



**FLORA AND VEGETATION ASSESSMENTS  
BINDOON BYPASS, GREAT NORTHERN HIGHWAY**

**OCTOBER 2020**

**INTEGRATED PROJECT TEAM (IPT)  
(MAIN ROADS WESTERN AUSTRALIA WITH THE ARUP JACOBS  
JOINT VENTURE)**

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## EXECUTIVE SUMMARY

Main Roads Western Australia (Main Roads) is upgrading the 218 km section of Great Northern Highway (GNH) between Muchea and Wubin. The improvements to be made include town bypasses, wider roads, more passing lanes, flattening crests and easing curves, safer roadsides, more rest stops and additional facilities for heavy vehicles. These works have and will significantly improve safety and amenity and facilitate the future movement of road trains along this section of highway.

As part of the GNH upgrades project, the Integrated Project Team (IPT) (Jacobs and Arup together with Main Roads) is also progressing work for a section of the GNH that will bypass the town of Bindoon (the Bindoon Bypass).

In 2016, Focused Vision Consulting Pty Ltd (FVC), supported by specialist sub-consultants, including Bamford Consulting Ecologists (BCE), were engaged by the IPT (formerly the Arup SKM Joint Venture (ASJV)) to conduct spring flora, vegetation, fauna and habitat assessments of three proposed corridors for the Bindoon Bypass section of the GNH upgrade project. The biological assessments continued throughout 2017 and 2018.

This report consolidates the results of the flora and vegetation assessments carried out to date, since the original 2016 surveys, and focuses on 2018 results. The 2018 surveys focused on:

- spring flora and vegetation assessments within gap areas (new sections of the proposal envelope arising from adjustments to the alignment and proposed footprint)
- a further phase of a spring detailed flora and vegetation assessment throughout the study area
- further targeted Threatened and Priority flora surveys
- a dedicated Banksia woodland assessment.

The key results and conclusions from the detailed flora and vegetation assessment, and targeted Threatened and Priority flora survey are as follows:

- No species of Threatened flora, including *Thelymitra stellata* and *Drakaea elastica* were recorded within the study area, despite intensive and systematic targeted surveys having been carried out, however three Threatened species were recorded outside the study area as part of regional surveys.
- A total of 14 species listed as Priority flora, *Synaphea panhesya* (with *Synaphea ?panhesya*) (P1), *Drosera sewelliae* (with *Drosera ?sewelliae*) (P2), *Leucopogon squarrosus* subsp. *trigynus* (P2), *Acacia drummondii* subsp. *affinis* (with *Acacia drummondii* subsp. *?affinis*) (P3), *Adenanthos cygnorum* subsp. *chamaephyton* (P3), *Halgania corymbosa* (P3), *Styphelia filifolia* (P3), *Verticordia rutilastra* (P3), *Anigozanthos humilis* subsp. *chrysanthus* (P4), *Conostephium magnum* (P4), *Hibbertia miniata* (P4), *Hypolaena robusta* (P4), *Jacksonia ?sericea* (P4) and *Verticordia paludosa* (with *Verticordia ?paludosa*) (P4) have been recorded within the study area since 2016.
- A collective total of 4,057 plants representing Threatened or Priority flora have been recorded as part of collective studies within the study area and in the surrounding region. Of these, no Threatened flora have been recorded within the study area, and 2,082 individual Priority flora plants have been recorded within the study area. The remaining 1,975 plants recorded occur outside the study area, in the surrounding region.
- It is considered possible that the distribution and abundance of the Priority flora recorded within the study area and in the surrounding region is greater than the assessment results

would suggest, and that additional numbers of Priority flora plants that were not recorded could occur, due to the inherent limitations associated with surveys across vast study areas.

- Two flora species, *Jacksonia ?sericea* (P4) and *Synaphea ?flabelliformis* were found to be occurring outside their known range, based on the distribution of WA Herbarium records.
- One State-listed Threatened Ecological Community (TEC) and two Priority Ecological Communities (PECs) are known to occur within or closely adjacent to the study area, with all three of these community types representative of the Commonwealth-listed Banksia Woodlands of the Swan Coastal Plan TEC (Banksia woodland TEC).
- The study area has been confirmed to support areas of the Commonwealth-listed Banksia woodland TEC, within 412 ha of the TEC mapped, consisting of occurrences of vegetation units BaXpAn, BaXpUa, EmXpAn, EtBeAn and EtEpAn.
- None of the Floristic Community Types (FCTs) of the study area vegetation are considered to represent State-listed TECs or PECs, based on a combination of data analysis efforts and based on the conservation status of ecological communities at the time of reporting.
- All of the recorded vegetation units have been determined to be of local, regional or national significance, or a combination of these levels of importance. All are locally significant due to supporting populations of Priority flora and many having a limited local representation. Other factors determining local significance are, being considered floristically diverse or locally uncommon. Vegetation units have been determined to be regionally significant due to being represented by less than 30% of their pre-European extent in the local government area, being limited to specific landform types, or being regionally uncommon. Five vegetation units (BaXpAn, BaXpUa, EmXpAn, EtBeAn and EtEpAn) are of national significance due to representing a TEC of Commonwealth significance.



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# 1 INTRODUCTION

## 1.1 BACKGROUND

Great Northern Highway (GNH) is one of Western Australia's main land transport links and is the only sealed road connecting Perth with the Northern Territory. The highway forms part of the National Land Transport Network, which is defined as a national network of important road and rail infrastructure links (Department of Infrastructure and Resource Development (DoIRD) 2018).

Main Roads Western Australia (Main Roads) is upgrading the 218 km section of GNH between Muchea and Wubin. Jacobs and Arup together with Main Roads have formed the Integrated Project Team (IPT) for the delivery of the upgrade project. The IPT completed a comprehensive planning review of the Muchea to Wubin section and prioritised a series of construction packages to be delivered over several years. The improvements to be made include town bypasses, wider roads, more passing lanes, flattening crests and easing curves, safer roadsides, more rest stops and additional facilities for heavy vehicles. These works have and will significantly improve safety and amenity and facilitate the future movement of road trains along this section of highway. As part of the GNH upgrades project, the IPT is also progressing work for a section of the GNH that will bypass the town of Bindoon (the Bindoon Bypass).

During 2016, Focused Vision Consulting Pty Ltd (FVC), supported by specialist sub-consultants, including Bamford Consulting Ecologists (BCE), were engaged by the IPT (formerly the Arup SKM Joint Venture (ASJV)) to conduct initial spring flora, vegetation, fauna and habitat assessments of three proposed corridors for the Bindoon Bypass section of the GNH upgrade project.

A preferred corridor, referred to as 'Western A' was selected in January 2017 to be pursued for the Bindoon Bypass. The FVC team was then engaged to undertake autumn, winter and spring assessments of the preferred alignment, including revisions to this alignment, which were incorporated into the project in 2017.

The study area addressed in this report addresses the project's current development envelope, plus some additional areas that reflect the extent of the majority of surveys conducted since 2016, herein referred to as the study area (**Figure 1**).

As a result of ongoing alignment and design revisions, some localised areas that fall outside the extent of flora and fauna studies conducted to 2017 were identified. Therefore, FVC was engaged by the IPT to conduct further gap-filling surveys and to carry out further assessments to contribute to the data and information gathered to date.

These 2018 surveys focused on:

- spring flora and vegetation assessments within gap areas (new sections of the proposal envelope arising from adjustments to the alignment and proposed footprint)
- a further phase of a spring detailed flora and vegetation assessment throughout the study area
- further targeted Threatened and Priority flora surveys
- a dedicated Banksia woodland assessment.

This report presents the results of the flora and vegetation assessments undertaken within the study area to date in accordance with current EPA guidance, as part of regulatory requirements of formal environmental approvals that will be sought for the Bindoon Bypass project. The report focuses on the results from the 2018 spring surveys, following the previous reporting of spring 2016, and autumn and spring 2017 results (FVC 2018a, 2018b, 2018c).



## 1.2 LOCATION

The study area is located in the Shires of Chittering and Gingin between the localities of Chittering in the south, to Wannamal in the north, from the existing Great Northern Highway at the southern end to the Moora-Bindoon Road in Wannamal then extending eastward through Wannamal to Great Northern Highway. Additional survey areas within the revised study area extend west to east along Gray and Mooliabeenee Roads and north-west to south-east along Crest Hill Road (**Figure 1**).







### 1.3 SCOPE OF WORK

Since previous surveys that were conducted in 2016 and 2017, the study area boundary has changed. The scope of this project was focused on gap-filling surveys and other supplementary studies, conducted in winter and spring 2018 to assess areas in the new, revised study area that had not been covered by previous surveys. The surveys were undertaken to refine the definition of biological values as well as to address additional areas encompassed within the revised study area.

To date, the flora and vegetation and related field studies have included (2016 and 2017 studies):

- the initial phase of a detailed (formerly referred to as 'Level 2') flora and vegetation assessment (spring 2016)
- an initial targeted Threatened flora survey focused on *Thelymitra stellata*, in selected sections of the study area (spring 2016)
- the second phase of a detailed flora and vegetation assessment, undertaking resampling of a selection of quadrats and sampling of some new quadrats (autumn 2017)
- targeted Threatened and Priority flora surveys within the study area, for relevant species in relation to flowering times (autumn 2017)
- the third phase of a detailed flora and vegetation assessment, undertaking resampling of a selection of quadrats and sampling of some new quadrats, studies in the surrounding region for context, and studies also focused on Banksia woodland as part of an initial stage of a targeted threatened ecological community (TEC) assessment (spring 2017).

Following on from these studies, the scope of the work undertaken during 2018 and the focus of this report includes:

- further selective detailed flora and vegetation assessment within "gap" areas arising out of alignment adjustments (spring 2018)
- further detailed flora and vegetation assessment in the surrounding region, for context (spring 2018)
- further efforts towards a targeted Banksia woodland TEC assessment (spring 2018)
- further efforts towards targeted Threatened and Priority flora surveys within the study area, for relevant species in relation to flowering times (winter and spring 2018)
- targeted Threatened and Priority flora surveys of documented populations within the region (within a 100 km buffer of the study area), for relevant species in relation to flowering times (winter and spring 2018).

## 2 LEGISLATIVE CONTEXT

The flora and vegetation assessments were conducted in accordance with the following legislation:

- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- Western Australian *Environmental Protection Act 1986* (EP Act)
- Western Australian *Biodiversity Conservation Act 2016* (BC Act)
- Western Australian *Wildlife Conservation Act 1950* (WC Act).

The assessments complied with requirements for environmental survey and reporting in Western Australia, as outlined in:

- EPA (2000) Position Statement No. 2: Environmental Protection of Native Vegetation in Western Australia
- EPA (2002) Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection
- EPA (2008) Guidance Statement No. 33: Environmental Guidance for Planning and Development
- EPA (2016) Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment
- Threatened Species Scientific Committee (2016) Approved Conservation Advice (incorporating listing advice) for the Banksia Woodlands of the Swan Coastal Plain Ecological Community
- Commonwealth of Australia (2013b) Guidelines for Detecting Orchids Listed as ‘Threatened’ Under the *Environment Protection and Biodiversity Conservation Act 1999*.

### 2.1 THREATENED AND PRIORITY FLORA

The Department of Biodiversity, Conservation and Attractions (DBCA) assigns State-level conservation status to endemic plant species that are geographically restricted to few known populations or threatened by local processes. Allocating conservation status to plant species assists in protecting populations and conserving species from potential threats (DBCA 2018b, DPaW (Department of Parks and Wildlife) 2016).

The *Biodiversity Conservation Act 2016* (BC Act) provides a statutory basis for the listing of threatened species, specially protected species, threatened ecological communities, critical habitat and key threatening processes (DBCA 2019). Whilst not awarded any statutory protection, DBCA also maintains the Priority flora list, for species of conservation concern. Priority flora are given consideration in environmental impact assessments (EIAs) and in the assessment of clearing permit applications, in accordance with the ten clearing principles. Therefore, both Threatened and Priority flora are important focuses of surveys conducted to inform the EIA process and their definitions are presented in **Table 1**.

**Table 1 - Definitions of Threatened and Priority Flora Species**

Conservation Code	Category
<b>T</b>	<p><b>Threatened Species</b></p> <p>Published as Specially Protected under the Wildlife Conservation Act, 1950 and listed under Schedules 1 to 4 of the Wildlife Conservation (Rare Flora) Notice for Threatened Flora.</p> <p>Flora that has been declared to be 'likely to become extinct or is rare, or otherwise in need of special protection', pursuant to section 23F (20) of the Wildlife Conservation Act.</p>
<b>P1</b>	<p><b>Priority 1 – Poorly Known Species</b></p> <p>Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey</p>
<b>P2</b>	<p><b>Priority 2 – Poorly Known Species</b></p> <p>Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.</p>
<b>P3</b>	<p><b>Priority 3 – Poorly Known Species</b></p> <p>Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.</p>
<b>P4</b>	<p><b>Priority 4 – Rare, Near Threatened and other species in need of monitoring</b></p> <p>(a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands.</p> <p>(b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for Vulnerable but are not listed as Conservation Dependent.</p> <p>(c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.</p>

Under the EPBC Act, actions that have, or are likely to have, a significant impact on a matter of national environmental significance (MNES) require approval from the Federal Minister for the Environment.

Species at risk of extinction are recognised as Threatened at a Commonwealth level and are categorised according to the EPBC Act as summarised in **Table 2**.

**Table 2 - Categories of EPBC Act Threatened Flora Species**

Conservation Code	Category
<b>Ex</b>	<b>Extinct</b> Taxa not definitely located in the wild during the past 50 years
<b>ExW</b>	<b>Extinct in the Wild</b> Taxa known to survive only in captivity
<b>CR</b>	<b>Critically Endangered</b> Taxa facing an extremely high risk of extinction in the wild in the immediate future
<b>EN</b>	<b>Endangered</b> Taxa facing a very high risk of extinction in the wild in the near future
<b>VU</b>	<b>Vulnerable</b> Taxa facing a high risk of extinction in the wild in the medium term
<b>CD</b>	<b>Conservation Dependent</b> Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classified as Vulnerable or more severely threatened.

Any species listed in State and Commonwealth legislation as being of conservation significance is said to be a significant species. This incorporates species that are endangered, vulnerable and rare or covered by international conventions. Significance is not limited to species covered by State and Commonwealth legislation and also includes species of local significance and species showing significant range extensions or at the edge of their known range.

## 2.2 THREATENED AND PRIORITY ECOLOGICAL COMMUNITIES

Threatened Ecological Communities (TECs) are naturally occurring biological assemblages that occur in a particular type of habitat, which are subject to processes that threaten to destroy or significantly modify the assemblage across its range (DEC 2007).

Vegetation communities in Western Australia are described as 'TECs' if they have been defined by DBCA's Species and Communities Branch and found to be Presumed Totally Destroyed (PD), Critically Endangered (CR), Endangered (EN) or Vulnerable (VU). The categories and the criteria for defining TECs have been described by English and Blyth (1997). A publicly available database, listing TECs within Western Australia is maintained by DBCA.

TECs in WA are protected under the BC Act and some are also are protected under the Commonwealth EPBC Act. The TECs on the Commonwealth register are also listed on the Department of the Environment and Energy (DEE) website, and in the Protected Matters Database.

Additional to TECs, ecological communities that are considered potentially of conservation significance (and potentially TECs) that do not currently meet survey criteria or that are not adequately defined, are rare but not threatened, have been recently removed from the TEC list or require regular monitoring are considered to be Priority Ecological Communities (PECs) (DEC 2013) and are required to be taken into consideration during environmental impact assessments.

## 2.3 LOCALLY OR REGIONALLY SIGNIFICANT VEGETATION

Vegetation may be locally or regionally significant in addition to significance according to statutory listings.

Vegetation communities are referred to as locally significant where they:

- support populations of Priority Flora species
- extend the geographic range of particular taxa from previously recorded locations
- are restricted to only one or a few locations
- occur as small isolated communities
- exhibit unusually high structural and species diversity.

Vegetation communities are referred to as regionally significant where they:

- are limited to specific landform types
- are uncommon or restricted plant community types within the regional context
- support populations of threatened flora.

Vegetation communities are referred to as Nationally significant where they:

- support populations of Threatened (EPBC listed) species
- support TECs listed as nationally (EPBC) significant.

The Technical Guidance for Flora and Vegetation Surveys for Environmental Impact Assessment (EPA 2016) also states that vegetation may be considered significant for a range of reasons, including but not limited to the following:

- being identified as threatened or priority ecological communities
- have a restricted distribution
- have a degree of historical impact from threatening processes
- have a role as a refuge
- provide an important function required to maintain ecological integrity of a significant ecosystem.

## 2.4 VEGETATION CLEARING, EXTENT AND STATUS

Clearing of native vegetation is regulated in WA under the EP Act and the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*. Any clearing of native vegetation is an offence, unless carried out under a clearing permit or if the clearing is for an exempt purpose (DWER 2018). A clearing permit is required under Part V of the EP Act, whereby permit applications to clear native vegetation must be assessed against the '10 Clearing Principles' as outlined in the regulations.

Where clearing of native vegetation is proposed to occur, there are several key criteria applied to the assessment of clearing permit applications, in the interests of biodiversity conservation. The criteria, as outlined in EPA's Position Statement No. 2 (EPA 2000) are used to help reverse the long-term decline in the quality and extent of Western Australia's native vegetation cover.



The criteria are as follows:

- the “threshold level” below which species loss appears to accelerate exponentially at an ecosystem level is regarded as being at a level of 30% of the pre-clearing extent of the vegetation type
- a level of 10% of the original extent is regarded as being a level representing “endangered”
- clearing which would put the threat level into the class below should be avoided
- from a biodiversity perspective, stream reserves should generally be in the order of at least 200 m wide.

The status of remaining vegetation can be delineated into five different classes:

- *Presumed extinct* - probably no longer present in the bioregion
- *Endangered* - <10% of pre-European extent remains\*
- *Vulnerable* - 10-30% of pre-European extent exists\*
- *Depleted* - >30% and up to 50% of pre-European extent exists\*
- *Least concern* - >50% pre-European extent exists and has been subject to little or no degradation over a majority of this area.

\* or a combination of depletion, loss of quality, current threats and rarity gives a comparable status.

## 2.5 ENVIRONMENTALLY SENSITIVE AREAS

Environmentally Sensitive Areas (ESAs) are areas that require special protection due to aspects such as landscape, wildlife or historical value and are generally considered to be areas of high conservation value. ESAs are declared in the Environmental Protection (Environmentally Sensitive Areas) Notice 2005, which was gazetted on 8 April 2005.

There are several types of ESAs relating to flora and vegetation, declared under Part V of the EP Act, which include:

- a defined wetland and the area within 50 m of that wetland
- the area covered by vegetation within 50 m of rare (Threatened) flora, to the extent where the vegetation is continuous with the vegetation in which the rare (Threatened) flora is located
- the area covered by a TEC
- Bush Forever sites
- areas covered by the following policies:
  - *Environmental Protection (Gnangara Mound Crown Land) Policy 1992*
  - *Environmental Protection (Western Swamp Tortoise) Policy 2002*
  - *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992*
  - *Environmental Protection (South West Agricultural Zone Wetlands) Policy 1998*
- areas of native fringing vegetation in the policy area as defined in *Environmental Protection (Swan and Canning Rivers) Policy 1998*.

## 2.6 INTRODUCED FLORA

To date, over 1,200 introduced (weed) species have been recognised to occur within Western Australia (EPA 2007). Introduced flora (weeds) are plants that are not indigenous to an area and have been introduced either directly or indirectly through human activity. They establish in natural ecosystems and adversely modify natural processes, resulting in the decline of the invaded community and the habitat value provided for native fauna. Weeds threaten the survival of many flora because of their rapid growth and the ability to out-compete native plants for available nutrients, water, space and sunlight.

### 2.6.1 Weeds of National Significance

Under the National Weed Strategy, there are currently 32 weed species listed as Weeds of National Significance (WoNS). Each weed was considered for inclusion based on the following criteria; invasive tendencies, impacts, potential for spread and socioeconomic and environmental values.

### 2.6.2 Declared Pest Plants

The Western Australian Organism List (WAOL) details organisms listed as Declared Pests, including pest plants, under the *Biosecurity and Agriculture Management Act 2007* (BAM Act) (DAFWA 2018a). Under the BAM Act, Declared Pests are listed under one of the following categories:

- C1 (exclusion), that applies to pests not established in Western Australia; control measures are to be taken to prevent their entry and establishment
- C2 (eradication), that applies to pests that are present in Western Australia but in low numbers or in limited areas where eradication is still a possibility
- C3 (management), that applies to established pests where it is not feasible or desirable to manage them in order to limit their damage.

### 2.6.3 Environmental Weeds

Introduced species have also been ranked by a number of attributes, including invasiveness, distribution and environmental impacts in the various regions in *An Environmental Weed Strategy* (CALM 1999). To advance the above categorisation, the Invasive Plant Prioritization Process for DBCA was developed in 2008 (DPaW 2013).

