City of Kalamunda

Cambridge Reserve
Community Enhancement Project



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Version 1.0	Last updated 30 June 2020

Cambridge Reserve Introduction Report

This report outlines the history and key features of the Cambridge Reserve Community Enhancement Project located in the City of Kalamunda (City). This report, prepared by the City addresses the lengthy history, strategic priority, delivery process and preliminary feasibility of transferring a portion of Cambridge Reserve from Local Open Space Reserve to Urban Development and to supplement the findings of the technical appendices.

Site History

Cambridge Reserve is located within the City of Kalamunda, approximately 1km from the Forrestfield District Activity Centre and 13km (approx. 30min drive) from the Perth CBD (refer Fig 1).

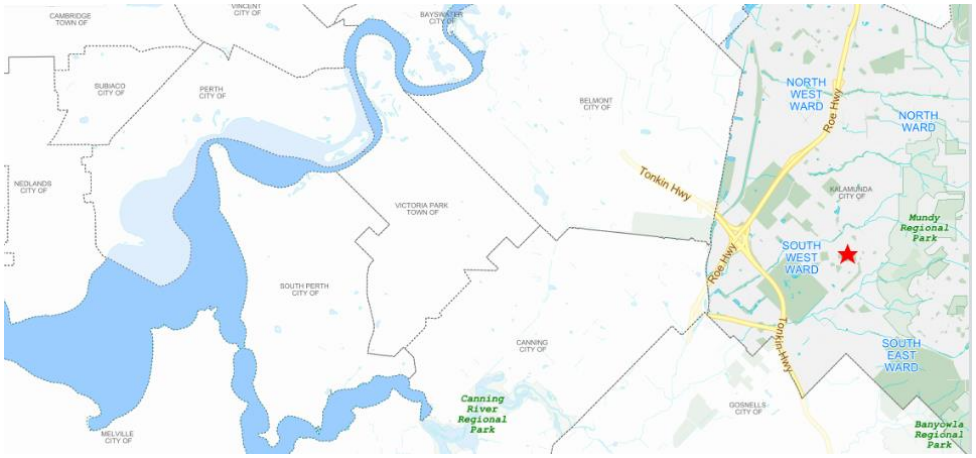


Figure 1 - Locality Plan



Figure 2 – Aerial locality plan

Nearby facilities include Forrestfield library, Forrestfield Police station, Hartfield Park recreation centre, Forrestfield Primary School and a number of commercial centres including two large commercial precincts located along Hale Road and two smaller centres located along Lincoln Road and Holmes Road respectively (refer Fig 2). The site is surrounded by residential housing, except to the east which is bordered by a vegetated Western Power easement adjoining Anderson Road. In 2018, an amendment to Local Planning Scheme No. 3 introduced Dual Density codes to the residential area surrounding Cambridge Reserve, generally allowing up to R25/R60 near Forrestfield Activity Centre to R25/R40 west of Anderson Road.



Figure 3. Map showing location of Dual Density zoning

It is worth noting the current condition of the reserve leaves much to be desired with rubbish dumping, burnt out cars, syringes, old asbestos fencing and evidence of homeless camps found onsite. Housing around the perimeter offers no surveillance, and the lack of lighting, formal paths and fencing means that the reserve safety remains unmanaged. Similarly, the site features areas of good quality vegetation but also areas of degraded vegetation, introduced species, and signs of erosion in places. It is likely to experience ongoing degradation of vegetation and drainage infrastructure without intervention (refer Images 1- 4).



Image 1: Existing playground



Image 2: Housing backing onto reserve



Image 3: Erosion and rubbish dumping



Image 4: Unfenced path through TEC with little passive surveillance and no lighting

Despite the neglected appearance Cambridge Reserve has been subject to revegetation programs, contains many areas of natural beauty, boasts views of the hills to the east, is close to hiking trails in Mundy Regional Park, and is valued by residents for the walking paths and the native bushland and wildlife. This project provides a mechanism by which funding from a developable portion of the reserve could be utilised to upgrade the LOS and facilities onsite to make it safer, more manageable and functional for residents. In conjunction, this project provides an opportunity to address a shortfall in aged care accommodation within the City more generally.

Timeline

Year	Action
2008	The City adopted an Aged Accommodation Strategy 2008. Objection 2 of the Strategy identified a need to facilitate aged care in appropriate locations to meet demand. The locational criteria is listed as sites with close proximity to medical, commercial, public transport, social and recreational facilities.
2011	Hester Land Asset Report (2011) identified Cambridge Reserve as suitable for a portion to be transferred to facilitate improvements to the reserve. Site valued at approximately $2 million.
2012	City undertook preliminary technical studies including: a. Site analysis report b. Environmental assessment report (including flora and fauna) c. Water monitoring d. Preliminary engineering services report e. Landscape cost estimate and concept plan
2013	The City's Local Planning Strategy (LPS) was endorsed by the WAPC in February 2013. The LPS included a strategy to provide housing for the ageing population with an initiative to rezone land for well located aged care facilities.
2013	Preliminary community consultation indicated the community were not receptive to the proposal and project was discontinued.
2014	The City's Local Housing Strategy was endorsed by the WAPC in 2014. The LHS includes a recommendation to implement the recommendations of the City's Aged Accommodation Strategy (refer above).
2016	Macroplan Aged Accommodation Strategy (2016) prepared and adopted by Council. Renewed focus on de-constraining City owned assets for aged care accommodation.
2017	City decides to revisit the project
2018	Preliminary community consultation undertaken Feb-March 2018. Outcomes inform preparation of a concept plan.
	Public advertising of the draft concept plan undertaken July-Aug 2018



2019

Concept plan adopted by Council 26 Feb 2019 and resolved to progress further technical studies and initiate the land transfer process.

Project sent to the Department of Planning, Lands, and Heritage (DPLH) for comment 27 Feb 2018.

March 2019 response received from the DPLH with concerns around flora survey methodology and results.

City engages independent consultants to undertake spring flora survey among other technical studies.

2020

Draft Local Housing Strategy 2020 adopted for advertising. Review of aged care indicated a shortfall of 500-900 beds by 2036. Also identified Cambridge Reserve as a key strategic project for further investigation.

Technical studies finalised and revised Concept Plans Option 1 & 2, prepared accounting for additional information.

Council Strategic briefing 5 May 2020 to consider results. Agreed advertising for the revised concept plan can occur concurrently with advertising of a proposed Local Planning Scheme Amendment.

The DPLH provides guidance on land transfer and financial considerations.

Revised concept plan and technical studies provided to the DPLH for comment.

Council to consider Cambridge Reserve proposed Local Planning Scheme Amendment for advertising, July/August 2020 Ordinary Council Meeting.

Concept Plan - Revision 1 (February 2019)

The concept plan originally adopted by Council in February 2019 featured a 1.4ha aged care site, 1.3ha consisting of 49 residential lots and 5.1ha (57%) retained as local open space (LOS). Most of the proposed development area was located to the north of the site to maximise vegetation retention and connectivity, with some residential lots abutting the western boundary (refer Fig 4). At the time there was no proposed change to the configuration of the drainage sump onsite and was to be confirmed with future water

modelling. The Council resolution included reference to further technical investigations being necessary, further discussion is provided below regarding the outcomes of these investigations.



Figure 4: Original Cambridge Reserve Concept Plan adopted February 2019

Revised Concept Plan

The revised concept plan was developed in response to information gained from the following technical studies undertaken in 2019/2020:

a. Flora survey 2019 and Floristic Community Type (FCT) Analysis
b. Water modelling and Local Water Management Strategy
c. Geotechnical Report
d. Bushfire Management Plan

In brief, the findings of the technical studies found there was TEC present onsite; that the existing drainage sump was too small to contain a 1 in 100 year flood event and required upgrading; and that the soil type was suitable for development. The revised concept plan therefore features retention of all known TEC onsite and a reconfigured 'constructed wetland' style drainage system which contains a larger volume of water and improved ecological function through water sensitive urban design (WSUD). The drainage design is also based on an assumption that a northern drainage basin may be installed within the Western Power easement north-east of the site. A small area of land on the northern side

of the drainage sump can be reclaimed for developable area, avoiding further removal of vegetation while the southern boundary of the drainage sump will remain so as not to disturb the adjoining TEC.

To maintain flexibility in the final product two concept plans were prepared; Option 1 features a 1.5ha aged care site (refer Fig 5) and 34 residential lots while Option 2 features a 1ha aged care site and 42 residential lots (refer Fig 6). Preliminary feedback from aged care providers indicates 1.5ha or larger is preferable for most providers, though a 1ha site will be feasible as shown by local examples such as Karingal Green. Each concept plan is briefly compared in Table 1 below.

Table 1. Concept Plan comparison

Original Concept	Revised Concept - Option 1	Revised Concept - Option 2
Features	Features	Features
• 57% LOS • 1.3ha ha aged care site • 50 residential lots • Drainage sump • Playground • Grassed open space • Trail network	• 57% LOS • 1.5ha aged care site • 34 residential lots • Constructed wetland • Playground • Basketball court • Trail network • Retention of all TEC	• 57% LOS • 1ha aged care site • 42 residential lots • Constructed wetland • Playground • Basketball court • Trail network • Retention of all TEC

The revised concept plans feature a larger playground, half basketball court to cater for a wider range of age groups, and a network of trails proposed to contain interactive features such as educational signage, nature-play, exercise equipment, barbeques, shelter and seating areas. It also eliminated the proposed western boundary lots, meaning less impact on adjoining properties and focusses the developable area within the northern and more centralised portion of the site. Areas of TEC are proposed to be retained, fenced off and managed with measures such as weed control, dieback prevention and revegetation as needed to improve the vegetation quality. Areas adjoining TEC are noted as managed veg which act concurrently as publicly accessible open space, an ecological buffer to the TEC reducing edge effects but also as a bushfire separation buffer. Striking a balance between the bushfire risk and ecological values will need to be addressed through the preparation of a future detailed landscaping plan.



Figure 5: Revised Cambridge Reserve Concept Plan Option 1



Figure 6: Revised Cambridge Reserve Concept Plan Option 2

Strategic Priority Aged Care Accommodation

The key feature of the Cambridge Reserve project is the provision of Aged Care accommodation which has been a strategic priority for the City for the past decade. Key strategic documents are listed in Table 2 as follows:

Table 2. Strategic document summary related to aged care

Document	Strategy /Action/Comment
Local Planning Strategy 2010 (endorsed by the WAPC 2014)	Part 2.4.3 - Proposed Scheme Amendments and Policy Initiatives • "*Rezone land for well located aged care facilities in Scheme"*
The Hester Land Asset Report 2011	Listed Cambridge Reserve as Priority 2 - R34364 Moira Ave, R31348 York Street and R27559 York Street • Options: "*Consider rationalisation and partial redevelopment of property to activate area an investment of funds to improve overall reserve"* • Recommendation: *"Property is considered to be ineffective as public open space area and should be developed with funds being re-invested into more strategic recreation reserves in district. Design process should be initiated to determine proportion of property to be retained for public open space purposes with balance being developed to support this use and provide passive surveillance and activation of the reserve"* • Land valued at $2 million
Aged Care Accommodation Strategy 2016 (Macroplan)	• The City should not directly undertake Aged Care developments. • The City should utilise government assets to encourage retirement living and aged care developments. • Encourage the expansion of existing providers and shared facilities; and, • Prioritise sites close to existing services and amenities.

City of Kalamunda Aged Care Committee comments on Aged Accommodation Strategy 2016	• The City should provide land at minimal cost to appropriate developers to encourage retirement and aged care facilities. • The City has a role in monitoring and stimulating service providers to develop in the City. The City should look at barriers to entry and eliminate red tape wherever possible.
Kalamunda Advancing Strategic Community Plan 2017-2027	• Strategy 1.1.1 *"Facilitate the inclusion of an ageing population and people with disability to have access to information, facilities and services";* • Strategy 3.1.1 *"Plan for diverse and sustainable housing, community facilities and industrial development to meet changing social and economic needs", and;* • Strategy 3.2.1 *"Optimal management of all assets"*
Aged Friendly Strategy and Action Plan 2017	• *"Advocate for the development of more aged accommodation in the City"*
Draft Local Housing Strategy 2020	• Draft Local Housing Strategy 2020 adopted for advertising. Review of aged care indicated a shortfall of 500-900 beds by 2036.

This was followed by the Public Open Space Strategy in 2018 which noted Forrestfield contains approximately 7ha of POS above the usual 10% benchmark and that most of Forrestfield was located within 400m of POS (refer Fig 7). This indicates that if a portion of Cambridge Reserve was developed then it would not reduce the overall POS allocation to less than 10% in the locality.



Figure 7: Extract of POS Strategy 2018 showing proportion of POS in Forrestfield.

Further, the draft Local Housing Strategy 2020 (advertised April-May 2020) showed the largest age demographic in the City was seniors aged 70 to 84 (refer Fig 8).

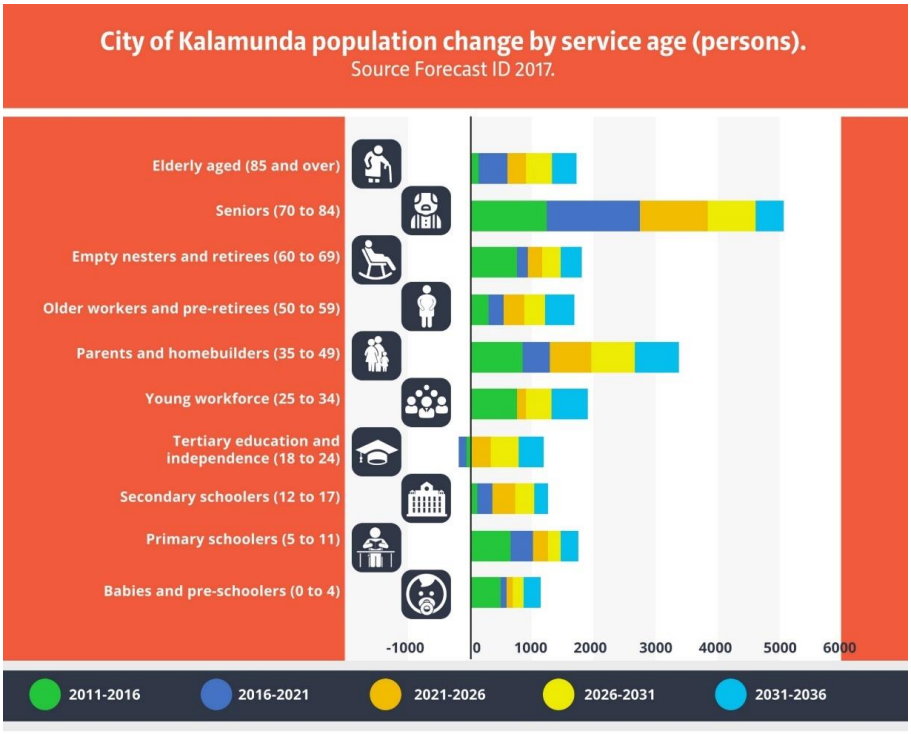


Figure 8: City of Kalamunda population projections to 2036

Analysis of the statistics, also cited through the draft Local Housing Strategy 2020, indicated a 500-900 bed shortfall in non-private aged care accommodation and included the following table which indicates only 314 additional beds may be provided by the market without intervention.

Table 3: Snapshot of aged care facilities in 2020

Facility, Address and Owner	No Beds Provided
Sunshine Park (Baptistcare) Brady Rd, Lesmurdie	36
Parry House (Amana Living) Warlingham Dr, Lesmurdie	40
Villa Maria (Mercy Health) Lesmurdie Rd, Lesmurdie	36
Donovan Village (Southern Cross) Lewis Rd, Forrestfield	65
Valencia Nursing Home Valencia Road, Carmel (Roshana Pty Ltd)	66
Total existing beds	243
Existing approvals (but not yet built)	No. Beds Proposed
Gavour Gavour Rd, Wattle Grove (Ross Leighton)	100
Valencia Nursing Home Valencia Road, Carmel (Roshana Pty Ltd)	120 proposed 66 existing (54 additional)
Karingal Green Calophylla Way, High Wycombe	160
Total beds approved but not built	314
Potential Development Applications	No. Beds Proposed
Parry House Warlingham Dr, Lesmurdie	96 total 40 existing (56 additional)
Heidelberg Park	100*
Potential future beds (pending development approval)	156

*Estimate based on land area, subject to detailed design.

The City currently contains approximately 243 aged care beds with potential for this to rise to around 713 depending on progress of existing or pending development approvals (refer Table 3). Occupancy rates of existing facilities average at 96% indicating a critical shortfall of

facilities within the City and surrounding areas. Given 1,135 persons are estimated to be in non-private dwelling accommodation by 2036 there is an estimated shortfall of approximately 892 beds based on a no-change scenario, or shortfall of 578 with consideration given to potential beds in the existing approvals scenario. The Cambridge Reserve revised concept plan is anticipated to be suitable for a multi-storey aged care facility catering for approximately 120 - 150 beds.

In summary, the City has an extensive strategic history of identifying sites which may be suitable for aged care accommodation. Cambridge Reserve is located close to shops, community services and amenities and has good access to services including sewer which is preferred for an intensive aged care development. Development of the proposed 3.5ha portion of Cambridge reserve is anticipated to generate the funds to make much needed upgrades to the reserve and potentially other community facilities in the locality (outlined in Feasibility - Table 4). The LOS improvements will also increase surveillance and activity on the reserve preventing anti-social behaviour and provides direct access to nature and outdoor exercise areas for both the proposed aged care and nearby residents.

Feasibility

Preliminary analysis undertaken by the City based on the technical investigations to date indicates that investment in the project is feasible under the Section 20A disposal process whereby the City purchases the developable land at 5% of its assessed market value.

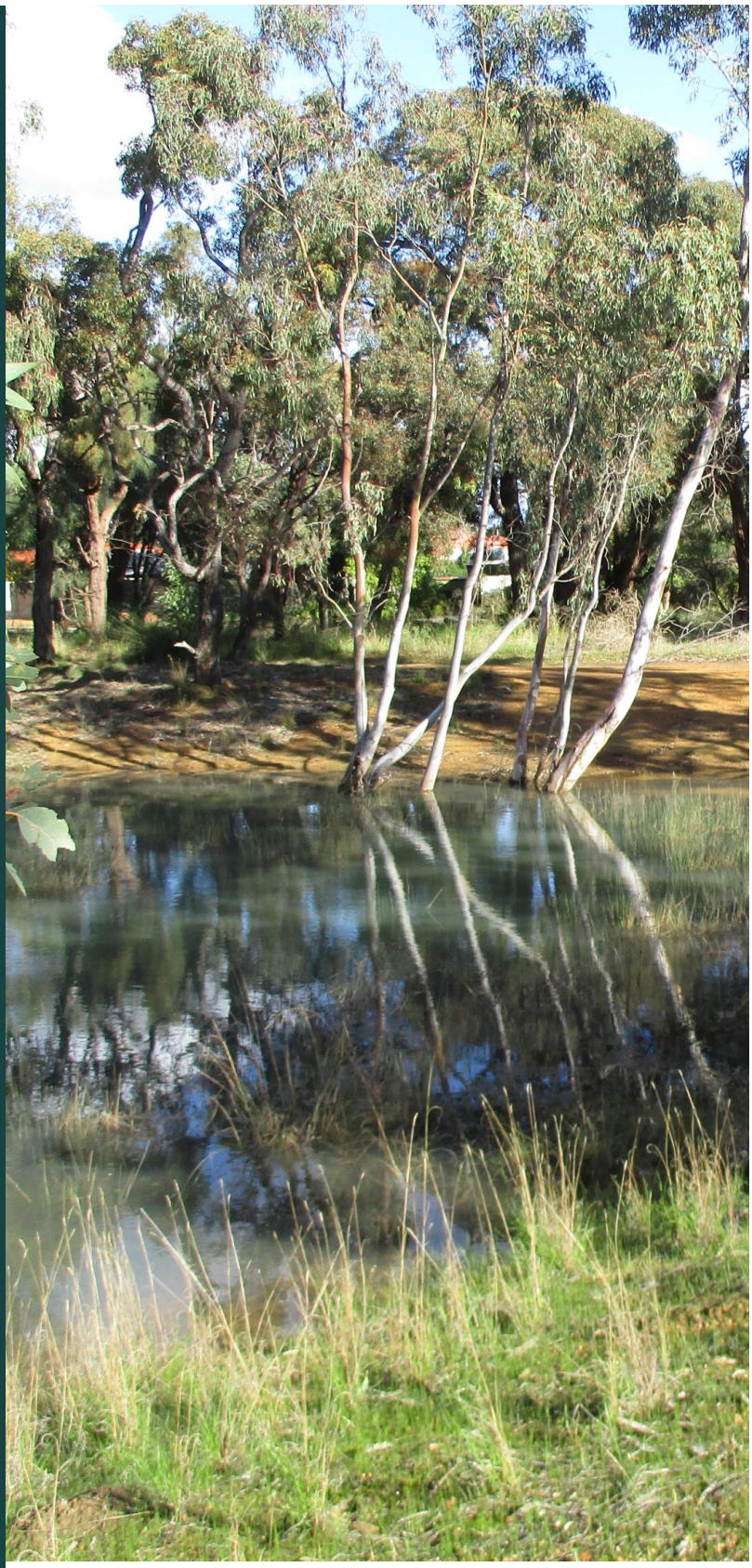
It is proposed that any possible revenue raised from the development of the site is placed in a restricted cash account (reserve fund) that is only to be utilised for reinvestment in community facilities and open space improvements for the Forrestfield locality.

Delivery

To implement the Cambridge Reserve Community Enhancement project, the City proposes that the next steps include:

1. Progress a Local Planning Scheme No. 3 Amendment;
2. Concurrently transfer the portion of developable land to the City;
3. Subject to the outcome of Local Planning Scheme Amendment and transfer process, the City will undertake an expressions of interest process to gauge interest from aged care providers;
4. The City will then consider sale of the aged care site;
5. The Council will consider a report on whether to engage a developer and property agent to manage subdivision, infrastructure works, marketing and land sales;

Subject to the Council's decision on the model of delivery, development works commence.



Appendix A – Summary Report


URBIS
CAMBRIDGE RESERVE
COMMUNITY ENHANCEMENT PROJECT CONCEPT PLAN REPORT
PREPARED FOR
CITY OF KALAMUNDA
APRIL 2020
FINAL VERSION
City of Kalamunda

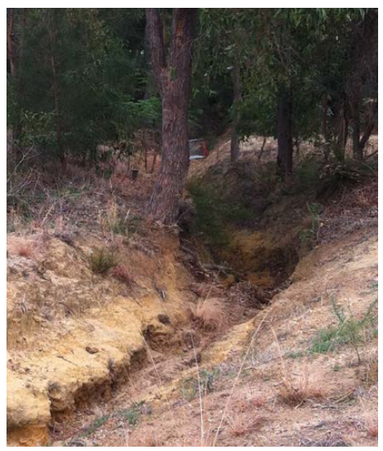










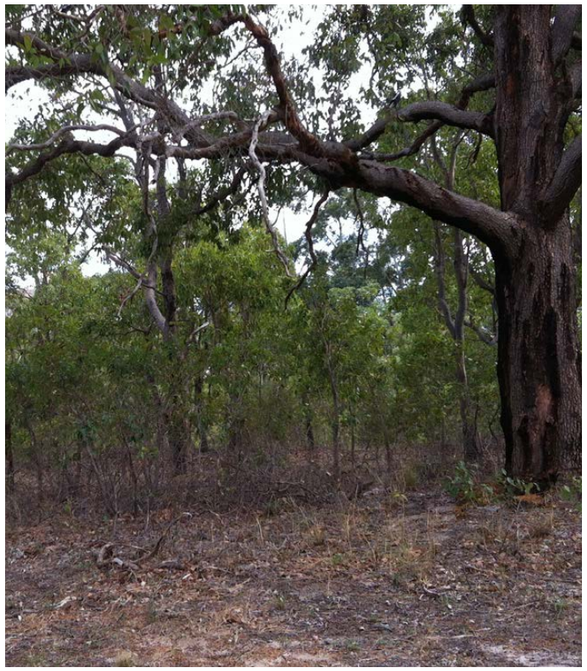




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1.0 PROJECT OUTLINE

Urbis was engaged by the City of Kalamunda to develop a concept plan that investigated the potential reuse and improvement of Cambridge Reserve. This site had been identified by the City through the Hester Property Solutions *Land Asset Assessment January 2011* as having potential for partial redevelopment. The City determined to investigate the improvement of this community asset with the objective to provide additional housing opportunities for the local area, including an aged care/ assisted living facility in line with the *City's Aged Accommodation Strategy 2016.*

The following outlines an opportunity to enhance the site, make use of underutilised land and offset the cost of improvement through the development of the site. The development area was primarily focused along the western edge of the reserve . This part of the site was generally flat, primarily contained introduced species and displayed the most antisocial behaviours as a result of limited surveillance of the Reserve.

A draft version of the plan was provided to the community for review and feedback. An initial community Pre-Consultation was undertaken in February – March 2018 including a workshop and survey. The outputs from this consultation influenced the concept designs and a draft plan was presented to the community through a workshop and survey in July-August 2018. The plans were generally well received, and the community identified additional features that were included in the final plan including additional seating, modified activity hub, additional shade and expanded bushland re-vegetation.

The initial concept plan was endorsed by the Council in February 2019 for the purposes of progressing further technical studies, consultation with the State Government authorities and preparing for the land administration process and Local Planning Scheme amendment to support the proposed improvements (see Appendix for original concept).

During consultation with State Government agencies in 2019, it became evident that further investigation was required to identify and protect environmental values on the site prior to progressing the concept. This process identified required modifications to the concept plan to protect Threatened Ecological Communities and provided an opportunity to reconsider modifications to the drainage basin to improve amenity, environmental and recreational outcomes. In late 2019 / early 2020, the City completed technical studies to support a modified concept plan including the following:

- Geotechnical;
- Hydrology;
- Environmental;
- Bushfire Risk; and
- Infrastructure and Servicing.

This report has been updated to reflect the modified concept plans prepared in early 2020 and will inform the land administration and Local Planning Scheme amendment process moving forward.

2.0 SITE UNDERSTANDING

Some of the key issues identified to engage and make best use of the site are as follows:

- **Retention of natural bushland and resolution of bushfire policy requirement** – A Preliminary Opportunities and Constraints Report was prepared by Strategen in 2012 that identified some broad bushland zones. A PlantEcology report was commissioned by Strategen in December 2012 to provide a detailed flora survey. These were further surveyed in 2017 by Eco-logical in their Australian Flora, Vegetation and Fauna Survey of Anderson Road Reserve. A final review was prepared by PVG Environmental in 2019-2020 to identify threatened Ecological communities. A key output from these reports was the identification of an expanse of natural bushland and the presence of threatened ecological communities. Additionally, the reports identified several significant remnant trees that could be retained across the site. The concept design works with the site to preserve the bushland and retain trees where appropriate to ensure they become an asset for the site. The site design considers the interface with retained bushland in line with bushfire policy requirement State Planning Policy 3.7 Planning in Bushfire Prone Areas (SPP3.7), and particularly in light of the addition of vulnerable elderly users.
- **Interface with the existing overhead power-line and easement** – The overhead power-line and associated easement running alongside Anderson Road is a visual impediment and serves to disconnect this edge of the site from the surrounding neighbourhood. Given that there is limited control over what can occur in this easement it is important that the site adequately addresses this interface and identifies a solution that creates an improved outcome not just for this site but helps to stitch it back into the wider community. There is also potential for the access road and northern drainage basin to be located in the power easement subject to support from Western Power.
- **Integration of the drainage basin** - The drainage basin on site provides a necessary function retaining water and run-off from the surrounding neighbourhood but in its current format is unsightly. With careful consideration in the design phase this basin could be filled to provide reclaimed land for development and avoid impact on existing areas of quality vegetation. The existing basin can be relocated and converted into wetlands and living streams providing not only visual amenity for the existing and new residents but also helping to re-establish habitat for the natural flora and fauna.
- **Provide safe and legible access to alternate movement systems** – A limitation on the elderly is reduction in independent mobility. It is important that alternative modes of transportation such as buses are available and within close proximity of housing. This includes not just the provision of bus stops, but clear, legible and safe connections between transit nodes and residences. Working with the topography of the site and ensuring that connections are well lit and have opportunity for natural surveillance will be critical to the sites success as a retirement or aged care use.
- **Integration into the existing neighbourhood –** Traditionally aged care and retirement villages were separated from the surrounding community in an effort to provide a safe environment for the elderly. Recent learnings have identified that whilst providing a safe and secure environment is important there is also significant benefit in establishing strong connections with the surrounding community. The concept design will need to establish a balance between these two objectives to ensure that the elderly are not isolated and provide opportunity for the community to benefit from the knowledge, presence and engagement of its elderly population.

3.0 VISION

Cambridge Reserve will be a transformative project that re-engages with this wonderful community asset and formalises many of the existing activities on the site. The inclusion of an aged care or retirement living on the site will provide additional activation and uplift as well as provide much needed housing opportunities for this sector of the community.

The clear delineation and retention of established native vegetation and the adaption of the detention basin on site will provide a manageable asset for the community both existing and future.

The provision of walking trails and regular activity nodes across the site will contribute to the wider engagement of the community and provide a formalisation of the existing informal trails. A new playground and active area is available to the wider community and provides a place to gather and play. This is targeted to a range of age groups ensuring use by the entire cross section of the community. This also provides a location for aged care residents to visit with their grandchildren and visitors.





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SITE ASSESSMENT

CAMBRIDGE RESERVE COMMUNITY ENHANCEMENT PROJECT

30.03.20

DATE: 11.09.2017

JOB NO: ND1980

DWG NO: FIG-3

REV: A

1:2,000 @ A3

0 20 40 60 80 100

4.0 DESIGN PRINCIPLES

From the analysis of the site some clear design principles have been established that will inform the concept moving forward.

Improve safety – Much of the site is located at the rear of the housing stock with rear fencing fronting onto Cambridge Reserve. Positioning of housing to the street edges will enable passive surveillance. The anticipated outcome is that this will have a reduction in antisocial behaviour.

Utilise site assets – the detention basin as currently sited provides a large and underutilised piece of land for much of the year. However, during wet periods, it becomes an important part of the natural ecosystem and a natural asset for the site. Through design intervention we hope to relocate this feature to the west of its current location and reconfigure it, increasing its catchment and transforming this feature into a site asset while avoiding development of vegetated areas.

Engage with the amenity – the site is located at the foot of the hills and provides a great view. Through orientation of the streets we hope to utilise this asset as a way-finding device and also add to the natural beauty of the site.

Celebrate the bushland – There is an expanse of bushland that provides a natural habitat and serves as an asset for the site. By formalising the perimeter of this bushland we hope to contain this asset and quarantine it from degradation.

Formalising site activation – The park already has a wide range of users and activity but many of the trails are informal and not always accessible to all. By designating trails we can provide formal routes through the site and protect the natural areas. We have observed a large amount of foot traffic using the site and will investigate opportunities to further encourage this community activation. These new trails will include nodes or stops that offer:

- interesting path treatments
- sensory experiences for young and old
- interactive signage
- exercise equipment
- nature play
- instalments to support cyclist and children on skateboards and scooters

Providing new housing opportunities – The community can be expanded bringing additional activation and life through the careful siting of new housing opportunities including aged and retirement living to cater for this population.











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OPPORTUNITIES AND CONSTRAINTS

CAMBRIDGE RESERVE COMMUNITY ENHANCEMENT PROJECT

30.03.20
DATE: 11.09.2017
JOB NO: ND1980
DWG NO: FIG-4
REV: A

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5.0 DESIGN CONCEPT

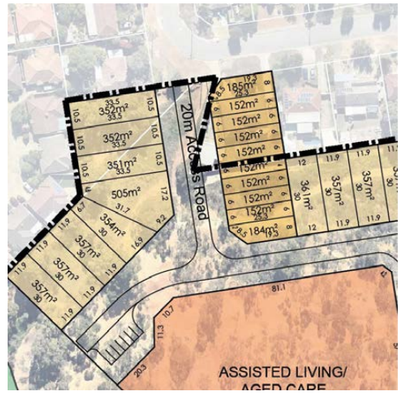
The design concept has been produced to meet the established principles and deliver a housing return in an order of magnitude to make the project feasible. A range of options were examined balancing the provision of natural assets on site, the highest and best return of land and the utilisation or enhancement of existing site features to ensure the best outcome.

Some of the key features of the proposal include:

- A connection to Mallow Way has been identified serving as an extension of the existing street network. This street would serve a limited number of properties and it provides a natural link to the existing street network and maintains and enhances existing pedestrian connections.
- The drainage basin has been increased in size, relocated and utilised as a feature of the site. During the winter months this forms a 'lake frontage' setting water feature' style setting and serves as an asset for the site.
- The northern and eastern edges of the site include a managed parkland and combine with a relocation and upgrade of the existing playground serving both the new and existing communities.
- Footpaths prescribe a boundary to the detention basin including a new pre-filtering area contained by a board-walk. By retaining water here this feature could provide a year round amenity.
- The southern edge of the basin retains the natural bushland and allows the continuation of the existing informal pathway.
- Connections to the detention basin have been identified for upgrade, channelling overland drainage into Water Sensitive Urban Design channels or through formal drainage networks across the site.
- Natural bushland has been preserved on the site and has been fenced to offer additional protection. These fenced areas contain the most significant local vegetation with dense undergrowth and represent the best local habitat on site. Setbacks to new properties from this retained vegetation have been provided in accordance with SPP3.7 requirements.
- Pathways have been provided across the site. The pathways correlate with and formalise existing movement patterns and form an interactive loop. Along the southern boundary the footpaths also serve as a fire-break between properties and the retained natural vegetation.
- An activity hub and youth and aged nature playground area has been located adjacent to the water feature and has immediate passive surveillance from new and existing residences adjacent.
- New residences have been oriented to ensure that they front onto the public open space to assist in the provision of passive surveillance.
- The new street has been aligned to take advantage of views to the hills and to provide a natural extension of the existing street network.
- The design of the new street incorporates fire separation requirements and provides a managed edge to the retained bushland.
- The site has also been designed with flexibility in mind with the block structure adaptable to changing market conditions.
- An interactive pathway can been introduced across the site. This pathway circuit provides opportunities for engagement through art installations, fitness equipment, interpretative signage,or scooter or skate track nodes at regular intervals.

DESIGN TESTING

An alternate access opportunity was identified during design testing that allowed for the integration of the adjacent Department of Communities property.



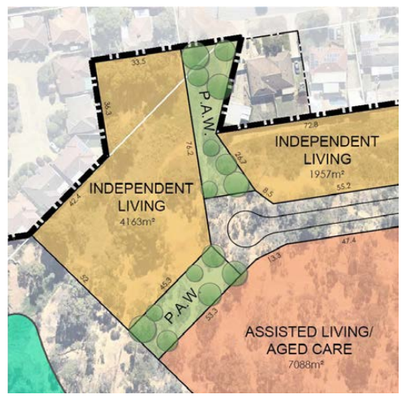
Alternate: Partnership with Department of Communities land

Alternatives sizes and layouts of the aged care site were explored.



Alternate: Connection to York Street and a potential 1 ha aged care site.

An alternate option was examined that explored a re-cut of the lots to provide for additional retirement or aged care / assisted living.



Alternate: Increasing retirement living component









LEGEND:

1. 600SQM PICNIC SHELTER AND PLAYGROUND
2. STORMWATER BASIN / SWALE
3. FENCED THREATENED ECOLOGICAL COMMUNITY (TEC)
4. SHADE STRUCTURE & SEATING NODE
5. BUSH RE-VEGETATION
6. BOARD-WALK
7. INTERACTIVE CYCLE AND PEDESTRIAN PATH NETWORK
8. 3M LIMESTONE MAINTENANCE TRACK
9. EXISTING PAW
10. EXISTING LOTS
11. PARALLEL VERGE PARKING
12. RELOCATED BUS STOP
13. PROPOSED FROG/ DUCK POND
14. (TEC) ZONE
15. FIRE HAZARD REDUCTION ZONE
16. BRICK ROAD TREATMENT - SLOW SPEED AREA

BENCH SEATING

INTERACTIVE WALKING AND CYCLE TRAIL STOP POINTS - INTERPRETATION/ EDUCATION/ WAYFINDING/ ART/ EXERCISE/ SENSORY EXPERIENCE

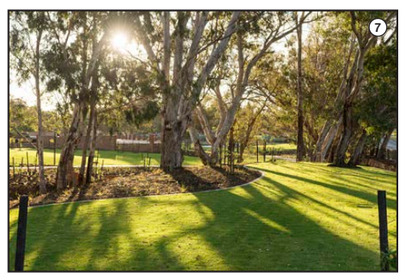
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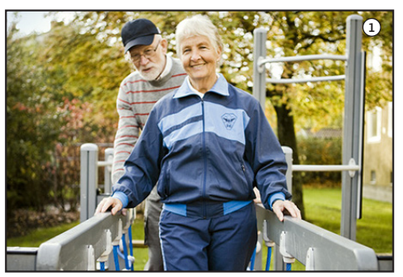
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4. Re-vegetation is to be carried out using endemic and / or native species.
5. Extent of all re-vegetation works are subject to Bushfire assessment and requirements.
6. Irrigation is to be limited to high use areas around activities nodes and play areas.
7. Path network will include cycle path connections, pedestrian paths as well as informal path networks within areas of re-vegetation.
8. Parking locations and quantities are indicative only and subject to technical advice.
9. TEC areas will be subject to rehabilitation/ re-vegetation as part of public open space upgrades
10. A drainage easement connectign Mallow Way may be required over the Aged Care site.











URBIS

CAMBRIDGE RESERVE
LANDSCAPE CONCEPT PLAN

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DATE: 04.05.2020
JOB NO: P0011135
DWG NO: AR-CD02
REV: F

6.0 SUBDIVISION, STAGING AND DELIVERY

Subdivision of the site has been arranged to provide a range of housing opportunities. The subdivision plan features:

- Connections to the detention basin have been identified for upgrade, channelling overland drainage into Water Sensitive Urban Design channels or through a formal drainage network across the site.
- Standardised lot frontages and depths with a variety in products provided.
- Lots opposite the vegetation retention area have been afforded extra depth to ensure a minimum 20m building zone.
- Buildings on these new lots are anticipated to be 2 storeys to provide passive surveillance of the park and playground.
- The road connects Cambridge Road through the site to Mallow Way
- Typical road reserve widths including 15.5m for standard roads, 12.5m for roads adjacent to Public Open Space. Movement priorities reflect this arrangement.
- A regular shaped Aged Care site has been provided to offer flexibility in layout and suitability for the market.
- Exclusive access from Mallow Way to the aged care site may be provided.

