10
Gompholobium tomentosum		0.1
Hibbertia hypericoides	0.5	20
Hibbertia subvaginata		0.1
**Hypochaeris glabra*		0.1
Leucopogon conostephioides	0.5	2
Lomandra caespitosa		0.1
Lomandra hermaphrodita		0.1
Lomandra preissii		0.1
Lyginia imberbis		0.1
Macrozamia fraseri	1.5	3

Patersonia occidentalis var. *occidentalis*		0.1
Persoonia saccata		0.1
Phyllanthus calycinus		0.1
Pterostylis ?vittata		0.1
Sowerbaea laxiflora		0.1
Stylidium neurophyllum ms		0.1
Stylidium schoenoides		0.1
Synaphea spinulosa subsp. *spinulosa*		0.1
Thysanotus manglesianus		0.1
**Ursinia anthemoides*		0.1
Xanthorrhoea preissii	1.5	4

PHOTO

Site Name:	IR-04 (Woodman Environmental)
Site Type:	QUADRAT
Dimensions:	10m x 10m
Survey Date:	15/09/2015
GPS Location:	GDA94 Zone 50 402244E 6517396N
Landform Type:	Mid Slope
Slope Class:	Gently Inclined (3 degrees)
Aspect:	S
Soil Type:	Sand
Soil Colour:	Yellow/Orange (other)
Rock Outcrop:	No bedrock exposed
Vegetation Condition:	2 - Excellent
Disturbance:	Exotic weeds, possible historical ground disturbance
Fire:	>5 years

DOMINANT TAXA IN VEGETATION STRATA

SPECIES LIST

Taxon Name	Avg. Height	Cover Alive
Acacia sessilis		0.1
Allocasuarina humilis	2	10
Anigozanthos humilis subsp. *humilis*		0.1
Boronia ramosa		0.1
Bossiaea eriocarpa		0.1
Brachyscome iberidifolia		0.1
**Briza maxima*		0.1
Caladenia flava		0.1
Calectasia narragara		0.1
Caustis dioica		0.1
Chamelaucium sp. Gingin (N.G. Marchant 6) (T-DRF)	1.5	20
Conostephium pendulum		0.1
Desmocladus flexuosus		0.1
Hibbertia hibbertioides var. *hibbertioides*		0.1
Hibbertia huegelii		0.1
Hibbertia hypericoides		0.1
Hybanthus calycinus		0.1
**Hypochaeris glabra*	0.1	15
Jacksonia sternbergiana	4	40
Laxmannia grandiflora subsp. *grandiflora*		0.1

Lepidobolus preissianus subsp. *preissianus*		0.1
Lomandra caespitosa		0.1
Lomandra hermaphrodita		0.1
Macrozamia fraseri		0.1
Mesomelaena pseudostygia		0.1
Patersonia occidentalis var. *occidentalis*		0.1
Phyllangium divergens		0.1
Phyllanthus calycinus		0.1
Podotheca gnaphalioides		0.1
Pterostylis sp. short sepals (W. Jackson BJ259)		0.1
Sowerbaea laxiflora		0.1
Stackhousia monogyna		0.1
Stylidium neurophyllum ms		0.1
Thysanotus manglesianus		0.1
Trachymene pilosa		0.1
**Ursinia anthemoides*		0.1
Xanthorrhoea preissii	2.5	8

PHOTO

Site Name:	IR-05 (Woodman Environmental)
Site Type:	QUADRAT
Dimensions:	10m x 10m
Survey Date:	15/09/2015
GPS Location:	GDA94 Zone 50 404933E 6515803N
Landform Type:	Dune Crest
Slope Class:	Level (0 degrees)
Soil Type:	Sand
Soil Colour:	Yellow
Rock Outcrop:	No bedrock exposed
Vegetation Condition:	1 - Pristine
Fire:	>5 years

DOMINANT TAXA IN VEGETATION STRATA

SPECIES LIST

Taxon Name	Avg. Height	Cover Alive
Acacia applanata		0.1
Alexgeorgea nitens		0.1
Astroloma pallidum		0.1
Banksia dallanneyi var. *dallanneyi*	0.2	2
Bossiaea eriocarpa		0.1
Burchardia congesta		0.1
Calectasia narragara		0.1
Calytrix flavescens		0.1
Calytrix sylvana		0.1
Conostephium pendulum	0.4	3
Conostylis aurea		0.1
Conostylis setigera subsp. *setigera*		0.1
Daviesia incrassata subsp. *incrassata*		0.1
Drosera erythrorhiza		0.1
Drosera pallida		0.1
Eucalyptus marginata	10	20
Gastrolobium capitatum		0.1
**Gladiolus caryophyllaceus*		0.1
Gompholobium knightianum		0.1
Gompholobium marginatum		0.1
Grevillea pilulifera		0.1
Haemodorum sp.		0.1
Hibbertia huegelii		0.1
Hibbertia hypericoides	0.5	25

Hibbertia subvaginata		0.1
Hovea trisperma		0.1
Lepidobolus preissianus subsp. *preissianus*		0.1
Lepidosperma pubisquameum		0.1
Leucopogon sp. D Perth Flora (aff. polymorphus)		0.1
Lomandra hermaphrodita		0.1
Lomandra sericea		0.1
Mesomelaena pseudostygia	0.4	15
Patersonia occidentalis var. *occidentalis*		0.1
Petrophile linearis		0.1
Philotheca spicata		0.1
Scaevola canescens		0.1
Stirlingia latifolia		0.1
Synaphea spinulosa subsp. *spinulosa*		0.1
Tetraria octandra		0.1
Thysanotus sparteus		0.1
Tricoryne elatior		0.1
Xanthorrhoea preissii	1.5	5
Xanthosia huegelii		0.1

PHOTO

Site Name:	IR-06 (Woodman Environmental)
Site Type:	QUADRAT
Dimensions:	10m x 10m
Survey Date:	16/09/2015
GPS Location:	GDA94 Zone 50 406209E 6516376N
Landform Type:	Crest
Slope Class:	Very Gently Inclined (1 degree)
Soil Type:	Sand
Soil Colour:	Yellow
Rock Outcrop:	No bedrock exposed
Vegetation Condition:	1 - Pristine
Disturbance:	Historical logging
Fire:	>5 years

DOMINANT TAXA IN VEGETATION STRATA

SPECIES LIST

Taxon Name	Avg. Height	Cover Alive
Acacia applanata		0.1
Acacia pulchella		0.1
Acacia sessilis		0.1
Alexgeorgea nitens		0.1
Anigozanthos manglesii		0.1
Astroloma pallidum		0.1
Astroloma xerophyllum	0.4	3
Bossiaea eriocarpa		0.1
Brachyscome iberidifolia		0.1
Burchardia congesta		0.1
Calectasia narragara		0.1
Calytrix sylvana		0.1
Conostephium minus		0.1
Conostephium pendulum		0.1
Conostylis aculeata subsp. *aculeata*		0.1
Conostylis setigera subsp. *setigera*		0.1
Dampiera linearis		0.1
Daviesia incrassata subsp. *incrassata*		0.1
Desmocladus flexuosus		0.1
Eucalyptus marginata	6	15
Gastrolobium capitatum		0.1
**Gladiolus caryophyllaceus*		0.1

Gompholobium knightianum		0.1
Gompholobium tomentosum		0.1
Haemodorum laxum		0.1
Hibbertia huegelii		0.1
Hibbertia hypericoides	0.4	10
Hibbertia sericosepala		0.1
Hibbertia subvaginata		0.1
**Hypochaeris glabra*		0.1
Hypolaena exsulca		0.1
Lepidosperma pubisquameum		0.1
Lepidosperma squamatum		0.1
Leucopogon sp. D Perth Flora (aff. polymorphus)		0.1
Leucopogon sp. Murdoch (M. Hislop 1037)		0.1
Lomandra hermaphrodita		0.1
Lomandra sericea		0.1
Mesomelaena pseudostygia	0.4	4
Patersonia juncea		0.1
Patersonia occidentalis var. *occidentalis*	0.4	5
Petrophile macrostachya		0.1
Philotheca spicata		0.1
Phyllanthus calycinus		0.1
Sowerbaea laxiflora		0.1
Stylidium cygnorum		0.1
Tetraria octandra		0.1
Tricoryne elatior		0.1
Tripterococcus brunonis		0.1
**Ursinia anthemoides*		0.1
Xanthorrhoea preissii	1.5	7
Xanthosia huegelii		0.1

PHOTO

Site Name:	IR-07 (Woodman Environmental)
Site Type:	QUADRAT
Dimensions:	10m x 10m
Survey Date:	16/09/2015
GPS Location:	GDA94 Zone 50 406229E 6516753N
Landform Type:	Crest
Slope Class:	Very Gently Inclined (1 degree)
Aspect:	S
Soil Type:	Sand
Soil Colour:	Yellow
Rock Outcrop:	No bedrock exposed
Vegetation Condition:	1 - Pristine
Disturbance:	Exotic weeds
Fire:	>5 years

DOMINANT TAXA IN VEGETATION STRATA

SPECIES LIST

Taxon Name	Avg. Height	Cover Alive
Acacia sessilis		0.1
Alexgeorgea nitens		0.1
Allocasuarina humilis	1.8	8
Anigozanthos humilis subsp. *humilis*		0.1
Astroloma xerophyllum		0.1
Banksia attenuate	1.5	1
Banksia dallanneyi var. *dallanneyi*		0.1
Banksia menziesii	2.5	1.5
Boronia ramose		0.1
Bossiaea eriocarpa		0.1
Burchardia congesta		0.1
Caladenia flava		0.1
Calothamnus sanguineus		0.1
Calytrix flavescens		0.1
Calytrix sylvana		0.1
Cassytha flava		0.1
Conostephium pendulum		0.1
Conostylis aculeata subsp. *aculeata*		0.1
Conostylis setigera subsp. *setigera*		0.1
Dampiera linearis		0.1
Desmocladus flexuosus		0.1

Drosera erythrorhiza		0.1
Eremaea pauciflora	0.6	4
Eucalyptus todtiana	6	7
Gastrolobium capitatum		0.1
**Gladiolus caryophyllaceus*		0.1
Gompholobium tomentosum		0.1
Hibbertia huegelii		0.1
Hibbertia hypericoides	0.4	4
Hibbertia subvaginata		0.1
Hybanthus floribundus subsp. *floribundus*		0.1
**Hypochaeris glabra*		0.1
Jacksonia floribunda		0.1
Lepidobolus preissianus subsp. *preissianus*		0.1
Lepidosperma sp.		0.1
Leucopogon conostephioides		0.1
Lomandra caespitosa		0.1
Lomandra hermaphrodita		0.1
Melaleuca trichophylla	0.3	3
Mesomelaena pseudostygia	0.4	15
Millotia tenuifolia var. *laevis*		0.1
Neurachne alopecuroidea		0.1
Patersonia occidentalis var. *occidentalis*		0.1
Petrophile macrostachya		0.1
Philotheca spicata		0.1
Podotheca gnaphalioides		0.1
Pterostylis sp. short sepals (W. Jackson BJ259)		0.1
Scaevola canescens		0.1
Stylidium albolilacinum		0.1
Stylidium cygnorum		0.1
Stylidium ?diuroides		0.1
Stylidium piliferum		0.1
Stylidium schoenoides		0.1
Synaphea spinulosa subsp. *spinulosa*		0.1
Tetratheca nuda		0.1
Thysanotus dichotomus		0.1
Trachymene pilosa		0.1
**Ursinia anthemoides*		0.1
Xanthorrhoea preissii	1.5	1.5
Xanthosia huegelii		0.1

PHOTO

Appendix D: Section of Classification Analysis Dendrogram Showing Proximity of SCP20a and Proposed Offset Site Quadrats (including weeds)

Appendix E: Results of Nearest Neighbour Analysis of Quadrat Data from the Proposed Offset Site

Study & Project Area Quadrat	Nearest Neighbour	Level of Similarity	SCP FCT
IR-01	KOON-1	0.536	20a
IR-02	MR09	0.5146	23b
IR-03	CAVS10	0.5844	21a
IR-04	GNAN03	0.6311	23a
IR-05	5C03	0.5699	20a
IR-06	SHENT-1	0.5833	28
IR-07	ELE24	0.4951	23b

Appendix F: Results of Indicator Species Analysis of Quadrat Data from the proposed Offset Site

Taxon	FCT				
	20a	21a	23a	23b	28
*Alexgeorgea nitens***	16	2	8	14	7
*Bossiaea eriocarpa****	8	6	8	7	4
*Burchardia congesta****	6	5	6	4	5
*Calectasia narragara**	19	1	4	6	6
*Conostylis aurea***	21	0	4	6	2
Conostylis setigera subsp. *setigera**	14	0	4	1	9
*Conospermum undulatum****	100	0	0	0	0
*Cyathochaeta equitans***	33	1	2	0	0
*Dasypogon obliquifolius***	55	0	2	1	1
Daviesia divaricata subsp. *divaricata* ms**	21	3	2	5	5
*Daviesia triflora**	17	2	15	9	9
*Hibbertia huegelii****	15	1	7	5	6
*Hibbertia hypericoides****	5	4	4	3	5
Lambertia multiflora var. *darlingensis***	37	0	0	0	0
*Mesomelaena pseudostygia****	11	1	3	3	11
*Monotaxis grandiflora***	33	3	4	4	7
Scaevola repens var. *repens***	24	1	9	5	4
*Stirlingia latifolia****	10	3	6	7	3
*Banksia menziesii****	5	4	13	12	6
*Gompholobium tomentosum****	5	7	9	5	6
*Laxmannia squarrosa**	5	7	22	4	3
*Lomandra hermaphrodita****	7	5	9	5	5
Patersonia occidentalis var. *occidentalis*, *Patersonia occidentalis****	5	4	6	5	2
*Schoenus curvifolius***	8	1	16	14	2
*Tricoryne tenella**	20	11	26	3	3
*Astroloma xerophyllum**	0	0	8	24	2
*Banksia attenuata****	6	7	8	9	6
*Beaufortia elegans**	0	0	7	31	1
*Conostephium minus**	8	3	6	44	9
Eremaea pauciflora var. *pauciflora*, *Eremaea pauciflora****	8	1	7	15	1
*Hibbertia subvaginata***	1	3	6	14	3
Jacksonia floribunda, *Jacksonia decumbens***	11	0	8	18	2
*Scholtzia involucrata****	0	3	16	16	1

Note: Shading denotes highest indicator values per taxon;
Indicator values (%) are shown only for taxa which were significant at P<0.05 (* = p <0.05; ** = p<0.01; *** = p <0.001)

APPENDIX G

Analysis of Floristic Data from Ioppolo Road and Hepburn Avenue to Assign Sites to Floristic Community Types

Analysis

of floristic data

from Ioppolo Road

and Hepburn Avenue

to assign sites to

floristic community types

Prepared for

Coffey Environments

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December 2015 (revised)

1.0 Introduction

This report presents and discusses floristic analyses aimed at assigning sites recorded at Ioppolo Road on the southern end of the Dandaragan Plateau and at Hepburn Avenue on the Swan Coastal Plain to a system of units produced by earlier studies (Gibson *et al* 1994 and the "System Six update" to that study).