## 3 EXISTING ENVIRONMENT

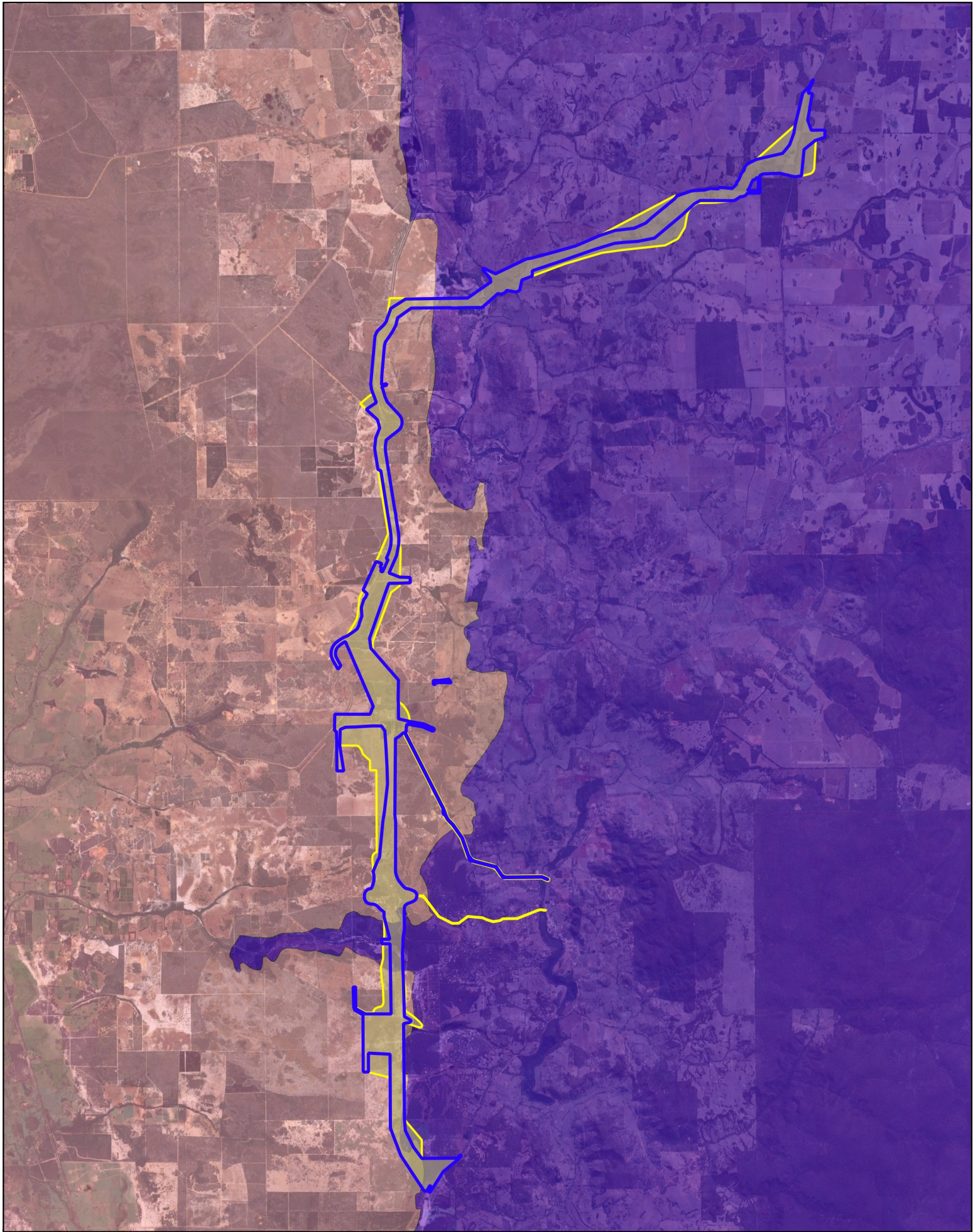
### 3.1 IBRA REGION

There are 89 recognised Interim Biogeographic Regionalisation for Australia (IBRA) regions across Australia that have been defined based on climate, geology, landforms and characteristic vegetation and fauna (Commonwealth of Australia 2013a). The study area lies within the Swan Coastal Plain and Jarrah Forrest IBRA regions (**Figure 2**). At a finer scale, the study area falls within the Dandaragan Plateau and the Northern Jarrah Forrest subregions.

The Dandaragan Plateau subregion of the Swan Coastal Plain is bordered by the Derby and Dandaragan Faults with cretaceous marine sediments mantled by sands and laterites. Vegetation of this subregion is characterised by Banksia low woodland, Jarrah–Marri woodland, Marri woodland and scrub heaths on laterite pavement and on gravelly sandplains. Large numbers of Threatened flora have been recorded from the area (Desmond 2001).

The Northern Jarrah Forest subregion incorporates the area east of the Darling Scarp, overlying Archaean granite and metamorphic rocks capped by an extensive lateritic duricrust (Williams and Mitchell 2001). Vegetation comprises Jarrah–Marri forest in the west with Bullich (*Eucalyptus megacarpa*) and Blackbutt (*E. patens*) in the valleys grading to Wandoo (*E. wandoo*) and Marri woodlands in the east with Powderbark (*E. accedens*) on breakaways. The extensive but localised sand sheets support Banksia low woodlands.





0 2 4 6 8 km

GDA 94 / MGA Zone 50



**Legend**

- Development Envelope
- Study Area
- Jarrah Forest
- Swan Coastal Plain

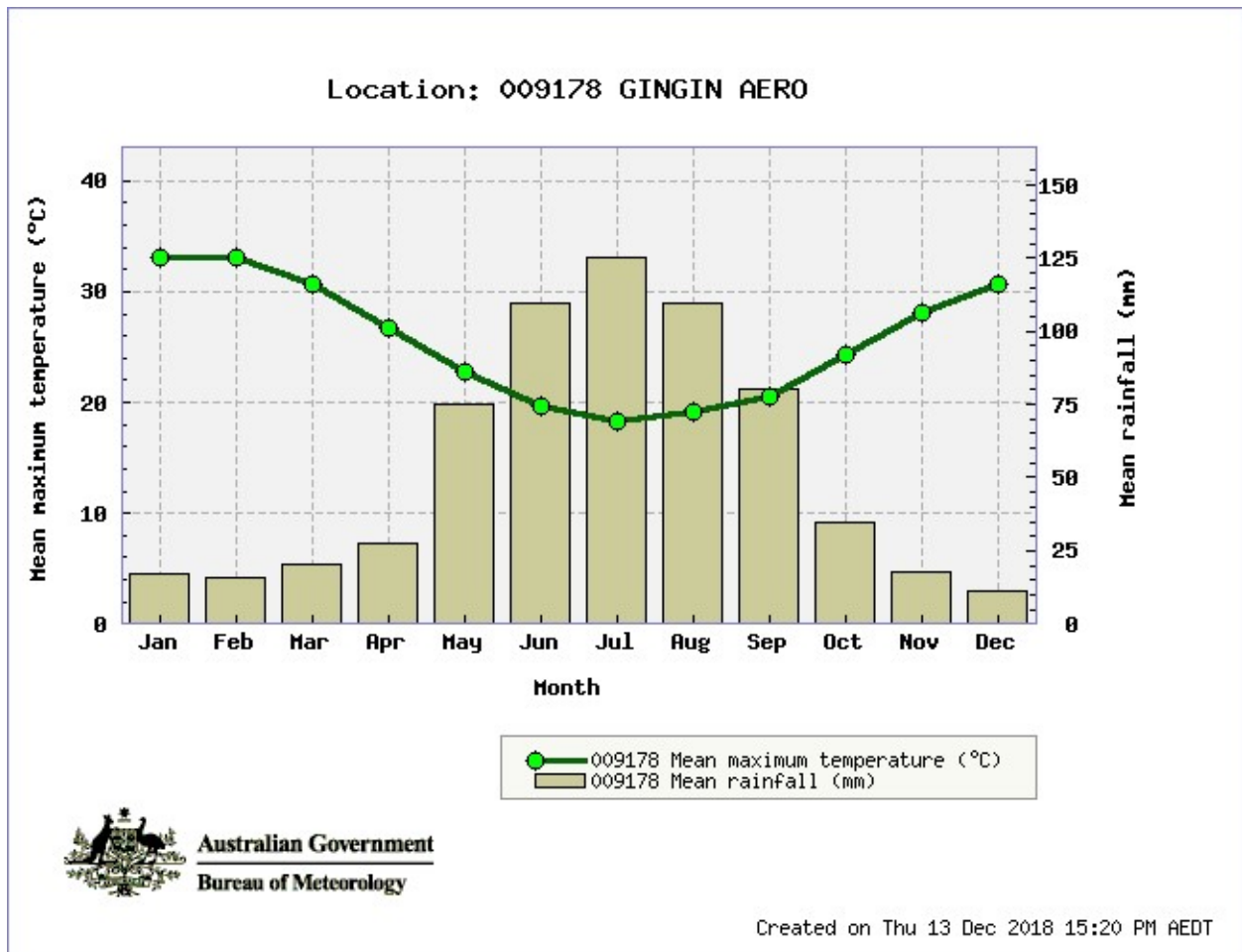


**Figure 2 - IBRA Regions**



### 3.2 CLIMATE

The Bindoon area experiences a warm and temperate climate, where the winter months experience greater rainfall than the summer months (Climatedata.org 2018). Gingin Aero (site number 9178) is the closest Bureau of Meteorology (BoM) recording station, which has been recording data since 1968 and has recorded an average annual rainfall of 649.6 mm. The annual mean maximum temperature ranges from 18.3°C in winter to 33.1°C in summer (BoM 2018) (**Figure 3**).



**Figure 3 - Climate Data for Gingin Aero**

#### 3.2.1 Rainfall Preceding Field Surveys

The monthly rainfall of 2018, which encompasses the spring survey period, the summer months thereafter (as relevant to ongoing targeted summer surveys) and the months preceding the surveys, for the BoM recording stations of Gingin Aero, Mooliabeenee and Wannamal are summarised in **Table 3**.

Rainfall data for the winter months preceding spring field surveys fluctuated, and late summer and autumn data shows that across the region of the study area, rainfall was significantly lower than average. August recorded high rainfall in the region, although a significantly drier than average September followed.



**Table 3 – Summary of Rainfall Observations and Statistics**

Recording Station	Rainfall (mm)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bindoon Monthly Mean	13.8	17.2	14.3	34.6	88.9	120.6	140.4	108.7	65.6	43.2	17.5	11.2	672.1
Bindoon 2018	74.0	6.0	3.2	15.2	62.6	121.6	157.6	201.2	24.0	58.9	6.6	2.6	733.5
Gingin Aero Monthly Mean	16.3	15.0	19.5	27.7	75.2	109.8	125.3	109.8	80.3	34.8	18.0	10.5	625.6
Gingin Aero 2018	0.2	1.4	1.0	13.2	67.2	94.2	113.4	162.8	16.0	29.8	1.4	0.4	501.0
Wannamal Monthly Mean	11.6	15.2	16.5	28.4	79.2	110.6	116.6	88.5	56.7	34.3	17.1	10.2	583.6
Wannamal 2018	61.5	10.2	0.8	8.8	53.8	92.1	123.5	158.0	19.3	49.5	0.8	1.0	579.3

Above average      Approximately average      Below average

### 3.3 GEOLOGY AND SOILS

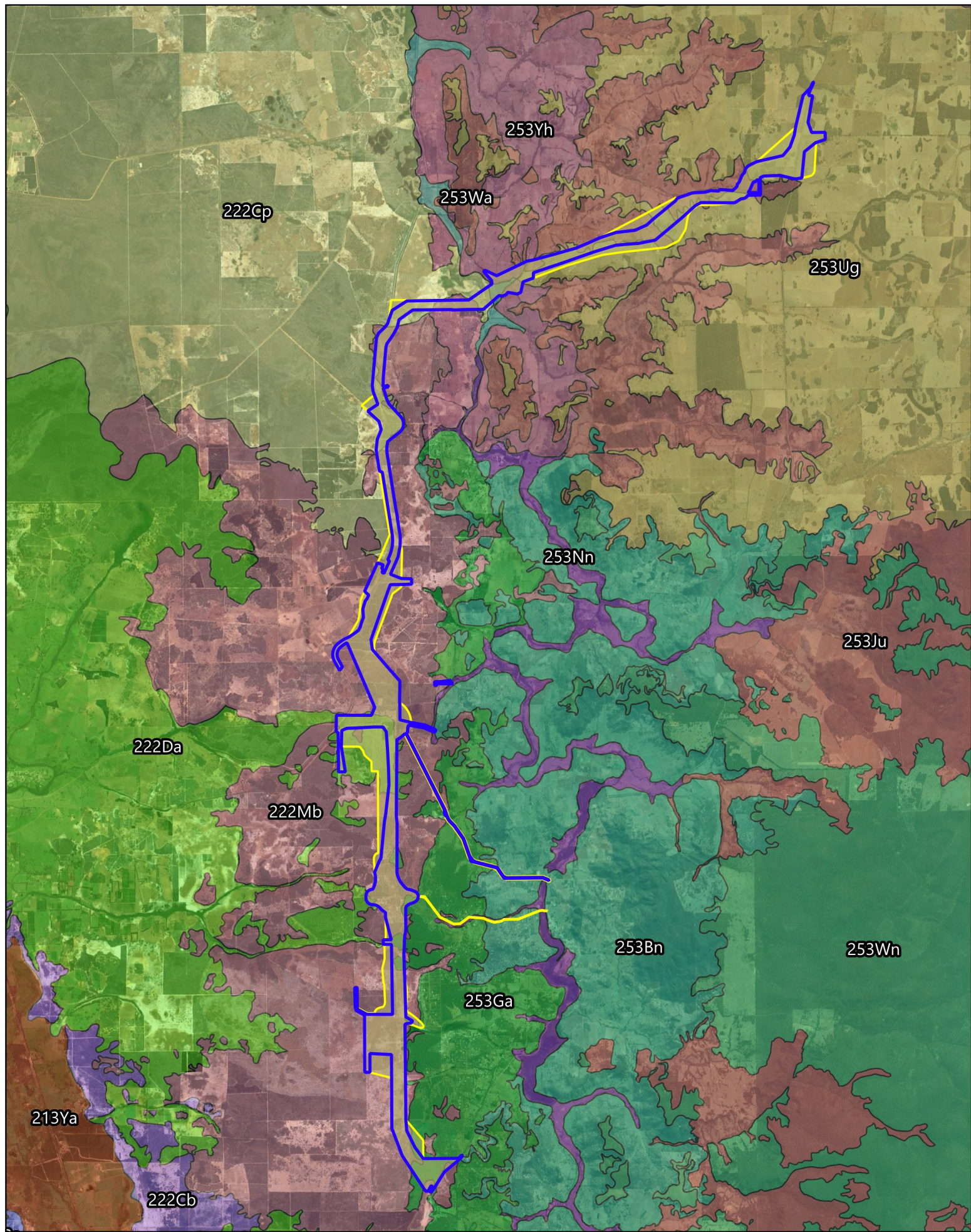
Soil-landscape mapping across Western Australia has been compiled by the Department of Agriculture and Food WA (DAFWA) (2018b) using various surveys at different scales varying between 1:20,000 and 1:3,000,000.

At the system scale, the study area traverses ten regional soil-landscape mapping systems, as summarised in **Table 4**, with their extent in the study area shown in **Figure 4**.

**Table 4 - Summary of Soil-Landscape Systems within the Study Area (DAFWA 2018b)**

Map Unit	Soil System	Description
222Cp	Capitella System	Subdued stripped lateritic plateau, undulating to gently undulating low rises with gently undulating plain including dunes; pale and yellow deep sands, sandy gravels, some duplex; from sandstones plus alluvial and aeolian deposits.
222Da	Dandaragan System	Subdued dissected lateritic plateau, undulating low hills and rises with narrow alluvial plains. Variable deep sands and sandy gravels plus minor earths, duplexes and clays. Marri woodlands and shrublands.
222Mb	Mogumber System	Gentle to moderate sloping sandplain, varying from pale to yellow clayey sand with gravel and laterised ridges. Low woodland and shrubland of, <i>C. calophylla</i> , <i>Banksia</i> and <i>Acacia</i> spp. Some tall <i>C. calophylla</i> and <i>E. marginata</i> .
253Bn	Bindoon System	Gentle to steep hills with gentle valleys on metamorphic gneiss and schist, and dolerite. Variable soils. Wandoo woodland with some <i>Casuarina huegeliana</i> in rocky areas and marri woodland on sandy areas, minor York gum woodland.
253Ga	Gabbla System	Western boundary of the Darling Plateau to the east of the Dandaragan plateau. Gently to moderately slopes. Yellow, red and grey loams and clays, with gravel common and sand pockets. <i>E. wandoo</i> and <i>E. loxophleba</i> on clay.
253Ju	Julimar System	Moderately dissected areas with gravelly slopes and ridges and minor rock outcrop on the eastern side of the Darling Plateau over weathered granite and granitic gneiss. Loamy gravel, shallow duplexes and pale deep sand common. Wandoo woodland.
253Nn	Nooning System	Brockman river valley flattish valley floors of the upper that is prone to salinity. Loams, clays and gleyed salty sandy clays and gravelly soils are present. <i>E. rudis</i> , <i>E. camaldulensis</i> , <i>Melaleuca</i> and <i>Casuarina obesa</i> in the saltiest areas.
253Ug	Udamong System	Northern Darling Range near New Norcia. Partially stripped lateritic plateau with undulating low hills to gently undulating rises. Loamy gravel, minor pale sand and clay; deep weathered granitic gneiss, gneiss and schist
253Wa	Wannamal System	Alluvial plain and fans; Brown and red loamy earths, Yellow/brown sandy duplexes, loamy duplexes
253Yh	Yarawindah System	Dissected lateritic plateau with rolling to undulating low hills and undulating rises; loamy gravel, loamy earth, loamy duplex, some rock; weathered schist and some gneiss





0 2 4 6 8 km

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**Figure 4 - Soils**

**Legend**

Development Envelope	222Cp	253By	253Ug	255Mv
Study Area	222Da	253Cc	253Wa	256Gh
212Bs	222Mb	253Ga	253Wn	256Gt
213Ya	222Re	253Ju	253Yh	
222Cb	253Bn	253Nn	255Dp	





### 3.4 VEGETATION

The vegetation within the study area has been broadly characterised as Banksia low woodland, Jarrah–Marri woodland, Marri woodland, Bullich (*Eucalyptus megacarpa*) and Blackbutt (*E. patens*) in the valleys and Wandoo (*E. wandoo*) and Marri woodlands with Powderbark (*E. accedens*) on breakaways (Desmond 2001, Mitchell and Williams 2001). The study area traverses eight vegetation associations characterised by Shepherd *et al.* (2002), and the general vicinity of the study area supports 20 vegetation associations, as summarised in **Table 5**.

Vegetation complexes within the study area have also been defined by Heddle *et al.* (1980) and Havel and Mattiske (2000). These complexes are based on vegetation in association with landforms and underlying geology. A collective total of nine vegetation complexes occur within the study area. These are described as follows:

1. **Bindoon Complex.** This complex is broadly characterised by *Eucalyptus loxophleba* (York gum) on the lower valley slopes, flanked by Wandoo higher upslope.
2. **Coolakin Complex in low rainfall.** Comprises of Woodlands of *Eucalyptus wandoo* with mixtures of *Eucalyptus patens*, *Eucalyptus marginata* subsp. *thalassica* and *Corymbia calophylla* on the valley slopes in arid and perarid zones.
3. **Cullulla Complex.** Mixture of low open forest of Banksia spp. *Eucalyptus todtiana* and open woodland *Corymbia calophylla* with second storey of *Eucalyptus todtiana*, *Banksia attenuata*, *Banksia menziesii* and *Banksia ilicifolia*.
4. **Michibin Complex.** Open woodland of *Eucalyptus wandoo* over *Acacia acuminata* with some *Eucalyptus loxophleba* on valley slopes, with low woodland of *Allocasuarina huegeliana* on or near shallow granite outcrops in arid and perarid zones.
5. **Mogumber Complex–South.** Open woodland of *Corymbia calophylla* with some mixture of *Eucalyptus marginata* subsp. *thalassica* and a second storey of *Eucalyptus todtiana*, *Banksia attenuata*, *Banksia menziesii*, *Banksia ilicifolia* on sandy gravels on the uplands in arid and perarid zones.
6. **Moondah Complex.** Low closed to low open forest of *Banksia attenuata*, *Banksia menziesii*, *Eucalyptus todtiana* and *Banksia prionotes* on slopes, open woodland of *Corymbia calophylla* and *Banksia* spp. in valleys.
7. **Nooning Complex.** This complex is restricted to the upper valley floors of the Brockman River. This complex is characterised by low open forest of *Casuarina obesa* (Swamp sheoak) and the presence of *Casuarina obesa*, *Eucalyptus rudis* and *Melaleuca raphiophylla* along streams.
8. **Wannamal Complex.** Low shrubland of the Dandaragan Plateau comprising of a mixture of low shrubland of *Melaleuca* spp. and open woodland of *Eucalyptus wandoo* and *Eucalyptus loxophleba*.
9. **Yalanbee Complex in low rainfall.** This complex is characterised by woodlands of *Eucalyptus wandoo*–*Eucalyptus accedens*, less consistently open forest of *Eucalyptus marginata* subsp. *thalassica*–*Corymbia calophylla* on lateritic uplands and breakaway landscapes in arid and perarid zones.

The extent of each of the regional vegetation associations (Shepherd *et al.* 2002) and vegetation complexes (Heddle *et al.* 1980) present within the study area is presented in **Figures 5** and **6**, respectively.

