Appendix A Great Eastern Highway Bypass Interchanges (Roe Highway and Abernethy Road) Biological Survey

Biota Environmental Sciences

Great Eastern Highway Bypass Interchanges (Roe Highway and Abernethy Road) Biological Survey

Prepared for Main Roads Western Australia

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Biota Environmental Sciences

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Great Eastern Highway Bypass Biological Survey

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1.0 Summary

1.1 Overview of the Project

Main Roads Western Australia proposes to undertake road construction works associated with the intersection of Roe Highway and the Great Eastern Highway Bypass Interchanges within the Cities of Swan and Kalamunda. Biota Environmental Sciences was commissioned to undertake a biological survey of the proposed works area (totalling 360.5 ha), as documented in this report. The survey area was divided into two parts, defined by Main Roads as the 'Reconnaissance (Level 1) survey area' and the 'Detailed (Level 2) survey area', reflecting the type of survey specified.

1.2 Vegetation and Flora

A desktop review and 12-day field survey were conducted by four botanists over a series of visits between early October 2019 and early May 2020. Additional sampling and resampling of selected quadrats was conducted over a 4-day field survey in early November 2020. The detailed vegetation survey included quadrat sampling, mapping of vegetation types and vegetation condition (based on sampling within the survey area, and extrapolation out to a 500 m buffer 'contextual area'). Targeted searches for significant flora were also completed, during which significant weeds (Declared Pests and Weeds of National Significance) were also recorded.

Almost three-quarters of the survey area (276.0 ha, or 76.6%) comprised cleared, modified or otherwise degraded areas. Thirteen intact vegetation types were identified for the remainder of the survey area, some of which were too small to contain replicate quadrats.

A total of six patches of the Commonwealth listed 'Banksia Woodlands of the Swan Coastal Plain ecological community' Threatened Ecological Community (TEC) were mapped as occurring either wholly or partially within the survey area. The extent within the survey area comprised 27.44 ha, or 22.1% of the total extent of this TEC mapped within the broader contextual area. These patches of TEC also correspond to the State-listed Priority Ecological Community of the same name. In addition, one patch of the Commonwealth listed 'Shrublands and Woodlands of the eastern Swan Coastal Plain' TEC, comprising 1.65 ha of the survey area, was mapped. This community also corresponds to a State-listed TEC.

A total of 287 native vascular flora taxa from 142 genera and 53 families were recorded from the survey area.

One species recorded within the survey area, *Conospermum undulatum*, is listed as Vulnerable under the EPBC Act and Threatened under the BC Act, and three individuals were recorded from three locations.

Four State-listed Priority species from natural populations were also recorded:

- *Johnsonia pubescens* subsp. *cygnorum* (Priority 2): 10 individuals recorded from two opportunistic locations and four quadrats within the survey area.
- *Isopogon autumnalis* (Priority 3): 128 individuals recorded from five opportunistic locations and two quadrats during the survey.
- *Hypolaena robusta* (Priority 4): one individual was recorded opportunistically.
- *Verticordia lindleyi* subsp. *lindleyi* (Priority 4): one individual was recorded opportunistically.

A total of 96 introduced species were recorded. These included several significant weed species, such as **Asparagus asparagoides* (Bridal Creeper), **Echium plantagineum* (Paterson's Curse), **Rubus ulmifolius* (Blackberry), **Solanum linnaeanum* (Apple of Sodom) and **Zantedeschia aethiopica* (Arum Lily).

1.3 Fauna

The survey confirmed three significant fauna species from the survey area, all from the Level 2 survey area:

- Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*) – Endangered under both the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the WA *Biodiversity Conservation Act 2016* (BC Act);
- Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*) – Vulnerable under both the EPBC Act and BC Act; and
- Quenda (*Isoodon fusciventer*) – listed at State level as Priority 4.

A total of 1,641 potential black cockatoo breeding habitat trees were recorded, comprising Flooded Gum, Marri, Jarrah, dead stags and Tuart. A total of 19 habitat trees were recorded in the Reconnaissance (Level 1) survey area, none of which contained hollows suitable for breeding. The Detailed (Level 2) survey area contained 1,622 habitat trees, of which four contained hollows potentially suitable for black cockatoo breeding. One of these hollows displayed chew marks around the entrance; a possible sign of recent or current use.

The Level 1 survey area contains 9.1 ha of potential black cockatoo foraging habitat consisting entirely of scattered trees. No evidence of foraging was identified during the field survey.

The Level 2 survey area contains multiple habitats suitable for black cockatoo foraging, including Banksia woodland with scattered Eucalyptus/Marri, Eucalyptus/Marri in road reserve, Scattered Eucalyptus/Marri in cleared areas, and Fabaceous heathland, totalling 88.4 ha. Black cockatoo foraging was recorded from each of these habitat types.

The Level 2 survey area also contains a combined 50.7 ha of Flooded gum over grasslands, Planted Eucalyptus/Marri, and Wetlands/River habitat. These habitats may occasionally be used for foraging, however, no evidence was recorded in this survey.

No evidence of roosting was recorded in either the Level 1 or Level 2 survey areas.

2.0 Introduction

2.1 Project Purpose, Background and Location

Main Roads Western Australia (Main Roads) proposes to undertake various upgrades and road works within the Cities of Swan and Kalamunda, approximately 14 km east of Perth (Figure 2.1). These works include:

- Grade separation at the intersection of Roe Highway and Great Eastern Highway Bypass (GEHB) Interchange (GEHBI) – Roe Highway SLK 37.54;
- Upgrade of GEHB (between Roe Highway and Abernethy Road);
- Upgrade of Roe Highway (between GEHB and Clayton Street) including a duplication of the bridge over the Helena River;
- A Principal Shared Path (PSP) connection south to Kalamunda Road and 300 m north of Clayton Street;
- Stirling Crescent will be changed to terminate in a cul-de-sac;
- Construction of a bridge at Lloyd Street over the Helena River; and
- Upgrade of Abernethy Road (grade separated at GEHB – SLK 12.84).

The information supplied in this biological survey report may be used to inform the environmental assessment and approvals process for the above works, hereafter referred to as 'the project', including the preparation of a Clearing Impact Assessment (CIA) and Vegetation Management Plan (VMP), and may be used in State or Commonwealth referral documentation.

2.2 Scope and Objectives of this Study

Main Roads commissioned Biota Environmental Sciences (Biota) to undertake a biological assessment of the project area, which was is divided into two survey areas, as per the consultant brief provided by Main Roads. These two areas were defined as the 'Reconnaissance (or Level 1) survey area' and the 'Detailed (or Level 2) survey area', within the overall 360.5 ha 'survey area'.

The survey area comprised corridors centred on Roe Highway, GEHB, Abernethy Road and Stirling Crescent (Figure 2.1). Vegetation mapping was extended over a 'contextual area' comprising a buffer of 500 m around the survey area. A desktop review was completed for a study area comprising a buffer of 5 km around the survey area. See Table 2.1 below for a breakdown of the components of the survey area and the type of survey effort applied.

Table 2.1 Breakdown of survey areas and survey effort completed within each area.

Area	Flora	Fauna
Level 1 Survey Area (169.9 ha)	• Reconnaissance flora survey. • Targeted significant flora searches. • Vegetation mapping.	• Level 1 Fauna Survey. • Targeted Cockatoo assessment.
Level 2 Survey Area (190.6 ha)	• Detailed single-phase flora survey. • Targeted significant flora searches. • Vegetation mapping. • Threatened Ecological Community (TEC) assessment and TEC/Priority Ecological Community (PEC) mapping. • Selected resampling	• Level 1 Fauna Survey. • Targeted Cockatoo assessment.
Contextual Area (1,586.9 ha)	• Extrapolated vegetation mapping. • Extrapolated TEC/PEC mapping.	N/A
Study Area (5 km buffer)	• Desktop study.	• Desktop study

The approach and methodology of the biological assessment was undertaken in accordance with all relevant legislation and Commonwealth and State policy, including the following:

- *Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment* (EPA 2016a);
- *Environmental Factor Guideline: Flora and Vegetation* (EPA 2016b);
- *Approved Conservation Advice for the Banksia Woodlands of the Swan Coastal Plain ecological community* (DotEE 2016);
- *Technical Guidance – Terrestrial Fauna Surveys* (EPA 2016c);
- *Technical Guidance – Sampling Methods for Terrestrial Vertebrate Fauna* (EPA 2016d);
- *EPBC Act referral guidelines for three Threatened black cockatoo species: Carnaby's cockatoo (Endangered)* Calyptorhynchus latirostris*, Baudin's cockatoo (Vulnerable)* Calyptorhynchus baudinii*, Forest red-tailed black cockatoo (Vulnerable)* Calyptorhynchus banksii naso (DSEWPaC 2012a); and
- Main Roads Environment and Heritage Data Standards.

This report documents the methods, results and key findings of the biological surveys conducted in 2019 and 2020 in the survey area. The specific objectives of this study were as follows:

1. Undertake a desktop assessment, including database and literature searches, to consolidate all available existing data relevant to the study area.
2. Undertake a field survey to:
    - describe, photograph and map the dominant vegetation units in the survey area, with extrapolation of the vegetation mapping over a contextual area of 500 m to either side;
    - assess and map vegetation condition through the survey area and contextual area;
    - identify any vegetation units of significance in the survey area, including assessment of potential TECs against relevant Commonwealth conservation advice, and assessment of potential PECs against information published by the State Department of Biodiversity, Conservation and Attractions (DBCA);
    - compile a list of vascular flora species for the survey area;
    - record and photograph flora of significance, including Threatened and Priority species and any other species of interest;
    - record any significant introduced flora species (weeds) occurring in the survey area;
    - undertake selective, low intensity sampling for species of significance;
    - map fauna habitats for the survey area based on the vegetation mapping, with a focus on identifying any that are suitable for significant fauna; and
    - undertake selective, low intensity sampling for fauna species of significance.
3. Collate, present and discuss all data from the 2019 and 2020 surveys, with a particular focus on identifying communities or species of significance.
4. Supply all relevant data to Main Roads in current data standards, submit flora specimens as required to the WA Herbarium, and submit report forms for all Threatened and Priority flora and fauna and any TECs or PECs to the DBCA.

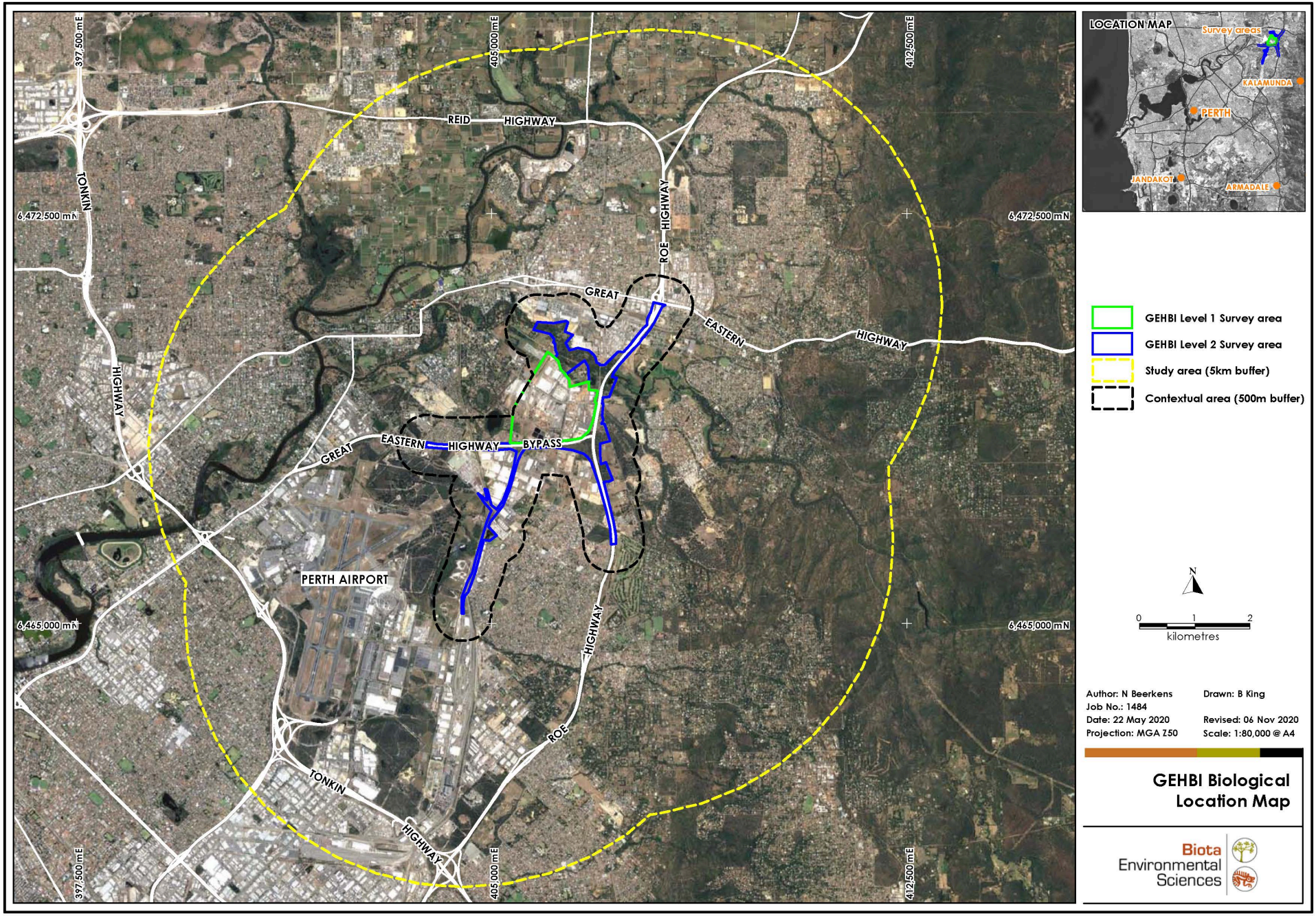

Figure 2.1: Location of the survey areas, study area and contextual area.

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3.0 Methodology

3.1 Definitions of Significant Communities and Species

3.1.1 Communities

In Western Australia, an ecological community that is presumed to be totally destroyed or at risk of becoming totally destroyed may be listed as a TEC by the Minister for the Environment under the BC Act. Communities may also be listed as TECs at the Commonwealth level under the Commonwealth EPBC Act.

Communities with insufficient information available to be considered a TEC, or which are rare but not currently threatened, are placed on the State Priority list and referred to as PECs. Further information regarding the framework for significance ranking of communities in WA is presented in Appendix 1.

3.1.2 Species

Native flora and fauna species that are rare, threatened with extinction, or have high conservation value, are specially protected by law under either or both of the WA BC Act and the Commonwealth EPBC Act. The WA DBCA also maintains a list of Priority species that are considered to be of significance, but which have not been assigned statutory protection under the BC Act.

Appendix 1 details the categories of significance recognised under the above frameworks and Table 3.1 outlines the codes used throughout this report for each category.

Table 3.1 Explanation of codes used to identify categories of significance for species.

Category	Listing		
	EPBC Act	BC Act	DBCA
Critically Endangered	CR	CR	-
Endangered	EN	EN	-
Vulnerable	VU	VU	-
Extinct	-	EX	-
Extinct in the Wild	-	EW	-
Conservation Dependent	CD	-	-
Near Threatened	NT	-	-
Migratory Species	MI	MI	-
Marine Species	M	-	-
Conservation Dependent Fauna	-	CD	-
Other Specially Protected Fauna	-	OS	-
Priority 1	-	-	P1
Priority 2	-	-	P2
Priority 3	-	-	P3
Priority 4	-	-	P4

3.1.3 Environmentally Sensitive Areas

Environmentally sensitive areas (ESAs) are declared by the WA Minister for the Environment under section 51B of the *Environmental Protection Act 1986* (EP Act). ESAs that could potentially be of relevance to the current study would comprise:

- A Bush Forever site;
- a defined wetland and the area within 50 metres of the wetland;
- the area covered by vegetation within 50 metres of Threatened flora; or
- the area covered by a TEC.

3.2 Desktop Review

A desktop review was undertaken to identify species and communities of significance that had already been recorded within the survey area or that were known from the study area (i.e. within 5 km of the survey area).

The review considered results of various database searches, previous biological surveys in the locality, and other relevant regional information, as discussed in the following sections.

3.2.1 Database Searches

The following databases were searched to assist in the determination of the biological features of significance that were potentially relevant to the survey area:

- NatureMap (https://naturemap.dpaw.wa.gov.au) is a joint project of the DBCA and the WA Museum (WAM). This database represents the most comprehensive source of information on the distribution of Western Australia's flora and fauna, comprising records from the WA Threatened and Priority Flora and Fauna Databases, the WA Herbarium Specimen Database and the Fauna Survey Returns Database (all managed by the DBCA), the WA Museum Specimen Database, and the BirdLife Australia Atlas of Australian Birds. NatureMap was searched primarily to identify records of significant fauna and flora known from the study area, using a 5 km buffer around a central coordinate for the study area (31°55'03"S, 116°00'52"E).
- The BirdLife Australia Birdata database (http://www.birdata.birdlife.org.au) was also searched separately for any additional records of Carnaby's Black-Cockatoos, as this data is uploaded to NatureMap intermittently.
- Specific searches of the DBCA Threatened and Priority Flora and Fauna Database were conducted using a buffer of 10 km around the survey area, and were supplied by Main Roads. Records within a 5 km radius were included in the desktop review.
- The DBCA's database of TECs, PECs and ESAs was also searched to identify significant communities known to occur in the study area.
- The Commonwealth Department of Agriculture, Water and the Environment's (DAWE) Protected Matters Search Tool was searched to identify significant communities and species listed under the PBC Act) that may occur in the locality. The EPBC Act Protected Matters database search used a 5 km buffer around a central coordinate for the survey area (31°55'03"S, 116°00'52"E).
- The DBCA's Nature Map database was searched for fauna records using a 5 km buffer around a central coordinate for the study area (31°55'03"S, 116°00'52"E).
- The Atlas of Living Australia (ALA) database was searched for fauna records using a 5 km buffer around a central coordinate for the study area (31°55'03"S, 116°00'52"E).
- Main Roads and Biota's internal databases of significant species from previous studies in the vicinity (within 5 km) were also searched.

Results from the various database searches are summarised in Appendix 2.

3.2.2 Literature Review

Published and unpublished reports relevant to the survey area were reviewed. These included:

- GEH Bypass Flora and Vegetation Survey (Strategen 2018a);
- Roe Highway Kalamunda Road Upgrade Flora, Vegetation and Fauna Survey (360 Environmental 2018);
- Banksia Woodlands of the Swan Coastal Plain: a nationally-protected ecological community (DoEE 2016);
- Black Cockatoo Habitat Assessment, Roe Highway (Strategen 2018b);
- Vegetation Mapping in the South West of Western Australia and Regional Forest Agreement vegetation complexes (Mattiske and Havel 1998);
- Vegetation complexes of the Darling System, WA, by Heddle et al. (1980);
- The extension of vegetation complex mapping to landform boundaries within the Swan Coastal Plain landform and forested region of south-west Western Australia (Webb et al. 2016) and
- John Beard's vegetation mapping (Beard 1981).

3.2.3 Likelihood Ranking for Significant Species

In order to determine which flora and fauna species of significance have the potential to occur in the survey area, consideration was given to:

- the results of the database and literature searches;
- the known habitat preferences against what is available within the survey area; and
- distributions and last known records for the species.

For each significant flora and fauna species, defined rankings and criteria were subsequently applied as per Table 3.2 (see Appendix 4b for fauna and Appendix 4a for flora). Throughout the remainder of this report, the term "close proximity" has been defined as being within 5 km of the survey area.

Two rankings were conducted:

- an initial assessment was made during the desktop review (Section 4.9; see Appendices 5a and 5b); and
- the assessment was revised based on the findings of the field surveys (see Appendix 4a for flora, and Section 4b for fauna).

Table 3.2 Ranking system used to assign the likelihood that flora and fauna of significance would occur in the survey area.

Rank	Criteria
Recorded	1. The species has been previously recorded in the survey area.
Likely to occur	1. There are existing records of the species within 5 km of the survey area; and • the species is strongly linked to a specific habitat, which is present in the survey area; or • the species has more general habitat preferences, and suitable habitat is present.
May occur	1. There are existing records of the species within 5 km of the survey area, however • the species is strongly linked to a specific habitat, of which only a small amount is present in the survey area; or • the species has more general habitat preferences, but only some suitable habitat is present. 2. There is suitable habitat in the survey area, but the species is recorded infrequently in the region.

Rank	Criteria
Unlikely to occur	1. The species is linked to a specific habitat, which is absent in the survey area; or 2. Suitable habitat is present, however there are no existing records of the species from within 5 km of the survey area despite reasonable previous search effort in suitable habitat; or 3. There is some suitable habitat in the survey area, however the species is very infrequently recorded in the region.
Would not occur	1. The species is strongly linked to a specific habitat, which is absent from the survey area; and/or 2. The species' range is very restricted and would not include the survey area.

3.2.4 Criteria to Determine the Presence of the Commonwealth Banksia Woodlands TEC

The Commonwealth 'Banksia Woodlands of the Swan Coastal Plain' TEC was listed in September 2016 as a TEC for the Swan Coastal Plain (SCP) under the EPBC Act, and is currently listed as Endangered. DotEE (2016) provides guidance for determining whether a *Banksia* woodland protected under the EPBC Act is present, which was considered likely for the survey area and therefore required specific survey attention. These criteria are summarised in Table 3.3.

Areas of mapped vegetation within the survey area that were considered to potentially align with the 'Banksia Woodlands of the Swan Coastal Plain' TEC were assessed in the field against the key diagnostic characteristics and condition thresholds, as per the approved conservation advice (DotEE 2016) and the Main Roads Technical Guidance Factsheet for this TEC (Main Roads 2019).

This assessment was only applied to patches occurring within the survey area; patches situated solely within the contextual area were not assessed using the key diagnostic characteristics and condition thresholds from the approved conservation advice.

A summary of these assessments is provided in Appendix 5, with relevant DBCA TEC/PEC Report Forms for all newly identified occurrences supplied to Main Roads separate to this report.

Table 3.3: Diagnostic characteristics and condition thresholds to determine the Commonwealth Banksia Woodlands TEC (DotEE 2016).

Diagnostic Characteristics / Condition Thresholds	Criteria
Determination of Floristic Community Type:	Location and physical environment: • Occurs in the Swan Coastal Plain IBRA bioregion. Soil and landform: • Typically occurs on well-drained, low-nutrient soils on sandplain landforms, particularly deep Bassendean and Spearwood sands and occasionally on Quindalup sands. Structure and composition: • The TEC encompasses a number of recognised sub-communities or Floristic Community Types (FCTs). The community in question must be representative of the relevant FCT.
Vegetation condition^ and minimum patch size threshold:	• 'Pristine' – no minimum • 'Excellent' – 0.5 ha or 5,000 m^2 • 'Very Good' – 1 ha or 10,000 m^2 • 'Good' – 2 ha or 20,000 m^2
Surrounding context:	Relevant criteria to consider: • "A patch is a discrete and mostly continuous area of the ecological community. A patch may include small-scale (<30 m) variations, gaps and disturbances, such as tracks, that do not significantly alter the overall functionality of the ecological community. Such breaks are generally included in patch size calculation. The landscape position of the patch, including its position relative to surrounding vegetation also influences how important it is in the broader landscape."

3.3 Survey Timing and Weather

3.3.1 Survey Team

The flora field survey was conducted during multiple visits between October 8 and November 6 in 2019, from May 7 to 8 in 2020, and November 3 to 6 in 2020, by Rebecca Mason, Chloe Flaherty, Ayesha Lapinski and Jason Teuber (all of Biota), and consulting botanist Malcolm Trudgen (Principal Consulting Botanist of M.E .Trudgen and Associates). A total of 35 person-days were spent on the vegetation and flora field component of this study. The Level 1 survey area was surveyed for flora on October 8 2019, while the Level 2 survey area was visited on all days of the flora field survey.

The fauna field survey was conducted during six visits between October 30 and November 8 in 2019, as well as visits on November 23 in 2019, January 21 and May 6 in 2020, by Brandon King, Nathan Beerkens, and Joshua Keen (all of Biota). Fauna survey effort comprised 17 person-days. The Level 1 survey area was surveyed for fauna on October 31 and November 6 and 8 in 2019, while the Level 2 survey area was visited on all days of the fauna field survey.

A summary of the field personnel and their respective roles in the survey is provided in Table 3.4.

Table 3.4: Summary of personnel involved in the survey.

Name	Position	Qualification	Years of Experience	Survey Role
Rebecca Mason	Botanist	BSc (Environmental Restoration & Conservation Biology)	9	Flora project manager; Vegetation mapping; Quadrat sampling; TEC assessment; Rare flora searches
Chloe Flaherty	Senior Botanist	BSc (Natural Resource Management (Hons))	11	Flora quadrat sampling
Ayesha Lapinski	Botanist	GradDip of Science (Botany)	3	Flora quadrat sampling; Rare flora searches
Malcolm Trudgen	Principal Consulting Botanist	BSc (Botany)	40	Flora quadrat sampling; Rare flora searches;
Jason Teuber	Graduate Botanist	BSc (Botany & Agricultural Science)	2	Flora quadrat sampling
Dan Kamien	Principal Zoologist	BSc Hons (Zoology)	>20	Fauna project manager
Brandon King	Graduate Zoologist	BSc Hons. MEnvSc (GIS & Environmental Management)	5	Level 1 fauna and Targeted surveys
Nathan Beerkens	Zoologist	BSc Hons (Conservation & Wildlife Biology)	4	Level 1 fauna and Targeted surveys
Joshua Keen	Zoologist	BSc Hons (Zoology)	4	Level 1 fauna and Targeted surveys
Garth Humphreys	Principal Ecologist / Director	BSc (Botany/Zoology) Hons (Zoology)	30	Quality assurance and final reviews

3.3.2 Daily Weather Observations

Weather observations were taken from the Perth Airport weather station (number 009021), located 2 km south west of the study area. Minimum temperatures ranged from 6.5ºC to 16.7ºC, while maximum temperatures ranged from 16.7ºC to 32.4ºC (Table 3.5). Information on how this rainfall compares to the long-term average is provided in Section 3.3.3, with arrows to indicate the months when survey work was completed.