Gibson *et al* 1994 includes a pattern analysis of flora lists from quadrats recorded in vegetation on the Swan Coastal Plain. As the data used in such analyses is lists of flora species, it is also referred to as a "floristic analysis". Subsequent to the 1994 publication, an "update" incorporating additional data (including about 100 sites from the Dandaragan Plateau from which no sites where included in Gibson *et al* 1994) was carried out (cited in *Perth's Bushplan* (Gov. W.A. 1998) as DEP1996) but is not published. The two studies (the latter incorporating the 509 sites from the former and adding a similar number of new sites) defined a series of "floristic community types", or groups of sites with similar species composition that are inferred to have similar conservation values.

The floristic community types defined in the two studies discussed above are used as a major factor in determination of conservation value for vegetation on the Swan Coastal Plain by both the Department of Parks and Wildlife (DPaW) and the Environmental Protection Authority (EPA). As the System Six update included sites from the Dandaragan Plateau, there are also some floristic community types that are known from there.

2.0 Gibson *et al* study, the System Six update, and the current analysis

To understand the analysis presented and discussed in this report, it is important to understand the basis and relevant attributes of the floristic community types defined in Gibson *et al* 1994 and the System 6 Update (DEP 1996). The area covered by the 1994 analysis (based on 509 sites) was the Swan Coastal Plain from the Gingin area to the southern end of that Plain. The System 6 Update added significantly more sites (so the combined data set has 1,098 sites) including about 100 from the Dandaragan Plateau. The Gibson *et al* (1994) survey covered a very large area with a diverse array of soil and habitat types and a large flora (ca. 2,000 species). Therefore, with 509 sites the 1994 survey is in one regard a very large amount of work and in another is data poor to document the variation in the floristic composition of the vegetation of the area surveyed.

The authors of Gibson *et al* (1994) chose to define thirty (30) floristic community types, nine of which had two or three subtypes (giving a total of 43 units). Thirty is a quite small number of floristic community types for the area surveyed and means that they are high order units; that is, they have a high level of synthesis. Appendix 1 is a table that attempts to put this in context and very strongly indicates that the 30 floristic community types are defined at a high level of synthesis; the subtypes (e.g. 1a, 1b) are also still high order units. It is also important to appreciate that the analysis is based on the presence and absence of flora species, without any weighting for the abundance of individual species. This is a common approach for analysing data from large areas, but also contributes to the limited number of floristic community types defined being rather abstract, as they can include a range of vegetation types with different species dominant and with different structure. This method (and the limited number of floristic community types defined in this case) necessarily limits the meaning of the results for understanding environmental aspects of vegetation that are important for using vegetation as a surrogate for other values, as dominance and structure are very important for environmental values (such as fauna habitat) dependent on vegetation type.

The Gibson *et al* (1994) study and the System Six update both used classifications produced using the pattern analysis program PATN (Belbin 1987). If the System Six update analysis had been carried out in exactly the same way as the 1994 study, it would have produced an entirely new classification, as the large amount of new data added would have created different possibilities for the formation of groups of sites (floristic community types) at the level (number of floristic community types) of the 1994 analysis (this can be seen in the larger segments of the Single Site insertion dendrogram reproduced in Appendix 2). To avoid this, the System Six update analysis was run using a component of PATN called "ALOC" with no "reallocation". This was used to maintain the previous classification into floristic community types and create new FCTs where new sites were "different". It could be inferred that many of the original FCTs were poorly defined; more than half (22) of the 43 FCTs were represented by less than 10 sites and a sixth had less than 5 sites. Other analyses have shown that when new sites are added to the Gibson et al 1994 dataset, significant changes in classifications can occur (e.g. Trudgen 1999). Therefore, it should be considered that

the allocation of floristic community types through the update process is tentative and not absolute. To clarify this, forcing the System Six Update sites into floristic community types defined in the Gibson *et al* (1994) classification is likely to have false positives, that is placing sites in floristic community types where they do not belong. Consequently, allocation of new sites (e.g. the new Ioppolo Road sites) based on comparison to the allocation of sites to floristic community types in the update should be treated with caution. Appendix 3 shows a comparison of the similarity of sites placed in FCT 20a to other sites placed in FCT 20a and sites from other floristic community types selected using the nearest neighbours method. It shows that some FCT 20a sites are in fact closer (more similar using PATN) to sites from FCT 23a and 23b. As a site (site 5c03) used in the System 6 Update from the Ioppolo Road area was placed in FCT 20a in that study, it became important for the for the purposes of this report to ascertain if this was a good allocation.

Inherently, if an original analysis is data poor for the area and environmental variation sampled, then adding more sites to the classification will mean that sites will be allocated into poorly defined units (floristic community types). In cases such as the present analysis, where the aim is to assign more newly recorded sites to the previously defined floristic community types then some difficulty must be anticipated.

The process of adding new sites to the existing classification can also be affected by the quality of new data. Factors such as the number of visits to the new quadrats (ideally at least two), the timing of visits, the experience of the survey botanists in searching the quadrats for flora species, the level of disturbance (including weed invasion, which displaces native species) of the sites sampled, and the accuracy of both field and herbarium identifications all affect data quality. It is noted in this context, that the nearly 300 sites recorded by E. A. Griffin that were included in the "update" were only visited once (but note, that fact that some of the new Ioppolo Road sites geographically close to some of these sites also come out close to some of them in the analyses indicates that the data is reasonably compatible).

Bearing all these factors in mind, new sites may or may not fit the existing classification well. In such cases it may be because of the constraints of the classification (i.e. sites may not fit well because there is no appropriate place for them) or because the new data is not of ideal quality.

3.0 Methods used

Three methods using different approaches based on the PATN pattern analysis package were used to investigate what floristic community types the new sites from Ioppolo Road and Hepburn Avenue should be assigned to. These were firstly using PATN to construct a dendrogram using all the new sites and the reference data set (the Gibson *et al* 1994 data and the System Six update data). This method is known to have problems if the new data has differences in quality from the reference data set. The second method used was the Nearest Neighbours approach, where sites are compared to see which sites have the most similar species lists. As not all species have the same influence in group formation using PATN, nearest neighbours can be skewed by species in common between sites that do not have as much influence on group formation as other species. The third approach used was "Single Site Insertion", in this technique a dendrogram is produced using PATN but only one new site at a time is compared to the reference data set. This avoids the problem of new sites grouping together because of survey characteristics (e.g. only one site visit, or timing of visits different to the timing of visits to the reference data sites).

The results of the three approaches were then compared to synthesise an overall result.

As three of the Ioppolo Road quadrats joined in the single site insertion method with a reference site (site 5c03, which was assigned to FCT 20a in the Update) recorded nearby in the Ioppolo Road bushland, the correct placement of this site was also investigated. This was necessary, as FCT 20a was originally defined based on sites recorded on the Swan Coastal Plain, making its occurrence on the Dandaragan Plateau unlikely (also see the section above). If site 5c03 was incorrectly assigned to FCT 20a, then comparing new sites to investigate their allocation to FCT 20a would be fundamentally flawed.

The new sites were compared to a reference data set made up of the Gibson *et al* (1994) sites and the sites used for the System 6 Update (DEP 1996). To make the use of species names in the reference data set as up to date as possible, an extensive updating of the names used in this data had been carried out. The names in the new (Ioppolo Road and Hepburn Avenue) data were carefully compared to those in the reference data set to make them as compatible as reasonably possible and where necessary reference was made to Florabase and other resources.

The analyses were made excluding weed species, as these taxa are not considered by the authors of this report to be at equilibrium in the areas concerned and thus can distort analyses. Also, most of the reference sites were chosen to be in areas of better condition, whereas some of the new sites (especially the Hepburn Avenue sites) have significant weed invasion. In such cases, including weeds would make interpreting the analyses more difficult.

4.0 Results

The results of the three approaches for the new quadrats are shown in Table 1 and are discussed for each quadrat below.

As site 5c03 (allocated to FCT 20a in the System 6 Update) was an outlying record of FCT 20a (on the Dandaragan Plateau, whereas all other records are on the Swan Coastal Plain), its allocation to FCT 20 needed to be examined prior to using this site as a reference site for FCT 20a (also see section above). The results of the investigation of site 5c03 using an analysis without using ALOC indicated that this site should be assigned to floristic community type 23b rather than to FCT 20a. The Nearest Neighbours method also suggested this assignment, but with less certainty (see Table 1). This is an important result, as it indicates that the assignment of this site to floristic community type 20a in the System Six update analysis was the result of the use of the ALOC function in PATN forcing this site to an inappropriate place (i.e., it was a false positive). As this site should not be considered to be a member of floristic community type 20a, this means that sites that are similar to it are also not floristic community type 20a.

Figure 1 is a section of the single site insertion dendrogram investigating the placement of site IR-01. It joins to site 5c03 and they join in the centre of nine sites that belong to FCT23b (and one site allocated to site s09 which may also be mis-allocated). The figure very strongly indicates that site 5c03 should be re-allocated to FCT 23b and that therefore site IR-01 should also be allocated to FCT 23b.

Figure1. A section of a single site insertion dendrogram including site 5c03
Note: Site 5c03 falls within a group of sites that with one exception have been placed in FCT 23b and the new site IR-01 is closest to 5c03.

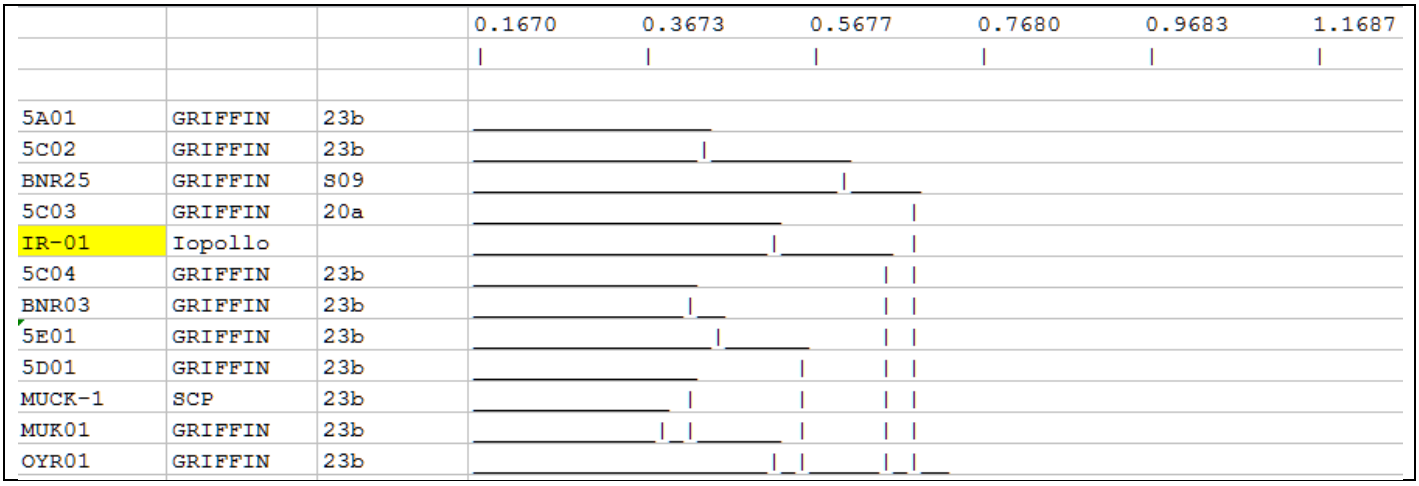

Table 1 (see below) shows the interpretation of the results of each of the three analyses carried out for each of the new sites and also for site 5c03. The analyses are single site insertion (each new site included by itself with the reference data), a dendrogram of all the new sites with the reference data and a nearest neighbours analysis. The single site insertion method avoids a the problem with the dendrogram of all sites

whereby new sites can cluster together because of a survey specific factor such as time of survey and therefore usually provides a better indication of best placement. As single site insertion uses the same algorithm as was used for the Gibson *et al* (1994) analysis, it also avoids the issue with nearest neighbours where species that do not have much impact in the analysis may indicate sites are nearest neighbours, when they are not placed closest in the dendrogram. For these reasons somewhat more weight is placed on the single site insertion method than on the other two methods, but each case needs to be judged individually.

For example, Appendix 2 has extracts from the single site insertion dendrograms for each of the new sites, one is also reproduced her as figure 2. Figure 2 shows how the new site HA-02 joins in a section of the dendrogram that has a mixture of sites from FCT 4 and FCT S02. Table 1 shows that a similar interpretation was made from the dendrogram for all sites and that the nearest neighbours method shows relationship to FCT SO2. The combined interpretation (see below Table 1) is that this site should be placed in FCT S02, but with some qualification.