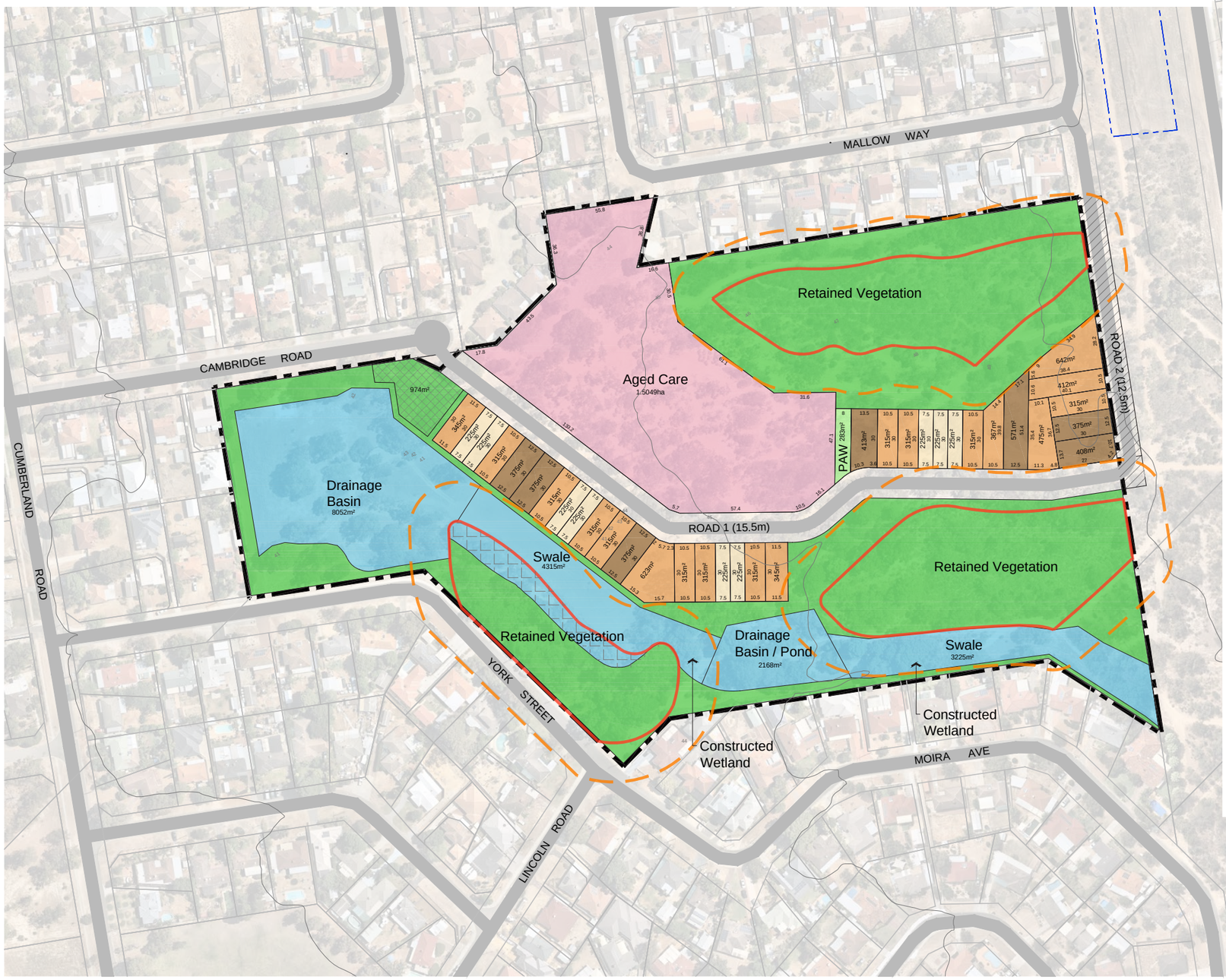
LOT TYPE	YIELD
200-299m²	9 Lots
300-399m²	18 Lots
400m²+	7 Lots
Aged Care	1 Lot

USE	apx AREA
Total Site Area	**9.0ha**
Public Open Space	**5.14 ha**
- Drainage	(1..58ha)
- Retained Vegetation	(3.86ha)
Total Development Area (Including Roads)	**3.85 ha**
- Aged Care	1.5 ha

An alternate version of has been provided with a reduced aged care site at 1 ha and a connection from Cambridge to York Street providing additional greentitle lots. This alternate layout can be seen in Appendix A. Further exploration of this option will depend on the needs of aged care providers as identified during an expressions of interests phase.

Both site options and proposed layouts present a range of staging and delivery opportunities. We anticipate the staging and delivery of the site as follows.

- The aged care site can be released separate to the rest of the site with a separate access from Mallow Way available.
- The central street will provide access to the remainder of the site.
- This central street may be developed in stages to enable cash flow and generate income for improvements across the remainder of the site.
- The new road doubles as a fire-break between the retained bushland and the housing site.



SUBJECT SITE (8.97ha)

RESIDENTIAL LOTS 7.5m FRONTAGE

RESIDENTIAL LOTS 10.5m FRONTAGE

RESIDENTIAL LOTS 12.5M frontage

AGED CARE

TEC (TO BE REHABILITATED & REVEGETATED)

TEC BUFFER (20m)

EXISTING DRAINAGE BASIN EXTENTS

PROPOSED DRAINAGE ARRANGEMENT (17761m²)

OPEN SPACE

PAW (8m)

INDICATIVE PLAYGROUND LOCATION

ROAD CONNECTION (1890m²)

LOT SUMMARY	
Number of Lots	34
Total Area of Lots	11591m²
Average Area of Lots	341m²
Minimum Lot Area	225m²
Maximum Lot Area	642m²

Notes:

- Lot summary excludes Aged Care.
- Drainage easement connecting Mallow Way to central drainage to be resolved at detailed design stage.

URBIS

Concept Plan

Cambridge Reserve

Level 14, The Quadrant, 1 William Street | Perth WA 6000 Australia | +61 8 9346 0500 | URBIS Pty Ltd | ABN 50 105 256 228

DATA SOURCE
Landgate

PROJECTION
MGA Zone 50

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PROJECT NO.
P0011135

DATE
27.05.2020

DRAWING NO.
01

REVISION
B1



LOT SUMMARY	
Number of Lots	42
Total Area of Lots	14510m²
Average Area of Lots	345m²
Minimum Lot Area	225m²
Maximum Lot Area	642m²

Note:

- Lot summary excludes Aged Care

URBIS

Concept Plan
Cambridge Reserve

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DATA SOURCE
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PROJECT NO.
P0011135

DRAWING NO.
01

DATE
01.05.2020

REVISION
C1

7.0 STATUTORY PROCESS

Cambridge Reserve Approach to Disposal and future planning.

The Crown Land Administration Practice Manual 2013 provides guidance to local authorities on the disposal of local reserves. In summary, in making a request to the Ministers responsible for Planning and Lands to dispose of a portion of Cambridge Reserve in order to fund redevelopment of the balance portions of the open space, the City will need to provide the following:

- Provide a summary for the reasons for disposal including evidence of sufficient open space in the locality.
- Identification of land involved and the proposed end use for these portions of land.
- Details of community consultation on the matter.

In the context of Cambridge Reserve, the Urbis prepared subdivision concept and landscape masterplan for the balance portion of the reserve will be critical. The narrative around the reasons for redeveloping a portion of the site to fund open space improvements elsewhere will be important in engaging the community. Preliminary estimates on income generated from the sale of the proposed land will be essential in this community discussion.

From a planning perspective, we consider there to be 2 clear potential approaches to the disposal and redevelopment of the subject portions of Cambridge Reserve. The following table considers the “pros and cons” of each approach.

Urbis recommends Approach No.2, which involves only divesting and rezoning the portion of land to be disposed of. Overall, whilst potentially losing some design flexibility, this approach will be far more palatable and from a community and political perspective in comparison to divesting the entire Cambridge Reserve and undertaking a structure plan process.

A table outlining the anticipated information requirements at the Local Planning Scheme No. 3 amendment and subdivision planning process has also been provided

APPROACH	PROS	CONS
1- Rezone the development portion of Cambridge Reserve to an 'Urban Development' Zone (including roads but excluding open space) subject to a future Structure Plan and Local Development Plan . The balance of the site to remain as POS reserve.	Provides absolute flexibility in defining those portions of the reserve to be retained and those to be developed for urban purposes. Flexibility may be essential from a drainage or environmental perspective.	Divesting an entire open space reserve (albeit much will be re- vested for open space purposes) will likely raise community concern.
	Structure Plans can be readily amended if design or development drivers for the project change over time.	At the conclusion of a structure plan process, the balance open space to remain will need to be re-vested after having been purchased by the City.
2- Rezone only those initially identified portions of Cambridge Reserve required for development purposes to a specific R-Code.	Politically a more palatable approach (doesn't look like Cambridge Reserve in its entirety is being removed). Far more easily communicated to the community.	Significantly reduced flexibility. Development bound by extent of zoning.
		Requires technical documentation and approvals to be undertaken upfront. No room for error in defining edge of open space/residential development.
		Scheme amendment requirement to amend development edges or residential coding (minimum 9- 12 month process).

Strategy / Plan	Local Planning Scheme No. 3 Amendment	Structure Plan	Subdivision
Local Water Management Strategy	✓		
Local Water and Drainage Management Plan		✓	
Acid Sulphate Soil Investigation		✓	
Flora and Vegetation Survey	✓		
Preliminary Environmental Management Plan	✓		
Bushland Management Plan		✓	
Landscaping Plans		✓	
Infrastructure Servicing Report	✓		
Earthworks, Retaining and Road Construction Plans			✓
Geotechnical Investigation	✓		✓
Traffic and Transport Statement	✓		
Bushfire Management Plan	✓		✓
Die-back Management Plan			✓

8.0 COST ESTIMATE

The following cost estimate has been provided outlining the potential cost of site upgrades. This is based on the upgrades to the site as illustrated in the Landscape Concept Plan.

Note these figures are based on an anticipated initial capital cost and do not include ongoing maintenance costs. Also note that the fire break along the rear of the Moira Avenue properties is not an asset protection zone.

1. This OPC is an order of magnitude assessment only. Key details that may impact a final price such as engineering design, final design levels etc are not available and have been considered from a high level only. Quantities have not been checked by a quantity surveyor.
2. Rates are based on recent and relevant market prices, but may be subject to future rise and fall depending on market conditions.
3. All figures exclude GST.
4. Total Area' calculated includes area of drainage reserve, POS, PAW, road verges (abutting POS or new development lots), Threatened Ecological Community zones and associated buffers. It does not include the colour rendered area on the landscape master plan that is east of the Cambridge Reserve site.

ITEM	DESCRIPTION	TOTAL
1	SITE PREPARATION & EARTHWORKS	
1.1	Allow for minor earth works as necessary and fine grading - excluding TEC zones.	$75,024.00
1.2	Allow for clearing of weed, weed removal & spraying as required - General Works	$18,756.00
1.3	Allow for clearing of weed, weed removal & spraying as required to TEC zones	$10,586.50
1.4	Allow for bushland weed management	$-
1.5	Allow for structural / cosmetic pruning & making safe of existing trees as required	$15,000.00
1.6	Allow for soil testing	$875.00
	Total Site Preparation & Earthworks	**$120,241.50**

2	SOIL PREPARATION	
2.1	Allow for the supply and installation of soil conditioner to shrub beds (100mm)	$21,022.50
2.2	Allow for the supply and installation of soil conditioner to TEC buffers (where required)	$30,412.50
2.3	Allow for the supply and installation of soil conditioner to 30/45lt Trees	$3,150.00
2.4	Allow for the supply and installation of soil conditioner to 90/100lt Trees	$4,400.00
2.5	Allow for the supply and installation of soil conditioner to turf areas	$79,425.00
	Total Soil Preparation	**$138,410.00**

3	MULCH	
3.1	Allow for the supply and installation of mulch shrub beds	$21,022.50
3.2	Allow for the supply and installation of enviro mulch to TEC buffers where required	$40,545.00
3.3	Allow for the supply and installation of mulch rings to trees in grassed areas	$945.00
	Total Mulch	**$62,512.50**

ITEM	DESCRIPTION	TOTAL

4	PLANTING	
4.1	Allow for the supply and installation of 130mm shrubs	$78,484.00
4.2	Allow for the supply and installation of tubestock / sedge stock to TEC zones (supplementary planting @ 0.5p/sqm)	$37,054.50
4.3	Allow for the supply and installation of tubestock / sedge stock to TEC Buffers (where required @2p/ sqm))	$56,770.00
4.4	Allow for the supply and installation of tubestock / sedge stock to living stream	$-
4.5	Allow for the supply and installation of 45L trees	$18,900.00
4.6	Allow for the supply and installation of 90/100 litre trees	$25,520.00
	Total Plantings	**$216,728.50**

5	TREE STAKES	
5.1	Allow for the supply and installation of painted tree stakes	$6,420.00
	Total Tree Stakes	**$6,420.00**

6	ROOT CONTROL BARRIERS	
6.1	Allow for the supply and installation of Root-stop root control barriers (6 l/m)	$1,800.00
	Total Root Control Barriers	**$1,800.00**

7	TURF	
7.1	Allow for the supply and installation of roll-on lawn	$142,965.00
	Total Turf	**$142,965.00**

8	EDGING	
8.1	Allow for the supply and installation of 150mm concrete edging to grassed areas adjoining shrub beds and mowing edge to walls.	$10,000.00
	Total Edging	**$10,000.00**

9	PAVING AND STEPS	
9.1	Allow for the supply and installation of feature boulders	$15,000.00
9.2	Allow for the supply and installation of coloured concrete path. Including ground preparation, compaction etc (Profile 1)	$106,400.00
9.3	Allow for the supply and installation of compacted limestone maintenance track	$15,720.00
9.4	Allow for the supply and installation of mortared stone pitched revetment	$60,500.00
9.5	Allow for the supply and installation of stone boulders to outlet	$-
	Total Paving and Steps	**$197,620.00**

10	WALLS	
10.1	Allow for supply and installation of blockwork retaining walls including ground preparation, ground compaction, cladding, graffiti protection & waterproof parging (height to 1m)	$20,000.00
10.2	Playground seatwalls	$5,000.00
	Total Walls	**$25,000.00**

ITEM	DESCRIPTION	TOTAL

11	FURNITURE and ELEMENTS	
11.1	Allow for the supply and installation of bench seating to parkland and bushland	$35,000.00
11.2	Allow for the supply and installation of shade structures	$80,000.00
11.3	Allow for the supply and installation of bin surrounds	$12,000.00
11.4	Allow for the supply and installation of BBQ	$7,500.00
11.5	Allow for the supply and installation of picnic settings (1 x table / 2 x benches)	$24,000.00
11.6	Allow for drinking fountains	$5,000.00
11.7	Fence to bushland	$82,670.00
11.8	Play equipment incl. sand/mulch softfall	$125,000.00
11.9	Raised boardwalk	$84,000.00
11.10	Interpretation / wayfinding elements	$13,500.00
	Total Furniture	**$466,670.00**

12	LIGHTING	
12.1	Parkland lights	$70,000.00
12.2	Lighting to Shade structures	$6,000.00
12.3	Cabling, controller	$30,000.00
	Total Lighting	**$106,000.00**

13	IRRIGATION	
	Allow for the supply and installation of: irrigation	
13.1	Connection to existing bore infrastructure	$1,000.00
13.2	Electrical connection to existing power source	$1,000.00
13.3	Supply & install new irrigation cabinet	$2,000.00
13.4	Supply & install irrigation controller	$1,500.00
13.5	Irrigation to shrub beds	$42,045.00
13.6	Irrigation to turf areas	$158,850.00
13.7	Bubblers to trees	$26,750.00
13.8	As Constructed drawings	$2,000.00
	Total Irrigation	**$235,145.00**

	"SUB- TOTAL LUMP SUM (excluding GST & Contingency)"	**$1,731,512.50**
	Contingency at 15%	**$259,726.88**
	LUMP SUM TOTAL (excluding GST)	**$1,991,239.38**

14	PROVISIONAL OPTIONAL ITEMS	
	Allow for the supply and installation of:	
14.1	Fitness equipment	$50,000.00
14.2	Scooter / skate track installations	$50,000.00
14.3	Large artwork installations / sculptural elements	$100,000.00
14.4	Small artwork /interpretation / sensory	$50,000.00
14.5	Optional items contingency	$50,000.00
	TOTAL PROVISIONAL OPTIONAL ITEMS	**$300,000.00**

	SUB- TOTAL LUMP SUM (INCL. PROVISIONAL OPTIONAL ITEMS) (excluding GST & Contingency)	**$1,981,512.500**
	SUB- TOTAL LUMP SUM (INCL. PROVISIONAL OPTIONAL ITEMS & CONTINGENCY) (excluding GST)	**$2,291,239.38**

Exclusions: Preliminaries, Civil contractor's margin (if landscape works commissioned under civil contract), Truck watering, Mulching of existing bushland vegetation, Irrigation sleeves / bore / filtration plant, Dust Management, Bulk earthworks, Rock breaking, Repair of theft and vandalism, Walls by Civil Contractor / lot retaining / fencing, Hydraulic and, Electrical Connections, Signage, Public Art, Bollards, Maintenance, Colour rendered area on master plan east of Cambridge Reserve site, Services upgrades beyond site boundary, Drainage / civil infrastructure, Road pavement upgrades / car bays

Notes: Quantities are estimates only
Rates are based on latest tender prices
All figures exclude GST
POS Estimate only



Appendix B – Community Engagement Technical Note

CAMBRIDGE RESERVE - TECNICAL NOTE

city of kalamunda URBIS

Community views of the existing Cambridge reserve:

TOP TEN LIKES

1. Bushland / Natural Feel
2. Walking / Trails
3. Nothing
4. Waterbody / Lake
5. Quietness
6. Proximity to Home
7. Size
8. Dog Walking
9. Family Orientated
10. Playground

MOST WANTED IMPROVEMENTS

1. Seating
2. Play Equipment
3. Shade / Shelter
4. BBQs
5. Toilets

BENCHES / SEATING

Is the quantity acceptable? 4.3% agree 80.9% disagree

Is the quality acceptable? 4.3% agree 73.9% disagree

PLAY EQUIPMENT

Is the quantity acceptable? 13.0% agree 69.6% disagree

Is the quality acceptable? 17.4% agree 52.2% disagree

IS CAMBRIDGE RESERVE IS A HIGH QUALITY OPEN SPACE THAT EVERYONE CAN ENJOY?

17.4% agree

73.9% disagree

Source: City of Kalamunda

DESIGN RATIONALE AND PHILOSOPHY

The decision to provide housing on open space is not one that is taken lightly, but one that in this case is justified given the current limited functional use of the site and the demand for aged housing in the vicinity. The following technical note outlines the approach undertaken in the design of the site in response to community feedback and provides a rationale behind the design decisions made.

Aged Accommodation Demand – The City of Kalamunda commissioned Macro Plan Dimasi to prepare an Aged Accommodation Strategy Report 2016 that identified a demand for Affordable Housing in the City. This report identified a growing demographic in the 65-84 age bracket and recommended the use of government sites as an opportunity to encourage retirement living and aged care developments in the local area. This has been a core focus of this plan on how to provide for this demographic.

In response a plan showing a 1.5ha aged care site and an alternate version showing a 1 ha site have been prepared locating the aged care in the centre of the site to specifically to address the aged demographic.

This site is generally flat and largely cleared and offers good view lines across the basin area offering both surveillance and amenity. The site is separated from the adjacent retained bushland by a managed parkland strip and is a short walk to the activity hub/ playground.

Additional Housing – Additional housing sites have been identified along a new street connecting Cambridge Road to Mallow Way. These housing sites provide additional surveillance opportunities of the retained bushland and aim to minimise antisocial behaviours that were occurring as a result of the open space backing onto rear fences. The associated road network has been designed to double as a firebreak from the retained bushland and ties in with the existing neighbourhood.

A strip of development has been located to separate the aged care from the new drainage basin and swale. Housing here will be provided an outlook over this feature and further towards retained bushland.



Image: Cambridge Reserve



Retained Bushland – A site assessment identified two areas along the eastern edge of the site with retained local bushland of a very good or better quality and a third strip of vegetation along York Street with similar qualities. The remainder of the site consisted of cleared land or degraded bushland containing non-native and invasive species. Based on this information, the retention of the quality bushland formed the focus of the design approach. Minimising impacts to this bushland through clear demarcation and the establishment of a fire buffer began to inform the remainder of the design parameters. Much of this fire buffer has been put in place through the careful placement of streets serving as access and separation. Managed parkland areas with an extensive pathway network make up the remainder of the buffer area providing additional separation between existing housing and the retained bushland. The network of pathways also intersects the bushland area offering a balance of access and preservation and opportunity for connection to the wider community.

Detention Basin - The reserve also serves as a detention basin during large storm events. Water is brought to the site from the hills and collects in a basin located along the western edge. This feature is often wet during winter months but dry during the summer period. The basin is currently undersized and is in need of expansion to accommodate new urban land to the north.

The design approach to this feature preserves the capacity of the basin but relocates the main basin to the west. This enables the retention of significant vegetation on site whilst freeing up land to accommodate the aged care. As part of this relocation of the basin, a small retention area has been identified to replicate a wetland feature mid point along the swale. This wetland features a boardwalk and weir that overflows to the larger basin providing an indication of function of the basin year round. Seating and shaded areas have been located around this feature in line with community feedback offering places of quiet respite or opportunities for viewing wildlife. This has been located adjacent to the aged care group housing site to provide surveillance and amenity for the future aged population.

The existing drainage channels directing water to the site will be formalised minimising erosion issues and offering the opportunity to introduce a living stream element to assist in water filtration. The stream can be located to provide a natural border to the retained bushland area and serve as a feature for the site.

Activity Hub/ Playground – Linked to the development of the site is an opportunity to relocate and upgrade the existing playground and parkland to provide a feature that has more accessibility and function for the surrounding residents. Informed by the community workshop this hub can feature an upgraded playground, including a basketball half court, a barbeque area and associated seating and shelters set amongst native planting. This site has good surveillance from the existing neighbourhood and from the proposed new housing sites and aged care site.

Interactive Trail – An interactive trail has been shown linking a series of nodes around the site. These follow and formalise the existing informal pathway across the site. Each node provides an opportunity for an interactive or engaging stop that could feature interactive art or signage, nature play, fitness equipment, skate or scooter installations and sensory interventions. A secondary informal trail weaves around the retained bushland offering a natural experience in contrast to the active walktrail.

Open Managed Parkland and Managed Bushland – The remainder of the site will operate as open managed parkland or managed bushland providing a buffer to the retained bushland and offering a more formal environment in which to recreate and enjoy Cambridge Reserve. Pathway networks are located across the site to link to existing access ways and ensure this resource is accessible to the surrounding community. Benches and seating is located at key sites along these pathways to provide respite opportunities.

Appendix C – Draft Concept Plan Option 1









LEGEND:

1. 600SQM PICNIC SHELTER AND PLAYGROUND
2. STORMWATER BASIN / SWALE
3. FENCED THREATENED ECOLOGICAL COMMUNITY (TEC)
4. SHADE STRUCTURE & SEATING NODE
5. BUSH RE-VEGETATION
6. BOARD-WALK
7. INTERACTIVE CYCLE AND PEDESTRIAN PATH NETWORK
8. 3M LIMESTONE MAINTENANCE TRACK'
9. EXISTING PAW
10. EXISTING LOTS
11. PARALLEL VERGE PARKING
12. RELOCATED BUS STOP
13. PROPOSED FROG/ DUCK POND
14. (TEC) ZONE
15. FIRE HAZARD REDUCTION ZONE
16. BRICK ROAD TREATMENT - SLOW SPEED AREA

BENCH SEATING

INTERACTIVE WALKING AND CYCLE TRAIL STOP POINTS - INTERPRETATION/ EDUCATION/ WAYFINDING/ ART/ EXERCISE/ SENSORY EXPERIENCE

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DATE: 04.05.2020
JOB NO: P0011135
DWG NO: AR-CD02
REV: F

Appendix D – Draft Concept Plan Option 2









LEGEND:

1. 600SQM PICNIC SHELTER AND PLAYGROUND
2. STORMWATER BASIN / SWALE
3. FENCED THREATENED ECOLOGICAL COMMUNITY (TEC)
4. SHADE STRUCTURE & SEATING NODE
5. BUSH RE-VEGETATION
6. BOARD-WALK
7. INTERACTIVE CYCLE AND PEDESTRIAN PATH NETWORK
8. 3M LIMESTONE MAINTENANCE TRACK'
9. EXISTING PAW
10. EXISTING LOTS
11. PARALLEL VERGE PARKING
12. RELOCATED BUS STOP
13. PROPOSED FROG/ DUCK POND
14. (TEC) ZONE
15. FIRE HAZARD REDUCTION ZONE
16. BRICK ROAD TREATMENT - SLOW SPEED AREA

BENCH SEATING

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CAMBRIDGE RESERVE
LANDSCAPE CONCEPT PLAN - OPTION 2

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Cadastral boundaries, areas and dimensions are approximate only.
Figured dimensions shall to preference to scaled dimensions.
No relevance should be placed on this plan for any financial detailing of the land.

1:1000 @ A1

DATE: 04.05.2020
JOB NO: P0011135
DWG NO: AR-CD06
REV: B

Appendix E – Local Planning Scheme Amendment Current Zones and Reserve Map



N

Cambridge Reserve - Existing Local Planning Zones & Reserves, Local Planning Scheme No. 3

<FNT style="Bold">Project Name: GIS_202000_014_STP</FNT> [Existing Zones & Reserves] Created by: GIS Support Officer Date Saved: 02-Jun-20 4:27 PM

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1:2,500 (at A3)

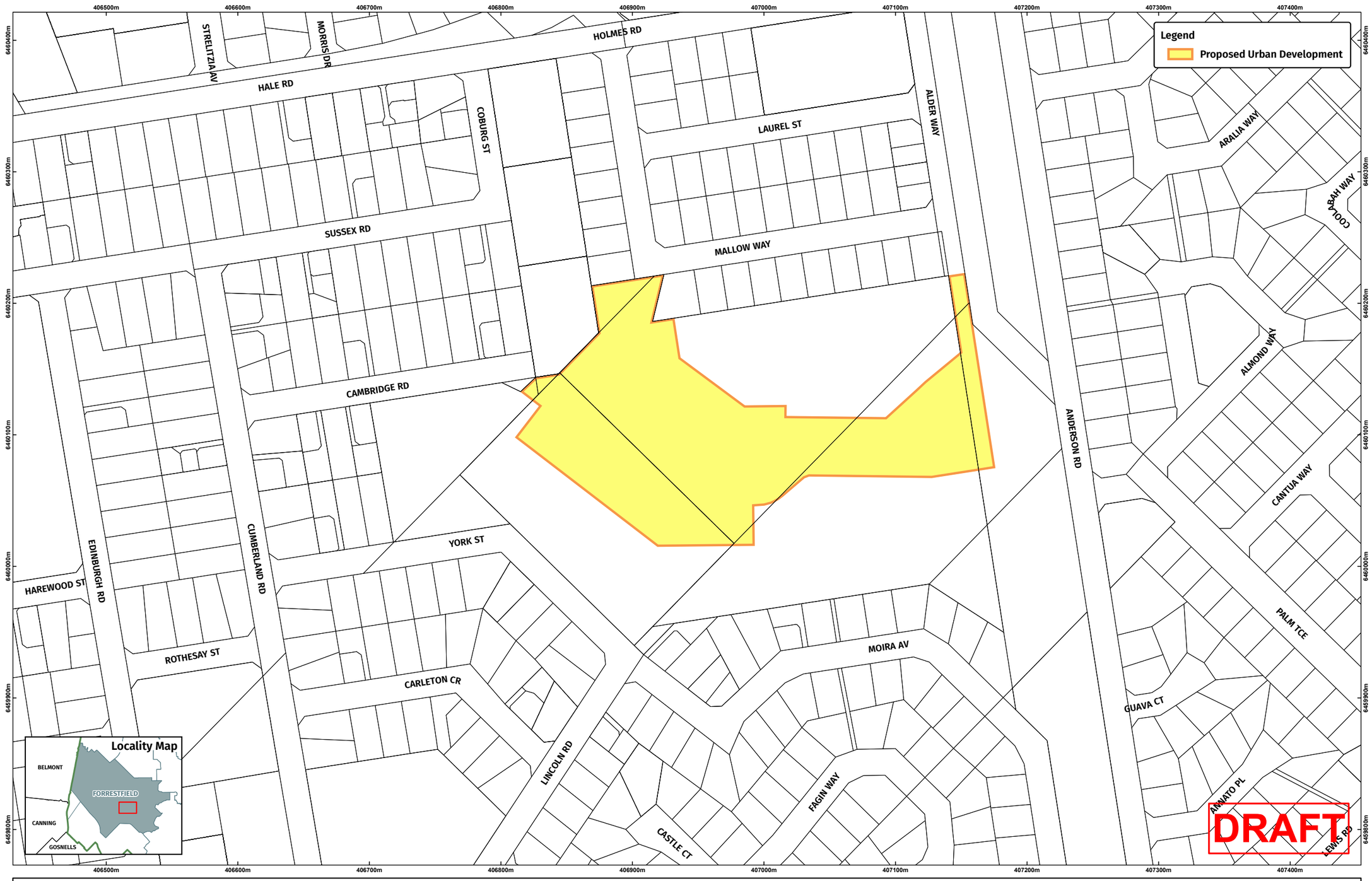
0 25 50 100 150

Metres

Horizontal Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia, Zone 50 (MGA)

City of Kalamunda

Appendix F – Local Planning Scheme Amendment Proposed Zoning Map



Cambridge Reserve - Proposed Urban Development Zone, Local Planning Scheme No. 3

Project Name: GIS_202000_014_STP [Proposed Zone] Created by: GIS Support Officer Date Saved: 02-Jun-20 4:30 PM

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N

1:2,500 (at A3)

0 25 50 100 150

Metres

Horizontal Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia, Zone 50 (MGA)

City of Kalamunda

Appendix G – Flora Survey PGV Environmental 2019

CAMBRIDGE RESERVE, KALAMUNDA

FLORA AND VEGETATION ASSESSMENT

Prepared for:	City of Kalamunda
Report Date:	16 December 2019
Version:	2
Report No.	2019-471



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Appendix 3: Floristic Community Type Analysis of Quadrats (Aecom)

1 INTRODUCTION

1.1 Background

Cambridge Reserve (the site) is an area of local open space located in Forrestfield in the City of Kalamunda, approximately 15km south-east of the Perth Central Business District (Figure 1). The Reserve currently consists of some native vegetation, planted trees, grassed areas, play equipment a large drainage basin and an informal walk trail. The Reserve is used for passive recreational uses by the local Forrestfield residents.

The City of Kalamunda Council resolved in February 2019 to adopt a Concept Plan for the Reserve which would see the open space facilities improved and an area partially developed for residential purposes, including an Aged Care and over 55s Retirement Village.

The proposed development that has been reviewed by the Department of Planning, Lands and Heritage (DPLH) and the Department of Biodiversity, Conservation and Attractions (DBCA). DBCA have informed the City of Kalamunda that the site contains vegetation that is likely to have some conservation significance in the area proposed to be developed for the residential component and that other areas may also contain significant flora and vegetation values.

Two flora and vegetation surveys of the site have previously been conducted for the City of Kalamunda (Plantecology, 2012; EcoLogical, 2017). DBCA considered that further analysis of the flora and vegetation values of the site was required in order to fully assess the environmental impact of the proposed development.

The City of Kalamunda commissioned PGV Environmental to identify the gaps in the previous flora and vegetation surveys of the reserve and to complete further studies to address the gaps.

1.2 Gap Analysis

PGV Environmental reviewed both the Plantecology and EcoLogical reports and liaised with DBCA to determine the gaps in information regarding the flora and vegetation values on the site. Both surveys mapped the vegetation types on the site and undertook computer analysis of vegetation data to determine Floristic Community Types (FCTs) and any Threatened Ecological Communities (TECs) arising from their analyses.

The computer analysis of quadrat data to assign FCTs to the vegetation on the site produced very different results in both reports. Plantecology considered that three of their vegetation types belonged to FCT 3c, which is a TEC at State and Commonwealth level. Plantecology recognised, however, that the association with FCT 3c was not close. The EcoLogical computer analysis showed very low similarity of any of their sample quadrats with any known FCTs. On that basis, EcoLogical concluded that none of the vegetation communities on the site were considered to represent TECs or PECs.

In reviewing the reports, PGV Environmental undertook a preliminary site investigation to assess the vegetation types and condition on the site in 2019. PGV Environmental concluded that the vegetation

mapping of Plantecology was more accurate than that of EcoLogical. Liaison with DBCA confirmed that DBCA's on-ground observations also supported the mapping in the Plantecology report. DBCA also partly supported the FCT analysis of Plantecology but thought further work was needed to assess the vegetation in areas not tested in the Plantecology report.

The following information provides background to the gap analysis and subsequent scope of works for this report:

- The Plantecology report described and mapped 7 vegetation zones on the site (Appendix 1). These zones have been used in this additional work.
- Plantecology considered vegetation in Zones 3, 5 and 7 to be FCT 3c which is a TEC.
- DBCA agreed that the vegetation in Zone 5 (at the northern end of the site) was likely to be FCT 3c and expanded the area marginally into a section of Zone 4 as well as a portion of Zone 1.
- DBCA also thought the vegetation in Zones 3 and 7 were likely to be a TEC but did not do any ground-truthing. DBCA thought the vegetation in Zone 7 might be more aligned to FCT 20a rather than 3c.
- DBCA indicated the vegetation in Zones 6 and 8 might align with a TEC (probably 3c). Plantecology did not do any analysis of their two quadrats sampled in Zones 6 and 8 presumably because the vegetation was in Completely Degraded condition.
- No Threatened flora species were recorded on the site in either the Plantecology or EcoLogical surveys. DBCA considered there was a reasonable possibility that the Threatened species *Conospermum undulatum* (Wavy-leaved Smokebush) could occur on the site.

1.3 Scope of Works

The Scope of Works as determined through the gap analysis and discussions with DBCA as follows:

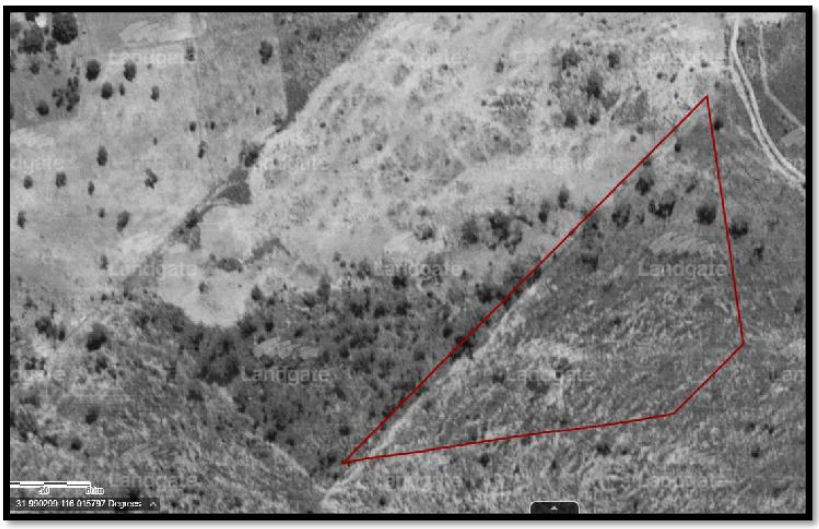
- Undertake a targeted survey for the Threatened species *Conospermum undulatum* (Wavy-leaved Smokebush);
- Provide an updated map of the vegetation condition over the site. This will focus survey efforts into areas containing the best quality vegetation that have a likelihood of being TECs;
- Sample two additional quadrats in Zone 7 to determine whether the vegetation in Zone 7 is FCT 3c or 20a (or another type) and to what extent;
- Sample a quadrat in a part of Zone 1 that DBCA considered as potentially being FCT 3c;
- Sample quadrats in Zone 5 and Zone 3 to provide additional information to the Plantecology quadrat data for these Zones and to assist in determining what FCT occurs in these areas and to what extent; and
- Analyse the quadrat data by computer to determine any affinities with potential TECs.

2 EXISTING ENVIRONMENT

2.1 Land Use

Earliest available aerial photography for the site shows that the northern and western parts of the site have been cleared, and native vegetation remains on the southern boundary. The south-eastern corner appears to be vegetated but potentially not in its natural state (Plate 1).

Plate 1: Aerial Photography from 1953 (Landgate, 2019)



The 1977 aerial photograph shows the central part of the site was completely cleared to construct a drainage basin (Plate 2). Native vegetation appears to remain in the south-eastern area and a strip around the southern boundary. Some re-growth of vegetation in the northern part is apparent.

Plate 2: Aerial Photography from 1977 (Landgate, 2019)



The 1983 aerial photograph shows planted vegetation on a part of the area previously cleared for the drainage basin. The south-eastern area remains vegetated although in variable condition (Plate 3).

Plate 3: Aerial Photography from 1983 (Landgate, 2019)



The 2019 aerial photo shows the current condition of the site. Vegetation, both the remnant and planted areas have regrown substantially since the 1983 photograph (Plate 4).

Plate 4: Aerial Photography from 2019 (Landgate, 2019)



2.2 Topography

The site is relatively flat apart from the large drainage basin. There is a gentle slope down from the east at approximately 50m Australian Height Datum (AHD) to 42mAHD at the western end (Figure 2).

2.3 Geology and Soils

The site is located on the eastern side of the Swan Coastal Plain. The site is mostly located on the Forrestfield System which is described as the laterised undulating foot slopes of the Darling and Whicher Scarps (Shire of Kalamunda, 2010). The soils are described as duplex sandy gravels, pale deep sands and grey deep sandy duplexes (DPIRD, 2019).

2.4 Hydrology

Groundwater under the site is at approximately 17mAHD (DWER, 2019), which is between 25m and 33m below ground level. There are no natural surface water features on the site but there is a large drainage basin located in the western part of the reserve. An open drain as well as piped drainage feeds stormwater into the basin.

3 METHODOLOGY

3.1 Targeted *Conospermum undulatum* Survey

A targeted survey for *Conospermum undulatum* (Wavy-leafed Smokebush) was undertaken by Dr Paul van der Moezel on 1 October 2019. *Conospermum undulatum* is easily recognisable at any time of the year by the wavy leaf and is even more recognisable when it is in flower from May to October.

The site was thoroughly traversed with a high site coverage due to the small areas of native vegetation and ease of access through the relatively open understorey.