Table 3.5: Daily meteorological observations for the Perth Airport weather station #009021.

Date	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Rainfall (mm)	Survey Type
08/10/19	31.0	13.1	0	Flora
09/10/19	29.9	10.0	0	Flora
10/10/19	24.1	11.6	0	Flora
11/10/19	21.2	11.1	0	Flora
29/10/19	27.8	13.9	0	Flora
30/10/19	23.4	12.1	0	Flora, Fauna
31/10/19	17.9	11.2	9.0	Fauna
01/11/19	19.5	11.0	0	Flora, Fauna
02/11/19	20.9	10.7	14.4	Fauna*
03/11/19	22.0	10.4	0	Fauna*
04/11/19	27.1	7.2	0	Flora, Fauna*
05/11/19	26.0	6.5	0	Flora, Fauna*
06/11/19	25.7	10.8	0	Flora, Fauna
07/11/19	28.1	14.3	0	Fauna
08/11/19	32.4	14.5	0	Fauna
23/11/19	31.9	14.6	0	Fauna
21/01/20	26.5	16.7	0	Fauna
06/05/20	16.7	11.3	12.6	Fauna
07/05/20	18.0	8.9	6.6	Flora
08/05/20	19.1	11.4	4.6	Flora
03/11/20	23.0	11.4	2.2	Flora
04/11/20	26.0	12.8	0	Flora
05/11/20	31.1	13.0	0	Flora, Fauna
06/11/20	29.2	15.8	0	Flora

* Active motion cameras only; no fauna field staff present.

3.3.3 Climate

The weather leading up to biological surveys is an important factor that influences both the number and type of species recorded from an area, particularly for flora. One of the more notable effects is the increased presence of annual flora species following high rainfall, in addition to a higher likelihood of plants bearing reproductive material (flowers and/or fruit). This typically results in a more complete list of species from the area, along with greater confidence in identifications.

The majority of the survey was undertaken in spring of 2019 and 2020, which is within the recommended season for botanical surveys in the Swan Coastal Plain bioregion (EPA 2016a). In addition, a small portion of the study area was sampled outside the recommended survey timing, in autumn 2020. Arrows displayed on Figure 3.1 indicate months where survey work was completed.

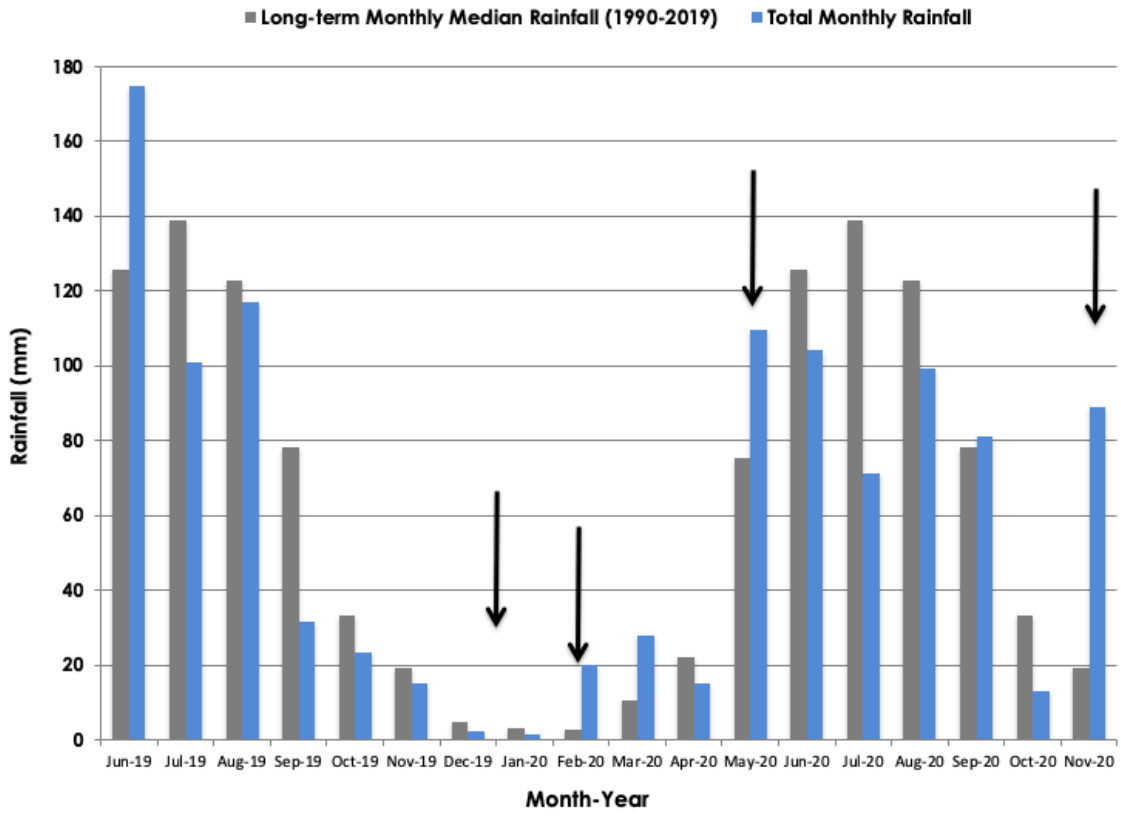

Figure 3.1: Total monthly rainfall for June 2019 to November 2020 from the Bureau of Meteorology Perth Airport weather station compared to the long-term climate-normal (1990-2019) median rainfall for the same months.

Total monthly rainfall data relevant to the study area were sourced from the Perth Airport weather station (Bureau of Meteorology station #9021), located approximately 2 km southwest of the survey area. Data for the 18 months preceding the final portion of the survey (completed in November 2020) were compared to the monthly median rainfall for the years 1990 – 2019 from the same station. A total of 250.0 mm of rainfall was received in the three months prior to the spring 2019 field survey (July – September 2019), which is approximately 30% less than the long-term median for the same period (339.7 mm; 1990 – 2019). The rainfall received over both months of the 2019 spring survey (October and November), 23.4 mm and 15.0 mm respectively, was also lower than the long-term medians for those months (33.1 mm and 19.1 mm). Whilst less rain was received overall compared to the long-term median, the 2019 spring survey timing was still considered adequate for the collection of ephemeral and cryptic perennial flora.

In the three months prior to the autumn 2020 survey, (representing a small portion of the total survey area), 61.4 mm of rainfall was received; almost double the long-term median rainfall for the same period (35.5 mm; 1990 – 2019). The autumn survey was concluded on May 8 2020, by which time 38.2 mm of rain had fallen. Whilst this portion of the survey was conducted outside recommended survey timing for botanical surveys in the Swan Coastal Plain bioregion (EPA 2016a), the autumn timing was still considerate adequate, but not optimal, for the collection of annual and perennial flora.

In the three months prior to the spring 2020 survey, 193.6 mm of rainfall was received, which is approximately 20% less than the long-term median for the same period (234 mm; 1990 – 2019). The 2020 spring survey timing was considered optimal for the collection of ephemeral and cryptic perennial flora.

3.4 Vegetation and Flora Field Survey

3.4.1 Floristic Data Collection: Assessment of Quadrats and Relevés

Indicative sampling locations were selected prior to the field survey. The survey area boundary was overlain on aerial imagery supplied by Main Roads, and sampling sites were then selected based on the broad habitats and vegetation types apparent. Once in the field, the actual locations of the sampling sites were adjusted as necessary (e.g. to be placed in the best representative area of the broader vegetation unit).

Sampling sites were established as either:

1. Quadrats: bounded floristic sampling sites. The standard for the Swan Coastal Plain bioregion comprises a 10 m x 10 m quadrat. Quadrats were measured using optical squares and measuring tapes, and permanently marked using steel fence droppers at each corner of the quadrat; or
2. Relevés: unbounded floristic sampling sites with a similar search area to a quadrat. Relevés were used where the vegetation stand was too small or too narrow to effectively establish a quadrat. The relevés sampled during the current survey were thoroughly surveyed for flora, but were not permanently marked.

A total of 23 quadrats and 15 relevés were assessed during the initial 2019 and May 2020 survey, six of which were resampled in November 2020. An additional eight quadrats were installed in November 2020, totalling 31 quadrats for the complete survey. Quadrats were assigned the prefix 'GBQ', while the relevés were assigned the prefix 'GEHREL'; each prefix was then followed by consecutive numbers. Locations of sampling sites are provided in Figure 3.2 below and Appendix 9. Raw data from the current quadrats and relevés are summarised in Appendix 8.

The following parameters were recorded for each site:

1. digital location using MGA coordinates (GDA94, zone 50K) recorded with a handheld Unistrong tablet with differential GPS capability with accuracy <1.5 m; coordinates were recorded for all four corners of each quadrat, and at least the central point of a relevé;
2. photographs of each site;
3. habitat description;
4. broad description of soil type;
5. fire history (approximate time since last fire, where applicable);
6. all species present and their estimated height and per cent foliar cover;
7. vegetation description based on the height and estimated percent foliar cover of dominant species using the vegetation structural scheme developed by Keighery (Keighery 1994) see Appendix 6); and
8. vegetation condition ranking according to EPA (2016a) (see Appendix 6).

Raw site data are provided in Appendix 8, along with coordinates of each corner point, and colour photographs of the overstorey and understorey.

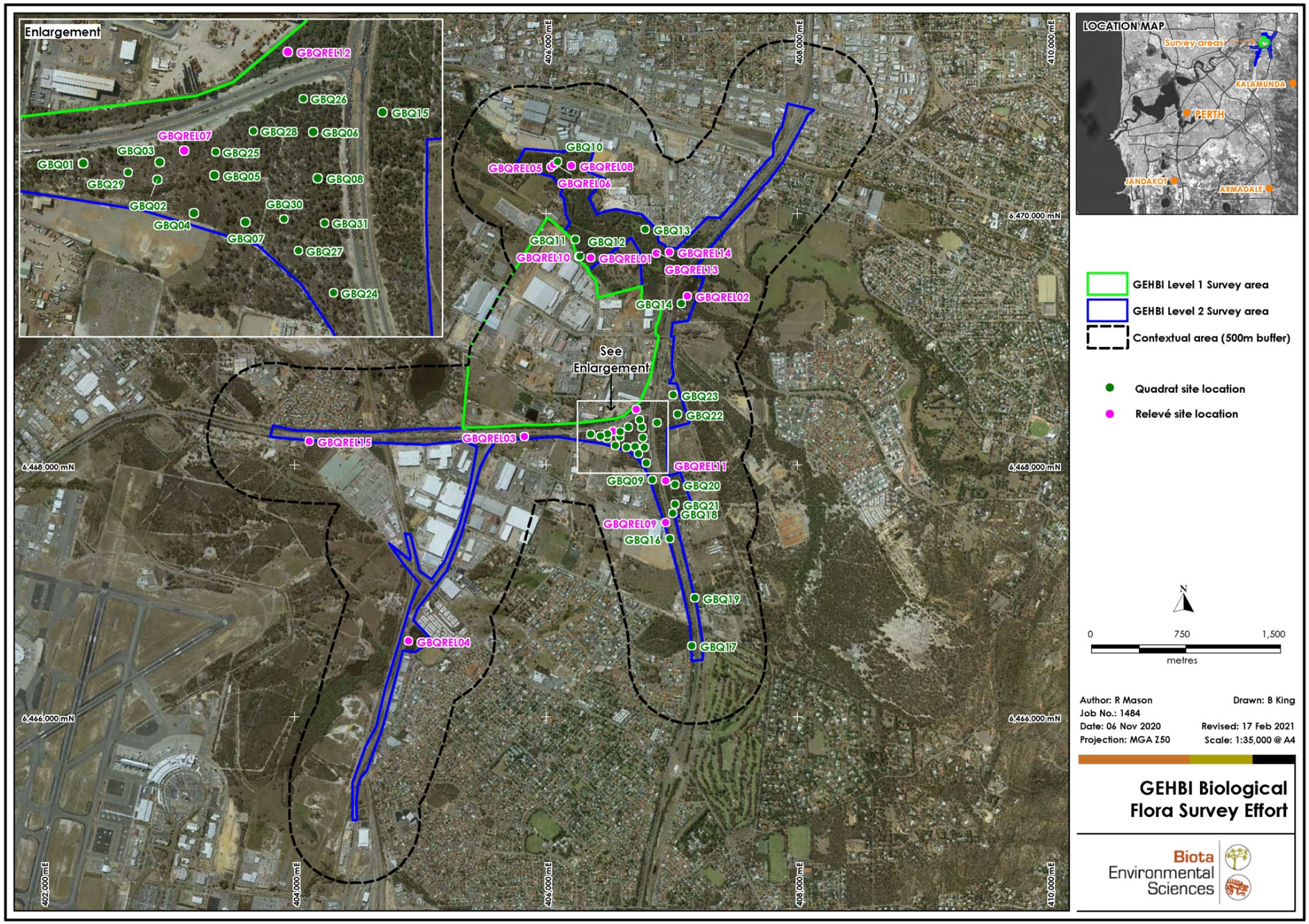

Figure 3.2 **Flora survey sampling effort.**

3.4.2 Vegetation Type Description and Mapping

Vegetation types in the study area were described at the sub-association level (Level VI as per the National Vegetation Information System[1]). The sub-association level includes information about the dominant growth form, height and cover for up to five species in all layers/sub-strata observed.

Field data and aerial imagery supplied by Main Roads were reviewed to determine boundaries of vegetation types, which were then described at the sub-association level (Level VI) as per the NVIS, and mapped to an appropriate scale (generally 1:10,000; with finer-scale mapping at 1:5,000 for TECs/PECs). The occurrence of the vegetation types was extrapolated outside the survey area to mapping within the contextual area.

Vegetation types were mapped by Rebecca Mason using Geographical Information System (GIS) software (QGIS v3.10). The final maps in Appendix 9 were produced by Melissa Robinson (Senior GIS Cartographer) of Biota, using MapInfo Professional GIS v12.

Full descriptions of each vegetation type are presented in Section 5.1. Once the vegetation types were defined, they were compared against the published descriptions of TECs and PECs to determine whether any of the vegetation in the survey area potentially corresponded to listed community types (see Section 5.3.1).

3.4.3 Vegetation Condition Mapping

In addition to spatially mapping the extent of vegetation throughout the study area, an assessment of the condition of the vegetation was also carried out (Appendix 11). Vegetation condition is determined in relation to the (perceived) ability of the vegetation to maintain itself (Keighery 1994). This is commonly interpreted from the visible amount of introduced species compared to native species. However, numerous other factors are also considered in the assessment of condition, including disturbance (e.g. grazing, erosion), degree of alteration to community and habitat structure, and overall site ecology.

The categories of vegetation condition used were consistent with the descriptive and qualitative method developed by Keighery (1994) (see Appendix 6).

3.4.4 Searches for Significant Flora and Weeds

The desktop review identified a subset of significant flora (i.e. Threatened and Priority listed species) from the locality that had either been previously recorded from the survey area, or were considered to have some potential to occur (see Appendix 4a). Targeted systematic searches for these species were then conducted on foot through the entire survey area.

Locations of species of significance or unknown taxa were recorded using a Unistrong tablet with accuracy equivalent to a differential GPS (<1.5 m). The number of individuals and extent of the population were also recorded for each location. DBCA Threatened and Priority Flora Report Forms were completed for all new populations of significant species recorded from the survey area (Appendix 10), and submitted to the DBCA.

Locations of any declared pests (weeds listed under the WA *Biosecurity and Agriculture Management Act 2007;* the BAM Act) or Weeds of National Significance (WoNS) were also recorded during the foot traverses, along with an estimate of their population size. Opportunistic records were also made of other introduced flora species, however no attempt was made to document all such species through the entire survey area.

[1] See the NVIS Information Hierarchy: http://www.environment.gov.au/land/publications/australian-vegetation-attribute-manual-v6/

3.4.5 Flora Specimen Identification, Nomenclature and Data Management

Flora species were identified either in the field, or in the office following the field survey. If a species was common and well known to the survey botanists, the identification was confirmed and noted in the field. If the species was difficult to determine without microscopic examination, belonged to a recognised species complex, or was poorly collected or otherwise unusual, a voucher specimen was collected. Specimens were pressed in the field, and then dried for further study and confirmation.

Voucher specimens were identified using flora keys, reference to appropriate publications, use of voucher reference collections and comparisons to the collections held at the WA Herbarium. Biota botanists Ayesha Lapinski and Rebecca Mason identified most specimens, with specimens confirmed by Principal Botanist Michi Maier.

Assistance was also sought from specialist taxonomist Mr Malcolm Trudgen (Principal of M.E. Trudgen & Associates), who was consulted to resolve for a range of more complex plant identifications during the study. A subset of specimens was also submitted to the WA Herbarium for paid identifications, which were completed by Mike Hislop.

All data were entered into a Microsoft Access Vegetation Database structure held internally at Biota. The database structure employed by Biota was developed by Ted Griffin (private consultant) at the request of Malcolm Trudgen (M.E. Trudgen and Associates). Nomenclature and significance rankings used in this report are in accordance with the current listing of WA flora recognised by the WA Herbarium, as listed on FloraBase[2] at the time of reporting.

A full list of vascular flora species recorded from the study area is presented in Appendix 7.

3.4.6 Analysis of Sampling Adequacy

Plots of species accumulation curves can be used to help assess sampling adequacy. When a survey has sampled an adequate proportion of the floristic assemblage, the curve should plateau and approach asymptote. PRIMER v6 (Clarke and Gorley 2006) was used to calculate smoothed species accumulation curves based on 999 random permutations of the species data. To avoid bias and chance effects, only quadrat data were used and opportunistic records were excluded.

Species accumulation curves alone cannot be reliably used to extrapolate predicted species richness for future biological sampling. In order to estimate predicted total richness for the survey area, the Chao 2 Mean and ICE Mean estimators were calculated using EstimateS (Colwell 2013).

3.4.7 Floristic Analysis to Identify TECs/PECs

Floristic analysis was conducted using PATN v4 to compare all the quadrats from the study area to the same Swan Coastal Plain vegetation data set and the same analysis software utilised by Gibson et al. (1994). The analysis was used to assign an FCT (as defined by Gibson et al. 1994) to each of the vegetation types within the study area, and to assist with determining the presence of significant vegetation, including TECs and PECs.

In keeping with the original floristic analysis completed by Gibson et al. (1994), the following protocols were used for the analysis and applied to the quadrat data set recorded during the current survey:

- Presence/absence data were used.
- All weeds were included.
- Some taxa were combined for the analysis. These were typically those that were considered difficult to accurately differentiate without sufficient flowering material (e.g. the taxa listed in

[2] http://florabase.dpaw.wa.gov.au

Appendix 3 of Gibson et al. 1994), or those that were represented by at species level rather than sub-species level.

- Records of taxa that were only identified to genus level (e.g. *Caladenia* sp.) were excluded, as these could refer to multiple taxa.

A test analysis was run using the Gibson data set, with the clustering analysis technique kept consistent with that used by Gibson et al. (1994):

- Sites were classified into 30 groups using the Bray Curtis (Czekanowski) association measure, followed by an agglomerative hierarchical fusion classification using "flexible unweighted pair-group mean average" (flexible UPGMA). The beta value was set at -0.1.
- Species were classified into 35 groups using the TWOSTEP association measure, followed by flexible UPGMA. The beta value was again set at -0.1.

Once the basic technique had been validated, the data from the quadrats and relevés suspected of being TEC/PEC were combined with the Gibson et al. (1994) data set. It is widely recognised that adding multiple new samples (in this case, quadrats) to a data set can result in considerable reassignment of samples to different groups than those produced through the original hierarchical clustering process. To minimise disruption to the existing floristic groups identified by Gibson et al. (1994), each quadrat was added individually to the data set, and clustering was checked against the original. This process was referred to as Single Site Insertion by Trudgen and Trudgen (2010); we have modified this to Single Sample Insertion (SSI), due to the use of the "single-site insertion" term in the genetics field.

A further analysis, Nearest Neighbour (NNB), was completed in PATN to determine the 20 original Gibson et al. (1994) sites that were most similar to the new quadrats. The NNB analysis determines the most similar sites on the basis of species composition, and forms linkages without imposing clustering. This technique often reveals relationships that may be lost when a clustering technique is used.

Summary outputs from all analyses are provided in Appendix 12. Due to the size of the data set, the input matrix has not been reproduced in this report, however it can be provided on request.

3.4.8 Floristic Analysis to Validate Vegetation Types

To investigate the similarity of quadrats based on their floristic composition, hierarchical clustering analyses were conducted using PRIMER v6 (Clarke and Gorley 2006).

To investigate whether there was floristic support for the vegetation types identified through the field survey, the percent cover data for all 31 quadrats and 15 relevés sampled within the survey area in 2019/2020 were included in the analysis. For this data set:

- Taxa that were only identified to genus level were excluded, as these could refer to multiple taxa.
- Taxa were referred to a single entity where considered appropriate (e.g. *Adenanthos cygnorum* with no subspecies determined was merged with *Adenanthos cygnorum* subsp. *cygnorum*; as were records of *Hibbertia hypericoides* subsp. *hypericoides* and *Hibbertia hypericoides* subsp. *septentrionalis* with *Hibbertia hypericoides*).
- All singleton taxa (those occurring in only one site) were excluded, to reduce 'noise' in the data set.

The analysis was run using percentage cover data. The Bray-Curtis measure of similarity was used to produce a similarity matrix and the group average method cluster analysis was used to determine floristic groups. Statistically different groups were identified through similarity profile analysis (SIMPROF). The similarity percentage test (SIMPER) was used to determine which species contributed most to the similarities between groups. Results were investigated through outputs including a dendrogram of site similarity, and Non-metric Multi-Dimensional Scaling plot (NMDS plots).

3.4.8.1 Comments Regarding the Floristic Analysis

The standard quadrat size for surveys in the Swan Coastal Plain bioregion is 10 m by 10 m, which is the smallest quadrat size in use in WA (20 m^2 to 50 m^2 quadrats are used in other regions). The 10 m by 10 m quadrats may not always sample all species characteristic of a community type, particularly if these only occur as scattered individuals through the vegetation. Individual quadrats in a particular vegetation type may therefore lack some key diagnostic species that would normally strongly influence site groupings.

Additionally, the small size of the remnant vegetation and reduced vegetation condition of various areas would have reduced the native species recorded in quadrats during the current survey and increased the number of weed species. These factors are considered to have reduced the strength of the resulting analyses (see Section 5.3 for further discussion).

3.5 Fauna Field Survey

3.5.1 Level 1 Fauna Survey

A Level 1 survey (Desktop study and Reconnaissance survey[3]) was conducted for the entire survey area (both the Level 1 and Level 2 survey areas), in accordance with EPA Technical Guidance (EPA 2016c) (see Section 3.2). The Reconnaissance survey involved recording all terrestrial fauna observed, as well as assessing the likelihood of occurrence of significant species identified during the desktop study. Most recording was opportunistic, with individual animals, scats, remains, and diggings recorded during targeted searches for black-cockatoos and fauna habitat ground-truthing.

3.5.2 Motion Cameras

Within the Level 2 survey area only, infrared motion cameras ('Reconyx® Hyperfire 2' model) were deployed at four locations considered most likely to record any significant fauna that may occur (Table 3.6). Cameras were baited with universal bait (peanut butter and oats). Site MC03 was decommissioned after one night due to a flooding risk.

Table 3.6 Motion camera site locations and effort within the Level 2 survey area.

Site Name	Latitude	Longitude	Date Opened	Date Closed	Effort (Nights)
MC01	31.917701	116.012845	30/10/2019	08/11/2019	9
MC02	31.904243	116.009358	30/10/2019	08/11/2019	9
MC03	31.897855	116.004225	30/10/2019	31/10/2019	1
MC04	31.904797	116.016858	03/11/2019	08/11/2019	5

3.5.3 Targeted Black Cockatoo Survey

3.5.3.1 Breeding Habitat Assessment

The study area lies within the known breeding distribution of Carnaby's Black-Cockatoo and Forest Red-tailed Black Cockatoo (Johnstone and Storr 1998), and the field assessment aimed to determine whether suitable breeding habitat for either of those species was present. It was considered that Baudin's Black Cockatoo would not breed within the survey area, as their most northern known breeding grounds are over 200 km south, at Lowden (Johnstone and Storr 1998).

The Commonwealth (DSEWPaC 2012a) defines breeding habitat as those species of trees known to support breeding within the range of the species, which either have a suitable nest hollow or

[3] Note that while the EPA Technical Guidance terminology for survey type was updated in 2020, the work reported here was undertaken while the EPA (2016c) guidance was still current policy and the framework of that document has therefore been retained here.

are of a suitable DBH to develop a nest hollow (being greater than 50 cm DBH for most Eucalypts, or 30 cm in the case of Wandoo and Salmon Gum).

The aim was to assess, as far as practicable, all potential breeding trees within the survey area. This was achieved throughout the survey area by zoologists walking transects with the aid of predetermined spatial layers on a GPS. Several trees in the Level 1 survey area were inaccessible by foot and were assessed from a distance using binoculars.

All individual trees of species with the potential to form hollows (primarily Flooded Gum, Marri, Jarrah and Tuart) and with sufficient diameter to be considered breeding habitat trees (i.e. DBH >50 cm) were recorded using a GPS accurate to within 1.5 m. The following parameters were recorded:

1. DBH (diameter at breast height; approximately 1.3 m above the ground);
2. tree species;
3. height above the ground of each hollow; and
4. the estimated size of entry of the hollow.

Hollows that met the "Suitable" or "Suitable with Evidence of Use" assessment criteria described in Table 3.7 were considered a potential breeding hollow warranting further investigation using a camera mounted on an extendable pole, as described in Section 3.5.3.2.

Table 3.7: Categories of hollow suitability for black cockatoo nesting.