A contrasting example is that the new site HA-01 was placed in the single site insertion dendrogram in a large group of sites from FCT 4 (see top of Appendix 2), was most likely FCT 4 from the dendrogram with all sites but also near FCTs S02 and S17, and from nearest neighbours was nearest FCT S02. In this case, the preponderance of sites from FCT4 in the block of the single site insertion dendrogram was interpreted as meaning site HA-01 should be placed in FCT 4. Similar judgements were made to place the other new sites.

Figure2. A section of a single site insertion dendrogram including site HA-02

			11/16/15 10:27:40.04 dend SVB Iopollo SSI no weeds Nov 2015
			0.1670 0.3673 0.5677 0.7680 0.9683 1.1687
ELE06	GRIFFIN	S02	
ELE40	GRIFFIN	4	
ELE31	GRIFFIN	S02	
MUK02	GRIFFIN	4	
ELE30	GRIFFIN	S02	
HA-02	HepAvSVB		
MELA-1	SCP	4	
MP03	GRIFFIN	4	
MP07	GRIFFIN	4	
MP11	GRIFFIN	S02	
ELE07	GRIFFIN	4	
ELE14	GRIFFIN	4	
ELE26	GRIFFIN	S02	
MR08	GRIFFIN	S02	
PLINE-4	SCP	4	

Table 1: Results of three methods of investigating assignment of the new sites to floristic community types.
Notes: References in the table to site 5c03 as FCT 20a should now be read as FCT23a and references to 20a in the Single Site insertion column to FCT 20 should be read as FCT23b as they are based on Site 5c03. The use of ? or ?? indicates the degree of uncertainty in some allocations. SSI means the results of the Single Site Insertion dendrogram. FCT-den means the results of the dendrogram for all sites. NNB means the results for the nearest Neighbours analysis. Where more than one possible FCT is given from a method, the order from left to right indicates the most strong relationship.

PROJ	SITE	SSI	FCT_den	NNB	NNB note
HepAvSVB	HA-01	4	4/S02/S17	S02/4	
HepAvSVB	HA-02	S02/4	4/S02/S17	S02	
HepAvSVB	HA-03	4/S02	4/S02/S17	S02/4	
Iopollo	IR-01	20a[sic 23b]/23b	??S09/S10	23b/20a	20a: LAND-1,5C03
Iopollo	IR-02	20d/?20a[sic 23b]/?23b	??S09/S10	23a/23b	
Iopollo	IR-03	?28	??S09/S10	?21a/23b	
Iopollo	IR-04	?28	??S09/S10	??23b/23a	
Iopollo	IR-05	20a [sic 23b]	??S09/S10	20a	20a:5C03
Iopollo	IR-06	?20b/3b	??S09/S10	?28/20a	20a:KOON-1,5C03
Iopollo	IR-07	?23b	??S09/S10	23a/23b	
	5C03		23b	?23b	related to sites nearby
	KOON-1		20a	20a	
	LAND-1		20a	20a	

From Table 1 (see also Appendix 2), the following interpretations for placing the new sites in floristic community types can be made:

- **HA-01** should be placed in FCT 4, with relationship to FCT S02.
- **HA-02** should be placed in FCT S02, with relationship to FCT 4 (it may be intermediate, or the data may not be adequate to properly place it (due to weed invasion) and it may be better placed in FCT 4.
- **HA-03** should be placed in in FCT 4, with relationship to FCT S02.
- **IR-01** should be placed in in FCT 23b, but with some tendency to FCT 20a. It may be that there is an analogue of FCT 20a (that is a similar type to FCT 20a, but with differences due to the different environment on the Dandaragan Plateau to on the Swan Coastal Plain) in the Ioppolo Road area, or that some vegetation there is intermediate between these two floristic community types.
- **IR-02** Cannot be placed readily in a floristic community type, but has some relationship to FCT 23 and FCT 20.
- **IR-03** should probably be placed in in FCT 28, but has some relationship to FCT23.
- **IR-04** should probably be placed in in FCT 28, but has some relationship to FCT23.
- **IR-05** should be placed in FCT 23a, with some relationship to Supplementary FCTs S09 and S10.
- **IR-06** is somewhat difficult to place, but seems to have some relationship to FCT 20a as on nearest neighbours it comes nearest FCT 28 then site KOON-1 (from Koondoola) that is FCT20a but the next nearest site is 5c03 (which we have moved to FCT 23b), however in the single site insertion dendrogram (see Appendix 2) it joins with sites from FCT20b before it joins with sites from FCT 20a. So it is probably best placed as FCT 20b/23b, with some (small) possibly of a Dandaragan Plateau analogue of 20a (i.e., there is some similarity to FCT20a, but it is low).
- **IR-07** should be placed in in FCT 23a, but with some relationship to other floristic community types.

5.0 REFERENCES

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6.0 APPENDICES

Appendix 1: Comparison of some studies of vegetation on the Swan Coastal Plain and adjoining areas to the commonly accepted structural/dominance classification of vegetation to indicate the approximate relationship of level of synthesis of these examples of various approaches used to describe vegetation.

Notes: Definitions of *alliance* and *society* follow Aplin (1979), the definition of *association* used is similar in meaning to that of Aplin. The definition of *biome* by various authors varies significantly, use here it is somewhat more restricted than by some authors (see Allaby 1998, p 54 for example) who would equate it to all examples of a particul formation or a climatic type, arguably could be above or below formation in the left hand column of this table (or in the column to the right at a higher level than land system (bioregion). Alliance and society are rarely used. Table adapted from Table 3 of Trudgen (1999) and later. The increase in level of synthesis from bottom to top approaches exponential. The left hand column is explanatory with general examples; the others give examples from the Swan Coastal Plain and Whicher Scarp.

Vegetation divided on structure only at the two upper level(s) and on structure and dominant genera or species at the lower levels **Biome**: A concept that is partly distinguished on structure and partly on being a geographical entity. For example, the tropical rainforests of the Amazon Basin are a biome. Obviously, such as a large entity would not be entirely one formation but would have inclusions of others that would occur in a related fashion. This concept therefore straddles the conceptual boundary between the units in this column and the next	**Vegetation divided on broad geomorphological boundaries (+/- land system) with some subdivision on structure and dominant species into ecologically associated groups of types**	**Vegetation divided on less broad geomorphological boundaries (+/- land unit) with subdivision on structure and dominant species into ecologically associated groups of types**	**Floristic analysis: vegetation divided on the basis of the presence or absence of flora species. Sometimes extended to include structure (dominance)** [Uses a concept that divides flora records for sites into a number of groups of sites on the basis of species presence and absence using programs such as PATN. The number of groups used being selected by the person doing the analysis. That is, level of units (floristic community types) varies from study to study.]
Vegetation Formation: A concept that covers vegetation of the same structure of the upper layer without reference to dominant species. While stands referred to a particular formation may have similar structure, they may have different dominant and associated species. For example a Banksia woodland with two shrub layers and a herb layer and a Casuarina woodland with virtually no understorey are both simply woodlands at the formation level. Aplin's (1979) modification of Specht provides a list of 29 formations	**Vegetation complex on the Swan Coastal Plain** A concept that covers a range of structural types that occur in a related pattern with borders defined by major geomorphological units with some subdivision on floristics between southern and northern parts of the geomorphological units. As mapped, fairly similar to CSIRO/ AGWA use of land systems with some subdivision. Co-incidentally, Heddle *et al* (1980) describe 29 vegetation complexes for the Swan CP, this would include vegetation from many of the formations listed by Aplin (1979)	**Vegetation complex on the Darling Plateau** A concept that covers a range of vegetation that occurs on one part of the range of geomorphology of the Plateau and the valleys incised into it, with subdivisions based on changes in vegetation related to broad climatic para meters. (Note: this reflects the fact that the Plateau/ Scarp complex has a higher range of topography and is older than the coastal plain, meaning that more diverse ecological situations have *developed. The result (with exceptions) is that there is less structural diversity in P/S vegetation complexes (Heddle *et al* 1980 gives 30 veg complexes for the Northern Jarrah Forest) (Variable? Possibly to sub-formation.)	**Swan Coastal Plain Survey (Gibson *et al* 1994) floristic community types**) 36 Floristic community types for the southern Swan Coastal Plain (Variable? Individual floristic community types possibly to sub-formation or even alliance level.)
Vegetation Sub-formation: At the sub-formation level, the genus of the dominant of the upper layer is included to group examples of the same formation with related species as the dominant(s). For example, *Eucalyptus* woodland.		**Mapping by McArthur and Mattiske** (1985) of the Bassendean Dunes of the Gnangara Mound. (Variable? Possibly to alliance (individual types).)	**Whicher Scarp Survey (Keighery *et al* 2008) level floristic community types**. Variable? At least some at vegetation alliance level. Those with one quadrat lower? (It depends on whether you look at how different they are from each other or how much variation they include: those with one site are very different from most others, but obviously don't have much variation in them)
Vegetation Alliance: This level groups vegetation associations that have the same dominant species. For example, *Eucalyptus marginata* (Jarrah) forest and may have the same or related species important in the understorey			↓
Vegetation Association: A concept that covers two or more plant communities with similar structure and dominant species. May vary significantly in associated species, but all stands referred to it will have some visual similarity. Some definitions require similar species lists.			
Society: A series of plant communities with the same structure and the same species dominant in the different strata			
Plant Community: The basic unit of vegetation classification. Standing at one place looking at a stand of vegetation one is looking at a physical example of a plant community. Extending this to several very similar stands introduces some variation and it becomes a plant community concept.			
Stand: A particular example of a plant community			

Note: The postion of surveys in the three columns right of the left had column indicates the aproximate relationship (level of synthesis) of their units to the structure/dominance units in the left hand column.

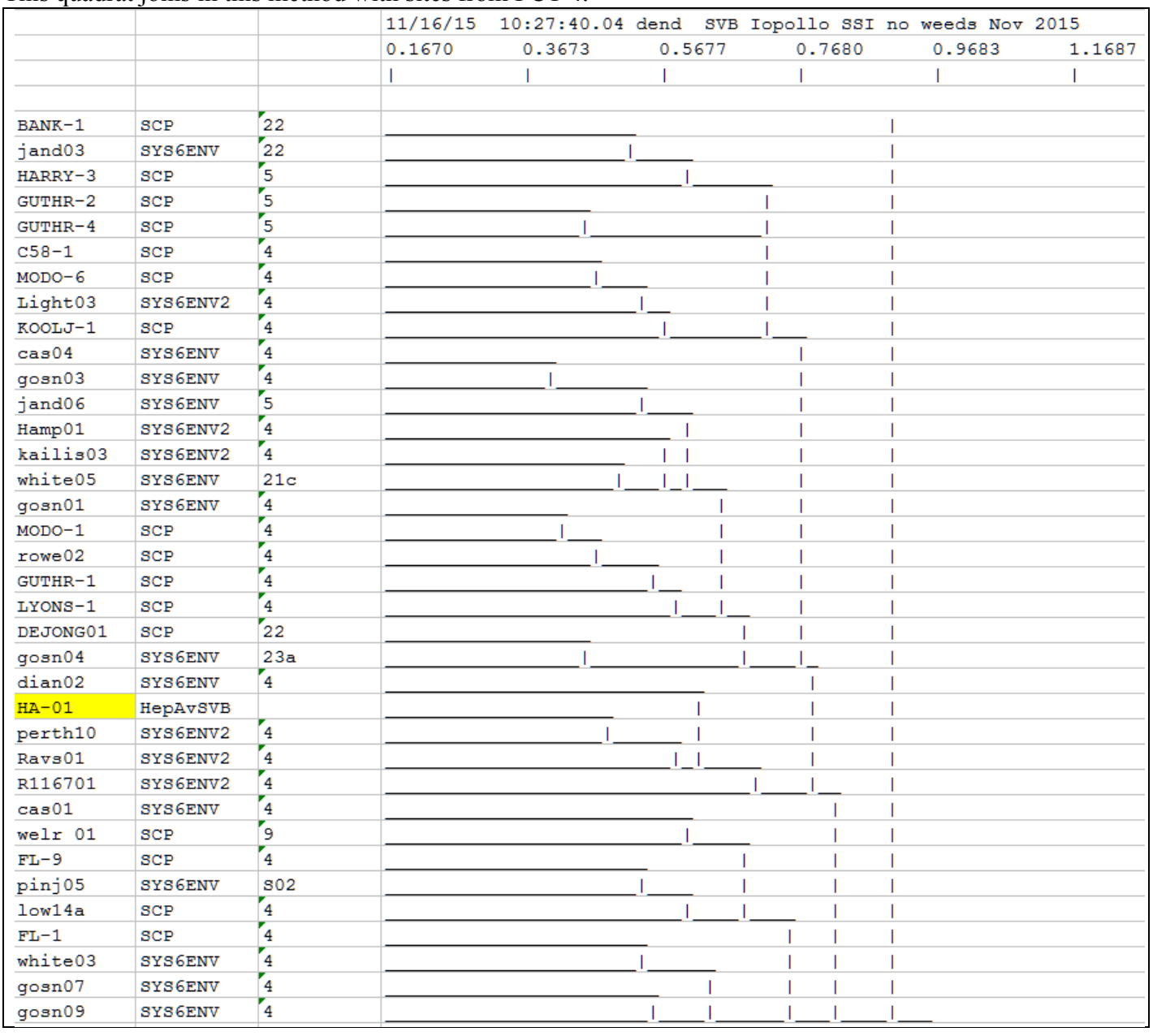
Appendix 2. Extracts from single site insertion dendrograms

One at a time, each of the new sites was included with the reference data set and PATN run to produce a dendrogram (Single Site Insertion). An extract from each run is provided to show where the new sites joined. As some of the new sites are from the Dandaragan Plateau, it was relevant to include the System Six update sites in the reference data. Where the new sites (highlighted in yellow) join is an indication of which floristic community type it should be assigned to, but other information also has to be taken into account.

The first column in the dendrogram extract is a site designation, the second indicates if the site is from the Gibson *et al* (1994) Southern Swan Coastal Plain (SCP) survey or the System Six update data (sites indicated as "Griffin" are sites recorded by EA. Griffin and used in the update). The third column indicates which floristic community type sites were referred to in those studies.