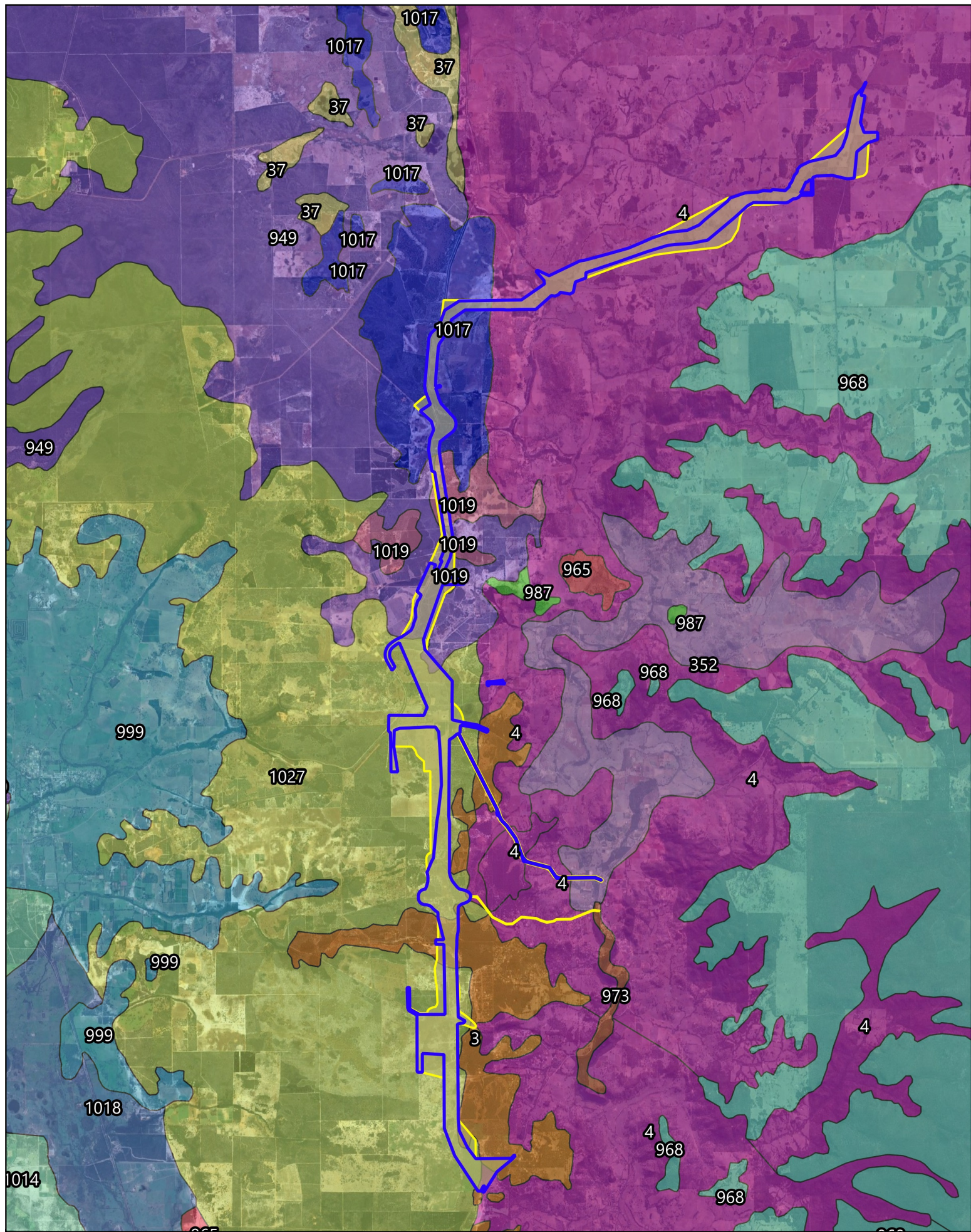
**Table 5 - Regional Vegetation of the Study Area and Surrounds (Shepherd *et al.* 2002)**

Shepherd Code	Short Description	Broad Vegetation Description
3	Medium forest; jarrah-marri	U <sup>^</sup> <i>Eucalyptus marginata</i> , <sup>^</sup> <i>Corymbia calophylla</i> , <i>Allocasuarina fraseriana</i> \tree\7;c;M <i>Acacia urophylla</i> , <i>Bossiaea aquifolium</i> , <i>Hakea cyclocarpa</i> \shrub\4;i;G <i>Macrozamia riedlei</i> , <i>Styphelia tenuiflora</i> , <i>Lepidosperma angustatum</i> \cycad,forb,shrub,sedge\2;i
4	Medium woodland; marri & wandoo	U <sup>^</sup> <i>Corymbia calophylla</i> , <sup>^</sup> <i>Eucalyptus wandoo</i> \tree\7;i;M <i>Acacia cyanophylla</i> , <i>Jacksonia sternbergiana</i> , <i>Xanthorrhoea preissii</i> \shrub, <i>Xanthorrhoea</i> \4;i
		U <sup>^</sup> <i>Corymbia calophylla</i> , <sup>^</sup> <i>Eucalyptus wandoo</i> , <i>Nuytsia floribunda</i> \tree\7;i;M <i>Daviesia horrida</i> , <i>Dryandra sessilis</i> , <i>Hakea cristata</i> \shrub\3;i;G <i>Acacia pulchella</i> , <i>Dryandra nivea</i> , <i>Hibbertia hypericoides</i> \shrub,cycad, <i>Xanthorrhoea</i> \2;i
37	Shrublands; teatree thicket	U <sup>^</sup> <i>Banksia littoralis</i> , <i>Melaleuca preissiana</i> \tree\6;r;M <sup>^</sup> <i>Melaleuca</i> sp., <i>Hakea</i> sp., <i>Beaufortia squarrosa</i> \shrub\3\d
		U <sup>^</sup> <i>Eucalyptus rudis</i> <sup>^</sup> <i>Melaleuca raphiophylla</i> \tree\7;cG <i>Viminaria denudata</i> \sedge\2;i
352	Medium woodland; York gum	U <sup>^</sup> <i>Eucalyptus loxophleba</i> \tree\7;i;M <i>Acacia acuminata</i> , <i>Acacia cyanophylla</i> \shrub\4;i
946	Medium woodland; wandoo	U <sup>^</sup> <i>Eucalyptus wandoo</i> \tree\7;i
949	Low woodland; banksia	U <sup>^</sup> <i>Banksia attenuata</i> , <i>Banksia menziesii</i> , <i>Eucalyptus todtiana</i> \tree\6;i;G <i>Conospermum incurvum</i> , <i>Verticordia nitens</i> \shrub\4;c
		U <sup>^</sup> <i>Banksia attenuata</i> , <i>Banksia menziesii</i> , <i>Eucalyptus todtiana</i> \tree\6;i;M <i>Calothamnus sanguineus</i> , <i>Petrophile brevifolia</i> , <i>Eremaea pauciflora</i> \shrub\4;i;G <i>Hibbertia hypericoides</i> , <i>Stirlingia latifolia</i> , <i>Synaphea polymorpha</i> \shrub,sedge\2;c
965	Medium woodland; jarrah & marri	U <sup>^</sup> <i>Eucalyptus marginata</i> , <sup>^</sup> <i>Corymbia calophylla</i> \tree\7;i
968	Medium woodland; jarrah, marri & wandoo	U <sup>^</sup> <i>Eucalyptus marginata</i> , <i>Banksia grandis</i> \tree\7;i;M <i>Acacia varia</i> var. <i>affinis</i> , <i>Adenanthos cygnorum</i> , <i>Allocasuarina humilis</i> \shrub\4;i;G <i>Anigozanthos humilis</i> , <i>Burchardia umbellata</i> , <i>Conostylis setosa</i> \forb,shrub,sedge\2;i
973	Low forest; paperbark ( <i>Melaleuca raphiophylla</i> )	U <sup>^</sup> <i>Eucalyptus rudis</i> , <sup>^</sup> <i>Melaleuca preissiana</i> \tree\7;c



Shepherd Code	Short Description	Broad Vegetation Description
987	Medium woodland; jarrah & wandoo	U^ <i>Eucalyptus marginata</i> , ^ <i>Eucalyptus wandoo</i> \tree\7\i
999	Medium woodland; marri	U^ <i>Corymbia calophylla</i> , <i>Eucalyptus loxophleba</i> , <i>Acacia cyanophylla</i> \tree\7\i; M <i>Acacia pulchella</i> , <i>Boronia scabra</i> , <i>Bossiaea</i> sp. \shrub, cypad, <i>Xanthorrhoea</i> \4\i; G <i>Hibbertia hypericoides</i> , <i>Hybanthus calycinus</i> , <i>Lechenaultia biloba</i> \shrub, forb\2\i
1008	Medium open woodland; marri	U^ <i>Corymbia calophylla</i> \tree\7\i
1009	Medium woodland; marri & river gum	U^ <i>Corymbia calophylla</i> , ^ <i>Eucalyptus rudis</i> \tree\7\i
1014	Mosaic: Low woodland; banksia / Shrublands; teatree thicket	U^ <i>Banksia attenuata</i> , <i>Banksia menziesii</i> \tree\6\i
1016	Mosaic: Low woodland; banksia / Shrublands; dryandra heath	M <i>Dryandra</i> sp. \shrub\3\c
1017	Medium open woodland; jarrah & marri, with low woodland; banksia	U^ <i>Eucalyptus marginata</i> , ^ <i>Corymbia calophylla</i> , <i>Banksia attenuata</i> \tree\7\i
1018	Mosaic: Medium forest; jarrah-marri / Low woodland; banksia / Low forest; teatree / Low woodland; <i>Casuarina obesa</i>	U^ <i>Eucalyptus marginata</i> , ^ <i>Corymbia calophylla</i> \tree\7\c; M <i>Melaleuca</i> sp., <i>Banksia</i> sp., <i>Casuarina obesa</i> \tree\6\c
1019	Medium sparse woodland; jarrah & marri	U^ <i>Eucalyptus marginata</i> , ^ <i>Corymbia calophylla</i> \tree\7\r
1027	Mosaic: Medium open woodland; jarrah & marri, with low woodland; banksia / Medium sparse woodland; jarrah & marri	U^ <i>Corymbia calophylla</i> , <i>Eucalyptus marginata</i> , ^^ <i>Banksia attenuata</i> \tree\7\I
1030	Low woodland; <i>Banksia attenuata</i> & <i>B. menziesii</i>	U^ <i>Banksia attenuata</i> , ^ <i>Banksia menziesii</i> \tree\6\i





0 2 4 6 8 km

GDA 94 / MGA Zone 50

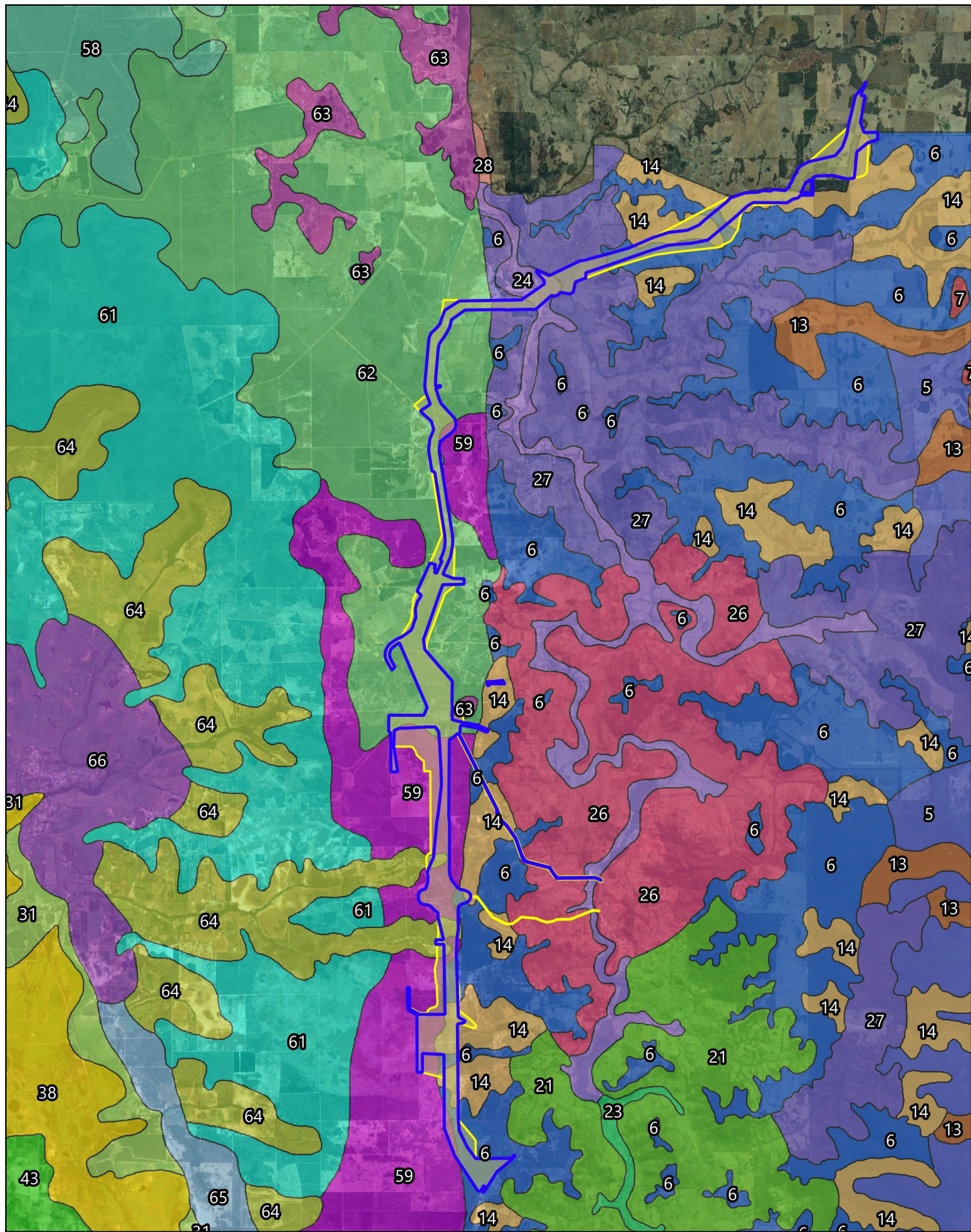


Legend			
	Development Envelope		37
	Study Area		968
	3		352
	4		987
	949		999
	965		1019
	1014		1020
	1017		1027
	1018		
	1019		
	973		
	968		



**Figure 5 - Regional Vegetation**





0 2 4 6 8 km  
 GDA 94 / MGA Zone 50



**Figure 6 - Vegetation Complexes**

Legend					
Development Envelope	7	23	31	59	65
Study Area	13	24	38	61	66
5	14	26	43	62	
6	21	27	45	63	
	28	58	64		





## 4 BIOLOGICAL CONTEXT

Numerous relevant surveys have been previously conducted within the area between Chittering and Bindoon to Wannamal and surrounds. A review of the most recent available studies was undertaken to collate existing information on Threatened and Priority Flora and previously mapped vegetation units of the study area and surrounding region. Detailed findings have been reported in the following:

- FVC (2018a) Memorandum – Phase 2 Autumn and Winter Flora and Vegetation Surveys, Great Northern Highway, Bindoon Bypass
- FVC (2018b) Memorandum – Great Northern Highway, Bindoon Bypass, Key Flora, Vegetation, Fauna and Habitat Constraints
- FVC (2018c) Detailed Flora and Vegetation Assessment, Bindoon Bypass, Great Northern Highway
- FVC (2017) Level 2 Flora and Vegetation Assessment and Targeted *Thelymitra stellata* Survey, Great Northern Highway, Muchea to Wubin Upgrades, Stage 2 – Bindoon Options
- Phoenix Environmental Sciences (2016) Flora and fauna assessment for Calingri to Wubin study areas. Great Northern Highway, Muchea to Wubin Upgrade Stage 2 Project
- Phoenix Environmental Sciences (2015) Flora and fauna assessment for Muchea North and Chittering study area
- GHD (2011a) Report for Great Northern Highway Upgrade: Muchea to Bindoon Environmental Impact Assessment (SLK 33.13 – 65.31)
- GHD (2011b) Report for Great Northern Highway Upgrade: Muchea to Bindoon Flora and Fauna Assessment (SLK 33.13 – 65.31)
- ENV (2007) Great Northern Highway Flora and Vegetation Assessment – SLK 89 to SLK 114
- KBR (2006) Environmental Impact Assessment and Management Plan. Great Northern Highway – Bindoon South SLK 54.6 to SLK 62.1
- Western Botanical (2006) Flora for extension of proposed disturbances on Great Northern Highway road reserve
- KBR (2005) Preliminary Environmental Impact Assessment. Great Northern Highway – Muchea (SLK 36) to Wubin (SLK 253)
- Goble-Garratt (2005) Great Northern Highway Upgrade – Bindoon South Section (Hart Drive to Bindoon Townsite SLK 54.6 to 62.0)
- Ecologia Environment (2004) Great Northern Highway: assessment of flora and vegetation.

These surveys form the basis of the literature review component of the desktop assessment and the key findings from each are summarised in **Table 6**.

**Table 6 - Summary of Key Findings from Recent Relevant Surveys**

Author, Area, Scope and Methodologies	Key Findings
<b>Focused Vision Consulting (2018c)</b>	
<ul style="list-style-type: none"> <li>Level 2 flora and vegetation assessment between April-November 2017 to supplement results of the spring 2016 study (FVC 2017) and to fill gaps in survey data. Additional quadrats sampled, a selection of existing quadrats re-sampled, further targeted significant flora surveys undertaken. Other verifications, revisions and supplementary observations made to update and confirm spatial mapping of vegetation units and condition throughout the study area</li> <li>Desktop review to determine significant flora species relevant to the new study area, and to locate suitable sites to target during autumn, winter and spring (based on existing survey data)</li> <li>Desktop review and field assessment to select suitable quadrats to resample during 2017, and new suitable quadrat sites to represent new survey areas in the wider region</li> <li>Desktop review to map and quantify likely extent of Banksia Woodland within and connected to the study area, for a targeted Banksia Woodlands TEC assessment</li> <li>Field assessment to fill survey gaps in properties not able to be accessed previously, of selected relevant areas targeting significant flora and Bankia woodland.</li> <li>Vegetation data was collected from a total of 89 quadrats (68 new, 21 resampled quadrats), 40 of which were located in the wider region, outside of the Bindoon Bypass corridor and contributed to the definition of regional context</li> </ul>	<ul style="list-style-type: none"> <li>No species of Threatened flora, including <i>Thelymitra stellata</i> and <i>Drakaea elastica</i> were recorded within the study area.</li> <li>Eight species listed as Priority Flora (<i>Drosera sewelliae</i> (with <i>Drosera ?sewelliae</i>) (P2), <i>Hibbertia glomerata</i> subsp. <i>ginginensis</i> (P2), <i>Acacia drummondii</i> subsp. <i>affinis</i> (with <i>Acacia drummondii</i> subsp. <i>?affinis</i>) (P3), <i>Adenanthos cygnorum</i> subsp. <i>chamaephyton</i> (P3), <i>Hibbertia miniata</i> (P4), <i>Hypolaena robusta</i> (P4), <i>Jacksonia ?sericea</i> (P4) and <i>Verticordia paludosa</i> (with <i>Verticordia ?paludosa</i>) (P4)) were recorded during the 2017 field assessments</li> <li>A collective total of 11 species listed as Priority Flora were recorded between the 2016 and 2017 field assessments. A collective total of 1,967 individual Priority flora plants were recorded in the study area between 2016 and 2017</li> <li>It is considered likely that the distribution and abundance of the Priority flora recorded within the study area is greater than the assessment results would suggest, and that additional species of Priority flora occur that were not recorded, due to the unfavourable season experienced by the region with lower than expected rainfall received during winter 2017</li> <li>Two flora species, <i>Jacksonia ?sericea</i> (P4) and <i>Synaphea ?flabelliformis</i> were found to be occurring outside their known range, based on distributions from the WA Herbarium</li> <li>One of the recorded weed species, <i>Chondrilla juncea</i> (Skeleton weed) is listed as category 'C2' Declared Pest plant under the BAM Act within the study area</li> <li>One State-listed TEC and two PECs known to occur within or closely adjacent to the study area</li> <li>Study area confirmed to support areas of the Commonwealth-listed Banksia Woodland TEC, within 476 ha of the TEC mapped, consisting of occurrences of vegetation units BaXpAn, BaXpJa, EmXpAn, EtBeAn and EtEpAn</li> <li>All of the recorded vegetation units have been determined to be of local, regional or national significance, or a combination of these levels of importance.</li> </ul>