3.2 Vegetation Condition

The condition of the vegetation was assessed according to the system of Keighery as described in Bush Forever (Government of Western Australia, 2000) (Table 1).

Table 1: Vegetation Condition Rating Scale

Condition	Description
Pristine	Pristine or nearly so, no obvious signs of disturbance.
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
Very Good	Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbance. Retains basic vegetation structure or ability to regenerate to it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

Source: Government of Western Australia, 2000

3.3 Quadrat Survey

Five additional quadrats were sampled as described in the Scope of Works in Zones 1, 3, 5 and 7.

The quadrats were assessed by Dr Paul van der Moezel of PGV Environmental on 1 October 2019.

The species composition, height and cover abundance were recorded in five 10m x 10m permanently marked quadrats.

Most plant species were identified in the field. Some specimens were photographed or taken for identification at the Perth Reference Herbarium or office using standard reference guides.

The co-ordinates of the five quadrats were:

- CR A 50 407070 E 6460160 N
- CR B 50 407080 E 6460023 N
- CR C 50 407160 E 6460005 N
- CR D 50 406944 E 6459998 N
- CR E 50 406801 E 6460116 N

3.4 FCT Analysis

The quadrat data were analysed using the multi-variate computer programme PRIMER by AECOM (Appendix 3). The analysis used the original Gibson *et al.* (1994) dataset of 508 10m x 10m quadrats as well as the Supplementary dataset of Keighery *et al.* (2012) which, together include 590 quadrats.

3.5 Survey Conditions

The conditions that the survey was undertaken in are presented in Table 2 in order to assess the adequacy of the survey. In summary, there were no constraints to the survey.

Table 2: Statement of Botanical Survey Conditions

Issue	Constraints (Y/N)*	Comment
Competency/experience of the consultant conducting the survey	No	Dr Paul van der Moezel has extensive botanical survey experience on the Swan Coastal Plain in the Perth Region.
Proportion of the flora identified^	No	The timing of the survey in early October was optimal to record most of the native species.
Sources of information (historic/recent or new data)	No	The flora in the Perth Region is well documented.
Proportion of the task achieved and further work that may need to be undertaken	No	No follow-up survey required as no Threatened Flora expected to occur in other seasons.
Timing/weather/season/cycle	No	The spring survey was optimal for most flora species. 2019 was a good year for ephemeral species.
Disturbances (Fire)	No	The fire age of the vegetation was greater than 5 years.
Intensity of survey (e.g. In retrospect was the intensity adequate)	No	The small site and ease of access made for a full coverage.
Completeness (e.g. was relevant area fully surveyed)	No	
Resources (e.g. degree of expertise available for plant identification)	No	Experienced botanist undertook most plant identifications on site.
Remoteness and/or access problems	No	Easily accessible site in the Perth Metropolitan Region.

Issue	Constraints (Y/N)*	Comment
Availability of contextual (e.g. bioregional) information for the study area.	No	Bush Forever, Gibson *et al*. (1994) Floristic Community Types

*Constraints have been rated as Significant, Moderate or No constraints

^Fungi and nonvascular flora (e.g. algae, mosses and liverworts) were not specifically surveyed for during the survey.

4 RESULTS

4.1 Targeted *Conospermum undulatum* Survey

The targeted survey for *Conospermum undulatum* did not record any occurrences of the species on the site. The easily recognisable nature of *C. undulatum* gives a very high confidence in the result.

4.2 Vegetation Condition

The results of the vegetation condition assessment are shown on Figure 3.

The vegetation condition map is similar to the Plantecology condition map with some changes.

Two areas were rated in Excellent condition on the site. These corresponded generally with vegetation Zones 5 and 7. Some parts of Zone 7 that Plantecology assessed as Very Good-Excellent were rated in this assessment as Degraded. Plate 5 shows an example of an area at the north-east end of Zone 7 that is predominantly planted seedlings and some regrowth and an abundance of weeds that PGV Environmental considers is more appropriately rated as Degraded.

Plate 5: Area rated as Degraded by PGV Environmental but Very Good-Excellent by Plantecology.



The southern portion of vegetation Zone 3 was rated as Very Good, with the balance Completely Degraded due predominantly to the absence of a native understorey.

The eastern end of Zone 5 was rated as Very Good, compared to the rest of Zone 5 which was Excellent, due to the abundance of Veldtgrass in this eastern area.

The remainder of the site was rated as Degraded where some native trees or shrubs occur among weeds or cleared areas, or Completely Degraded.

4.3 Quadrat Data

A summary of the quadrat data is provided in Table 3. Full quadrat data are provided in Appendix 3.

Quadrats CR A and CR B were located in Excellent condition vegetation. The high number of native species and low number of introduced species reflects the Excellent condition.

The second quadrat sampled in Zone 7 (CR C) was located in an area that was rated as Degraded. The quadrat had a much lower native species richness. The location of the quadrat in this part of the site was deliberate as this part of Zone 7 had potential to be mapped as a TEC.

Quadrat CR D was positioned in a part of Zone 3 that was some distance from the Plantecology quadrat in the same zone and was assessed to determine whether the vegetation type and FCT was similar to that in the Plantecology report. The vegetation in this section of Zone 3, however, was found to be Completely Degraded. The very low species richness reflects the poor condition of the vegetation.

Quadrat CR E was located in a part of the site that DBCA considered may have been a TEC. The area assessed was a fenced-off revegetation area that was planted by the City of Kalamunda as part of an offset for the development of Lot 97 Adelaide Street, Hazelmere. The quadrat and other parts of the revegetation area contained few native species and many weeds and overall was in a Degraded condition. The vegetation in the revegetation area was considered too degraded to be representative of any FCT. Weeding of the area and further planting with appropriate native species could result in the offset planting having similar characteristics to the TEC in Zone 5.

Table 3: Summary of Quadrat Data

Quadrat	Zone	Vegetation	Condition	Native spp	Introduced spp.	Total spp
CR A	5	*Hakea trifurcata/ Leptospermum erubescens* Open Heath over *Mesomelaena tetragona* Low Shrubland	Excellent	34	5	39
CR B	7	*Eucalyptus marginata* Low Open Woodland over *Hakea trifurcata/ Lambertia multiflora/ Xanthorrhoea brunonis/ Allocasuarina humilis* Closed Heath	Excellent	42	5	47
CR C	7	*Allocasuarina fraseriana/ Eucalyptus marginata* Low Woodland over *Lambertia multiflora/Xanthorrhoea preissii/ Allocasuarina humilis* Low Shrubland	Degraded	16	11	27
CR D	3	*Eucalyptus marginata/ Angophora costata* Low Woodland over weeds	Completely Degraded	1	6	7
CR E	1	*Corymbia calophylla* Low Woodland over *Hakea trifurcata/Hakea undulata/ Acacia saligna* Open Shrubland	Degraded	6	9	15

4.4 Computer Analysis

The analysis of quadrat data to determine FCTs relies on very good quality floristic information to come up with meaningful results. Analysis of quadrats that have a paucity of native species and an abundance of weed species is likely to result in anomalous results or the quadrat being one of the weed-dominated FCTs such as FCT 6 "Weed dominated wetlands on heavy soils".

PGV Environmental considered the computer analysis of quadrats CR C, CR D and CR E which had vegetation in Degraded to Completely Degraded condition would not result in a useful assessment of FCTs and potential TEC on the site.

Therefore, only the two quadrats in Excellent condition, CR A and CR B, were analysed. The results of the computer analysis are provided in Appendix 2.

The results of the computer analysis are summarised below:

- **Quadrat CR A (Zone 5)** - *Hakea trifurcata/Leptospermum erubescens* Open Heath over *Mesomelaena tetragona* Low Shrubland

The highest similarity was to FCT 3b '*Corymbia calophylla – Eucalyptus marginata* woodlands on sandy-clay soils'. Other associations included FCT 20b, 3a and 3c. Both FCT 3b and FCT 3c '*Corymbia calophylla-Xanthorrhoea preissi* woodlands and shrublands' were considered suitable candidates.

- **Quadrat CR B (Zone 7)** - *Eucalyptus marginata* Low Open Woodland over *Hakea trifurcata/Lambertia multiflora/Xanthorrhoea brunonis/Allocasuarina humilis* Closed Heath

The highest similarity was to FCT 20a '*Banksia attenuata* woodlands over species rich dense shrublands'. Aecom commented that the result of CR B having the highest similarity to FCT 20a was problematic as no *Banksia attenuata* was present in the quadrat, or in the general area. This is not an unusual result for FCT 20a. The computer analysis of FCTs is based on the composition of the whole quadrat with each individual species having equal weight. The absence of one species, even one as obvious as a Banksia tree, does not necessarily change the analysis. The Banksia trees may be absent for a number of reasons (eg. dieback, clearing, fire) or may not have ever been on the site. When FCTs were described 25 years ago in Gibson *et al.* (1994) they were given a name based on the composition of most of the quadrats assessed as that FCT. For FCT 20a, *Banksia attenuata* was present in most of the Gibson *et al.* (1994) quadrats and was therefore included in the title of the FCT. However, *B. attenuata* is not an essential species if all the other species in the quadrat are characteristic of 20a.

4.5 Threatened Ecological Communities

Based on the computer analysis of quadrat data in both the Plantecology report and this report PGV Environmental concludes that all areas of vegetation in Very Good or Excellent condition on the site are representative of one or more of the following TECs:

- FCT 3b – '*Corymbia calophylla – Eucalyptus marginata* woodlands on sandy-clay soils'
- FCT 3c – '*Corymbia calophylla-Xanthorrhoea preissi* woodlands and shrublands'
- FCT 20a – '*Banksia attenuata* woodlands over species rich dense shrublands'

The rationale for the assessment is as follows:

- Zone 5 – Plantecology determined FCT 3c occurred on the site based on the analysis of their quadrat number 5. The additional quadrat sampled at the eastern end of Zone 5 by PGV Environmental resulted in the vegetation being FCT 3b but with similarities to FCT 3c as well. On this basis, the vegetation in Zone 5 is mapped in this report as FCT 3b/c. Both FCT 3b and 3c are TECs.
- Zone 7 – The Plantecology results for the quadrat in Zone 7 resulted in FCT 6 which is a weed-dominated FCT on heavy soils. Plantecology concluded this result to be an error and considered the vegetation in Zone 7 was similar to Zone 5 and wass therefore more likely to be FCT 3c. The analysis of the PGV Environmental quadrat in Zone 7 resulted in a very good match for FCT 20a. FCT 20a is therefore considered to represent all the vegetation in Zone 7 that is in Excellent condition.
- Zone 3 –Plantecology concluded that the vegetation in Zone 3 was FCT 3c, based on their quadrat in the western half of the Zone. The quadrat sampled by PGV Environmental in the eastern half was too degraded to be analysed for a FCT. PGV Environmental accepts the assessment that the vegetation in Zone 3 is likely to be FCT 3c which is a TEC.

Based on the results above, the areas of TEC mapped on the site are shown in Figure 5.

5 SUMMARY AND CONCLUSIONS

The 2019 Flora and Vegetation assessment of Cambridge Reserve resulted in the following findings:

- No Threatened species, including *Conospermum undulatum* (Wavy-leaved Smokebush), occur on the site;
- An updated map of the vegetation condition of the site resulted in two areas being assessed as Excellent at the north-eastern and south-eastern parts of the site. An area of Very Good condition vegetation occurred along the southern boundary and patches of Good vegetation occurred near the eastern boundary. The vegetation in the balance of the site was Degraded to Completely Degraded;
- Analysis of quadrat data additional to those assessed in the 2012 Plantecology report, confirmed the presence of a Threatened Ecological Community (FCT 3b and/or 3c) in the Zone 5 vegetation type at the north-eastern end of the site. The Excellent quality vegetation in Zone 7 was determined to be FCT 20a which is a TEC. The extent of the TEC vegetation in Zone 3 (FCT 3c) was reduced to the area in Very Good condition; and
- The vegetation in the revegetation area at the north-west part of Zone 1 was too degraded to be representative of any FCT, and therefore of a TEC. The revegetation area was planted as part of an offset for a development elsewhere in the City of Kalamunda. Weeding of the revegetation area and replanting with suitable species could result in this area having the characteristics of the TEC in Zone 5.

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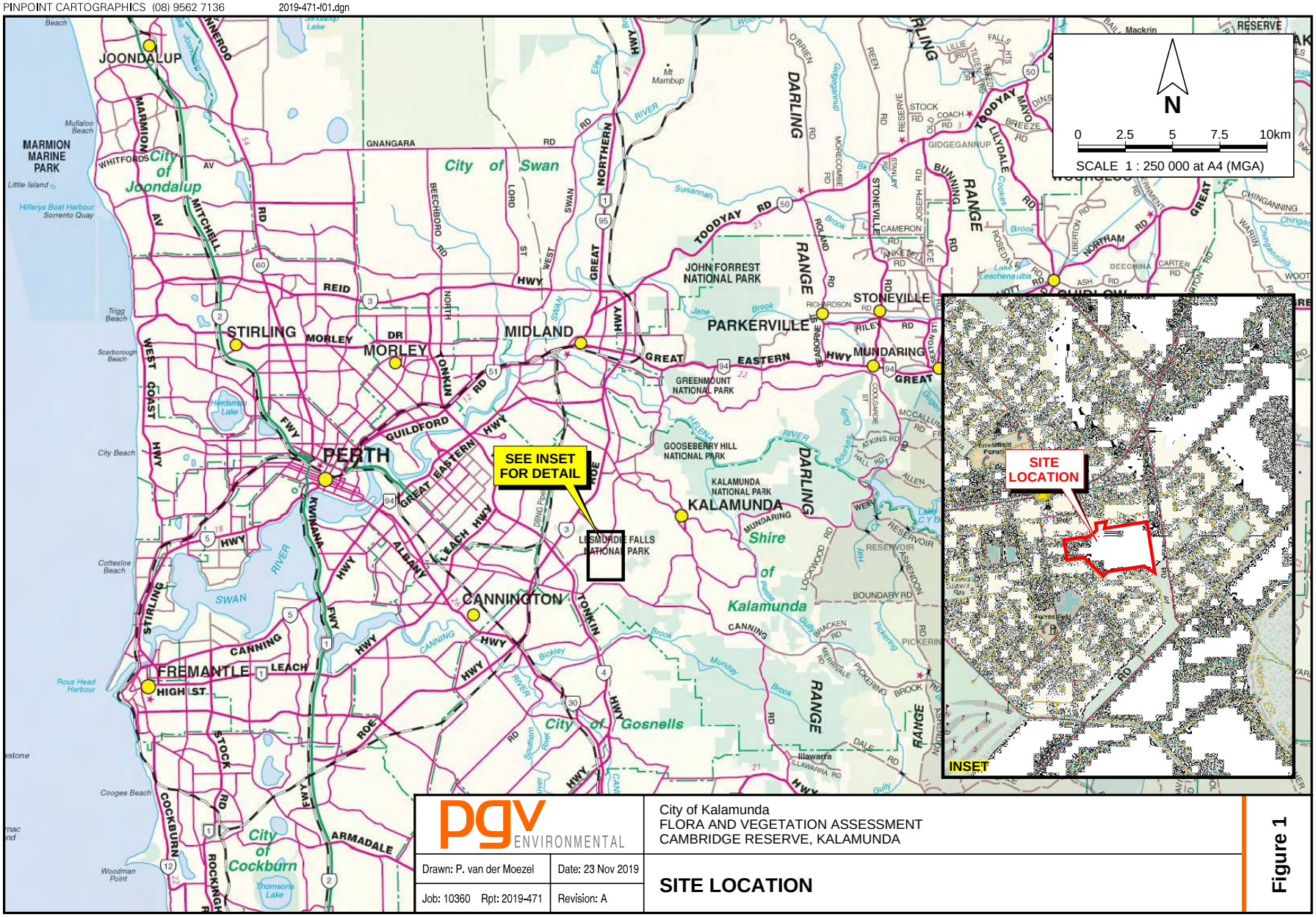
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PINPOINT CARTOGRAPHICS (08) 9562 7136
2019-471-f01.dgn
N
0 2.5 5 7.5 10km
SCALE 1 : 250 000 at A4 (MGA)
SEE INSET FOR DETAIL
SITE LOCATION
INSET
JOONDALUP
MARMION MARINE PARK
City of Joondalup
GNANGARA
City of Swan
STIRLING
MORLEY
MIDLAND
PARKERVILLE
STONEVILLE
MUNDARING
JOHN FORREST NATIONAL PARK
GREENMOUNT NATIONAL PARK
GOOSEBERRY HILL NATIONAL PARK
KALAMUNDA NATIONAL PARK
KALAMUNDA
Shire of Kalamunda
PERTH
CANNINGTON
FREMANTLE
City of Gosnells
City of Cockburn
ARMADALE
SWAN
DARLING RANGE
pgv ENVIRONMENTAL
Drawn: P. van der Moezel
Date: 23 Nov 2019
Job: 10360 Rpt: 2019-471
Revision: A
City of Kalamunda
FLORA AND VEGETATION ASSESSMENT
CAMBRIDGE RESERVE, KALAMUNDA
SITE LOCATION
Figure 1



N

0 10 20 30 40 50m

SCALE 1 : 1 600 at A3 (MGA)

Legend

- Site Boundary
- Cadastral Boundary
- Easement Boundary
- Topographic Contour

CONTOUR SOURCE: Dept. of Agriculture, 2000.
CADASTRAL SOURCE: Landgate, October 2019.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown October 2019.

PINPOINT CARTOGRAPHICS (08) 9562 7136 2019-471-t02.dgn

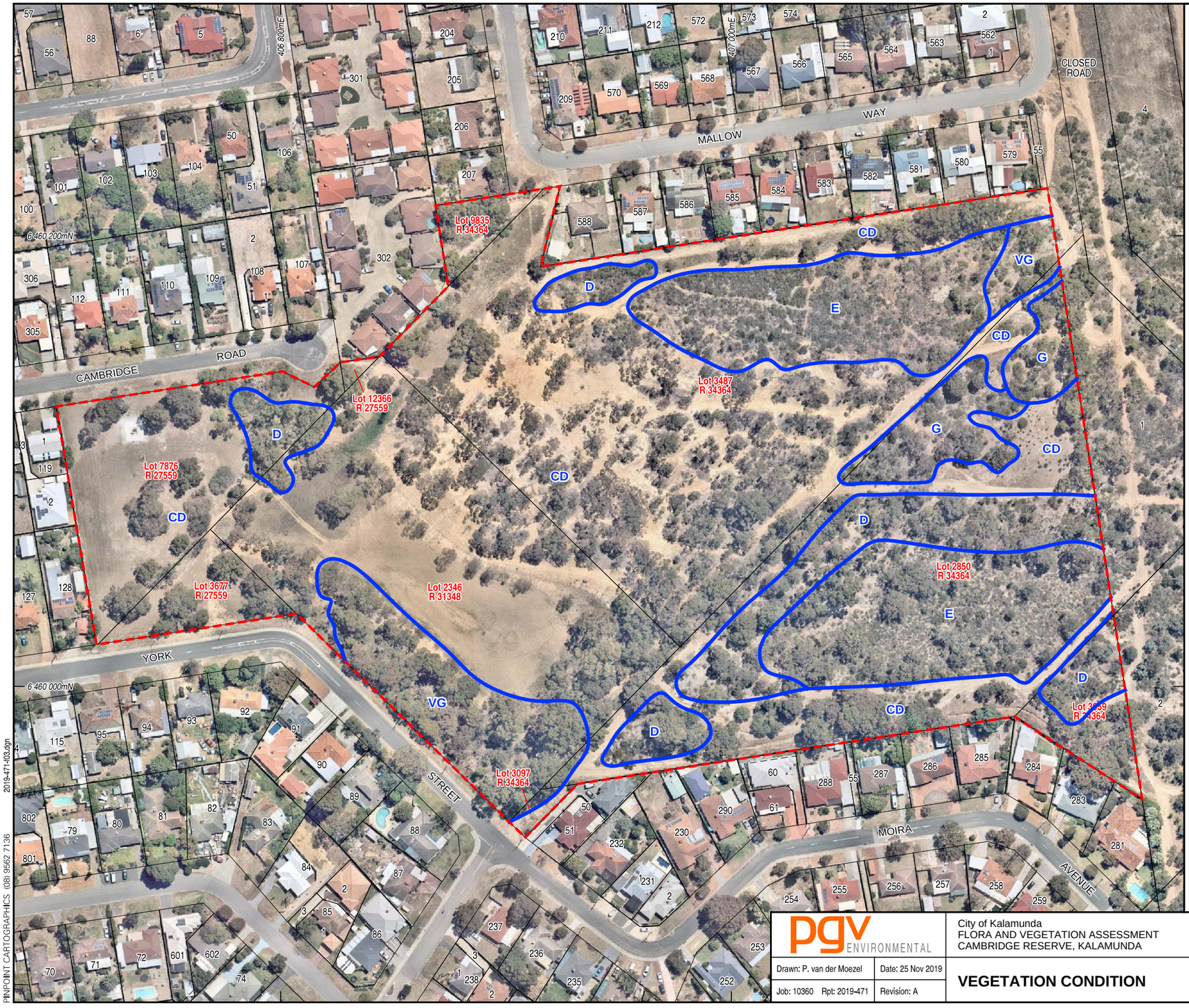
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City of Kalamunda
FLORA AND VEGETATION ASSESSMENT
CAMBRIDGE RESERVE, KALAMUNDA

Drawn: P. van der Moezel | Date: 23 Nov 2019
Job: 10360 Rpt: 2019-471 | Revision: A

SITE BOUNDARY

Figure 2



N

0 10 20 30 40 50m

SCALE 1 : 1 600 at A3 (MGA)

Legend

- Site Boundary
- Cadastral Boundary
- Easement Boundary
- Vegetation Condition Boundary
- VG Vegetation Condition

Vegetation Condition (Keighery, 1994)

P - Pristine
Pristine or nearly so, no obvious signs of disturbance.

E - Excellent
Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.

VG - Very Good
Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing

G - Good
Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.

D - Degraded
Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.

CD - Completely Degraded
The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

CADASTRAL SOURCE: Landgate, October 2019.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown October 2019.

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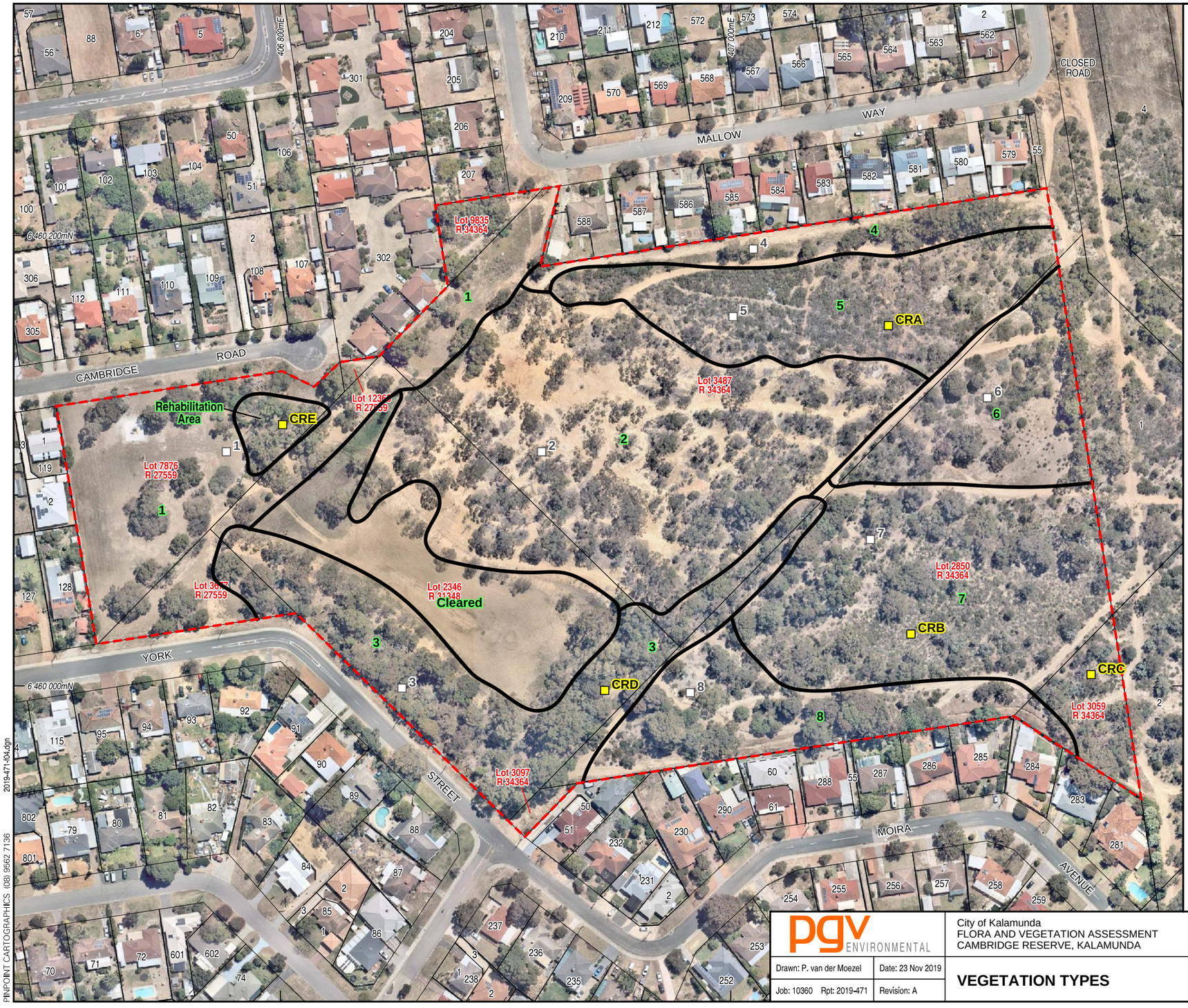
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City of Kalamunda
FLORA AND VEGETATION ASSESSMENT
CAMBRIDGE RESERVE, KALAMUNDA

Drawn: P. van der Moezel | Date: 25 Nov 2019
Job: 10360 Rpt: 2019-471 | Revision: A

VEGETATION CONDITION

Figure 3



N

0 10 20 30 40 50m

SCALE 1 : 1 600 at A3 (MGA)

Legend

- Site Boundary
- Cadastral Boundary
- Easement Boundary
- Quadrat Location - Plantecology
- Quadrat Location - PGV
- Vegetation Type Boundary
- 2 Vegetation Type

Vegetation Types (Plantecology, 2012)

1 - Zone 1
Parkland of *Corymbia calophylla* and ornamental eucalypts over mixed grassland

2 - Zone 2
Open parkland of ornamental eucalypts over very sparse understorey on yellow sands

3 - Zone 3
Open woodland of *Eucalyptus marginata* and *Allocasuarina fraseriana* over open shrubland of *Xanthorrhoea preissii* over sedgeland of *Mesomelaena tetragona*, *Mesomelaena pseudostygia* and *Dasypogon bromeliifolius*

4 - Zone 4
Occasional trees of *Eucalyptus ?rudis* and *Eucalyptus camaldulensis* subsp. *obtusa* over open shrubaln d of *Hakea trifurcata* over grassland of **Ehrharta calycina* and **Pennisetum clandestinum*

5 - Zone 5
Open heath of Hakea trifurcata and Leptospermum erubescens over sedgeland of Mesomelaena tetragona

6 - Zone 6
Open woodland of *Eucalyptus wandoo* subsp. *wandoo* and ornamental eucalypts over open shrubland of *Hakea trifurcata* and *Isopogon dubius* over grassland of **Ehrharta calycina*

7 - Zone 7
Open woodland of *Eucalyptus marginata* and *Allocasuarina fraseriana* over open shrubland of *Xanthorrhoea preissii* over sedgeland of *Mesomelaena tetragona*, *Mesomelaena pseudostygia* and *Dasypogon bromeliifolius*

8 - Zone 8
Open woodland of *Eucalyptus marginata* and *Eucalyptus camaldulensis* subsp. *obtusa*

CADASTRAL SOURCE: Landgate, October 2019.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown October 2019.

2019-471-004.dgn

PINPOINT CARTOGRAPHICS (08) 9562 7136

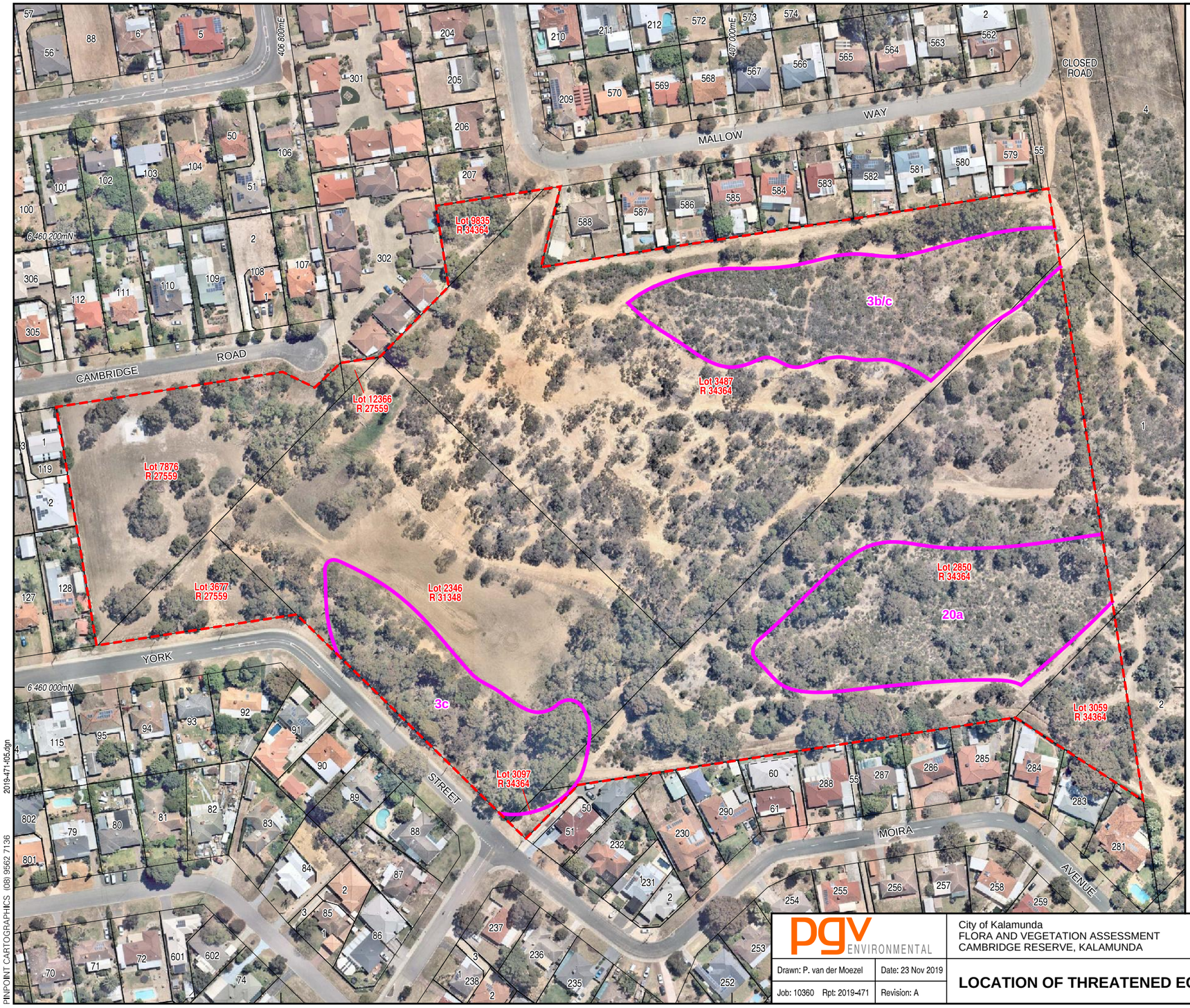
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City of Kalamunda
FLORA AND VEGETATION ASSESSMENT
CAMBRIDGE RESERVE, KALAMUNDA

VEGETATION TYPES

Figure 4



N

0 10 20 30 40 50m

SCALE 1 : 1 600 at A3 (MGA)

Legend

- Site Boundary
- Cadastral Boundary
- Easement Boundary
- Threatened Ecological Community Boundary
- 2 Threatened Ecological Community

CADASTRAL SOURCE: Landgate, October 2019.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown October 2019.

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City of Kalamunda
FLORA AND VEGETATION ASSESSMENT
CAMBRIDGE RESERVE, KALAMUNDA

Drawn: P. van der Moezel | Date: 23 Nov 2019
Job: 10360 Rpt: 2019-471 | Revision: A

LOCATION OF THREATENED ECOLOGICAL COMMUNITIES

Figure 5

APPENDIX 1

Plantecology 2012 Report

York Road Reserve Forrestfield Level 2 Flora and Vegetation Survey



DECEMBER 2012

Plantecology

Plantecology Consulting
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Executive Summary

Plantecology Consulting was commissioned by Strategen to undertake a detailed spring flora and vegetation survey of the York St Reserve, Forrestfield (the site) in the Shire of Kalamunda. The purpose of the survey was to provide a detailed assessment of botanical values within the site, which could then inform the development process regarding future usage. The Reserve is located less than 1 km from areas of remnant vegetation in Hartfield Park and is approximately 8.8 ha in size.

A reconnaissance survey undertaken in May 2012 described eight vegetation zones within the reserve. Five of these zones were described as generally being in a degraded state, having been subject to considerable disturbance in the form of trail bike use and rubbish dumping over an extended period of time. Three zones of remnant vegetation were identified: Zones 3, 5 and 7. Zone 3 is a jarrah woodland in reasonable condition with Zone 7 containing similar vegetation that has less evidence of disturbance. Zone 5 is a heath of *Hakea trifurcata* over sedges.

A detailed survey of the vegetation was undertaken by a botanist from Plantecology Consulting on the 2nd November 2012. Eight sampling points, one in each vegetation type (zone) identified in the May 2012 reconnaissance survey, was used to sample the vegetation.A total of 97 native and 57 introduced (non-native) taxa were recorded within the site, representing 47 families and 115 genera. No Threatened Flora pursuant to the *Wildlife Conservation Act (1950)* nor the *EPBC Act (1999)* were recorded during the survey. Also, no Priority Flora listed by the DEC were recorded during the survey.

The vegetation types within the site largley correspond to the zones identified by Strategen (2012), except for Zones 3 and 7, which are floristically similar and have been combined into the one vegetation type (Figure 2). The seven vegetation types are:

Vegetation Type 1: Parkland of *Corymbia calophylla* and ornamental eucalypts over mixed grassland.

Vegetation Type 2: Open parkland of ornamental eucalypts over very sparse understorey on yellow sands

Vegetation Type 3/7: Open woodland of *Eucalyptus marginata* and *Allocasuarina fraseriana* over open shrubland of *Xanthorrhoea preissii* over sedgeland of *Mesomelaena tetragona, Mesomelaena pseudostygia* and *Dasypogon bromeliifolius*

Vegetation Type 4: Occasional trees of *Eucalyptus ?rudis and Eucalyptus camaldulensis* subsp. *obtusa* over open shrubland of *Hakea trifurcata* over grassland of **Ehrharta calycina* and **Pennisetum clandestinum*

Vegetation Type 5: Open heath of *Hakea trifurcata* and *Leptospermum erubescens* over sedgeland of *Mesomelaena tetragona*

Vegetation Type 6: Open woodland of *Eucalyptus wandoo* subsp. *wandoo* and ornamental eucalypts over open shrubland of *Hakea trifurcata* and *Isopogon dubius* over grassland of **Ehrharta calycina*

Vegetation Type 8: Open woodland of *Eucalyptus marginata* and *Eucalyptus camaldulensis* subsp. *obtusa* over open shrubland of *Xanthorrhoea preissii* over introduced grasses.

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The results of the cluster analysis determined that both Vegetation Type 3/7 and Vegetation Type 5 belong in FCT 3c: *Corymbia calophylla – Xanthorrhoea preissii* woodlands and shrublands. FCT 3c is a TEC, listed as Endangered pursuant to the EPBC Act and as Critically Endangered under DEC criteria. FCT 3c is restricted to the eastern side of the Swan Coastal Plain and has been extensively cleared. According to the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC), approximately 97% of the community's original extent may have been cleared, leaving only about 41 ha extant today. Among the threats to the remaining stands of this community are clearing, invasive species, and changes in hydrology and fire frequency.

In addition to listing as a TEC, the vegetation within the site is part of the Forrestfield Vegetation Complex. Only 9% of this vegetation complex remains (Government of Western Australia 2000) and is therefore considered a Critical Asset by the EPA.

Given the ecological values of the site, it is suggested that:

- Development of the site include plans or policies to improve the vegetation condition of the remnant vegetation within the York St Reserve.

Furthermore, it is recommended that:

- No clearing of Vegetation Types 3/7 and 5 be approved; and
- Any development of the site includes appropriate buffers or barriers to minimise adverse impacts to the native vegetation within the reserve.

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1 Introduction

Plantecology Consulting was commissioned by Strategen to undertake a detailed spring flora and vegetation survey of the York St Reserve, Forrestfield (the site) in the Shire of Kalamunda (Figure 1). A reconnaissance survey of the site had already been undertaken as part of a Constraints and Opportunities study in May 2012 (Strategen 2012) for the Shire of Kalamunda, which was evalusting the development potential of the site. The reconnaissance survey found that most of the site to be disturbed and in poor condition. However, some areas of good quality native vegetation were also present and it was recommended that a more detailed assessment was required to identify the ecological values of the site.

1.1 Purpose

The purpose of the survey was to provide a detailed assessment of botanical values within the site, which could then inform the development process regarding future usage.

The objectives of the survey were to:

- Undertake a detailed spring flora and vegetation survey in accordance with the Environmental Protection Authority's (EPA) Guidance Statement No. 51 – *Terrestrial flora and vegetation survey environmental impact assessment in Western Australia* (2004).
- Undertake a desktop review by examining other local flora and vegetation reports and undertaking an on-line search of government databases;
- Identify the plant associations present and assign them to the Swan Coastal Plain Floristic Community Type classification (Gibson et al., 1994).
- Identify the presence of any Threatened Ecological Communities (TECs) and Priority Ecological Communities (PECs);
- Undertake a systematic search for all vascular flora taxa present; and
- Record the locations and numbers present of any Threatened Flora and Priority Flora.

1.2 Location

York Street Reserve is located in Forrestfield (Figure 1), and is bounded by York Street and Moira Avenue along the southern boundary, a transmission line easement in the east, Mallow Way residences and Cambridge Road in the north, and Cumberland Road residences in the west. The Reserve is located less than 1 km from areas of remnant vegetation in Hartfield Park and is approximately 8.8 ha in size.