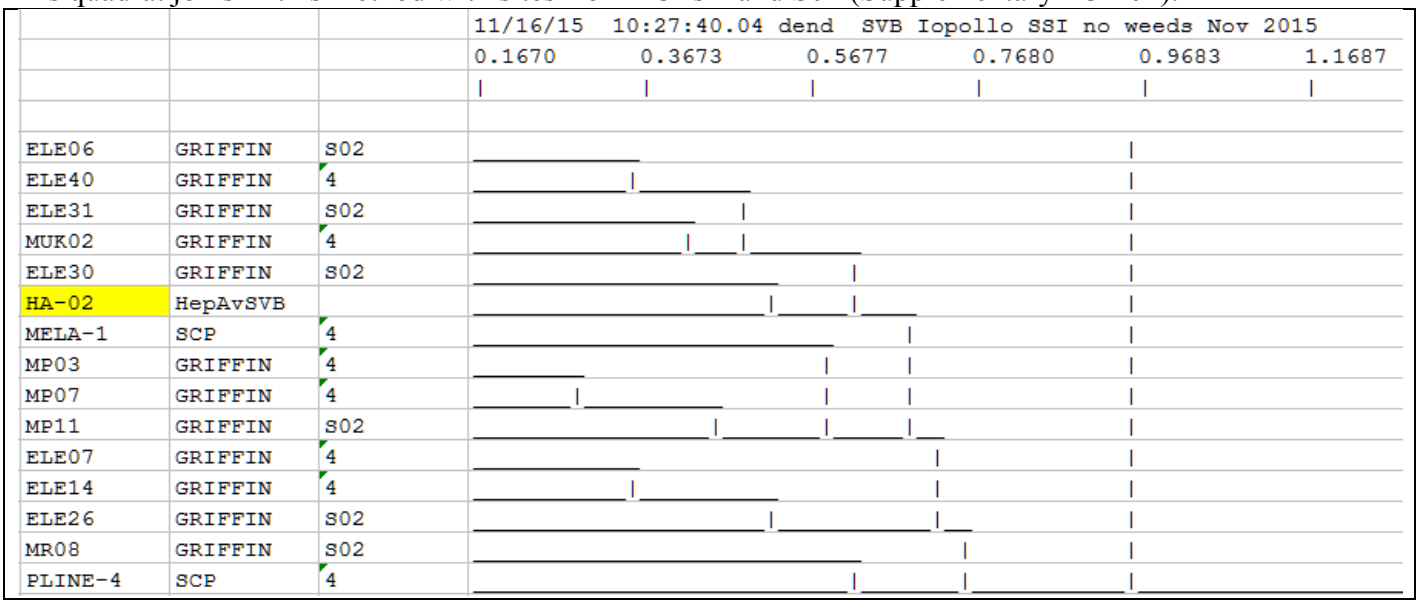
Quadrat HA-01

This quadrat joins in this method with sites from FCT 4.



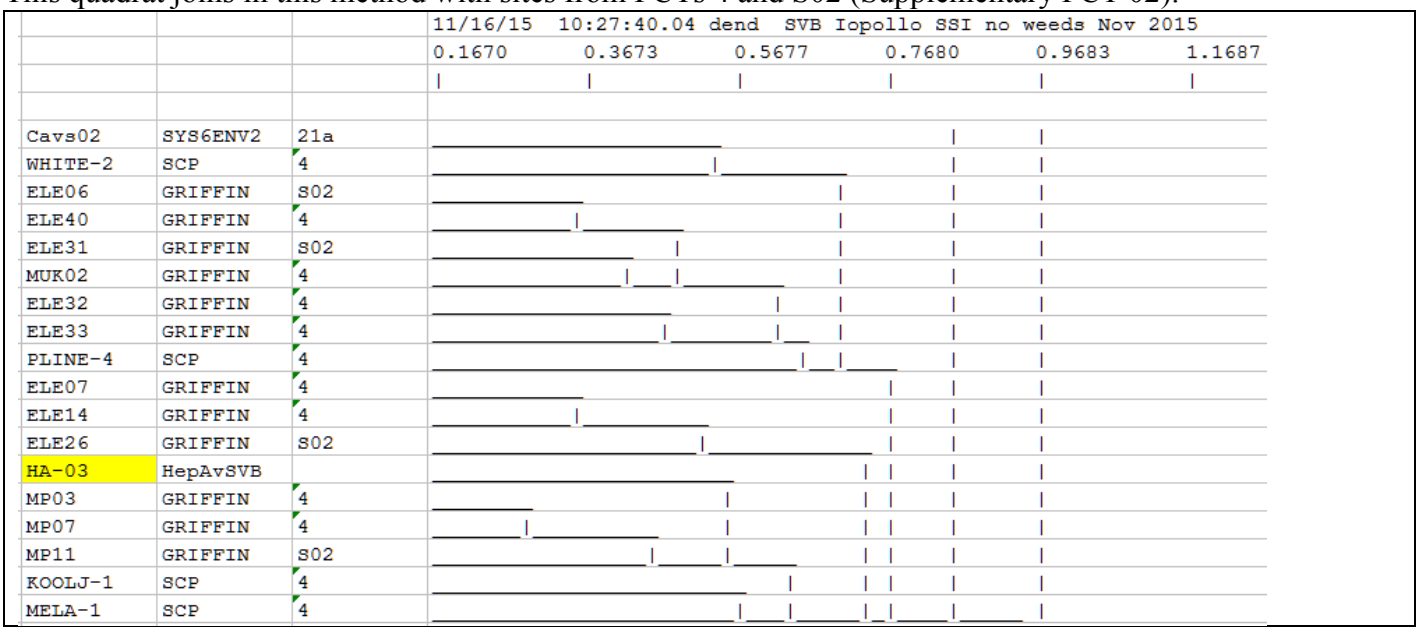
Quadrat HA-02

This quadrat joins in this method with sites from FCTs 4 and S02 (Supplementary FCT 02).



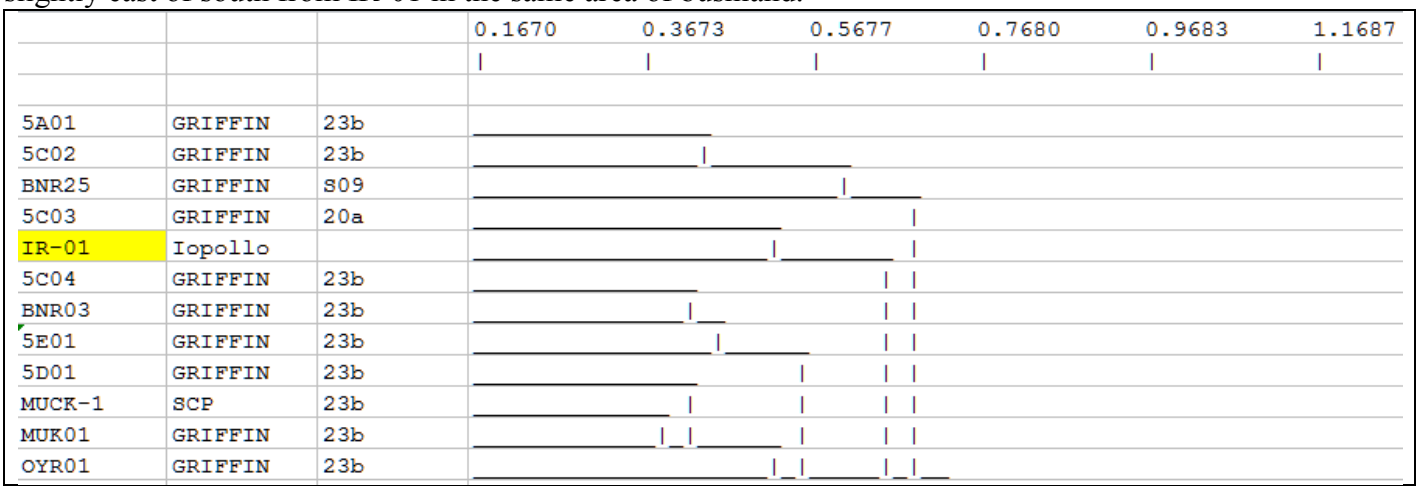
Quadrat HA-03

This quadrat joins in this method with sites from FCTs 4 and S02 (Supplementary FCT 02).



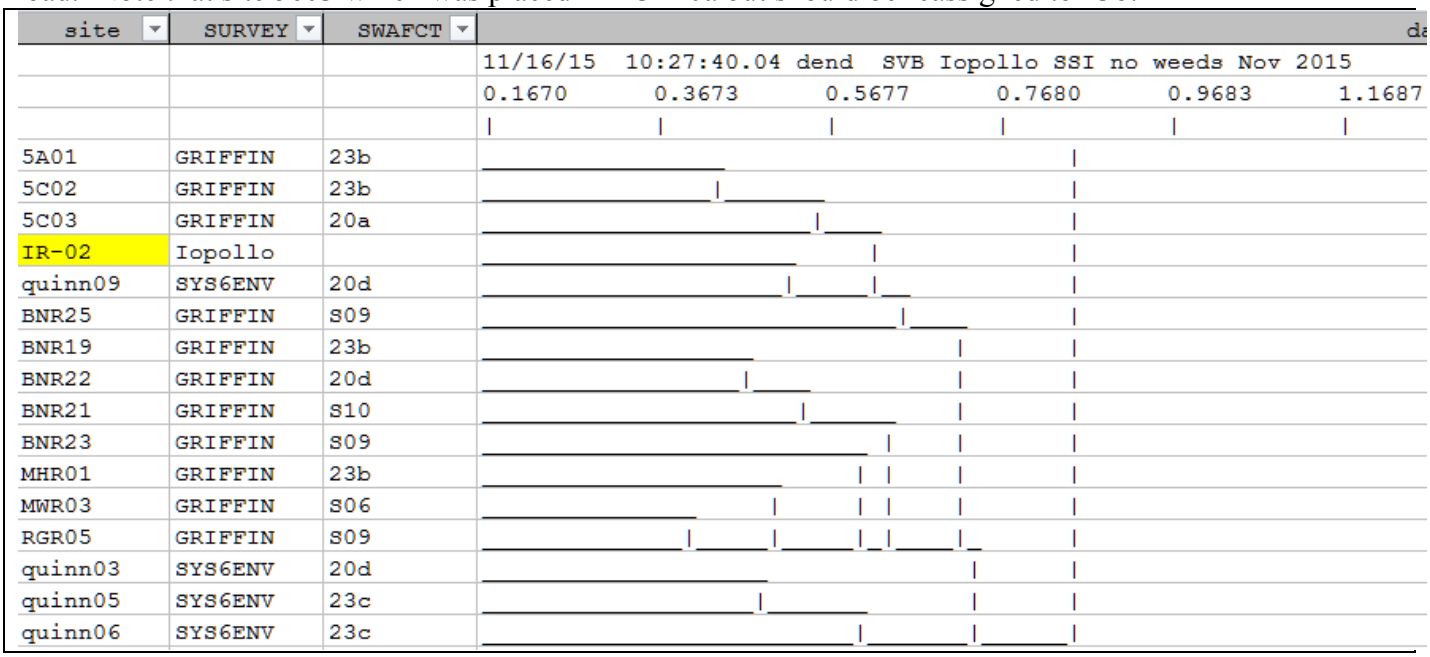
Quadrat IR-01

This quadrat joins in this method with site 5c03 which was placed in FCT20a but should be reassigned to FCT 23b and with less similarity with other sites from FCT 23b. Site 5c03 is located some 750 metres slightly east of south from IR-01 in the same area of bushland.



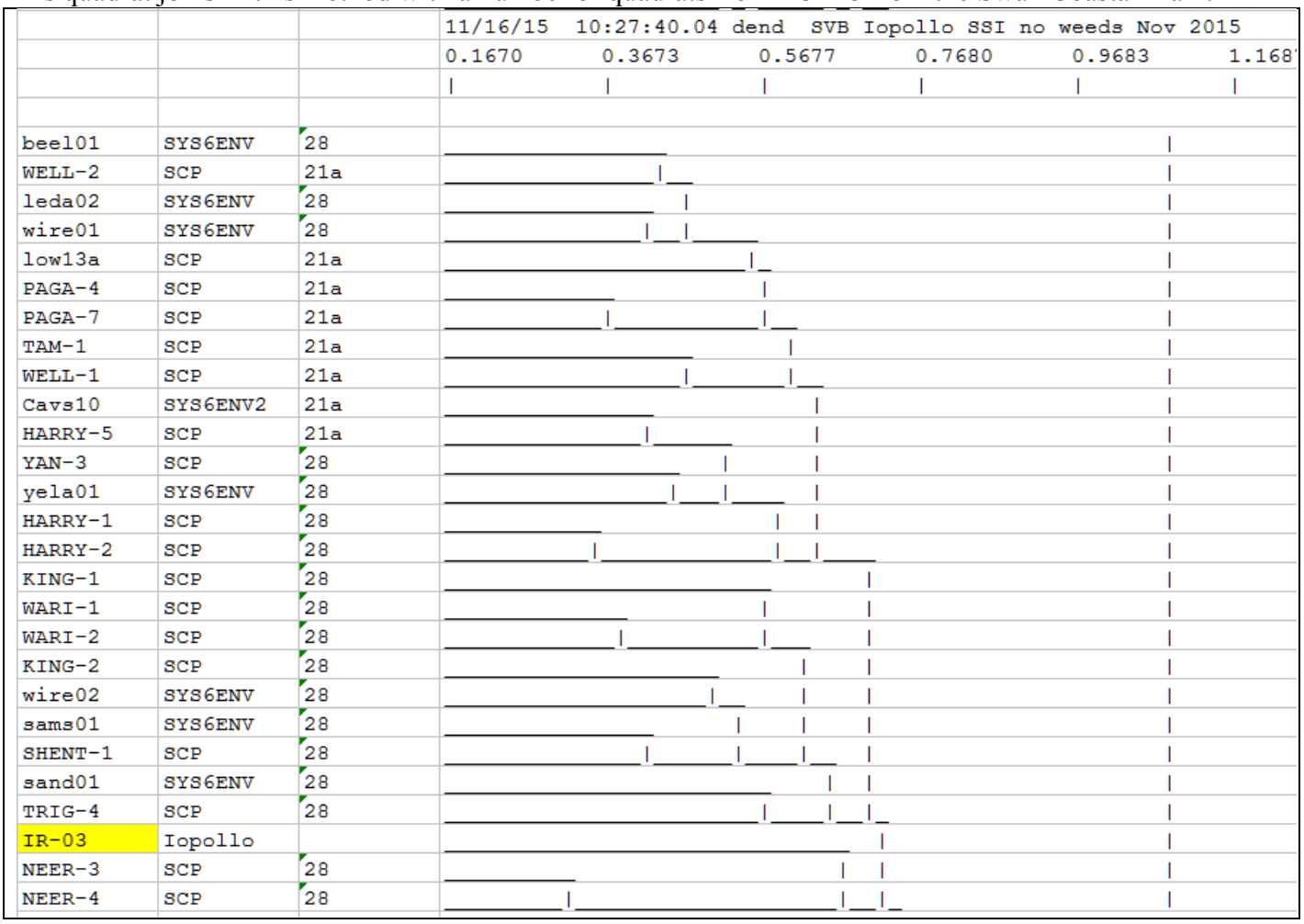
Quadrat IR-02

This quadrat joins in this method with a site (quinn09) from FCT 20d and at lesser similarity with sites from FCT 23b. Site quinn09 is located on the Dandaragan Plateau some 50 km slightly west of north of Ioppolo Road. Note that site 5c03 which was placed in FCT20a but should be reassigned to 23b.