Author, Area, Scope and Methodologies	Key Findings
<b>Focused Vision Consulting (2018a)</b>	
<ul style="list-style-type: none"> <li>Level 2 Flora and Vegetation assessment of the preferred corridor (Western A) for the Bindoon Bypass</li> <li>Vegetation unit/condition mapping, targeted searches for conservation significant flora, vegetation and declared pest plants (weeds), quadrat re-sampling and gap filling undertaken</li> <li>Autumn surveys conducted March to May 2017</li> <li>Winter surveys conducted June to August 2017</li> <li>A total of 47 quadrats and two releves from 13 vegetation associations recorded during spring 2016 assessment of the three route options</li> <li>A total of 17 quadrats established in 2016 were resampled and an additional 13 new quadrats were established and recorded during autumn/winter 2017</li> </ul>	<ul style="list-style-type: none"> <li>During autumn and winter phase assessments, three Threatened flora and 17 Priority flora were targeted, based on suitable flowering times. Of these, seven Priority flora were targeted during the autumn phase and three Threatened flora and 13 Priority flora were targeted during the winter phase.</li> <li>Two Priority flora species recorded, <i>Verticordia paludosa</i> (P4) recorded during autumn phase of assessment at three confirmed locations. One additional collection of a possible <i>Verticordia paludosa</i> (P4) was recorded. Initial taxonomic identification of this species indicated that it was possibly <i>Verticordia paludosa</i> (P4), however it was not possible to definitively confirm the species due to lack of flowering material.</li> <li><i>Adenanthos cygnorum</i> subsp. <i>chamaephyton</i> (P3) recorded from one location north of Teatree road, where majority of population occurs outside the study area</li> <li>Initial assessment of quadrat data collected during the autumn and winter phase flora and vegetation assessment verified vegetation unit and vegetation condition mapping conducted during 2016.</li> <li>No changes in vegetation unit composition, spatial extent or vegetation condition were noted at the time of the interim reporting.</li> </ul>
<b>Focused Vision Consulting (2018b)</b>	
<ul style="list-style-type: none"> <li>Focused Vision Consulting (FVC) were engaged by the Integrated Project Team (IPT) to conduct spring flora, vegetation, fauna and habitat assessments of the Bindoon Bypass alignment, across spring 2016 and into autumn, winter and spring 2017</li> <li>The following relevant key biological constraints were reported: <ul style="list-style-type: none"> <li>Threatened and Priority Flora</li> <li>Banksia Woodland TEC</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>No Threatened Flora recorded</li> <li>Various Priority Flora recorded including: <ul style="list-style-type: none"> <li><i>Synaphea panhesya</i> (P1) and <i>Synaphea ?panhesya</i> (P1)</li> <li><i>Hibbertia glomerata</i> subsp. <i>ginginensis</i> (P2)</li> <li><i>Drosera sewelliae</i> (P2) and <i>Drosera ?sewelliae</i> (P2)</li> <li><i>Acacia drummondii</i> subsp. <i>affinis</i> (P3) and <i>Acacia drummondii</i> subsp. <i>?affinis</i> (P3)</li> <li><i>Adenanthos cygnorum</i> subsp. <i>chamaephyton</i> (P3)</li> <li><i>Anigozanthos humilis</i> subsp. <i>chrysanthus</i> (P4)</li> <li><i>Hibbertia miniata</i> (P4)</li> <li><i>Hypolaena robusta</i> (P4)</li> <li><i>Jacksonia ?sericea</i> (P4)</li> <li><i>Verticordia paludosa</i> (P4) and <i>Verticordia ?paludosa</i> (P4)</li> </ul> </li> <li>Banksia Woodland likely to be equivalent to Banksia Woodland of the Swan Coastal Plain TEC was recorded within study area</li> </ul>

Author, Area, Scope and Methodologies	Key Findings
<b>Focused Vision Consulting (2017)</b>	
<ul style="list-style-type: none"> <li>• Level 2 flora and vegetation assessment of three proposed route options for the Great Northern Highway Bindoon Bypass; broken down into four survey areas (collectively the 'study area'):               <ul style="list-style-type: none"> <li>○ Common Area (common to the southern commencement of both Areas 1 and 2) – Area 1</li> <li>○ Western Bypass A – Area 2</li> <li>○ Western Bypass B – Area 3</li> <li>○ Eastern Bypass – Area 4</li> </ul> </li> <li>• Total survey effort of 18-person days conducted during October 2016</li> <li>• Total of 46 pegged quadrats and two relevés were established and sampled</li> <li>• Targeted survey conducted for <i>Thelymitra stellata</i> in November 2016 within selected areas with a total of 21-person days invested.</li> <li>• Aim to survey at least 50% of suitable habitat areas for <i>Thelymitra stellata</i> within the study area</li> </ul>	<ul style="list-style-type: none"> <li>• Total of 13 different vegetation communities recorded in study area</li> <li>• Seven Priority Flora recorded: <i>Synaphea panhesya</i> (P1), <i>Gastrolobium ?crispatum</i> (P1), <i>Drosera sewelliae</i> (with <i>Drosera ?sewelliae</i>) (P2), <i>Acacia drummondii</i> subsp. <i>affinis</i> (P2), <i>Adenanthos cygnorum</i> subsp. <i>chamaephyton</i> (P3), <i>Anigozanthos humilis</i> subsp. <i>chrysanthus</i> (P3) and <i>Hibbertia miniata</i></li> <li>• Considered likely that distribution and abundance of Priority flora recorded is greater than the recorded population extents and sizes and that additional species of Priority flora occur that were not recorded, due to a focus on quadrats and vegetation definition rather than targeted flora surveys</li> <li>• Further, more detailed surveys to target Priority flora were recommended</li> <li>• No species of Threatened flora, including <i>Thelymitra stellata</i> were recorded within study area</li> <li>• One State-listed TEC and two PECs are known to occur (based on database search results) within or near study area; with all three ecological communities' representative of the Commonwealth-listed <i>Banksia</i> woodlands of the Swan Coastal Plain TEC</li> <li>• The spring 2016 assessment scope was developed prior to the <i>Banksia</i> Woodlands of the Swan Coastal Plain being announced as a Commonwealth-listed TEC, in September 2016. However, future assessments will focus on <i>Banksia</i> woodlands and will enable assessment against the key diagnostic characteristics (Threatened Species Committee 2016) for determination of the presence of the TEC with certainty</li> <li>• The total area of likely <i>Banksia</i> woodland TEC within study area is 22.67ha, consisting of occurrences of vegetation communities BaXpAn, EtBeAn (including ?EtBeAn) and EtEpAn all occurring within the Western A (Area 2) study area</li> <li>• Further assessment work is required to accurately characterize and map the extent of <i>Banksia</i> woodland (Commonwealth) TEC within study area, due to prescriptive requirements of its definition</li> <li>• All of the recorded vegetation communities have been determined to be of local, regional or national significance, or a combination of these levels of importance.</li> </ul>



Author, Area, Scope and Methodologies	Key Findings
<b>Phoenix Environmental Sciences (2015)</b>	
<ul style="list-style-type: none"> <li>• Level 2 Flora assessment of work package 1 (Muehea North – SLK 10.9 to SLK 46.44) and work package 2 (Chittering – SLK 46.44 to SLK 51.82) of Great Northern Highway Upgrade Area</li> <li>• Spring surveys conducted October 2014 (Phase 1) and September 2015 (Phase 2)</li> <li>• Additional targeted species searches where conducted in May 2015</li> <li>• Average width of study area was 200 m with an approximate total survey area of 302.6 ha</li> <li>• Included vegetation type/condition mapping, targeted searches for conservation significant flora, vegetation and declared pest plants (weeds)</li> <li>• A total of 32 quadrats and 17 relevés sampled</li> </ul>	<ul style="list-style-type: none"> <li>• Phoenix (2015) study area is approximately 600 m south of current study area at the closest point along Great Northern Highway</li> <li>• Database searches identified the potential for 17 Threatened Flora listed under the EPBC Act, 18 flora listed under the WC Act 15 State Priority Flora and seven Declared Pest plants</li> <li>• A total of 273 taxa recorded, including seven conservation significant flora; <i>Darwinia foetida</i> (T; CE), <i>Stylidium squamellosum</i> (P2), <i>Acacia drummondii</i> subsp. <i>affinis</i> (P3), <i>Haemodorum loratum</i> (P3), <i>Verticordia serrata</i> var. <i>linearis</i> (P3), <i>Verticordia serrata</i> var. <i>linearis</i> (P4), <i>Eucalyptus caesia</i> (P4)</li> <li>• Targeted surveys conducted for <i>Darwinia foetida</i> (CE), <i>Trichocline</i> sp. <i>Treeton</i> (P2), <i>Daviesia debilior</i> subsp. <i>sinuans</i> (P3) and <i>Verticordia lindleyi</i> subsp. <i>lindleyi</i> (P4)</li> <li>• No Commonwealth or State listed TECs or PECs recorded, however five TECs and three PECs occur between 200 m and 4.5 km from the study area</li> <li>• 19 vegetation associations defined within the study area, none considered to be representative of known TECs or PECs</li> <li>• 16 vegetation associations may be considered to be locally significant due to limited representation of the vegetation type within the study area or as they represent habitat for conservation significant flora recorded within the study area</li> <li>• Vegetation condition ranged from ‘Completely Degraded’ to ‘Pristine’</li> </ul>

Author, Area, Scope and Methodologies	Key Findings
<b>GHD (2011a)</b>	
<ul style="list-style-type: none"> <li>• Preferred general corridor alignment for Great Northern Highway between Muchea and Bindoon (northern portion overlaps with FVC study area); 19 km by approximate width of 160m</li> <li>• EIA prepared through desktop assessments of relevant literature and databases; field assessments where appropriate</li> <li>• Included; Level 2 flora and vegetation, Level 1 fauna, dieback, contaminated sites, noise, ethnographic/indigenous/European heritage</li> </ul>	<ul style="list-style-type: none"> <li>• A number of impacts to flora and fauna identified through EIA including; impact to Bindoon and Chittering Lakes and associated vegetation, clearing of vegetation with less than 30% of pre-European extent remaining, potential impacts to listed Threatened fauna species such as Carnaby's Black-cockatoos, dieback and weeds</li> <li>• No Commonwealth or State listed TECs or PECs identified through database searches or field assessment</li> <li>• Database searches identified 12 Threatened Flora and 32 Priority Flora likely to occur within 10 km of the study area</li> <li>• Three Priority flora recorded; <i>Millotia tenuifolia</i> var. <i>laevis</i> (P2), <i>Acacia drummondii</i> subsp. <i>affinis</i> (P3), <i>Persoonia sulcata</i> (P4)</li> <li>• Vegetation clearing considered to be at or may be at variance with Principles (b), (e), (f), (h) and (i) of the ten clearing principles</li> <li>• Three Nature Reserves (A Class: Bindoon and Chittering Lakes Nature Reserve, Barracca Nature Reserve and C Class; Burroloo Well Nature Reserve) occur within the vicinity of the study area. Small area of Bindoon and Chittering Nature Reserve likely to be impacted</li> </ul>
<b>GHD (2011b)</b>	
<ul style="list-style-type: none"> <li>• Flora and fauna assessment of corridor alignment for upgrades and realignment of Great Northern Highway between Muchea and Bindoon, extends 19 km (northern portion overlaps with FVC study area)</li> <li>• Level 2 Flora and vegetation assessment in September 2010</li> </ul>	<ul style="list-style-type: none"> <li>• Approximately 119 ha of vegetation ranging from Pristine to Completely Degraded. Predominately considered to be in Degraded to Completely Degraded condition</li> <li>• A total of 277 taxa were recorded and 13 vegetation types described within the study area</li> <li>• Database search results identified two PECs within 10 km of the study area; Banksia Woodlands of the Gingin area restricted to soils dominated by yellow to orange sands (Priority 2) and Northern <i>Banksia attenuata</i>-<i>Banksia menziesii</i> woodlands (SCP23b) (Priority 3).</li> <li>• Two vegetation types (CcAcXpCaLs and AcCsMp) reported to exhibit similarities to (at the time) Endangered ecological community – <i>Banksia attenuata</i> woodland over species rich dense shrublands (SCP 20a) and Priority 3 ecological community – Northern <i>Banksia attenuata</i>-<i>Banksia menziesii</i> woodlands (SCP 23b). Both of which now correspond to Commonwealth-listed Banksia Woodlands of the Swan Coastal Plain TEC. However, advice from DEC confirmed that neither is representative of these communities based on location, soil type and species richness</li> <li>• Two vegetation types are represented by less than 30% of their pre-European extent and are considered Vulnerable</li> <li>• Three new Priority flora species populations were recorded by GHD (2011b); <i>Millotia tenuifolia</i> var. <i>laevis</i> (P2), <i>Acacia drummondii</i> subsp. <i>affinis</i> (P3) and <i>Persoonia sulcata</i> (P4). <i>Adenanthos cygnorum</i> subsp. <i>chamaephyton</i> (P3) was located within the current study area and <i>Verticordia lindleyi</i> subsp. <i>lindleyi</i> (P4) was recorded within the A Class Barracca Nature Reserve</li> </ul>

Author, Area, Scope and Methodologies	Key Findings
<b>ENV (2007)</b>	
<ul style="list-style-type: none"> <li>• Great Northern Highway south of New Norcia SLK 89 to SLK 114</li> <li>• Occurs to the north-east of the FVC study area, approximately 30 km north of Bindoon township along Great Northern Highway</li> <li>• Total survey length of 24 km</li> <li>• Level 2 Spring Flora and Vegetation survey conducted in November 2006</li> <li>• A total of 48 quadrats sampled</li> </ul>	<ul style="list-style-type: none"> <li>• A total of 357 taxa recorded, including eight current Priority flora</li> <li>• Priority flora recorded were; <i>Hemigenia curvifolia</i> (P2), <i>Synaphea rangiferops</i> (P2), <i>Acacia anarthros</i> (P3), <i>Acacia drummondii</i> subsp. <i>affinis</i> (P3), <i>Grevillea florida</i> (P3), <i>Hakea lasiocarpa</i> (P3), <i>Persoonia rudis</i> (P3) and <i>Grevillea drummondii</i> (P4)</li> <li>• No Threatened flora recorded</li> <li>• 18 vegetation types described.</li> <li>• At the time of reporting there were no TECs listed for the study area</li> <li>• Declared Pest plants and WONS; <i>Asparagus asparagoides</i> and <i>Echium plantagineum</i> recorded</li> <li>• The vegetation condition varied from Completely Degraded to Excellent, however the majority of the road verge vegetation was found to be in Very Good or Excellent condition</li> </ul>
<b>Western Botanical (2006)</b>	
<ul style="list-style-type: none"> <li>• Flora and vegetation survey of eight work packages along Great Northern Highway from Brand Highway to Bindi Bindi-Toodyay Road</li> <li>• Work packages ranging in length from 3.49 km to 13.02 km; total survey length of 68.5 km</li> <li>• Level 1 spring flora and vegetation and an intensive Threatened and Priority flora survey, conducted between September and November 2005</li> </ul>	<ul style="list-style-type: none"> <li>• 290 native species and 26 introduced flora species recorded</li> <li>• A total of 10 current Priority flora species recorded</li> <li>• 34 vegetation types delineated; with those in the southern work packages predominantly consisting of Marri/Jarra/Wandoo/Powderbark woodlands, Banksia Woodlands, Casuarina Woodlands and creek line and swamp vegetation; and the northern work packages predominately consisting of York Gum/Salmon Gum/Wandoo/Powderbark Woodlands, Banksia Woodlands, Casuarina Woodlands, Mallee shrublands and succulent steppes with samphire</li> <li>• No determination of TECs or PECs made</li> <li>• Conservation significance of the vegetation within the road reserve was considered to be high due to the excellent condition, low weed invasion, the high number of Priority flora present and the extent of existing clearing that has occurred within the agricultural landscape</li> </ul>

Author, Area, Scope and Methodologies	Key Findings
<b>KBR (2006)</b>	
<ul style="list-style-type: none"> <li>• Great Northern Highway Bindoon South SLK 54.6 to SLK 62.1</li> <li>• EIA documented significant environmental aspects and management commitments of the GNH upgrade</li> <li>• Flora assessment undertaken as part of the EIA (Goble-Garret 2005) in late spring to early summer 2004/2005, encompassing roadsides of highway and areas immediately adjacent to footprint</li> </ul>	<ul style="list-style-type: none"> <li>• Close proximity to FVC study area along Great Northern Highway between Hart Drive and Bindoon townsite</li> <li>• A total project footprint of 15 ha (7 ha native vegetation and 8 ha of agricultural land)</li> <li>• EIA identified impacts pertaining to flora including disturbance to the Chittering Lakes Nature Reserve, dieback, weeds and presence of two Priority flora species; <i>Acacia drummondii</i> subsp. <i>affinis</i> and <i>Adenanthos cygnorum</i> subsp. <i>chamaephyton</i></li> <li>• Consultation with the DPaW (now DBCA) regarding the presence of Priority flora concluded that; while both populations of Priority flora would be significantly impacted, both populations would be retained with reasonable numbers of plants and each taxa is well represented in the local area</li> <li>• Dieback assessment conducted in 2004 identified the majority of the study area to be dieback infected or at high risk of being infected</li> <li>• No TECs recorded</li> </ul>
<b>Goble-Garratt (2005)</b>	
<ul style="list-style-type: none"> <li>• Hart Drive to Bindoon Townsite SLK 54.6 to 62.0</li> <li>• General flora survey in November 2004. Follow-up survey during September 2005 targeting Priority flora</li> </ul>	<ul style="list-style-type: none"> <li>• Study area considered to be a floristically rich area</li> <li>• A total of 117 taxa recorded, considered to be low in comparison with the region survey due to small size of the survey area and mostly disturbed condition of remnant vegetation present</li> <li>• Two P3 flora species recorded (<i>Acacia drummondii</i> subsp. <i>affinis</i> and <i>Adenanthos cygnorum</i> subsp. <i>chamaephyton</i>)</li> <li>• Seven vegetation units determined, none are considered to be comparable to TECs</li> </ul>
<b>KBR (2005)</b>	
<ul style="list-style-type: none"> <li>• Great Northern Highway – Muchea (SLK 36) to Wubin (SLK 253), 217 km in length</li> <li>• PEIA documented environmental aspects that are likely to be of concern and aimed to identify whether the project would be required to be referred to the EPA</li> </ul>	<ul style="list-style-type: none"> <li>• Numerous Threatened and Priority Flora identified through DBCA database searches. Two Threatened flora, <i>Banksia serratulooides</i> subsp. <i>serratulooides</i> (Vulnerable) and <i>Stylidium semaphorum</i> (Critically Endangered) identified within road reserve</li> <li>• The section between SLK 79.17 and SLK 105.42 was considered particularly important due to 64% of Threatened or Priority flora species recorded falling within this area</li> <li>• One State-listed TEC (Coombdale Chert) identified to occur near existing Great Northern Highway</li> <li>• Three A Class Nature Reserves and numerous C Class Reserves identified</li> </ul>



Author, Area, Scope and Methodologies	Key Findings
<b>Ecologia Environment (2004)</b>	
<ul style="list-style-type: none"> <li>• Great Northern Highway – Muchea (SLK 36) to Wubin (SLK 253) 217 km in length</li> <li>• Numerous vegetation surveys previously conducted however considered outdated; therefore, desktop flora assessment was undertaken as part of PEIA and included DBCA Threatened and Priority Flora and TEC database searches</li> </ul>	<ul style="list-style-type: none"> <li>• Literature review of Ninnox Wildlife Consulting (1989) identified 300 flora taxa from 22 quadrats between SLK 37 and 149.</li> <li>• A total of 50 vegetation assemblages described.</li> <li>• DBCA database searches identified 28 species of Threatened and Priority flora to occur between SLK 36 to SLK 253 within 1 km of the road centerline. Of these 11 are known to occur within the road reserve, although the survey conducted by Sinclair Knight Mertz (2003) did not identify the presence of any conservation significant flora</li> <li>• DBCA database search identified the Coomberdale Chert State-listed TEC to occur near the existing Great Northern Highway, however, due to the absence of characteristic dominant flora species, it was determined that none of the communities described during the survey were representative of this TEC</li> <li>• Five additional WA TECs were identified outside the 500 m corridor. These were: <ul style="list-style-type: none"> <li>○ <i>Corymbia calophylla-Xanthorrhoea preissii</i> woodlands and shrublands, (SCP 3c) – Critically Endangered</li> <li>○ Perth to Gingin Ironstone Association (NTHIRON) – Critically Endangered</li> <li>○ Communities of Tumulus Springs (Organic Mound Springs, Swan Coastal Plain) (Mound Springs SCP) – Critically Endangered</li> <li>○ <i>Banksia attenuata</i> and/or <i>Eucalyptus marginata</i> woodlands on the eastern side of the Swan Coastal Plain (SCP 20b) - Endangered</li> <li>○ Herb rich saline shrublands in clay pans (SCP 07) – Vulnerable</li> </ul> </li> </ul>

## 4.1 THREATENED AND PRIORITY FLORA

A desktop review for Threatened and Priority Flora was conducted using the EPBC MNES Protected Matters Search Tool, DPaW (DBCA) NatureMap, DPaW (2016) database searches and a review of all literature reviewed as part of the desktop assessment. The review identified the presence or potential presence of 109 Threatened or Priority flora within the study area plus a 4 km buffer. This included 38 species protected under the EPBC Act, 38 WA Threatened flora (including the 36 EPBC-listed species), nine Priority 1, 14 Priority 2, 29 Priority 3 and 19 Priority 4 species. This complete list of previously recorded or potentially occurring Threatened and Priority flora relevant to the study area is presented in **Appendix A**.

The likelihood of conservation significant flora occurring within the study area was assessed based on known records, proximity to the study area, the age of records and the presence of suitable habitat. Five of the 109 species resulting from the desktop assessment were recorded to regionally occur by FVC, six have been determined to be 'likely' to occur in the study area, with 31 classified as 'may occur' and 53 considered 'unlikely' to occur (**Appendix A**). The remaining 14 species were recorded during the field assessments within the study area.