Category	Characteristics
Not Suitable	Not a hollow, or hollow not suitable for black cockatoo nesting.
Suitable	• Entrance greater than 10 cm. • Branch width and depth large enough to support a nesting chamber. • Angle of entrance/egress suitable for black cockatoo. • Entrance is clear of large branches would block access for black cockatoo.
Suitable with Evidence of Use	As for "Suitable" above, but also showing evidence of use that may be from black cockatoos. The following represent the types of use that were searched for: • Fresh chews around the rim and inside of the hollow. • Freshly cleared vegetation around the entrance. • Eggs that were similar in appearance to those of black cockatoos.

3.5.3.2 Breeding Hollow Assessment

For observed hollows greater than approximately 10 cm diameter, a follow-up examination was conducted using a video camera mounted on an extendable pole. This allowed for more accurate assessment of hollow suitability and evidence of black cockatoo use.

Prior to filming, the side of the tree was raked with a branch to encourage black cockatoos to emerge, if present. This provides an indication of hollow use and reduced the risk of cockatoo disturbance from the camera. Camera footage was live streamed onto a Unistrong tablet to ensure that usable footage was obtained.

Photographs of each hollow were also taken as a visual reference and to aid future identification of each specific tree. These were also assessed in detail to determine if they represented suitable hollows and/or if they showed any signs of current or previous use by black cockatoos (e.g. chew marks around hollow entrance).

Breeding suitability of hollows examined were assessed against the criteria detailed in Table 3.7.

3.5.3.3 Foraging Habitat Assessment

The study area lies within the known foraging distribution of all of Western Australia's three species of black cockatoo (Johnstone and Storr 1998), and the field assessment aimed to determine whether suitable foraging habitat for any of those species was present. Foraging habitat is defined as areas including plants of species known to support foraging within the range of each cockatoo species. Marri and Jarrah woodlands are particularly important to Baudin's Black-Cockatoo and the Forest Red-tailed Black-Cockatoo, while proteaceous heaths (i.e. shrublands dominated by *Banksia, Hakea*

and *Grevillea* species) are also important to Carnaby's Black-Cockatoo (DSEWPaC 2012a), as are introduced pines, particularly on the Swan Coastal Plain (Johnstone and Kirkby 2011).

In defining the quality of black cockatoo foraging habitat, the criteria detailed in both the current referral guideline (DSEWPaC 2012a) and the draft revised referral guideline (DotEE 2017a) were incorporated. These include foraging plant composition and density, the provision of continuity to wider areas of foraging habitat, foraging evidence, proximity to known roosting areas and proximity to known breeding areas.

3.5.3.4 Roosting Habitat Assessment

Roosting habitat is defined as areas within the range of each black cockatoo species which provide black cockatoos with shelter during the heat of the day and safe resting places at night (DotEE 2017a). Black cockatoos favour roost sites within close access to both water and foraging habitat (DSEWPaC 2012a, EPA 2019). Black cockatoos use a variety of vegetation species as roost sites, particularly tall species of *Eucalyptus* and Marri (DSEWPaC 2012a, EPA 2019). Evidence of black cockatoo roosting was searched for opportunistically, and previously-known roost sites were identified from DBCA and Birdata database searches.

3.5.4 Targeted Carter's Mussel Survey

A targeted survey was conducted to determine the presence of the Vulnerable Carters' Freshwater Mussel (*Westralunio carteri*) and to assess the suitability of riverine habitat for this species.

The section of the Helena River intersecting the survey area was traversed by a zoologist on 5 November 2020. The following methodologies were utilised in attempt to search for mussels or evidence of their occurrence:

- visual searches for live mussels, dead shells or mussel tracks in the sediment;
- raking sediment with a triangle dip net at 9 locations for ten minutes at each location along the river (Table 3.8); and
- habitat descriptions and photographs at 12 locations.

Table 3.8 Sampling and habitat description locations within the survey area.

Site Name	Method	Latitude	Longitude	Date
GEH01SRE	Visual, dip net and habitat	-31.9051	116.0157	05/11/2020
GEH02SRE	Visual, dip net and habitat	-31.9049	116.0152	05/11/2020
GEH03SRE	Visual, dip net and habitat	-31.9043	116.0140	05/11/2020
GEH04SRE	Visual, dip net and habitat	-31.9035	116.0134	05/11/2020
GEH05SRE	Visual and habitat*	-31.9026	116.0109	05/11/2020
GEH06SRE	Visual, dip net and habitat	-31.9010	116.0091	05/11/2020
GEH07SRE	Visual and habitat*	-31.9006	116.0082	05/11/2020
GEH08SRE	Visual, dip net and habitat	-31.8997	116.0070	05/11/2020
GEH09SRE	Visual and habitat*	-31.8985	116.0060	05/11/2020
GEH10SRE	Visual, dip net and habitat	-31.9055	116.0165	05/11/2020
GEH11SRE	Visual, dip net and habitat	-31.9057	116.0182	05/11/2020
GEH12SRE	Visual, dip net and habitat	-31.9059	116.0186	05/11/2020

*Indicates sites that could not be sampled using a dip net due to abundance of weeds.

Habitat descriptions were also conducted at two nearby reference locations where Carter's Freshwater Mussel has been recently recorded (Table 3.9). This was done to compare habitat of the survey area with habitat known to contain Carter's Freshwater Mussel populations.

Table 3.9: Reference sites visited to assess habitat at known Carter's Freshwater Mussel records.

Site Name	Location	Distance from Study Area (km)	Latitude	Longitude	Date
GEH13SRE	Helena River-downstream	~2.5 km west of survey area	-31.9033	115.9775	05/11/2020
GEH14SRE	Bennett Brook	~5 km northwest of survey area	-31.8732	115.9576	05/11/2020

3.5.5 Fauna Habitat Mapping

Fauna habitat mapping was primarily based on vegetation units, with consideration of substrate, landform and the ecological niches relevant to significant fauna. Habitat types were assessed in the field using a combination of foot traverses and vehicle traverses along existing roads, complemented by quadrat data, vegetation mapping and aerial imagery.

3.5.6 Nomenclature

Consistent with the EPA Technical Guidance (EPA 2016e), species nomenclature for herpetofauna and mammals follows the standards of the WA Museum fauna taxonomic checklist, which is revised and released every six months or as necessary. Nomenclature for avifauna used here follows Christidis and Boles (2008).

3.6 Limitations of the Study

The results of the field surveys provide an adequate representation of the flora, vegetation and fauna values of the survey area. However, there are limitations to this study that must be considered when reviewing and applying the results detailed in this report. As per the EPA's Technical Guidance for flora and fauna surveys for EIA (EPA 2016a, 2016e), potential constraints and consequent limitations of this survey assessment are summarised in Table 3.10.

Table 3.10: Potential constraints and limitations of the current surveys.

Potential Constraint	Statement of Limitations
1. Availability of contextual information at a regional and local scale	• Previous biological surveys have been completed within the locality of the survey area and several unpublished reports, as well as regional data sets, were considered as part of the desktop review. Publicly available databases of rare species and communities information were also searched. The current survey added new data specific to the study area. • Contextual information is therefore not considered to be a limiting factor for this study.
2. Competency/ experience of the team carrying out the survey, including experience in the bioregion surveyed	• The field personnel were suitably qualified to identify flora and fauna, and all team members were considered experienced in conducting biological surveys. • There were therefore no limitations due to experience of personnel.
3. Proportion of flora recorded and/or collected, any identification issues	• All vascular flora encountered in the current study area were recorded, comprising 287 native taxa from 142 genera and 53 families, and 96 weed species. The majority (95%) the flora specimens collected during the current field survey were of sufficient quality to be fully determined to the lowest relevant taxonomic level. Fungi and non-vascular flora (algae, mosses and liverworts) were not systematically surveyed, which is consistent with the accepted level of effort for a survey of this type and scale. • The proportion of flora recorded was not considered to be a limitation.

Potential Constraint	Statement of Limitations
4. Appropriate area fully surveyed (effort and extent)	• The scope of works required a detailed survey for vegetation and flora, together with a targeted survey for significant flora (terms as described in EPA 2016a). A total of 35 person days were spent surveying the flora and vegetation of the survey area. The entire survey area was searched on foot for rare flora. Vegetation mapping was prepared for the survey area and extended over a 500 m corridor to either side. A total of 31 quadrats and 15 relevés were completed in the survey area. Of the 13 vegetation types identified, five did not have replicate sites due to the overall size of the units within the survey area. • The survey area is considered to have been fully surveyed.
5. Access restrictions within the survey area	• Access to the survey area was provided incrementally due to delays in accessing certain private properties. These restrictions meant that the surveys were conducted over multiple events in different seasons, rather than consecutive field days. • Access restrictions meant that one potential black cockatoo breeding hollow was examined outside of the recommended window, in May 2020 (the hollow was found to be unsuitable). • Access restrictions within the survey area were considered to be a limitation that impacted on survey timing, however all areas were ultimately accessed.
6. Survey timing, rainfall, season of survey	• The majority of the flora and vegetation survey was completed between early October and early November 2019, and November 2020 for the additional survey. This was considered adequate for the recording of annual and cryptic perennial species (see Section 3.3.3). A small sub-section of the survey was completed in May 2020, outside the recommended timing for a Swan Coastal Plain survey (described in EPA 2016a). • Overall, timing of the flora and vegetation survey was not considered a significant limitation for the assessment of the survey area values.
7. Disturbance that may have affected the results of survey such as fire, flood or clearing	• Areas of historical clearing and parkland plantings were present in the study area, which influenced the presence of introduced flora in the area. However, introduced flora is common within remnant vegetation on the Swan Coastal Plain and regional data sets (e.g. Gibson et al. 1994) account for this. • Disturbance is not considered to be a limitation to the study.

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4.0 Desktop Assessment

4.1 IBRA Bioregion and Subregion

The survey area lies within the Swan Coastal Plain 2 (SWA02) subregion of the Swan Coastal Plain (SWA) bioregion, as defined by the Interim Biogeographic Regionalisation for Australia (IBRA) (DSEWPaC 2012b). The SWA02 subregion is described by Mitchell et al. (2003) as:

> "Low lying coastal plain, mainly covered with woodlands. It is dominated by Banksia or Tuart on sandy soils, *Allocasuarina obesa* on outwash plains, and paperbark in swampy areas. In the east, the plain rises to duricrusted Mesozoic sediments dominated by Jarrah woodland. Warm Mediterranean. Three phases of marine sand dune development provide relief. The outwash plains, once dominated by *A. obesa*-marri woodlands and *Melaleuca* shrublands, are extensive only in the south."

4.2 Conservation Reserves in the Locality

Within the study area, 11 parcels of land are vested for the purposes of the Conservation of Flora and Fauna (Figure 4.1) comprising:

- Greenmount National Park;
- Gooseberry Hill National Park;
- Kalamunda National Park;
- Beelu National Park;
- Talbot Road Nature Reserve (Class-A);
- R 49079 Hawkesvale Bushland Nature Reserve (Class-A);
- R 48325 Swan River Reserve;
- Four un-named, non-gazetted Nature Reserves; and
- John Forest National Park.

None of these reserves occur within the survey area itself, however Hawkesvale Bushland Nature Reserve abuts the southern section of the survey area. In addition, 24 ha of Crown Freehold land was identified within the study area, with no legal purpose specified.

4.3 Geomorphic Wetlands

Geomorphic Wetland data sets are managed by DBCA to assist in the protection of wetlands in the southwest of Western Australia. Wetlands on the Swan Coastal Plain are evaluated and assigned managed categories to provide guidance on use and protection, with the categories comprising: Conservation, Resource Enhancement and Multiple use(DBCA 2017). Geomorphic wetlands intersected by the contextual area and survey area are outlined in Table 4.1 and shown on Figure 4.2. The 'multiple use' management category was most common within the survey and contextual areas.

Table 4.1 Geomorphic Wetlands as described by DBCA 2017.

Management Category	Contextual Area (ha)/%	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Survey Area (ha)/%
Conservation	77.4 (4.9%)	-	41.3	41.3 (11.5%)
Resource Enhancement	96.5 (6.1%)	2.1	3.9	6.0 (1.7%)
Multiple Use	434.6 (27.4%)	80.6	37.5	118.2 (32.8%)

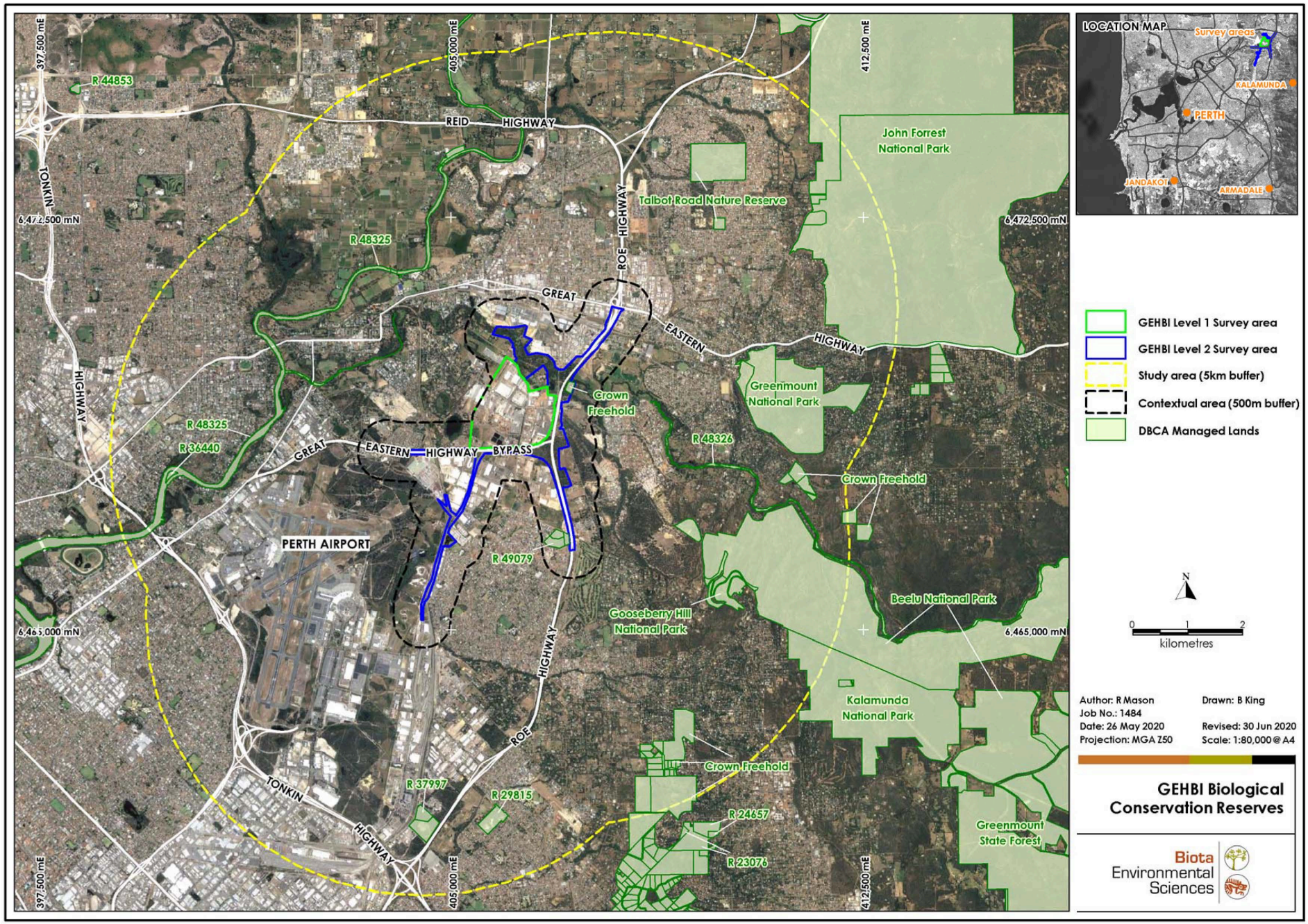

Figure 4.1: Conservation estate in the locality.

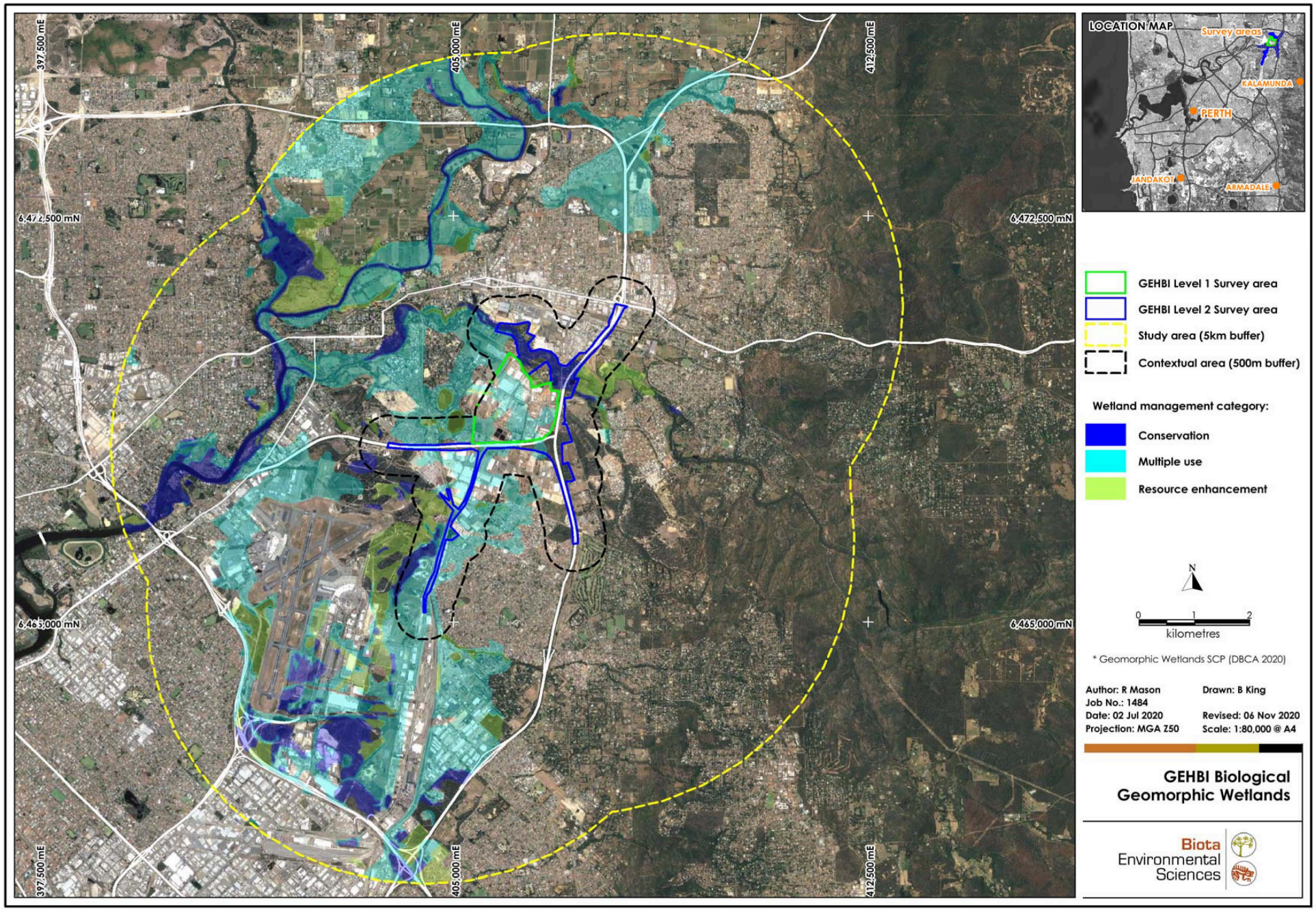

Figure 4.2: Geomorphic wetlands in the locality.

4.4 Surface Geology

Geological units for the locality were mapped at 1:50,000 scale on the Perth (20342) map sheet by Geological Survey of Western Australia (2001) as part of the Geological Survey of WA series. Geological units intersected by the contextual area and survey area are outlined in Table 4.2 and shown on Figure 4.3. Sand (S10) is the most common geological unit within the survey area (62.3% in total); S10 also comprises 43.7% of the contextual area.

Table 4.2: Surface geology units as described and mapped by Geological Survey of Western Australia (2001).

Unit	Description	Contextual Area (ha)/%	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Survey Area (ha)/%
Cm2	**Clay** - dark strong brown, hard when dry, soft when moist, variable silt content, no sand, of alluvial origin.	99.0 (6.2%)	0.2	49.7	49.9 (13.8%)
Cps	**Peaty clay** - dark grey and black with variable sand content of lacustrine origin.	48.6 (3.1%)	7.7	-	7.8 (2.2%)
Mgs1	**Pebbly silt** - strong brown silt with common, fine to occasionally coarse-grained, sub-rounded laterite quartz, heavily weathered granite pebble, some fine to medium-grained quartz sand, of alluvial origin.	416.0 (26.2%)	7.4	36.0	43.4 (12.0%)
S8	**Sand** - very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz, moderately well sorted of eolian origin.	312.5 (19.7%)	0.2	31.7	31.8 (8.8%)
S10	**Sand** - very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz, moderately well sorted of eolian origin.	693.4 (43.7%)	154.3	70.4	224.7 (62.3%)
WATER	Any areas of permanent water.	17.3 (1.1%)	0.1	2.9	2.9 (0.8%)
	TOTAL	**1,586.9**	**169.9**	**190.7**	**360.5**

4.5 Soils

With regards to soil-landscapes, the survey area occurs within the Bassendean Zone of the Swan Province. The Bassendean Zone is described as "*Mid-Pleistocene Bassendean sand. Fixed dunes inland from coastal dune zone. Non-calcareous sands, podsolised soils with low-lying wet areas*" (Purdie et al. 2004).

Soil units for the locality were mapped at 1:1,000,000 by Northcote et al. (1967) as part of the Atlas of Australian Soils (Table 4.3). Soil units intersected by the contextual area and survey area are shown in Table 4.3 and on Figure 4.4. The majority (94.6%) of the survey area is mapped as leached sands, sometimes with a clay horizon (Cb38); this soil type is widespread in the contextual area.

Table 4.3: Soil types in the survey area as described and mapped by Northcote et al. (1967).

Unit	Description	Contextual Area (ha)/%	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Survey Area (ha)/%
Cb38	Sandy dunes with intervening sandy and clayey swamp flats: chief soils are leached sands (Uc2.33) and (Uc2.21), sometimes with a clay D horizon below 5 ft, on the dunes and sandy swamps. Associated are various soils in the clayey swamps, such as (Ug6.4) and some (Dy) and (Dg) soils.	1,362.2 (85.8%)	169.9	171.4	341.3 (94.6%)

Unit	Description	Contextual Area (ha)/%	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Survey Area (ha)/%
Mu11	River terraces: chief soils are neutral red earths (Gn2.15) and neutral yellow earths (Gn2.25) on the higher terrace. Associated are (Um6.11) soils on the lower terrace and some areas of (Dy3.4) soils.	163.5 (10.3%)	-	17.3	17.3 (4.8%)
Sp2	Gently sloping bench or terrace--the Ridge Hill Shelf: chief soils are hard acidic yellow soils (Dy2.61) containing ironstone gravels. Associated are brown sands (Uc4.2) often containing ironstone gravels at depth and forming a western fringe to the bench; and some (Dy3.4) soils on dissected areas. As mapped, areas of units Wd6 and Gb16 may be included.	16.2 (1.0%)	-	-	-
Wd6	Plain: chief soils are sandy acidic yellow mottled soils (Dy5.81), some of which contain ironstone gravel, and in some deeper varieties (18 in. of A horizon) (Uc2.22) soils are now forming. Associated are acid yellow earths (Gn2.24). Other soils include (Dy3.81) containing ironstone gravel; (Dy3.71); low dunes of (Uc2.33) soils; and some swamps with variable soils.	45.0 (2.8%)	-	1.9	1.9 (0.5%)
	TOTAL	**1,586.9**	**169.9**	**190.7**	**360.5**

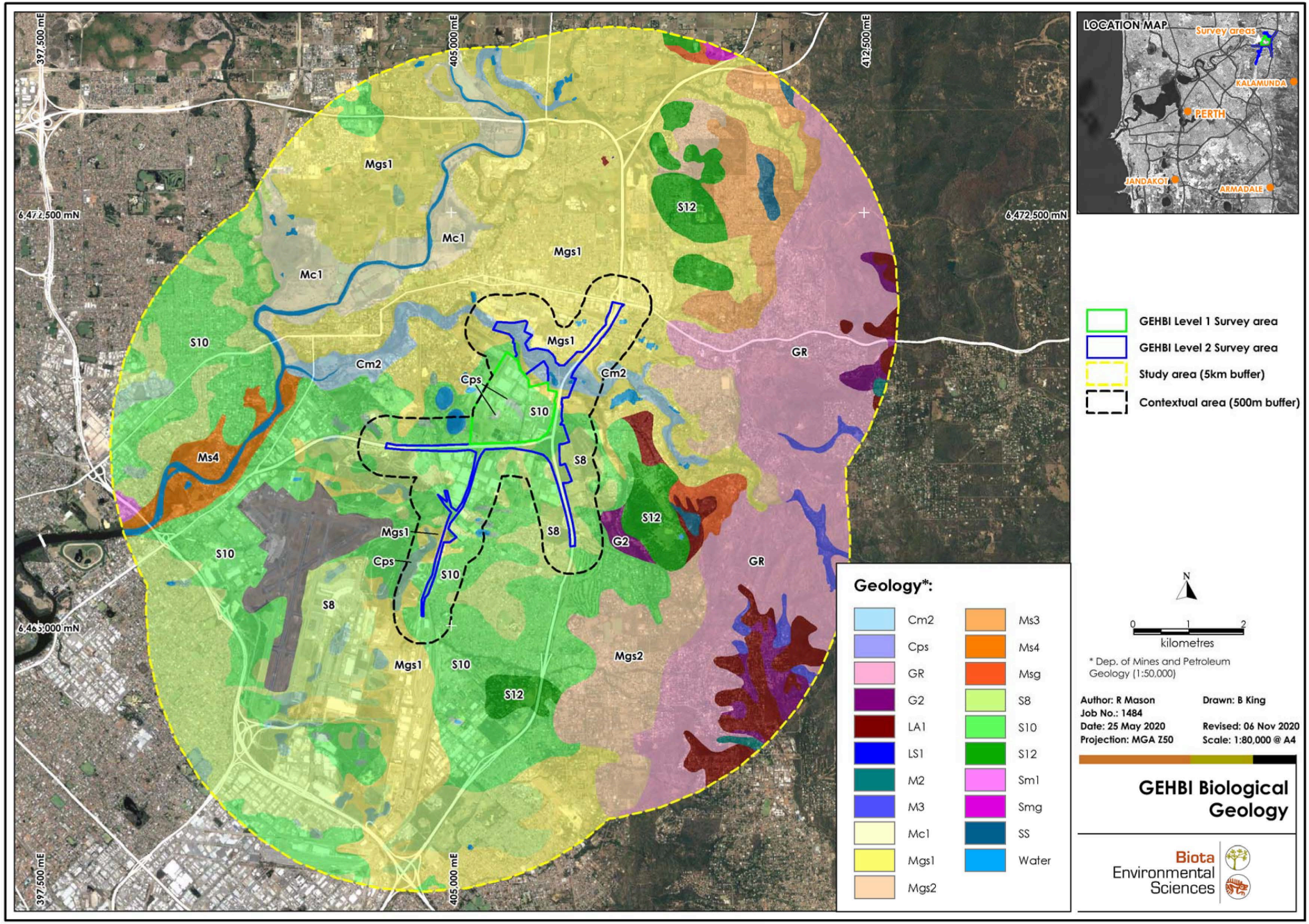

Figure 4.3: Geological units mapped for the study area.