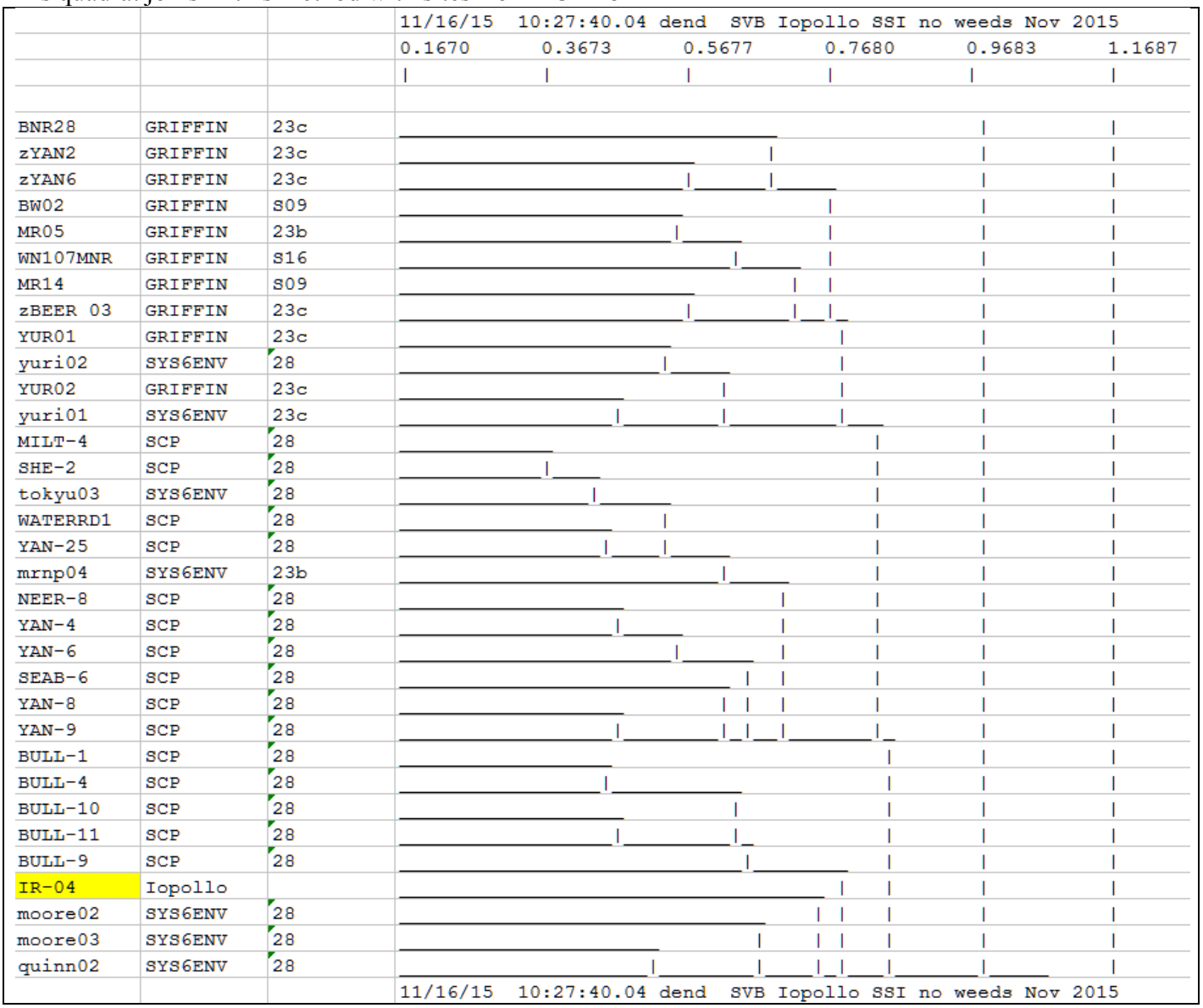
Quadrat IR-03

This quadrat joins in this method with a number of quadrats from FCT28 from the Swan Coastal Plain.



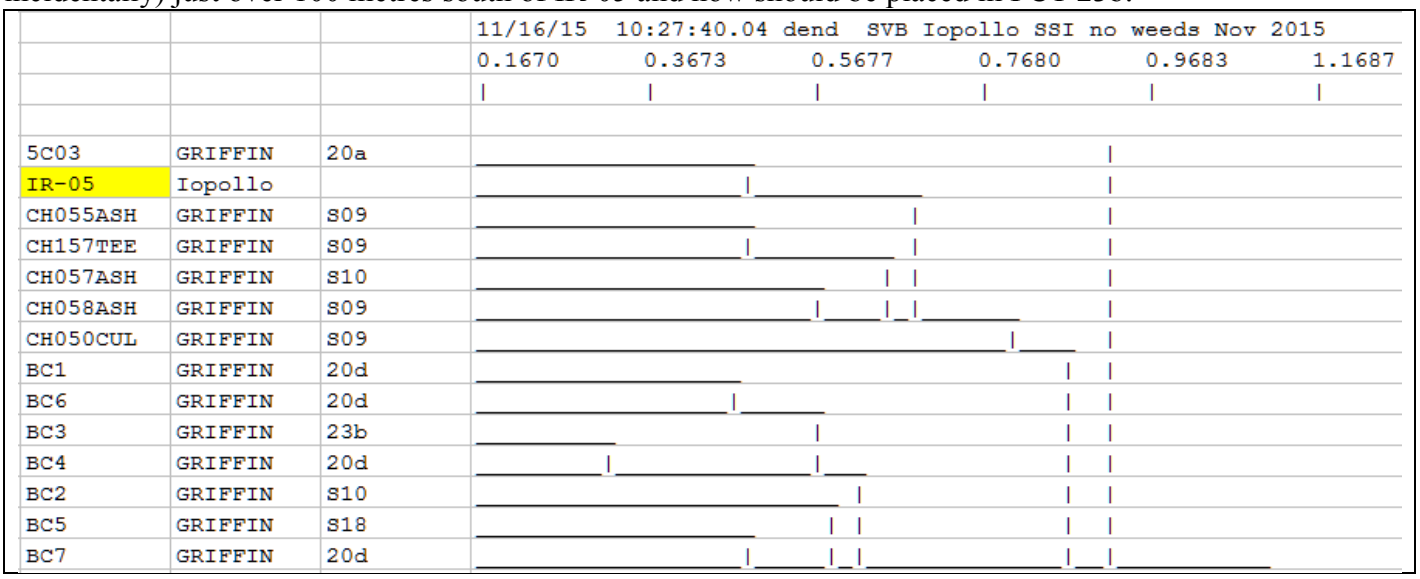
Quadrat IR-04

This quadrat joins in this method with sites from FCT 28



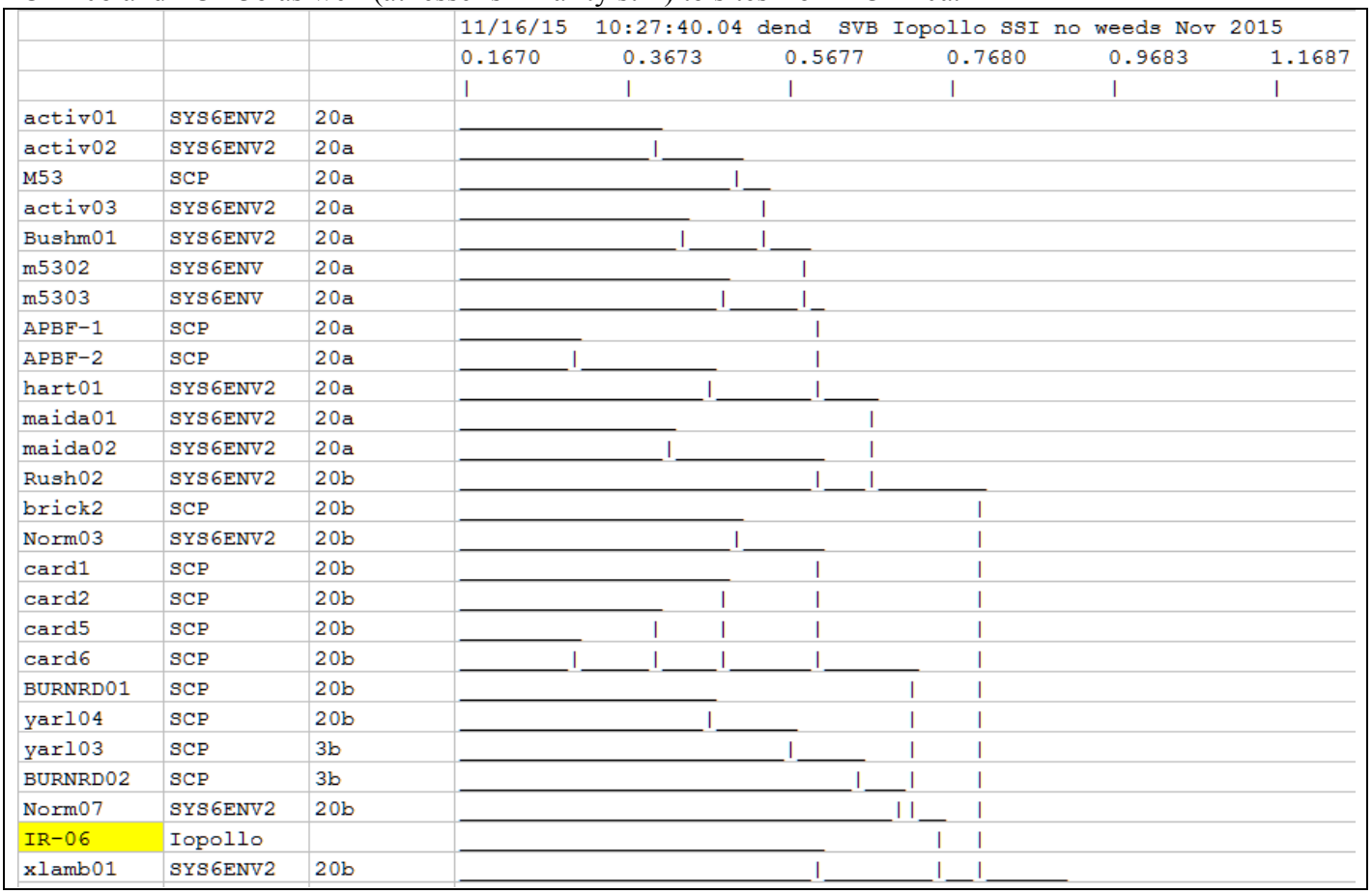
Quadrat IR-05

This quadrat joins in this method with site 5cO3 that was previously assigned to FCT 20a but now is assigned to FCT 23b and with less similarity to sites from FCT S09 and FCT S010. Site 5c03 is located (co-incidentally) just over 100 metres south of IR-05 and now should be placed in FCT 23b.