Species that have been recorded within the within the study area, regionally recorded by FVC and those that are likely to occur are summarised in **Table 7**.

The distribution of known Threatened and Priority flora occurring in the region of the study area (based on desktop assessment results only) is spatially presented in the **Figure 7** series.

**Table 7 - Threatened and Priority Flora Occurring or Likely to Occur Within the Study Area**

Species	EPBC Act Cons. Status	WA Cons. Status	Description	Preferred Habitat	Likelihood of Occurrence	Source
<i>Grevillea althoferorum</i> subsp. <i>fragilis</i>	Endangered	Critically Endangered	Bluish green, lignotuberous shrub. Flowers yellow with reddish to reddish-brown buds, in spring	Base of the Darling Scarp in greyish-yellow colluvial sand. Banksia woodland	<b>Recorded</b> regionally by Phoenix and FVC	Phoenix (2015) FVC
<i>Chamelaucium</i> sp. Gingin (N.G. Marchant 6)	Endangered	Vulnerable	Open straggly shrub 1-2 m high, slender, stiff branches with numerous axillary shoots. Flowers pale pinkish-white, buds tinged deeper pink. Flowers September to December.	White/yellow sand supporting open low banksia woodland	<b>Recorded</b> regionally by FVC, known to occur in Bindoon and Chittering area	EPBC FVC
<i>Gastrolobium crispatum</i>		Priority 1	Tall shrub, to 2.5 m high. Flowers yellow and orange and red, September to October	Yellow or brown sandy loam, red laterite soils. Steep gullies, slopes, ridges, breakaways	<b>Recorded</b> during FVC (2017) study, recorded plant identified as possibly this species.	DPaW (2016) FVC
<i>Hibbertia glomerata</i> subsp. <i>ginginensis</i>		Priority 1	Erect shrub, to 0.5 m high. Flowers yellow, July to September	In <i>Eucalyptus-Dryandra-Xanthorrhoea</i> woodland. Sand, brown clay, laterite. Near roadsides	<b>Recorded regionally</b> by FVC spring 2017 study, previously recorded within 300 m of study area	DPaW (2016) NatureMap Phoenix (2015) FVC
<i>Synaphea panhesya</i>		Priority 1	Erect shrub, 0.3-0.6 m high. Flowers yellow, August to September	Gravelly loam & sandy gravel	<b>Recorded</b> regionally by FVC	DPaW (2016) FVC
<i>Drosera sewelliae</i>		Priority 2	Fibrous-rooted, rosetted perennial, herb, to 0.06 m high, to 0.025 m wide. Flowers orange, October	Laterite & silica sand soils	<b>Recorded</b> by FVC to occur within the study area	DPaW (2016) FVC
<i>Leucopogon squarrosus</i> subsp. <i>trigynus</i>		Priority 2	Erect shrub to 1.5 m. Flowers white	Banksia Woodland. White sand	<b>Recorded</b> by FVC to occur within the study area	FVC
<i>Stylidium squamellosum</i>		Priority 2	Caespitose perennial, herb, 0.12-0.35 m high. Inflorescence racemose. Flowers yellow, October to November	Brown to red-brown clay loam. Winter-wet habitats and depressions, open woodland, shrubland	<b>Likely</b> to occur, recorded by Phoenix (2015)	Phoenix (2015)
<i>Acacia drummondii</i> subsp. <i>affinis</i>		Priority 3	Erect shrub, 0.3-1 m high. Flowers yellow, July to August	Jarraah woodland. Plateau, laterite. Lateritic gravelly soils	<b>Recorded</b> by FVC to occur within the study area	DPaW (2016) NatureMap Phoenix (2015) GHD (2011b) Western Botanical (2006) KBR (2006) Ecologia (2004) FVC

Species	EPBC Act Cons. Status	WA Cons. Status	Description	Preferred Habitat	Likelihood of Occurrence	Source
<i>Adenanthos cygnorum</i> subsp. <i>chamaephyton</i>		Priority 3	Prostrate, mat-forming, non-lignotuberous shrub, to 0.3 m high. Flowers white-cream-pink-green/green, July or September to December or January	Low Heath with <i>Allocasuarina humilis</i> , <i>Calothamnus sanguineus</i> , <i>Hibbertia hypericoides</i> . Grey sand, lateritic gravel	<b>Recorded</b> by FVC to occur study area	DPaW (2016) NatureMap KBR (2006) FVC
<i>Grevillea florida</i>		Priority 3	Erect shrub, to 0.9 m high. Flowers cream-yellow, July to September	In open low woodland of <i>Eucalyptus drummondii</i> , and <i>E. calophylla</i> . Sandy clay, gravel, laterite. Sandplain, slopes, road verges	<b>Likely</b> to occur; previously recorded within adjacent study area (Area 2)	DPaW (2016)
<i>Haemodorum loratum</i>		Priority 3	Bulbaceous, perennial, herb, 0.45-1.2(-2) m high. Flowers black/brown-black/green, November	Grey or yellow sand, gravel	<b>Likely</b> to occur, recorded by Phoenix (2015)	Phoenix (2015)
<i>Stylidium cymiferum</i>		Priority 3	Perennial herb. Flowers yellow, laterally paired. Juvenile buds pendulous. Flowers October to November	In open Wandoo forest with <i>Stylidium caricifolium</i> . Loam and lateritic soils	<b>Likely</b> to occur, recorded Caligiri - Wongan Hills Road within 25 m of study area boundary	DPaW (2016)
<i>Styphelia filifolia</i>		Priority 3	Erect shrub to 0.5 m high, Flowers white	Banksia Woodland	<b>Recorded regionally</b> by FVC during 2018 survey	FVC
<i>Verticordia rutilastra</i>		Priority 3	Shrub to 0.9 m high. Flowers yellow, September to November	Sand and lateritic gravel. Hill	<b>Recorded</b> by FVC during 2018 within study area	FVC
<i>Verticordia serrata</i> var. <i>linearis</i>		Priority 3	Shrub, to 1 m high, Flowers September to October	White sand, gravel. Open woodland	<b>Likely</b> to occur, recorded by Phoenix (2015)	Phoenix (2015) Ecologia (2004)
<i>Anigozanthos humilis</i> subsp. <i>chrysanthus</i>		Priority 4	Rhizomatous, perennial, herb, 0.2-0.4 (-0.8) m high. Flowers yellow, July to October	Banksia Woodland. Grey or yellow sand	<b>Recorded</b> by FVC within the study area	DPaW (2016)
<i>Conostephium magnum</i>		Priority 4	Erect, compact, many-stemmed shrub, to 2 m high. Flowers pink-purple, July to September	White-grey sands sometimes associated with laterite gravels. Sand dunes, swampland, disturbed roadside, drainage channels, open woodland.	<b>Recorded regionally</b> by FVC	FVC
<i>Hibbertia miniata</i>		Priority 4	Decumbent or erect shrub, 0.1-1 m high. Flowers orange/orange-red, August to November	Open Woodland of <i>Corymbia calophylla</i> . Lateritic gravelly soils	<b>Recorded</b> by FVC to occur within the study area	DPaW (2016) NatureMap Ecologia (2004)
<i>Hypolaena robusta</i>		Priority 4	Dioecious rhizomatous, perennial, herb, ca 0.5 m high. Flowers September to October	White sand. Sandplains	<b>Recorded</b> by FVC to occur within the study area	Phoenix (2015)

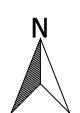
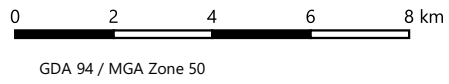
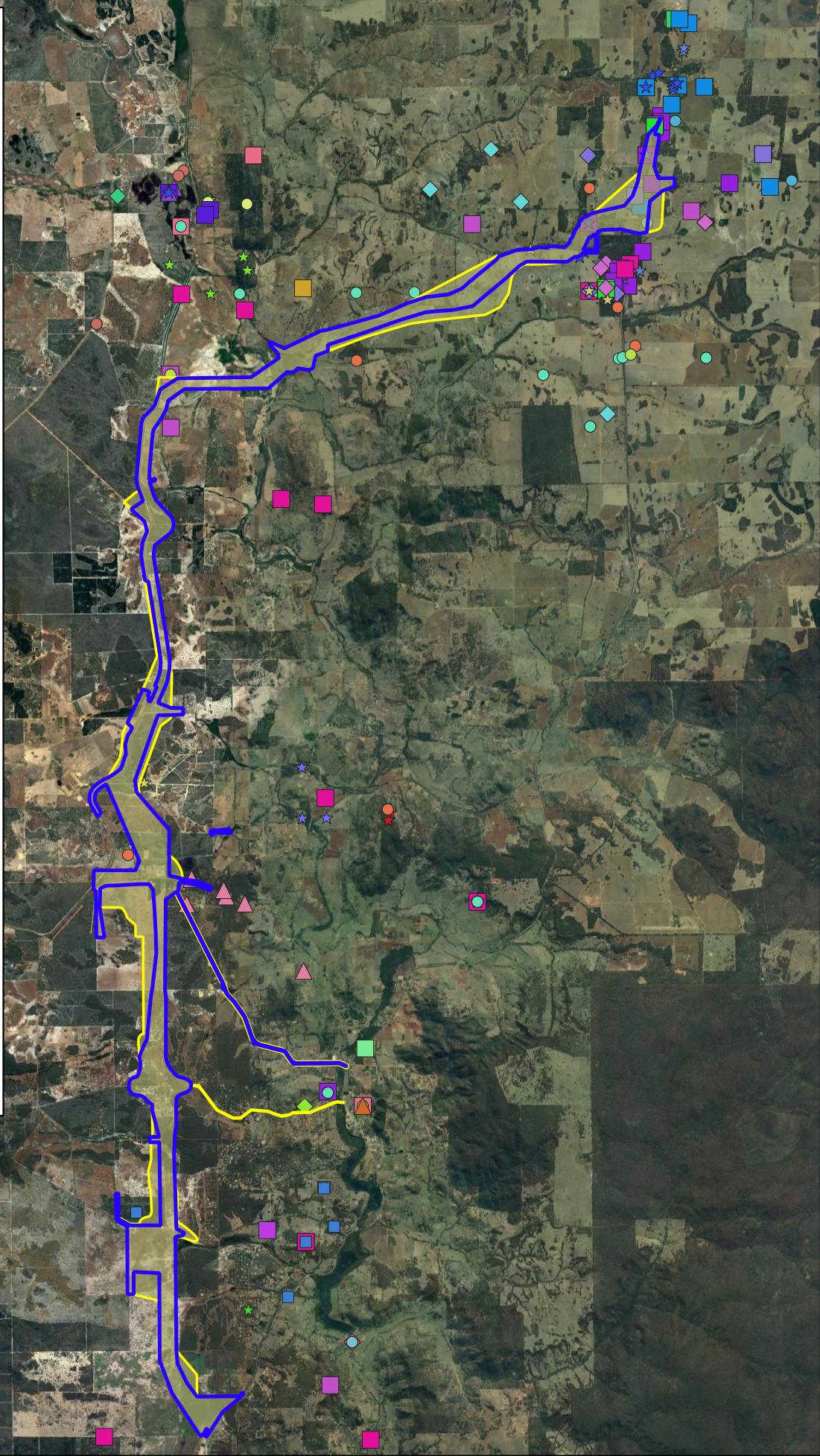


Species	EPBC Act Cons. Status	WA Cons. Status	Description	Preferred Habitat	Likelihood of Occurrence	Source
<i>Jacksonia sericea</i>		Priority 4	Low spreading shrub, to 0.6 m high. Flowers orange usually December or January to February	Calcareous and sandy soil	<b>Recorded</b> during FVC spring 2017 study	DBCA (2018a) FVC
<i>Verticordia lindleyi</i> subsp. <i>lindleyi</i>		Priority 4	Erect shrub, 0.2-0.75 m high. Flowers pink, May or November to December or January	Sand, sandy clay. Winter-wet depressions. Banksia and Melaleuca winter wetland	<b>Likely</b> to occur, recorded by Phoenix (2015), study area supports suitable habitat	Phoenix (2015) Western Botanical (2006) KBR (2005) Ecologia (2004)
<i>Verticordia paludosa</i>		Priority 4	Erect shrub, 0.3-0.9 m high. Flowers pink-white, January to May	White/grey sand. Winter-wet flats	<b>Recorded</b> during FVC (2018a) study, study area supports suitable habitat	DPaW (2016) FVC



# Legend

- Development Envelope
  - Study Area
  - ★ *Asterolasia nivea*
  - ★ *Darwinia acerosa*
  - ★ *Drakaea elastica*
  - ★ *Eleocharis keigheryi*
  - ★ *Goodenia arthrotricha*
  - ★ *Grevillea corrugata*
  - ★ *Spirogardnera rubescens*
  - ★ *Stylidium semaphorum*
  - ★ *Thelymitra stellata*
  - ▲ *Hibbertia glomerata* subsp. *ginginensis*
  - ▲ *Lasiopetalum* sp. *Toodyay* (F. Hort 2689)
  - ▲ *Senecio gilbertii*
  - ◆ *Acacia browniana* var. *glaucescens*
  - ◆ *Cyanicula ioioides* subsp. *candida*
  - ◆ *Gastrolobium nudum*
  - ◆ *Stylidium glabrifolium*
  - ◆ *Verticordia lindleyi* subsp. *lindleyi*
  - ◆ *Verticordia serrata* var. *Udumung* (D. Hunter & B. Yarran 941006)
  - *Acacia anarthros*
  - *Acacia drummondii* subsp. *affinis*
  - *Acacia oncinophylla* subsp. *oncinophylla*
  - *Acacia pulchella* var. *reflexa acuminatae* bracteole variant (R.J. Cumming 882)
  - *Adenanthos cygnorum* subsp. *chamaephyton*
  - *Allocausarina ramosissima*
  - *Dielsiodoxa leucantha* subsp. *leucantha*
  - *Grevillea florida*
  - *Guichenotia tuberculata*
  - *Halgania corymbosa*
  - *Stylidium sacculatum*
  - *Tetratheca pilifera*
  - *Stylidium cymiferum*
  - *Anigozanthos humilis* subsp. *chrysanthus*
  - *Boronia tenuis*
  - *Calothamnus pachystachyus*
  - *Grevillea drummondii*
  - *Hibbertia miniata*
  - *Oxymyrrhine coronata*
  - *Persoonia sulcata*
  - *Synaphea grandis*
- 
- Key**
- P1
  - P2
  - P3
  - P4
  - ★ Priority



**Figure 7 - Previously Recorded Threatened and Priority Flora**



## 4.2 THREATENED AND PRIORITY ECOLOGICAL COMMUNITIES

The DBCA database search results revealed that at a State level, the study area and the immediate surrounds are known to support the following TEC and two PECs:

- TEC:
  - SCP 20a – *Banksia attenuata* woodlands over species rich dense shrublands (EN)
- PECs:
  - Banksia woodlands of the Gingin area restricted to soils dominated by yellow to orange sands (P2)
  - SCP 23b – Northern Swan Coastal Plain *Banksia attenuata* – *Banksia menziesii* woodlands (P3).

All three of these vegetation types are also representative of the Commonwealth-listed TEC, *Banksia Woodlands of the Swan Coastal Plain ecological community* (Threatened Species Scientific Committee 2016), which was further supported by the results of the EPBC Act MNES database search.

The known extent of these ecological communities in accordance with results of the DPaW (2016) database search results is presented in **Figure 8**, showing that two occurrences of the 'Banksia Woodlands of the Gingin area restricted to soils dominated by yellow to orange sands' or their buffers intersect with the study area. **Figure 8** also shows that there are occurrences of both of the other ecological communities listed above, or their buffers, in proximity of the study area:

- SCP 23b – Northern Swan Coastal Plain *Banksia attenuata* – *Banksia menziesii* woodlands, within 1 km of the boundary of the north-west extent of the study area, but not intersecting the study area
- Banksia Woodlands of the Gingin area restricted to soils dominated by yellow to orange sands, intersects the study area north of Mooliabeenee Road and along Teatree Road.

### 4.2.1 Banksia Woodland of the Swan Coastal Plain TEC

TECs are naturally occurring biological assemblages that occur in a particular type of habitat, which are subject to processes that threaten to destroy or significantly modify the assemblage across its range (DEC 2007). Vegetation communities in Western Australia may be considered threatened once they have been identified as such by the Western Australian Threatened Ecological Communities Scientific Advisory Committee.

With regards to Commonwealth significance, some TECs of State (WA) significance are representative of TECs listed under the EPBC Act. Under the EPBC Act, a person must not take an action that has or will have significant impact on a listed TEC without approval from the Commonwealth Minister for the Environment, unless those actions are not prohibited under the Act.

The Banksia Woodland TEC was approved for inclusion as an Endangered TEC under the EPBC Act on 16 September 2016. This ecological community is woodland associated with some soils of the Swan Coastal Plain with a prominent tree layer of *Banksia* with scattered Eucalypts and other tree species among or emerging above the canopy. The understorey is comprised of a species rich mix of sclerophyllous shrubs, graminoids and forbs (Threatened Species Scientific Committee 2016).

The Banksia Woodland TEC is largely restricted to the Swan Coastal Plain IBRA bioregion, within the Perth (SWA02) and the Dandaragan (SWA01) sub-regions. It extends into the adjacent Jarrah Forrest IBRA region (JA01 and JA02 sub-regions) and areas of the Whicher Darling escarpments where pockets

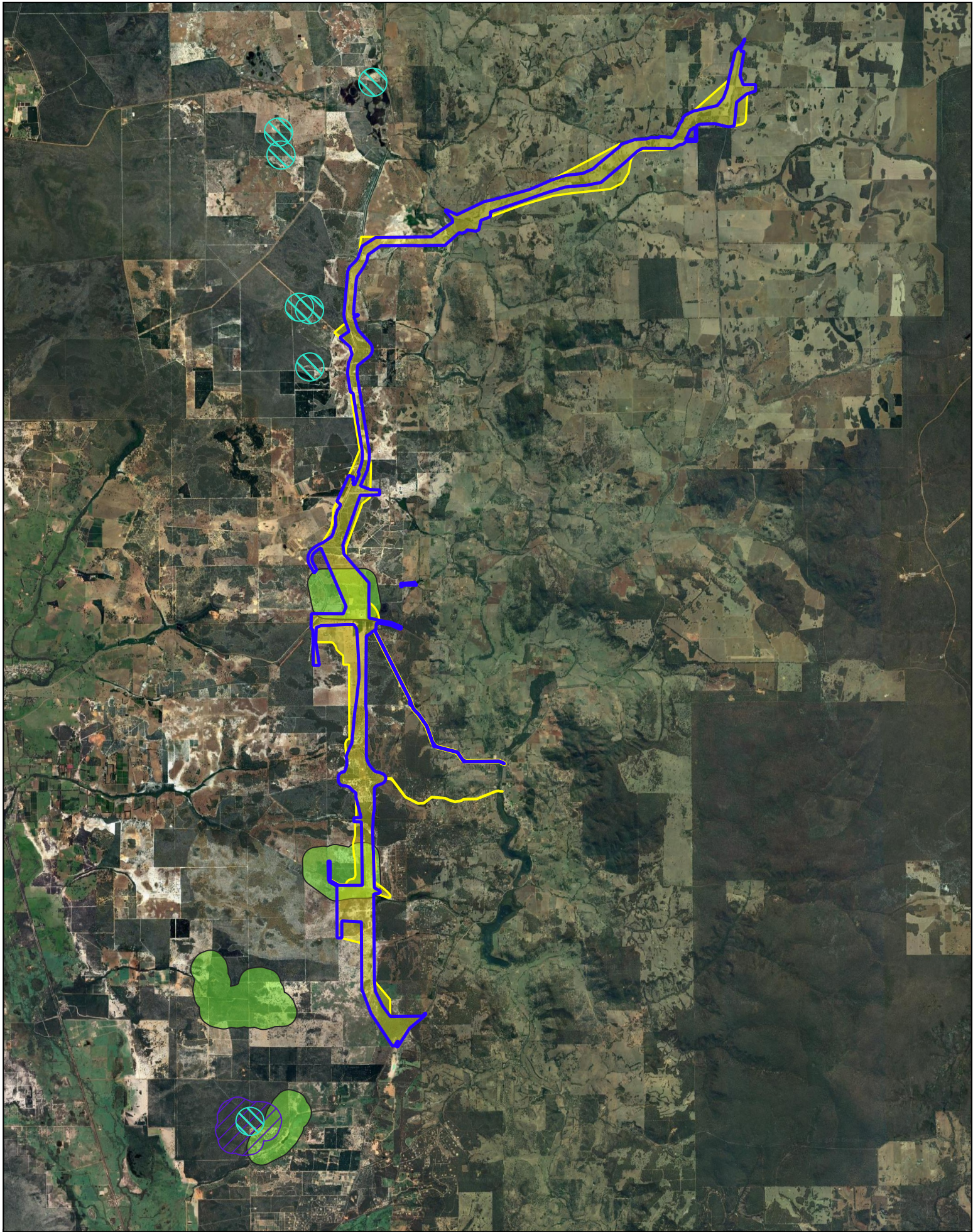
of *Banksia* woodland may occur. This TEC mainly occurs on deep Bassendean and Spearwood sand or occasionally on Quindalup sands at the eastern edge (Threatened Species Scientific Committee 2016).