1.3 Existing Environment

The reconnaissance survey described eight vegetation zones within the reserve. Five of these zones were described as generally being in a degraded state, having been subject to considerable disturbance in the form of trail bike use and rubbish dumping over an extended period of time. The site has been extensively cleared and used for passive recreation, with many walk trails crossing the reserve. Playground equipment has been installed in the westernmost section of the reserve (Zone 1). Zone 2 is the most extensive zone and has been planted with ornamental eucalypts with little to no understorey. It also contains a large sump. Three zones of remnant vegetation were

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identified: Zones 3, 5 and 7. Zone 3 is a jarrah woodland in reasonable condition with Zone 7 containing similar vegetation that has less evidence of disturbance. Zone 5 is a heath of *Hakea trifurcata* over sedges (Strategen 2012).

1.4 Climate

The Forrestfield area experiences a dry Mediterranean climate of hot dry summers and cool wet winters. Long-term climatic averages indicate the site is located in an area of moderate to high rainfall, receiving 775.3 mm on average annually (data for Perth Airport, the nearest currently reporting station) (Bureau of Meteorology 2012) with the majority of rainfall received between June and August. The area experiences rainfall on an average of 86 days per year. Mean maximum temperatures range from 17.9 °C in July to 31.9 °C in February. Mean minimum temperatures range from 8.0 °C in July and August to 17.5 °C in February.

1.5 Vegetation Complexes

The vegetation of the site forms part of the Forrestfield Vegetation Complex, which ranges from an open forest of *Corymbia. calophylla, Eucalyptus wandoo* and *Eucalyptus marginata* to an open forest of *Eucalyptus marginata, Corymbia calophylla, Allocasuarina fraseriana* and *Banksia* species. A fringing woodland of *Eucalyptus. rudis* may occur in gullies within this landform (Heddle et al. 1980). Only 9% remains of the original pre-European extent of the Forrestfield Vegetation Complex (Government of Western Australia 2000). EPA Position Statement No.9 identifies vegetation complexes with less than 10% of their original extent remaining in constrained areas (such as the Perth Metropolitan Area) on the Swan Coastal Plain, to be critical assets. Any clearing of a critical asset would generally be at variance to clearing principles contained within Schedule 5 of the Environmental Protection Act 1986.

1.6 Soils

The major soil formations within the site is the Forrestfield Soil Formation, which is expressed as gently undulating spurs at the foot of the Darling Scarp and is dominated by gravelly and sandy soils (Churchward and McArthur 1980). The Atlas of Australian Soils maps the soils for the majority of the site as Map Unit Sp2, which are "hard acidic yellow soils (Dy2.61) containing ironstone gravels. Associated are brown sands (Uc4.2) often containing ironstone gravels at depth and forming a western fringe to the bench; and some (Dy3.4) soils on dissected areas" (Natural Resource Information Centre 1991). In the extreme west of the site, a small area of Map Unit Cb38, which comprises "Sandy dunes with intervening sandy and clayey swamp flats: chief soils are leached sands (Uc2.33) and (Uc2.21), sometimes with a clay D horizon below 5 ft, on the dunes and sandy swamps. Associated are various soils in the clayey swamps, such as (Ug6.4) and some (Dy) and (Dg) soils" (Natural Resource Information Centre 1991).

1.7 Conservation Significant Flora

Under the *Wildlife Conservation Act 1950* ('*WC Act*'), the Minister for the Environment produces a gazetted '*Wildlife Conservation (Rare Flora) Notice*' that lists Threatened (or Declared Rare) Flora under two Schedules; extant and presumed extinct. The DEC also produces a list of Priority Flora that have not been assigned statutory protection under the *WC Act* but may be under some degree of threat. The DEC recognises five Priority Flora levels. The definitions for each category of Threatened and Priority Flora are shown in Table 1.

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Table 1: Definitions for categories of Threatened and Priority Flora (Department of Environment and Conservation 2012)

Category	DEC Definition
Schedule 1—Extant Flora **T: Threatened Flora (Declared Rare Flora – Extant)**	Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such (Schedule 1 under the *Wildlife Conservation Act 1950*). Threatened Flora (Schedule 1) are further ranked by the Department according to their level of threat using IUCN Red List criteria: ▪ CR: Critically Endangered – considered to be facing an extremely high risk of extinction in the wild ▪ EN: Endangered – considered to be facing a very high risk of extinction in the wild ▪ VU: Vulnerable – considered to be facing a high risk of extinction in the wild
Schedule 2—Extinct Flora **X: Presumed Extinct Flora (Declared Rare Flora - Extinct)**	Taxa which have been adequately searched for and there is no reasonable doubt that the last individual has died, and have been gazetted as such (Schedule 2 under the *Wildlife Conservation Act 1950*).
P1: Priority One: Poorly Known	Species that are known from one or a few collections or sight records (generally less than five), all on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, Shire, Westrail and Main Roads WA road, gravel and soil reserves, and active mineral leases and under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes.
P2: Priority One: Poorly Known	Species that are known from one or a few collections or sight records, some of which are on lands not under imminent threat of habitat destruction or degradation, e.g. national parks, conservation parks, nature reserves, State forest, vacant Crown land, water reserves, etc. Species may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes.
P3: Priority One: Poorly Known	Species that are known from collections or sight records from several localities not under imminent threat, or from few but widespread localities 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 localities but do not meet adequacy of survey requirements and known threatening processes exist that could affect them.

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Category	DEC Definition
P4: Priority Four: Rare, Near Threatened and other species in need of monitoring	**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. **b.** Near Threatened. Species that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable. **c.** Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.
P5: Priority Five: Conservation Dependent Species	**P5: Priority Five - Conservation Dependent Species**:- Species that are not threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.

As well as protection under State legislation, selected flora species are also afforded statutory protection at a Federal level pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The EPBC Act provides for the protection of Threatened species, pursuant to Schedule 1 of the Act, and are defined as "Critically Endangered", "Endangered", "Vulnerable" or "Conservation Dependent" under Section 179. Definitions of these categories are shown in Table 2. Any action likely to have a significant impact on a species listed under the EPBC Act requires approval from the Commonwealth Minister for Sustainability, Environment, Water, Population and Communities.

Database searches conducted by Strategen (2012) identified 23 taxa with the potential to occur within the site. Of these taxa, eleven were considered more likely to occur within the site due to the proximity of previous records and/or the habitat within the site. *Banksia mimica* and *Conospermum undulatum* have both been recorded from nearby Hartfield Park. *Macarthuria keigheryi* is currently known from six populations of which two are in metropolitan Perth (Welshpool and Kewdale), where it occurs in low-lying winter-wet damp, grey/white sands. *Boronia tenuis, Acacia oncinophylla* subsp. *patulifolia, Haemodorum loratum, Isopogon drummondii, Lasiopetalum bracteatum, Pithocarpa corymbulosa, Senecio leucoglossus* and *Thelymitra stellata* are known to occur in soil types that exist within the site.

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Table 2: Categories of protection for species and communities listed under the EPBC Act.

EPBC Act Category	DSEWPC Definition
Extinct	A native species is eligible to be included in the extinct category at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
Extinct in the wild	A native species is eligible to be included in the extinct in the wild category at a particular time if, at that time: (a) it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
Critically endangered	A native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
Endangered	A native species is eligible to be included in the endangered category at a particular time if, at that time (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
Vulnerable	A native species is eligible to be included in the vulnerable category at a particular time if, at that time: (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.
Conservation dependent	A native species is eligible to be included in the conservation dependent category at a particular time if, at that time: (a) the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered; or (b) the following subparagraphs are satisfied: (i) the species is a species of fish; (ii) the species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long term survival in nature are maximised; (iii) the plan of management is in force under a law of the Commonwealth or of a State or Territory; (iv) cessation of the plan of management would adversely affect the conservation status of the species.

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Table 3: Threatened and Priority Flora potentially occurring within the survey area.

Taxa	DEC Rating	EPBC Act Category
Acacia oncinophylla subsp. *patulifolia*	P3	
Andersonia gracilis	T	Endangered
Banksia mimica	T	Endangered
Boronia tenuis	P4	
Byblis gigantea	P3	
Calytrix breviseta subsp. *breviseta*	T	Endangered
Centrolepis caespitosa	P4	Endangered
Chamelaucium sp. Gingin (N.G.Marchant 6)	T	Endangered
Conospermum undulatum	T	Vulnerable
Darwinia foetida	T	Critically Endangered
Eucalyptus balanites	T	Endangered
Grevillea curviloba subsp. *incurva*	T	Endangered
Haemodorum loratum	P3	
Isopogon drummondii	P3	
Lasiopetalum bracteatum	P4	
Lepidosperma rostratum	T	Endangered
Macarthuria keigheryi	T	Endangered
Ornduffia calthifolia	T	Critically Endangered
Pithocarpa corymbulosa	P3	
Senecio leucoglossus	P4	
Synaphea sp. Fairbridge Farm (D.Papenfus 696)	T	Critically Endangered
Thelymitra magnifica	P1	Endangered
Thelymitra dedmaniarum (formerly *T. manginii* K.Dixon & Batty ms)	T	Endangered
Thelymitra stellata	T	Endangered
Verticordia fimbrilepis subsp. *fimbrilepis*	T	Endangered

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1.8 Conservation Significant Communities

The DEC defines an ecological community as "a naturally occurring assemblage that occurs in a particular type of habitat" (DEC 2012). A Threatened Ecological Community (TEC) is one that has declined in area or was originally limited in distribution. Uncommon ecological communities that do not strictly meet TEC defined criteria, or are inadequately defined, are listed by the DEC as a Priority Ecological Community (PEC). Definitions of the categories of Threatened and Priority Ecological Communities are given in Table 4.

As well as protection under State legislation, selected ecological communities are also afforded statutory protection at a Federal level pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The EPBC Act provides for the protection of TECs, which are listed under section 181 of the Act, and are defined as "Critically Endangered", "Endangered" or "Vulnerable" under Section 182. Similar to flora species listed under the EPBC Act, any action likely to have a significant impact on a TEC listed under the EPBC Act requires Commonwealth approval.

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Table 4: Categories and definitions of Threatened and Priority Ecological Communities (DEC 2012)

Category	DEC definition
PD: Presumed Destroyed	An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be totally destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future.
Critically Endangered	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated.
Endangered	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future.
Vulnerable	An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range.
Priority 1	Ecological communities that are known from very few occurrences with a very restricted distribution (generally ≤5 occurrences or a total area of ≤ 100ha). Occurrences are believed to be under threat either due to limited extent, or being on lands under immediate threat (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) or for which current threats exist.
Priority 2	Communities that are known from few occurrences with a restricted distribution (generally ≤10 occurrences or a total area of ≤200ha). At least some occurrences are not believed to be under immediate threat of destruction or degradation.

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Category	DEC definition
Priority 3	(i) Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation or: (ii) communities known from a few widespread occurrences, which are either large or with significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat, or; (iii) communities made up of large, and/or widespread occurrences, that may or may not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes.
Priority 4	Ecological communities that are adequately known, rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list. These communities require regular monitoring. (i) Rare. Ecological communities known from few occurrences 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 communities are usually represented on conservation lands. (ii) Near Threatened. Ecological communities that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable. (iii) Ecological communities that have been removed from the list of threatened communities during the past five years.
Priority 5	Ecological communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.

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2 Methods

2.1 Field Survey

The field survey was conducted by a botanist from Plantecology Consulting on the 2nd November 2012, using a standard phytosociological approach in accordance with EPA Guidance Statement No. 51.

A detailed survey of the vegetation was undertaken at 8 sampling points, one in each vegetation type (zone) identified in the May 2012 reconnaissance survey. In the stands of remnant native vegetation (i.e. Zones 3, 5 and 7) 400 m^2 relevés (quadrats) were established, selected to adequately sample the flora within a stand. Relevés were positioned to sample a representative and homogeneous (i.e. not located in transitional areas between communities) area of each community.

The location of each corner of a relevé was recorded with a hand-held GPS unit and a photograph taken looking inward to the quadrat. All vascular plant species were recorded and an estimate of the Foliage Projective Cover (FPC) percentage was made for each species. In addition, opportunistic plant taxa that were observed, but not located at a particular survey location, were also recorded throughout the course of the survey.

Environmental data recorded included topographic position, aspect, slope, soil colour and texture class, rock outcropping, litter cover as well as the degree of disturbance and an estimate of the time since the last fire event. The condition of the vegetation of the site was assessed to update the previous surveys and assist in determining the conservation values of the site. The vegetation condition was rated according to Keighery (1994), a vegetation condition scale commonly used in the Metropolitan Region. The categories are listed and defined in Table 5. Data on the vegetation structure was also recorded and included the height of the three main strata and the dominant species within each stratum. The vegetation structural description follows that of the National Vegetation Information System (Thackway *et al.* 2006).

In addition to the relevés, the vegetation of disturbed and parkland-cleared zones was sampled using mapping points (unbound plots) at one site within each zone. At each mapping point, the same environmental and vegetation structure data described previously was recorded and a search made for any Priority or Threatened flora, and a an inventory of the species present taken.

All plant specimens collected during the field survey were dried, pressed and then sorted in accordance with requirements of the Western Australian Herbarium. Identification of specimens occurred through comparison with named material and through the use of taxonomic keys. Taxonomic determinations were made using reference material at the Western Australian State Herbarium. Taxa names utilise the current terminologies from FloraBase (2012). Family names utilise the revised phylogeny of the Angiosperm Phylogeny Group - APGIII (FloraBase 2012).

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Table 5: Vegetation Condition Scale (Keighery 1994)

Vegetation Condition	Definition
Pristine (1)	Pristine or nearly so, no obvious signs of disturbance.
Excellent (2)	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
Very Good	Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

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2.2 Data analysis and Classification

The relevé data for each stand of remnant native vegetation was assigned a FCT using presence/absence species data so that a comparison could be made against the DEC's TEC database. The site data was reconciled with the SCP dataset of Gibson *et al*. (1994) by standardising the names of taxa with those used in the earlier study. This was necessary due to changes in nomenclature in the intervening period. Taxa that were only identified to genus level were excluded while some infra-species that have been identified since 1994 were raised to species level. The combined dataset was then analysed using a Sorenson distance measure (equivalent to the Czekanowski distance measure for presence/absence data used in the original analysis) with Group Average loinkage in the analysis package PC-ORD (McCune and Mefford 2006). The analysis was first run without the addition of the York St reserve data to check for misclassifications against the original output. There were some sites misclassified, but these were considered minor as other methods that were tried produced far more misclassifications. As data from a localised study is often highly spatially correlated compared to the data from a regional study, the York St Reserve data was added to the SCP dataset and analysed for each individual sample site. This removes the influence of spatial correlation when assigning a FCT to the local plant communities.

2.3 Study Limitations and Survey Effort

Various factors can limit the effectiveness of a vegetation survey. Pursuant *to EPA Guidance Statement 51* (EPA 2004), these factors have been identified and their potential impact on the effectiveness of the survey has been assessed (Table 5).

There were no factors identified that were considered as being major impediments the effectiveness of the vegetation survey.

Table 5: Potential limitations affecting the vegetation survey

Potential limitations	Constraint	Comment
Competency and experience of the botanists undertaking the survey	No	The survey was undertaken by botanist with a comprehensive knowledge of Swan Coastal Plain vegetation, with at least 10 years experience in vegetation surveys in Western Australia.
Seasonality	Minor constraint	Rainfall was about average for Septmeber but well below average for October 2012. Rainfall therefore may be considered a minor survey constraint as the dry conditions in October could have affected the flowering of some species.
Adequate ground coverage and intensity of survey effort	No	The survey area was traversed on foot. It is considered the survey quadrats and mapping points provided adequate coverage given the degraded nature of most of the site.
Proportion of Flora identified	No	The small size of the rederve and limited number of quadrats doesn't allow for analysis of the proportion of the flora sampled. However, single visit surveys in southwestern Australia of similar intensity usually sample between 75% and 85% of the estimated total flora.
Burn Cycle	No	There were no signs of recent fires.
Resources	No	Adequate resources were available to conduct the survey.
Access restrictions	No	There were no access restrictions and all requisite areas were visited. All areas were accessible.

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3 Results

3.1 Flora

3.1.1 Floristic Summary

A total of 97 native and 57 introduced (non-native) taxa were recorded within the site, representing 47 families and 115 genera. Introduced taxa included Australian native species that do not naturally occur within the local area but have been planted as ornamentals within the site. The dominant families containing mostly native taxa were Myrtaceae (13 native taxa, 9 introduced taxa), Fabaceae (12 native, 7 introduced taxa) and Proteaceae (12 native, no weed taxa). The most common genus was *Eucalyptus* spp. (10 taxa). For a complete species list and the individual site data refer to Appendix A and Appendix C, respectively.

3.1.2 Threatened and Priority Flora

No Threatened Flora pursuant to the *Wildlife Conservation Act (1950)* nor the *EPBC Act (1999)* were recorded during the survey. Also, no Priority Flora listed by the DEC were recorded during the survey.

3.2 Vegetation

The vegetation types within the site largley correspond to the zones identified by Strategen (2012), except for Zones 3 and 7, which are floristically similar and have been combined into the one vegetation type (Figure 2). The seven vegetation types are:

Vegetation Type 1: Parkland of *Corymbia calophylla* and ornamental eucalypts over mixed grassland.

Vegetation Type 2: Open parkland of ornamental eucalypts over very sparse understorey on yellow sands

Vegetation Type 3/7: Open woodland of *Eucalyptus marginata* and *Allocasuarina fraseriana* over open shrubland of *Xanthorrhoea preissii* over sedgeland of *Mesomelaena tetragona, Mesomelaena pseudostygia* and *Dasypogon bromeliifolius*

Vegetation Type 4: Occasional trees of *Eucalyptus ?rudis and Eucalyptus camaldulensis* subsp. *obtusa* over open shrubland of *Hakea trifurcata* over grassland of **Ehrharta calycina* and **Pennisetum clandestinum*

Vegetation Type 5: Open heath of *Hakea trifurcata* and *Leptospermum erubescens* over sedgeland of *Mesomelaena tetragona*

Vegetation Type 6: Open woodland of *Eucalyptus wandoo* subsp. *wandoo* and ornamental eucalypts over open shrubland of *Hakea trifurcata* and *Isopogon dubius* over grassland of **Ehrharta calycina*

Vegetation Type 8: Open woodland of *Eucalyptus marginata* and *Eucalyptus camaldulensis* subsp. *obtusa* over open shrubland of *Xanthorrhoea preissii* over introduced grasses.

In five of the described zones the vegetation has been disturbed in the past and replaced with non-native species, including ornamental eucalypts not endemic to the area. Zone 1 is at the western end of the reserve and has been parkland cleared and playground equipment installed. Zone 2 is a rehabilitated area and includes a drainage sump. The trees in this zone are mostly ornamental eucalypts such as *Angophora costata* and *Eucalyptus conferruminata.* The sump was vegetated with weed species such as *Pennisetum clandestinum* (kikuyu) and *Arundo donax.* Zones 4 and 6 were also a highly

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disturbed areas with open overstories of eucalypt species and occasional native shrubs such as *Hakea trifurcata.* The groundlayer consisted of introduced grasses such kikuyu and perennial veldt grass (*Ehrharta calycina*). Zone 8 is near the southern boundary of the site and has been heavily disturbed in the past.

The two native vegetation types are Vegetation Type 3/7 and Vegetation Type 5. The lower-storeys of both vegetation types share many of the same sedge species but Vegetation Type 5 lacks the overstorey of *Eucalyptus marginata* and *Allocasuarina fraseriana*. Vegetation Type 5 is also dominated by heath of *Hakea trifurcata.*

3.2.1 Assignment of Plant Associations

The results of the cluster analysis determined that both Vegetation Type 3/7 and Vegetation Type 5 belong in FCT 3c: *Corymbia calophylla – Xanthorrhoea preissii* woodlands and shrublands (Appendix D). The Zone 5 quadrat was most closely associated with sites in the FCT 3c group, as was the Zone 3 quadrat. The association was not close, however, but this is often observed when adding new data to the dataset. The Zone 7 quadrat was grouped with sites belonging to FCT 6: Weed dominated wetlands on heavy soil. This is an anomylous result given the similarity between the Zone 7 and Zone 3 vegetation, but is often observed when the groundlayer contains many introduced species and/or when taxa uncommon or not included in the original SCP dataset are present at a site. It is reasonable, therefore, to infer that the vegetation within Zone 7 also belongs to FCT 3c.

3.2.2 Vegetation Condition

The majority of the site is in a "Completely Degraded" condition and retains little of its original botanical value (Figure 3). The original structure of Vegetation Types 1, 4, 6 and 8 has been extensively altered with the upper- and mid-storeys now very open. The groundlayers are dominated by mainly introduced grasses. In Zone 2, the vegetation appears to have been completely cleared and rehabilitated with ornamental eucalypts. Almost no ground- or mid-storey exists.

The native remnants in Vegetation Types 3/7 and 5 are mostly in "Very Good" condition with some areas in "Excellent" condition. Some areas in Zones 3 and 5 where there is more extensive weed invasion have been rated in "Good" condition.

3.3 Weeds

Over one third of the taxa recorded during the survey were naturalised weeds or species not endemic to the local area. Sixteen of the weed species were introduced grasses and all of the daisy species (Asteraceae spp.) recorded were weeds. A number of eucalypts not endemic to the area but commonly planted as ornamentals in the Perth region we rerecorded and included *Eucalyptus grandis, Eucalyptus conferuminata, Eucalyptus pulverulenta, Corymbia maculata* and *Angophora costata.*

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4 Discussion

The cluster analysis determined the native vegetation of the York St Reserve to be FCT 3c. Whilst this result needs to be confirmed by the DEC's Species and Communities Branch, the result is consistent with descriptions given by Gibson *et al.* (1994). Most of the typical species listed for FCT 3c were present, including *Eucalyptus wandoo* in Zone 6, which is an occasional dominant in this community. It is likely that the original vegetation of most of the reserve belonged to FCT 3c but has now been cleared.

FCT 3c is a TEC, listed as Endangered pursuant to the EPBC Act and as Critically Endangered under DEC criteria. FCT 3c is restricted to the eastern side of the Swan Coastal Plain and has been extensively cleared. According to the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC), approximately 97% of the community's original extent may have been cleared, leaving only about 41 ha extant today. Among the threats to the remaining stands of this community are clearing, invasive species, and changes in hydrology and fire frequency.

In addition to listing as a TEC, the vegetation within the site is part of the Forrestfield Vegetation Complex. Only 9% of this vegetation complex remains (Government of Western Australia 2000) and is therefore considered a Critical Asset by the EPA. Clearing of this vegetation would likely be considered as being at variance to Principle (E) of Schedule 5 of the *Environmental Protection Act 1986*.

A number of invasive weeds, mostly grasses, were recorded from the site. Whilst none are Declared Plants pursuant to the *Agricultural and Related Resources Protection Act 1976,* many are very invasive and may have a high impact on ecological processes. Grasses such as **Ehrharta calycina, *Eragrostis curvula, *Hyparrhenia hirta* and **Tribolium uniolae* may invade disturbed sites quickly and outcompete native species. The effects of weed invasion is evident in parts of the native vegetation stands within the reserve where disturbance to the understorey has resulted in replacement to varying degrees by invasive species.

It is unlikely that clearing of the remnant vegetation within the reserve would be approved. The disturbed areas present little impediment to development but the interface with the stands of native vegetation will be very important. Buffers or barriers should be designed to minimise impacts upon the vegetation such as changes in hydrology and weed invasion.

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5 Summary and Recommendations

The remnant native vegetation within the York St Reserve retains high ecological value. As part of the Forrestfield Vegetation Complex, it is considered a Critical Asset by the EPA and is afforded statutory protection pursuant to thw EPBC Act and under DEC policies. Given the ecological values of the site, it is suggested that:

- Development of the site include plans or policies to improve the vegetation condition of the remnant vegetation within the York St Reserve.

Furthermore, it is recommended that:

- No clearing of Vegetation Types 3/7 and 5 be approved; and
- Any development of the site includes appropriate buffers or barriers to minimise adverse impacts to the native vegetation within the reserve.

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7 Figures

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Figure 1: Locality Plan

Figure 2: Vegetation Types

Figure 3: Vegetation Condition

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Appendix A

List of flora recorded within the survey area

NB: * indicates introduced flora

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Family	Non-native	Taxon
Colchicaceae		*Burchardia congesta*
Orchidaceae	*	*Disa bracteata*
Boryaceae		*Borya sphaerocephala*
Iridaceae	*	*Freesia alba x leichtlinii*
	*	*Gladiolus caryophyllaceus*
		Patersonia juncea
		Patersonia occidentalis
	*	*Romulea rosea*
Xanthorrhoeaceae		*Xanthorrhoea ?brunonis*
		Xanthorrhoea preissii
Asparagaceae		*Laxmannia squarrosa*
		Lomandra hermaphrodita
		Lomandra sericea
		Thysanotus dichotomus
		Thysanotus thyrsoideus
		Thysanotus triandrus
Hemerocallidaceae		*Tricoryne elatior*
Haemodoraceae		*Anigozanthos manglesii* subsp. *manglesii*
		Conostylis juncea
		Conostylis setigera
		Haemodorum laxum
Dasypogonaceae		*Dasypogon bromeliifolius*
Juncaceae		*Juncus pallidus*
Cyperaceae		*Cyathochaeta avenacea*
		Cyperus involucrata
		Lepidosperma leptostachyum
		Lepidosperma pubisqameum
		Leptospermum erubescens
		Mesomelaena pseudostygia
		Mesomelaena tetragona
		Schoenus clandestinus
		Schoenus grammatophylla
		Schoenus sp.
		Tetraria octandra
Anarthriaceae		*Lyginia imberbis*
Restionaceae		*Desmocladus fasciculatus*
Poaceae	*	*Aira caryophyllea*
		Amphipogon turbinatus

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Family	Non-native	Taxon
	*	*Arundo donax*
		Austrostipa campylachne
		Austrostipa elegantissima
	*	*Avena barbata*
	*	*Briza maxima*
	*	*Briza minor*
	*	*Bromus diandrus*
	*	*Cynodon dactylon*
	*	*Ehrharta calycina*
	*	*Eragrostis curvula*
	*	*Hyparrhenia hirta*
	*	*Lolium rigidum*
	*	*Melinis repens*
		Neurachne alopecuroidea
	*	*Pennisetum clandestinum*
	*	*Pentameris pallida*
		Rytidosperma caespitosum
	*	*Tribolium uniolae*
	*	*Vulpia* sp.
Papaveraceae	*	*Fumaria capreolata*
Proteaceae		*Banksia dallanneyi* subsp. *dallanneyi* var.
		Banksia sessilis
		Grevillea bipinnatifida subsp. *bipinnatifida*
		Hakea incrassata
		Hakea ruscifolia
		Hakea trifurcata
		Hakea undulata
		Isopogon dubius
		Lambertia multiflora var. *darlingensis*
		Petrophile macrostachya
		Stirlingia latifolia
		Synaphea petiolaris subsp. *petiolaris*
Dilleniaceae		*Hibbertia hypericoides*
Crassulaceae		*Crassula colorata*
Haloragaceae		*Gonocarpus cordiger*
Fabaceae		*Acacia applanata*
	*	*Acacia leiophylla*
		Acacia nervosa
		Acacia pulchella var. *pulchella*
		Acacia willdenowiana
	*	*Chamaecytisus palmensis*
		Cristonia biloba subsp. *biloba*
		Daviesia decurrens
		Daviesia nudiflora subsp. *nudiflora*
Fabaceae		*Gastrolobium ebracteolatum*
		Gompholobium confertum

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Family	Non-native	Taxon
		Gompholobium marginatum
		Gompholobium tomentosum
		Jacksonia lehmannii
	*	*Lotus subbiflorus*
	*	*Lupinus cosentinii*
	*	*Medicago polymorpha*
	*	*Trifolium angustifolium*
	*	*Trifolium campestre*
Polygalaceae		*Comesperma calymega*
Polygonaceae	*	*Rumex crispus*
Rhamnaceae		*Stenanthemum tridentatum*
Casuarinaceae		*Allocasuarina fraseriana*
		Allocasuarina humilis
Oxalidaceae	*	*Oxalis pes-caprae*
Euphorbiaceae	*	*Ricinus communis*
Violaceae		*Hybanthus calycinus*
Myrtaceae	*	*Angophora costata*
		Baeckea camphorosmae
	*	*Callistemon* sp.
		Calothamnus quadrifidus
		Corymbia calophylla
	*	*Corymbia maculata*
		Eremaea pauciflora var. *pauciflora*
		Eucalyptus ?lane-poolei
		Eucalyptus ?rudis
		Eucalyptus camaldulensis subsp. *obtusa*
	*	*Eucalyptus conferruminata*
	*	*Eucalyptus grandis*
		Eucalyptus marginata
	*	*Eucalyptus pulverulenta*
		Eucalyptus rudis subsp. *rudis*
	*	*Eucalyptus* sp. (juvenile)
		Eucalyptus wandoo subsp. *wandoo*
		Kunzea glabrescens
	*	*Leptospermum laevigatum*
	*	*Melaleuca nesophila*
		Melaleuca seriata
Anacardiaceae	*	*Schinus terebinthifolia*
Meliaceae	*	*Melia azedarach*
Thymelaeaceae		*Pimelea suaveolens* subsp. *suaveolens*
Tropaeolaceae	*	*Tropaeolum majus*

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Family	Non-native	Taxon
Brassicaceae	*	*Raphanus raphanistrum*
Loranthaceae		*Nuytsia floribunda*
Droseraceae		*Drosera platystigma*
		Drosera porrecta
Amaranthaceae		*Ptilotus manglesii*
Ericaceae		*Andersonia involucrata*
		Leucopogon sp. Great Southern
Rubiaceae		*Opercularia vaginata*
Boraginaceae	*	*Echium plantagineum*
Solanaceae	*	Solanaceae sp.
		Solanum nigrum
Plantaginaceae	*	Plantaginaceae sp.
	*	*Plantago lanceolata*
Orobanchaceae	*	*Orobanche minor*
Campanulaceae		*Isotoma hypercrateriformis*
	*	*Wahlenbergia capensis*
Stylidiaceae		*Stylidium brunonianum*
		Stylidium piliferum
Goodeniaceae		*Lechenaultia biloba*
		Scaevola repens
Asteraceae	*	*Arctotheca calendula*
	*	*Dimorphotheca ecklonis*
	*	*Gazania linearis*
	*	*Hypochaeris glabra*
	*	*Sonchus oleraceus*
	*	*Ursinia anthemoides*
Apiaceae	*	*Foeniculum vulgare*
		Pentapeltis peltigera
		Xanthosia huegelii

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Appendix B

Species presence in each recorded community within the survey area

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	Taxon	Community						
		Vegetation Type 1	**Vegetation Type 2**	**Vegetation Type 3/7**	**Vegetation Type 4**	**Vegetation Type 5**	**Vegetation Type 6**	**Vegetation Type 8**
	Acacia applanata			X		X		
*	*Acacia leiophylla*			X				
	Acacia nervosa					X		
	Acacia pulchella var. *pulchella*	X		X				
	Acacia willdenowiana					X		
*	*Aira caryophyllea*	X		X				
	Allocasuarina fraseriana	X		X			X	
	Allocasuarina humilis	X		X				
	Amphipogon turbinatus					X		
	Andersonia involucrata					X		
*	*Angophora costata*		X		X		X	
	Anigozanthos manglesii subsp. *manglesii*			X				
*	*Arctotheca calendula*	X						
*	*Arundo donax*	X						
	Austrostipa campylachne	X		X			X	
	Austrostipa elegantissima					X		
*	*Avena barbata*	X	X		X		X	
	Baeckea camphorosmae			X			X	
	Banksia dallanneyi subsp. *dallanneyi* var.	X		X				
	Banksia sessilis			X	X		X	
	Borya sphaerocephala					X		
*	*Briza maxima*	X	X	X	X	X		X
*	*Briza minor*		X	X				
*	*Bromus diandrus*	X				X		
	Burchardia congesta			X				
*	*Callistemon* sp.			X				X

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Taxon		Community						
		Vegetation Type 1	**Vegetation Type 2**	**Vegetation Type 3/7**	**Vegetation Type 4**	**Vegetation Type 5**	**Vegetation Type 6**	**Vegetation Type 8**
	Calothamnus quadrifidus				X			
*	*Chamaecytisus palmensis*	X		X	X			
	Comesperma calymega			X				
	Conostylis juncea			X				
	Conostylis setigera					X		
	Corymbia calophylla	X	X	X				
*	*Corymbia maculata*	X						
	Crassula colorata			X				
	Cristonia biloba subsp. *biloba*			X				
	Cyathochaeta avenacea					X		
*	*Cynodon dactylon*	X			X			
	Cyperus involucrata		X					
	Dasypogon bromeliifolius			X				
	Daviesia decurrens			X				
	Daviesia nudiflora subsp. *nudiflora*			X				
	Desmocladus fasciculatus			X		X		
*	*Dimorphotheca ecklonis*	X						X
*	*Disa bracteata*			X			X	
	Drosera platystigma					X		
	Drosera porrecta			X				
*	*Echium plantagineum*	X						
*	*Ehrharta calycina*	X		X	X		X	X
*	*Eragrostis curvula*	X	X	X	X	X	X	X
	Eremaea pauciflora var. *pauciflora*			X				
	Eucalyptus ?lane-poolei			X				
	Eucalyptus ?rudis		X					
	Eucalyptus camaldulensis subsp. *obtusa*	X	X	X	X			
*	*Eucalyptus conferruminata*		X					

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	Taxon	Community						
		Vegetation Type 1	**Vegetation Type 2**	**Vegetation Type 3/7**	**Vegetation Type 4**	**Vegetation Type 5**	**Vegetation Type 6**	**Vegetation Type 8**
*	*Eucalyptus grandis*			X				
	Eucalyptus marginata	X		X				X
*	*Eucalyptus pulverulenta*	X						
	Eucalyptus rudis subsp. *rudis*				X		X	
*	*Eucalyptus* sp. (juvenile)						X	
	Eucalyptus wandoo subsp. *wandoo*						X	
*	*Foeniculum vulgare*	X						
*	*Freesia alba x leichtlinii*			X	X	X	X	
*	*Fumaria capreolata*							X
	Gastrolobium ebracteolatum			X		X	X	
*	*Gazania linearis*	X		X	X		X	
*	*Gladiolus caryophyllaceus*	X		X		X	X	X
	Gompholobium confertum					X		
	Gompholobium marginatum			X			X	
	Gompholobium tomentosum						X	
	Gonocarpus cordiger					X		
	Grevillea bipinnatifida subsp. *bipinnatifida*					X		
	Haemodorum laxum	X		X		X		
	Hakea incrassata	X		X				
	Hakea ruscifolia			X				
	Hakea trifurcata	X			X	X	X	
	Hakea undulata					X		
	Hibbertia hypericoides	X		X				
	Hybanthus calycinus			X				
*	*Hyparrhenia hirta*	X						
*	*Hypochaeris glabra*	X		X				X
	Isopogon dubius						X	
	Isotoma hypercrateriformis			X				

DRAFT

Taxon		Community						
		Vegetation Type 1	**Vegetation Type 2**	**Vegetation Type 3/7**	**Vegetation Type 4**	**Vegetation Type 5**	**Vegetation Type 6**	**Vegetation Type 8**
	Jacksonia lehmannii			X				
	Juncus pallidus		X					
	Kunzea glabrescens				X			
	Lambertia multiflora var. *darlingensis*			X				
	Laxmannia squarrosa						X	
	Lechenaultia biloba			X		X	X	
	Lepidosperma leptostachyum						X	
	Lepidosperma pubisqameum			X		X		
	Leptospermum erubescens				X	X	X	
*	*Leptospermum laevigatum*	X			X			
	Leucopogon sp. Great Southern					X		
*	*Lolium rigidum*		X					
	Lomandra hermaphrodita			X				
	Lomandra sericea			X				
*	*Lotus subbiflorus*	X			X			
*	*Lupinus cosentinii*	X			X		X	
	Lyginia imberbis			X		X		
*	*Medicago polymorpha*		X					
*	*Melaleuca nesophila*	X						
	Melaleuca seriata					X		
*	*Melia azedarach*	X						
*	*Melinis repens*			X			X	
	Mesomelaena pseudostygia			X				X
	Mesomelaena tetragona	X		X	X	X	X	
	Neurachne alopecuroidea	X		X	X	X		
	Nuytsia floribunda	X						
	Opercularia vaginata			X			X	
*	*Orobanche minor*	X						

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	Taxon	Community						
		Vegetation Type 1	**Vegetation Type 2**	**Vegetation Type 3/7**	**Vegetation Type 4**	**Vegetation Type 5**	**Vegetation Type 6**	**Vegetation Type 8**
*	*Oxalis pes-caprae*	X						
	Patersonia juncea					X		
	Patersonia occidentalis			X		X	X	
*	*Pennisetum clandestinum*		X		X			
*	*Pentameris pallida*	X						
	Pentapeltis peltigera			X				
	Petrophile macrostachya			X				
	Pimelea suaveolens subsp. *suaveolens*			X				
*	*Plantaginaceae* sp.		X					
*	*Plantago lanceolata*		X					X
	Ptilotus manglesii					X		
*	*Raphanus raphanistrum*		X					
*	*Ricinus communis*							X
*	*Romulea rosea*	X		X	X	X		X
*	*Rumex crispus*		X					
	Rytidosperma caespitosum	X				X		
	Scaevola repens			X			X	
*	*Schinus terebinthifolia*	X						
	Schoenus clandestinus			X		X		
	Schoenus grammatophyllus					X		
	Schoenus sp.					X		
*	*Solanaceae* sp.	X						
	Solanum nigrum							X
*	*Sonchus oleraceus*		X					
	Stenanthemum tridentatum					X		
	Stirlingia latifolia			X				
	Stylidium brunonianum					X		
	Stylidium piliferum					X	X	

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	Taxon	Community						
		Vegetation Type 1	**Vegetation Type 2**	**Vegetation Type 3/7**	**Vegetation Type 4**	**Vegetation Type 5**	**Vegetation Type 6**	**Vegetation Type 8**
	Synaphea petiolaris subsp. *petiolaris*					X		
	Tetraria octandra			X		X		
	Thysanotus dichotomus		X					
	Thysanotus thyrsoideus			X				
	Thysanotus triandrus					X		
*	*Tribolium uniolae*	X					X	
	Tricoryne elatior			X			X	
*	*Trifolium angustifolium*	X	X	X	X		X	X
*	*Trifolium campestre*			X				
*	*Tropaeolum majus*			X				
*	*Ursinia anthemoides*	X		X	X		X	X
*	*Vulpia* sp.	X						
*	*Wahlenbergia capensis*						X	
	Xanthorrhoea ?brunonis			X				
	Xanthorrhoea preissii	X		X				
	Xanthosia huegelii			X				