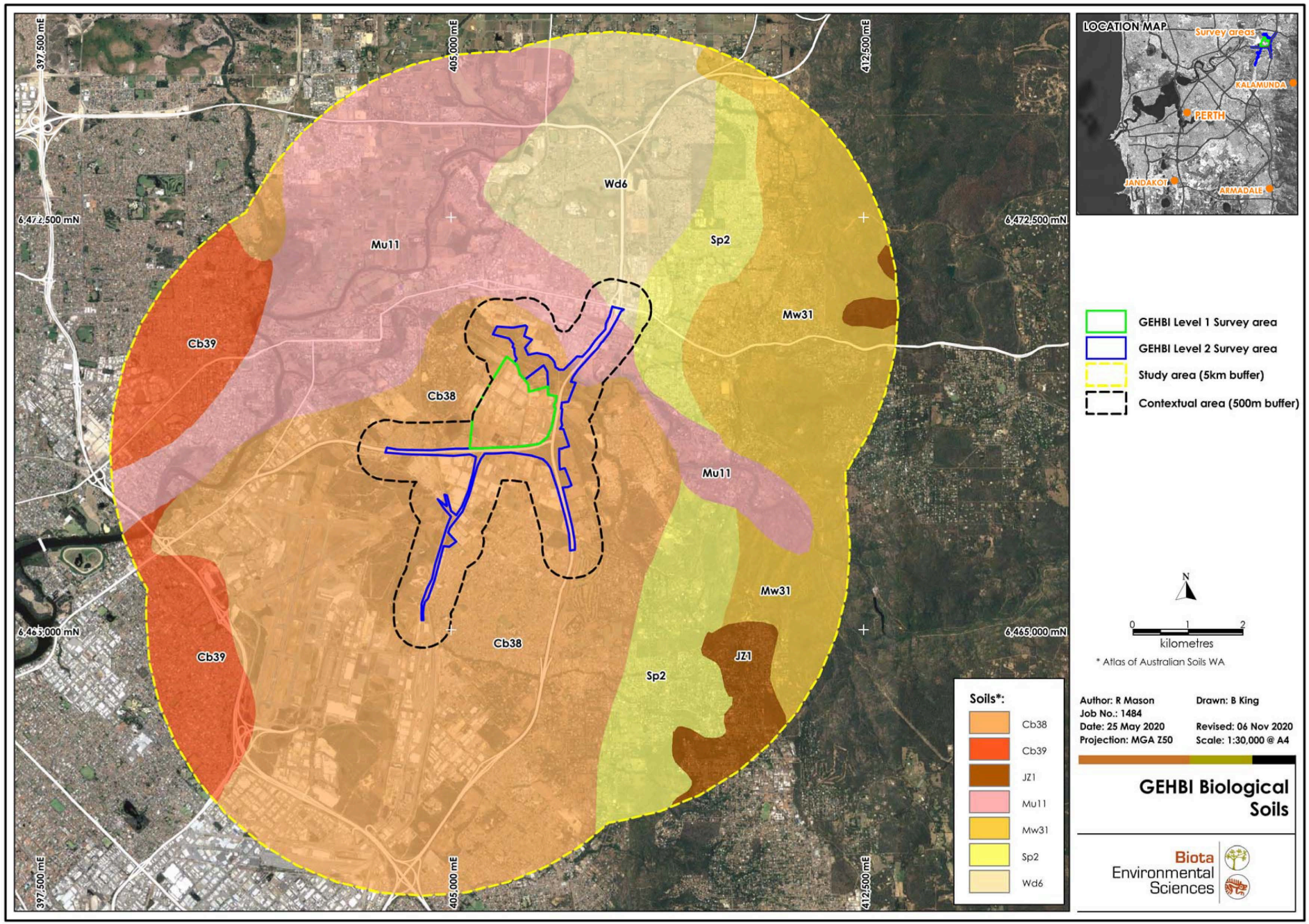

Figure 4.4: Soil units mapped for the study area.

4.6 Bush Forever

Bush Forever is a State government policy and program, which identified 51,200 ha of regionally significant bushland on the Swan Coastal Plain for protection (WA Planning Commission 2000a). Bush Forever areas are protected as ESAs pursuant to the EP Act. One Bush Forever Site was identified as occurring within the survey area; Site 481 'Stirling Crescent Bushland'. Four additional Bush Forever Sites were identified within the contextual area:

- Bush Forever Site 122 (Hawkesvale Nature Reserve);
- Bush Forever Site 213;
- Bush Forever Site 311; and
- Bush Forever Site 386.

None of these sites extend into the survey area.

4.7 Regional Vegetation Mapping

4.7.1 Pre-European Vegetation Mapping of Beard (1981)

John Beard mapped the vegetation of the Swan Coastal Plain at 1:1,000,000 scale (Beard 1981). Based on Beard's mapping, the survey area lies within three vegetation system associations (see Table 4.4 and Figure 4.5). The majority (69.5%) of the survey area was mapped as Bassendean 1001, comprising Medium to very sparse woodland; jarrah, with low woodland; banksia & casuarina. This vegetation system association was also widespread within the contextual area. Given the necessarily broad scale of Beard's mapping (contributing to a State-wide data set), these units are only broadly applicable to the vegetation types occurring on site (see Section 5.1).

Table 4.4: Vegetation associations in the survey area as described and mapped by Beard (1981).

Beard's Vegetation System Association	Description (NVIS Level V)	Contextual Area (ha)/%	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Survey Area (ha)/%
Bassendean 1001	**Beard:** Medium very sparse woodland; jarrah, with low woodland; banksia & casuarina **NVIS Level V:** U^^Banksia attenuata, Banksia menziesii, Eucalyptus todtiana\tree\6\i **NVIS Level V1:** U1 Banksia attenuata, Banksia menziesii, Eucalyptus todtiana, Allocasuarina fraseriana, Banksia ilicifolia\tree\6\i	803.4 (50.6%)	152.9	97.7	250.6 (69.5%)
Bassendean 1018	**Beard:** Mosaic: Medium forest; jarrah-marri / Low woodland; banksia / Low forest; teatree / Low woodland; Casuarina obesa **NVIS Level V:** U+ ^^Eucalyptus sp.,Allocasuarina acutivalvis,Banksia sp.\tree mallee,shrub\5\i;M Acacia sp.,Allocasuarina sp.,Dryandra sp.\shrub\3\c **NVIS Level V1:** U1+ ^Eucalyptus marginata,^Corymbia calophylla\^tree\7\c;M1 ^Melaleuca sp.,Banksia sp.,Casuarina obesa\^tree\6\c	415.6 (26.2%)	16.9	34.1	51.0 (14.1%)

Beard's Vegetation System Association	Description (NVIS Level V)	Contextual Area (ha)/%	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Survey Area (ha)/%
Pinjarra Plain 1009	**Beard:** Medium woodland; marri & river gum **NVIS Level V:** U Corymbia calophylla, Eucalyptus rudis\tree\7\i **NVIS Level V1:** U1 Corymbia calophylla, Eucalyptus rudis\tree\7\i	367.9 (23.2%)	-	58.9	58.9 (16.3%)
	TOTAL	**1,586.9**	**169.9**	**190.7**	**360.5**

4.7.2 Vegetation Complex Mapping of Heddle et al. (1980)

The vegetation complexes of the Swan Coastal Plain have been mapped by Heddle et al. (1980) at a scale of 1:250,000. The study area contains five vegetation complexes as outlined by Heddle et al. (1980), four of which occur with the survey and contextual areas (see Table 4.5, Figure 4.6). The majority (79%) of the survey area was mapped as the Southern River complex, comprising open woodlands of *Corymbia calophylla*, *Eucalyptus marginata* and *Banksia* species with fringing woodland of *Eucalyptus rudis* and *Melaleuca rhaphiophylla*. The Southern River complex is also widely represented in the contextual area.

Table 4.5: Vegetation complexes in the survey area as described by Heddle et al. (1980).

Heddle vegetation complexes	Description	Contextual Area (ha)	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Survey Area (ha)
Forrestfield Complex	Vegetation ranges from open forest of *Corymbia calophylla* (Marri) - *Eucalyptus wandoo* (Wandoo) - *Eucalyptus marginata* (Jarrah) to open forest of *Eucalyptus marginata* - *Corymbia calophylla* - *Allocasuarina fraseriana* (Sheoak) - *Banksia* species. Fringing woodland of *Eucalyptus rudis* (Flooded Gum) in the gullies that dissect this landform.	283.3 (17.3%)	-	38.4	38.4 (10.7%)
Guildford Complex	A mixture of open forest to tall open forest of *Corymbia calophylla* - *Eucalyptus wandoo* - *Eucalyptus marginata* and woodland of *Eucalyptus wandoo* (with rare occurrences of *Eucalyptus lane-poolei* (Salmon White Gum)). Minor components include *Eucalyptus rudis* - *Melaleuca rhaphiophylla* (Swamp Paperbark).	196.9 (12.4%)	0.5	24.9	25.4 (7.0%)
Swan Complex	Fringing woodland of *Eucalyptus rudis* - *Melaleuca rhaphiophylla* with localised occurrence of low open forest of *Casuarina obesa* (Swamp Sheoak) and *Melaleuca cuticularis* (Saltwater Paperbark).	158.8 (10%)	-	11.8	11.8 (3.3%)
Southern River Complex	Open woodland of *Corymbia calophylla* - *Eucalyptus marginata* - *Banksia* species with fringing woodland of *Eucalyptus rudis* - *Melaleuca rhaphiophylla* along creek beds.	947.9 (59.7%)	169.4	115.6	285.0 (79.0%)
	TOTAL	**1,586.9**	**169.9**	**190.7**	**360.5**

4.7.3 Remaining Remnant Vegetation

The current extent of native vegetation was mapped for WA at a scale of 1:20,000 by the Department of Agriculture (DAFWA 2016). Within the survey area, 14.8% of the area remains as remnant vegetation; within the contextual area 11% is remnant vegetation (see Table 4.6 and Figure 4.7).

Table 4.6: Remnant vegetation remaining in the survey area.

Boundary	Area (ha)		Area (%)
	Total	Remnant Vegetation	
Contextual	1,586.9	174.6	11.0
Level 1 Survey	169.9	0.9	0.5
Level 2 Survey	190.7	52.5	27.6
Total Survey Area	**360.6**	**53.4**	**14.8**

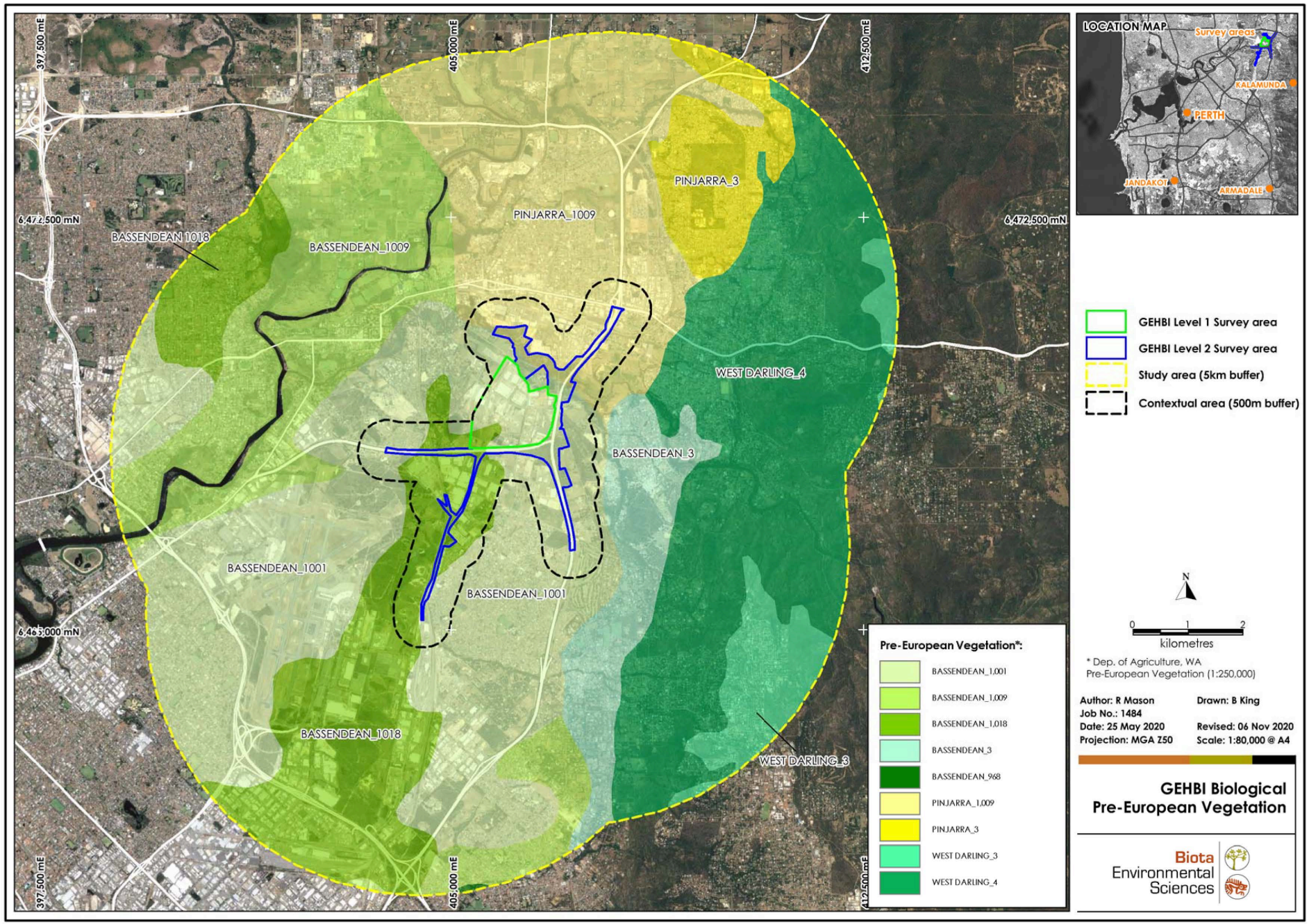

Figure 4.5: Beard's (1981) vegetation associations mapped within the study area.

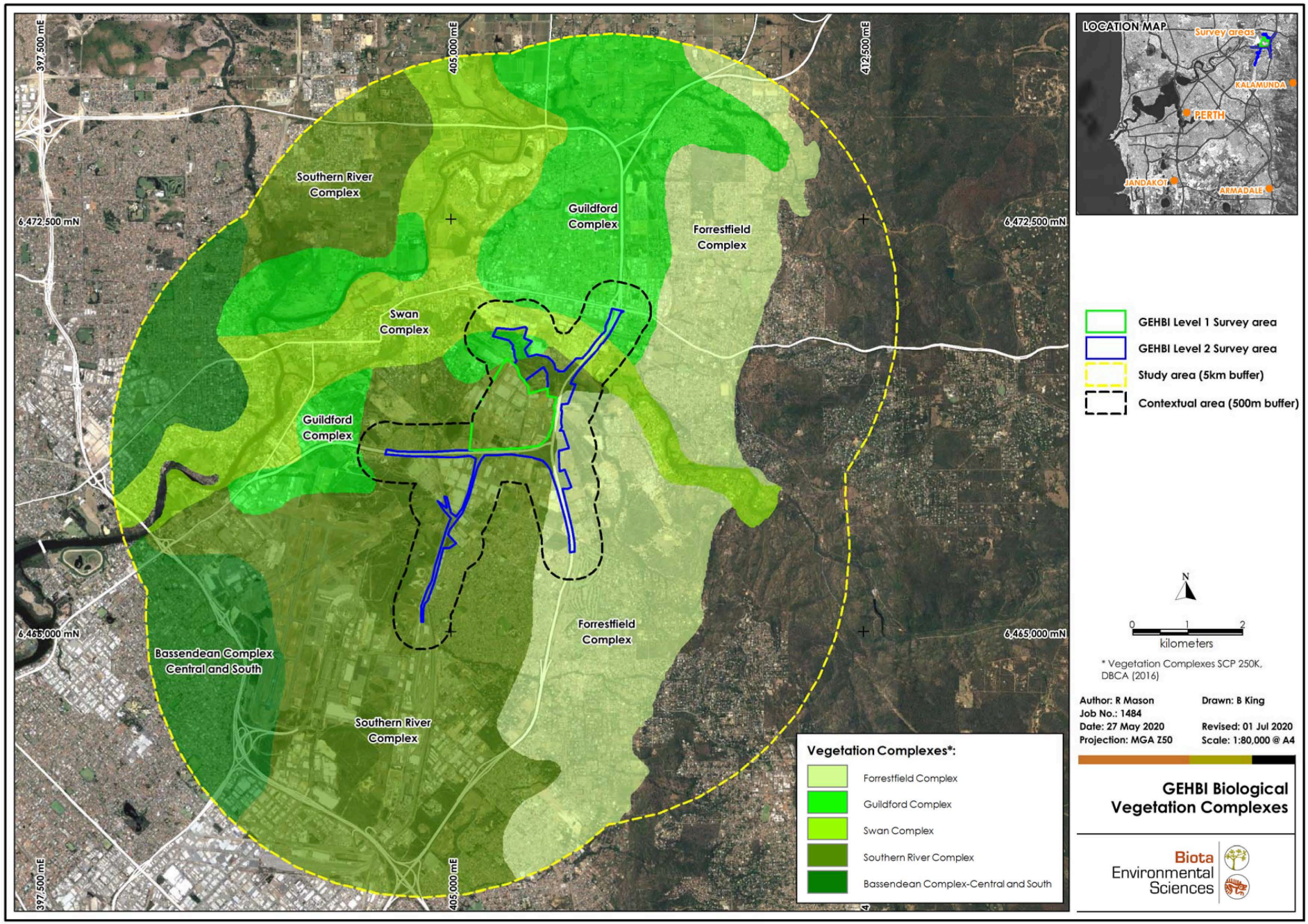

Figure 4.6: Heddle (1980) vegetation complexes mapped within the study area.

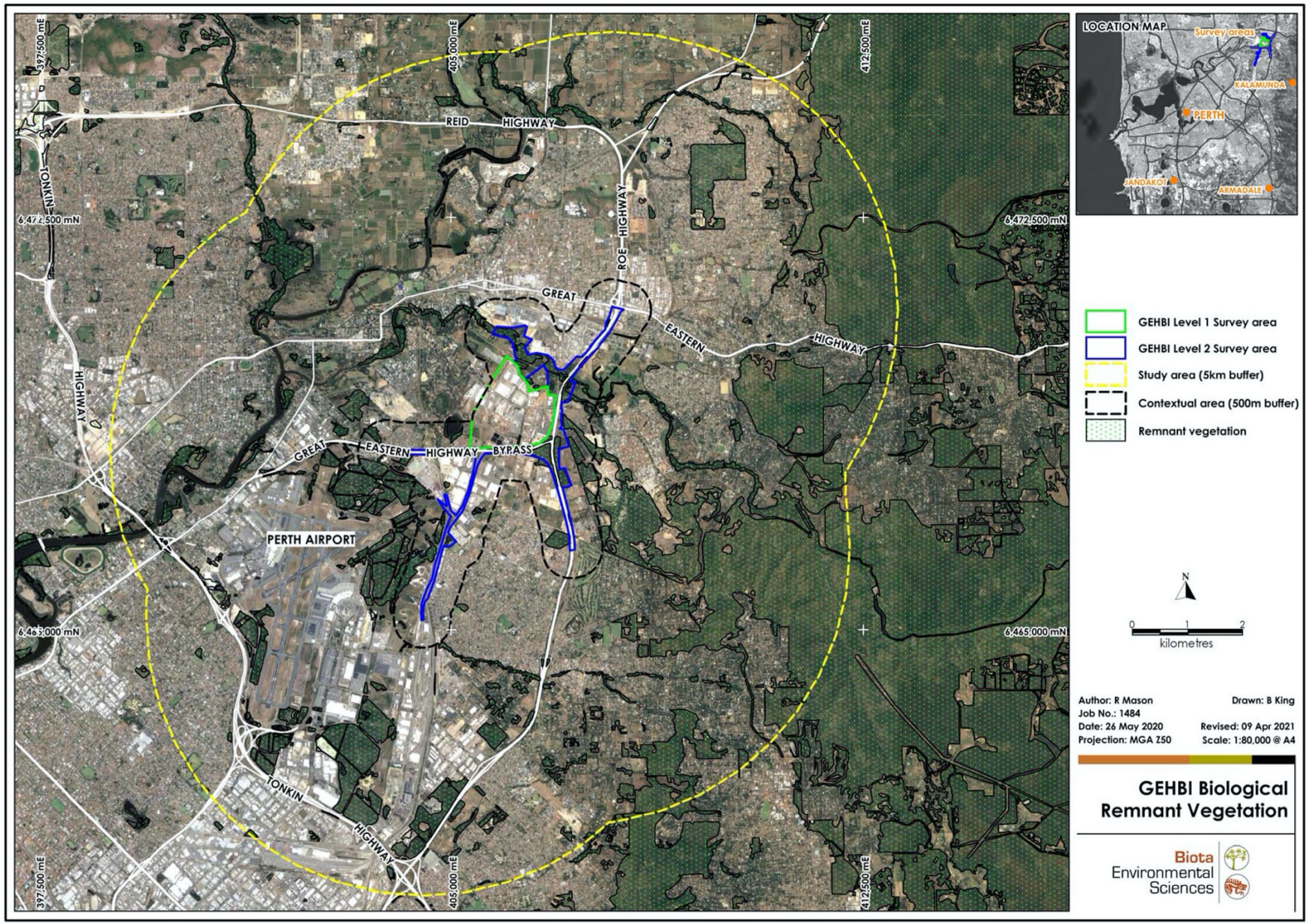

Figure 4.7: Remnant vegetation within the study area (DAFWA 2016).

4.8 Communities of Significance

4.8.1 Threatened and Priority Ecological Communities

Communities listed as TECs are of significance at the State level and are protected as ESAs under the EP Act. Twenty-five of the 69 TECs listed in WA are also nationally recognised and listed under the Commonwealth EPBC Act. The description, area, and condition thresholds that apply to any EPBC-listed TEC also apply to any corresponding equivalent State-listed PEC of the same name (DBCA 2021).

PECs are added to the DBCA's PEC list under Priorities 1 (highest priority), 2 and 3. Ecological communities that are: 1) adequately known; 2) rare but not threatened, or meet criteria for Near Threatened; or 3) have been recently removed from the Threatened list, are placed in Priority 4. Conservation dependent ecological communities are placed in Priority 5 (see Appendix 1).

The latest State listing of TECs (DBCA 2018) recognises 23 such communities from the Swan Coastal Plain bioregion. Fifteen of these TECs are listed under the EPBC Act.

Based on database search results, three Commonwealth-listed TECs (Figure 4.8) as well as two State-listed PECS and four State-listed TECS were identified as occurring within the study area (Figure 4.9).

The likelihood that each vegetation community would occur in the study area was then assessed (Table 4.7). The 'Clay pans of the Swan Coastal Plain' and 'Banksia Woodlands of the Swan Coastal Plain' Commonwealth TECs are also both listed as Priority PECs for WA, as Priority 1 and Priority 3 respectively. The 'Shrublands and Woodlands of the eastern Swan Coastal Plain' Commonwealth TEC is listed as Critically Endangered at the State level (as 'Shrublands and woodlands of the eastern side of the Swan Coastal Plain') and Endangered at the Commonwealth level.

Table 4.7: Threatened and Priority Ecological Communities identified during the desktop review and the likelihood that they would occur in the study area.

Community Name EPBC Act (State-level)	**Status**		**Likelihood of Occurrence**
	EPBC Act	**State-level**	
Clay pans of the Swan Coastal Plain (Claypans with mid dense shrublands of *Melaleuca lateritia* over herbs)	Critically Endangered	Priority 1	**May potentially occur**: potential suitable habitat.
(Herb rich saline shrublands in clay pans)	-	Vulnerable	**Occurs:** previously identified within the study area.
Banksia Woodlands of the Swan Coastal Plain (Banksia woodlands of the Swan Coastal Plain)	Endangered	Priority 3	**Occurs:** previously identified within the study area.
(Banksia attenuata woodland over species rich dense shrublands)	-	Endangered	**Occurs:** previously identified within the study area.
(Banksia attenuata and/or Eucalyptus marginata woodlands of the eastern side of the Swan Coastal Plain)	-	Endangered	**Occurs:** previously identified within the study area.
Shrublands and woodlands of the eastern Swan Coastal Plain (Shrublands and woodlands of the eastern side of the Swan Coastal Plain)	Endangered	Critically Endangered	**Occurs:** previously identified within the study area.