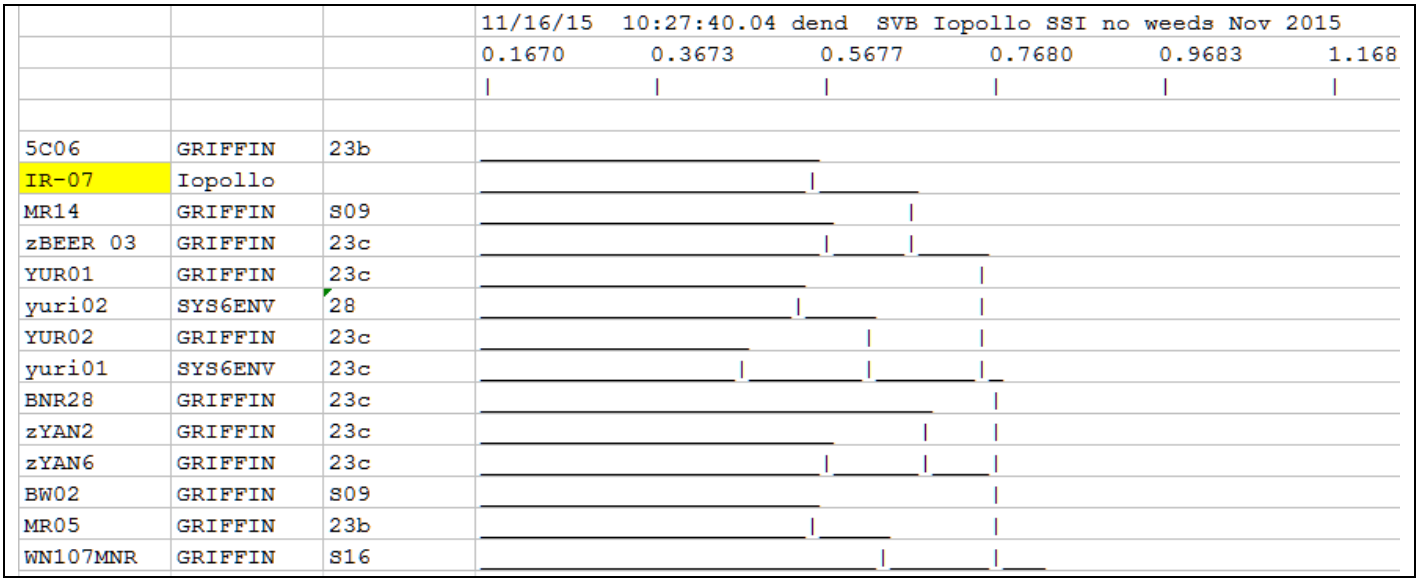
Quadrat IR-06

This quadrat joins in this method with a site from FCT 20b, and at lesser similarity with other sites from FCT 20b and FCT 3b as well (at lesser similarity still) to sites from FCT 20a.



Quadrat IR-07

This quadrat joins in this method with a site (5c06) from FCT23b and then at lesser similarity to sites from FCTs S09 and 23c. Site 5c06 is located in the same area of bushland as site IR-07



Appendix 3. Comparison of sites placed in FCT 20a to selected other sites

The numbers in the cells are a measure of dissimilarity (coloured from green to red on increase in dissimilarity).

SURVEY	S_ID	g50	FCT	BNR01	SA01	SC03	BNR19	activ01	activ02	M53	activ03	Bushm01	m5302	m5303	APBF-1	APBF-2	hart01	maida01	maida02	Norm03	MILT-4	5E01	YAN-20	jand08	dian01	Tele01	BULL-3	perth06	perth08	Light02	perth04	perth07	GOLF-1	KOON-1	KOON-2	LAND-1
				GRIFFII	GRIFFII	GRIFFII	GRIFFII	SYS6EI	SYS6EI	SCP	SYS6EI	SYS6EI	SYS6EI	SYS6EI	SCP	SCP	SYS6EI	SYS6EI	SCP	SYS6EI	SCP	GRIFFIN	SCP	SYS6EI	SYS6EI	SYS6EI	SCP	SYS6EI	SYS6EI	SYS6EI	SYS6EI	SYS6EI	SCP	SCP	SCP	SCP
				1	1	1	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	10	13	13	13	13	13	13	13	13	13	13	13	13	13	13
				S09	23b	20a	23b	20a	20a	20a	20a	20a	20a	20a	20a	20a	20a	20a	20a	20a	20b	28	23b	23b	23a	23a	23a	23a	23a	23a	23a	20a	20a	20a	20a	20a
GRIFFIN	BNR01	1	S09		0.596	0.5	0.57	0.603	0.686	0.652	0.664	0.667	0.731	0.741	0.656	0.683	0.635	0.774	0.76	0.74	0.742	0.565	0.478	0.586	0.727	0.608	0.495	0.509	0.628	0.592	0.643	0.619	0.694	0.663	0.55	0.6	0.597
GRIFFIN	5A01	1	23b	0.596		0.5	0.527	0.552	0.62	0.583	0.645	0.667	0.654	0.741	0.721	0.65	0.656	0.721	0.76	0.74	0.765	0.613	0.522	0.604	0.636	0.608	0.608	0.515	0.527	0.571	0.596	0.6	0.649	0.662	0.612	0.624	0.532	0.655	0.597
GRIFFIN	5C03	1	20a	0.5	0.5		0.474	0.61	0.626	0.59	0.615	0.638	0.623	0.678	0.629	0.656	0.642	0.744	0.765	0.768	0.635	0.511	0.611	0.679	0.615	0.525	0.571	0.596	0.6	0.649	0.626	0.6	0.612	0.624	0.504	0.607	0.586
GRIFFIN	BNR19	1	23b	0.57	0.527	0.474		0.635	0.667	0.649	0.736	0.735	0.67	0.739	0.669	0.698	0.709	0.79	0.778	0.87	0.659	0.495	0.655	0.651	0.66	0.571	0.578	0.624	0.608	0.712	0.673	0.67	0.66	0.618	0.762	0.664
SYS6ENV 2	activ01	4	20a	0.603	0.552	0.61	0.635		0.399	0.475	0.504	0.574	0.556	0.464	0.417	0.423	0.476	0.591	0.639	0.67	0.616	0.509	0.579	0.667	0.612	0.521	0.53	0.597	0.533	0.582	0.528	0.533	0.642	0.474	0.485	0.515
SYS6ENV 2	activ02	4	20a	0.686	0.62	0.626	0.667	0.399		0.493	0.418	0.532	0.573	0.483	0.544	0.51	0.588	0.563	0.591	0.65	0.616	0.647	0.594	0.591	0.567	0.587	0.533	0.628	0.568	0.568	0.561	0.584	0.594	0.493	0.518	0.489
SCP	M53	4	20a	0.652	0.583	0.59	0.649	0.475	0.493		0.469	0.6	0.552	0.577	0.594	0.575	0.664	0.662	0.686	0.632	0.6	0.628	0.591	0.603	0.5	0.567	0.496	0.594	0.462	0.654	0.571	0.613	0.59	0.53	0.573	0.556
SYS6ENV 2	activ03	4	20a	0.664	0.645	0.615	0.736	0.504	0.418	0.469		0.433	0.539	0.519	0.482	0.564	0.521	0.516	0.558	0.642	0.62	0.638	0.565	0.675	0.467	0.571	0.594	0.635	0.514	0.616	0.593	0.64	0.649	0.516	0.529	0.559
SYS6ENV 2	Bushm01	4	20a	0.667	0.667	0.638	0.735	0.574	0.532	0.6	0.433		0.613	0.529	0.563	0.629	0.548	0.482	0.517	0.611	0.653	0.643	0.649	0.692	0.559	0.597	0.6	0.656	0.559	0.591	0.6	0.627	0.703	0.588	0.6	0.567
SYS6ENV 2	m5302	4	20a	0.731	0.654	0.623	0.67	0.556	0.573	0.552	0.539	0.613		0.476	0.561	0.615	0.597	0.616	0.691	0.651	0.687	0.706	0.669	0.683	0.607	0.578	0.633	0.696	0.593	0.672	0.617	0.556	0.64	0.636	0.617	0.645
SYS6ENV	m5303	4	20a	0.741	0.741	0.678	0.739	0.464	0.483	0.577	0.519	0.529	0.476		0.5	0.507	0.587	0.533	0.525	0.583	0.671	0.754	0.654	0.697	0.643	0.603	0.682	0.677	0.667	0.612	0.669	0.633	0.707	0.639	0.652	0.603
SCP	APBF-1	4	20a	0.656	0.721	0.629	0.669	0.417	0.544	0.594	0.482	0.563	0.561	0.5		0.311	0.409	0.594	0.594	0.669	0.632	0.617	0.655	0.768	0.63	0.606	0.623	0.708	0.603	0.657	0.579	0.651	0.69	0.511	0.522	0.62
SCP	APBF-2	4	20a	0.683	0.65	0.656	0.698	0.423	0.51	0.575	0.564	0.629	0.615	0.507	0.311		0.477	0.589	0.667	0.698	0.653	0.627	0.664	0.75	0.654	0.6	0.588	0.641	0.645	0.652	0.588	0.645	0.685	0.562	0.544	0.6
SYS6ENV 2	hart01	4	20a	0.635	0.654	0.642	0.709	0.476	0.588	0.664	0.521	0.548	0.597	0.587	0.409	0.477		0.536	0.546	0.651	0.716	0.686	0.686	0.783	0.675	0.633	0.667	0.75	0.704	0.672	0.635	0.722	0.694	0.57	0.533	0.677
SYS6ENV 2	maida01	4	20a	0.774	0.757	0.744	0.79	0.591	0.563	0.662	0.516	0.482	0.616	0.533	0.594	0.589	0.536		0.405	0.561	0.669	0.77	0.667	0.741	0.75	0.7	0.695	0.805	0.647	0.624	0.651	0.731	0.721	0.652	0.649	0.659
SYS6ENV 2	maida02	4	20a	0.76	0.74	0.765	0.778	0.639	0.591	0.686	0.558	0.517	0.691	0.525	0.594	0.667	0.546	0.405		0.535	0.723	0.796	0.692	0.707	0.717	0.695	0.707	0.815	0.654	0.678	0.676	0.712	0.682	0.641	0.603	0.65
SYS6ENV 2	Norm03	4	20b	0.742	0.742	0.768	0.87	0.67	0.65	0.632	0.642	0.611	0.651	0.583	0.669	0.698	0.651	0.561	0.535		0.61	0.758	0.618	0.633	0.623	0.674	0.688	0.762	0.629	0.604	0.692	0.691	0.7	0.655	0.596	0.611
SCP	MILT-4	10	28	0.565	0.613	0.635	0.659	0.616	0.616	0.6	0.62	0.653	0.687	0.671	0.632	0.653	0.716	0.669	0.723	0.61		0.557	0.362	0.471	0.547	0.504	0.443	0.53	0.563	0.563	0.556	0.641	0.557	0.489	0.543	0.417
GRIFFIN	5E01	13	23b	0.478	0.522	0.511	0.495	0.509	0.647	0.628	0.638	0.643	0.706	0.754	0.617	0.627	0.686	0.77	0.796	0.758	0.557		0.578	0.519	0.581	0.464	0.519	0.5	0.5	0.546	0.573	0.563	0.616	0.486	0.574	0.554
SCP	YAN-20	13	23b	0.586	0.604	0.611	0.655	0.579	0.594	0.591	0.565	0.649	0.669	0.654	0.655	0.664	0.686	0.667	0.692	0.618	0.362	0.578		0.496		0.517	0.465	0.46	0.53	0.566	0.607	0.617	0.576	0.438	0.559	0.435
SYS6ENV	jand08	13	20a	0.727	0.667	0.679	0.651	0.667	0.591	0.603	0.675	0.692	0.683	0.697	0.768	0.75	0.783	0.741	0.707	0.633	0.471	0.519	0.496		0.529	0.478	0.46	0.525	0.526	0.484	0.57	0.561	0.47	0.606	0.635	0.554
SYS6ENV	dian01	13	20a	0.608	0.608	0.615	0.66	0.612	0.567	0.5	0.467	0.559	0.607	0.643	0.63	0.654	0.675	0.75	0.717	0.623	0.547	0.581	0.516	0.529		0.464	0.447	0.496	0.46	0.552	0.525	0.604	0.544	0.452	0.529	0.496
SYS6ENV 2	Tele01	13	23a	0.495	0.515	0.525	0.571	0.521	0.587	0.567	0.571	0.597	0.578	0.603	0.606	0.6	0.633	0.7	0.695	0.674	0.504	0.464	0.517	0.478	0.464		0.426	0.439	0.437	0.47	0.436	0.495	0.453	0.397	0.496	0.445
SCP	BULL-3	13	23a	0.509	0.527	0.571	0.578	0.53	0.533	0.496	0.594	0.6	0.633	0.682	0.623	0.588	0.667	0.695	0.707	0.688	0.443	0.519	0.465	0.46	0.447	0.426		0.39	0.404	0.5	0.488	0.561	0.487	0.433	0.492	0.446
SYS6ENV	perth06	13	23a	0.628	0.529	0.596	0.624	0.597	0.628	0.594	0.635	0.656	0.696	0.677	0.708	0.641	0.75	0.805	0.815	0.762	0.53	0.5	0.546	0.525	0.496	0.439	0.39		0.491	0.517	0.487	0.528	0.596	0.563	0.61	0.557
SYS6ENV 2	perth08	13	23a	0.592	0.49	0.6	0.608	0.533	0.568	0.462	0.514	0.559	0.593	0.667	0.603	0.645	0.704	0.647	0.654	0.629	0.563	0.5	0.53	0.526	0.46	0.437	0.404	0.491		0.535	0.431	0.51	0.562	0.478	0.526	0.559
SYS6ENV 2	Light02	13	23a	0.643	0.661	0.649	0.712	0.582	0.568	0.654	0.616	0.591	0.672	0.612	0.657	0.652	0.672	0.624	0.678	0.604	0.563	0.546	0.566	0.484	0.552	0.47	0.5	0.517	0.535		0.48	0.517	0.445	0.519	0.531	0.485
SYS6ENV	perth04	13	23a	0.619	0.562	0.626	0.673	0.528	0.561	0.571	0.593	0.6	0.617	0.669	0.579	0.588	0.635	0.651	0.676	0.692	0.556	0.573	0.607	0.57	0.525	0.436	0.488	0.487	0.431	0.48		0.413	0.589	0.541	0.537	0.6
SYS6ENV	perth07	13	20a	0.694	0.612	0.6	0.67	0.533	0.584	0.613	0.64	0.627	0.556	0.633	0.651	0.645	0.722	0.731	0.712	0.691	0.641	0.563	0.617	0.561	0.604	0.495	0.561	0.528	0.51	0.517	0.413		0.619	0.548	0.597	0.593
SCP	GOLF-1	13	20a	0.663	0.624	0.612	0.66	0.642	0.594	0.59	0.649	0.703	0.64	0.707	0.69	0.685	0.694	0.721	0.682	0.7	0.557	0.616	0.576	0.47	0.544	0.453	0.487	0.596	0.562	0.445	0.589	0.619		0.492	0.539	0.388
SCP	KOON-1	13	20a	0.55	0.532	0.504	0.618	0.474	0.493	0.53	0.516	0.588	0.636	0.639	0.511	0.562	0.57	0.652	0.641	0.655	0.489	0.486	0.438	0.606	0.452	0.397	0.433	0.563	0.478	0.519	0.541	0.548	0.492		0.291	0.328
SCP	KOON-2	13	20a	0.6	0.655	0.607	0.762	0.485	0.518	0.573	0.529	0.6	0.617	0.652	0.522	0.544	0.533	0.649	0.603	0.596	0.543	0.574	0.559	0.635	0.529	0.496	0.492	0.61	0.526	0.531	0.537	0.597	0.539	0.291		0.415
SCP	LAND-1	13	20a	0.597	0.597	0.586	0.664	0.515	0.489	0.556	0.559	0.567	0.645	0.603	0.62	0.6	0.677	0.659	0.65	0.611	0.417	0.554	0.435	0.554	0.496	0.445	0.446	0.557	0.559	0.485	0.6	0.593	0.388	0.328	0.415	

APPENDIX H

Further information on *Darwinia foetida*

MWH.