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Appendix C

Sampling plot raw data

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Site Number	Zone 1	**Date**	2/11/12
Recorder/s	SC		
Datum	GDA94	**Zone**	50
Photo No.	**Easting**	**Northing**	
7136-7140	406776	6460104	
Observations	Parkland of marri over introduced grasses. Playground equipment installed		
Environment			
Soils:	**Soil texture**	**Soil Colour**	**Soil Comments**
	Gravelly clay loams	light brown	
Outcrop	**Type**	**Amount**	**Bare Ground (%)**
		none	15
Geomorphology:	**Topography**	**Aspect**	**Slope (o)**
	flat	0	0
Weeds:	**% Cover**	**No. Plants**	
	80	>1000	
Disturbance:	**Type**	**Time Since Fire**	**Level of Human Impact**
	clearing , tracks recreational usage	>10	high
Vegetation Condition	CD		
Vegetation Structure			
Strata	**Canopy Height (m)**	**Dominant Species**	**% Cover**
Upper	9	*Corymbia calophylla*	4
Mid	4	*Melaleuca nesophila, Leptospermum laevigatum*	<1
Lower	1	*Eragrostis curvula, Avena barbata*	80

Floristics

	Species
	Acacia pulchella var. *pulchella*
*	*Aira caryophyllea*
	Allocasuarina fraseriana
	Allocasuarina humilis
*	*Arctotheca calendula*
*	*Arundo donax*
	Austrostipa campylachne
	Austrostipa campylachne
*	*Avena barbata*
	Banksia dallanneyi subsp. *dallanneyi* var. *dallanneyi*
*	*Briza maxima*
*	*Bromus diandrus*
*	*Chamaecytisus palmensis*
	Corymbia calophylla
*	*Corymbia maculata*
*	*Cynodon dactylon*
*	*Dimorphotheca ecklonis*
*	*Echium plantagineum*
*	*Ehrharta calycina*
*	*Eragrostis curvula*
	Eucalyptus camaldulensis subsp. *obtusa*
	Eucalyptus marginata
*	*Eucalyptus pulverulenta*
*	*Foeniculum vulgare*
*	*Gazania linearis*
*	*Gladiolus caryophyllaceus*
	Haemodorum laxum
	Hakea incrassata
	Hakea trifurcata
	Hibbertia hypericoides
*	*Hyparrhenia hirta*
*	*Hypochaeris glabra*
*	*Leptospermum laevigatum*
*	*Lotus subbiflorus*
*	*Lupinus cosentinii*
*	*Melaleuca nesophila*
*	*Melia azedarach*
	Mesomelaena tetragona
	Neurachne alopecuroidea
	Nuytsia floribunda
*	*Orobanche minor*
*	*Oxalis pes-caprae*
	Pentameria pallida
	Romulea rosea
	Rytidosperma caespitosum
*	*Schinus terebinthifolia*
*	Solanaceae sp.
*	*Tribolium uniolae*

*	*Trifolium angustifolium*
*	*Ursinia anthemoides*
*	*Vulpia* sp.
	Xanthorrhoea preissii



Site Number	Zone 2	**Date**	2/11/12
Recorder/s	SC		
Datum	GDA94	**Zone**	50
Photo No.	**Easting**	**Northing**	
7144-7148	406916	6460104	
Observations	Rehabilitation with exotic eucalypts. Groundlayer bare		
Environment			
Soils:	**Soil texture**	**Soil Colour**	**Soil Comments**
	clay	Orange	hard packed with some surface gravel
Outcrop	**Type**	**Amount**	
		none	
Geomorphology:	**Topography**	**Aspect**	**Slope**
	flat	0	0
Weeds:	**% Cover**	**No. Plants**	
	<1	>100	
Disturbance:	**Type**	**Time Since Fire**	**Level of Human Impact**
	some rubbish. vehicle access	>10	
Vegetation Condition	CD		
Vegetation Structure			
Strata	**Canopy Height (m)**	**Dominant Species**	**% Cover**
Upper	10	*Angophora costata*	8
Mid	1.5	*Hakea trifurcata*	+
Lower	0.5	*Tribolium uniolae*	+

Floristics

	Species
*	*Angophora costata*
*	*Avena barbata*
*	*Briza maxima*
*	*Briza minor*
	Corymbia calophylla
	Cyperus involucrata
	Drosera platystigma
*	*Eragrostis curvula*
	Eucalyptus ?rudis
	Eucalyptus camaldulensis subsp. obtusa
*	*Eucalyptus conferruminata*
	Hakea trifurcata
	Juncus pallidus
*	*Lolium rigidum*
*	*Medicago polymorpha*
*	*Pennisetum clandestinum*
*	Plantaginaceae sp.
*	*Plantago lanceolatum*
*	*Raphanus raphanistrum*
*	*Rumex crispus*
*	Solanaceae sp.
*	*Sonchus oleraceus*
	Thysanotus dichotomus
*	*Trifolium angustifolium*
*	*Tribolium uniolae*



Site Number	Zone 3	**Date**	2/11/12
Recorder/s	SC		
Datum	GDA94	**Zone**	50
Photo No.	**Easting**	**Northing**	
7181 - 7186	406854	6459999	
Observations			
Environment			
Soils:	**Soil texture**	**Soil Colour**	**Soil Comments**
	Silty clay loams	orange - grey	Yellow orange at depth
Outcrop	**Type**	**Amount**	**Bare Ground**
	None	none	15
Geomorphology:	**Topography**	**Aspect**	**Slope (o)**
	Flat	0	0
Weeds:	**% Cover**	**No. Plants**	
Disturbance:	**Type**	**Time Since Fire**	**Level of Human Impact**
	Weeds	>5	Low
Vegetation Condition	VG-E		
Vegetation Structure			
Strata	**Canopy Height (m)**	**Dominant Species**	**% Cover**
Upper	8	*Eucalyptus marginata, Allocasuarina fraseriana*	10
Mid	1.5	*Petrophile macrostachya, Lambertia multiflora*	15
Lower	0 .3	*Hibbertia hypericoides*	40

Floristics

	Species
	Acacia pulchella var. *pulchella*
	Allocasuarina fraseriana
	Allocasuarina humilis
	Austrostipa campylachne
	Banksia dallanneyi subsp. *dallanneyi* var. *dallanneyi*
*	*Briza minor*
	Burchardia congesta
*	*Callistemon* sp.
*	*Chamaecytisus palmensis*
	Corymbia calophylla
	Dasypogon bromeliifolius
	Daviesia decurrens
	Daviesia nudiflora subsp. *nudiflora*
	Desmocladus fasciculatus
*	*Disa bracteata*
	Drosera porrecta
*	*Ehrharta calycina*
*	*Eragrostis curvula*
*	*Eucalyptus grandis*
	Eucalyptus marginata
*	*Freesia alba x leichtlinii*
	Gastrolobium ebracteolatum
*	*Gazania linearis*
	Haemodorum laxum
	Hakea incrassata
	Hakea ruscifolia
	Hibbertia hypericoides
	Hybanthus calycinus
	Lambertia multiflora var. *darlingensis*
	Lomandra hermaphrodita
	Lomandra sericea
	Mesomelaena pseudostygia
	Patersonia occidentalis
	Pentapeltis peltigera
	Petrophile macrostachya
*	*Romulea rosea*
	Scaevola repens
	Tetraria octandra
	Tricoryne elatior
*	*Trifolium angustifolium*
*	*Trifolium campestre*
*	*Tropaeolum majus*
	Xanthorrhoea preissii
	Xanthosia huegelii



Site Number	Zone 4	**Date**	2/11/12
Recorder/s	SC		
Datum	GDA94	**Zone**	50
Photo No.	**Easting**	**Northing**	
7143-7147	407010	6460194	
Observations	Disturbed area of mainly grasses		
Environment			
Soils:	**Soil texture**	**Soil Colour**	**Soil Comments**
	loamy sands	grey - cream	hard packed with some surface gravel
Outcrop	**Type**	**Amount**	
		none	
Geomorphology:	**Topography**	**Aspect**	**Slope (o)**
	flat	0	0
Weeds:	**% Cover**	**No. Plants**	
	>90	>1000	
Disturbance:	**Type**	**Time Since Fire**	**Level of Human Impact**
	some rubbish. vehicle access	>10	
Vegetation Condition	CD		
Vegetation Structure			
Strata	**Canopy Height (m)**	**Dominant Species**	**% Cover**
Upper	6	*Eucalyptus ?rudis*	3
Mid	2.5	*Hakea trifurcata*	5
Lower	1	*Ehrharta calycina, Pennisetum clandestinum*	80

Floristics

	Species
*	*Angophora costata*
*	*Avena barbata*
	Banksia sessilis
*	*Briza maxima*
	Calothamnus quadrifidus
*	*Chamaecytisus palmensis*
*	*Cynodon dactylon*
*	*Ehrharta calycina*
*	*Eragrostis curvula*
	Eucalyptus camaldulensis subsp. *obtusa*
	Eucalyptus ?rudis
*	*Freesia alba x leichtlinii*
*	*Gazania linearis*
	Hakea trifurcata
	Kunzea glabrescens
	Leptospermum erubescens
*	*Leptospermum laevigatum*
*	*Lotus subbiflorus*
*	*Lupinus cosentinii*
	Mesomelaena tetragona
	Neurachne alopecuroidea
	Pennisetum clandestinum
*	*Romulea rosea*
*	*Trifolium angustifolium*
*	*Ursinia anthemoides*



Site Number	Zone 5	**Date**	2/11/12
Datum	GDA94	**Zone**	50
Photo No.	**Easting**	**Northing**	
7158	407001	6460184	
7159	407021	6460184	
7160	407021	6460164	
7161	407002	6460163	
7162	**Ground**		
Observations			
Environment			
Soils:	**Soil texture**	**Soil Colour**	**Soil Comments**
	Gravelly clay loams	light brown	
Outcrop	**Type**	**Amount**	
		none	
Geomorphology:	**Topography**	**Aspect**	**Slope (o)**
	flat	0	0
Weeds:	**% Cover**	**No. Plants**	
	<1	>100	
Disturbance:	**Type**	**Time Since Fire**	**Level of Human Impact**
	Some rubbish ,	>5	Low
Vegetation Condition	VG - E		
Vegetation Structure			
Strata	**Canopy Height (m)**	**Dominant Species**	**% Cover**
Mid	2	*Hakea trifurcata, Leptospermum erubescens*	35
Lower	0.5	*Mesomelaena tetragona*	15

Floristics

	Species
	Acacia applanata
	Acacia nervosa
	Acacia willdenowiana
	Amphipogon turbinatus
	Andersonia involucrata
	Austrostipa elegantissima
	Borya sphaerocephala
*	*Briza maxima*
*	*Bromus diandrus*
	Conostylis setigera
	Cyathochaeta avenacea
	Desmocladus fasciculatus
	Drosera platystigma
*	*Eragrostis curvula*
*	*Freesia alba x leichtlinii*
	Gastrolobium ebracteolatum
*	*Gladiolus caryophyllaceus*
	Gompholobium confertum
	Gonocarpus cordiger
	Grevillea bipinnatifida subsp. *bipinnatifida*
	Haemodorum laxum
	Hakea trifurcata
	Hakea undulata
	Lechenaultia biloba
	Lepidosperma pubisqameum
	Leptospermum erubescens
	Leucopogon sp. Great Southern
	Lyginia imberbis
	Melaleuca seriata
	Mesomelaena tetragona
	Neurachne alopecuroidea
	Patersonia juncea
	Patersonia occidentalis
	Ptilotus manglesii
*	*Romulea rosea*
	Rytidosperma caespitosum
	Schoenus clandestinus
	Schoenus grammatophyllus
	Schoenus sp.
	Stenanthemum tridentatum
	Stylidium brunonianum
	Stylidium piliferum
	Synaphea petiolaris subsp. *petiolaris*
	Tetraria octandra
	Thysanotus triandrus



Site Number	Zone 6	**Date**	2/11/12
Recorder/s	SC		
Datum	GDA94	**Zone**	50
Photo No.	**Easting**	**Northing**	
7163-7167	407114	6460128	
Observations	Some rubbish, past disturbance		
Environment			
Soils:	**Soil texture**	**Soil Colour**	**Soil Comments**
	gravelly silty loams	grey	
Outcrop	**Type**	**Amount**	
Geomorphology:	**Topography**	**Aspect**	**Slope (o)**
	flat	0	0
Weeds:	**% Cover**	**No. Plants**	
	30	>1000	
Disturbance:	**Type**	**Time Since Fire**	**Level of Human Impact**
	clearing	>5	high
Vegetation Condition	CD		
Vegetation Structure			
Strata	**Canopy Height (m)**	**Dominant Species**	**% Cover**
Upper	6	*Angophora costata*	1
Mid	2	*Hakea trifurcata*	5
Lower	0.7	*Isopogon dubius, Ehrharta calycina*	30

Floristics

	Species
	Allocasuarina fraseriana
*	*Angophora costata*
*	*Austrostipa campylachne*
*	*Avena barbata*
	Baeckea camphorosmae
	Banksia sessilis
*	*Disa bracteata*
*	*Ehrharta calycina*
*	*Eragrostis curvula*
	Eucalyptus rudis subsp. rudis
*	*Eucalyptus sp. (juvenile)*
	Eucalyptus wandoo subsp. wandoo
*	*Freesia alba x leichtlinii*
	Gastrolobium ebracteolatum
*	*Gazania linearis*
*	*Gladiolus caryophyllaceus*
	Gompholobium marginatum
	Gompholobium tomentosum
	Hakea trifurcata
	Isopogon dubius
	Laxmannia squarrosa
	Lechenaultia biloba
	Lepidosperma leptostachyum
	Leptospermum erubescens
*	*Lupinus cosentinii*
*	*Melinis repens*
	Mesomelaena tetragona
	Opercularia vaginata
	Patersonia occidentalis
	Scaevola repens
	Stylidium piliferum
*	*Tribolium uniolae*
	Tricoryne elatior
*	*Trifolium angustifolium*
*	*Ursinia anthemoides*
*	*Wahlenbergia capensis*



Site Number	Zone 7	**Date**	2/11/12
Recorder/s	SC		
Datum	GDA94	**Zone**	50
Photo No.	**Easting**	**Northing**	
7168 - 7172	407062	6460065	
Observations			
Environment			
Soils:	**Soil texture**	**Soil Colour**	**Soil Comments**
	Silty clay loams	orange - grey	Yellow orange at depth
Outcrop	**Type**	**Amount**	
Geomorphology:	**Topography**	**Aspect**	**Slope (o)**
	flat	0	0
Weeds:	**% Cover**	**No. Plants**	
	<1	>100	
Disturbance:	**Type**	**Time Since Fire**	**Level of Human Impact**
	Some rubbish	>5	low
Vegetation Condition	E		
Vegetation Structure			
Strata	**Canopy Height (m)**	**Dominant Species**	**% Cover**
Upper	10	*Eucalyptus marginata* , *Eucalyptus camaldulensis subsp. obtusa*	10
Mid	3	*Allocasuarina fraseriana* , *Xanthorrhoea preissii*	12
Lower	0.5	*Mesomelaena tetragona* , *Dasypogon bromeliifolius* , *Mesomelaena pseudostygia*	25

Floristics

	Species
	Acacia applanata
	Acacia pulchella var. *pulchella*
*	*Aira caryophyllea*
	Allocasuarina fraseriana
	Austrostipa campylachne
	Baeckea camphorosmae
	Banksia dallanneyi subsp. *dallanneyi* var. *dallanneyi*
*	*Briza maxima*
	Burchardia congesta
	Comesperma calymega
	Conostylis juncea
	Crassula colorata
	Cristonia biloba subsp. *biloba*
	Dasypogon bromeliifolius
	Daviesia decurrens
	Daviesia nudiflora subsp. *nudiflora*
*	*Disa bracteata*
*	*Ehrharta calycina*
	Eremaea pauciflora var. *pauciflora*
	Eucalyptus camaldulensis subsp. *obtusa*
	Eucalyptus marginata
*	*Freesia alba x leichtlinii*
	Gastrolobium ebracteolatum
*	*Gladiolus caryophyllaceus*
	Gompholobium marginatum
	Hibbertia hypericoides
	Hybanthus calycinus
*	*Hypochaeris glabra*
	Isotoma hypercrateriformis
	Jacksonia lehmannii
	Lechenaultia biloba
	Lepidosperma pubisqameum
	Lomandra hermaphrodita
	Lomandra sericea
	Lyginia imberbis
*	*Melinis repens*
	Mesomelaena pseudostygia
	Mesomelaena tetragona
	Neurachne alopecuroidea
	Opercularia vaginata
	Scaevola repens
	Schoenus clandestinus
	Stirlingia latifolia
	Tetraria octandra
	Thysanotus thyrsoideus
	Tricoryne elatior
*	*Ursinia anthemoides*
	Xanthorrhoea preissii
	Xanthosia huegelii



Site Number	Zone 8	**Date**	2/11/12
Recorder/s	SC		
Datum	GDA94	**Zone**	50
Photo No.	**Easting**	**Northing**	
7176-7180	406982	6459997	
Observations	Parkland of jarrah and river gum over introduced grasses.		
Environment			
Soils:	**Soil texture**	**Soil Colour**	**Soil Comments**
	loamy sands	cream	
Outcrop	**Type**	**Amount**	
		none	
Geomorphology:	**Topography**	**Aspect**	**Slope (o)**
	flat	0	0
Weeds:	**% Cover**	**No. Plants**	
	50	>1000	
Disturbance:	**Type**	**Time Since Fire**	**Level of Human Impact**
	clearing tracks, recreational usage	>10	high
Vegetation Condition	CD		
Vegetation Structure			
Strata	**Canopy Height (m)**	**Dominant Species**	**% Cover**
Upper	7	*Eucalyptus marginata , Eucalyptus camaldulensis subsp. obtusa*	4
Mid	2	*Hakea trifurcata , Xanthorrhoea preissii*	1
Lower	0.5	*Ehrharta calycina, Rytidosperma caespitosum*	50

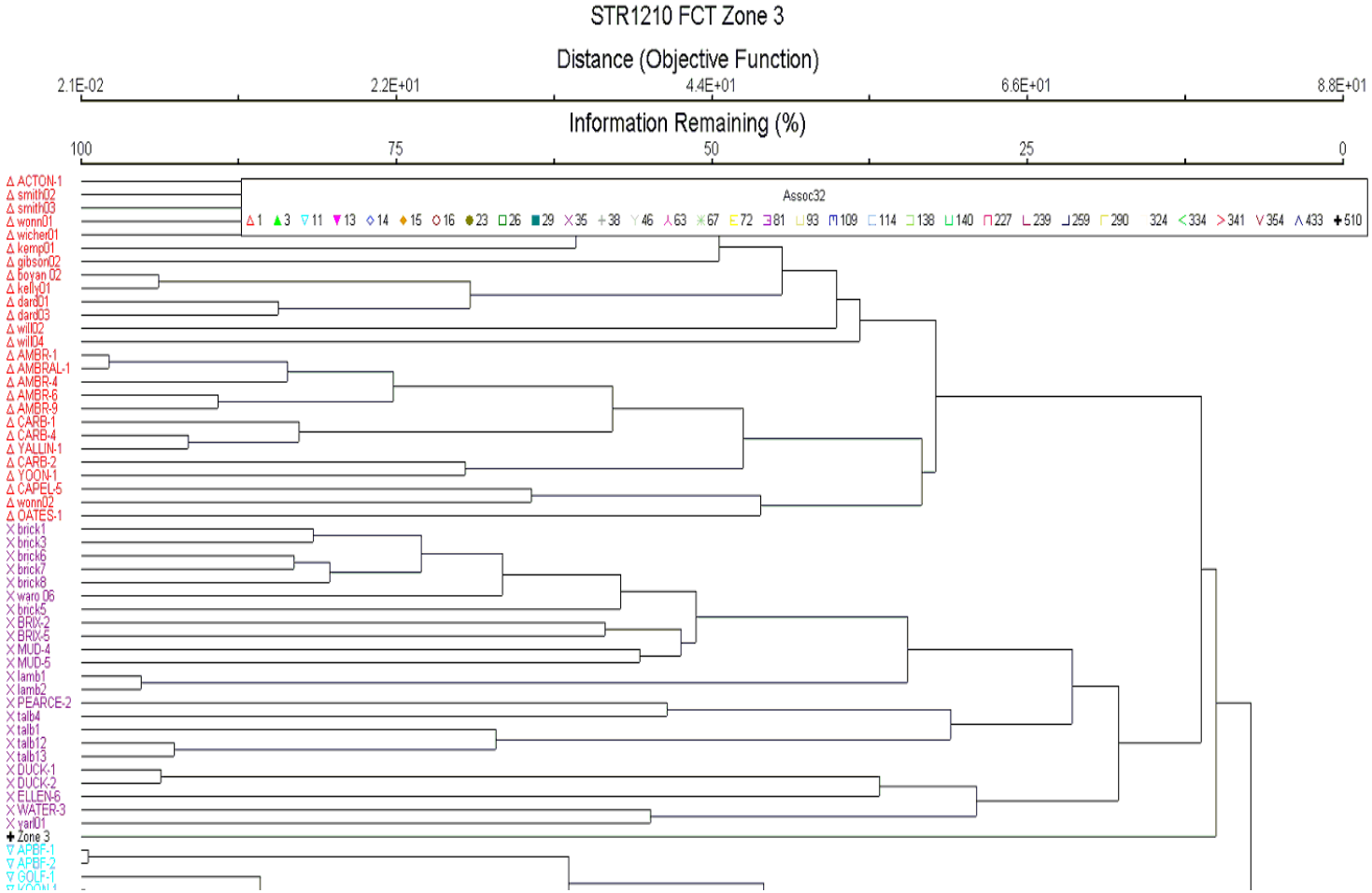
Floristics

	Species
*	*Briza maxima*
*	*Callistemon* sp.
*	*Dimorphotheca ecklonis*
*	*Ehrharta calycina*
*	*Eragrostis curvula*
	Eucalyptus camaldulensis subsp. *obtusa*
	Eucalyptus marginata
*	*Fumaria capreolata*
*	*Gladiolus caryophyllaceus*
	Hakea trifurcata
*	*Hypochaeris glabra*
*	*Melinis repens*
	Mesomelaena pseudostygia
*	*Plantago lanceolata*
*	*Ricinus communis*
*	*Romulea rosea*
	Rytidosperma caespitosum
*	*Solanum nigrum*
*	*Trifolium angustifolium*
*	*Ursinia anthemoides*
	Xanthorrhoea preissii

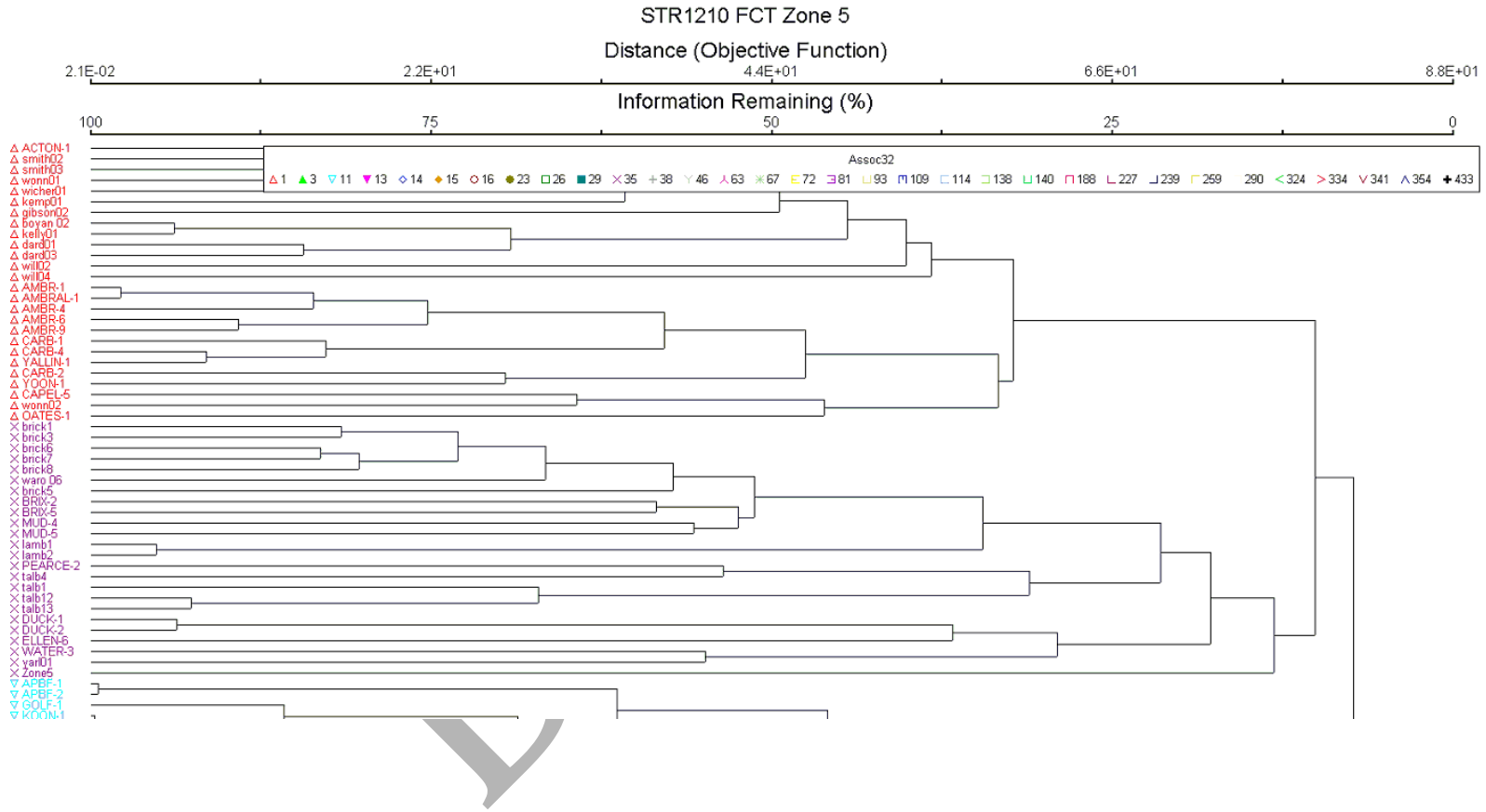
Appendix D

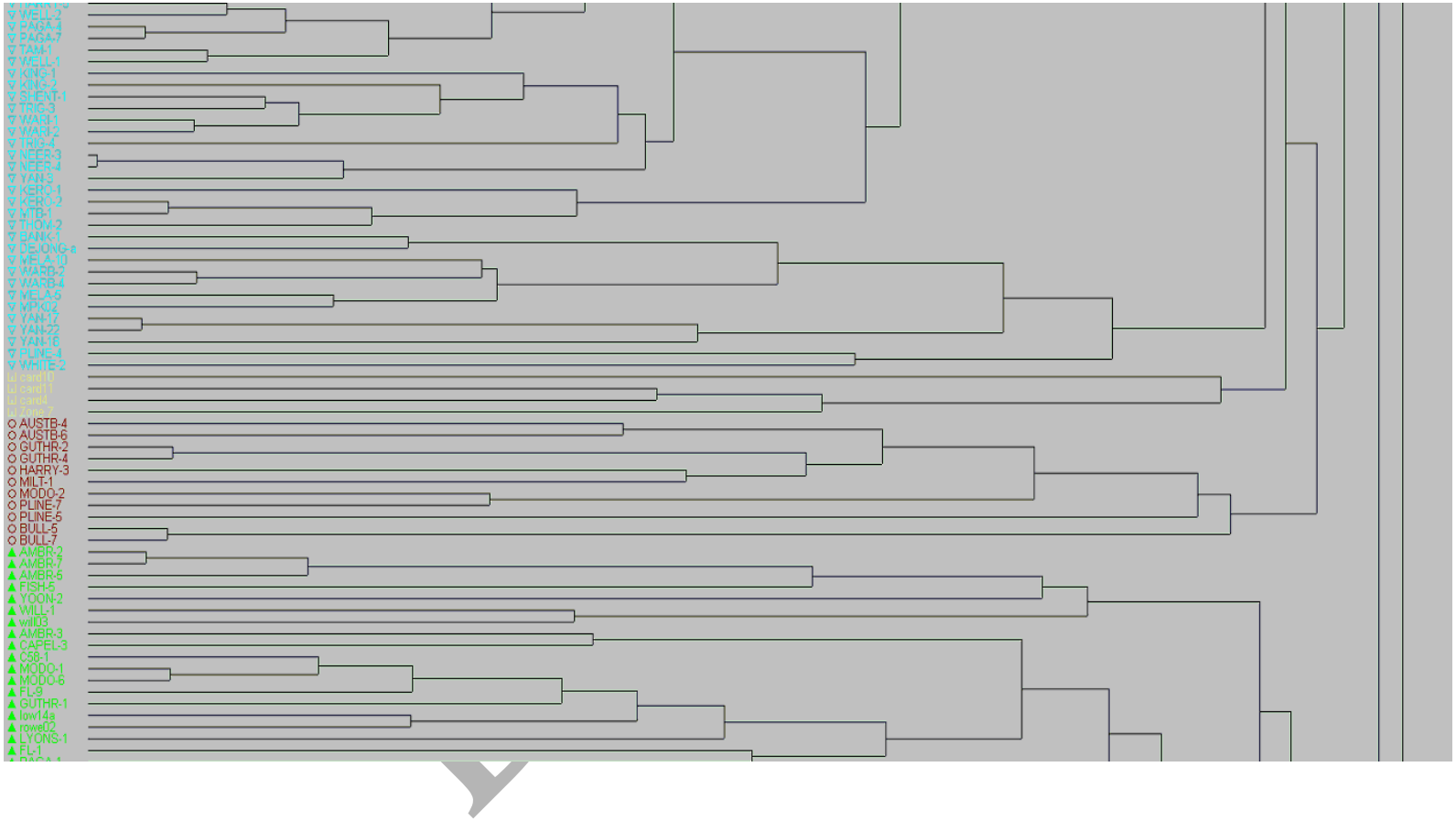
Cluster Dendrogram

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STR1210 FCT Zone 3
Distance (Objective Function)
2.1E-02
2.2E+01
4.4E+01
6.6E+01
8.8E+01
Information Remaining (%)
100
75
50
25
0
Assoc32
ACTON-1
smith02
smith03
wonn01
wicher01
kemp01
gibson02
boyan 02
kelly01
dard01
dard03
will02
will04
AMBR-1
AMBRAL-1
AMBR-4
AMBR-6
AMBR-9
CARB-1
CARB-4
YALLIN-1
CARB-2
YOON-1
CAPEL-5
wonn02
OATES-1
brick1
brick3
brick6
brick7
brick8
waro 06
brick5
BRIX-2
BRIX-5
MUD-4
MUD-5
lamb1
lamb2
PEARCE-2
talb4
talb1
talb12
talb13
DUCK-1
DUCK-2
ELLEN-6
WATER-3
yan01
Zone 3
APBF-1
APBF-2
GOLF-1

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STR1210 FCT Zone 5
Distance (Objective Function)
2.1E-02
2.2E+01
4.4E+01
6.6E+01
8.8E+01
Information Remaining (%)
100
75
50
25
0
Assoc32
1 3 11 13 14 15 16 23 26 29 35 38 46 63 67 72 81 93 109 114 138 140 188 227 239 259 290 324 334 341 354 433
ACTON-1
smith02
smith03
wonn01
wicher01
kemp01
gibson02
boyan 02
kelly01
dard01
dard03
will02
will04
AMBR-1
AMBRAL-1
AMBR-4
AMBR-6
AMBR-9
CARB-1
CARB-4
YALLIN-1
CARB-2
YOON-1
CAPEL-5
wonn02
OATES-1
brick1
brick3
brick6
brick7
brick8
waro 06
brick5
BRIX-2
BRIX-5
MUD-4
MUD-5
lamb1
lamb2
PEARCE-2
talb4
talb1
talb12
talb13
DUCK-1
DUCK-2
ELLEN-6
WATER-3
yarl01
Zone5
APBF-1
APBF-2
GOLF-1
KOON-1


WELL-2
PAGA-4
PAGA-7
TAM-1
WELL-1
KING-1
KING-2
SILENT-1
TRIC-3
WARI-1
WARI-2
TRIC-4
NEER-3
NEER-4
YAN-3
KERO-1
KERO-2
MTB-1
THOM-2
BANK-1
DEJONG-a
WELA-10
WARD-2
WARB-4
WELA-5
WPK02
YAN-17
YAN-22
YAN-16
PLINE-4
WHITE-2
AUSTB-4
AUSTB-6
GUTHR-2
GUTHR-4
HARRY-3
MILT-1
MODO-2
PLINE-7
PLINE-5
BULL-5
BULL-7
AMBR-2
AMBR-7
AMBR-5
FISH-5
YOON-2
WILL-1
will03
AMBR-3
CAPEL-3
C58-1
MODO-1
MODO-6
FL-9
GUTHR-1
low14a
rowe02
LYONS-1
FL-1

Appendix E

Matters of National Environmental Significance Report

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Australian Government
Department of Sustainability, Environment, Water, Population and Communities

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

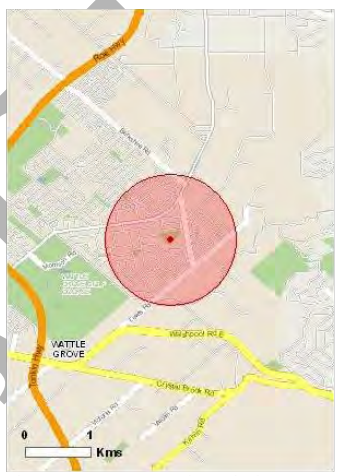
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 07/12/12 11:18:17

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 1.0Km



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Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Areas:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	23
Listed Migratory Species:	9

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate.

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	6
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves:	None

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Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

Place on the RNE:	None
State and Territory Reserves:	None
Regional Forest Agreements:	1
Invasive Species:	17
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Calyptorhynchus banksii naso Forest Red-tailed Black-Cockatoo [67034]	Vulnerable	Species or species habitat may occur within area
Calyptorhynchus baudinii Baudin's Black-Cockatoo, Long-billed Black-Cockatoo [769]	Vulnerable	Roosting known to occur within area
Calyptorhynchus latirostris Carnaby's Black-Cockatoo, Short-billed Black-Cockatoo [59523]	Endangered	Breeding likely to occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe [77037]	Vulnerable	Species or species habitat may occur within area
Insects		
Synemon gratiosa Graceful Sun Moth [66757]	Endangered	Species or species habitat may occur within area
Mammals		
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat likely to occur within area
Phascogale calura Red-tailed Phascogale [316]	Endangered	Species or species habitat may occur within area
Setonix brachyurus Quokka [229]	Vulnerable	Species or species habitat may occur within area
Plants		

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Name	Status	Type of Presence
Andersonia gracilis Slender Andersonia [14470]	Endangered	Species or species habitat may occur within area
Calytrix breviseta subsp. breviseta Swamp Starflower [23879]	Endangered	Species or species habitat may occur within area
Centrolepis caespitosa [6393]	Endangered	Species or species habitat likely to occur within area
Chamelaucium sp. Gingin (N.G.Marchant 6) Gingin Wax [64649]	Endangered	Species or species habitat may occur within area
Conospermum undulatum Wavy-leaved Smokebush [24435]	Vulnerable	Species or species habitat likely to occur within area
Darwinia foetida Muchea Bell [83190]	Critically Endangered	Species or species habitat likely to occur within area
Eucalyptus balanites Cadda Road Mallee, Cadda Mallee [24264]	Endangered	Species or species habitat may occur within area
Grevillea curviloba subsp. incurva Narrow curved-leaf Grevillea [64909]	Endangered	Species or species habitat may occur within area
Macarthuria keigheryi Keighery's Macarthuria [64930]	Endangered	Species or species habitat likely to occur within area
Synaphea sp. Fairbridge Farm (D.Papenfus 696) Selena's Synaphea [82881]	Critically Endangered	Species or species habitat may occur within area
Thelymitra manginii K.Dixon & Batty ms. [67443]	Endangered	Species or species habitat likely to occur within area
Thelymitra stellata Star Sun-orchid [7060]	Endangered	Species or species habitat likely to occur within area
Verticordia fimbrilepis subsp. fimbrilepis Shy Featherflower [24631]	Endangered	Species or species habitat may occur within area
Villarsia calthifolia Mountain Villarsia [10886]	Endangered	Species or species habitat likely to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area

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Name	Threatened	Type of Presence
Migratory Terrestrial Species		
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Leipoa ocellata		
Malleefowl [934]	Vulnerable	Species or species habitat may occur within area
Merops ornatus		
Rainbow Bee-eater [670]		Species or species habitat may occur within area
Migratory Wetlands Species		
Ardea alba		
Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis		
Cattle Egret [59542]		Species or species habitat may occur within area
Rostratula benghalensis (sensu lato)		
Painted Snipe [889]	Vulnerable*	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba		
Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis		
Cattle Egret [59542]		Species or species habitat may occur within area
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Merops ornatus		
Rainbow Bee-eater [670]		Species or species habitat may occur within area
Rostratula benghalensis (sensu lato)		
Painted Snipe [889]	Vulnerable*	Species or species habitat may occur within area

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Extra Information

Regional Forest Agreements	[Resource Information]

Note that all areas with completed RFAs have been included.