Twenty-one Floristic Community Types (FCTs) described by Gibson *et al.* (1994), in Bush Forever (Government of Western Australia 2000), Keighery *et al.* (2008) and Urban Bushland Council (2011) best correspond to the *Banksia* Woodland TEC (Threatened Species Scientific Committee 2016) and these are summarised in **Table 8**.

**Table 8 - Floristic Community Types Corresponding to the *Banksia* Woodland TEC**

FCT	FCT Name	WA TEC/PEC	EPBC TEC
<b>Supergroup 3 – Uplands centred on Bassendean Dunes and Dandaragan Plateau</b>			
20a	<i>Banksia attenuata</i> woodlands over species rich dense shrublands	Endangered	
20b	Eastern <i>Banksia attenuata</i> and/or <i>Eucalyptus marginata</i> woodlands	Endangered	
20c	Eastern shrublands and woodlands	Critically Endangered	Endangered
21a	Central <i>Banksia attenuata</i> - <i>Eucalyptus marginata</i> woodlands		
21b	Southern <i>Banksia attenuata</i> woodlands	P3	
21c	Low lying <i>Banksia attenuata</i> woodlands or shrublands	P3	
22	<i>Banksia ilicifolia</i> woodlands	P2	
23a	Central <i>Banksia attenuata</i> - <i>Banksia menziesii</i> woodlands		
23b	Northern <i>Banksia attenuata</i> - <i>Banksia menziesii</i> woodlands	P3	
23c	North-eastern <i>Banksia attenuata</i> - <i>Banksia menziesii</i> woodlands		
S09	<i>Banksia attenuata</i> woodlands over dense low shrublands		
<b>Supergroup 4 – Uplands centred on Spearwood and Quindalup Dunes</b>			
24	Northern Spearwood shrublands and woodlands	P3	
25	Southern <i>Eucalyptus gomphocephala</i> – <i>Agonis flexuosa</i> woodlands	P3	
28	Spearwood <i>Banksia attenuata</i> or <i>Banksia attenuata</i> – <i>Eucalyptus</i> woodlands		
<b>Whicher Scarp FCTs (Keighery <i>et al.</i> 2008)</b>			
A1	Central Whicher Scarp Mountain Marri Woodland WHSFCT_A1	P1	
A2	North Whicher Scarp Jarrah and Woody Pear woodland WHSFCT_A2		
A3	North Whicher Scarp <i>Banksia</i> and Woody Pear woodland WHSFCT_A3		
A4	Whicher Scarp <i>Banksia grandis</i> , Jarrah and Marri woodland WHSFCT_A4		
B1	Swan Coastal Plain /North Whicher Scarp <i>Banksia attenuata</i> woodland WHSFCT_B1		
B2	West Whicher Scarp <i>Banksia attenuata</i> woodland WHSFCT_B2		
C2	Whicher Scarp Jarrah woodland on deep coloured sands WHSFCT_C2		










0 2 4 6 8 km

GDA 94 / MGA Zone 50



**Legend**

-  Development Envelope
-  Study Area
-  Banksia yellow-orange sands
-  SCP20a
-  SCP23b



**Figure 8 - Known TECs and PECs**



## 5 METHODOLOGY

All surveys and reporting for the winter and spring 2018 flora and vegetation assessments of the updated Bindoon Bypass study area were carried out in accordance with the following:

- EPA (2016) Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment
- Commonwealth of Australia (2013b) Guidelines for Detecting Orchids Listed as ‘Threatened’ Under the *Environment Protection and Biodiversity Conservation Act 1999*.
- Threatened Species Scientific Committee (2016) Approved Conservation Advice (incorporating listing advice) for the Banksia Woodlands of the Swan Coastal Plain Ecological Community.

Multiple phases of detailed spring flora and vegetation assessments have been carried out within the study area since spring 2016, including during spring 2018. From previous surveys conducted by FVC in 2016 and 2017, the presence of Banksia woodland was recorded within the study area. A targeted Banksia woodland TEC assessment, in accordance with the TECs Conservation Advice (Threatened Species Scientific Committee 2016), was commenced during 2017 and continued further during spring 2018 to confirm the extent of the Banksia woodland in the area, and to assign FCTs to each of the Banksia woodland vegetation units.

Furthermore, continued targeted surveys for flora species of conservation significance, with the potential to occur within the gap areas of the study area (arising from alignment adjustments) were also conducted in winter and spring 2018, in accordance with the general approaches described in Commonwealth of Australia (2013b).

### 5.1 DESKTOP ASSESSMENT

The desktop assessment included a review of all available, relevant published and unpublished reports and documents. Database searches for Threatened and Priority flora and ecological communities for the study area and surrounds were initially requested from DPaW (now DBCA) on 30 September 2016 and have been used as the basis for all studies, including the review in this report. The Threatened and Priority flora search was conducted for the study area extent plus a 4 km buffer (search reference 40-1016FL). The Threatened and Priority ecological community database search was conducted for a geographical bounding box, as defined by DPaW within the following corners:

- north-west -14.788854, 113.765525
- south-west -35.005719, 113.765525
- north-east -14.788854, 128.870214
- south-east -35.005719, 128.870214.

The collective information from the desktop assessment and literature review formed the foundation of the field survey and was used to generate potential species lists for the study area, with a focus on Threatened and Priority flora.

The sources consulted for the desktop review included the following:

- DEE MNES search tool
- DPaW (DBCA) NatureMap search
- Threatened and Priority taxa listed under the WC Act and listed by DBCA
- TECs and PECs listed by DBCA
- Declared Pests listed under the BAM Act.

The results of the desktop assessment are presented in **Sections 4** and **6** of this report.

## 5.2 FIELD ASSESSMENT

The 2018 flora and vegetation field assessments were carried out by Principal Ecologist, Kellie Bauer-Simpson; and Senior Botanists, Lisa Chappell, Shenaye Hummerston, Catherine Krens and Kylie Del Fante, supported by field technicians William Bauer-Simpson and Nicki Thomson between July and November 2018, with a total survey effort of 38 person-days (plus survey effort of 87 person-days throughout 2017 and 18 person-days in 2016; with a cumulative total of 143 person-days to date) (**Section 9, Table 21**).

The surveys were undertaken to supplement results of the studies previously carried out during spring 2016 and autumn and spring 2017 (FVC 2017; 2018c) and to fill any gaps in survey data (i.e. areas of vegetation within the current (revised) proposed corridor, not previously surveyed). Additional quadrats were sampled, vegetation mapping was verified and in-filled and further targeted significant flora surveys were undertaken. Other verifications, revisions and supplementary observations were made to update and confirm spatial mapping of vegetation units and condition, as well as other floristic values throughout the study area.

A collective total of 160 quadrats (inclusive of two relevés) have been sampled in the study area since October 2016 (**Figure 9**). During the 2018 field assessments, vegetation data was collected from a total of 22 pegged 10 m x 10 m quadrats, which focused on the Banksia woodland assessment (**Table 9**). Of the total quadrats sampled, 54 are located in the wider region, outside of the study area and contribute to the definition of regional context.

**Table 9 - Summary of Sampled Quadrats**

Quadrat Location	Timing					
	Spring 2016	Resampled Autumn/Winter 2017	Newly Established Autumn/Winter 2017	Resampled Spring 2017	Newly Established Spring 2017	Newly Established Spring 2018
Within the study area	33	12	10	4	20	22
Regional (outside of study area)	16	5	3	0	35	0
<b>TOTAL</b>	<b>49</b>	<b>17</b>	<b>13</b>	<b>4</b>	<b>55</b>	<b>22</b>
<b>GRAND TOTAL</b>						<b>160</b>

Field data from quadrats and opportunistic observations was collected using electronic tablets equipped with the mobile mapping software, Mappt™. This methodology allowed in-field spatial mapping of boundaries for vegetation units and condition, as well as the collection of spatial point data where other observations or photographs were captured. Physical data from each quadrat was also recorded electronically in the software, with species recorded by hand for later entry with identified collected specimens.

Vegetation mapping was conducted in the field and refined afterwards by defining the different plant communities based on vegetation structure, dominant species and species composition, and extrapolated based on the appearance in aerial imagery.



A single permanent peg was installed at the north-west corner of each quadrat and marked with the quadrat number. Measuring tapes and temporary pegs marked the quadrat boundary during sampling, but were then removed, leaving only the north-west corner peg, to minimise impact on the landscape and private properties.

Quadrats that had been previously established and re-scored were differentiated by a decimal point followed by a number (e.g. B02.2, numbered as the rescore of quadrat B02). New quadrats established for the first time during the second phase assessment were differentiated with a number 2 and a decimal point prior to the new quadrat/site number (e.g. B2.01 as the first quadrat of the second phase assessment, and distinct from quadrat B01). During spring 2018, as the focus was on definition of Banksia woodland types (FCTs), the quadrats were prefixed with 'BW' (e.g. BW01 for the first quadrat for the spring 2018 study).

The following information was collected from within each quadrat sampled:

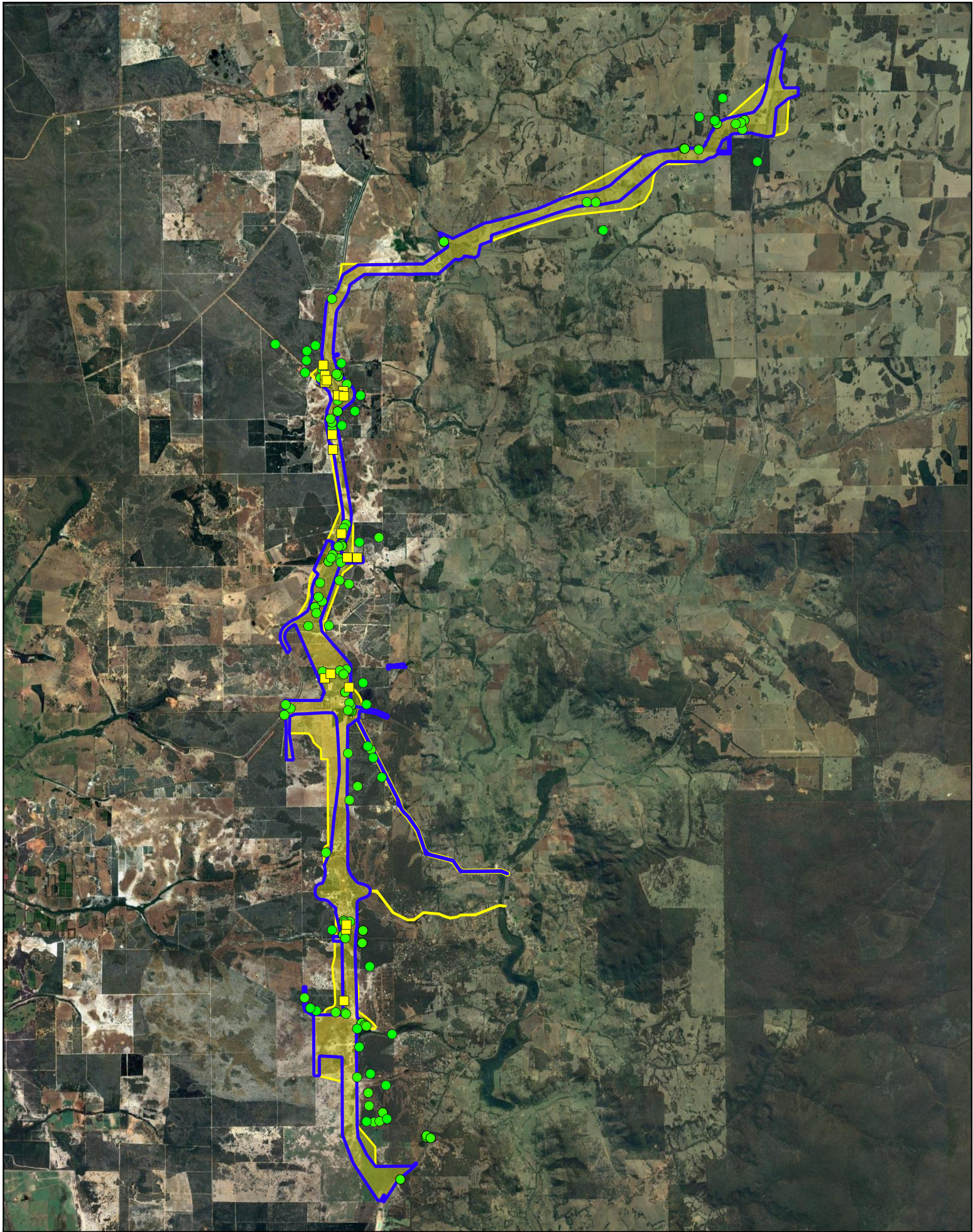
- date
- botanist name
- quadrat or relevés and dimensions
- location (GPS co-ordinates of the north-west corner peg in GDA94)
- digital photograph taken from the north-west corner peg
- habitat or landscape position
- topography/slope
- surface features
- soil type/texture and colour
- rock presence, type, size and abundance
- vegetation condition/degradation/disturbances (e.g. weed invasion, fire)
- time since fire (estimated)
- leaf litter distribution and abundance
- flora inventory, and for each species:
  - average height
  - total projected foliage cover within quadrat
  - dominance
- vegetation units
- vegetation condition, assessed against the currently accepted scale as required by EPA (2016); an adaptation of the Keighery (1994) and Trudgen (1991) condition scales.

The varying vegetation condition within the study area was documented continuously throughout the survey, as well as from within quadrats, which was then mapped in accordance with an adaptation of the Keighery (1994) and Trudgen (1991) condition scales (as per EPA 2016 and DBCA (2018b)).

The flora data collected from the combination of quadrats and continuous opportunistic observations contributed to the flora inventory for the study.

Flora specimens were collected, pressed, dried and fumigated in accordance with the protocols of the Western Australian Herbarium, for later identification.









0 2 4 6 8 km

GDA 94 / MGA Zone 50



**Legend**

-  Development Envelope
-  Study Area
-  2016-2017 Quadrats
-  2018 Quadrats



**Figure 9 - Quadrat Locations**



### 5.3 TARGETED THREATENED AND PRIORITY FLORA SURVEY

Targeted searches for relevant Threatened and Priority flora were conducted in suitable habitats, within pre-determined areas selected during the desktop assessment. A systematic method was utilised, via parallel meandering transects across the better condition areas of the study area, to target Threatened and Priority flora species. These searches were conducted in areas of better-quality vegetation, along disturbance areas such as tracks and firebreaks (to target disturbance opportunists), when traversing to and between quadrats, and whilst carrying out the dedicated targeted surveys in selected sites. Given the level of detail of previously targeted searches conducted within the study area during spring 2016 and during autumn and spring of 2017, survey effort in spring 2018 was concentrated in vegetation units that had previously recorded conservation significant flora (**Figure 10**).

A dedicated targeted *Thelymitra stellata* (Star Sun-orchid) survey was conducted between 6-11 November 2018 by Principal Ecologist, Kellie Bauer-Simpson and Senior Botanists, Lisa Chappell, Shenaye Hummerston, Catherine Krens and Kylie Del Fante, supported by field technicians William Bauer-Simpson and Nicki Thomson. A total survey effort of 6 person-days was invested within the study area, with 4 person-days invested in the survey of documented regional populations outside the study area. Targeted searches for other species of conservation significance were carried out concurrently with the detailed flora and vegetation assessments, and across numerous dates during summer, autumn, winter and spring 2018.

The targeted survey conducted during winter (19 July to 23 August) 2018 focused on winter flowering or emergent species, including the Threatened orchid species, *Drakaea elastica*, which has a leaf which will best identify the species during winter, and the flower can then confirm the identification in spring.

Methodologies for the targeted survey of all species, and specifically for Threatened orchid species, *Thelymitra stellata* and *Drakaea elastica*, were conducted in accordance with the DEE's *Guidelines for Detecting Orchids Listed as 'Threatened'*.

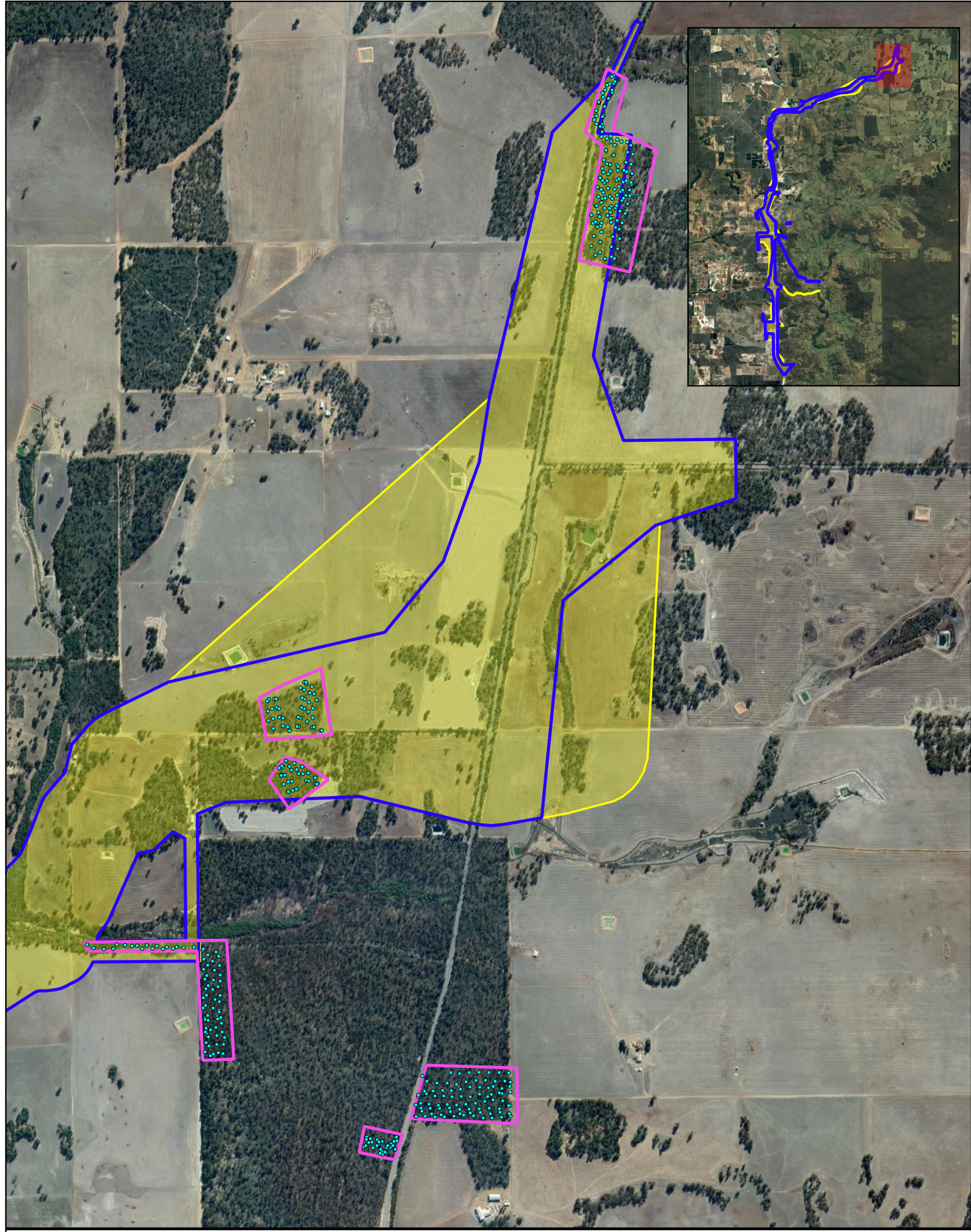
Species of Threatened flora determined to possibly occur in the study area and Priority flora previously recorded within the study area or previously determined to be likely to occur were collated. Documented populations of these species within 100 km of the study area that occur on DBCA-managed lands (and therefore able to be easily accessed) were included in the targeted surveys during relevant seasons, based on flowering times. The results of the targeted survey of regional populations were then able to be used to provide context for populations or possible occurrences of conservation-significant flora within the study area, such as the regional extent, condition of populations/health and vigour of plants, flowering status or current existence.

All walked transects were tracked on GPS to verify and present the locations and extent of traversed and searched areas.

Where Threatened or Priority flora plants were observed, the following data was to be recorded:

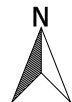
- GPS location of each individual plant
- vegetation type and condition at the recorded location
- condition of plants/populations recorded.