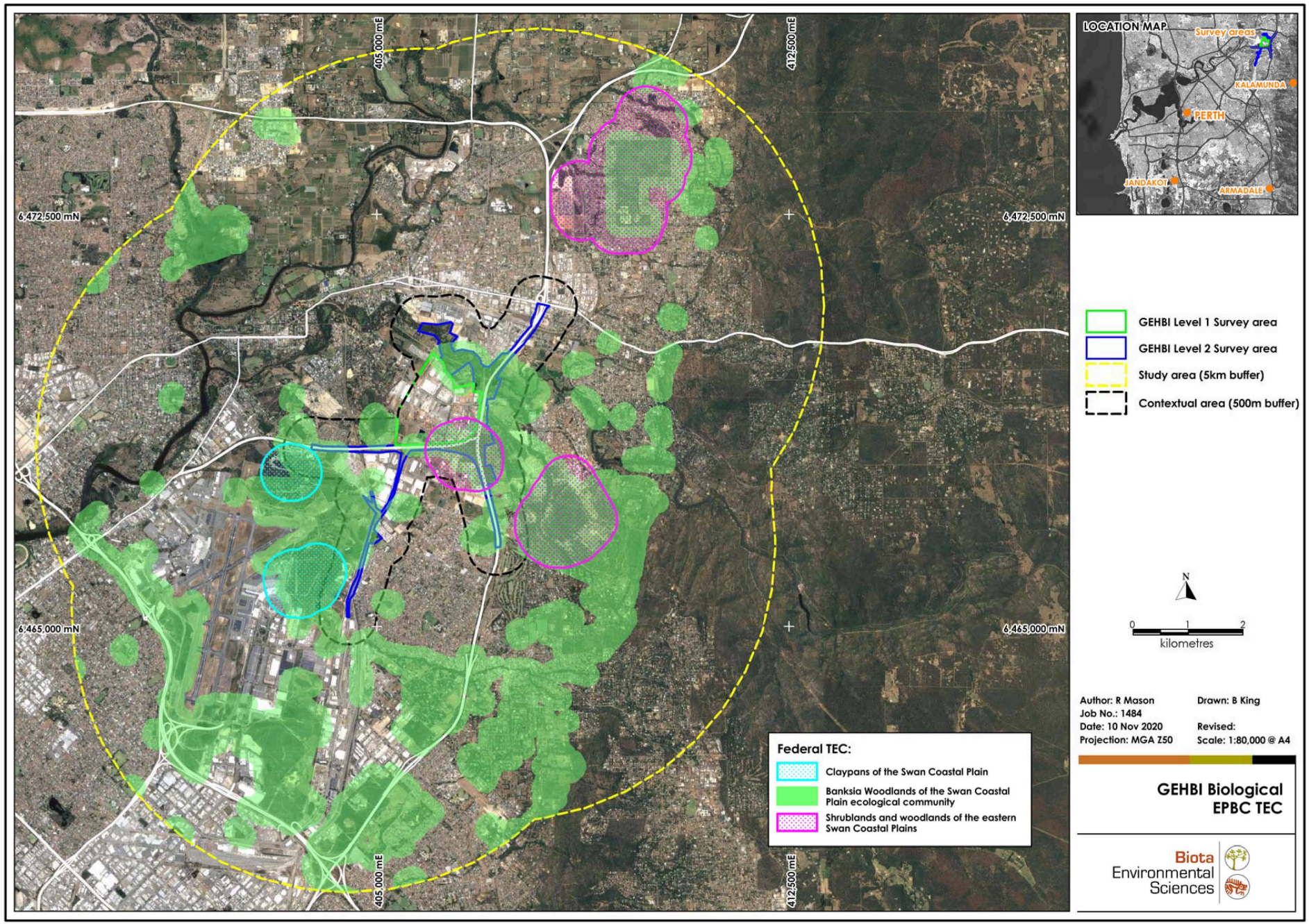

Figure 4.8: Records of Commonwealth TECs within the study area.

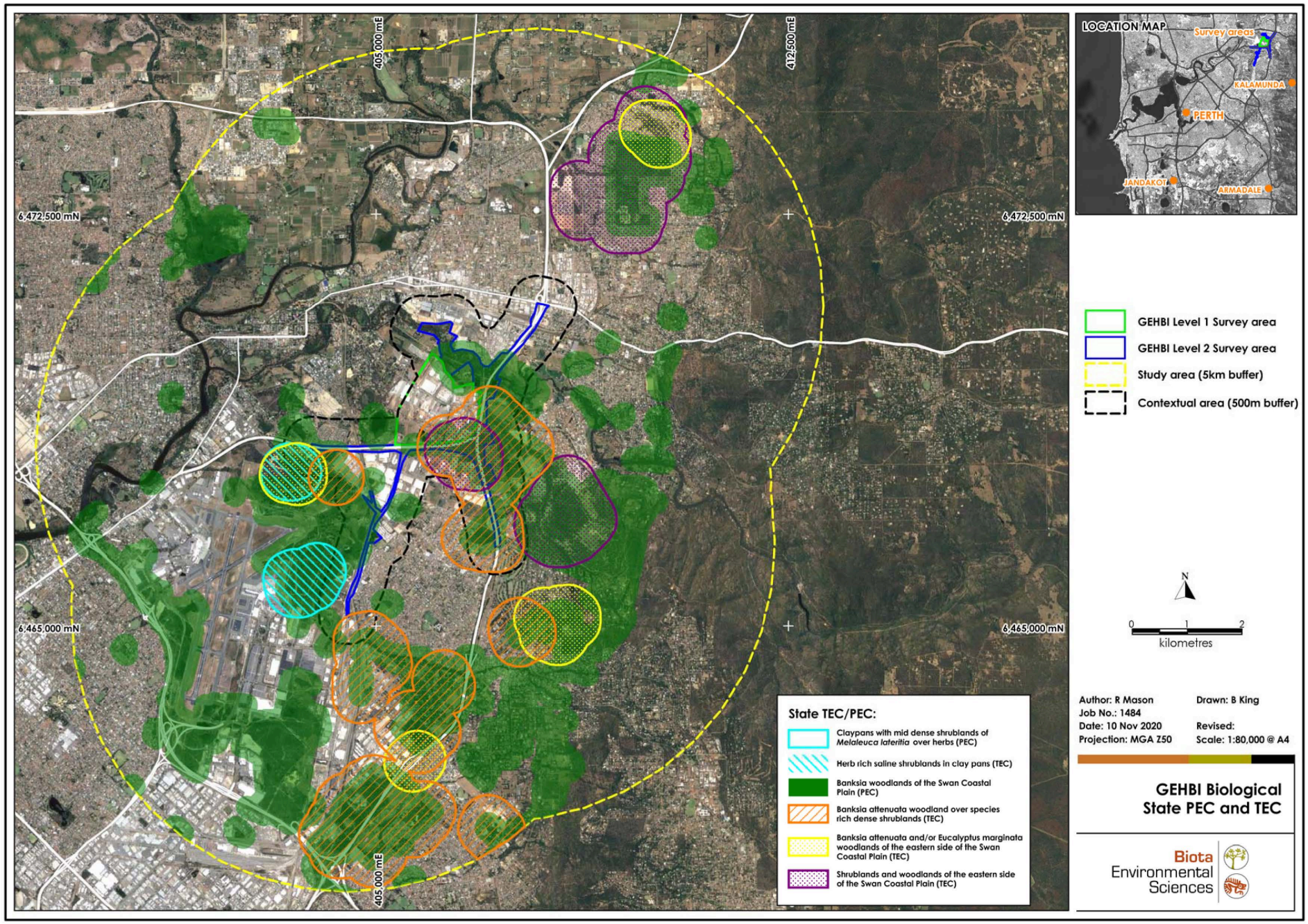

Figure 4.9 Records of State-listed TECs and PECs within the study area.

4.9 Significant Species Known from the Locality

4.9.1 Flora

A total of 24 Threatened flora species and 43 Priority flora species were identified through the desktop review as having been recorded from the study area or having the potential to occur (i.e. within 5 km of the survey area; see Appendix 4a). An assessment of the likelihood of occurrence of each of these species within the survey area was completed, based on the habitats and vegetation types known to be present, as well as the currency of records in close proximity.

Prior to the field survey it was identified that one Threatened species (*Conospermum undulatum*) and three Priority species (*Lepyrodia curvescens* – P2, *Isopogon autumnalis (*previously *Isopogon drummondii*) - P3 and *Schoenus griffinianus* – P4) were recorded previously in the survey area.

It was considered that 30 additional species had some potential to occur in the survey area, three of which were "likely to occur" and another 27 species "may potentially occur" (see Appendix 4a).

4.9.2 Vertebrate Fauna

A total of 280 native vertebrate species and eight introduced mammals were identified as potentially occurring in the locality of the survey area, based on the results of the desktop assessment (Table 4.8; Appendix 3).

Of these, 53 are State and Commonwealth-listed significant fauna species. Nineteen of the 43 significant bird species identified are listed as protected Marine fauna, despite being common and terrestrial-bound species. As such, these 19 species are not considered to be of genuine significance, or relevant to the assessment of the survey area, and are not described further. Appendix 4b presents the likelihood of occurrence of each non-Marine significant species that was determined through the desktop review.

This identified that one mammal, seven bird, and one reptile species of significance had either been recorded or had some potential to occur in the survey area (i.e. were "likely to occur" or "may potentially occur"). The potential occurrence of these species within the survey area was reassessed after taking into account the results of this survey.

Table 4.8: Vertebrate species identified from the desktop review.

Fauna Group	Number of Species
Amphibians	16
Reptiles	59
Avifauna	188
Native Mammals	17
Introduced Mammals	8
Total	**288**

The desktop study also identified three significant invertebrate species which may potentially occur within the study area. These species are reported in Appendix 4b but are outside of the scope of this survey and are not discussed further.

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5.0 Vegetation

5.1 Vegetation Types of the Survey Area

Vegetation types were mapped for the survey area utilising data from sampling sites and foot traverses, whilst vegetation mapping within the contextual area was based solely on extrapolation of those units identified within the survey area. Thirteen vegetation types were identified and described at the sub-association level within the survey area and contextual area, as discussed in Sections 5.1.1 to 5.1.13 below. Five other units not assessed as vegetation associations in the field were also identified and mapped; these comprised areas of Commercial/Residential Mixed Use, Private Property/Mixed Use, Planted/Revegetated, Cleared, and Bitumen Roads (see Sections 5.1.13 and 5.1.14).

Seven vegetation types were associated with wetlands or damplands within the survey area. Vegetation types P3 (Flooded Gum over Weedy Grasses on Floodplain) and P6 (Flooded Gum over Weedy Understorey on Riverbank) were associated with the Helena River. These vegetation types comprised a combined area of 36.8 ha and were in the north of the survey area. Vegetation type P8 (*Melaleuca* Low Open Forest over Weedy Understorey) and L3 (Marri over *Melaleuca* Low Open Woodland on Clay Pits) represent vegetation surrounding small lakes and clay pits, comprising 6.8 ha. Vegetation types L1 (*Melaleuca* over Sedges), L2 (Swamp Teatree over Sedges) and L4 (Mixed Sedge Dampland) are associated with seasonally damp areas and comprise 1.6 ha of the survey area.

Within the Level 1 survey area, the P1 vegetation type was the only intact vegetation identified, with a total area of 0.1 ha (Table 5.1).

The most widespread intact vegetation types in the Level 2 survey area were P3 (33.3 ha), P1 (19.9 ha) and P7 (12.1 ha). Similarly, in the survey and contextual areas combined, P1 (96.7 ha), P7 (61.9 ha) and P3 (50.0 ha) were the most widespread associations.

Maps showing the distribution of the 13 vegetation types and five other mapping units in the survey area and contextual area are presented in Appendix 9.

Table 5.1: Extent of the mapping units within the survey area and contextual area.

Mapping Unit Code: Description		Contextual Area (ha)	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Survey Area (ha)
Vegetation Types					
L1:	*Melaleuca* over Sedges	0.5	-	0.5	0.5
L2:	Swamp Teatree over Sedges	0.3	-	0.3	0.3
L3:	Marri over *Melaleuca* Low Open Woodland on Clay Pits	4.9	-	4.9	4.9
L4:	Mixed Sedge Dampland	0.7	-	0.7	0.7
L5:	*Jacksonia* over *Xanthorrhoea* with Sedges	0.9	-	0.9	0.9
P1:	*Allocasuarina* and *Banksia* over *Xanthorrhoea* with Sedges	96.7	0.1	19.8	19.9
P2:	Marri over *Kingia australis* with Sedges	6.0	-	3.1	3.1
P3:	Flooded Gum over Weedy Grasses on Floodplain	50.0	-	33.3	33.3
P4:	*Eremaea* Open Heath	0.4	-	0.4	0.4
P5:	Jarrah over *Xanthorrhoea* with Mixed Shrubs and Herbs	2.9	-	2.9	2.9
P6:	Flooded Gum over Weedy Understorey on Riverbank	17.9	-	3.5	3.5
P7:	Jarrah and *Banksia* over *Xanthorrhoea* with Sedges	61.9	-	12.1	12.1
P8:	*Melaleuca* Low Open Forest over Weedy Understorey	50.6	-	1.9	1.9
Modified Areas					
CR:	Commercial/Residential Mixed Use	778.9	134.4	0.5	134.9
PR:	Private Property/Mixed Use	189.4	3.0	8.2	11.2
RE:	Planted/Revegetated	93.2	2.8	46.0	48.9
Cleared Areas					
CL:	Cleared	180.7	21.7	20.3	41.9
RD:	Bitumen Roads	50.9	7.8	31.3	39.1
	TOTAL	**1,586.9**	**169.9**	**190.7**	**360.5**

5.1.1 L1: *Melaleuca* over Sedges

Vegetation Code	L1
Vegetation Sub-Association (NVIS Level VI)	U1+ ^Melaleuca rhaphiophylla, Melaleuca preissiana\Melaleuca\^tree\6\c; M1 ^Hakea varia, Jacksonia sternbergiana, Viminea juncea\Hakea\^shrub\6\r; G1 ^Lepidosperma striatum, Cyathochaeta avenacea, Lepidosperma longitudinale, Lyginia barbata\Lepidosperma\^sedge, rush\3,d; G2 ^Caesia sp. Wongan, Thysanotus dichotomous\Caesia\^forb\2\r
Vegetation Type Description	*Melaleuca rhaphiophylla, (Melaleuca preissiana)* low open forest over *Hakea varia, Jacksonia sternbergiana, (Viminaria juncea)* tall open shrubland over *Lepidosperma striatum, Cyathochaeta avenacea, Lepidosperma longitudinale, Lyginia barbata, (Lepidosperma oldhamii/calcicola, Lepyrodia muirii, Patersonia occidentalis)* closed sedgeland over *Caesia* sp. Wongan (K.F. Kenneally 8820), *Thysanotus dichotomus* very open herbland.
Distribution	This vegetation type (Plate 5.1) occurred in a very specific portion of the study area, in a low lying damp depression, east of Roe Highway and north of Helena Valley Road (see Appendix 9).
Quadrats	GBQ14
Vegetation Condition	Excellent.

Plate 5.1: Representative photographs of the L1 vegetation type.

5.1.2 L2: Swamp Teatree over Sedges

Vegetation Code	L2
Vegetation Sub-Association (NVIS Level VI)	M1 ^Adenanthos cygnorum\Adenanthos\^shrub\4\bc; M2+ ^Pericalymma ellipticum var. floridum, Verticordia densiflora var. densiflora, Melaleuca seriata\Pericalymma\^shrub\3\d; G1 ^Lyginia imberbis, Hypolaena exsulca\Lyginia\^sedge\2\i; G2 ^Ehrharta calycina, Pentameris airoides subsp. airoides, Vulpia bromoides\Ehrharta\^tussock grass\2\r; G1 ^Ursinia anthemoides\Ursinia\^forb\1\bc
Vegetation Type Description	*Adenanthos cygnorum* scattered tall shrubs over *Pericalymma ellipticum* var. *floridum, Verticordia densiflora* var. *densiflora, Melaleuca seriata* closed heath over *Lyginia imberbis, Hypolaena exsulca* open sedgeland over **Ehrharta calycina, *Pentameris airoides* subsp. *airoides, Vulpia bromoides* very open grassland over **Ursinia anthemoides* scattered herbs.
Distribution	This vegetation type (Plate 5.2) occurred in a very specific portion of the study area; a seasonally damp depression, south-west of the intersection of the Great Eastern Bypass and Roe Highway (see Appendix 9).

Quadrats	GBQ04
Vegetation Condition	Excellent.

Plate 5.2: Representative photographs of the L2 vegetation type.

5.1.3 L3: Marri over *Melaleuca* Low Open Woodland on Clay Pits

Vegetation Code	L3
Vegetation Sub-Association (NVIS Level VI)	U1 ^Corymbia calophylla\Corymbia\^tree\7\r; U2+ ^Melaleuca rhaphiophylla\Melaleuca\^tree\6\c; G1 ^Bromus diandrus, Briza maxima, Briza minor, Ehrharta calycina, Avena fatua\Bromus\^tussock grass\2\r; G2 ^Schoenus clandestinus, Juncus articulatus, Juncus capitatus, Isolepis cernua var. setiformis, Cycnogeton huegelii\Schoenus\^sedge, rush\2\c
Vegetation Type Description	*Corymbia calophylla* open woodland over *Melaleuca rhaphiophylla* low open forest over **Bromus diandrus, *Briza maxima,*Briza minor, *Ehrharta calycina, *Avena fatua* very open tussock grassland over *Schoenus clandestinus, *Juncus articulatus, *Juncus capitatus, Isolepis cernua* var. *setiformis* sedgeland over *Cycnogeton huegelii* scattered herbs.
Distribution	This vegetation type (Plate 5.3) occurred to the east and west of Military Road, in association with man-made clay pits (see Appendix 9).
Quadrats	GEHREL02
Vegetation Condition	Good to Degraded.

Plate 5.3: Representative photographs of the L3 vegetation type.

5.1.4 L4: Mixed Sedge Dampland

Vegetation Code	L4
Vegetation Sub-Association (NVIS Level VI)	G1+ ^Bolboschoenus caldwellii, Juncus bufonius, Typha domingensis\Bolboschoenus\^sedge,rush\3\c; G2 ^Isolepis prolifera, Cyperus alterniflorus, Bromus hordeaceus, Lotus subbiflorus\Isolepis\^rush, tussock grass, forb\2\r
Vegetation Type Description	*Bolboschoenus caldwellii*, **Juncus bufonius*, *Typha domingensis* tall sedgeland over *Isolepis prolifera*, *Cyperus alterniflorus* very open sedgeland over **Bromus hordeaceus* very open grassland over **Lotus subbiflorus* very open herbland.
Distribution	This vegetation type (Plate 5.4) occurred only in conjunction with a small low-lying modified area between the Helena River and Stirling Crescent (see Appendix 9).
Quadrats	GEHREL01
Vegetation Condition	Degraded.


Plate 5.4: Representative photographs of the L4 vegetation type.

5.1.5 L5: *Jacksonia* over *Xanthorrhoea* with Sedges

Vegetation Code	L5
Vegetation Sub-Association (NVIS Level VI)	M1 ^Jacksonia floribunda\Jacksonia\^shrub\6\bc; M2 ^Xanthorrhoea preissii, Melaleuca seriata\Xanthorrhoea\^grass-tree, shrub\3\r; G1 ^Ehrharta calycina, Pentameris pallida\Ehrharta\^tussock grass\2\bc; G2 ^Lyginia barbata, Lyginia imberbis\Lyginia\^sedge\2\i; G3+ ^Alexgeorgea nitens, Dasypogon bromeliifolius, Ursinia anthemoides\Alexgeorgea\^rush, forb\1\c
Vegetation Type Description	*Jacksonia floribunda* scattered tall shrubs over *Xanthorrhoea preissii*, *Melaleuca seriata* open shrubland over **Ehrharta calycina*, **Pentameris pallida* scattered grasses over *Lyginia barbata*, (*Lyginia imberbis*) open sedgeland over *Alexgeorgea nitens*, (*Dasypogon bromeliifolius*, **Ursinia anthemoides*) herbland.
Distribution	This vegetation type (Plate 5.5) occurred in one patch, south of the Great Eastern Bypass and east of Stirling Crescent (see Appendix 9).
Quadrats	GBQ02, GBQ29
Vegetation Condition	Good.


Plate 5.5: Representative photographs of the L5 vegetation type.

5.1.6 P1: *Allocasuarina* and *Banksia* over *Xanthorrhoea* with Sedges

Vegetation Code	P1
Vegetation Sub-Association (NVIS Level VI)	U1 ^Allocasuarina fraseriana\Allocasuarina\^tree\7\r; U2+ ^Eucalyptus todtiana, Banksia menziesii, Banksia attenuata\Eucalyptus\^tree\7\i; M1 ^Jacksonia floribunda\Jacksonia\^shrub\4\bc; M2 ^Xanthorrhoea preissii\Xanthorrhoea\^grass-tree\3\r; M3 ^Hibbertia hypericoides subsp. hypericoides, Bossiaea eriocarpa, Stirlingia latifolia, Scaevola repens var. repens\Hibbertia\^shrub\2\r; G1 ^Mesomelaena pseudostygia, Lyginia barbata\Mesomelaena\^sedge\2\r; G2 ^Alexgeorgea nitens\^sedge\1\r
Vegetation Type Description	*Allocasuarina fraseriana* open woodland over *Eucalyptus todtiana*, *Banksia menziesii* (*Banksia attenuata*) low woodland over *Jacksonia floribunda* scattered tall shrubs over *Xanthorrhoea preissii* open shrubland over *Hibbertia hypericoides* subsp. *hypericoides*, *Bossiaea eriocarpa*, *Stirlingia latifolia*, *Scaevola repens* var. *repens* low open shrubland over *Mesomelaena pseudostygia*, *Lyginia barbata* very open sedgeland over *Alexgeorgea nitens* very open herbland.
Distribution	This vegetation type (Plate 5.6) occurred throughout the survey and contextual area. Within the survey area, the largest patches surrounded the intersection of Roe Highway and the Great Eastern Bypass. In the contextual area, the largest patch occurred adjacent to Old Midland Road (see Appendix 9).
Quadrats	GBQ01, GBQ06, GBQ08, GBQ15, GBQ19, GBQ23, GBQ24, GBQ26, GBQ28, GBQ31, GEHREL12, GEHREL15
Vegetation Condition	Excellent to Degraded, with the majority considered Very Good.


Plate 5.6: Representative photographs of the P1vegetation type.

5.1.7 P2: Marri over *Kingia australis* with Sedges

Vegetation Code	P2
Vegetation Sub-Association (NVIS Level VI)	U1 ^Corymbia calophylla\Corymbia\^tree\6\r; M1 ^Kingia australis\Kingia\^grass-tree\4\r; M2 ^Xanthorrhoea preissii\Xanthorrhoea\^grass-tree\3\r; M3+ ^Verticordia densiflora, Banksia dallanneyi var. dallanneyi, Stirlingia latifolia\Verticordia\^shrub\3\i; G1 ^Caustis dioica, Mesomelaena pseudostygia, Mesomelaena tetragona, Lyginia imberbis, Patersonia occidentalis var. occidentalis\Caustis\^sedge, forb\3\i; G2 ^Alexgeorgea nitens, Desmocladus fascicularis\Alexgeorgea\^sedge\1\r
Vegetation Type Description	*Corymbia calophylla* low open woodland over *Kingia australis* tall open shrubland over *Xanthorrhoea preissii* open shrubland over *Verticordia densiflora*, *Banksia dallanneyi* var. *dallanneyi*, *Stirlingia latifolia* low shrubland over *Caustis dioica*, *Mesomelaena pseudostygia*, *M. tetragona*, *Lyginia imberbis*, *Patersonia occidentalis* var. *occidentalis* open sedgeland over *Alexgeorgea nitens*, *Desmocladus fasciculatus* very open herbland.
Distribution	This vegetation type (Plate 5.7) occurred in only one patch within the survey area, situated between patches of P1, near the intersection of Roe Hwy and the Great Eastern Bypass (see Appendix 9).
Quadrats	GBQ05, GBQ07, GBQ25, GBQ27, GBQ30
Vegetation Condition	Excellent to Very Good.


Plate 5.7: Representative photographs of the P2 vegetation type.

5.1.8 P3: Flooded Gum over Weedy Grasses on Floodplain

Vegetation Code	P3
Vegetation Sub-Association (NVIS Level VI)	U1+ ^Eucalyptus rudis subsp. rudis\Eucalyptus\^tree\7\c; G1 ^Bromus diandrus, Avena fatua, Ehrharta longiflora\Bromus\^tussock grass\3\c; G2 ^Fumaria capreolata\Fumaria\^forb\2\c
Vegetation Type Description	*Eucalyptus rudis* subsp. *rudis* open forest over **Bromus diandrus*, **Avena fatua*, **Ehrharta longiflora* grassland over **Fumaria capreolata* herbland.
Distribution	This vegetation type (Plate 5.8) occurred extensively in the northern part of survey area, surrounding the Helena River (see Appendix 9).
Quadrats	GBQ10, GBQ11, GBQ13, GEHREL08
Vegetation Condition	Degraded.

Plate 5.8: Representative photographs of the P3 vegetation type.

5.1.9 P4: *Eremaea* Open Heath

Vegetation Code	P4
Vegetation Sub-Association (NVIS Level VI)	M1 ^Jacksonia floribunda\Jacksonia\^shrub\4\bc; M2+ ^Eremaea pauciflora\Eremaea\^shrub\3\c; M3 ^Astroloma xerophyllum\Astroloma\^shrub\3\r; G1 ^Lyginia imberbis\Lyginia\^sedge\2\r
Vegetation Type Description	*Jacksonia floribunda* tall shrubs over *Eremaea pauciflora* open heath over *Astroloma xerophyllum* low open shrubs over *Lyginia imberbis* open sedgeland.
Distribution	This vegetation type (Plate 5.9) occurred in one small patch within the survey area, between patches of P1, south-west of the intersection (see Appendix 9).
Quadrats	GBQ03, GEHREL07
Vegetation Condition	Excellent to Very Good.

Plate 5.9: Representative photographs of the P4 vegetation type.