Name	State
South West WA RFA	Western Australia

Invasive Species	[Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Mammals		
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Asparagus asparagoides Bridal Creeper, Bridal Veil Creeper, Smilax, Florist's Smilax, Smilax Asparagus [22473]		Species or species habitat likely to occur within area
Brachiaria mutica Para Grass [5879]		Species or species habitat may occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat may occur within area
Chrysanthemoides monilifera Bitou Bush, Boneseed [18983]		Species or species habitat may occur within area

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Name	Status	Type of Presence
Genista sp. X Genista monspessulana Broom [67538]		Species or species habitat may occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		Species or species habitat may occur within area
Olea europaea Olive, Common Olive [9160]		Species or species habitat may occur within area
Pinus radiata Radiata Pine Monterey Pine, Insignis Pine, Wilding Pine [20780]		Species or species habitat may occur within area
Rubus fruticosus aggregate Blackberry, European Blackberry [68406]		Species or species habitat likely to occur within area
Salix spp. except S.babylonica, S.x calodendron & S.x reichardtii Willows except Weeping Willow, Pussy Willow and Sterile Pussy Willow [68497]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area

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Coordinates

-31.9915 116.0156

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

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Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
-State Forests of NSW
-Geoscience Australia
-CSIRO
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

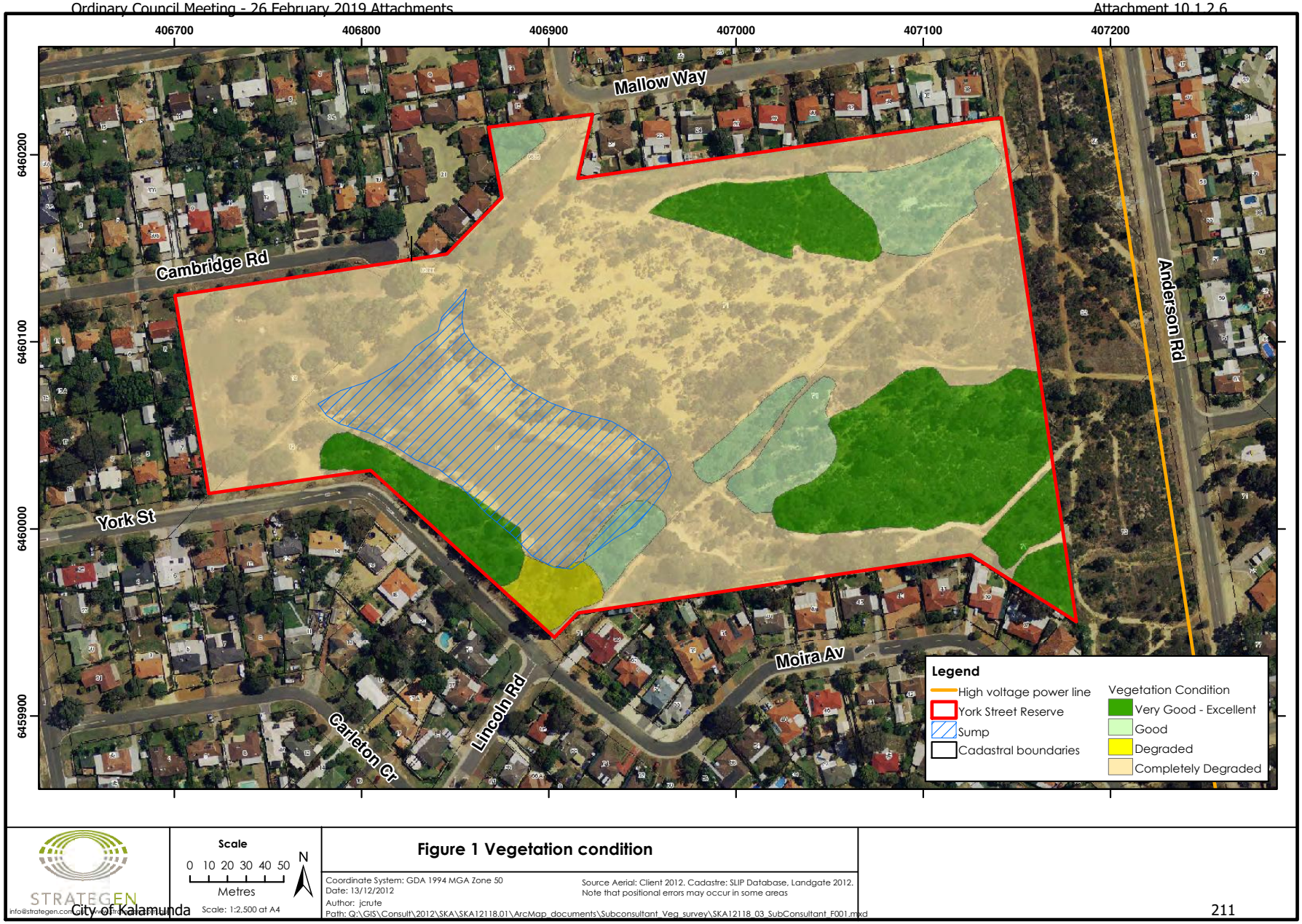
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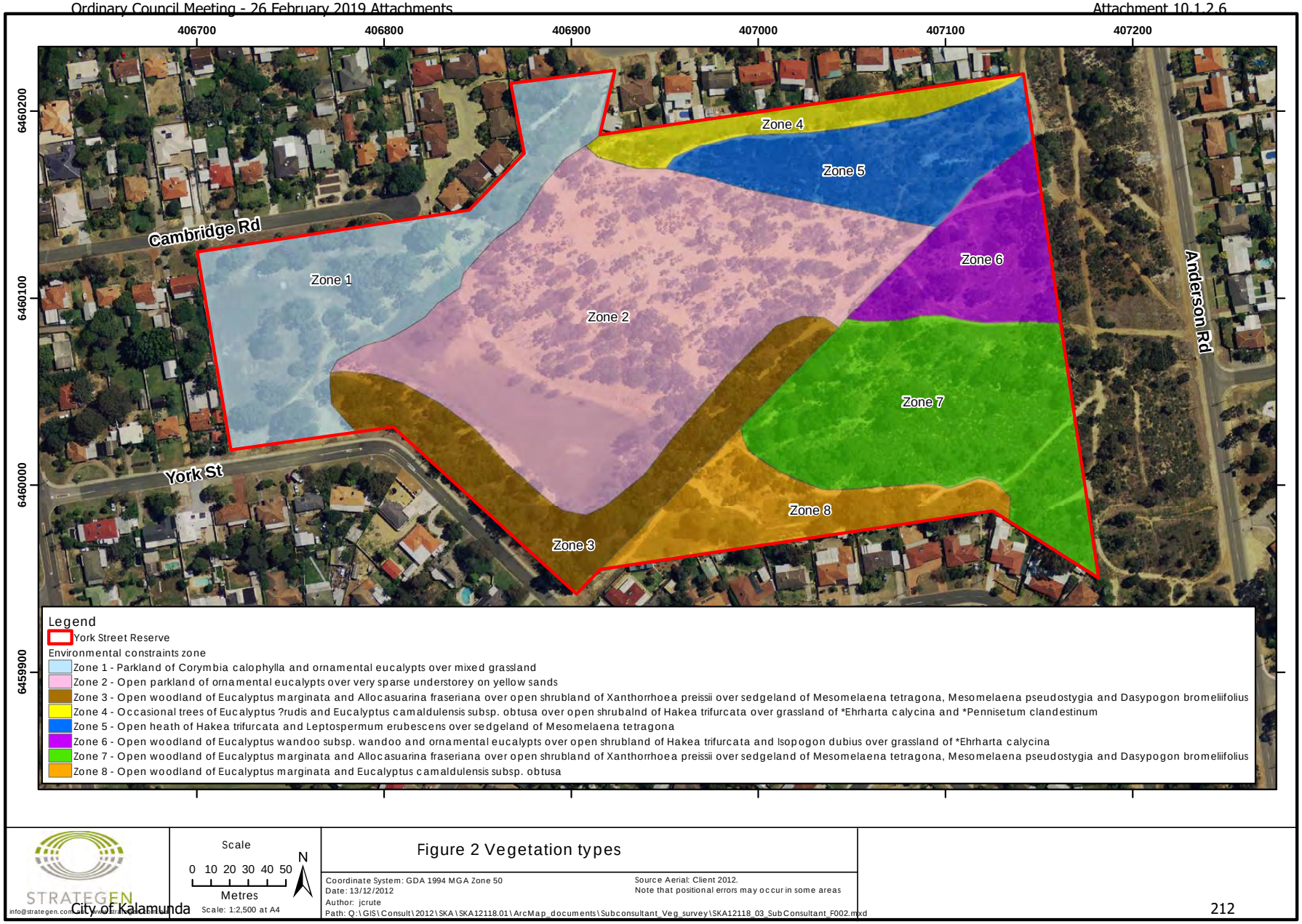
Department of Sustainability, Environment, Water, Population and Communities
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

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3.0 MAPPING


406700
406800
406900
407000
407100
407200
6460200
6460100
6460000
6459900
Mallow Way
Cambridge Rd
Anderson Rd
York St
Moira Av
Lincoln Rd
Carleton Cr
Legend
High voltage power line
York Street Reserve
Sump
Cadastral boundaries
Vegetation Condition
Very Good - Excellent
Good
Degraded
Completely Degraded
Scale
0 10 20 30 40 50
Metres
Scale: 1:2,500 at A4
N
STRATEGEN
City of Kalamunda
Figure 1 Vegetation condition
Coordinate System: GDA 1994 MGA Zone 50
Date: 13/12/2012
Author: jcrute
Path: Q:\GIS\Consult\2012\SKA\SKA12118.01\ArcMap_documents\Subconsultant_Veg_survey\SKA12118_03_SubConsultant_F001.mxd
Source Aerial: Client 2012. Cadastre: SLIP Database, Landgate 2012.
Note that positional errors may occur in some areas
211


406700
406800
406900
407000
407100
407200
6460200
6460100
6460000
6459900
Cambridge Rd
York St
Anderson Rd
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
Zone 7
Zone 8
Legend
York Street Reserve
Environmental constraints zone
Zone 1 - Parkland of Corymbia calophylla and ornamental eucalypts over mixed grassland
Zone 2 - Open parkland of ornamental eucalypts over very sparse understorey on yellow sands
Zone 3 - Open woodland of Eucalyptus marginata and Allocasuarina fraseriana over open shrubland of Xanthorrhoea preissii over sedgeland of Mesomelaena tetragona, Mesomelaena pseudostygia and Dasypogon bromeliifolius
Zone 4 - Occasional trees of Eucalyptus ?rudis and Eucalyptus camaldulensis subsp. obtusa over open shrubalnd of Hakea trifurcata over grassland of *Ehrharta calycina and *Pennisetum clandestinum
Zone 5 - Open heath of Hakea trifurcata and Leptospermum erubescens over sedgeland of Mesomelaena tetragona
Zone 6 - Open woodland of Eucalyptus wandoo subsp. wandoo and ornamental eucalypts over open shrubland of Hakea trifurcata and Isopogon dubius over grassland of *Ehrharta calycina
Zone 7 - Open woodland of Eucalyptus marginata and Allocasuarina fraseriana over open shrubland of Xanthorrhoea preissii over sedgeland of Mesomelaena tetragona, Mesomelaena pseudostygia and Dasypogon bromeliifolius
Zone 8 - Open woodland of Eucalyptus marginata and Eucalyptus camaldulensis subsp. obtusa
STRATEGEN
info@strategen.com.au www.strategen.com.au
City of Kalamunda
Scale
0 10 20 30 40 50
Metres
Scale: 1:2,500 at A4
N
Figure 2 Vegetation types
Coordinate System: GDA 1994 MGA Zone 50
Date: 13/12/2012
Author: jcrute
Source Aerial: Client 2012.
Note that positional errors may occur in some areas
Path: Q:\GIS\Consult\2012\SKA\SKA12118.01\ArcMap_documents\Subconsultant_Veg_survey\SKA12118_03_SubConsultant_F002.mxd
212

APPENDIX 2

Floristic Community Type Analysis of Quadrats (Aecom)

Shire of Kalamunda
29-Sep-2017

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Floristic Community Type Analysis

Forrestfield North Detailed Flora and Vegetation Assessment



D R A F T

Floristic Community Type Analysis

Forrestfield North Detailed Flora and Vegetation Assessment

Client: Shire of Kalamunda

ABN: 60 741 095 678

Prepared by

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ABN 20 093 846 925

29-Sep-2017

Job No.: 60527304

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Revision C – 29-Sep-2017
Prepared for – Shire of Kalamunda – ABN: 60 741 095 678

D R A F T

Quality Information

Document Floristic Community Type Analysis

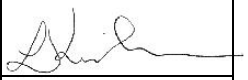
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Executive Summary

The Shire of Kalamunda required Floristic Community Type (FCT) analysis to determine the significance of native vegetation at the State level within a defined survey area in Forrestfield. Quadrat data from the 2016 Level 2 Flora and Fauna Assessment (AECOM, 2016) was assessed against the Keighery (2012) Swan Coastal Plain dataset to infer the relevant FCT.

Firstly a review of the desktop study and historical surveys was undertaken. This provided an overview of existing environment and potential State significant vegetation communities that may be present. Four communities listed as Threatened Ecological Communities (TECs) were considered to potentially occur within the survey area, including:

- FCT3a *Corymbia calophylla – Kingia australis* Woodlands on Heavy Soils
- FCT3c *Corymbia calophylla – Xanthorrhoea preissii* Woodlands and Shrublands
- FCT7 Herb-rich Saline Shrublands in Clay Pans
- FCT20a *Banksia attenuata* Woodlands over Species Rich Dense Shrublands.

Another two significant communities listed by Department of Biodiversity, Conservation and Communities (DBCA) were identified:

- FCT2 Southern Wet Shrublands
- Banksia Dominated Woodlands of the Swan Coastal Plain.

Within the survey area three Banksia/Jarrah Woodlands, one heath community, and one riparian community represented native vegetation. These were represented by 12 quadrats. These quadrats were individually compared to the SCP dataset. All quadrats showed the highest similarity to those in the SCP dataset representing FCT20a *Banksia attenuata* Woodlands over Species Rich Dense Shrublands. Similarities differed from 32-52%. The low similarity is likely to be a reflection of the single scoring event and limited time spent at each quadrat (<1 hr). This FCT represents an Endangered TEC at both the State and Federal level.

Verification of the Banksia Woodlands of the SCP was also undertaken. The native vegetation within the survey area was divided into five patches and each assessed against the key diagnostic criteria, condition assessment and minimum patch size. All patches met most of the diagnostic criteria with the exception of the overstorey dominance/co-dominance aspect. The vegetation within the survey area was dominated by *Eucalyptus marginata* and *Allocasuarina fraseriana* with less *Banksia attenuata/Banksia menziesii*, or sometimes these species were absent. Despite this, the desktop study found multiple known locations of the Banksia Woodland TEC within the survey area, indicating that all native vegetation in Good or better condition represents this Federally listed TEC. In this case, the lack of a dominant *Banksia* tree stratum appears to have no effect on the presence of this TEC.

This leads back to the FCT analysis. Perhaps the location of the survey area on the eastern SCP presents a unique composition of overstorey species which has led to the lower similarity of survey quadrats to SCP quadrats representing FCT20a. Furthermore, the desktop study found numerous locations of the Priority 3 Banksia Dominated Woodlands within the survey area. Despite this, all quadrats were aligned with FCT20a. Lacking key diagnostic characteristics for the Priority community, it is uncertain what the differentiating factor is between FCT20a and the Banksia Dominated Woodlands. Consultation with DBCA was undertaken however the response was inconclusive. Both represent the Federally listed Banksia Woodlands.

In conclusion, all native vegetation in Good or better condition within the survey area is considered to represent the Federally listed Banksia Woodlands of the SCP. FCT analysis indicates that this same extent represents the State listed TEC FCT20a.

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1.0 Introduction

1.1 Background

The Shire of Kalamunda is proposing to re-zone an area currently zoned as urban-deferred. Part of this process will require subdivision of properties and clearing of native vegetation for urban development. A detailed flora and vegetation assessment, and a level 1 fauna assessment (including Black Cockatoo survey) was undertaken in November 2016. At this time, the Federally listed Banksia Woodlands of the Swan Coastal Plain Threatened Ecological Community (Banksia Woodland TEC) was identified and mapped, and a number of Floristic Community Types (FCTs) have been referenced as potentially occurring in the survey area.

To further support the Banksia Woodlands TEC mapping, and assess the local and regional significance of vegetation on the Swan Coastal Plain (SCP), FCT analysis is required. FCT analysis is undertaken using a statistical program to assess the similarity of quadrat data obtained from the 2016 survey to the comprehensive SCP dataset. This report includes an overview of the desktop study, the results of the FCT analysis and a more comprehensive Banksia Woodlands assessment. FCT analysis is important on the Swan Coastal Plain as it provides a comparable dataset to determine relative species richness and local and regional significance of the patch at State-level by determining the TEC/PEC status.

1.2 Location

The survey area is located between Maida Vale Road (north), Dundas Road (west), Sultana Road West (south) and Roe Highway (east) in the suburb of High Wycombe. It includes 144 ha of land, of which 116.2 ha is cleared and 27.80 ha is considered native vegetation. The location and extent of the survey area is shown in Figure 1.

1.3 Scope of work

The objective of the FCT analysis is to determine the significance of native vegetation within the survey area at the State level. Specifically:

- Vegetation quadrats from the 2016 Assessment were compared to the SCP dataset
- Analysis in accordance with the draft DPaW statistical analysis methods (2015) was undertaken to identify quadrats in the SCP dataset that are most similar to quadrats within the survey area
- The analysis outcomes were used to identify the FCT most representative of the vegetation types.

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Base Data: (c) Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2016).

LEGEND

- Survey Area
- Highway
- Minor Road

Survey Area

SHIRE OF KALAMUNDA

FORRESTFIELD NORTH

Figure

1

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2.0 Methods

2.1 Floristic Community Type Analysis

A detailed flora and vegetation survey was undertaken in November 2016 (Forrestfield North Level 2 Flora and Fauna Survey; AECOM, 2016). At this time floristic data was collected from 12 quadrats and six relevés. Floristic quadrat data is presented in Appendix A. Relevé data was not further considered as it is not suitable for statistical analysis at this level (DPaW, 2015). Quadrats within the survey area were subject to one scoring event. This deviates from the two events recommended in the DPaW FCT draft analysis methods (2015) and it may cause a low similarity and reduce compatibility of the datasets.

The Keighery (2012) SCP dataset was used for the FCT analysis. A sub-set of this data was defined using a 25 km radius from the survey area. This reduces 'noise' in the data analysis from quadrats located a considerable distance away. It also excludes FCTs that do not occur in the local area. The subset includes 261 SCP quadrats representing 43 FCTs.

The survey area data was reconciled with this dataset and all species coded using the three first letters of the genus and species, reducing infra-specific names. All nomenclature of species followed the WA Plant Census.

The program PC Ord was used to undertake the Bray Curtis distance measure. The Bray Curtis dissimilarity measure was used to quantify the compositional dissimilarity between the quadrats based on presence absence data. Subtracting the results from 1 gives the similarity index, also known as the Bray Curtis index. This method is easily interpretable and provides meaningful results. A sense check was completed incorporating appropriate geology, soils, landscape and the description provided in the Gibson *et al.* (1994) reference material and Bush Forever (Government of WA, 2000).

2.2 Banksia Woodlands of the Swan Coastal Plain verification

Within the survey area native vegetation was separated into five patches. Patches were based on areas that were, at least for the most part, isolated from other areas of native vegetation and in Good or better condition. This approach was used in order to further refine condition categories and potentially inform management actions. Another option would have been to assess the area as one patch. The defined patches comprise of multiple vegetation communities as mapped in the AECOM (2016) report.

The Threatened Species Scientific Committee (TSSC) developed a comprehensive conservation advice document (2016) which provides a detailed description, methods for identifying the community, current threats, research priorities and conservation actions required. Identifying this community is described in detail using four steps:

- Step 1: use key diagnostic characteristics to determine if TEC is present
- Step 2: determine condition of patch
- Step 3: consider if patch meets minimum size threshold
- Step 4: surrounding context of a patch must be taken into account when considering factors that add to the importance of a patch that meets the condition thresholds.

The key diagnostic characteristics summarise the main features that characterise the Banksia Woodland. The condition categories are applied to identify the varying quality of patches, usually as a result of degradation, and ensure that patches of high quality are considered a Matter of National Significance (MNES). The condition of the patch is informed by species richness of quadrat data compared to available datasets, most notably the Gibson *et al.* (1994) and Keighery *et al.* (2012) Swan Coastal Plain datasets, and weed cover. The condition of the patch and size thresholds are then used to determine whether the quality of the patch is suitable to meet MNES standards.

Floristic data collected from permanent quadrats should be used to inform the TEC assessment. This will not only support the condition category assessment, but also identify the associated Floristic Community Type (FCT) that is inferred for these quadrats.

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2.2.1 Key Diagnostic Features

Key diagnostic characteristics
Location and physical environment
Patch on Swan Coastal Plain or adjacent lower parts of the Darling and Whicher escarpments that lie within the Jarrah Forest bioregion to the immediate east and south of the Swan Coastal Plain.
Soils and landform
Typically occurs on: deep Bassendean, Spearwood sands, occasionally on Quindalup sands, sandy colluvium and Aeolian sands of the Ridge Hill Shelf, Whicher Scarp and Dandaragan Plateau. Sometimes on transitional substrates, sandflats.
Structure: The structure of the ecological community is a low woodland to forest with the following features:
Distinctive upper sclerophyllous layer of low trees typically dominated or co-dominated by one or more of the *Banksia* species identified below; AND Emergent trees *Eucalyptus* or *Allocasuarina* species may sometimes be present above the *Banksia* canopy; AND Highly species-rich understorey that consists of a layer of sclerophyllous shrubs of various heights and a herbaceous ground layer of cord rushes, sedges and perennial and ephemeral forbs that sometimes includes grasses.
Composition
Canopy is most commonly dominated or co-dominated by *Banksia attenuata* and/or *Banksia menziesii.* Other *Banksia* species that dominate in some examples of the ecological community are *B. prionotes* or *B. ilicifolia*; AND Must include at least one of the following diagnostic species: · *Banksia attenuata* · *Banksia menziesii* · *Banksia prionotes* · *Banksia ilicifolia.* Emergent tree layer often includes *Corymbia calophylla, E. marginata,* or less commonly *E. gomphocephala*; AND Other trees of a medium height may be present and may be co-dominant with the *Banksia* species across a patch, include *E. todtiana, Nuytsia floribunda, Allocasuarina fraseriana, Callitris arenaria, Callitris pyramidalis* and *Xylomelum occidentale*.
Contra-indicators
Patches clearly dominated by *Banksia littoralis* are not part of the TEC
Patches clearly dominated by *Banksia burdettii* are not the TEC
FCT 20c – Eastern shrublands and woodlands, corresponds with a separate EPBC ecological community listing, Shrublands and Woodlands of the eastern Swan Coastal Plain. Occurrences of this FCT should be considered under that separate listing.

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2.2.2 Condition assessment

The condition of vegetation of each patch needs to be determined in accordance with the following:

- The condition assessment of a patch should be centred on the area of highest native floristic diversity and/or cover of the patch
- Timing of surveys and recent disturbance should be taken into account
- Surrounding context of a patch should be considered
- Certain vegetation components of Banksia Woodlands community merit consideration as critical elements to protect. Three components are recognised as threatened in their own right i.e. Priority Ecological Communities
- A relevant expert may be useful to help identify the ecological community and its condition
- Vegetation must be in 'Good' or better condition in accordance with Table 1.

Table 1 Condition Table

Keighery (1994) Vegetation Condition Scale	Indicative condition measures/thresholds	
	Typical native vegetation composition	Typical weed cover
Pristine No obvious signs of disturbance.	Native plant species diversity fully retained or almost so[1]	Zero or almost no weed cover/abundance
Excellent Vegetation structure intact, disturbance only affecting individual species, weeds are non-aggressive species.	High native plant species diversity[1]	Less than 10%
Very Good Vegetation structure altered, obvious signs of disturbance (e.g. repeated fires, dieback, logging, grazing). Aggressive weeds present.	Moderate native plant species diversity[1]	5 – 20%
Good Vegetation structure altered but retains basic vegetation structure or ability to regenerate it. Obvious signs of disturbance (from partial clearing, dieback, logging, grazing). Presence of very aggressive weeds.	Low native plant species diversity[1]	5 – 50%
Degraded Basic vegetation structure severely impacted by disturbance. Requires intensive management. Disturbance evident such as partial clearing, dieback, logging and grazing. Presence of very aggressive weeds at high density.	Very low native plant species diversity[1]	20 – 70%
Completely Degraded Vegetation structure is no longer intact and the area is completely or almost completely without native flora. Equivalent to 'Parkland Cleared'.	Very low to no native species diversity[1]	Greater than 70%

1. relative to expected natural range of diversity for that vegetation unit e.g. Floristic Community Type where comparative data exists.

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2.2.3 Patch size thresholds

Different minimum patch sizes apply to different levels of condition, as outlined below:

- Pristine – no minimum patch size
- Excellent – 0.5 ha or 5,000 m^2 (50 x 100 m)
- Very Good – 1 ha or 10,000 m^2 (100 x 100 m)
- Good – 2 ha or 20,000 m^2 (200 x 100 m).

2.2.4 Additional information

The following information should be taken into consideration when applying the key diagnostic criteria and condition thresholds:

- Land use history and landscape position of patch including position relative to surrounding vegetation
- A patch is a discreet and mostly continuous area of the ecological community and may include small-scale variations (<30 m), gaps and disturbances such as tracks paths or breaks that do not significantly alter the overall functionality of the ecological community.
- Variation in canopy cover, quality or condition of vegetation across a patch should not be considered evidence of multiple patches
- A buffer zone is a contiguous area immediately adjacent to a patch of the ecological community. The recommended minimum buffer zone is 20-50 m. Larger buffer zones should be considered for patches of particularly high conservation value, or if patches are down slope of drainage lines or a source of nutrient enrichment, or groundwater drawdown.
- Restored vegetation is not excluded provided it meets the key diagnostic criteria, condition threshold and patch size.
- Sampling protocols includes developing a quick map of the vegetation, landscape qualities and management history. Following this, a thorough sampling exercise must be undertaken to represent the range of variation. At least one hour per plot in early to mid-spring and a second survey in late spring may be required to detect the majority of species. plots to be at least 100 m^2 (10 x 10 m). Search effort (number of person hours per plot across entire patch) and surveyor's level of expertise can be useful for future reference.
- Timing of surveys should allow a reasonable interval after a disturbance. Surveys at least one year post fire may be required to assess a site against the key diagnostic characteristics and minimum condition thresholds.
- Surrounding environment, landscape context and other significance considerations:
  - patches that are more species rich and less disturbed are likely to provide greater biodiversity value
  - patches that provide corridors or linkages within a largely modified landscape are particularly important.

The Conservation Advice provides an additional ten indicators to be considered when assessing impacts of actions or proposed actions under the EPBC Act. These are not further listed here.

2.2.5 Protected in reserves

The level of protection in reserves has been published based on estimated extent of major and partially corresponding vegetation system associations. This is shown in Table 2.

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Table 2 Extent of Banksia Woodlands ecological community estimated to be protected in reserves

Subregion	Current extent (ha)	Extent in reserves (ha)	% Protected
Dandaragan (SWA01)	81,067.8	24,671.2	30.43
Perth (SWA02)	253,540.6	57,054.9	22.50
Jarrah Forests (JAF01/02)	1,881.4	105.9	5.63
TOTAL	**336,489.9**	**81,832.0**	**24.32**

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3.0 Summary of Historical Surveys

3.1 Threatened and Priority communities

A desktop review was undertaken as part of this report to provide a comprehensive overview of the potential threatened ecological communities that may occur within the survey area. The desktop study took into account the government database results undertaken as part of the detailed flora and vegetation assessment (AECOM, 2016), the Strategen (2012) Environmental Review document and the Keighery (2012) Floristic Community Type dataset. The Keighery (2012) dataset was consulted within 4km of the survey area to identify potential significant communities that occur in close proximity of the survey area. A summary of the results is presented in Table 3.

Table 3 Threatened communities identified in the desktop study informed by various sources

FCT	Community Name	Cons. Status		Source
		DBCA	EPBC Act	
2	Southern Wet Shrublands	Endangered	-	Keighery
3a	*Corymbia calophylla – Kingia australis* Woodlands on Heavy Soils	Critically Endangered	Endangered	Keighery Strategen
3c	*Corymbia calophylla – Xanthorrhoea preissii* Woodlands and Shrublands	Critically Endangered	Endangered	Strategen
7	Herb-rich Saline Shrublands in Clay Pans	Vulnerable	Critically Endangered	Keighery
20a	*Banksia attenuata* Woodlands over Species Rich Dense Shrublands	Endangered	Endangered	Database, Keighery
?	Banksia Dominated Woodlands of the Swan Coastal Plain.	Priority 3		Database

Southern wet shrublands is listed by DBCA as Endangered. It is known in the vicinity of the survey area from one location on the corner of Roe Highway and Tonkin Highway. This community is described by Gibson *et al.* (1994) as shrublands or open low woodlands occurring on seasonally inundated sandy clay soils.

The ***Corymbia calophylla – Kingia australis* Woodlands TEC** occurs on the eastern side of the Swan Coastal Plain. The floristic composition varies with water regime across its distribution (DotEE, 2017a). The community is associated with areas where groundwater is less than 3m from the natural ground surface, indicating a high level of dependence on groundwater. There are 41 occurrences of this community extending across 192.5 ha between Ruabon and Guildford. There is one occurrence of this community within 1.3km of the survey area, located east of Roe Highway associated with Bush Forever Site 319 Dundas Road Bushland. Due to its restricted distribution, no condition thresholds are applicable to this community, with all areas meeting the description are considered habitat critical to the survival of this community.

The ***C. calophylla – Xanthorrhoea preissii* Woodlands TEC** is not known to occur within 5km of the survey area. It is known to occur on heavy soils of the eastern side of the Swan Coastal Plain. Dominant species include *C. calophylla,* occasionally *Eucalyptus wandoo*. This community is currently known from 115 ha located between Bullsbrook and Capel. Similarity with this community, due to its restricted distribution, no condition thresholds are applicable to this community.

Herb-rich saline shrublands in claypans are listed under “Clay Pans of the Swan Coastal Plain” federally listed Critically Endangered community. This community is unique in its composition of geophytes and annual flora that germinates, grows and flowers sequentially as the areas dry over summer (TSSC, 2012). This community is located within the Perth Airport land tenement.

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The **Banksia Woodlands TEC**, described by the Threatened Species Scientific Committee (TSSC, 2016) incorporates Woodland of *Banksia* species with scattered eucalypts and other tree species over a species rich mix of sclerophyllous shrubs, graminoids, and forbs. The community shows high endemism and considerable local variation in species composition across its range. It is restricted to the southwest of WA on the Swan Coastal Plain. It occurs mainly on deep Bassendean and Spearwood sands or occasionally on Quindalup sands.

At the State level, this Banksia Woodlands community is represented by a number of FCTs as defined in Bush Forever (Government of WA, 2000) and Gibson *et al.* (1994). Within the survey area, the Banksia Woodlands TEC is represented by FCT20a *Banksia attenuata* woodlands over species rich dense shrublands. This community is listed as an Endangered TEC by Department of Biodiversity, Conservation and Attractions (DBCA). In addition, the TEC is also represented by a Priority 3 ecological community (PEC) listed as 'Banksia Dominated Woodlands of the Swan Coastal Plain'. This community is directly aligned with the EPBC Act listed TEC.

3.2 Vegetation communities

Five vegetation communities were described and mapped within the survey area (Table 4). These encompassed:

- Three *Banksia/E. marginata* Woodlands, AfHhMp, EmAcMt, EmToDo
- one Heath community VaCd
- one Riparian community ErApEh
- one significantly disturbed community, mapped as 'Trees'.

For the purpose of the FCT analysis, only the three Woodlands and one Heath community were included.

Table 4 Vegetation community descriptions recorded and mapped in the survey area including survey effort, species richness and total extent

Community Description	Additional Details
AfHhMp *Allocasuarina fraseriana*, *Banksia attenuata, Banksia menziesii* and occasional *Nuytsia floribunda* low woodland over *Xanthorrhoea preissii, Lambertia multiflora, Adenanthos cygnorum* subsp. *cygnorum* and *Xanthorrhoea acanthostachya* mid sparse shrubland over *Hibbertia hypericoides, Banksia dallanneyi* var. *dallanneyi, Bossiaea eriocarpa, Calothamnus torulosus* and *Petrophile macrostachya* low sparse shrubland with *Mesomelaena pseudostygia, Schoenus brevisetis, Lepidosperma leptostachyum*, *Caustis dioica* and *Tricostularia exsul* tall open sedgeland with *Dasypogon obliquifolius*, *Scaevola repens* var. *repens*, *Haemodorum laxum*, *Gladiolus caryophyllaceus**, *Burchardia congesta* and *Anigozanthos manglesii* low sparse forbland.	Survey effort: four quadrats (1, 4, 6, 9) Species richness: 92 native, seven weed species. Area: 5.5 ha
EmAcMt *Eucalyptus marginata* and *Banksia menziesii* low open woodland over *Adenanthos cygnorum* subsp. *cygnorum*, *Lambertia multiflora* and *Xanthorrhoea acanthostachya* mid open shrubland over *Melaleuca trichophylla*, *Hibbertia hypericoides, Eremaea pauciflora* var. *pauciflora, Allocasuarina humilis* and *Stirlingia latifolia* low shrubland with *Mesomelaena pseudostygia*, *Cyathochaeta avenacea, Tricostularia exsul* and *Lepidosperma leptostachyum* mid to low sedgeland over *Tricoryne elatior, Dasypogon obliquifolius, Lyginia barbata, Scaevola repens* var. *repens, Haemodorum laxum* and *Lomandra sericea* low sparse forbland.	Survey effort: three quadrats (2, 5, 10), one relevè (14). Species richness: 79 native, four weed species, Area: 3.51 ha

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Community Description	Additional Details
EmToDo *Eucalyptus marginata* and *Allocasuarina fraseriana* mid woodland over Banksia *attenuata, Banksia menziesii* and *Persoonia elliptica* low woodland over *Lambertia multiflora* and *Xanthorrhoea preissii* mid open shrubland over *Banksia dallanneyi* var. *dallanneyi, Hibbertia hypericoides, Bossiaea eriocarpa*, *Stirlingia latifolia*, and *Gastrolobium capitatum* low shrubland with *Tetraria octandra, Mesomelaena pseudostygia, Mesomelaena tetragona* and *Lepidosperma leptostachyum* low sedgeland over *Dasypogon obliquifolius*, *Patersonia occidentalis, Dampiera linearis, Haemodorum laxum, Scaevola repens* var. *repens* and *Lomandra preissii* low sparse forbland.	Survey effort: five quadrats (3, 11, 13, 16, 17), three relevès (12, 15 and 18). Species richness: 87 native, eight weed species. Area: 10.32 ha
ErApEh *Corymbia calophylla* and *Eucalyptus rudis* tall woodland over *Trymalium odoratissimum* thicket over *Acacia pulchella*, *Hibbertia hypericoides* and *Xanthorrhoea preissii* mid sparse shrubland over **Ehrharta calycina, *Cynodon dactylon, *Gladiolus caryophyllaceus* and *Tetraria octandra* grassland/herbland on clay soils within Poison Gully.	Area: 0.18 ha
VdCd *Eucalyptus marginata* subsp. *marginata* mid isolated trees over *Verticordia densiflora* var. *densiflora, Daviesia angulata, Hypocalymma angustifolium, Stirlingia latifolium* and *Banksia bipinnatifida* subsp. *bipinnatifida* low open shrubland with *Caustis dioica, Mesomelaena tetragona, Tetraria octandra* and *Schoenus brevisetis* tall open sedgeland over *Patersonia occidentalis, Lyginia barbata, Haemodorum spicatum*, *Tricoryne elatior* and *Anigozanthos manglesii* low open forbland.	Survey effort: two quadrats (7, 8) Species richness: 45 native, five weed species. Area: 2.65 ha

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4.0 Results

4.1 FCT Analysis

The FCT analysis results identified FCT20a Banksia Woodlands over Species-rich Dense Shrublands as the most representative FCT to survey area quadrats. This community is listed as Endangered by DBCA and represents the Banksia Woodlands of the Swan Coastal Plain Federally listed TEC.

Communities AfHhMp and EmAcMr showed a 46-52% similarity to FCT20a, with the three top matches all representing quadrats assigned to FCT20a (Table 5). AfHhMp and EmAcMr have a high species richness (34-67 species/quadrat), low historical disturbance and are mapped in Excellent condition.

EmToDo also shows the highest similarity to quadrats representing FCT20a, however results were lower with 32-47% similarity. Survey quadrats had a species richness slightly lower than the other two Banksia communities at 32-50 species/quadrat. Condition was mapped as Very Good to Excellent.

Gibson *et al.* (1994) describes FCT20a as occurring in deep sands at the base of the Scarp in Forrestfield covering the Southern River unit and Karrakatta unit. This woodland is either represented by *B. attenuata* woodlands or *E. marginata-B. attenuata* woodlands and has an average species richness of 67.4 species/quadrat. The description of this FCT matches those of the three Woodland communities mapped in the survey area.

Some factors that should be considered regarding the moderate percentage similarity include:

- survey quadrats were scored once which is a reduced survey effort compared to the SCP dataset
- the survey was undertaken late in the season (November 2016) which may have affected presence of early-flowering annuals
- more time allowed for each quadrat (1 hour) may have allowed for additional species to be recorded, the survey was very time-restricted.

The inference of FCT20a being present at all patches of native vegetation (represented by a quadrat) in the survey area is contradictory to the desktop study. The database results show 26 locations of the Priority 3 “Banksia Dominated Woodlands” community. This P3 community is not associated with a particular FCT and is therefore difficult to identify. The FCT results therefore imply that the native vegetation represents an Endangered State and Federally listed TEC, however the desktop study implies that only one patch represents FCT20a.

DBCA was consulted to ascertain the difference between the Banksia Dominated Woodland to other FCTs however their response was inconclusive.

Community VcCa had cryptic results that varied between several FCTs, with FCT20a showing the closest resemblance. The other two inferred FCTs are associated with wetland communities and were therefore discounted. However, this community lacked any overstorey species and field observations indicate historical clearing followed by potential rehabilitation of native species? The community is very unique in its composition and implies human-disturbance/influence.

None of the quadrats showed any similarity to quadrats representing FCT2, 3a, 3c, 7, or 20c. For this reason, the other TECs can be excluded from being present in the survey area.