BUILDING A BETTER WORLD

Client Ref: ENAUPERT04483AA

26 February 2016

Coffey Environments Australia Pty Ltd
Suite2, 53 Burswood Road
BURSWOOD, WA 6100
AUSTRALIA

Attention: **David Morley**
Senior Environmental Consultant

Muchea Bell (*Darwinia foetida*) population located adjacent to the proposed Perth-Darwin National Highway

Dear David

This letter report provides information on the population of the Endangered *Darwinia foetida* located within the Great Northern Highway drain near Muchea. The report details the known extent of *Darwinia foetida* in the Muchea/Bullsbrook region, preferred habitat and determines if the proposed Perth-Darwin National Highway (PDNH) Project will have a significant impact to the population, based on the significant impact criteria for Matters of National Environmental Significance (DoE 2013).

Background

The NorthLink WA Project is a program of road projects proposed to be undertaken by Main Roads Western Australia (Main Roads), which form vital components of a wider series of improvements to the PDNH. The NorthLink WA Project comprises two constituent parts:

- Perth–Darwin National Highway (Swan Valley Section) (herein referred to as the PDNH project) – a new 37 km highway link between the junction of Reid Highway and Tonkin Highway in Malaga and Great Northern Highway and Brand Highway in Muchea.
- Tonkin Grade Separations (TGS project) – the grade separation of the intersections of Tonkin Highway with Collier Road, Morley Drive and Benara Road, together with associated works.

TGS has received Commonwealth and State environmental approval and will not be discussed further within this letter report. The PDNH project is currently being assessed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as a Public Environment Report and under the Western Australian *Environmental Protection Act 1986* (EP Act) as a Public Environmental Review (PER) level of assessment.

Phoenix Environmental Services Pty Ltd (Phoenix) completed a Level 2 flora and vegetation survey of a portion of the Great Northern Highway for a separate project on behalf of Main Roads. The area surveyed by Phoenix, incorporated a portion of the PDNH Project north of the current Brand Highway intersection.

Phoenix identified seven individuals of the EPBC Act listed and State listed threatened *Darwinia foetida* or Muchea Bell within a portion of the PDNH Project. The location of the seven individuals is from a small road drain on the northern end of a rest stop approximately 600 m to the north of the Brand Highway intersection. *Darwinia foetida* has not previously been recorded from within the PDNH Project (Coffey 2015).

Based on the current design of the PDNH Project and the location of the seven individuals, it is anticipated that there will be no direct impacts to the population, however the indirect impacts need to be determined based on current design and the known local and regional extent of the threatened flora.

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Coffey Environments Australia Pty Ltd (Coffey) commissioned MWH Australia Pty Ltd (MWH) to undertake a site visit to accurately identify the location of the seven individuals with respect to the current PDNH Project design and search for any additional individuals in close proximity to the seven plants. In addition, Coffey has requested MWH to prepare a short letter report (this report) detailing the known extent and the habitat that could be considered critical to the long-term survival of the threatened taxon at the location near the PDNH Project. The PDNH Project in relation to the population of *Darwinia foetida* has also been assessed against the significant impact criteria for Matters of National Environmental Significance (DoE 2013).

Darwinia foetida

Darwinia foetida is listed as a Schedule 2 (Endangered) taxon under the Western Australian *Wildlife Conservation Act 1950* (WC Act). Schedule 2 flora are considered to be threatened species facing a high risk of extinction in the wild. In addition, *Darwinia foetida* is listed as Critically Endangered under the EPBC Act, having met the category for Criterion 2, which is, having a very restricted geographic distribution which is precarious for the survival of the species.

Darwinia foetida is an erect, or spreading, shrub to 0.7 m high, often using other shrubs for support (**Plate 1**) (Keighery 2009). Young branches are slender, green-brown with prominent, decurrent leaf bases, becoming grey and woody (Keighery 2009). *Darwinia foetida* produces green-brown flowers in late spring, from October to November (Keighery 2009, WAH 2016). The habitat consists of grey-black sandy rises in winter-damp to wet clay flats under *Regelia inops– Kunzea recurva* tall shrubland over *Hypocalymma angustifolium* low shrubland or low *Melaleuca* shrubland (Keighery 2009).

Plate 1: *Darwinia foetida* located within the Great Northern Highway road culvert/drain

Methods and Approach

The field survey was undertaken on 23 February 2016, and involved traversing the known location of the seven individuals to accurately record, photograph and note their location with relation to the current PDNH Project design. The Great Northern Highway road reserve was traversed to the north (approximately 400 m) of the rest stop on both sides of the road, while an adjacent property with vegetation and habitat that may support the species was also searched. The field survey was undertaken by Clinton van den Bergh, a senior ecologist with MWH. All specimens collected from the field were taken under a flora collecting licence (SL011498), pursuant to the WC Act Section 23C and a Declared Rare Flora permit (8-1516), pursuant to the WC Act Section 23F.

To support the information recorded from the field, a literature review was undertaken to identify the known habitat requirements and the local and regional extent of all known individuals. To support the literature

review, advice was sought from the Department of Parks and Wildlife (DPaW) on known habitat. The documents and online resources reviewed during the literature review included:

- Keighery (2009), Six new and rare species of *Darwinia* (Myrtaceae) in Western Australia;
- WAH (2016), FloraBase; the Western Australian Flora;
- DPaW (2015); Threatened and Priority flora database custom search results;
- DoE (2016), *Darwinia foetida* species profile and threats database; and
- Phoenix (2015), Flora and fauna assessment for Muchea North and Chittering study area.

Discussion

Known records

Prior to the work completed by Phoenix (2015) along the Great Northern Highway, only four populations were known to exist in the Muchea/Bullsbrook area. One population is known to occur within a Nature Reserve and adjacent road reserve, while another is from a water reserve (DoE 2016). The remaining two populations are located on private property (DoE 2016, WAH 2016). In 2009, the area of occupancy was estimated to be 0.03 km^2 with an estimated population size of 1,300 mature individuals, with an additional 185 seedlings recorded from one population (DoE 2016). The work undertaken in 2009 consisted of only the first three populations (Populations 1a and b, 2 and 3a and b), as the fourth population had not yet been confirmed.

A population census for *Darwinia foetida* was undertaken in 2006 at three of the locations (i.e. Populations 1a and b, 2 and 3a and b, **Table 1**) to further define the extent and health of the threatened taxon. In 2007, an additional population was recorded from private property in Bullsbrook, which was later confirmed by DPaW in 2010, bringing the total known extent to four populations.

The additional records made by Phoenix, one located adjacent to the PDNH Project and the other a significant distance away (greater than 1 km) from the PDNH Project, increases the known populations to six. However, both Phoenix populations are located within the Great Northern Highway road reserve and are currently impacted by introduced grasses and other weeds.

Based on the information available (DPaW 2015, Phoenix 2015) and review of specimen information (WAH 2016), there is currently in excess of 1,890 mature individuals with an additional 469 seedlings (**Table 1**). As discussed above, there has not been a population census for *Darwinia foetida* since 2006, so actual mature individuals and seedling numbers may differ substantially.

Table 1: **Darwinia foetida *known records***

Source	Population	Vesting/purpose	Mature	Seedlings
DPaW (2015)	1a	Nature Reserve	250	0
	1b	Road verge	0	469
	2	Unallocated crown land	500	0
	3a	Private (Bush Forever)	1,000	0
	3b	Private (Bush Forever)	100	0
	4	Private	25	0
Phoenix (2015)	5	Road verge	7	0
	6	Road verge	10	0
Total			1,892	469

Note: Population 5 is located adjacent to the PDNH Project and the subject of this letter report.
Note: population numbering for the Phoenix records have been created by the author and may not match actual population numbering held by DPaW

Known Habitat

Keighery (2009) noted that *Darwinia foetida* occurs on grey-black sandy rises in winter-damp to wet clay flats under *Regelia inops– Kunzea recurva* tall shrubland over *Hypocalymma angustifolium* low shrubland or low

Melaleuca shrubland. A review of the Western Australian Herbarium (WAH) specimen database indicates that plants are found alongside a sumpland wetland (WAH 2016).

The four known records have all been recorded from the Muchea area, approximately 70 km north of Perth (DoE 2016, Keighery 2009). The estimated area of occupancy based on the information known in 2009 was 0.03 km^2 (DoE 2016)

All four previously known populations have been recorded from either palusplain or sumpland wetlands, as mapped by the *Geomorphic Wetlands Swan Coastal Plain dataset*. Populations 1, 3 and 4 are from palusplain wetland, while Population 2 is from (or adjacent to) a sumpland (**Table 2**).

As a result of the wetlands, the supporting vegetation consists of wetland species with the presence of transitional species (i.e. *Corymbia calophylla*) where the habitat allows (**Table 2**).

Table 2: Habitat details for the four known populations

Population	Wetland type	Wetland category	Soil	Landform	Vegetation
1a 1b	Palusplain	Multiple Use	Grey sand, peaty sandy clay	Low plain	*Regelia inops, Melaleuca incana, Kunzea recurva, Hypocalymma angustifolia, Xanthorrhoea preissii, Allocasuarina humilis, Hibbertia hypericoides, Patersonia occidentalis, Bossiaea eriocarpa, Banksia dallanneyi*
2	Sumpland	Conservation	Grey Sand	Wetland	*Pericalymma ellipticum, Astartea* aff. *fascicularis, Melaleuca rhaphiophylla, Banksia littoralis*
3a 3b	Palusplain	Conservation	Brown loamy sand, grey sand	Wetland	*Melaleuca* sp., *Banksia menziesii, Viminaria juncea, Xanthorrhoea* sp., *Nuytsia floribunda*
4	Palusplain	Multiple Use	Dark grey sand	Wetland	*Melaleuca rhaphiophylla, Hypocalymma angustifolia, Acacia pulchella* shrubland beneath marri, with invasion by blackberry, brazilian peppertrees, weedy grasses.

Site records

Phoenix (2015) identified seven individuals from Population 5 within the road drain located adjacent to the PDNH Project. Following the site visit and further refinement of the population, it is considered that approximately 16 mature individuals and one seedling occur within this small area of occupancy. It was noted that several individuals were hidden by large clumps of **Eragrostis curvula* and **Watsonia meriana*. It was also difficult to discern individuals as the majority of them were growing as a large clump. As a result there may be additional individuals not accounted for which were obscured by weeds at the time of the site visit. This may also explain why Phoenix only recorded seven individuals at the time of their survey.

Although the timing of the February site visit is not considered to be optimal and outside of the known flowering time for *Darwinia foetida*, the plants located during the site visit match with the Phoenix GPS coordinates. A specimen collected at the time of the site visit included an old flower, and based on the description of the taxon from Keighery (2009) the population is considered to match *Darwinia foetida* with a high confidence.

The 16 individuals expands on the previous seven individuals recorded by Phoenix (2015) (**Table 3**), however the area of occupancy within the drain does not increase as all individuals were recorded within the bounds of the Phoenix GPS coordinates.

A stretch of 400 m to the north of the rest stop within the road drain on either side of the Great Northern Highway was traversed, with no further individuals recorded. The rest stop was also traversed with no individuals recorded.

The additional population (nominally Population 6) identified by Phoenix (2015) (located to the south along Great Northern Highway) was also searched on foot. Phoenix (2015) had previously recorded ten individuals, however following the site visit, the total count is approximately 20 mature individuals with three dead adults and no seedlings (**Table 3**). The increase in the number of individuals at the nominal Populations 5 and 6 increases the total known extent from 1,892 mature individuals and 469 seedlings to 1,911 mature individuals and 470 seedlings.

Table 3: Population count for Great Northern Highway locations

Population	Mature		Seedlings		Dead	
	Phoenix	MWH	Phoenix	MWH	Phoenix	MWH
5 (Northern)	7	16	0	1	0	0
6 (Southern)	10	20	0	0	0	3

Site description and habitat

The individuals of *Darwinia foetida* within Population 5 were recorded within the Great Northern Highway road drain (**Attachment A** and **Attachment B**). The base of the road drain was dominated by **Watsonia meriana*, while the *Darwinia foetida* individuals were located on the slope of the drain nearest the highway and the rest stop. The slopes, in addition to *Darwinia foetida*, consisted of **Eragrostis curvula* clumps and scattered **Briza maxima* (**Plate 2**). The surrounding vegetation had isolated clumps of *Regelia ciliata* with scattered *Callitris pyramidalis* and *Hypocalymma angustifolium* (**Plate 2**). A cleared paddock was located on the western side of the road drain.

The vegetation recorded within the road drain had similarities to habitat previously recorded to occur in association with *Darwinia foetida* (Keighery 2009), as described above.

Plate 2: *Darwinia foetida* localised habitat

Known threats and potential PDNH Project threats

The major threats to Muchea Bell include grazing by rabbits, weed invasion, changes in hydrology, inappropriate fire regimes, land clearing and dieback caused by *Phytophthora cinnamomi* (DoE 2016).