5.1.10 P5: Jarrah over *Xanthorrhoea* with Mixed Shrubs and Herbs

Vegetation Code	P5
Vegetation Sub-Association (NVIS Level VI)	U1+ ^Eucalyptus marginata subsp. marginata\Eucalyptus\^tree\7\c; M1 ^Adenanthos cygnorum, Xanthorrhoea preissii\Adenanthos\shrub, grass-tree\4\r; M2 ^Hibbertia hypericoides, Gompholobium tomentosum\Hibbertia\^shrub\3\bc; G1 ^Eragrostis curvula, Briza maxima\Eragrostis\^tussock grass\3\r; G2 ^Lyginia barbata, Lomandra preissii\^sedge, rush\2\bc; G1 ^Alexgeorgea nitens\Alexgeorgea\^sedge\1\i

Vegetation Type Description	*Eucalyptus marginata* subsp. *marginata* open forest over *Adenanthos cygnorum*, *Xanthorrhoea preissii* tall open shrubland over *Hibbertia hypericoides*, *Gompholobium tomentosum* scattered low shrubs over **Eragrostis curvula *Briza maxima* very open grassland over *Lyginia barbata*, *Lomandra preissii* scattered sedges over *Alexgeorgea nitens* open herbland.
Distribution	This vegetation type (Plate 5.10) occurred immediately east of Roe Highway, in the southern portion of the study area (see Appendix 9).
Quadrats	GBQ09, GBQ16, GEHREL09
Vegetation Condition	Very Good to Degraded, with the majority considered being Very Good.


Plate 5.10: Representative photographs of the P5 vegetation type.

5.1.11 P6: Flooded Gum over Weedy Understorey on Riverbank

Vegetation Code	P6
Vegetation Sub-Association (NVIS Level VI)	U1+ ^Eucalyptus rudis subsp. rudis\Eucalyptus\^tree\7\c; U2 ^Melaleuca rhaphiophylla\Melaleuca\^tree\6\r; G1 ^Ehrharta longiflora, Bromus diandrus\Ehrharta\^tussock grass\2\i; G1 ^Fumaria capreolata, Cycnogeton huegelii\Fumaria\^forb, rush\2\i
Vegetation Type Description	*Eucalyptus rudis* subsp. *rudis* open forest over *Melaleuca rhaphiophylla* low open woodland over **Ehrharta longiflora*, **Bromus diandrus* open grassland over **Fumaria capreolata*, *Cycnogeton huegelii* open herbland.
Distribution	This vegetation type (Plate 5.11) occurred only along the banks of the Helena River (see Appendix 9).
Quadrats	GEHREL05, GEHREL06, GEHREL13
Vegetation Condition	Degraded.


Plate 5.11: Representative photographs of the P6 vegetation type.

5.1.12 P7: Jarrah and *Banksia* over *Xanthorrhoea* with Sedges

Vegetation Code	P7
Vegetation Sub-Association (NVIS Level VI)	U1+ ^Eucalyptus marginata subsp. marginata, Banksia attenuata, Allocasuarina fraseriana, Banksia menziesii\Eucalyptus\^tree\7\r; M1 ^Xanthorrhoea preissii, Allocasuarina humilis\Xanthorrhoea\^shrub\4\r; G1 ^Dasypogon bromeliifolius, Hibbertia hypericoides, Bossiaea eriocarpa, Banksia dallanneyi var. dallanneyi\Dasypogon\^shrub\2\r; G2 ^Mesomelaena pseudostygia, Schoenus efoliatus, Alexgeorgea nitens\Mesomelaena\^sedge, rush\2\r
Vegetation Type Description	*Eucalyptus marginata* subsp. *marginata*, *Banksia attenuata*, *Allocasuarina fraseriana* and *Banksia menziesii* low open woodland over *Xanthorrhoea preissii*, *Allocasuarina humilis* open shrubland over *Dasypogon bromeliifolius*, *Hibbertia hypericoides*, *Bossiaea eriocarpa*, *Banksia dallanneyi* var. *dallanneyi* low open shrubland over *Mesomelaena pseudostygia*, *Schoenus efoliatus* very open sedgeland over *Alexgeorgea nitens* scattered herbs.
Distribution	This vegetation type (Plate 5.12) occurred on either side of Roe Highway, south of the intersection, in both the survey and contextual areas (see Appendix 9).
Quadrats	GBQ17, GBQ18, GBQ20, GBQ21, GBQ22, GEHREL11
Vegetation Condition	Excellent to Degraded, with the majority considered Very Good.


Plate 5.12: Representative photographs of the P7 vegetation type.

5.1.13 P8: *Melaleuca* Low Open Forest over Weedy Understorey

Vegetation Code	P8
Vegetation Sub-Association (NVIS Level VI)	U1+ ^Melaleuca rhaphiophylla, Melaleuca preissiana, Eucalyptus rudis subsp. rudis\Melaleuca\^tree\6\c; G1 ^Ehrharta longiflora, Bromus diandrus\Ehrharta\^tussock grass\2\r; G2 ^Fumaria capreolata, Sonchus oleraceus\Fumaria\^forb\2,c
Vegetation Type Description	*Melaleuca rhaphiophylla*, (*Melaleuca preissiana*, *Eucalyptus rudis* subsp. *rudis*) low open forest over **Ehrharta longiflora*, **Bromus diandrus* very open grassland over **Sonchus oleraceus*, **Fumaria capreolata* herbland.
Distribution	This vegetation type (Plate 5.13) occurred in small patches on the south of the Helena River within the survey area, and was inferred in three patches west of Abernethy Road, within the contextual area (see Appendix 9).
Quadrats	GBQ12, GEHREL10
Vegetation Condition	Excellent to Degraded.


Plate 5.13: Representative photographs of the P8 vegetation type.

5.1.14 Modified Areas

Three distinct categories of areas within both the survey and contextual areas (Appendix 9) were assessed as being modified and disturbed to some extent (Table 5.1). These areas comprised the following:

1. **CR**: Commercial/Residential Mixed Use

   These comprised areas utilised for commercial and/or residential infrastructure, totalling 134.9 ha (37.4 %) of the survey area, and extended into the contextual area (778.8 ha).

2. **PR**: Private Property/Mixed Use

   Areas of the survey area that constituted private property with mixed land uses, were given the 'PR' category i.e. Hillview Golf Course. Most patches consisted of low density commercial or residential areas with acreage, private buildings, exposed sands and scattered remnant trees, not forming a coherent vegetation type. Private Property/Mixed Use totalled 9.4 ha (2.6%) of the survey area, and extended into the contextual area.

3. **RE**: Planted/Revegetated

   A significant portion of the survey area (13.5%, 48.9 ha) comprised planted, revegetated or naturally regenerated patches of vegetation, particularly along roadsides. No coherent vegetation types could be discerned due to the ad-hoc nature of the plantings over consecutive years and the variable species selected, therefore no attempt was made to produce separate mapping units based on dominant species. Two sites, GEHREL03 and GEHREL04, were surveyed in revegetated areas. Planted/Revegetated areas extended into the contextual area.

5.1.15 Cleared Areas

Two distinct categories within both the survey and contextual areas (CL and RD), had been cleared for roads, dual-use paths or firebreaks (see Appendix 9).

1. **CL**: Cleared Areas

A total of 11.6% (41.9 ha) of the survey area was mapped and categorised as 'CL', which represents bare areas of ground that were devoid of native flora at the time of survey, predominantly as a result of historical and/or maintenance land clearing activities.

2. RD: Bitumen Roads

Land cleared for construction of roads was categorised as 'RD', and represented 10.7% (39.1 ha) of the survey area, and extended into the contextual area (50.9 ha).

5.2 Condition of the Vegetation Units

The condition of vegetation in the survey area and contextual area is presented in Appendix 11. The vegetation condition assessments were based on the ranking scale of Keighery (1994), which is equivalent to the scale utilised by the EPA (EPA 2016a). The rankings considered the degree of invasion by introduced flora (weeds), impact from historical and ongoing human activity, and the structural integrity of the vegetation (see Appendix 6).

No patches of vegetation within the survey area were considered to have a 'Pristine' condition ranking. Vegetation mapped as Cleared Areas (CL) were automatically assigned the 'Cleared' ranking, and areas of Revegetation (RE) were assigned a condition ranking of 'Degraded'.

Condition of the vegetation on the Level 1 survey area ranged from 'Good' to 'Completely Degraded', which was expected given that very little remnant vegetation remained intact (Table 5.2) due to historical clearing for industrial and commercial purposes, and the prevalence of weed species. Within the Level 2 survey area, vegetation condition ranged from 'Excellent' to 'Completely Degraded', with weed species being a dominant factor (Table 5.2).

Bitumen Roads (RD) and Commercial/Residential Mixed Use (CR) were not assessed for vegetation condition, nor were several areas of Private Property/Mixed use (e.g. Hillview Golf Course and surrounding property) within the contextual area, due to the nature of land use. These areas, in addition to the 'CL' classification, were collectively classified as 'Cleared' for the purposes of vegetation condition mapping, and constitute 59.9% of the total survey area (Table 5.2).

Numerous weed species were encountered across the survey area (see Section 6.5), and the locations recorded represent an underestimate of their extent. Dense patches of herbaceous weed species occurred through the entirety of the survey area along roadsides and cleared areas.

Table 5.2: Extent of vegetation condition categories within the survey area and contextual area.

Condition Ranking	Total Contextual Area (ha)	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Survey Area (ha)
Pristine	-	-	-	-
Excellent	1.1	-	1.1	1.1
Excellent-Very Good	61.8	-	8.6	10.2
Very Good	17.0	-	13.6	13.1
Very Good-Good	84.5	-	2.5	2.5
Good	72.7	1.7	20.7	21.3
Degraded	218.5	3.8	91.1	94.9
Completely Degraded	58.3	0.4	1.0	1.5
Cleared	1,072.8	163.9	52.1	216.0
TOTAL	**1,586.8**	**169.9**	**190.7**	**360.5**

5.3 Results of the Floristic Analysis

5.3.1 Identification of TECs and PECs

Hierarchical clustering analyses were conducted using PATN v4 (Belbin 2020), to assist with determining which FCTs described by Gibson et al. (1994) were equivalent to the vegetation types in the survey area. No FCTs associated with the Claypans TEC were identified through these analyses. Floristic community types that occur on the Swan Coastal Plain and have relationships to the 'Banksia Woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC are listed in Table 5.3 below.

Table 5.3: Floristic community types that occur on the Swan Coastal Plain and have relationships to the 'Banksia Woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC (DotEE 2016).

Floristic Community Type Name	Floristic Community Type (Gibson et al. 1994)	State Listing
Banksia attenuata woodlands over species rich dense shrublands	FCT 20a	Threatened (Endangered)
Eastern *Banksia attenuata* and/or *Eucalyptus marginata* woodlands	FCT 20b	Threatened (Endangered)
Eastern shrublands and woodlands	FCT 20c	Threatened (Critically Endangered)
Central *Banksia attenuata - Eucalyptus marginata* woodlands	FCT 21a	–
Southern *Banksia attenuata* woodlands	FCT 21b	Priority 3
Low lying *Banksia attenuata* woodlands or shrublands	FCT 21c	Priority 3
Banksia ilicifolia woodlands	FCT 22	Priority 3
Central *Banksia attenuata - Banksia menziesii* woodlands	FCT 23a	–
Northern *Banksia attenuata - Banksia menziesii* woodlands	FCT 23b	Priority 3
North-eastern *Banksia attenuata - Banksia menziesii* woodlands	FCT 23c	–
Northern Spearwood shrublands and woodlands	FCT 24	Priority 3
Southern *Eucalyptus gomphocephala – Agonis flexuosa* woodlands	FCT 25	Priority 3
Spearwood *Banksia attenuata* or *Banksia attenuata* - Eucalyptus woodlands	FCT 28	–
Banksia attenuata woodlands over dense low shrublands	FCT S9	–

Analyses utilised the Swan Coastal Plain survey by Gibson et al. (1994) together with the presence/absence data from those quadrats and relevés sampled during the current survey potentially representing a TEC/PEC. The floristic analysis placed these sites within the following FCTs:

- FCT 5 (Mixed Shrub Damplands) – quadrat GBQ04;
- FCT 6 (Weed dominated wetlands on heavy soils) – quadrat GBQ23 and relevé GEHREL15;
- FCT 21c (Low lying *Banksia attenuata* woodlands or shrublands) – quadrat GBQ22;
- FCT 20a (*Banksia attenuata* woodlands over species rich dense shrublands) – quadrats GBQ15, GBQ17, GBQ18, GBQ19, GBQ21 and relevé GEHREL11;
- FCT 20c (Eastern shrublands and woodlands) – quadrat GBQ07, GBQ27, GBQ30;
- FCT23a (Central *Banksia attenuata-B. menziesii* woodlands) – quadrats GBQ02, GBQ05, GBQ06, GBQ08, GBQ09, GBQ24, GBQ25, GBQ28, GBQ29, GBQ31 relevé GEHREL12; and
- FCT28 (Spearwood *Banksia attenuata* or *Banksia attenuata – Eucalyptus* woodlands) – quadrats GBQ01, GBQ20, GBQ26.

A summary of the determinations of floristic groupings is provided in Table 5.4, with further explanation provided below for those that correspond to FCTs associated with TECs and/or PECs. Quadrats that have been resampled are denoted with an 'R', e.g. 'GBQ04R' (Table 5.4), and analysis applies to both phases of data. Extracts of the dendrograms of the SSI process are provided in Figures 1 to 26 in Appendix 12. A table summarising the data from the 20 most similar sites (NNB analysis) is provided in Table 2 of Appendix 12, along with a list of species that were omitted for the analysis (Table1).

FCT 21c (Low lying *Banksia attenuata* woodlands or shrublands)

The results of the UPGMA classification initially grouped quadrat GBQ22 with the FCT 6 cluster, however the broader secondary grouping of FCT 21c was considered more accurate due to the presence of *Banksia menziesii*, *Thysanotus manglesianus* and *Gompholobium tomentosum* as typical species of FCT 21c. In addition, the most similar site to GBQ22 from the NNB analysis was from the FCT 21c group, further supporting the assignment of GBQ22 to FCT 21c (Table 5.4). This FCT has a relationship to the 'Banksia Woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC and is also listed as a Priority 3 PEC at State level (see Table 5.3).

FCT 20a (*Banksia attenuata* woodlands over species rich dense shrublands)
Five quadrats and one relevé (GBQ15, GBQ17, GBQ18, GBQ19, GBQ21 and GEHREL11) were considered to align with FCT 20a (Table 5.4). GBQ15, GBQ17, GBQ21 and GEHREL11 were most closely grouped with FCT 20a by both the UPGMA classification and the NNB analysis. GBQ18 was most closely grouped with sites from FCT 20a by the UPGMA classification, and when focused on the 20 most similar sites for NNB analysis, sites representing FCT 20a were the most common. Quadrat GBQ19 clustered broadly with sites within the FCT 20 group (a, b and c) under the UPGMA classification, and FCT 20a and FCT 20c were most common from the 20 site NNB analysis. The presence of dominant species from GBQ19, including *Banksia attenuata*, more accurately reflect FCT 20a rather than FCT 20c (Gibson et al. 1994). FCT 20a is related to the 'Banksia Woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC and is also listed as 'Endangered' at State level (see Table 5.3).

FCT 20c (Eastern shrublands and woodlands)
Three quadrats were considered to align with FCT 20c (Table 5.4). Quadrat GBQ07 was most closely grouped with FCT 4 through the UPGMA classification, however it more broadly grouped with FCTs 20b and 20c, which is more appropriate given the high species richness of the site (Table 5.4). Through NNB analysis, the two most similar reference sites were from FCT 20c, as well as this being the most common FCT within the 20 most similar sites, therefore FCT20c was assigned to GBQ07.

After the additional sampling effort in November 2020, Quadrats GBQ27 and GBQ30 were also assigned to FCT 20c:

- Quadrat GBQ27 grouped with FCT 21c through UPGMA, then more broadly with FCTs 20a, 20b and 20c. Six of 20 reference sites most similar to GBQ27 were FCT 20c. That, plus previous mapping by DBCA in the area, supports this FCT assignment.
- GBQ30 was nearest to reference site talb9 (FCT 20c) for NNB analysis, and also grouped with talb9 for UPGMA clustering, supporting the FCT 20c assignment.

FCT20c is related to the 'Banksia Woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC, and is also listed as 'Critically Endangered' at State level (see Table 5.3). In addition, it is listed as the 'Shrublands and Woodlands of the Eastern Swan Coastal Plain' Commonwealth TEC (see Section 4.8.1 and Table 4.7).

FCT 23a (Central *Banksia attenuata-B. menziesii* woodlands)
Ten quadrats and one relevé (GBQ02, GBQ05, GBQ06, GBQ08, GBQ09, GBQ24, GBQ25, GBQ28, GBQ29, GBQ31 and GEHREL12) were assessed as representing FCT 23a (Table 5.4). Quadrats GBQ06 and GBQ09 both broadly clustered with FCT 23a in the UPGMA classification, which was also supported by the NNB analysis. The results of the UPGMA classification for three quadrats and one relevé (GBQ02, GBQ05, GBQ08 and GEHREL12) were varied and inconclusive. For these sites, the NNB analysis was relied upon to determine classification of the most appropriate FCT. The most similar sites to GBQ02 and GBQ08 through NNB analysis were from FCT 23a, and sites from FCT 23a were also the most common. The sites most similar to GBQ05 were varied with their FCT classification, however NNB analysis shows that sites from FCT 23a were most common, when focused on the 20 most similar sites. GEHREL12 joined with sites from FCT 20a in the UPGMA classification, but due to the number of weed species contained within this site, FCT 20a was not considered appropriate classification. GEHREL11 was assigned the FCT 23a classification through NNB analysis, where FCT 23a was most common of the first 10 most similar sites.

Additional sampling was undertaken in November 2020 in an effort to confirm the FCT assignment of areas mapped as FCT23a. Alongside PATN analysis, the species listed in 'Remnant Vegetation on the Alluvial Soils of the Eastern Side of the Swan Coastal Plain' (Keighery and Trudgen 1992), plus an additional suite of indicator species including *Jacksonia lehmannii*, *Cristonia biloba* and *Bossiaea eriocarpa* (large leaf form), were used in an attempt to differentiate between FCT 23a and FCT 20a in situ, and in conjunction with site data (Val English, DBCA, pers. comm. 2020). These species were taken into consideration, along with the results of UPGMA clustering and NNB analysis.

The results of UPGMA clustering for GBQ24, GBQ25, GBQ29 and GBQ31 were somewhat inconclusive, but these November 2020 quadrats were most commonly associated with FCT 23a reference sites in the NNB analysis. Quadrat GBQ28 clearly aligned to FCT 23a through both clustering and NNB analyses. It is considered that GBQ24, GBQ25, GBQ28, GBQ29 and GBQ31 most probably align with FCT 23a. FCT 23a has a relationship to the 'Banksia Woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC (see Table 5.3).

FCT28 (Spearwood *Banksia attenuata* or *Banksia attenuata – Eucalyptus* woodlands)
Quadrats GBQ01 and GBQ20 were considered to align with FCT 28 (Table 5.4). GBQ01 neatly clustered with all FCT 28 sites through the UPGMA classification and this was supported by the NNB analysis, where the most similar reference site to GBQ01 (and the most common) belonged to FCT 28. Results of the UPGMA classification for GBQ20 were inconclusive, however through NNB analysis, the most similar site was FCT 28, and also the most common when considering the 20 most similar sites.

Further sampling undertaken in November 2020 and subsequent clustering analyses confirmed that GBQ26 aligns with FCT 28, rather than FCT 23 or FCT 20a as predicted during an in-situ visual inspection (Val English, DBCA, pers. comm. 2020). Using UPGMA clustering, GBQ26 paired with reference site KING-1 (FCT 28) and clustered with 27 other reference sites, all of which are from FCT 28. KING-2 (FCT 28) was also the most similar site to GBQ26 using NNB analysis. Both KING-1 and KING-2 are situated approximately 17 km west of GBQ26. Additional indicators including typical species and mean species richness factors from Gibson et al. (1994) were also considered when arriving at this determination. GBQ26 contained *Banksia attenuata, Hibbertia hypericoides* subsp. *hypericoides, Mesomelaena pseudostygia* and *Trachymene pilosa*, all typical FCT 28 species. The species richness from GBQ26 (51 species), was similar to the mean of FCT 28 sites at 55 species, whereas sites representing FCT 20a and FCT23 typically contained a mean of 67.4 species and 62.8 species respectively (Gibson et al. 1994). FCT 28 has a relationship to the 'Banksia Woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC (see Table 5.3).

Table 5.4 Summary of floristic community types identified by the current study.

Quadrat	FCT from Flexible UPGMA	Comments on the UPGMA Classification	FCTs of the 20 Most Similar sites from NNB Analysis	Comments on the NNB Analysis	Most Probable FCT
GBQ01	28	GBQ01 joined the cluster of 38 sites exclusively within FCT 28.	20a, 20c, 21a, 21c, 23a, 28	Most similar site is from FCT 28 which is also the most common FCT.	FCT 28
GBQ02R	21a, 21b, 21c	GBQ02R joined closest to FCT 21a sites YULE-3, TWIN-7 and TWIN-8, however clustered more broadly with FCT 21c as a result of shared dominant species. Inconclusive.	6, 28, 20a, 20c, 21a, 21c, 23a, 23b	Most similar site is from FCT 23a, which is also the most common FCT. Contains *Banksia menziesii, Bossiaea eriocarpa, Dampiera linearis* and *Leucopogon conostephioides,* supporting FCT 23a rather than FCT 21 group.	FCT 23a
GBQ04R	5, 6, 11	GBQ04R grouped closest to sites from FCT 5.	4, 5, 6, 11, 20c, 28	Most similar sites is from FCT 6, however 60% of the 10 nearest sites and 55% of the 20 NNB sites are represented by FCT 5.	FCT 5
GBQ05R	4, 5, 6, 21c	GBQ05R most similar to FCT 4 site FL-1, however clusters broadly with FCTs 5, 6 and 21c. Inconclusive.	3a, 4, 20a, 20b, 20c, 21a, 21c, 22, 23a, 23a	Most similar site is from 3a. Has been previously mapped as 20c. The NNB analysis shows FCT supergroup 23a/23b are the most common. No *Banksia* species in quadrat but present in surrounds. Surrounding vegetation classified as FCT 23a.	FCT 23a with affinity to FCT 23b
GBQ06	20a, 20c, 21c, 23a, 23b	GBQ06 joined closest to FCT 20a site M53, however clustered more broadly with FCTs 23a and 23b as a result of shared dominant species.	20a, 20c, 21c, 23a, 23b, 28	Most similar site is from FCT 23a, which is also the most common FCT.	FCT 23a
GBQ07R	4, 20a, 20b, 20c, 21c	GBQ07R is most similar to FL-1 (FCT 4), which clustered within FCT 21c sites YULE-3, TWIN-7 and TWIN-8. However, overall, GBQ07 clustered more broadly with FCT 20b and FCT 20c as a result of shared dominant species.	3a, 3b, 4, 20a, 21a, 20c, 21c, 28, 23a	FCT is varied but the most similar site is from FCT 20c, which is also the most common FCT.	FCT 20c
GBQ08R	20a, 3b, 20b 20c	GBQ08R joined closest to FCT 20a site M53, then more broadly with FCTs 20b, 20c and also 3b. Inconclusive.	20a, 20c, 21b, 23a, 28	GBQ08 is most similar to KOON-1 from FCT 20a, however 80% of the 10 nearest sites and 50% of the 20 NNB sites are represented by FCT 23a.	FCT 23a
GBQ09R	20a, 20c, 21c, 23a, 23b	GBQ09R joined closest to FCT 20a site M53, then more broadly with FCTs 23a and 23b, which represented the majority of sites.	20a, 21a, 23a, 23b, 28	GBQ09 is most similar to sites from FCT 23a, with 50% of the 20 NNB sites represented by FCT 23a.	FCT 23a
GBQ15	20a, 20b,20c, 3b,	GBQ15 grouped closest to sites from FCT 20a.	20a, 20c, 21a, 23a, 28	FCT varied. Most similar sites were from FCT 23a, however dominant shrub layer more similar to FCT 20a.	FCT 20a