D R A F T

Table 5 Inferred FCT for Forrestfield North including quadrat condition, species richness h the Project quadrat, the SCP FCT quadrat, and % similarity)

Quadrat	Condition	Sp. Richness	Quadrat (FCT; % similarity)	Review of Result	Final FCT
AfHhMp					
HW01	Excellent	67	Activ03 (20a; 52%) Activ01 (20a; 48%) Wire01 (28; 45%)	Consistent results for all quadrats in this community for FCT20a.	According to database records, this represents the P3 Banksia Woodlands.
HW04	Excellent	48	Activ03 (20a; 45%) APBF-1 (20a; 45%) Activ01 (20a; 43%)		According to database records, this represents the P3 Banksia Woodlands.
HW06	Excellent	34	Activ01 (20a; 41%) APBF-2 (20a; 38%)		According to database records, this represents the P3 Banksia Woodlands.
HW09	Excellent	54	Activ01 (20a; 46%) Activ03 (20a; 45%)		FCT20a *Banksia attenuata* woodlands over species rich dense shrublands.
EmAcMt					
HW02	Excellent	54	Activ01 (20a; 46%) M5303 (20a; 40%)	Consistent results for all quadrats in this community for FCT20a.	FCT20a *Banksia attenuata* woodlands over species rich dense shrublands.
HW10	Excellent	43	Activ01 (20a; 49%) APBF-2 (20a; 47%) APBF-1 (20a; 46%)		
EmToDo					
HW03	Excellent	34	Activ03 (20a; 32%) Hart01 (20a; 31%) APBF-1 (20a; 31%) KING-2 (28; 31%)	Consistent results for all quadrats in this community for FCT20a.	According to database records, this represents the P3 Banksia Woodlands.
HW13	Excellent	50	Activ03 (20a; 47%) M5303 (20a; 43%)		According to database records, this represents the P3 Banksia Woodlands.
HW16	Excellent	41	APBF-1 (20a; 44%) Activ03 (20a; 42%)		According to database records, this represents the P3 Banksia Woodlands.
HW17	Very Good	32	Active03 (20a; 38%) M5303 (20a; 35%)		

D R A F T

Quadrat	Condition	Sp. Richness	Quadrat (FCT; % similarity)	Review of Result	Final FCT
VcCa					
HW07	Excellent	31	FL-1 (4; 37%) M5302 (20a; 37%) Cavs02 (21a; 31%)	Definitely not 4 *Melaleuca preissiana* damplands.	FCT20a *Banksia attenuata* woodlands over species rich dense shrublands – cryptic as this patch appears to represent historically cleared area.
HW08	Excellent	38	M5302 (S11; 46%) M5303 (20a; 42%)	Definitely not S11 Northern *Acacia rostellifera-Melaleuca acerosa* shrublands.	

D R A F T

4.2 Banksia Woodlands Assessment

The three Woodland communities mapped within the survey area all appear to meet the Banksia Woodlands of the Swan Coastal Plain Assessment. It should be noted that in all communities, *Eucalyptus marginata* was the dominant tree species, along with dense patches of *Allocasuarina fraseriana*, often forming a top canopy stratum over *Banksia attenuata* and *Banksia menziesii* in lower percentages. This may reflect the location at the foothills.

4.2.1 Banksia Woodland Patch 1

Location	Patch 1 is located on the eastern border of the survey area, bounded by Roe Highway (east) and cleared paddock (west and north) and Conospermum Way (south).
Key diagnostic characteristics	Meets all key diagnostic characteristics.
Condition	Excellent, 92 species recorded in this patch and less than 2% weed cover. Mean species richness was 52 species/quadrat compared to FCT20a at 67.4 species/quadrat, the mean species richness represents 77% of anticipated species richness.
Patch size	2.33 ha
Additional features	The small size of the patch may imply higher risk of degradation from competing land uses. Patch supports population of Threatened *Conospermum undulatum* species.
Land use history	Unknown.
Any variations in patch	The patch comprises of variable condition native vegetation. The roadside vegetation along the south is in Good condition, comprising of a narrow strip of vegetation between cleared paddocks and the road. Several *C. undulatum* species occur in this corridor and therefore was considered important as a link between this patch and the adjacent patch. The remainder of the patch represents intact Excellent vegetation, dissected by one old track. Some weeds and rubbish was evident as a result of edge effects from Roe Highway and the paddocks adjacent. The northern tip is mapped as Degraded as a result of historical clearing and partial regrowth.
Buffer zone present	This patch has no buffer between adjacent conflicting land uses.
Sampling protocol	Assessed based on one scoring event of three quadrats in November, 2016.
Disturbance history	Unknown.
Surrounding environment	Paddock, minor road, and highway roadside. Paddock is proposed for further development.

Key diagnostic characteristics	**Response**
Location and physical environment	
Patch on Swan Coastal Plain or adjacent lower parts of the Darling and Whicher escarpments that lie within the Jarrah Forest bioregion to the immediate east and south of the Swan Coastal Plain.	Swan Coastal Plain
Soils and landform	
Typically occurs on: deep Bassendean, Spearwood sands, occasionally on Quindalup sands, sandy colluvium and Aeolian sands of the Ridge Hill Shelf, Whicher Scarp and Dandaragan Plateau. Sometimes on transitional substrates, sandflats.	Located on Forrestfield Complex in the foothills.

D R A F T

Key diagnostic characteristics	Response
Structure: The structure of the ecological community is a low woodland to forest with the following features:	
Distinctive upper sclerophyllous layer of low trees typically dominated or co-dominated by one or more of the *Banksia* species identified below; AND Emergent trees *Eucalyptus* or *Allocasuarina* species may sometimes be present above the *Banksia* canopy; AND Highly species-rich understorey that consists of a layer of sclerophyllous shrubs of various heights and a herbaceous ground layer of cord rushes, sedges and perennial and ephemeral forbs that sometimes includes grasses.	The overstorey is patchy, varying from 2-20% and includes *E. marginata, A. fraseriana, B. attenuata* and *B. menziesii.* Understorey comprises 41 slerophyllous shrubs and 35 herbaceous species (total), including 3 rushes and 11 sedges.
Composition	
Canopy is most commonly dominated or co-dominated by *Banksia attenuata* and/or *Banksia menziesii.* Other *Banksia* species that dominate in some examples of the ecological community are *B. prionotes* or *B. ilicifolia*; AND Must include at least one of the following diagnostic species: · *Banksia attenuata* · *Banksia menziesii* · *Banksia prionotes* · *Banksia ilicifolia* Emergent tree layer often includes *Corymbia calophylla, E. marginata,* or less commonly *E. gomphocephala*; AND Other trees of a medium height may be present and may be co-dominant with the *Banksia* species across a patch, include *E. todtiana, Nuytsia floribunda, Allocasuarina fraseriana, Callitris arenaria, Callitris pyramidalis* and *Xylomelum occidentale*.	Low trees comprising of *B. menziesii* and *B. attenuata* (4-6%) along with *E. marginata* (10-15%) and *A. fraseriana* (2%).
Contra-indicators	
Patches clearly dominated by *Banksia littoralis* are not part of the TEC	No
Patches clearly dominated by *Banksia burdettii* are not the TEC	No
FCT20c – Eastern shrublands and woodlands, corresponds with a separate EPBC ecological community listing, Shrublands and Woodlands of the eastern Swan Coastal Plain. Occurrences of this FCT should be considered under that separate listing.	No

D R A F T

4.2.2 Banksia Woodland Patch 2

Location	Patch 2 includes 29, 31, and 37 Brand Road.
Key diagnostic characteristics	It meets all key diagnostic characteristics.
Condition	Very Good. Species richness is moderate with 66 species/3 quadrats, a mean species richness of 37 species/quadrat compared to FCT20a with 67.4 species/quadrat. Weed cover was less than 5%. Condition could potentially be Excellent if another quadrat scoring event was undertaken.
Patch size	2.13 ha
Additional features	Large population of *C. undulatum* present in patch.
Land use history	Unknown.
Any variations in patch	Varied from Very Good to Excellent with degradation caused by firebreak clearing and edge effects of adjacent conflicting land use. Patch represented by AfHhMp and EmAcMt which represents the variation in canopy cover of *E. marginata* and *A. fraseriana* and dominance of sedges and shrubs.
Buffer zone present	No buffer zone present, adjacent land predominantly cleared.
Sampling protocol	Represented by three quadrats (HW04, HW05 and HW06) that have been scored once in November 2016.
Disturbance history	Unknown.
Surrounding environment	Adjacent land represents private property and includes open paddock with scattered native trees, and private gardens comprising of introduced/planted species and housing.

Key diagnostic characteristics	**Response**
Location and physical environment	
Patch on Swan Coastal Plain or adjacent lower parts of the Darling and Whicher escarpments that lie within the Jarrah Forest bioregion to the immediate east and south of the Swan Coastal Plain.	Swan Coastal Plain
Soils and landform	
Typically occurs on: deep Bassendean, Spearwood sands, occasionally on Quindalup sands, sandy colluvium and Aeolian sands of the Ridge Hill Shelf, Whicher Scarp and Dandaragan Plateau. Sometimes on transitional substrates, sandflats.	Forrestfield complex on the foothills.

D R A F T

Key diagnostic characteristics	Response
Structure: The structure of the ecological community is a low woodland to forest with the following features:	
Distinctive upper sclerophyllous layer of low trees typically dominated or co-dominated by one or more of the *Banksia* species identified below; AND Emergent trees *Eucalyptus* or *Allocasuarina* species may sometimes be present above the *Banksia* canopy; AND Highly species-rich understorey that consists of a layer of sclerophyllous shrubs of various heights and a herbaceous ground layer of cord rushes, sedges and perennial and ephemeral forbs that sometimes includes grasses.	Tree stratum varies in co-dominance between *E. marginata* (0-20% at two sample points), *A fraseriana* (0.5-8% at two sample points), *B. attenuata* (2-8% at two sample points), and *B. menziesii* (3% at one sample point). Understorey stratum includes 33 shrub species, 18 herbs and eight ruses and sedges.
Composition	
Canopy is most commonly dominated or co-dominated by *Banksia attenuata* and/or *Banksia menziesii.* Other *Banksia* species that dominate in some examples of the ecological community are *B. prionotes* or *B. ilicifolia*; AND Must include at least one of the following diagnostic species: · *Banksia attenuata* · *Banksia menziesii* · *Banksia prionotes* · *Banksia ilicifolia* Emergent tree layer often includes *Corymbia calophylla, E. marginata,* or less commonly *E. gomphocephala*; AND Other trees of a medium height may be present and may be co-dominant with the *Banksia* species across a patch, include *E. todtiana, Nuytsia floribunda, Allocasuarina fraseriana, Callitris arenaria, Callitris pyramidalis* and *Xylomelum occidentale*.	Canopy is dominated by *E. marginata* and *A. fraseriana* with variable cover of relevant Banksia species. Other tree species included *B. grandis*.
Contra-indicators	
Patches clearly dominated by *Banksia littoralis* are not part of the TEC	No
Patches clearly dominated by *Banksia burdettii* are not the TEC	No
FCT20c – Eastern shrublands and woodlands, corresponds with a separate EPBC ecological community listing, Shrublands and Woodlands of the eastern Swan Coastal Plain. Occurrences of this FCT should be considered under that separate listing.	No

D R A F T

4.2.3 Banksia Woodland Patch 3

Location	63 & 67 Brae Road, and 62, 70 & 78 Brand Road.
Key diagnostic characteristics	Patch is dominated by *E. marginata* and *A. fraseriana* with some areas of *B. menziesii* and very low percent cover of *B. attenuata*.
Condition	Patch is considered in Very Good condition. Species richness was 83 plants/5 sample points. Using quadrat data only, mean species richness was 38 species/quadrat. This is moderate compared to FCT20a at 67.4 species/quadrat. Weeds predominantly below 1% with the exception of one degraded area where Veldt Grass was recorded at 20% cover.
Patch size	2.76 ha
Additional features	Supports population of Threatened *Conospermum undulatum*. Provides linkage from this patch to the adjacent patch (patch 4) separated by degraded vegetation.
Land use history	Unknown.
Any variations in patch	Edge effects have caused minor degradation on edge of Excellent condition vegetation. Patch is represented by all three Banksia woodland communities. Variation is evident in density of *E. marginata, A. fraseriana,* and *Banksia* trees and large variation in understorey dominance between sedges and shrubs.
Buffer zone present	No buffer zone present with the exception of planted road verge and adjacent private property gardens.
Sampling protocol	Patch 3 is represented by thee quadrats including HW9, HW10 and HW11, and two relevés HW14r and HW15r. The quadrats and relevés were scored/sampled once in November 2016.
Disturbance history	Unknown.
Surrounding environment	Patch of vegetation is adjacent to planted gardens, housing infrastructure and roads. In close proximity to Poison Gully riparian vegetation.

Key diagnostic characteristics	**Response**
Location and physical environment	
Patch on Swan Coastal Plain or adjacent lower parts of the Darling and Whicher escarpments that lie within the Jarrah Forest bioregion to the immediate east and south of the Swan Coastal Plain.	Swan Coastal Plain
Soils and landform	
Typically occurs on: deep Bassendean, Spearwood sands, occasionally on Quindalup sands, sandy colluvium and Aeolian sands of the Ridge Hill Shelf, Whicher Scarp and Dandaragan Plateau. Sometimes on transitional substrates, sandflats.	Forrestfield Complex, on the foothills.

D R A F T

Key diagnostic characteristics	Response
Structure: The structure of the ecological community is a low woodland to forest with the following features:	
Distinctive upper sclerophyllous layer of low trees typically dominated or co-dominated by one or more of the *Banksia* species identified below; AND Emergent trees *Eucalyptus* or *Allocasuarina* species may sometimes be present above the *Banksia* canopy; AND Highly species-rich understorey that consists of a layer of sclerophyllous shrubs of various heights and a herbaceous ground layer of cord rushes, sedges and perennial and ephemeral forbs that sometimes includes grasses.	Dominated by *E. marginata* (8-40% at all sample points) and *A. fraseriana* (3-15% at all sample points) with *B. menziesii* (2-10% at two sample points) and some *B. attenuata* (5-8% at two sample points). Understorey is comprised of 38 sclerophyllous shrubs, ten rushes and sedges of variable dominance, and 28 herbs all less than 2% cover.
Composition	
Canopy is most commonly dominated or co-dominated by *Banksia attenuata* and/or *Banksia menziesii.* Other *Banksia* species that dominate in some examples of the ecological community are *B. prionotes* or *B. ilicifolia*; AND Must include at least one of the following diagnostic species: · *Banksia attenuata* · *Banksia menziesii* · *Banksia prionotes* · *Banksia ilicifolia* Emergent tree layer often includes *Corymbia calophylla, E. marginata,* or less commonly *E. gomphocephala*; AND Other trees of a medium height may be present and may be co-dominant with the *Banksia* species across a patch, include *E. todtiana, Nuytsia floribunda, Allocasuarina fraseriana, Callitris arenaria, Callitris pyramidalis* and *Xylomelum occidentale*; AND	Canopy is dominated by *E. marginata* and *A. fraseriana* at all four sample point locations with patches of relevant *Banksia* species in two of the four sample point locations.
Contra-indicators	
Patches clearly dominated by *Banksia littoralis* are not part of the TEC	No
Patches clearly dominated by *Banksia burdettii* are not the TEC	No
FCT20c – Eastern shrublands and woodlands, corresponds with a separate EPBC ecological community listing, Shrublands and Woodlands of the eastern Swan Coastal Plain. Occurrences of this FCT should be considered under that separate listing.	No

D R A F T

4.2.4 Banksia Woodland Patch 4

Location	Patch 4 is nestled between Brae Road, Brand Road, and Sultana Road West.
Key diagnostic characteristics	Overstorey is dominated by *E. marginata* and *A. fraseriana* with 0-15% of *Banksia* species present.
Condition	Patch condition is Very Good to Excellent with low species richness accounting for the lower score. There are 80 species within the patch represented by four sample point locations. Mean species richness is 40 species/quadrat which is moderate compared to FCT20a with 67.4 species/quadrat. Species richness may be higher with another quadrat scoring event. Weed cover is less than 5%.
Patch size	7.00 ha
Additional features	Supports population of Threatened *Conospermum undulatum*. Provides linkage between patch 2, 3 and 5. Plays important habitat corridor role for Bush Forever block located nearby and Poison Gully riparian vegetation.
Land use history	Unknown. Semi-rural development in area has created isolated 'backyard' patches of native vegetation separated by firebreaks, fences, roads and backyards.
Any variations in patch	Highly variable condition reflecting landowner maintenance, historical clearing and low-level grazing from livestock. Firebreaks are prone to erosion as highly mobile sand is exposed, exacerbating degradation in some localised areas. Weed invasion is also significant in some areas.
Buffer zone present	No buffer zone is present.
Sampling protocol	Patch is represented by two quadrats (HW13, HW16) and two relevés (HW12r, HW18r). All sample point locations were subject to one scoring event in November 2016.
Disturbance history	Unknown.
Surrounding environment	The area is surrounded by private properties which include some areas of native vegetation and planted gardens as well as infrastructure.

Key diagnostic characteristics	**Response**
Location and physical environment	
Patch on Swan Coastal Plain or adjacent lower parts of the Darling and Whicher escarpments that lie within the Jarrah Forest bioregion to the immediate east and south of the Swan Coastal Plain.	Swan Coastal Plain
Soils and landform	
Typically occurs on: deep Bassendean, Spearwood sands, occasionally on Quindalup sands, sandy colluvium and Aeolian sands of the Ridge Hill Shelf, Whicher Scarp and Dandaragan Plateau. Sometimes on transitional substrates, sandflats.	Crosses from Southern River Complex onto Forrestfield Complex.

D R A F T

Key diagnostic characteristics	Response
Structure: The structure of the ecological community is a low woodland to forest with the following features:	
Distinctive upper sclerophyllous layer of low trees typically dominated or co-dominated by one or more of the *Banksia* species identified below; AND Emergent trees *Eucalyptus* or *Allocasuarina* species may sometimes be present above the *Banksia* canopy; AND Highly species-rich understorey that consists of a layer of sclerophyllous shrubs of various heights and a herbaceous ground layer of cord rushes, sedges and perennial and ephemeral forbs that sometimes includes grasses.	Dominated by *E. marginata* (8-40%, all sample locations) and *A. fraseriana* (3-15%, all sample locations) with *B. menziesii* (0-10%, two sample locations) and some *B. attenuata* (0-8%, two sample locations). Understorey is comprised of 36 sclerophyllous shrubs, 11 rushes and sedges of variable dominance, and 24 herbs.
Composition	
Canopy is most commonly dominated or co-dominated by *Banksia attenuata* and/or *Banksia menziesii.* Other *Banksia* species that dominate in some examples of the ecological community are *B. prionotes* or *B. ilicifolia*; AND Must include at least one of the following diagnostic species: · *Banksia attenuata* · *Banksia menziesii* · *Banksia prionotes* · *Banksia ilicifolia* Emergent tree layer often includes *Corymbia calophylla, E. marginata,* or less commonly *E. gomphocephala*; AND Other trees of a medium height may be present and may be co-dominant with the *Banksia* species across a patch, include *E. todtiana, Nuytsia floribunda, Allocasuarina fraseriana, Callitris arenaria, Callitris pyramidalis* and *Xylomelum occidentale*.	Canopy is dominated by *E. marginata* and *A. fraseriana* with patches of relevant *Banksia* species at two of the four sample point locations.
Contra-indicators	
Patches clearly dominated by *Banksia littoralis* are not part of the TEC	No
Patches clearly dominated by *Banksia burdettii* are not the TEC	No
FCT20c – Eastern shrublands and woodlands, corresponds with a separate EPBC ecological community listing, Shrublands and Woodlands of the eastern Swan Coastal Plain. Occurrences of this FCT should be considered under that separate listing.	No

D R A F T

4.2.5 Banksia Woodland Patch 5

Location	Patch 5 is located on the north side of Brae Road between Sultana Road West and Stewart Road.
Key diagnostic characteristics	Meets most key diagnostic criteria. As with all other patches in this area, the overstorey is dominated by *E. marginata* with minor areas of *Banksia* if present at all.
Condition	Condition is considered Very Good. Despite the low species richness, this is a direct reflection of sample effort rather than condition of the patch. Species richness is 32 species/quadrat, considered moderate to low compared to FCT20a with 67.4 species/quadrat. Additional quadrats in the patch in Excellent condition vegetation and more scoring events may influence this assessment. Weeds represent less than 3% of total foliage cover, taking into account the quadrat was located away from the edge of the patch.
Patch size	1.08 ha
Additional features	Represents extension of habitat corridor/area between Bush Forever Site, other patches of native vegetation, and Poison Gully.
Land use history	Unknown. Partial clearing for housing and associated infrastructure.
Any variations in patch	Significant variation in condition of native vegetation reflecting landowner use of area and land use history.
Buffer zone present	No buffer zone present.
Sampling protocol	Patch represented by one quadrat, HW17, sampled once in November 2016. Low representation of patch in suitable quadrats is likely to have affected the assessment.
Disturbance history	Unknown.
Surrounding environment	Surrounded by semi-rural urbanisation including gardens, paddocks with livestock, housing and a road.

Key diagnostic characteristics	**Response**
Location and physical environment	
Patch on Swan Coastal Plain or adjacent lower parts of the Darling and Whicher escarpments that lie within the Jarrah Forest bioregion to the immediate east and south of the Swan Coastal Plain.	Swan Coastal Plain
Soils and landform	
Typically occurs on: deep Bassendean, Spearwood sands, occasionally on Quindalup sands, sandy colluvium and Aeolian sands of the Ridge Hill Shelf, Whicher Scarp and Dandaragan Plateau. Sometimes on transitional substrates, sandflats.	Southern River Complex.

D R A F T

Key diagnostic characteristics	Response
Structure: The structure of the ecological community is a low woodland to forest with the following features:	
Distinctive upper sclerophyllous layer of low trees typically dominated or co-dominated by one or more of the *Banksia* species identified below; AND Emergent trees *Eucalyptus* or *Allocasuarina* species may sometimes be present above the *Banksia* canopy; AND Highly species-rich understorey that consists of a layer of sclerophyllous shrubs of various heights and a herbaceous ground layer of cord rushes, sedges and perennial and ephemeral forbs that sometimes includes grasses.	Patch is dominated by *E. marginata* and *A. fraseriana* with occasional *Banksia* species. Undesrtorey includes 12 sclerophyllous shrubs, 12 herbs and three sedges. Additional survey effort is likely to increase these numbers.
Composition	
Canopy is most commonly dominated or co-dominated by *Banksia attenuata* and/or *Banksia menziesii.* Other *Banksia* species that dominate in some examples of the ecological community are *B. prionotes* or *B. ilicifolia*; AND Must include at least one of the following diagnostic species: · *Banksia attenuata* · *Banksia menziesii* · *Banksia prionotes* · *Banksia ilicifolia* Emergent tree layer often includes *Corymbia calophylla, E. marginata,* or less commonly *E. gomphocephala*; AND Other trees of a medium height may be present and may be co-dominant with the *Banksia* species across a patch, include *E. todtiana, Nuytsia floribunda, Allocasuarina fraseriana, Callitris arenaria, Callitris pyramidalis* and *Xylomelum occidentale*; AND	No, the canopy is dominated by *E. marginata* and *A. fraseriana.*
Contra-indicators	
Patches clearly dominated by *Banksia littoralis* are not part of the TEC	No
Patches clearly dominated by *Banksia burdettii* are not the TEC	No
FCT20c – Eastern shrublands and woodlands, corresponds with a separate EPBC ecological community listing, Shrublands and Woodlands of the eastern Swan Coastal Plain. Occurrences of this FCT should be considered under that separate listing.	No

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LEGEND
Survey Area
Banksia Woodlands of the Swan Coastal Plain
Excellent Condition
Very Good Condition
Good Condition

Threatened Ecological Communities

SHIRE OF KALAMUNDA

FORRESTFIELD NORTH

Figure 2

Map Document: \\AUPER1FP001.AU.AECOMNET.COM\Projects\605X\605273041. Tech Work Area\4.99 GIS\02_MXDs\Forrestfield_North_Jan2016\G60527304_Fig2_ThreatenedCommunities_v5_A4.mxd (fotheringhamd)

A4 size

D R A F T

5.0 Conclusion

The native vegetation mapped as Woodlands in Good or better condition within the Forrestfield North survey area represents the Federally listed Banksia Woodlands of the Swan Coastal Plain. This community extends for 15.30 ha and is considered in Very Good to Excellent condition in accordance with the Banksia Woodlands key diagnostic criteria.

This outcome is further supported by the FCT analysis which showed all quadrats within the survey area represent FCT20a Banksia Woodlands over Species-rich Dense Shrublands. This community is listed as Endangered by DBCA and under the EPBC Act. This is at odds with the desktop study which also showed a considerable presence of the Priority 3 community (as listed by DBCA) named Banksia Dominated Woodlands of the SCP. This community is not associated with a particular FCT and its diagnostic features are undefined.

The similarity of survey quadrats to the SCP dataset was moderate, at 32-52% similarity to SCP quadrats representing FCT20a. This low similarity is likely a factor of survey effort and timing. The description of FCT20a, its known location, and identifying features as published in Gibson *et al.* (1994) match the description of the three Woodlands mapped within the survey area.

D R A F T

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D R A F T

Appendix A

Quadrat Data

Plot Data

Site No: HW01	**Type: Quadrat**	**Longitude: 116.009195**	**Latitude: -31.96267**
Date: 11/22/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: AfHhMp		Fire History: 10+	
Vegetation Condition: E. Edge Effect			





Taxon	Cons. Code	Height (cm)	% Alive
Adenanthos cygnorum subsp. *cygnorum*		250	2
Aira caryophyllea	*	10	0.1
Alexgeorgea nitens		5	2
Allocasuarina fraseriana		800	10 in landscape
Allocasuarina humilis			Oppo
Anigozanthos manglesii		60	0.3
Banksia attenuata			Oppo
Banksia dallanneyi var. *dallanneyi*		10	3
Banksia menziesii		500	2
Bossiaea eriocarpa		20	0.3
Briza maxima	*	30	0.5
Burchardia congesta		30	0.2
Caesia micrantha		70	0.1
Calothamnus torulosus			Oppo
Caustis dioica			Oppo
Conospermum undulatum			
Conostephium pendulum			Oppo
Dampiera linearis		15	0.1
Dasypogon obliquifolius		30	1
Daviesia divaricata			Oppo
Daviesia nudiflora subsp. *nudiflora*		50	0.3
Desmocladus fasciculatus		5	0.1
Ehrharta calycina	*	100	0.3
Eucalyptus marginata subsp. *marginata*		1200	8 in landscape
Gastrolobium capitatum		40	0.1
Gladiolus caryophyllaceus	*	50	0.5
Gompholobium knightianum		2	0.1
Gompholobium tomentosum			Oppo
Haemodorum laxum		120	0.5
Hakea conchifolia			Oppo
Hakea incrassata			Oppo
Hibbertia hypericoides		30	2
Hypochaeris glabra	*	30	0.1
Jacksonia floribunda			Oppo
Lambertia multiflora		100	2
Lepidosperma leptostachyum		80	0.2

Taxon	Cons. Code	Height (cm)	% Alive
Levenhookia pusilla		5	0.1
Lomandra preissii		40	0.3
Lomandra sericea		30	0.1
Lomandra suaveolens		10	0.1
Melaleuca trichophylla		40	4
Mesomelaena pseudostygia		30	10
Mesomelaena tetragona		50	1
Nuytsia floribunda			Oppo
Opercularia vaginata		15	2
Patersonia occidentalis			Oppo
Petrophile macrostachya			Oppo
Petrophile linearis		40	0.5
Philotheca spicata			Oppo
Phyllanthus calycinus			Oppo
Pimelea ciliata subsp. *ciliata*			Oppo
Rhodanthe citrina		10	0.1
Scaevola canescens		3	0.2
Scaevola repens var. *repens*		15	3
Schoenus brevisetis		30	8
Stirlingia latifolia			Oppo
Stylidium diuroides subsp. *diuroides*		10	0.1
Isopogon drummondii	P3	100	0.5
Boronia ramosa subsp. *anethifolia*		30	0.2
Synaphea sp.			Oppo
Tetraria octandra		30	6
Trachymene pilosa		4	0.1
Tricoryne elatior		25	0.2
Tricostularia exsul		80	0.5
Ursinia anthemoides	*	20	0.1
Xanthorrhoea acanthostachya		100	8
Xanthorrhoea preissii			Oppo
Xanthosia huegelii		10	0.1

Site No: HW02	Type: Quadrat	Longitude: 116.009435	Latitude: -31.962045
Date: 11/23/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: EmAcMt		Fire History: 10+	
Vegetation Condition: E. Rubbish, Edge effect			





Taxon	Cons. Code	Height (cm)	% Alive
Adenanthos cygnorum subsp. *cygnorum*		350	6
Allocasuarina humilis		60	2
Astroloma stomarrhena		5	0.1
Banksia dallanneyi var. *dallanneyi*		30	2
Banksia menziesii		500	6
Bossiaea eriocarpa		15	0.2
Briza maxima	*	30	0.1
Burchardia congesta		30	0.1
Caesia micrantha			oppo
Caladenia sp.		5	0.1
Calothamnus torulosus		40	0.2
Conospermum undulatum		160	0.3
Conostylis aurea		20	0.1
Conostylis serrulata			oppo
Conostylis setigera		15	0.1
Conostylis setosa			oppo
Cyathochaeta avenacea		100	1
Dasypogon bromeliifolius			oppo
Dasypogon obliquifolius		20	1
Daviesia angulata		100	0.6
Daviesia nudiflora subsp. *nudiflora*		40	0.3
Desmocladus fasciculatus		10	0.1
Desmocladus flexuosus		30	0.6
Eucalyptus marginata subsp. *marginata*		600	10
Gastrolobium capitatum		20	0.1
Gastrolobium capitatum		40	0.1
Gladiolus caryophyllaceus	*	50	0.1
Gompholobium tomentosum			oppo
Haemodorum laxum		140	1
Hemiphora bartlingii		20	0.1
Hibbertia hypericoides		30	6
Jacksonia lehmannii		40	0.1
Kennedia prostrata			oppo
Lambertia multiflora		80	1
Lepidosperma leptostachyum		60	1
Lomandra sericea		30	0.2
Lyginia barbata			oppo

Taxon	Cons. Code	Height (cm)	% Alive
Melaleuca trichophylla		40	6
Mesomelaena pseudostygia		50	15
Patersonia occidentalis		30	0.4
Petropile linearis		30	0.2
Pimelea ciliata subsp. *ciliata*		20	0.1
Scaevola repens var. *repens*		10	1
Stirlingia latifolia		50	0.3
Stylidium piliferum		10	0.1
Boronia ramosa subsp. *anethifolia*		30	0.1
Synaphea sp.		40	0.1
Tetraria octandra		60	15
Thysanotus arbuscula		30	0.1
Tricoryne elatior		30	0.1
Tricoryne elatior		30	1
Tricostularia exsul		100	3
Ursinia anthemoides	*	10	0.1
Vellereophyton dealbatum		5	0.1
Xanthorrhoea acanthostachya		230	0.5
Xanthorrhoea gracilis		60	5

Site No: HW03	Type: Quadrat	Longitude: 116.010158	Latitude: -31.960788
Date: 11/23/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: EmToDo		Fire History: 10+	
Vegetation Condition: E. Weeds			





Taxon	Cons. Code	Height (cm)	% Alive
Alexgeorgea nitens		30	25
Allocasuarina fraseriana		250	2
Banksia attenuata		500	4
Banksia dallanneyi var. *dallanneyi*		20	2
Bossiaea eriocarpa		30	1.5
Briza maxima	*	30	0.2
Burchardia congesta		60	0.2
Calothamnus quadrifidus subsp. *quadrifidus*			oppo
Conospermum undulatum		50	0.2
Cyathochaeta avenacea		100	4
Dampiera alata		30	0.2
Dasypogon obliquifolius		30	0.2
Daviesia nudiflora subsp. *nudiflora*		40	0.5
Ehrharta calycina	*	100	0.4
Eragrostis curvula	*	130	1
Eucalyptus marginata subsp. *marginata*		1300	15
Gastrolobium capitatum		40	0.1
Gladiolus caryophyllaceus	*	80	0.1
Gompholobium confertum			oppo
Gompholobium knightianum		10	0.1
Haemodorum laxum		130	2
Hemiandra pungens		20	0.3
Jacksonia floribunda		40	0.2
Lepidosperma sp.		30	15
Lomandra sericea		30	0.2
Lomandra sericea		40	0.3
Melaleuca trichophylla		40	0.3
Petrophile linearis		50	0.1
Scaevola repens var. repens		10	4
Schoenus brevisetis		40	1
Stirlingia latifolia		50	0.6
Synaphea sp.		20	1
Thysanotus arbuscula		80	0.1
Tricoryne elatior		40	0.5
Xanthorrhoea preissii		100	5

Site No: HW04	Type: Quadrat	Longitude: 116.006648	Latitude: -31.962009
Date: 11/23/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: AfHhMp		Fire History: 10+	
Vegetation Condition: E.			





Taxon	Cons. Code	Height (cm)	% Alive
Adenanthos cygnorum subsp. *cygnorum*		350	15
Allocasuarina fraseriana		300	0.5
Allocasuarina humilis		70	1
Banksia attenuata		500	2
Banksia dallanneyi		30	0.2
Banksia dallanneyi var. *dallanneyi*		20	4
Banksia grandis		500	5
Bossiaea eriocarpa		30	0.4
Burchardia congesta		40	0.2
Caesia micrantha		70	0.1
Calothamnus torulosus		20	0.1
Calytrix sp.			Oppo
Conospermum undulatum		20	0.1
Conostylis juncea		5	0.1
Cyathochaeta avenacea		110	0.2
Dampiera linearis		5	0.1
Dasypogon bromeliifolius		50	3
Dasypogon obliquifolius		20	0.5
Daviesia nudiflora subsp. *nudiflora*		30	0.2
Desmocladus fasciculatus		10	0.1
Eucalyptus marginata subsp. *marginata*		1400	20
Gastrolobium capitatum		30	0.1
Gompholobium confertum			Oppo
Haemodorum laxum		20	0.1
Haemodorum spicatum		100	0.1
Hakea lissocarpha		80	0.5
Hemiphora bartlingii			Oppo
Hibbertia huegelii		20	0.1
Hibbertia hypericoides		40	4
Lambertia multiflora		90	0.5
Lomandra hermaphrodita		20	0.1
Lomandra sericea		30	0.1
Lyginia barbata		60	1
Melaleuca trichophylla		40	0.5
Mesomelaena tetragona		50	10
Patersonia occidentalis		40	0.5
Petrophile linearis		30	0.2

Taxon	Cons. Code	Height (cm)	% Alive
Petrophile macrostachya		50	0.4
Philotheca spicata		100	0.2
Scaevola repens var. *repens*		15	1
Stachystemon vermicularis		40	1
Stirlingia latifolia		50	1.5
Isopogon drummondii	P3	80	1
Thysanotus affinis		20	0.1
Tricoryne elatior		30	0.1
Tricostularia exsul		80	15
Xanthorrhoea acanthostachya		80	4
Xylomelum occidentale		30	0.1

Site No: HW05	Type: Releve	Longitude: 116.007014	Latitude: -31.962401
Date: 11/23/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition:	
Community: EmAcMt		Fire History:	
Vegetation Condition: VG.			





Taxon	Cons. Code	Height (cm)	% Alive
Adenanthos cygnorum subsp. *cygnorum*		400	25
Allocasuarina fraseriana		250	0.5
Allocasuarina humilis		80	0.5
Bossiaea eriocarpa		30	0.2
Conospermum undulatum			Oppo
Cyathochaeta avenacea		120	0.5
Dampiera linearis		10	0.1
Dasypogon obliquifolius		40	0.1
Daviesia nudiflora subsp. *nudiflora*			Oppo
Eremaea pauciflora var. *pauciflora*		50	0.5
Eucalyptus marginata subsp. *marginata*		300	1
Gompholobium confertum		20	0.1
Gompholobium tomentosum		40	0.3
Haemodorum laxum			Oppo
Hemiphora bartlingii		30	0.2
Hibbertia hypericoides		30	1
Johnsonia pubescens subsp. *pubescens*			Oppo
Kunzea glabrescens		250	1
Lambertia multiflora		100	0.5
Lyginia barbata		50	0.2
Lysinema pentapetalum			Oppo
Petrophile linearis			Oppo
Schoenus brevisetis			Oppo
Stirlingia latifolia		40	0.5
Isopogon drummondii	P3	60	0.4
Synaphea sp.			Oppo
Tricostularia exsul		100	20
Xanthorrhoea preissii		80	3

Site No: HW06	Type: Quadrat	Longitude: 116.007671	Latitude: -31.961865
Date: 11/23/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: AfHhMp		Fire History: 10+	
Vegetation Condition: E.			





Taxon	Cons. Code	Height (cm)	% Alive
Allocasuarina fraseriana		700	8
Allocasuarina humilis		60	2
Banksia attenuata		500	8
Banksia dallanneyi var. *dallanneyi*		10	1
Banksia menziesii		400	3
Bossiaea eriocarpa		30	0.2
Briza maxima	*	30	0.1
Burchardia congesta		40	0.1
Calothamnus torulosus		30	1
Caustis dioica		40	0.3
Conostephium pendulum		40	0.1
Cyathochaeta avenacea		100	0.5
Dasypogon bromeliifolius		30	0.5
Dasypogon obliquifolius		30	2
Daviesia nudiflora subsp. *nudiflora*		50	0.2
Ehrharta calycina	*	100	4
Gastrolobium capitatum		20	0.1
Gladiolus caryophyllaceus	*	60	0.2
Gompholobium confertum		25	0.1
Gompholobium tomentosum		30	0.1
Haemodorum laxum		70	0.1
Hemiandra pungens		20	0.2
Hemiphora bartlingii		25	0.1
Hibbertia hypericoides		40	2
Lepidosperma leptostachyum		60	1
Mesomelaena pseudostygia		30	5
Petrophile macrostachya		40	0.3
Petrophile rigida		40	0.2
Scaevola repens var. *repens*		10	0.2
Schoenus brevisetis		40	1
Isopogon drummondii	P3	100	3
Tricoryne elatior		30	0.1
Tricostularia exsul		60	1
Xanthorrhoea preissii		100	6

Site No: HW07	Type: Quadrat	Longitude: 115.995246	Latitude: -31.952148
Date: 11/23/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: White	
Rocky Type:		Soil Condition: Dry	
Community: VdCd		Fire History: 10+	
Vegetation Condition: VG.			





Taxon	Cons. Code	Height (cm)	% Alive
Alexgeorgea nitens		15	0.2
Anigozanthos manglesii		30	0.3
Banksia dallanneyi var. *dallanneyi*		10	0.2
Briza maxima	*	30	0.1
Caesia micrantha		25	0.1
Caustis dioica		30	2
Conostylis juncea		20	0.1
Cyathochaeta avenacea		120	0.5
Dasypogon bromeliifolius			Oppo
Daviesia angulata		60	0.3
Ehrharta calycina	*	120	0.3
Eucalyptus marginata subsp. *marginata*		2000	2
Gladiolus caryophyllaceus	*	40	0.1
Grevillea bipinnatifida subsp. *bipinnatifida*		40	0.3
Haemodorum spicatum		100	1
Hypocalymma angustifolium			Oppo
Hypolaena exsulca		25	0.1
Jacksonia lehmannii		15	0.1
Lomandra micrantha		25	0.1
Lyginia barbata		50	1
Mesomelaena tetragona		60	0.5
Patersonia occidentalis		40	1
Pentameris airoides subsp. *airoides*	*	20	0.5
Scaevola canescens		10	0.1
Schoenus brevisetis		50	1
Stirlingia latifolia		60	2
Boronia ramosa subsp. *anethifolia*		20	0.1
Tricoryne elatior		30	0.2
Ursinia anthemoides	*	15	1
Verticordia densiflora var. *densiflora*		50	6
Xanthorrhoea preissii		70	0.5

Site No: HW08	Type: Quadrat	Longitude: 115.995632	Latitude: -31.953041
Date: 11/23/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: VdCd		Fire History: 10+	
Vegetation Condition: E.			