0 0.25 0.5 0.75 1 km

GDA 94 / MGA Zone 50



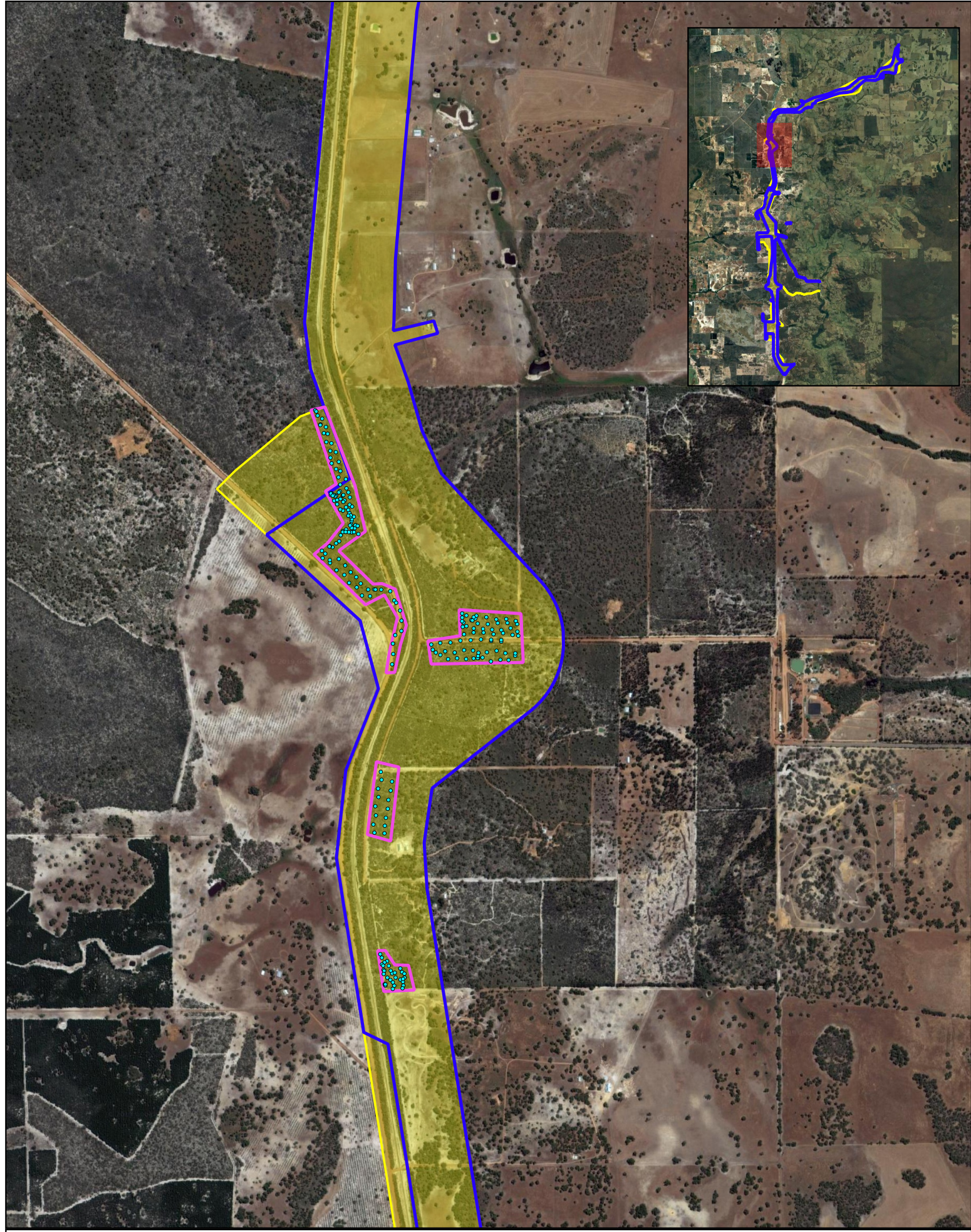
**Legend**

- Development Envelope
- Study Area
- 2018\_Combined\_Walked\_Tracks
- 2018 Targeted Search Areas



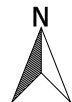
**Figure 10a - Walked Tracks for threatened and Priority Flora**





0 0.25 0.5 0.75 1 km

GDA 94 / MGA Zone 50



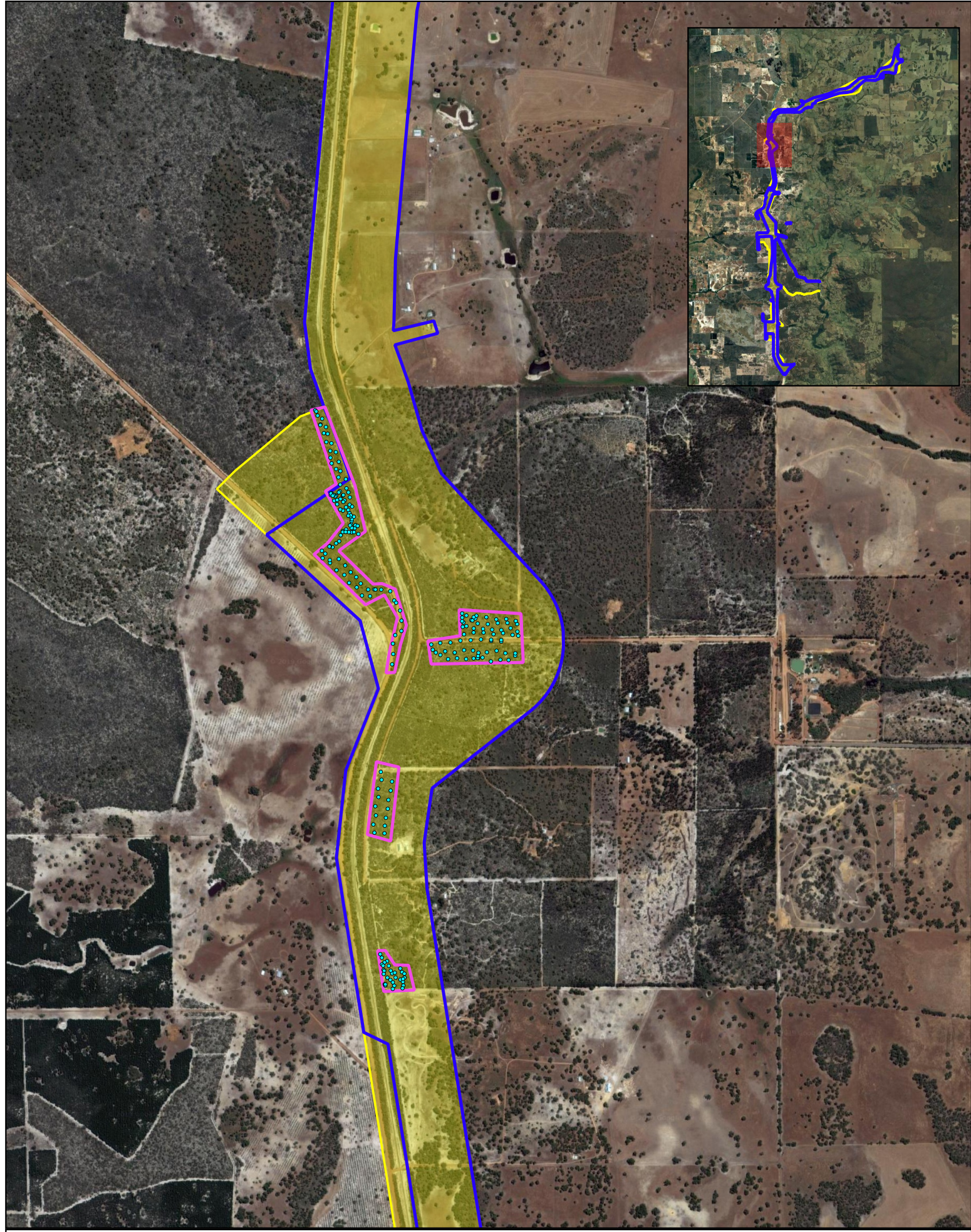
**Legend**

- Development Envelope
- Study Area
- 2018\_Combined\_Walked\_Tracks
- 2018 Targeted Search Areas



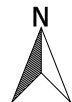
**Figure 10b - Walked Tracks for threatened and Priority Flora**





0 0.25 0.5 0.75 1 km

GDA 94 / MGA Zone 50



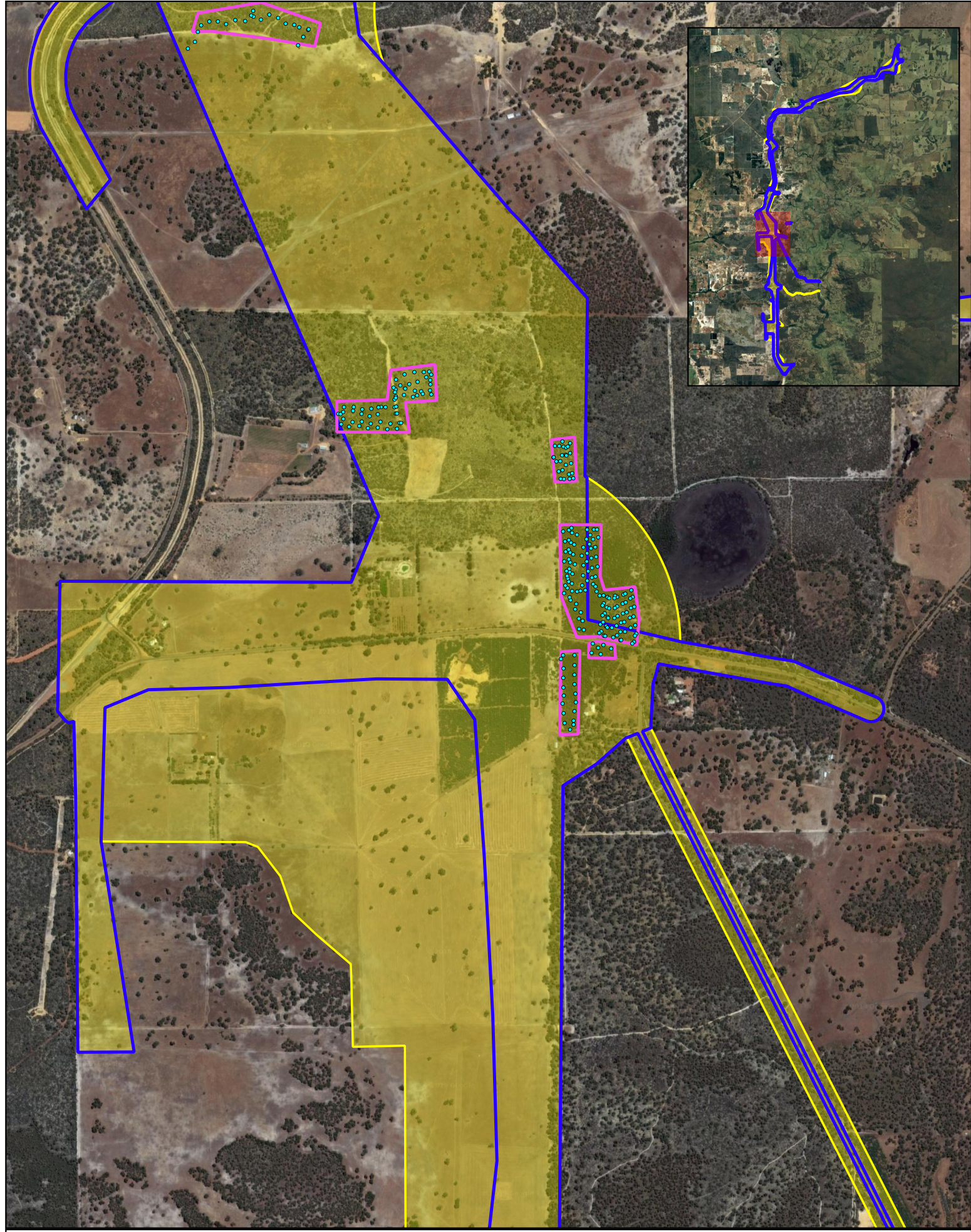
**Legend**

- Development Envelope
- Study Area
- 2018\_Combined\_Walked\_Tracks
- 2018 Targeted Search Areas



**Figure 10b - Walked Tracks for threatened and Priority Flora**





0 0.25 0.5 0.75 1 km

GDA 94 / MGA Zone 50



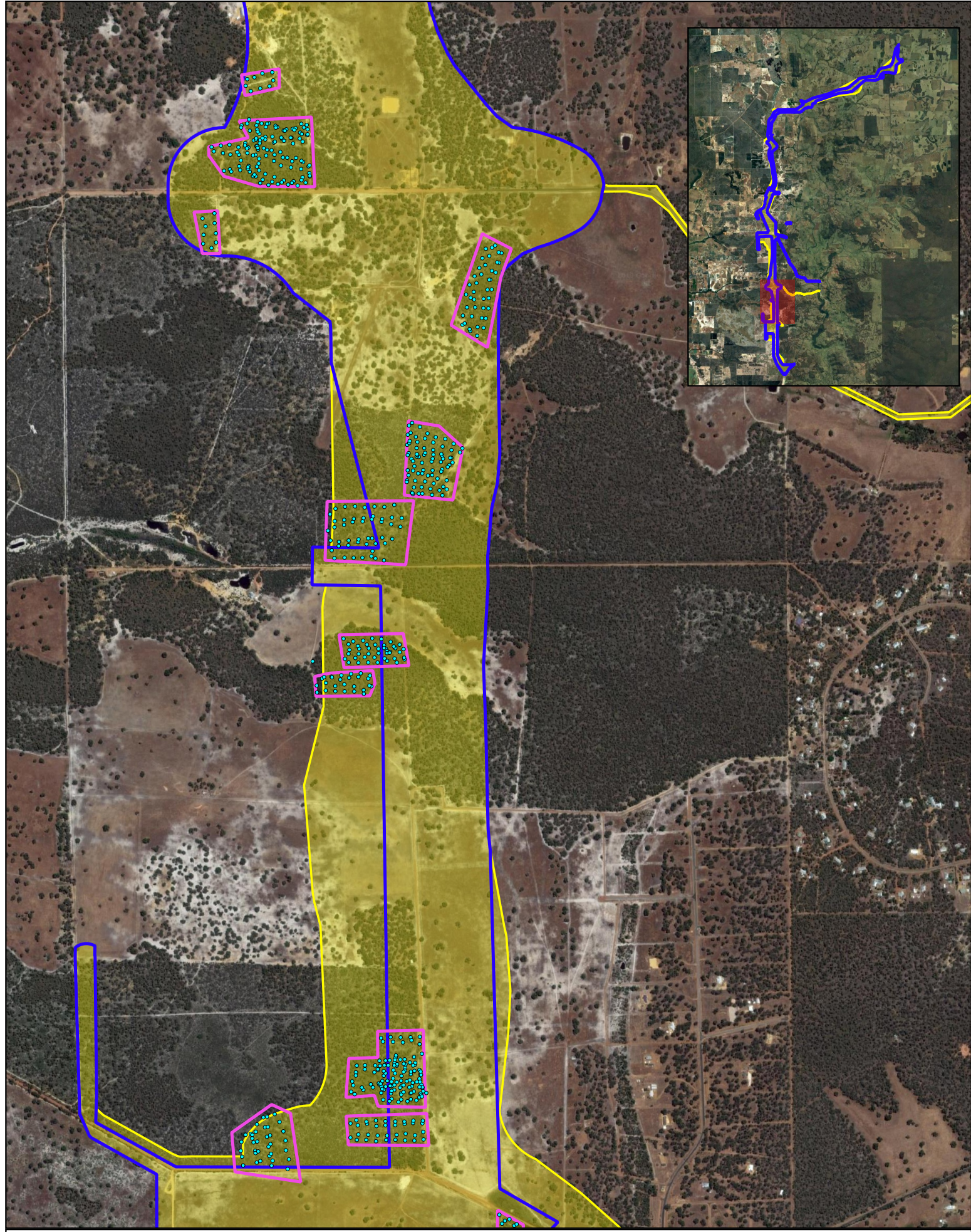
**Legend**

- Development Envelope
- Study Area
- 2018\_Combined\_Walked\_Tracks
- 2018 Targeted Search Areas



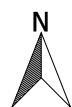
**Figure 10d - Walked Tracks for threatened and Priority Flora**





0 0.25 0.5 0.75 1 km

GDA 94 / MGA Zone 50



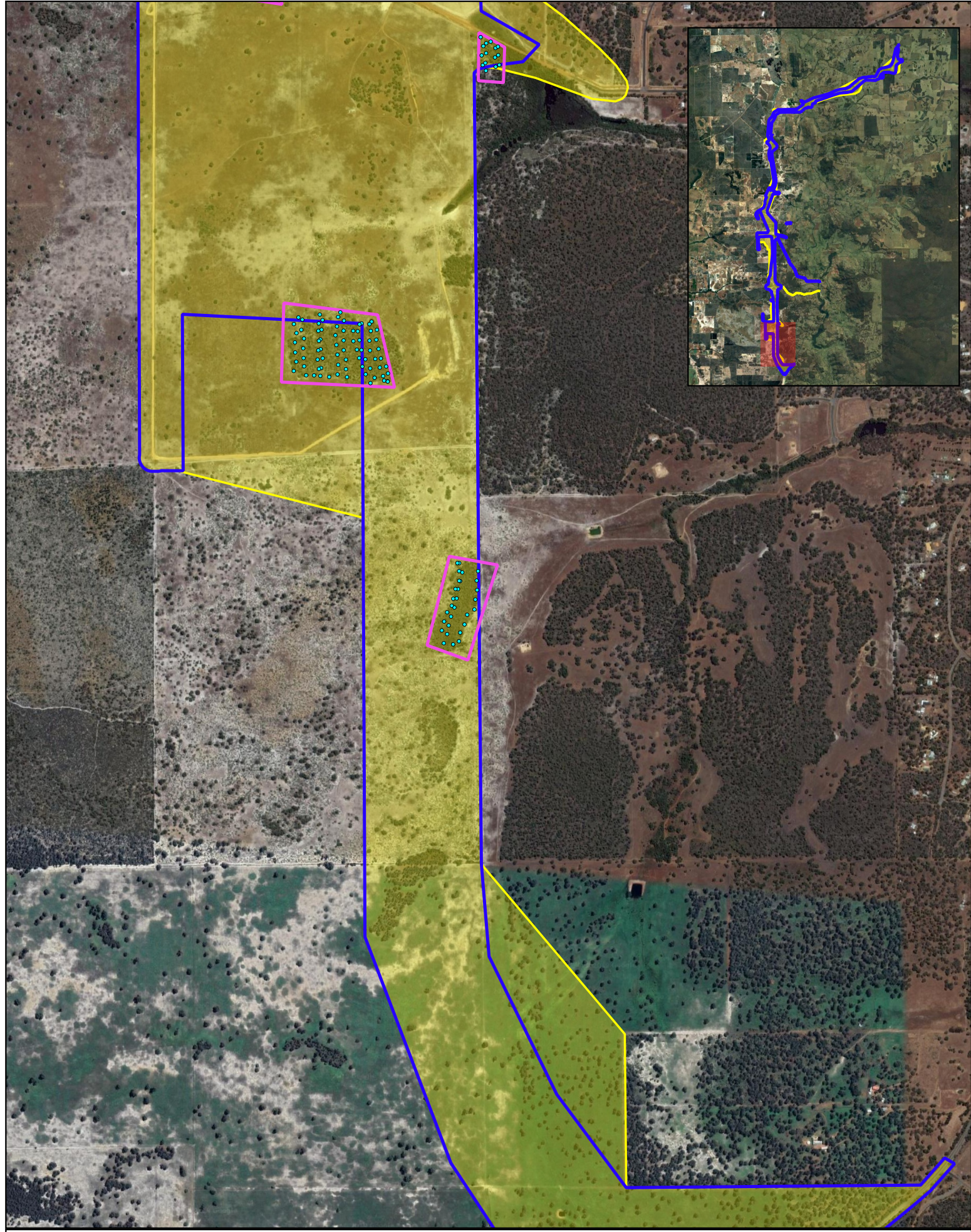
**Legend**

- Development Envelope
- Study Area
- 2018\_Combined\_Walked\_Tracks
- 2018 Targeted Search Areas



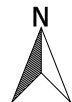
**Figure 10e - Walked Tracks for threatened and Priority Flora**





0 0.25 0.5 0.75 1 km

GDA 94 / MGA Zone 50



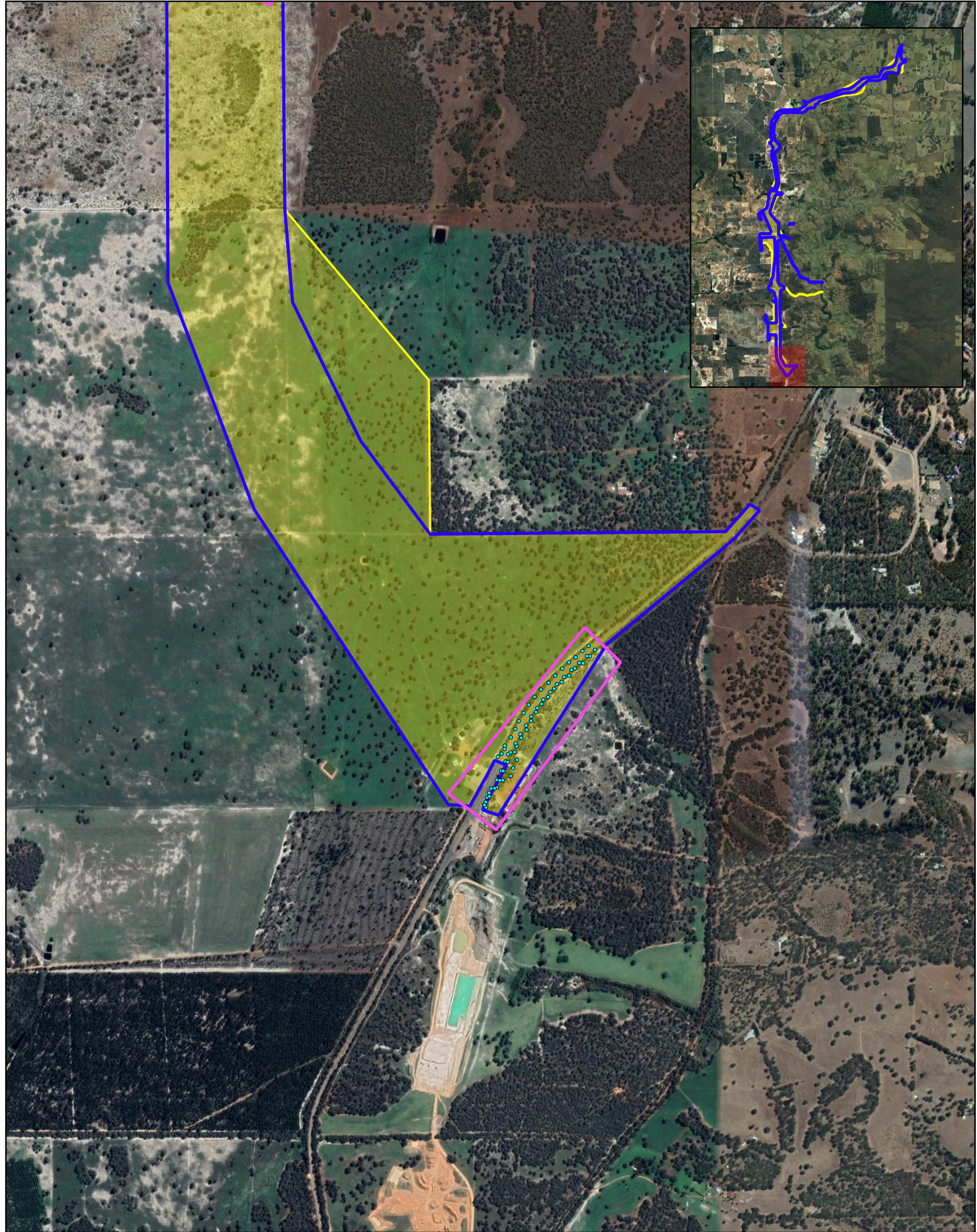
**Legend**

- Development Envelope
- Study Area
- 2018\_Combined\_Walked\_Tracks
- 2018 Targeted Search Areas



**Figure 10f - Walked Tracks for threatened and Priority Flora**





0 0.25 0.5 0.75 1 km

GDA 94 / MGA Zone 50



**Legend**

- Development Envelope
- Study Area
- 2018\_Combined\_Walked\_Tracks
- 2018 Targeted Search Areas



**Figure 10g - Walked Tracks for threatened and Priority Flora**



## 5.4 BANKSIA WOODLAND ASSESSMENT

Banksia woodland is known to be supported by the study area, and therefore, during spring 2017, an initial assessment was carried out to diagnose/characterise, map and quantify the extent of Banksia woodland TEC within and connected to the study area.