Quadrat	FCT from Flexible UPGMA	Comments on the UPGMA Classification	FCTs of the 20 Most Similar sites from NNB Analysis	Comments on the NNB Analysis	Most Probable FCT
GBQ17	20a, 20b, 20c	GBQ17 clustered closest with sites from FCT 20a, however overall groupings are distributed evenly between FCTs 20a, 20b and 20c.	3b, 20a, 20b, 20c, 21a, 23a, 28	Most similar site is from FCT 20a and 50% if the 10 NNB sites are 20a. Of the 20 most similar sites through NNB analysis, FCT 20b is the most common.	FCT 20a: affinity with 20b
GBQ18	20a, 20b, 20c, 21a, 21b, 21c, 22, 23a, 23b, 28	GBQ18 clustered closely with sites from FCT 20a, however more broadly, GQB18 is grouped most commonly with sites from FCT 23b.	20a, 20b, 20c,21a, 23a, 28	Most similar site is from FCT 20c, however the most common FCT overall is FCT 20a.	FCT 20a
GBQ19	21a, 20a, 20c, 23a, 24, 28	The most similar site to GBQ19 is FL-4 (FCT 21a), however more broadly, 96% of sites occurred in FCTs 20a, b or c.	20a, 20c, 20b, 21a, 23a, 24, 28	Most similar site is from FCT 28, however the most common groupings occurred in sites associated with FCT 20a or 20c. Dominant species most accurately reflect FCT 20a.	FCT 20a
GBQ20	21c,21a, 21b	GBQ20 joined with Twin-7 and Twin-8 of FCT 21c, however more broadly grouped with FCT 21a sites. Inconclusive.	20a, 20c, 21a, 21c, 24, 28	Most similar site is from FCT 28, which is also the most common FCT.	FCT 28
GBQ21	20a, 20b, 20c	GBQ21 joined closely with sites within FCT 20a.	20a, 20b, 20c, 21a, 23a, 24, 28	Most similar site is from FCT 20a, which is also the most common FCT.	FCT 20a
GBQ22	4, 5,6, 21c	The most similar sites to GBQ22 were card-11 and card-4 (FCT 6). More broadly, FCTs 4,5 and 21c were also included in the groupings.	6, 20a, 20c, 21a, 21c, 23a, 24, 28	Most similar site is from FCT 21c, which is also the most common FCT in the 10 NNB analysis. FCT 21a is the most common overall, however not strongly so.	FCT 21c
GBQ23	6	GBQ23 clustered with all FCT 6 sites due to number of weed species.	4, 6, 20c, 21a, 21c, 22, 23a, 23b, 24, 28	Most similar site is from FCT 6.	FCT 6
GBQ24	20a, 20b, 20c, 28, 21c	GBQ24 grouped closest to BULL-10 and BULL-11 (FCT 28). At the next level of clustering, GBQ24 is grouped with sites from FCT 20c, and more broadly with FCT 20a and FCT 20b. Inconclusive.	20a, 21b, 20c, 23a, 23b, 28	The most similar site to GBQ24 is BULL-11 (FCT28), however sites from FCT 23a were the most common (70% of the 10 most similar sites are FCT 23a as well as 45% of the 20 most similar sites).	FCT 23a with affinity to FCT 28.
GBQ25	4, 5, 21c	GBQ25 paired to FCT 4 site FL-1, within a FCT 21c cluster. Inconclusive.	3a, 3b, 4, 20b, 20c, 21c, 23a, 28	FL-1 (FCT 4) is the most similar site to GBQ25. Has been previously mapped as FCT 20c, however only one of the 20 most similar sites represents FCT 20c. FCT 23a is the most common through NNB analysis.	FCT 23a
GBQ26	28	GBQ26 paired with KING-1 (FCT 28) and clustered with 27 other sites exclusively from FCT 28.	20a, 20c, 21a, 21c, 23a, 28	GBQ26 is most similar to KING-2 (FCT28). Sites from FCT 23a were the most common, however not strongly so. When considering UPGMA groupings, strong support for FCT 28 can be found.	FCT 28

Quadrat	FCT from Flexible UPGMA	Comments on the UPGMA Classification	FCTs of the 20 Most Similar sites from NNB Analysis	Comments on the NNB Analysis	Most Probable FCT
GBQ27	20a, 20b, 20c, 21c	GBQ27 paired with YULE-3 (FCT 21c), which clustered within 9 sites from FCT 20c, and more broadly with FCT 20a and 20b.	20c, 21a, 21c, 23c, 28	GBQ27 is most similar to FCT 23a site YULE-1, and FCT 23a is also the most common FCT. However, there is support for FCT 20c when considering UPGMA classification. The area has been previously mapped as such, and 6 of the 20 most similar sites to GBQ27 represent this FCT.	FCT 20c
GBQ28	23a, 23b	GBQ28 is grouped closest to YULE-1 and YULE-2 (FCT 23a) and more broadly to additional sites representing FCT 23a.	21a, 23a, 23b, 28	GBQ28 is most similar to sites from FCT 23a, with 80% of the 10 NNB sites and 55% of the the 20 NNB sites represented by FCT 23a.	FCT 23a
GBQ29	20a, 20b, 20c, 21c	GBQ29 paired to YULE-3 (FCT 21c) and is grouped closest to other sites within FCT 21c. The next closest grouping contained sites from FCT 20c and then more broadly with FCT 20a and FCT 20b. Inconclusive.	20c, 21a, 23a, 23b, 28	GBQ29 is most similar to talb7 (FCT 20c). However the majority of sites (60%) represent the FCT 23a/b supergroup. *Banksia menziesii* is dominant in the tree layer, supporting the FCT 23a classification, rather than the FCT 20 supergroup, in which this tree species is absent.	FCT 23a
GBQ30	20a, 20b, 20c, 21c	GBQ30 clustered closest to talb08 and talb09 (FCT 20c). Overall GBQ30 grouped with 7 sites from FCT 20a, 9 from FCT 20b and 9 from FCT 20c.	3a, 4, 20c, 21c, 23a	GBQ30 is most similar to talb9 and talb8 (FCT 20c). Whilst FCT 23a is most common of the 20 nearest sites to GBQ30, support can be found for FCT 20c when considering UPGMA clustering.	FCT 20c
GBQ31	20a, 20b, 20c	GBQ31 paired with M53 (FCT 20a), within a FCT 20a cluster. At a broader level of clustering, 9 sites from FCT 20b and 9 sites from 20c are included.	20a, 20b, 21a, 21cb, 21c, 23a, 23b	GBQ31 was most similar to AUSTRA-1 (FCT21a). Overall, multiple FCTs shared similarity the GBQ31, with FCT supergroup 23(a/b) being dominant, but not strongly so. Due to the 'Degraded' vegetation condition of GBQ31, FCT 20a is not considered an appropriate FCT assignment.	FCT 23a; with affinity to 23b
GEHREL11	20a, 20b, 20c	GEHREL11 clusters closest to sites representing FCT 20a.	20a, 20c, 21a, 23a, 23b, 28	Most similar site is from FCT 20a, which is also the most common FCT.	FCT 20a
GEHREL12	20a, 20b, 20c	GEHREL12 clusters closest to sites representing FCT 20a.	20a, 21a, 21c, 23a, 23b, 24, 28	Most similar site is FCT 24, however when considering the first 10 nearest sites, FCT 23a is the most common; in NNB 20 FCT 23b is most common overall. Due to the level of weed species present, FCT 20a is not considered appropriate.	FCT 23a; with affinity to 23b
GEHREL15	6	GEHREL15 clustered with all FCT6 sites due to number of weed species.	6, 21a, 21c, 23a, 24, 28	Inconclusive.	FCT 6

5.3.2 Validation of Vegetation Types

A separate floristic analysis was completed to validate the vegetation types determined during mapping and used only those sites from the current survey. The dendrogram and NMDS plot are provided below (see Figure 5.1 and Figure 5.2; Appendix 13). Table 1 in Appendix 13 lists taxa that were omitted or treated as other taxa for the purposes of the floristic analysis. Table 2 in Appendix 13 summarises the key species contributing the greatest amount to the similarity of sites in each floristic group based on cover.

There was relatively good congruence between the number of the vegetation types identified on the basis of structure and dominant species and the floristic groups identified through the PRIMER analyses. Based on the analyses of sites from the current survey, and using cover data (unless otherwise specified):

- Of the 18 floristic groups identified, 13 floristic groups contained single sites. This was not unexpected, given the small size of the survey area, limiting opportunities to replicate all vegetation types encountered.
- As all Planted/Revegetation sites were assigned the same vegetation code despite significant variation in species composition, it was expected that there would be little similarity between these sites.
- Sites in vegetation types P3, P6, L3 and P8 occurred in a distinctly separate group to other sites (*FGr*), where *Eucalyptus rudis* subsp. *rudis* contributed the most towards clustering.
- All *Banksia* Woodland sites, and sites adjacent to *Banksia* woodland formed a distinct group at 10% similarity, based on percentage cover (see Figure 2, Appendix 13). Overlap at 25% is seen in vegetation types P1, P5, and P7, which all contain *Banksia* species.
- The majority of sites in P1 grouped at *FGo* on the basis of the presence of species such as *Banksia menziesii*, *Alexgeorgea nitens*, *Hibbertia hypericoides subsp. hypericoides* and *Adenanthos cygnorum* subsp. *cygnorum*. Two sites grouped at *FGb* by sharing *Eucalyptus todtiana, Banksia menziesii, Gompholobium tomentosum and Ursinia anthemoides* subsp. *anthemoides* as common dominant species. Two additional P1 sites grouped individually in *FGc* and *FGj* due to reduced vegetation condition and species diversity.
- Sites in the P5 vegetation type clustered together into *FGc*, where *Eucalyptus marginata* subsp. *marginata*, *Xanthorrhoea preissii*, *Alexgeorgea nitens* and *Lyginia barbata* contributed 63.7% to cumulative similarity (see Table 2 in Appendix 13).
- Of the six sites in vegetation type P7, 50% grouped into *FGn,* where *Banksia menziesii*, *Mesomelaena pseudostygia* and *Xanthorrhoea preissii* were dominant. The remaining three sites were placed in separate floristic groups (*FGk*, *FGl* and *FGm*). The overall similarity of sites mapped as P7 was 25%.
- GBQ03, GEHREL07, which comprise the P4 vegetation type, clustered neatly into *FGe*, where *Eremaea pauciflora* var. *pauciflora* contributed the most to similarity between sites.
- The sites in P2 vegetation type clustered into three separate floristic groups. One site grouped individually into *FGg*. GBQ27 and GBQ30 grouped into *FGh,* where *Caustis dioica* contributed the most toward cumulative similarity. GBQ05R and GBQ25 formed a group at *FGi,* where *Corymbia calophylla* was the dominant tree species.
- GEHREL01 (L4 vegetation type) and GEHREL04 (Revegetation) were grouped into *FGp* solely on the basis of the presence and similarity of the weed **Cynodon dactylon*, however they are clearly distinct groups based on the NMDS plot (see Figure 2, Appendix 13).

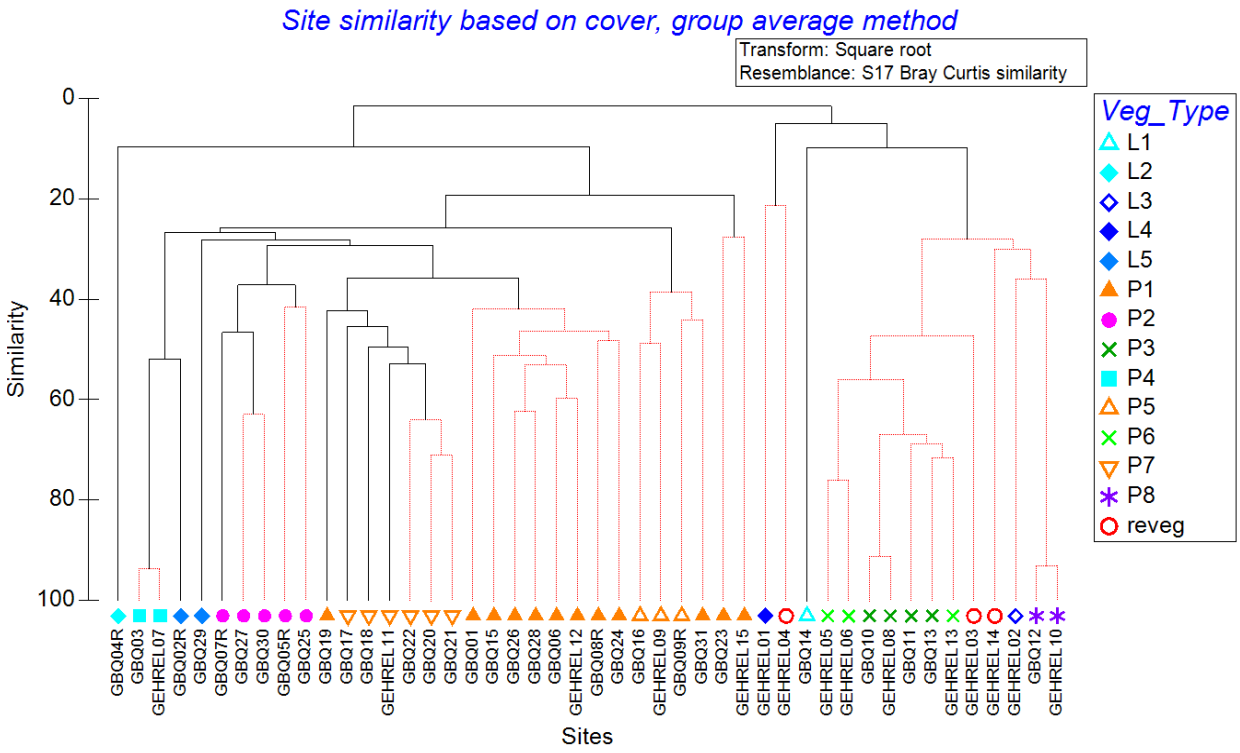

Figure 5.1: **Dendrogram from floristic clustering analysis of sites from the current survey (based on percent cover of all annual and perennial taxa, excluding singletons; coded by vegetation type).**

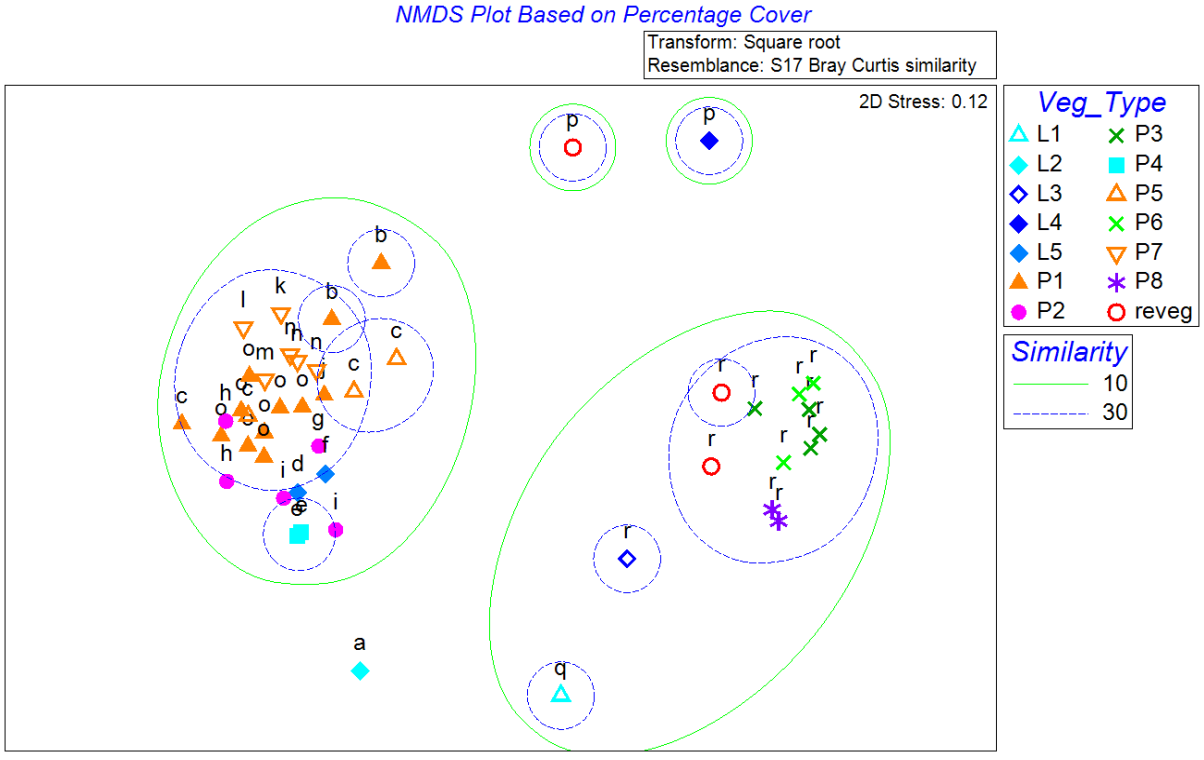

Figure 5.2: **NMDS plot based of sites from the current survey (based on percent cover of all annual and perennial taxa, excluding singletons; coded by vegetation type).**

5.4 Significant Vegetation

TECs and corresponding PECs were identified within the survey area and contextual area based on the vegetation types described (Section 5.1) the quadrat data (Appendix 8), TEC patch assessments (Appendix 5), and the floristic analysis using PATN (Section 5.3.1). Areas considered to be either a TEC or PEC within the survey area (Figure 5.3 and Figure 5.4) were based on quantitative data, whilst those areas mapped within the contextual area were solely based on extrapolation of vegetation mapping from the aforementioned survey area.

5.4.1 Threatened Ecological Communities

5.4.1.1 Commonwealth Threatened Ecological Communities

Prior to the field survey, two Commonwealth listed TECs were expected to occur within the Level 2 survey area and elsewhere in the immediate vicinity, as previously identified by the DBCA (see Section 4.8.1). The 'Banksia Woodlands of the Swan Coastal Plain' and 'Shrublands and Woodlands of the eastern Swan Coastal Plain' TEC were both confirmed to occur within the Level 2 survey area as a result of 13 independent in situ field patch assessments (see Section 3.2.4, Appendix 5) and subsequent consideration of whether each patch met the criteria for recognition as these TECs (Appendix 5). The 'Shrublands and Woodlands of the eastern Swan Coastal Plain' TEC is not only a component of the 'Banksia woodlands of the Swan Coastal Plain' Commonwealth TEC, but also represents a separate Commonwealth TEC in its own right.

A total of nine remnant vegetation patches of varying size were considered to be representative of the 'Banksia woodlands of the Swan Coastal Plain' TEC; one of these patches should be considered under 'Shrublands and Woodlands of the eastern Swan Coastal Plain' (see Figure 5.3 below for patch mapping and Plate 5.14 to Plate 5.16 for representative photos of these two TECs). A total of six patches occurred either wholly or partially within the survey area, with three additional inferred patches occurring only within the contextual area (see Figure 5.3). The extent of 'Banksia woodlands of the Swan Coastal Plain' TEC within the survey area comprised 27.44 ha, 1.65 ha of which also represented the 'Shrublands and Woodlands of the eastern Swan Coastal Plain' TEC specifically, with a further 96.56 ha located within the broader contextual area, meaning that 22.1% of the local extent occurs within the survey area (see Table 5.5).

Table 5.5 Extent of Commonwealth Listed TECs within the survey areas.

EPBC TEC	Status	Contextual Area Only (ha)	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Extent (ha)
Banksia woodlands of the Swan Coastal Plain ecological community	Endangered	96.56	-	27.44	124.0
Shrublands and Woodlands of the eastern Swan Coastal Plain	Endangered	(1.72)	-	(1.65)	(3.37)

Plate 5.14: **Representative photographs of the Banksia Woodlands of the Swan Coastal Plain ecological community TEC.**

Plate 5.15: **Representative photographs of the Banksia Woodlands of the Swan Coastal Plain ecological community TEC.**

Plate 5.16: **Representative photographs of the Shrublands and Woodlands of the eastern Swan Coastal Plain TEC.**

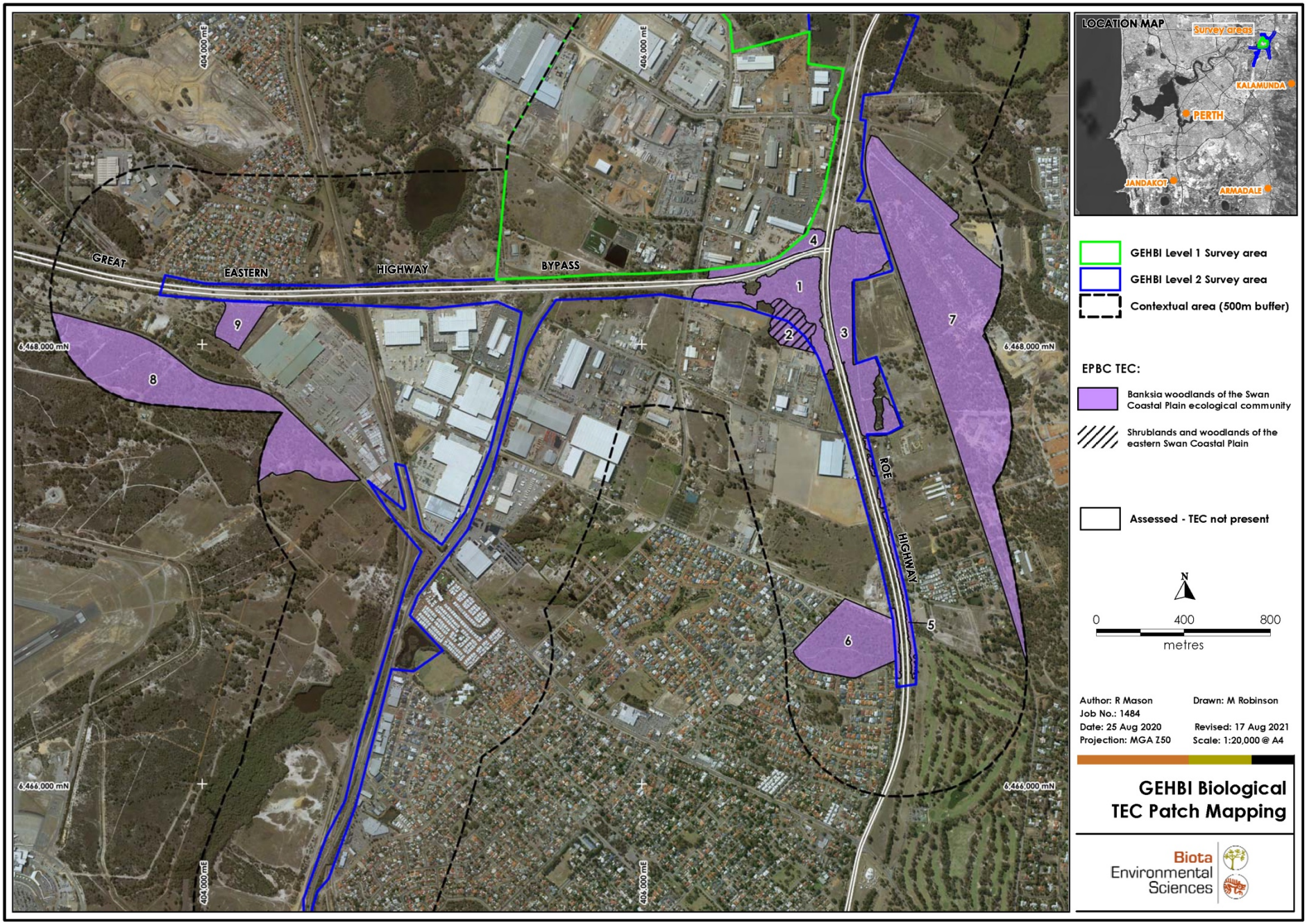

Figure 5.3: Commonwealth TEC patch assessment within the survey area and contextual area (numbers indicate patch number; Appendix 5).

5.4.1.2 State-Listed Threatened Ecological Communities and Priority Ecological Communities

Table 5.6 below provides a breakdown of the individual floristic community types identified within the survey area which have relationships to the 'Banksia woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC. Two of the five FCTs identified are listed as TECs at state level (FCT 20a and FCT 20c). '*Banksia attenuata* woodlands over species rich dense shrublands' (FCT 20a) comprised 11.12 ha of the survey area, whilst 1.65 ha of 'Eastern shrublands and woodlands' (FCT 20c) was identified.

The Priority 3 'Banksia woodlands of the Swan Coastal Plain' PEC was identified throughout the survey area (see Appendix 5 and Figure 5.4, Figure 5.5), and the floristic analysis demonstrated support for the presence of the Priority 3 'Low lying *Banksia attenuata* woodlands or shrublands' PEC (FCT 21c) sub-community, totalling 2.53 ha (Table 5.6).

An additional eight quadrats were installed in November 2020 to refine potential State PEC/TEC boundaries within the portion of Banksia woodlands of the Swan Coastal Plain' PEC surrounding Roe Highway / Great Eastern Highway Bypass intersection. The quadrat locations and corresponding FCT assignments are shown in Figure 5.5.

Three patches of 'Banksia woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC within the contextual area were inferred as '*Banksia attenuata* woodlands over species rich dense shrublands'(FCT 20a) based on extrapolated mapping, and are included within the area calculations (Table 5.6, Figure 5.4).

As the 'Banksia woodlands of the Swan Coastal Plain' State-listed PEC is equivalent to the Commonwealth TEC, the patches within the survey area and contextual area that were representative of the PEC similarly comprised 27.44 ha and 96.56 ha respectively (Table 5.6).

Table 5.6 Floristic community types that occur in the survey area and have relationships to the 'Banksia Woodlands of the Swan Coastal Plain ecological community' Commonwealth TEC.