Population 5 recorded by Phoenix (2015) within the road verge is currently being impacted by invasive weeds (**Plate 2**). The supporting vegetation was dominated by **Watsonia meriana* and **Eragrostis curvula*. In addition, the plants are located in close proximity to other potential threats, i.e. within a road drain between the Great Northern Highway and cleared paddock, while a rest stop is located along the southern boundary of the plants. Additional threats, though not noted in the field, would include grazing by rabbits and potential changes to the local hydrology. The natural hydrology would have changed significantly over time through land clearing and the creation of drains along the Great Northern Highway.

Habitat that may be considered critical

An interim recovery plan has not been developed for *Darwinia foetida*, resulting in no formal description of critical habitat for the Endangered species. However, it has been assumed that critical habitat for *Darwinia foetida* would include the area of occupancy for all known populations, areas of similar habitat surrounding known populations and vegetation that links populations. In addition, as the taxon occurs within wetland habitats, the local catchment and hydrology would also be considered critical for the long-term survival of a population.

Based on the information presented above, habitat that could be deemed as critical for the population would include an area of approximately 0.12 ha of roadside vegetation located adjacent to the Great Northern Highway. The critical habitat extends from the end of the rest stop, where the 16 individuals are located, north approximately 80 m to a major drain that passes under the Great Northern Highway.

The main reasons for the determination of the critical habitat are:

- The supporting vegetation, including *Regelia ciliata* and *Hypocalymma angustifolium*, are present within the area;
- The habitat includes a sumpland (in this case a man-made drain that collects water) with upland slopes, as described by WAH (2016);
- The hydrology across the critical habitat is similar as it is all located within the same road drain. On the northern boundary of the critical habitat, the hydrology changes from a sumpland to a creek/channel that funnels all surface and underground water west along the creek/channel towards Ellen Brook;
- North of the critical habitat the soil changes to more clay based, while the vegetation changes significantly, with native sedges being the dominant understorey, with *Melaleuca concreta* in the upper stratum; and
- The population is fragmented from the remaining populations with major highways, cleared paddocks and infrastructure present.

Significant Impact Criteria

The proposed action (i.e. construction of the PDNH Project adjacent to the population) is not considered to have a significant impact (**Attachment C**) to the Commonwealth (Critically Endangered) and State (Endangered) listed *Darwinia foetida*, according to the description of the PDNH Project and the Significant Impact Criteria (DoE 2013).

The habitat supporting the *Darwinia foetida* individuals is located within the road drain which is a highly degraded strip of vegetation dominated by invasive weeds. The habitat is highly altered and disturbed through ongoing impacts associated with weeds, altered hydrology and the potential altered changes to the fire regime resulting from an increase in fuel load from the weeds and the refuse and waste located along the verge from the users of the Highway.

It is assumed that the construction of the PDNH Project will be undertaken in accordance with Environmental Management Plans that will identify management measures to reduce the likelihood of spreading weeds, diseases (*Phytophthora* Dieback) and igniting fires, while also ensuring there is no deviation away from the approved clearing boundary. Additionally, it is understood that in line with current designs for the project, the

current site hydrology will be maintained with the retention of the road drains. As a result, the local catchment and hydrology will, at the least, be maintained ensuring the local conditions do not alter significantly.

Provided that indirect impacts (i.e. introduction and/or spread of weeds, hydrological changes, diseases) are minimised, the population may persist for the medium to long-term future, assuming routine road reserve maintenance takes into account the significant environmental values.

Conclusion

The population of *Darwinia foetida* recorded by Phoenix (2015) and further refined in this document (Population 5, located to the north of the rest stop on Great Northern Highway in Muchea) is considered to be a new record of the threatened flora on the Swan Coastal Plain. Previous knowledge on the threatened taxon indicated that only four populations were known to occur, totalling approximately 1,875 mature individuals and 469 seedlings. The new population, along with an additional population recorded further south by Phoenix (2015) within the road verge of the Great Northern Highway (located approximately 500 m north of the Wandena Road turnoff) increases the known extent to 1,911 mature individuals and 470 seedlings.

Based on the current design, the PDNH Project will not directly impact the new population located within the road verge, however indirect impacts may affect the population and habitat if not appropriately managed. The indirect impacts may include an increase in and/or introduction of weeds, diseases, altered fire regime and altered hydrology. The population is currently under threat from an altered hydrology and a high density of weeds, thus potentially increasing the likelihood of fire.

The PDNH Project is unlikely to have a significant impact to the population, based on the significant impact guidelines (DoE 2013), if appropriate management measures are implemented. It is assumed that the construction of the PDNH Project will occur in accordance with an appropriate Environmental Management Plan.

If you wish to discuss any aspect of this document, please do not hesitate to contact the undersigned.

Yours sincerely

Clinton van den Bergh
Senior Ecologist
MWH Australia Pty Ltd

Attachment A: Population, habitat and site photos
Attachment B: Field Sketch of Darwinia foetida individuals from Population 5
Attachment C: Significant impact criteria for *Darwinia foetida*

References

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Attachment A

Population, habitat and site photos

Darwinia foetida habit.

Darwinia foetida habit and the location to the road edge

Darwinia foetida individual being smothered by **Eragrostis curvula* (the individual is difficult to see but is located within the centre of the image)

Note the dominance of weeds (**Eragrostis curvula* and **Watsonia meriana*)

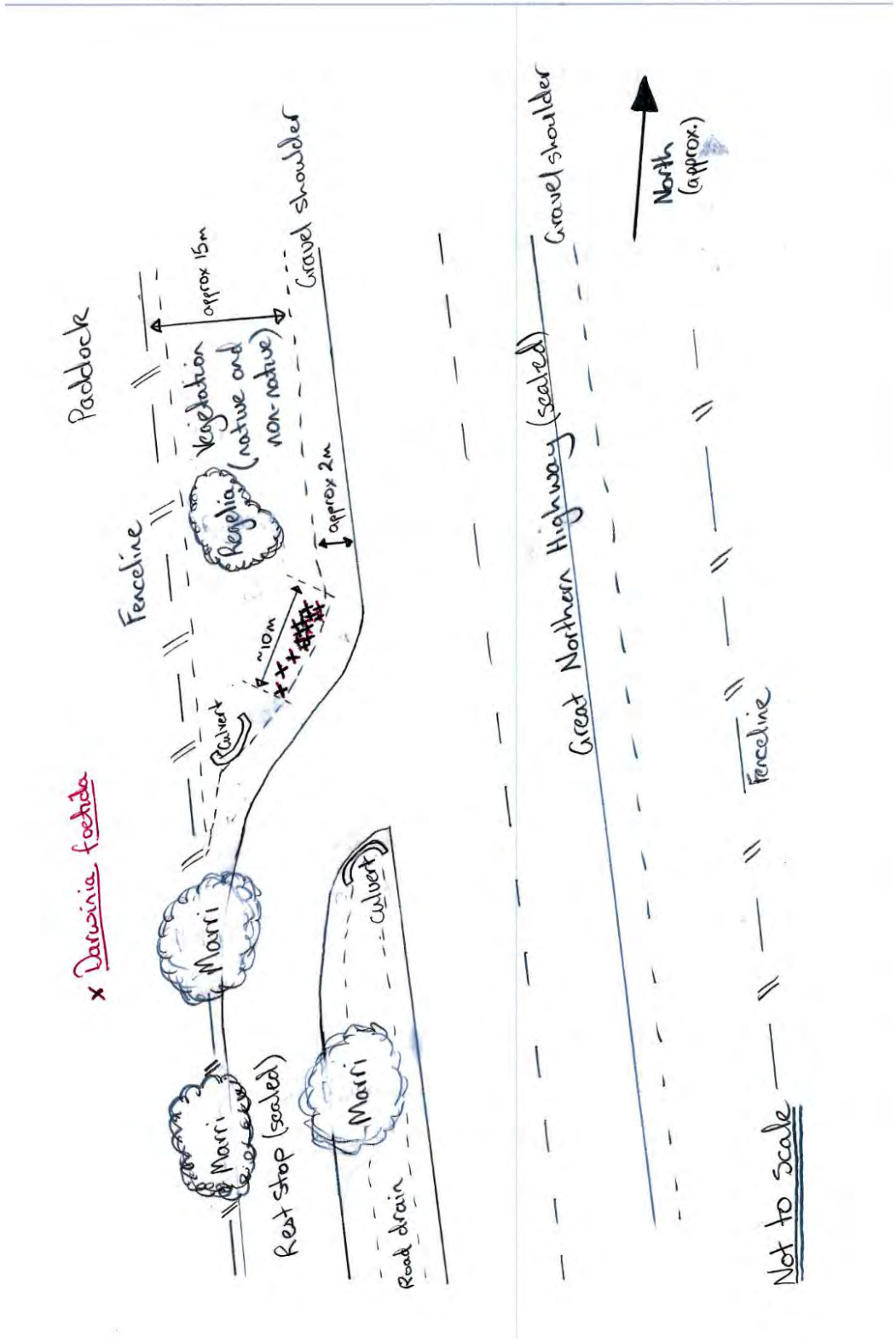
Darwinia foetida showing domed shape

Close-up of old flower on *Darwinia foetida*

Annotated photo showing location of *Darwinia foetida* individuals in relation to the gravel shoulder and sealed rest stop

Attachment B

Field Sketch of* Darwinia foetida *individuals from Population 5



Attachment C

***Significant Impact Criteria for Population 5 of* Darwinia foetida**

An action is likely to have a significant impact on a critically endangered species if there is a real chance or possibility that it will	Significant Impact?	Comment
Lead to a long-term decrease in the size of a population	No	The PDNH Project will not lead to a long-term decrease in the size of the population. The individuals are currently persisting in a highly altered environment with significant threats associated with weeds and hydrology (resulting from the current Great Northern Highway). The PDNH Project may provide a positive influence to the population with the implementation of appropriate management measures during construction, including the maintenance and improvement of the current hydrology. The population is fragmented and under significant, ongoing threats, if left unchecked, the population may decrease naturally in the short to medium-term future.
Reduce the area of occupancy of the species	No	The current estimated area of occupancy is 0.03 km^2 (DoE 2016) or 3 ha. With the addition of the two new population identified by Phoenix (2015) and further refined by this document, the area of occupancy is not considered to increase significantly (approximately 0.03 ha increase) as the new populations are small and restricted. The PDNH Project will avoid directly impacting the population, as such the area of occupancy will not be reduced. The PDNH Project has been designed to avoid any direct impacts, with all disturbances to be located within the current road alignment and rest stop. The potential indirect impacts from the PDNH Project (i.e. weeds, changed hydrology, introduced diseases) are considered to already be present and the construction may reduce the severity of the indirect impacts through appropriate construction management.

An action is likely to have a significant impact on a critically endangered species if there is a real chance or possibility that it will	Significant Impact?	Comment
Fragment an existing population into two or more populations	No	The PDNH Project will not fragment the population located within the Great Northern Highway road drain. The population itself is highly fragmented from all other known populations. The nearest population is located over 2 km to the south-west.
Adversely affect habitat critical to the survival of a species	No	Habitat that may be considered critical for the species is estimated to be 0.12 ha in size and extends approximately 80 m north of the rest stop (on the western side of the Great Northern Highway) within the road drain. The current project design will not directly impact the critical habitat. The habitat that may be considered critical is already under threat through introduced weeds, hydrology changes, changes to the fire regime (as a result of the significant fuel load present from the introduced grasses) and the degradation of the habitat through waste and refuse from the highway. Management measures implemented during construction may reduce the severity of these ongoing threats and provide a more stable habitat for long-term survival.
Disrupt the breeding cycle of a population	No	The breeding cycle of *Darwinia foetida* is not currently known, however, the majority of *Darwinia* species are pollinated by insects and possibly birds for some species. Insects will remain present during and after the construction of the PDNH Project. It is not known whether a unique insect (e.g. native wasp) is required for pollination. The PDNH Project will not disrupt the breeding cycle of the population, as no direct impacts will occur. Provided that indirect impacts are minimised, the habitat quality will remain stable or may improve following implementation of management measures related to weeds, diseases and hydrology.

An action is likely to have a significant impact on a critically endangered species if there is a real chance or possibility that it will	Significant Impact?	Comment
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	No	Based on the current design, the PDNH Project will not directly impact on the availability of habitat for *Darwinia foetida* within the road drain. The PDNH Project may indirectly modify or decrease the availability of habitat through alterations to the hydrology. However based on the PDNH Project design, impacts to hydrology that would affect the habitat for *Darwinia foetida* are considered to be minimal. The current quality of the habitat would be considered to be low due to the dense coverage of introduced weeds, including **Eragrostis curvula* and **Watsonia meriana* (**Attachment A**). Through appropriate weed and hygiene management measures the likelihood of introducing new species is considered to be low. The availability and quality of habitat is expected to remain the same following implementation of management measures to reduce indirect impacts.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat	No	The location of the population within the road verge is already heavily impacted by invasive weeds, including **Watsonia meriana, *Eragrostis curvula, *Avena barbata* and **Briza maxima*. The proposed action would be undertaken in accordance with specific weed hygiene management measures to reduce the likelihood of introduction and spread of invasive weeds. Additionally, the population is located adjacent to a rest stop and a major highway, which would have a large number of current potential vectors (i.e. trucks and cars). The implementation of appropriate weed management measures could reduce this existing threat.

An action is likely to have a significant impact on a critically endangered species if there is a real chance or possibility that it will	Significant Impact?	Comment
Introduced disease that may cause the species to decline	No	The road verge has been subjected to a dieback assessment in 2014 (Terratree 2014) and was mapped as 'Excluded'. As such, the current presence of introduced diseases is unknown. However, any disturbances associated with the PDNH Project should be undertaken in accordance with specific management measures to reduce the spread and/or introduction of *Phytophthora* Dieback and other introduced diseases.
Interfere with the recovery of the species	No	The potential direct and indirect impacts to the population are not considered to interfere with the recovery of the species. Critical habitat for the species is located outside of the project footprint. The population is located within a highly disturbed and altered road drain. The majority of the known populations are within larger, less disturbed blocks of native vegetation, which would form the main populations for recovery actions.