The Banksia woodland assessment methodology requires sampling of quadrats and analysis of this data to determine FCTs based on analysis against the Gibson *et al.* (1994) and Keighery (2008) datasets. Areas of Banksia woodland within the study area were sampled from 36 pegged 10 m x 10 m quadrats during 2017.

Further effort was then invested in the targeted Banksia woodland assessment during spring 2018, which focused on a greater density of quadrats which would enable more accurate FCT analysis. Accurate determination and mapping of FCTs is important where offsets may be required, since some FCTs represent more valuable examples of the TEC and are required to be offset “like for like”.

FVC utilises a tailored diagnostic tool for determination and characterisation of the Banksia woodland TEC. The diagnostic tool consists of a checklist that has been developed in direct reference to the key characterisation criteria as extracted from the Conservation Advice (Threatened Species Scientific Committee 2016), which incorporates assessment of the following:

- IBRA region
- soil and landform systems
- overstorey layer (*Banksia* species)
- emergent or other tree layer (associated non-*Banksia* tree species)
- understorey/mid-ground sclerophyllous shrub layer species
- herbaceous ground layer species
- FCT
- continuity/connectedness
- condition.

Much of the above checklist relies on specific data collection during the field assessment, which was a key focus of the targeted Banksia woodland assessment.

Spatial mapping of patches of Banksia woodland and the buffers around these was also confirmed from initial 2017 mapping, by grouping areas of Banksia woodland of adequate condition separated by less than 30 m.

## 5.5 DATA PROCESSING AND ANALYSIS

Flora identifications were undertaken by specialist taxonomists, Dr Udani Sirisena and Shibi Chandran. Plant group specialist taxonomists were consulted where required for challenging identifications. Taxonomy and nomenclature followed current protocols of the WA Herbarium.

Following the completion of field assessments, field data collected on tablets within the mobile mapping software program, Mappt™ within customised data forms and spatial mapping shapefiles were downloaded for collation for the report.

Quadrat species lists, and flora identifications were entered into a customised Microsoft Access™ database called FloraData, which contains the WA flora inventory. The data was then able to be loaded into the PATN™ software (Belbin 2013) for floristic analysis.

Data was prepared for analysis including the grouping of some taxa to minimise or exclude ambiguity that could possibly be due to the identification of plants rather than a true difference in species composition. For example, removing infra-specific epithets and using only the specific epithet, considering uncertain species identification (indicated with '?') as the proper identification (e.g. *Drosera ?sewelliae* treated as *Drosera sewelliae*).

Data analysis carried out for flora quadrat data utilising PATN™ (Belbin 2013) involves multivariate cluster analysis of species presence/absence. An association matrix of the Bray-Curtis coefficient was generated from the presence and absence site by species matrix using the software. The resultant dendrogram identified clusters of the quadrats from the surveys within the study area, which were then grouped into vegetation units and described at NVIS Levels III and VI.

Vegetation datasets from recent and relevant studies in the surrounding region were analysed using PATN™ in comparison to collected field data (a consolidation of data from quadrats recorded by FVC in 2016 and 2017 and Phoenix (2015), providing a total of 117 sampling points) to determine floristic similarities and enable a further analysis of local and regional representation of the vegetation. The most recent and relevant dataset was that of Phoenix (2015) for the Muchea North and Chittering study area for the Great Northern Highway project.

Once grouped and described, each local scale vegetation unit from the study area was then rationalised with regional vegetation associations as per Shepherd *et al.* (2002), based on qualitative descriptions focused on dominant flora in each stratum. This rationalisation enabled an analysis of regional extent and representation, and therefore regional significance of recorded vegetation units.

The collective results of the quadrat sampling were used to determine the distribution of varying FCTs within the study area, with a focus on areas of Banksia woodland. All of the quadrat data collected from within the study area during 2016, 2017 and 2018 was collated and floristic (PATN™) analysis was carried out in reference to the Gibson (1994) and Keighery (2008) datasets. The resulting dendrogram enabled representative FCTs to be inferred for each quadrat, where applicable (for those on occurring on the Swan Coastal Plain or with conclusive results). Once FCTs had been inferred for each quadrat, the site-specific species data and geographical location (soil-landscape mapping for that location) were reviewed to verify the inferred FCT. In some cases, it was appropriate to adjust the concluded FCT and in other cases, no FCT was able to be inferred (usually because no defined FCT exists in the literature for that vegetation type in that location).

Each quadrat identified through PATN™ analysis to show affinity with a FCT that is representative of the Banksia woodland TEC was also then assessed against the aforementioned Banksia woodland



characterisation criteria checklist. The likelihood of each quadrat being representative of the TEC was based on fulfillment of the key diagnostic criteria.

Where dendrograms resulting from PATN™ analysis do not provide definitive results and a clear cohesion of recorded quadrats with regional quadrats (of Gibson *et al.* 1994 and Keighery (2008)), FCT affinities can be further tested by carrying out an analysis of flora species presence-absence data. This simplified comparison was also carried out for collected quadrat data in comparison to the consolidated Gibson *et al.* (1994) and Keighery (2008) dataset, to provide numbers of species in common and further justification for FCT inferences applied to each quadrat.

The results of the above range of analyses and inferred FCTs for each quadrat then enabled conclusions to be drawn regarding TEC and PEC status of the vegetation of the study area.

## 5.6 STUDY LIMITATIONS

The limitations of the flora and vegetation assessment have been considered in accordance with the Technical Guidance (EPA 2016) and these are summarised in **Table 10**.

**Table 10 - Study Limitations**

Aspect	Constraint?	Commentary
Availability of regional data	No	A number of studies have been previously completed within the local study area and wider region, reflected in the broad range of previous study reports reviewed as part of the desktop assessment.
Scope (detail)	No	Detailed flora and vegetation assessments were carried out in accordance with EPA (2016). A collective total of 160 quadrats (inclusive of two relevés) have been sampled in the study area since October 2016. During the 2017 field assessments, field data was collected from a total of 89 pegged 10 m x 10 m quadrats. During 2018 an additional 22 quadrats were established specifically targeting Banksia Woodlands within the study area. Survey effort was also invested in selective targeted surveys for Threatened and Priority flora, as well as separate intensive surveys dedicated to searching for two species of Threatened orchids; <i>Thelymitra stellata</i> and <i>Drakaea elastica</i> .
Experience of personnel	No	All of the personnel undertaking the field assessment, flora identifications, data analysis, vegetation mapping and reporting are experienced botanists, with specialist skills in their respective fields. All botanists have a minimum of eight and up to 20 years' experience. Field botanists are all experienced in undertaking surveys in the region, and in undertaking targeted significant flora surveys. Taxonomic identifications were undertaken by specifically trained taxonomists, including specialists in relevant groups, who were consulted where required.
Survey effort/detail/intensity	No	Flora and vegetation surveys have been conducted within the study area since 2016. A total of 160 quadrats have been established by FVC within areas of intact remnant vegetation within the study area and in the surrounding region, as part of the multiple phase flora and vegetation assessments.
Seasonal timing and climatic conditions	Potentially somewhat	The field assessments were conducted during the full range of seasons, including spring surveys carried out during the optimal spring season, between October and November 2016, between September and November 2017 and September and November 2018. Targeted surveys for significant flora were conducted during optimal flowering times for each target species, including the targeted <i>Thelymitra stellata</i> survey conducted in November since. A targeted <i>Drakaea elastica</i> survey was conducted during July 2017 and August 2018.  Rainfall data for the winter months preceding spring field surveys fluctuated, whilst late summer and autumn rainfall was significantly lower than average. August recorded high rainfall across the study area region, although a significantly drier than average

Aspect	Constraint?	Commentary
		September followed. This could have resulted in rapid loss of annual and ephemeral plant abundance and poor flowering, as good rainfall may have encouraged early germination and blooming, but the dry conditions that followed would have had a negative impact on plant vigour.
Access	Somewhat	The majority of the study area is easily accessible and being linear corridors, most areas are accessible at least on foot from nearby roads or properties. One significant sized area comprising 89.05 ha (2.60% of the study area), west of the railway line along Cullulla Road near Barn Road was unable to be accessed due to safety limitations associated with the operational railway line and was therefore not mapped ( <b>Figure 13</b> ). However, this area is now unlikely to be impacted.
Mapping reliability	No	The mapping has been prepared at a scale based on mostly ground-truthed areas, with limited extrapolation given the good accessibility for most of the study area. Therefore, mapping reliability based on scale is considered high.
Disturbances	No	A large proportion (69.8%) of the total study area supports pasture with occasional trees or planted areas which include plantations and some small areas of rehabilitated vegetation. Only 21.8% of the study area was mapped to be in Good condition or better. However, significant areas (8.2% of the study area) were found to be in Very Good to Excellent and Excellent condition. The higher quality vegetation in a regional context of largely cleared vegetation is of greater significance in terms of conservation. Dieback infestations are apparent in some areas and weed invasion adjacent to pastoral areas are evident, however, within intact remnants, disturbance is mostly limited and is not considered to affect collected data.
Survey completeness	No	Most areas were easily accessible and there have been numerous surveys conducted in the study area over multiple seasons. The initial detailed flora and vegetation assessment was conducted in October 2016 with 47 quadrats and two relevés across 13 vegetation units. The second phase (autumn) detailed flora and vegetation assessment was conducted between March and August 2017 with 17 previously established quadrats re-sampled and an additional 13 new quadrats established. The third phase (spring) detailed flora and vegetation assessment was conducted between September and November 2017 with four previously established quadrats re-sampled and an additional 55 new quadrats established, of which 33 were regional quadrats. The spring 2017 assessment consolidated the vegetation into 12 separate units. The 2018 spring assessment established a further 22 quadrats during spring. Quadrat frequency provides at least three quadrats per vegetation unit and the total of 572 taxa recorded across the assessments suggests adequate survey effort.



## 6 RESULTS

### 6.1 DESKTOP ASSESSMENT

#### 6.1.1 Threatened and Priority Flora

The desktop review determined that a total of 109 flora species of conservation significance have the potential to occur within the study area, based on previous records within or in the vicinity of the study area. Since 2016, a total of 14 Priority flora species have been recorded within the study area. Three of these species were not able to be identified with certainty but are expected to be Priority flora (**Appendix A, Table 7**).

Five of the 109 species resulting from the desktop assessment were also recorded to regionally occur by FVC, six have been determined to be 'likely' to occur in the study area, with 31 classified as 'may occur' and 53 considered 'unlikely' to occur based on the proximity of previous records, currency of data, and whether suitable habitat is provided in the study area. The remaining 14 species were recorded during the field assessments to occur within the study area.

#### 6.1.2 Banksia Woodlands of the Swan Coastal Plain TEC

Banksia woodland is known to be supported by the study area, and therefore, during spring 2017, an initial assessment was carried out to diagnose/characterise, map and quantify the extent of Banksia woodland TEC within and connected to the study area.

A total of 89 quadrats were sampled in 2017 (FVC 2018c). An additional 22 quadrats specifically sampling Banksia woodland were recorded in 2018. Analysis utilising a checklist based on the Conservation Advice (Threatened Species Scientific Committee 2016) determined that 36 of the 89 quadrats sampled represent the Banksia woodland TEC in accordance with the key diagnostic characteristics. The Conservation Advice (Threatened Species Scientific Committee 2016) states that the Banksia woodland TEC "typically occurs on well drained, low nutrient soil on sandplain landforms, particularly deep Bassendean and Spearwood sands and occasionally on Quindalup sands", and that the community "is also common on sandy colluvium and aeolian sands of the Ridge Hill Shelf, Whicher Scarp and Dandaragan Plateau; and may also occur in other limited scenarios".

### 6.2 FIELD ASSESSMENT

#### 6.2.1 Flora

A collective total of 572 flora taxa from 218 genera and 63 families have been recorded throughout the study area between spring 2016 and spring 2018.

During the 2018 field assessment, a total of 214 taxa from 115 genera and 39 families were recorded from 22 quadrats. This included 199 (93.1%) native and 15 (6.9%) introduced (weed) species. The dominant family species recorded were Fabaceae (20 (9.7%) species), Proteaceae (18 (8.3%) species) and Myrtaceae (25 (11.5%) species). The full list of vascular flora species recorded during 2018 is presented in **Appendix B**, with individual quadrat data presented in **Appendix C**. The species lists and site data from previous studies is presented in previous reports (FVC 2017; 2018c).

None of the recorded introduced (weed) species recorded since 2016 studies, are listed WONS. One recorded weed species, *Chondrilla juncea* (Skeleton weed) is listed as a Declared Pest plant under the BAM Act across most of the State, including within the Shires of Chittering and Gingin, where it is listed under the category, 'C2' – Eradication (DPIRD 2018).

### 6.2.2 Conservation Significant Flora

None of the flora listed as Threatened under the WC Act or under the EPBC Act resulting for the desktop assessment (**Appendix A**) were recorded within the study area during the 2018 survey, nor during any of the previous assessments since 2016. However, three Threatened flora species; *Chamelaucium* sp. Gingin (N.G. Marchant 6), *Grevillea curviloba* subsp. *incurva* and *Grevillea althoferorum* subsp. *fragilis*, where recorded during regional surveys outside of the study area.

Since 2016, 14 Priority flora have been recorded within the study area. Three of the Priority flora species, *Leucopogon squarrosus* subsp. *trigynus* (P2), *Verticordia rutilastra* (P3) and *Halgania corymbosa* (P3), were newly recorded within quadrats established in spring 2018. Conservation flora species, their conservation status and the survey areas, quadrats and vegetation units in which they were recorded are presented below in **Table 11** and their recorded locations within the study area presented in the **Figure 11** series. Threatened and Priority flora recorded during regional targeted surveys are spatially presented in **Figure 12**.

Based on the results from collective field assessments conducted between 2016 and 2018, there have been 2,082 individual Priority flora plants recorded within the study area. The population numbers are summarised in **Table 11**.

A total of 50 targeted search areas were systematically searched during 2018 within and outside of the study area, specifically targeting Threatened and Priority flora considered likely to occur, particularly *Thelymitra stellata* and *Drakaea elastica* (**Figure 10**). Despite the intensive surveys which focused on areas of optimal habitat for *Thelymitra stellata* and *Drakaea elastica*, no individuals of either Threatened orchid were recorded within the study area.

Two of the recorded flora species, *Jacksonia ?sericea* (P4) and *Synaphea ?flabelliformis*, recorded during previous surveys (FVC 2018c) were found to be occurring outside their known range of distribution, based on Western Australian Herbarium records.



**Table 11 - Recorded Conservation Significant Flora**

Species	EPBC Conservation Status	WA Conservation Status	Total Number of Individuals Recorded	Total Number Recorded Within the Study Area	Total Number Recorded Outside of the Study Area	Recorded from Quadrat or Location	FVC Recorded Vegetation Unit/s
<i>Chamelaucium</i> sp. Gingin (N.G. Marchant 6)	Endangered	Vulnerable	111	0	111	Breera Road Nature Reserve Unnamed Nature Reserve (R50678) Ippolo Road	NA
<i>Grevillea curviloba</i> subsp. <i>incurva</i>	Endangered	Endangered	13	0	13	Unnamed Nature Reserve (R2336) Muchea South Road	NA
<i>Grevillea althoferorum</i> subsp. <i>fragilis</i>	Endangered	Critically Endangered	19	0	19	Bullsbrook Nature Reserve	NA
<i>Gastrolobium crispatum</i> (with <i>Gastrolobium ? crispatum</i> )		P1	2	0	2	B40^	CcXpBe (FVC 2017) does not occur in study area
<i>Synaphea panhesya</i> (with <i>Synaphea ? panhesya</i> *)		P1	14	5	9	B04^, B04.2^, B12^, B40^, B45.2^	BaXpAn, EmXpHh, EmBsHh, ErXpBm
<i>Drosera sewelliae</i> (with <i>Drosera ? sewelliae</i> *)		P2	303	234	69	B08, B16R, B18, B19, B27, B31, B04^, B04.2^, B2.01^, B2.04^, B2.12, B2.13^, B2.14^, B2.22^, B2.27^, B28, , B2.35^, B2.38^, B2.50, B31	EmBsHh, EmXpHh, EmXpAn, ErXpBm, EwBeNa, EwXpHh, EtBeAn, BaXpUa, BaXpAn
<i>Hibbertia glomerata</i> subsp. <i>ginginensis</i>		P2	383	0	383	B2.10^ Boonarring Nature Reserve	EmXpHh
<i>Leucopogon squarrosus</i> subsp. <i>trigynus</i>		P2	5	5	0	BW07, BW08, BW09, BW13, BW14	BaXpAn, EtBeAn
<i>Acacia drummondii</i> subsp. <i>affinis</i> (with <i>Acacia drummondii</i> subsp. <i>? affinis</i> )		P3	342	58	284	B2.43^, B44^ Udamung Nature Reserve, Private property north of Hay Flat Road	EmBsHh, EmXpHh
<i>Adenanthos cygnorum</i> subsp. <i>chamaephyton</i>		P3	1,068	23	1,045	B38^, B39^, B40^ Julimar State Forest, Mundaring State Forest	EmBsHh, ErXpBm, BaXpAn, BmKgHg

Species	EPBC Conservation Status	WA Conservation Status	Total Number of Individuals Recorded	Total Number Recorded Within the Study Area	Total Number Recorded Outside of the Study Area	Recorded from Quadrat or Location	FVC Recorded Vegetation Unit/s
<i>Halgania corymbosa</i>		P3	2	2	0	BW16, BW17	BaXpAn
<i>Styphelia filifolia</i>		P3	1	1	0	BW01^	BaXpUa
<i>Verticordia rutilastra</i>		P3	2	2	0	BW07, BW08	EtBeAn
<i>Anigozanthos humilis</i> subsp. <i>chrysanthus</i>		P4	11	5	6	B31^, B38^, B39^, B40^	PEwMrCo, EwBeNa (Quadrat outside study area)
<i>Conostephium magnum</i>		P4	1	1	0	BW05^	EtEpAn
<i>Hibbertia miniata</i>		P4	1,494	1,463	0	B28.2, B28	EmBsHh, EmXpHh, EwXpHh, PCc, PEw
<i>Hypolaena robusta</i>		P4	4	1	3	B2.17^, B2.20^, B2.43^, B2.50	BaXpAn, BaXpUa, EwXpHh
<i>Jacksonia ?sericea</i> *		P4	1	1	0	C08^	EtBeAn
<i>Verticordia paludosa</i> (with <i>Verticordia ?paludosa</i> *)		P4	281	281	0	B28.2	BaXpUa, EmBsHh, EtBeAn, EtEpAn
<b>TOTAL</b>			<b>4,057</b>	<b>2,082</b>	<b>1,975</b>		

\* from specimen collections unable to be identified with certainty due to lack of identifiable material

^ denotes regional quadrats