Community Name	Floristic Community Type (Gibson et al. 1994)	PEC Name	State Listing	Contextual Area Only (ha)	Level 1 Survey Area (ha)	Level 2 Survey Area (ha)	Total Extent (ha)
Low lying *Banksia attenuata* woodlands or shrublands	FCT 21c	Low lying *Banksia attenuata* woodlands or shrublands ('floristic community type 21c')	Priority 3	0.02	-	2.53	2.55
Banksia attenuata woodlands over species rich dense shrublands	FCT 20a	Banksia woodlands of the Swan Coastal Plain	Threatened (Endangered)	94.82	-	11.12	105.94
Shrublands and woodlands of the eastern side of the Swan Coastal Plain	FCT 20c		Threatened (Critically Endangered)	1.72	-	1.65	3.37
Central *Banksia attenuata* - *Banksia menziesii* woodlands	FCT 23a		Priority 3	-	-	8.98	8.98
Spearwood *Banksia attenuata* or *Banksia attenuata* - Eucalyptus woodlands	FCT 28		Priority 3	-	-	3.16	3.16
TOTAL				**96.56**	**-**	**27.44**	**124.0**

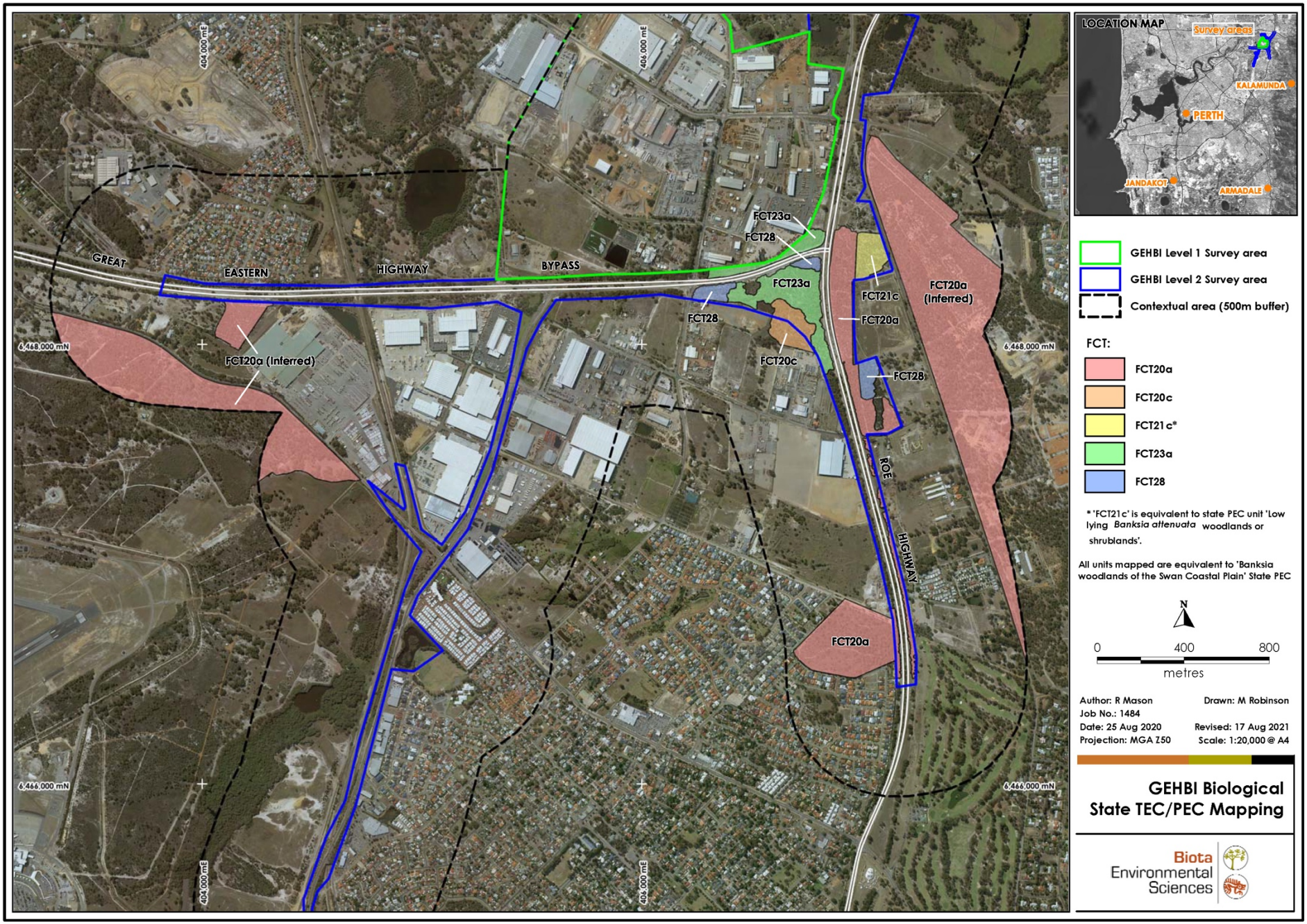

Figure 5.4: State TEC and PEC occurrences within the survey area and contextual area.

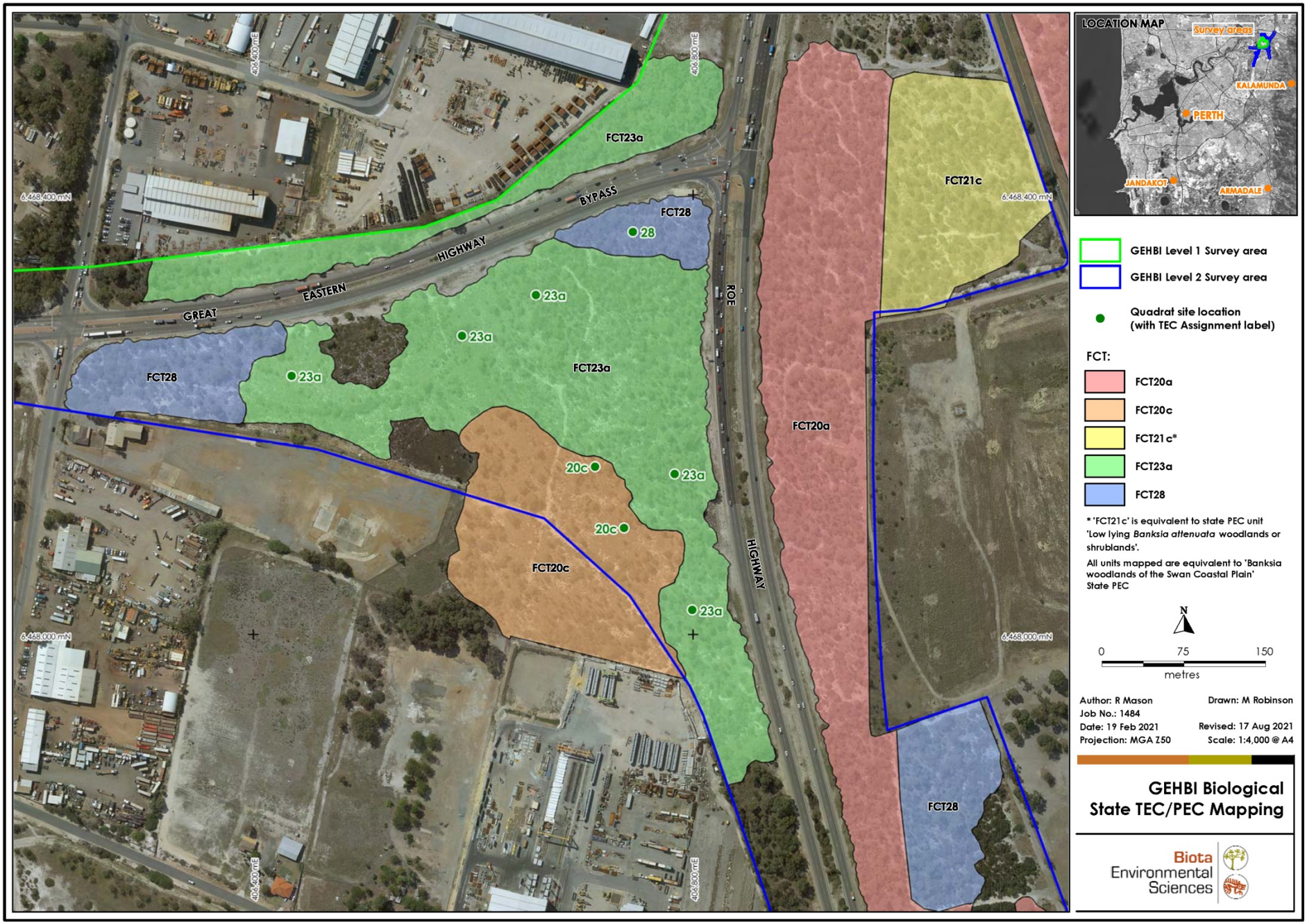

Figure 5.5: Additional quadrats and associated State TEC and PEC assignments.

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6.0 Flora

6.1 Overview

A total of 287 native vascular flora taxa from 145 genera and 53 families were recorded from the survey area (see Appendix 7). In addition, 96 introduced flora species were recorded, as discussed in Section 6.5.

The dominant native plant families and genera recorded from the survey area are typically well represented in species lists from the Swan Coastal Plain (see Table 6.1).

Table 6.1: Native families and genera with the highest species richness in the survey area.

Family	No. of Native Species	Genus	No. of Native Species
Myrtaceae	41	*Melaleuca*	12
Fabaceae	28	*Acacia*	7
Proteaceae	25	*Lomandra*	8
Cyperaceae	26	*Haemodorum*	6
Asparagaceae	16	*Daviesia*	6
Haemodoraceae	15	*Thysanotus*	6
Poaceae	10		

6.2 Unresolved Taxa

Most taxa (95%) were able to be determined with confidence to the lowest level possible within the currently available taxonomic framework. The remaining species generally lacked sufficient material for identification.

Lepidosperma sp. warrants particular comment: specimens were submitted to the WA Herbarium but could not be further determined, as the genus is currently undergoing revision by Dr Russell Barrett. Numerous new entities will be formally described, however the distinguishing characters have not yet been made available (M. Hislop, WA Herbarium, pers. comm. 2020).

6.3 Sampling Adequacy

The species accumulation curve generated from the data from the 52 sampling sites (31 quadrats, six resamples and 15 relevés) surveyed in 2019/2020 (Sobs data) is approaching a plateau, indicating that the sampling of the survey area was relatively thorough (Figure 6.1).

The two estimates of species richness (ICE and Chao2) suggested that the actual number of species present in the sampled area was approximately 467, which would mean that 72% of the total flora (native flora only) was recorded during the site sampling for the current study (Table 6.2). However, when the additional species and weeds that were recorded opportunistically are included, the species recorded from the survey area represent 87% of the total species estimated to occur in the sampling area.

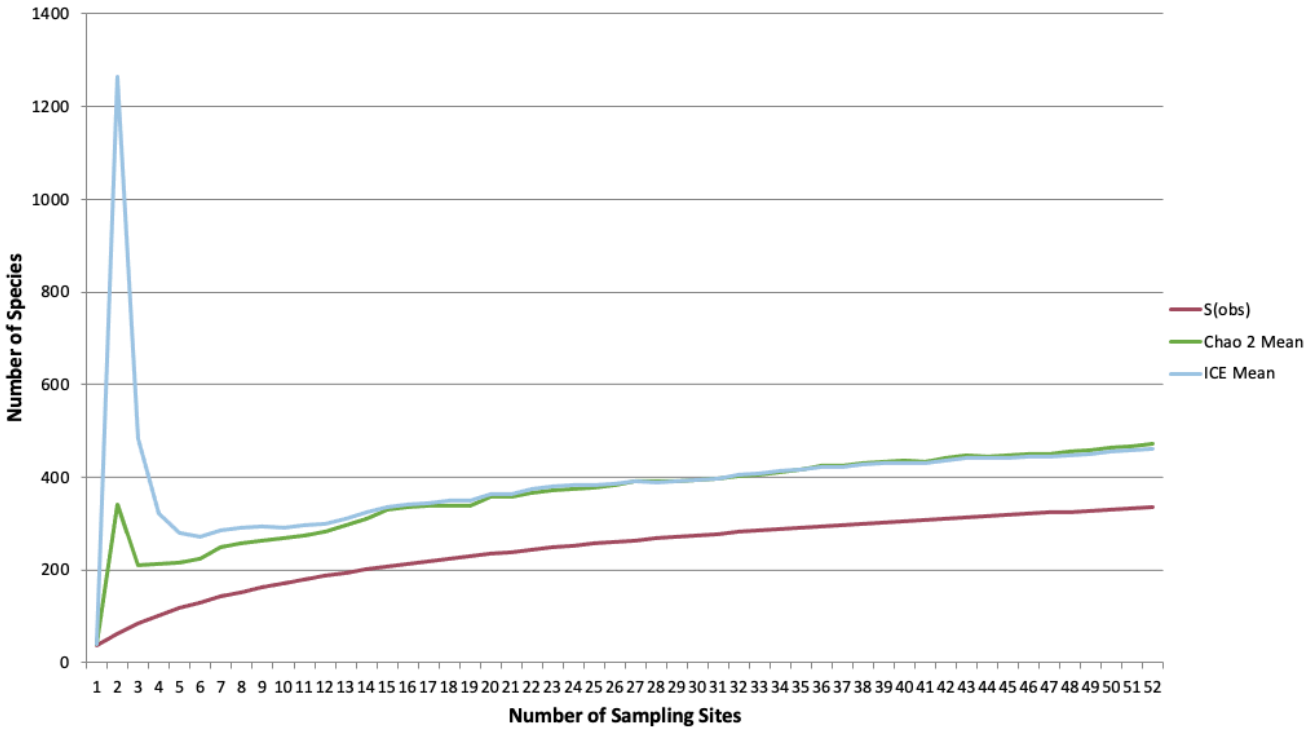

Figure 6.1: **Species accumulation curve based on actual observations at the sampling sites (S(obs)), together with two estimates of species richness (ICE and Chao 2).**

Table 6.2: **Recorded species richness compared with predicted species richness using incidence-based estimators (without opportunistic records).**

Parameter		Number of Species	Percentage of Estimated Richness Recorded
Number of species recorded		335	N/A
Estimated Number of Species	Chao 2 Mean	472	71%
	ICE Mean	462	72%

6.4 Significant Flora

6.4.1 Threatened Flora

One species recorded within the survey area, *Conospermum undulatum*, is listed as both Vulnerable under the EPBC Act and Threatened under the BC Act. The locations of this taxon are presented in Appendix 10 and on Figure 6.2. A brief description of the taxon is provided below.

Conospermum undulatum **(Threatened)**

Conospermum undulatum is an erect, multi-stemmed shrub to 1.5 m tall with hairless leaves having characteristically wavy margins (Plate 6.1). The woolly flowers have long, white hairs, and are produced in inflorescences held well above the leaves (DEWHA 2009). It is a geographically restricted species recorded in 216 locations within the Jarrah Forest and Swan Coastal Plain IBRA regions, in association with *Banksia* and Jarrah/Marri woodland (WA Herbarium 2020). Prior to the field survey, it was known to occur at five locations within the study area. Three individuals were recorded from two previously known locations in the survey area during the current study: two individuals were recorded from GBQ17, located in vegetation type P7, and one individual was recorded through the targeted survey, adjacent to an existing record (see Appendix 10 and Figure 6.2).

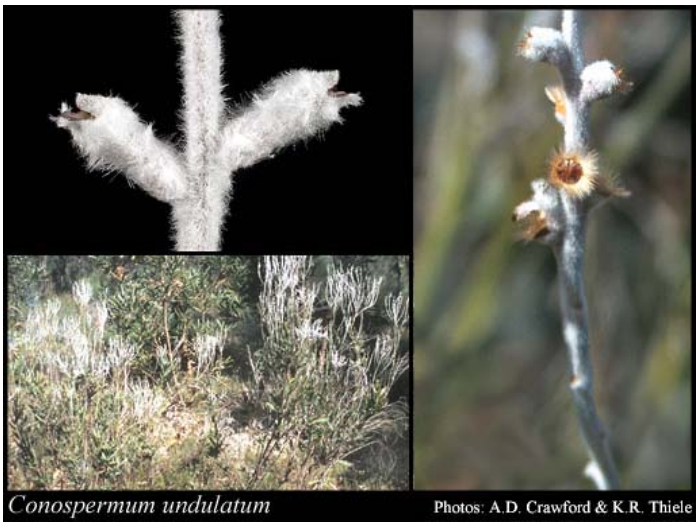

Plate 6.1: ***Conospermum undulatum***

Photography by A.D Crawford & K. R. Thiele. Image used with the permission of the WA Herbarium, DBCA (https://florabase.dpaw.wa.gov.au/help/copyright). Accessed on Wednesday, 17 June 2020.

6.4.2 Priority Flora

Natural populations of one Priority 2, one Priority 3 and two Priority 4 taxa were identified and counted in the survey area. Detailed location information for each Priority taxon is presented in Appendix 10 and on Figure 6.2 with a brief summary of each taxon and selected photographs provided below. In addition, *Melaleuca viminalis* (Priority 2) was encountered at GEHREL04. As it is a planted species it is not considered a natural Priority species population.

Johnsonia pubescens* subsp. *cygnorum **(Priority 2)**

This tufted perennial herb has white to green flowers and strappy leaves, and has been recorded on grey-white sands in *Banksia* woodlands and in seasonally wet sites of the Swan Coastal Plain IBRA region (WA Herbarium 2020). *Johnsonia pubescens* subsp. *cygnorum* has been recorded from 17 locations between Perth and Pinjarra, distributed over a range of 71 km (DBCA 2020). A total of 10 individuals were recorded from four quadrats (GBQ03, GBQ05, GBQ07, GBQ30) and two locations during the survey, in the P2 and P4 vegetation types.

Plate 6.2 ***Johnsonia pubescens* subsp. *cygnorum*.**

Isopogon autumnalis **(Priority 3)**

Isopogon autumnalis is a multi-stemmed shrub to 1m high, with curved, simple terete leaves and pale yellow flowers (Plate 6.2). It has been recorded from 59 locations between Leeman and Mandurah, distributed over a range of 260 km. 128 individuals were recorded from five locations through the targeted survey and two quadrats during the survey, within the P7 vegetation unit.

Plate 6.3: ***Isopogon autumnalis.***

Hypolaena robusta **(Priority 4)**

This species is a rhizomatous, perennial herb growing to approximately 50 cm and is found on white sands (Plate 6.4). The distribution of this species extends across 480 km, from Eneabba to Augusta. During the survey, one individual was recorded from just outside quadrat GBQ06 in the P1 vegetation type.

Plate 6.4: ***Hypolaena robusta.***

Photography by A.D. Crawford. Image used with the permission of the WA Herbarium, DBCA (https://florabase.dpaw.wa.gov.au/help/copyright). Accessed on Wednesday, 17 June 2020.

Verticordia lindleyi* subsp. *lindleyi **(Priority 4)**

Verticordia lindleyi subsp. *lindleyi* is an erect shrub, growing upwards of 75 cm, with pink flowers. It favours winter wet depressions in sandy soils. One individual was recorded opportunistically during the survey from within the L2 vegetation type.

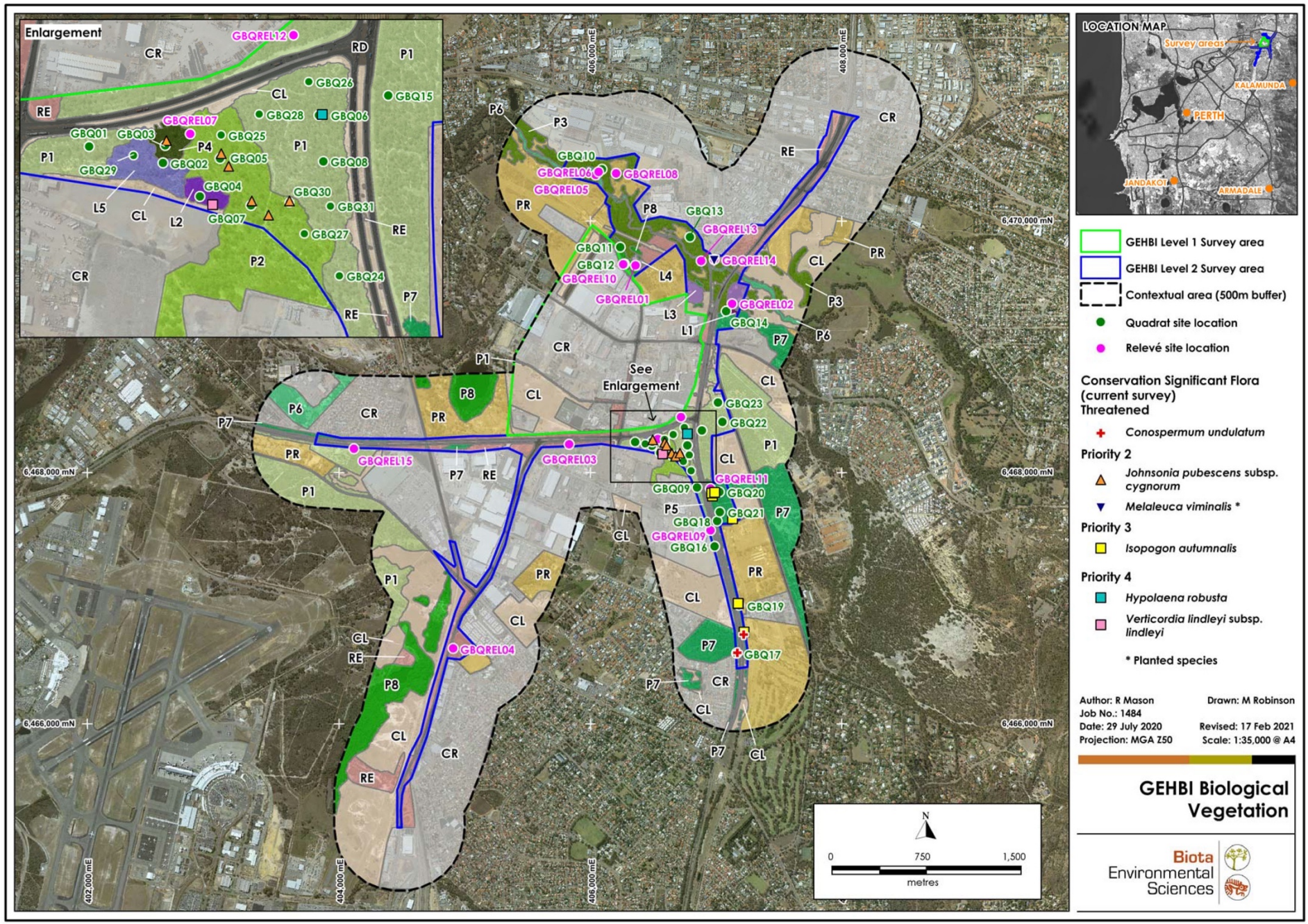

Figure 6.2: Locations of significant flora recorded within the survey area and contextual area.

6.4.3 Potential for Other Significant Flora

Collections of the Priority 2 sedge *Lepyrodia curvescens* and Priority 4 sedge *Schoenus griffinianus* were both recorded previously within a seasonally wet area of the survey area. Despite targeted searches at this location, these species were not recorded during the field survey.

None of the other significant species known to occur in the locality are considered to occur in the survey area; all are perennial species that should have been recorded during the field survey, if present (see Appendix 4a).

6.5 Introduced Flora

Introduced flora were common through the entirety of the survey area, given its landscape setting. A total of 96 species from 76 genera and 35 families were recorded opportunistically or within quadrats and/or relevés. Due to the number of introduced species and their abundance it was not practical to fully map and record numbers of individuals of all introduced species during the field survey. A list of the locations recorded is presented in Appendix 11.

The Department of Parks and Wildlife (now DBCA) Swan Region Species Prioritisation Process rated weed species known from the region against their qualitatively assessed 'Ecological Impact' and 'Invasiveness', whilst taking into account the potential distribution and current distribution (Appendix 11). Whilst a large amount of weed species recorded from the study area had an Ecological Impact ranking of 'Unknown' through this process the majority had an Ecological Impact ranking of 'High' and an Invasiveness ranking of 'Rapid'. A list of all 96 species and their corresponding Ecological Impact and Invasiveness rankings is provided in Appendix 11.

6.5.1 Weeds of National Significance and Declared Pest Plants

Thirty-two species of weeds have been federally declared as WoNS based on their invasiveness, potential for spread, and for environmental, social, and economic impacts (DPaW 2012). To protect agriculture in WA, the Department of Primary Industry and Regional Development (DPIRD) regulates harmful plants under the BAM Act. Plants that are prevented entry into the state or have control or keeping requirements in WA are known as Declared Pests (DPIRD 2020).

Two of the species recorded, **Asparagus asparagoides* (Bridal Creeper) and **Rubus ulmifolius* (Blackberry) are listed as WoNS (Thorp and Lynch 2000)[4], and Declared Pests under the BAM Act. Additionally, **Echium plantagineum*, **Hydrocotyle ranunculoides* (Robust Pennywort), **Solanum linnaeanum* (Apple of Sodom) and **Zantedeschia aethiopica* (Arum Lily) are listed as Declared Pests and were recorded within the survey area. Further details on each species are provided below.

6.5.1.1 ****Asparagus asparagoides*** (Bridal Creeper)

**Asparagus asparagoides* is both a WoNS and Declared Pest, and is a herbaceous climbing plant from the family Asparagaceae that is native to Southern Africa. Bridal Creeper has been recorded across the Avon Wheatbelt, Coolgardie, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Mallee, Swan Coastal Plain, and Warren IBRA bioregions (WA Herbarium 2020). The species is regarded as one of the worst weeds in Australia because of its invasiveness, potential for spread, and economic and environmental impacts (DoAWE 2020).

Twelve individuals from nine locations were recorded in the survey area (see Appendix 11).

6.5.1.2 ****Echium plantagineum*** (Paterson's Curse)

**Echium plantagineum,* a Declared Pest, is a typical weed of roadsides, pastures, vacant lands and disturbed grounds. It has been recorded across 13 IBRA regions throughout WA (WA Herbarium 2020). Paterson's Curse is regarded as a serious environmental weed due to its seed, which can remain dormant for up to six years, and its ability to adapt to a wide range of soils.

1,230 records from nine locations were recorded from the survey area, including GEHREL01 and GEHREL01, where10% cover was recorded in both (see Appendix 11).

[4] http://www.weeds.org.au/WoNS/

6.5.1.3 **Hydrocotyle ranunculoides* (Robust Pennywort)

Native to South America, **Hydrocotyle ranunculoides* is a Declared Pest, and is an aquatic stoloniferous herb, with an ability to cover large areas of fresh, still water (Hussey et al. 2007). It has been recorded in aquatic areas on the Swan Coastal Plain IBRA region (WA Herbarium 2020).

One record of this species was made in GEHREL04 (see Appendix 11).

6.5.1.4 **Rubus ulmifolius* (Blackberry)

**Rubus ulmifolius* is both a WoNS and Declared Pest, and is a straggling perennial shrub, originating in northern Africa and Europe. Blackberry has been recorded across the Jarrah Forest, Swan Coastal Plain and Warren IBRA bioregions (WA Herbarium 2020). The complex of *Rubus* species are regarded as some of the worst weeds in Australia because of their invasiveness, potential for spread, and economic and environmental impacts (DoAWE 2020).

Seventy individuals were encountered opportunistically from two locations, plus an additional record of 5% cover recorded within GEHREL05 (see Appendix 11).

6.5.1.5 **Solanum linnaeanum* (Apple of Sodom)

Declared Pest **Solanum linnaeanum* is a spreading shrub with stout prickles, originating in southern Africa. It has been recorded across the Avon Wheatbelt, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain Warren IBRA bioregions (WA Herbarium 2020).

One record of this species was encountered from one opportunistic location during the survey (see Appendix 11).

6.5.1.6 *Zantedeschia aethiopica (Arum Lily)

**Zantedeschia aethiopica*, a Declared Pest, is a perennial herb typically found in low-lying swampy areas and is native to South Africa. It was introduced for horticultural purposes. Arum Lily has been recorded from Geraldton to Albany, and is toxic to animals (WA Herbarium 2020).

Ten individuals of this species were recorded from five locations within the survey area (see Appendix 11).

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