Taxon	Cons. Code	Height (cm)	% Alive
Agrostocrinum scabrum		30	0.1
Allocasuarina humilis		60	1
Anigozanthos manglesii		60	0.2
Babingtonia camphorosmae		30	0.2
Banksia dallanneyi var. *dallanneyi*		20	0.1
Bossiaea eriocarpa		30	0.2
Briza maxima	*	30	0.2
Burchardia congesta		40	0.2
Caustis dioica		50	10
Cheiranthera preissiana			0.1
Conostylis aurea		15	0.2
Dasypogon bromeliifolius		30	1
Daviesia angulata		90	8
Daviesia preissii			Oppo
Desmocladus fasciculatus		10	0.1
Eucalyptus marginata subsp. *marginata*		2500	5
Gastrolobium capitatum		20	0.2
Gladiolus caryophyllaceus	*	40	0.2
Goodenia caerulea		15	0.1
Grevillea bipinnatifida subsp. *bipinnatifida*		30	0.6
Haemodorum laxum		80	0.1
Hibbertia hypericoides		50	0.4
Hyalosperma cotula		10	0.1
Hypocalymma angustifolium		50	3
Hypolaena exsulca		20	0.4
Hypolaena exsulca		30	0.2
Lyginia barbata		40	1
Mesomelaena tetragona		70	3
Patersonia occidentalis		30	2
Philotheca spicata		60	0.3
Scaevola repens var. *repens*		10	0.2
Stirlingia latifolia		50	0.5
Boronia ramosa subsp. *anethifolia*		20	0.1

Taxon	Cons. Code	Height (cm)	% Alive
Tetraria octandra		40	2
Thysanotus patersonii			0.1
Tricoryne elatior		20	0.6
Verticordia densiflora var. *densiflora*		50	1
Xanthorrhoea preissii		80	2
Xanthosia huegelii		15	0.2

Site No: HW09	Type: Quadrat	Longitude: 116.007428	Latitude: -31.956075
Date: 11/23/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: AfHhMp		Fire History: 10+	
Vegetation Condition:			





Taxon	Cons. Code	Height (cm)	% Alive
Acacia pulchella var. pulchella		80	0.6
Adenanthos cygnorum subsp. *cygnorum*		200	
Alexgeorgea nitens		10	0.2
Allocasuarina fraseriana		600	10
Allocasuarina humilis			Oppo
Anigozanthos manglesii		60	0.2
Avena barbata	*		Oppo
Banksia armata var. *armata*			Oppo
Banksia attenuata		400	
Banksia dallanneyi var. *dallanneyi*		20	1
Bossiaea eriocarpa		40	2
Briza maxima	*	20	0.2
Burchardia congesta		50	0.2
Caesia micrantha			Oppo
Calothamnus torulosus		30	0.2
Caustis dioica		50	8
Conostephium pendulum			Oppo
Conostylis setigera		15	0.1
Cyathochaeta avenacea		110	0.4
Dampiera linearis		15	0.1
Dasypogon obliquifolius		30	0.5
Daviesia angulata		60	0.4
Daviesia nudiflora subsp. *nudiflora*			Oppo
Desmocladus fasciculatus		10	1
Ehrharta calycina	*		Oppo
Gastrolobium capitatum		30	0.5
Gladiolus caryophyllaceus	*	50	0.2
Haemodorum laxum		130	2
Haemodorum spicatum			Oppo
Hakea conchifolia		60	0.4
Hemiandra linearis			Oppo
Hemiphora bartlingii			Oppo
Hibbertia hypericoides		60	20
Jacksonia lehmannii		25	0.1
Lambertia multiflora		150	8
Lechenaultia biloba			Oppo
Lepidosperma leptostachyum		40	0.5

Taxon	Cons. Code	Height (cm)	% Alive
Lomandra sericea		30	0.4
Lyginia barbata		40	0.2
Mesomelaena pseudostygia		50	6
Mesomelaena tetragona		50	2
Monotaxis grandiflora var. *grandiflora*			Oppo
Nuytsia floribunda		700	2
Patersonia occidentalis			Oppo
Petrophile macrostachya		50	0.8
Philotheca spicata		60	0.2
Pimelea ciliata subsp. *ciliata*		50	0.1
Scaevola repens var. *repens*		10	0.2
Schoenus brevisetis		40	0.4
Stylidium piliferum		10	0.1
Isopogon drummondii	P3		Oppo
Synaphea sp.			Oppo
Thomasia macrocarpa			Oppo
Thysanotus arbuscula		20	0.2
Vellereophyton dealbatum		5	0.1
Xanthorrhoea preissii		120	1

Site No: HW10	Type: Quadrat	Longitude: 116.008553	Latitude: -31.957151
Date: 11/23/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: EmAcMt		Fire History: 10+	
Vegetation Condition: E.			





Taxon	Cons. Code	Height (cm)	% Alive
Acacia pulchella var. *pulchella*		100	1.5
Alexgeorgea nitens		10	0.2
Allocasuarina humilis		80	4
Banksia armata var. *armata*			Oppo
Banksia attenuata		400	1
Banksia dallanneyi var. *dallanneyi*		10	1
Banksia menziesii		500	15
Banksia sphaerocarpa		40	1
Bossiaea eriocarpa		30	0.5
Briza maxima	*	30	0.1
Burchardia congesta		40	0.1
Calothamnus torulosus			
Conospermum undulatum		80	0.2
Conostephium pendulum		50	0.2
Conostylis aurea			Oppo
Dasypogon obliquifolius		20	1
Daviesia nudiflora subsp. *nudiflora*		40	0.2
Desmocladus fasciculatus		10	0.1
Eremaea pauciflora var. *pauciflora*		40	2
Eucalyptus marginata subsp. *marginata*		2000	10
Gastrolobium capitatum			Oppo
Gladiolus caryophyllaceus	*	40	0.2
Haemodorum laxum			Oppo
Haemodorum sp.		10	0.1
Hemiandra pungens			Oppo
Hibbertia hypericoides		40	8
Jacksonia floribunda		50	0.2
Lambertia multiflora		100	2
Lepidosperma leptostachyum		40	2
Leucopogon sp.		40	0.1
Lomandra sericea		30	0.1
Lyginia barbata		40	1
Melaleuca trichophylla		40	3
Mesomelaena pseudostygia		40	1
Monotaxis grandiflora var. *grandiflora*		5	0.2
Patersonia occidentalis			Oppo
Petrophile macrostachya		50	1.5

Taxon	Cons. Code	Height (cm)	% Alive
Scaevola repens var. *repens*		15	0.3
Stirlingia latifolia		40	1
Isopogon drummondii	P3	80	3
Synaphea sp.		50	0.5
Tricoryne elatior		30	0.7
Tricostularia exsul		40	10
Xanthorrhoea preissii		90	1

Site No: HW11	Type: Releve	Longitude: 116.009061	Latitude: -31.957063
Date: 11/23/2016		Soil Types:	
Topography: Flat		Soil Colour:	
Rocky Type:		Soil Condition:	
Community: EmToDo		Fire History:	
Vegetation Condition: E.			





Taxon	Cons. Code	Height (cm)	% Alive
Allocasuarina fraseriana		1300	15
Allocasuarina humilis		60	0.5
Banksia sphaerocarpa		50	0.5
Bossiaea eriocarpa		30	1
Burchardia congesta		40	0.3
Cheiranthera preissiana			0.1
Eucalyptus marginata subsp. *marginata*		1600	20
Gladiolus caryophyllaceus	*	40	0.1
Gompholobium knightianum		40	0.1
Hakea conchifolia		70	0.2
Hemiandra pungens			Oppo
Lyginia barbata			Oppo
Mesomelaena pseudostygia		40	10
Nuytsia floribunda		200	1
Patersonia occidentalis		30	1
Petrophile macrostachya		200	1
Scaevola repens var. *repens*		10	0.5
Tetraria octandra		30	20
Xanthorrhoea preissii		90	2

Site No: HW12r	Type: Releve	Longitude: 116.005128	Latitude: -31.960586
Date: 11/28/2016		Soil Types: Loam sand	
Topography: Flat		Soil Colour: Dark Brown	
Rocky Type:		Soil Condition: Dry	
Community: EmToDo		Fire History: 10+	
Vegetation Condition: VG.			





Taxon	Cons. Code	Height (cm)	% Alive
Acacia sp.	Pl		Oppo
Adenanthos cygnorum subsp. *cygnorum*			Oppo
Allocasuarina fraseriana		400	10
Allocasuarina humilis			Oppo
Asteraceae (planted)	Pl	60	2
Banksia attenuata		350	8
Banksia dallanneyi		30	4
Banksia grandis		60	0.1
Banksia menziesii		400	2
Banksia sessilis var. *sessilis*			Oppo
Briza maxima	*	40	2
Conostephium pendulum			Oppo
Dampiera linearis		20	0.2
Dasypogon bromeliifolius		30	0.2
Dasypogon obliquifolius			Oppo
Desmocladus fasciculatus			Oppo
Eucalyptus marginata subsp. *marginata*		700	40
Haemodorum laxum			Oppo
Hibbertia hypericoides			Oppo
Hypochaeris glabra	*		0.5
Lambertia multiflora			Oppo
Lepidosperma leptostachyum		40	2
Mesomelaena tetragona			Oppo
Patersonia occidentalis		40	0.2
Persoonia elliptica		400	3
Petrophile macrostachya			Oppo
Stirlingia latifolia		40	0.2
Isopogon drummondii	P3	80	0.2
Tetraria octandra		40	10
Tricostularia exsul			Oppo
Xanthorrhoea preissii		100	0.5

Site No: HW13	Type: Quadrat	Longitude: 116.006285	Latitude: -31.959895
Date: 11/28/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: EmToDo		Fire History: 10+	
Vegetation Condition: E.			





Taxon	Cons. Code	Height (cm)	% Alive
Allocasuarina fraseriana		400	15
Banksia dallanneyi var. *dallanneyi*		30	10
Banksia grandis			Oppo
Bossiaea eriocarpa		40	1
Briza maxima	*	30	3
Burchardia congesta		40	0.2
Conospermum undulatum		100	0.4
Conostephium pendulum		40	0.1
Cyathochaeta avenacea		70	0.2
Dampiera alata		20	0.1
Dampiera linearis		15	0.2
Dasypogon obliquifolius		40	2
Daviesia divaricata		20	0.1
Daviesia nudiflora subsp. *nudiflora*		50	0.3
Desmocladus fasciculatus		10	1
Ehrharta calycina	*	80	0.1
Eucalyptus marginata subsp. *marginata*		1800	10
Gladiolus caryophyllaceus	*	60	0.1
Gompholobium knightianum		20	0.2
Gompholobium tomentosum		40	0.2
Haemodorum laxum		100	0.2
Hakea conchifolia			Oppo
Hemiandra pungens		20	1
Hemiphora bartlingii			Oppo
Hibbertia hypericoides		20	0.5
Lambertia multiflora		160	8
Lechenaultia biloba		5	0.1
Lepidosperma leptostachyum		50	2
Leucopogon ?conostephioides		30	0.2
Lomandra preissii		20	0.1
Lyginia barbata		40	0.5
Melaleuca trichophylla		50	0.5
Mesomelaena pseudostygia		40	4
Mesomelaena tetragona		40	0.5
Monotaxis grandiflora var. *grandiflora*		20	0.1
Opercularia vaginata		30	0.1
Patersonia occidentalis		30	0.2

Taxon	Cons. Code	Height (cm)	% Alive
Persoonia elliptica			Oppo
Petrophile linearis		15	0.2
Pimelea ciliata subsp. *ciliata*		30	0.2
Scaevola repens var. *repens*		10	0.2
Stirlingia latifolia			Oppo
Boronia ramosa subsp. *anethifolia*		20	0.1
Synaphea sp.		30	0.3
Tetraria octandra		40	8
Tricoryne elatior		20	0.2
Tricostularia exsul		60	2
Vellereophyton dealbatum		5	0.1
Xanthorrhoea acanthostachya		70	0.3
Xanthorrhoea preissii		80	8

Site No: HW14r	Type: Releve	Longitude: 116.007548	Latitude: -31.958775
Date: 11/29/2016		Soil Types:	
Topography: Flat		Soil Colour:	
Rocky Type:		Soil Condition:	
Community: EmAcMt		Fire History:	
Vegetation Condition: G.			





Taxon	Cons. Code	Height (cm)	% Alive
Adenanthos cygnorum subsp. *cygnorum*		350	15
Alexgeorgea nitens			Oppo
Allocasuarina fraseriana			Oppo
Allocasuarina humilis		40	0.2
Amphipogon strictus		20	0.5
Banksia attenuata			Oppo
Banksia dallanneyi var. *dallanneyi*		20	0.5
Banksia menziesii		400	5
Billardiera fraseri			0.2
Briza maxima	*	30	5
Cyathochaeta avenacea		130	0.3
Dasypogon obliquifolius			Oppo
Daviesia preissii		60	0.2
Desmocladus fasciculatus			Oppo
Ehrharta calycina	*	100	20
Eremaea pauciflora var. *pauciflora*		30	5
Eucalyptus marginata subsp. *marginata*		700	5
Gladiolus caryophyllaceus	*		Oppo
Haemodorum spicatum		100	0.1
Lambertia multiflora		220	0.5
Lyginia barbata		40	0.5
Melaleuca trichophylla		40	6
Mesomelaena pseudostygia		50	3
Nuytsia floribunda		400	Oppo
Petrophile linearis			Oppo
Ptilotus manglesii		30	0.5
Stirlingia latifolia		40	2
Boronia ramosa subsp. *anethifolia*			Oppo
Tricoryne elatior		30	0.5
Ursinia anthemoides	*		Oppo
Vellereophyton dealbatum			Oppo
Xanthorrhoea preissii		70	1

Site No: HW15r	Type: Releve	Longitude: 116.008478	Latitude: -31.95808
Date: 11/29/2016		Soil Types:	
Topography: Flat		Soil Colour:	
Rocky Type:		Soil Condition: Dry	
Community: EmToDo		Fire History: 10+	
Vegetation Condition: E.			





Taxon	Cons. Code	Height (cm)	% Alive
Allocasuarina humilis		100	1
Banksia attenuata			Oppo
Banksia dallanneyi var. *dallanneyi*		20	5
Banksia menziesii			Oppo
Bossiaea eriocarpa		30	8
Burchardia congesta		60	0.1
Caustis dioica		30	1
Dasypogon obliquifolius		30	4
Desmocladus fasciculatus		20	0.2
Ehrharta calycina	*	80	1
Eucalyptus marginata subsp. *marginata*		800	25
Gastrolobium capitatum		40	0.2
Gladiolus caryophyllaceus	*	70	0.2
Gompholobium knightianum			Oppo
Hakea costata		220	0.5
Hibbertia hypericoides		30	0.5
Lambertia multiflora		160	1
Lepidosperma leptostachyum		60	2
Melaleuca trichophylla		40	2
Mesomelaena tetragona		50	10
Opercularia vaginata		30	0.3
Patersonia occidentalis		40	1
Petrophile macrostachya		100	1
Petrophile linearis			Oppo
Philotheca spicata		50	0.2
Schoenus brevisetis		30	1
Stirlingia latifolia		40	0.5
Tetraria octandra		30	1
Tricostularia exsul		60	1
Xanthorrhoea acanthostachya		100	1
Xanthorrhoea preissii		100	5

Site No: HW16	Type: Quadrat	Longitude: 116.004122	Latitude: -31.960853
Date: 11/29/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Grey	
Rocky Type:		Soil Condition: Dry	
Community: EmToDo		Fire History: 10+	
Vegetation Condition: E.			





Taxon	Cons. Code	Height (cm)	% Alive
Alexgeorgea nitens		10	0.2
Allocasuarina fraseriana		600	10
Allocasuarina humilis		40	0.2
Banksia attenuata		600	5
Banksia dallanneyi var. *dallanneyi*		20	5
Banksia menziesii		300	10
Bossiaea eriocarpa		30	3
Burchardia congesta		40	0.2
Caesia micrantha		30	0.1
Conostephium pendulum		30	0.2
Cyathochaeta avenacea		70	1
Dampiera linearis		20	0.5
Dasypogon obliquifolius		50	4
Daviesia nudiflora subsp. *nudiflora*			Oppo
Daviesia preissii			Oppo
Eucalyptus marginata subsp. *marginata*		800	8
Gastrolobium capitatum		30	1
Haemodorum laxum		80	0.2
Hemiandra pungens		20	2
Hemiphora bartlingii		20	0.3
Hibbertia hypericoides		40	4
Hypolaena exsulca		40	1
Lambertia multiflora		160	6
Lechenaultia biloba		10	0.1
Lomandra preissii		30	0.2
Mesomelaena tetragona		40	10
Patersonia occidentalis		30	0.5
Persoonia elliptica		400	0.5
Petrophile linearis		20	0.1
Pimelea ciliata subsp. *ciliata*		30	0.2
Scaevola repens var. *repens*		10	0.2
Schoenus brevisetis		30	1
Stachystemon vermicularis		60	3
Stirlingia latifolia		50	3
Isopogon drummondii	P3	60	0.5
Synaphea sp.			Oppo

Taxon	Cons. Code	Height (cm)	% Alive
Tetraria octandra		40	5
Thysanotus arbuscula		10	0.1
Tricostularia exsul		60	4
Xanthorrhoea preissii		100	8
Xylomelum occidentale		400	1.5

Site No: HW17	Type: Quadrat	Longitude: 116.001698	Latitude: -31.957207
Date: 11/29/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Dark Brown	
Rocky Type:		Soil Condition: Dry	
Community: EmToDo		Fire History: 10+	
Vegetation Condition: VG. Weeds, edge effect			





Taxon	Cons. Code	Height (cm)	% Alive
Allocasuarina fraseriana		600	10
Anigozanthos manglesii		100	0.2
Babingtonia camphorosmae		40	0.5
Banksia dallanneyi var. *dallanneyi*		30	8
Bossiaea eriocarpa		20	1
Briza maxima	*	30	1
Conospermum undulatum		130	0.3
Dampiera alata		10	0.2
Dampiera linearis		10	0.2
Dasypogon obliquifolius			Oppo
Daviesia preissii			Oppo
Ehrharta calycina	*	120	1
Eucalyptus marginata subsp. *marginata*		2000	20
Gastrolobium capitatum		30	1
Gladiolus caryophyllaceus	*	70	0.5
Haemodorum laxum		120	0.5
Hibbertia hypericoides		40	3
Lambertia multiflora		110	0.3
Lepidosperma leptostachyum		40	3
Lomandra sericea		30	0.2
Mesomelaena tetragona		40	4
Monotaxis grandiflora var. *grandiflora*		15	1
Opercularia vaginata		30	0.2
Persoonia elliptica		300	2
Scaevola repens var. *repens*		10	0.2
Stirlingia latifolia		40	1
Boronia ramosa subsp. *anethifolia*		10	0.3
Tetraria octandra		30	5
Thysanotus arbuscula		20	0.1
Tricoryne elatior		20	0.2
Xanthorrhoea gracilis		60	3
Xanthosia huegelii		30	0.3

Site No: HW18r	Type: Releve	Longitude: 116.006067	Latitude: -31.958544
Date: 11/30/2016		Soil Types: Sand	
Topography: Flat		Soil Colour: Medium Brown	
Rocky Type:		Soil Condition: Dry	
Community: EmToDo		Fire History: 10+	
Vegetation Condition: VG.			





Taxon	Cons. Code	Height (cm)	% Alive
Adenanthos cygnorum subsp. cygnorum		300	1
Allocasuarina fraseriana		500	3
Banksia armata var. armata		50	1
Banksia dallanneyi var. *dallanneyi*		20	0.5
Banksia menziesii			Oppo
Bossiaea eriocarpa		20	0.5
Briza maxima	*	40	0.5
Caustis dioica		30	0.4
Conostylis aurea		30	0.1
Cyathochaeta avenacea		120	0.5
Dasypogon obliquifolius		30	1
Daviesia nudiflora subsp. *nudiflora*		40	0.5
Desmocladus fasciculatus		10	0.1
Ehrharta calycina	*	80	4
Eucalyptus gomphocephala		1500	1
Eucalyptus marginata subsp. *marginata*		800	25
Gastrolobium capitatum		30	0.5
Gladiolus caryophyllaceus	*	100	0.3
Gompholobium knightianum		30	0.2
Haemodorum laxum		160	0.2
Haemodorum sp.		30	0.1
Hemiandra linearis		10	0.01
Hibbertia hypericoides		50	1
Lambertia multiflora		120	0.5
Lepidosperma leptostachyum		50	0.1
Lomandra preissii		30	0.5
Lyginia barbata		50	0.2
Mesomelaena pseudostygia		40	4
Microtis media		20	0.01
Patersonia occidentalis		40	0.2
Petrophile linearis		40	0.2
Scaevola repens var. *repens*			Oppo
Isopogon drummondii	P3	100	0.3

Taxon	Cons. Code	Height (cm)	% Alive
Tetraria octandra		40	5
Tricoryne elatior		30	0.1
Tricostularia exsul		80	8
Ursinia anthemoides	*	15	0.02
Verticordia densiflora var. *densiflora*		150	0.5
Xanthorrhoea preissii		100	4

APPENDIX 3

Quadrat Data

QUADRAT CR A

50 407070 E 6460160 N

Vegetation: *Hakea trifurcata/Leptospermum erubescens* Open Heath over *Mesomelaena tetragona* Low Shrubland
Condition: Excellent
Soil Type: Hard gravel
Landform: Flat



QUADRAT (10 x 10m)

SPECIES	HEIGHT (m)	COVER (%)
Corymbia calophylla	28	2
Hakea trifurcata	1.8	20
Leptospermum erubescens	1.6	20
Grevillea bipinnatifida	0.8	<1
**Gladiolus caryophyllaceus*	0.6	<1
**Ehrharta calycina*	0.6	<1
Mesomelaena tetragona	0.4	20
Hypocalymma angustifolium	0.4	4
Verticordia huegelii	0.4	2
Thelymitra crinita	0.4	<1
Cyathochaeta avenacea	0.4	<1
Lepidosperma leptostachyum	0.4	<1
Agrostocrinum scabrum	0.4	<1
Acacia nervosa	0.3	3
Schoenus grammatophyllus	0.3	<1
Lepidosperma pubisquameum	0.3	<1
Babbingtonia camphorosmae	0.3	<1
Lomandra sericea	0.3	<1

SPECIES	HEIGHT (m)	COVER (%)
Andersonia involucrata	0.3	<1
Haemodorum laxum	0.3	<1
Stylidium repens	0.2	10
**Freesia alba x leichtlinii*	0.2	2
Conostylis aculeata	0.2	1
Johnsonia lupulina	0.2	1
Stylidium brunonianum	0.2	<1
Stylidium piliferum	0.2	<1
Banksia sessilis (seedling)	0.2	<1
Tripterococcus brunonis	0.2	<1
**Trifolium arvense*	0.2	<1
Neurachne alopecuroidea	0.1	2
Borya sphaerocephala	0.1	2
Laxmannia squarrosa	0.1	<1
**Briza maxima*	0.1	<1
Stylidium bulbiferum	0.1	<1
Chamaescilla corymbosa	0.1	<1
Drosera platystigma	Flat	<1
Drosera pulchella	Flat	<1
Cassytha racemosa	Climber	1
Drosera menziesii	Climber	<1

* introduced species

QUADRAT CR B

50 407080 E 6460023 N

Vegetation: *Eucalyptus marginata* Low Open Woodland over *Hakea trifurcata/Lambertia multiflora/Xanthorrhoea brunonis/Allocasuarina humilis* Closed Heath
Condition: Excellent
Soil Type: Orange-brown sand
Landform: Flat



Quadrat (10 x 10m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus marginata	8	2
Hakea trifurcata	1.7	2
Lambertia multiflora	1.1	4
Allocasuarina humilis	0.8	5
**Gladiolus caryophyllaceus*	0.8	<1
Xanthorrhoea preissii	0.7	4
Xanthorrhoea brunonis	0.7	1
Mesomelaena pseudostygia	0.5	10
Tetraria octandra	0.5	5
Hibbertia hypericoides	0.5	4
Daviesia nudiflora	0.5	4
Eremaea pauciflora	0.5	1
Stirlingia latifolia	0.5	<1
Petrophile macrostachya	0.4	4
Mesomelaena tetragona	0.4	2
Melaleuca seriata	0.4	1
Thysanotus thyrsoideus	0.4	<1
Tricoryne elatior	0.4	<1

Lomandra sericea	0.4	<1
Babbingtonia camphorosmae	0.4	<1
Patersonia occidentalis	0.4	<1
Burchardia congesta	0.4	<1
Acacia stenoptera	0.4	<1
Gompholobium confertum	0.4	<1
Dasypogon obliquifolius	0.3	2
Banksia dallanneyi	0.3	1
Conostylis aurea	0.3	<1
**Briza maxima*	0.3	<1
Lomandra hermaphrodita	0.3	<1
Hibbertia racemosa	0.3	<1
Trachymene pilosa	0.2	<1
Caladenia flava	0.2	<1
Acacia teretifolia	0.2	<1
**Ursinia anthemoides*	0.2	<1
**Romulea rosea*	0.2	<1
Xanthosia huegelii	0.2	<1
Stylidium repens	0.2	<1
Synaphea spinulosa	0.2	<1
Lechenaultia biloba	0.2	<1
Laxmannia sessiliflora	0.1	<1
Neurachne alopecuroidea	0.1	<1
**Freesia alba x leichtlinii*	0.1	<1
Desmocladus fasciculatus	0.1	<1
Chamaescilla corymbosa	<0.1	<1
Drosera erythrorhiza	Flat	<1
Cassytha racemosa	Climber	<1
Drosera menziesii	Climber	<1

* introduced species

QUADRAT CR C

50 407160 E 6460005 N

Vegetation: *Allocasuarina fraseriana/Eucalyptus marginata* Low Woodland over *Lambertia multiflora/Xanthorrhoea preissii/Allocasuarina humilis* Low Shrubland
Condition: Degraded
Soil Type: Yellow-brown sand
Landform: Flat



QUADRAT (10 x 10m)

SPECIES	HEIGHT (m)	COVER (%)
Allocasuarina fraseriana	5	20
Eucalyptus marginata	5	2
Xanthorrhoea preissii	1.2	3
**Ehrharta longiflora*	1	1
Xanthorrhoea brunonis	1	1
Lambertia multiflora	0.8	2
**Brassica tournefortii*	0.7	2
Eremaea pauciflora	0.7	2
Allocasuarina humilis	0.7	1
Nuytsia floribunda	0.5	<1
Tricoryne elatior	0.5	<1
Dasypogon obliquifolius	0.4	10
Mesomelaena tetragona	0.4	4
**Sonchus oleraceus*	0.4	<1
Melaleuca seriata	0.4	<1
**Gladiolus caryophyllaceus*	0.4	<1

SPECIES	HEIGHT (m)	COVER (%)
Banksia dallanneyi	0.3	<1
Hibbertia hypericoides	0.3	<1
Drosera stolonifera	0.3	<1
**Silene gallica*	0.3	<1
**Romulea rosea*	0.2	5
**Freesia alba x leichtlinii*	0.2	<1
**Lysimachia arvensis*	0.2	<1
**Lotus subbiflorus*	0.1	<1
**Hypochaeris glabra*	Flat	4
Thysanotus patersonii	Climber	<1
**Fumaria capreolata*	Climber	<1

* introduced species

QUADRAT CR D

50 406944 E 6459998 N

Vegetation: *Eucalyptus marginata/Angophora costata* Low Woodland over weeds
Condition: Completely Degraded
Soil Type: Compacted orange-brown loamy clay
Landform: Raised path above drainage basin



QUADRAT (10 x 10m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus marginata	6	20
**Angophora costata*	5	10
**Allocasuarina* sp.	4	2
**Acacia podalyriifolia*	1.5	1
**Ehrharta calycina*	0.6	5
**Briza maxima*	0.3	2
**Freesia alba x leichtlinii*	0.2	10

* introduced species

QUADRAT CR E

50 406801 E 6460116 N

Vegetation: *Corymbia calophylla* Low Woodland over *Hakea trifurcata/Hakea undulata/Acacia saligna* Open Shrubland
Condition: Degraded
Soil Type: Brown sand
Landform: Flat



QUADRAT (10 x 10m)

SPECIES	HEIGHT (m)	COVER (%)
Corymbia calophylla	7	15
Acacia saligna	3	5
**Chamaecytisus palmensis*	3	2
Hakea undulata	1.9	4
Hakea trifurcata	1.2	2
**Avena fatua*	1.1	5
**Callitris preissii*	1.1	2
**Osteospermum ecklonis*	1	15
**Callistemon sp*	0.8	5
**Eragrostis curvula*	0.6	2
**Ehrharta longiflora*	0.5	70
**Fumaria capreolata*	0.5	<1
**Sonchus oleraceus*	0.3	<1
Banksia dallanneyi	0.3	<1
Hakea prostrata	0.2	<1

* introduced species

FIGURES

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Memorandum

To	Paul van der Moezel	Page	1
CC	Stephanie Brokenshire		
Subject	Floristic Community Type Analysis of Quadrats		
From	Floora de Wit		
File/Ref No.	60611889	Date	9-12-2019

AECOM Australia Pty Ltd (AECOM) was engaged by City of Kalamunda to conduct Floristic Community Type Analysis for quadrats completed in Cambridge Reserve. PGV Environmental recently conducted a spring flora survey for the City of Kalamunda in Cambridge Reserve, Forrestfield. Two quadrats in very good to excellent condition were scored by Paul van der Moezel in Spring, 2019.

This letter presents the results of Floristic Community Type analysis conducted for the two Cambridge Reserve quadrats, CR A and CR B.

Methods

Quadrat presence absence data was provided by Paul van der Moezel. The Cambridge street data was reconciled with the Keighery *et al* (2012) Swan Coastal Plain dataset (SCP dataset).

The program PC Ord was used to conduct the Bray Curtis analysis on presence/absence data. The Bray Curtis dissimilarity measure was used to quantify the compositional dissimilarity between the quadrats based on presence absence data. Subtracting the results from 1 gives the similarity index, also known as the Bray Curtis index. This method is easily interpretable and provides meaningful results. The method also complies with DBCA draft statistical analysis guidelines.

The quadrat data was added one at a time to run the analysis to avoid the influence of spatial correlation that is often caused by adding a small survey dataset. A sense check was completed incorporating appropriate geology, soils, landscape and the description provided in the Gibson *et al.* (1994) reference material and Bush Forever (Government of WA, 2000).

The statistical analysis methods follow the DPaW (2015) draft guidelines.

Limitations

- Data quality was reliant on the standards of PGV Environmental.
- Quadrats were 10x10m which coincides with the SCP dataset.
- It was assumed that time was not a restriction for accuracy (i.e. time spent scoring each quadrat was adequate).
- A single scoring event was included which does not correspond to the SCP dataset. This is likely to have influenced level of similarities observed.
- Condition of the vegetation may influence the outcome. It is understood that reasonable effort was made to put quadrats in the best vegetation condition at each location.

Results

Quadrat CR A had low species diversity (38 species) and results were not definitive. The highest similarity was to Gibson *et al.* (1994) site Norm04 which represents FCT3b *E. calophylla – E. marginata* woodlands on sandy-clay soils. Other associations included FCT20b, 3a and 3c. Both FCT3b and FCT3c appear as suitable candidates.

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Quadrat CR B showed the highest correlation to FCT20a *Banksia attenuata* woodlands over species rich dense shrublands. The three sites with highest similarity all represent FCT20a (43-50% similarity). The only other inferred FCT in the top 5 sites was FCT20b, also a Banksia woodland. None of these are likely representatives of the vegetation community as no Banksia overstorey species (apart from *B. sessilis*) was recorded.

Table 1 Floristic Community Type analysis results for two quadrats from Cambridge Reserve

Quadrat	Sp. Richness	Quadrat (FCT; % similarity)	Review of Result
CR A	38	Norm04 33% 3b Talb13 27% 3c Rush01 26% 20b Talb4 25% 3c MUD-5 25% 3a	It is not 3a or 20b as it lacks key species (*Kingia australis* for 3a, and *Banksia attenuata* for 20b). FCT3c aligns with previous study (Plantecology, 2012). Species richness is comparable (48 species/quadrat). Includes *E. wandoo* in some occurrences and lacks *Bossiaea eriocarpa, Stylidium piliferum* and *Conostylis juncea, Acacia drewiana, Hakea incrassata* and *Lepyrodia macra*. FCT3b is differentiated by presence of *Bossiaea eriocarpa* and *Conostylis juncea.* Species richness in 3b anticipated at 61 species/quadrat. Results unclear as low similarity across all sites.
CR B	54	Hart01 50% 20a Maida01 45% 20a Maida02 43% 20a Activ01 42% 20a Card5 42% 20b	Despite missing *B. attenuata* species, FCT20a *Banksia attenuata* woodlands over species rich dense shrublands is the likely inferred FCT for this quadrat.

Discussion

To accurately determine the likely FCT associated with vegetation at Cambridge Reserve, additional information was considered including publicly available information (obtained from the SLIP portal) such as pre-European vegetation mapping and soil mapping. The quadrats are located on the southern edge of the Bassendean System, close to the Pinjarra System. Pre-European mapping defines the area as “Mainly Jarrah and Marri *Eucalyptus marginata*, *Corymbia calophylla*”. Soil landscape mapping describes the surface as “undulating foot slopes of the Darling and Whicher Scarps with Duplex sandy gravels, pale deep sands and grey deep sandy duplexes supporting *E. marginata, C. calophylla* and Wandoo and some *B. grandis*.

For CR A the low similarity to any quadrat makes it difficult to determine any FCT with confidence. It is possible that with a second scoring event in late spring more species would be recorded and similarity may be higher. Potentially disturbance and the presence of invasive weeds such as *Freesia* and *Ehrharta* have influenced the results.

A logical argument for CR A can be presented for the inferred community 3b:

- Community 3b has the highest similarity to quadrat CR A
- Species including *Bossiaea eriocarpa* and *Conostylis juncea* are absent from the quadrat and from community 3b
- Community 3b is found on sandy clay soils.

When reviewing the suitability of FCT3c *Corymbia calophylla – Xanthorrhoea preissii* woodlands and shrublands a notable absence from the quadrat is *Xanthorrhoea preissii*. Furthermore, Gibson describes several species that are not present in community 3c including *Stylidium piliferum,* which was present in the quadrat.

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It would therefore be reasonable to assume that the vegetation type represented by quadrat CR A infers FCT3b *C. calophylla – E. marginata* woodlands on sandy-clay soils.

The analysis of quadrat CR B shows a high similarity to FCT20a *Banksia attenuata* woodlands over species-rich dense shrublands. Despite the absence of *B. attenuata* from the quadrat there are a number of supporting arguments for the inferred community 20a:

- the high similarity of the top four SCP dataset quadrats (42-50% similarity)
- community 20a is known from the base of the Scarp at Forrestfield
- high species richness (54 species in CR B) compared to the Gibson community at 67.4 per quadrat
- three of the five differentiating species of the 20a subgroup were present in the quadrat including *Daviesia nudiflora, Hibbertia racemosa* and *Synaphea spinulosa*.

Based on these lines of evidence, it is likely that the vegetation represented in CR B infers FCT20a *Banksia attenuata* woodlands over species rich dense shrublands.



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Vegetation survey methods and analysis to determine floristic community types on the southern Swan Coastal Plain.

Draft, May 2015

1. Quadrat analysis

The best way to determine the floristic community types (FCTs) present at a new survey site on the southern Swan Coastal Plain is to repeat methods as described in the Gibson *et al.* (1994) report. That is, to establish 10 by 10m quadrats in vegetation in best condition and not in ecotones, and score them (ie record all the flora species present) at least twice at appropriate times. A form that provides standard format for recording quadrat-based data occurs in Keighery (1994). Permanent markers such as fence droppers or cut down star pickets should be used to mark corners, and corner locations preferably recorded with a Differential GPS. A photo of the quadrat should be taken from a specified corner; typically the north east corner, using a standard lens.

The scoring of quadrats should be planned around the flowering times of the majority of the species present. This will vary depending on whether the site is a wetland, and will also depend on the latitude, and specific characteristics of the season (late or early rains etc). Spring and late spring are usually best (September, and late October /early November). A third or even fourth scoring was sometimes undertaken for quadrats established for Gibson *et al.* (1994), especially in wetlands. In addition, some quadrats were scored over a series of years for Gibson *et al.* (1994), due to poor seasonal rains. It is therefore possible that climate will influence results for quadrats established, and scorings across a series of additional seasons or even years may be indicated.

A good (flowering) voucher specimen of every taxon encountered should be collected, and lodged with the WA herbarium. The cost of vouchering needs to be considered. Any new taxa recorded at each scoring should also be vouchered.

Taxonomy should be reconciled between datasets to current or historic species names. The species data from quadrats established should then be compared and analysed against quadrat data held in Gibson *et al.* (1994), or preferably the more comprehensive dataset available on Naturemap, Keighery *et al.* (2012) using appropriate statistical techniques and parameters (eg PATN, Primer or PC-ORD). The reporting should note the closest matches for FCTs present at the new site.

Unless the new data are of similar quality, that is, where similar numbers of native plant taxa are recorded when compared to average species richness in quadrats established for the Gibson *et al.* (1994) report and Keighery *et al.* (2012), then results could be unreliable and potentially misleading. Determining appropriate locations for quadrats may be quite critical in this regard, in that they should be placed in areas in best condition.

The importance of the application of this quadrat-based method is highlighted where few taxa are recorded. Relevé data are generally not comparable with the quadrats for Gibson *et al.* (1994) or Keighery *et al.* (2012). In addition, it is generally not possible to exactly relocate relevés, so they can't easily be rescored.

Analyses should be carried out against the quadrat data from Gibson *et al.* (1994) or preferably Keighery *et al.* (2012) so that conclusions are logical and valid. That is, full species lists for all quadrats held in Gibson *et al.* (1994) or Keighery *et al.* (2012) should be utilised for these comparisons not partial species lists held in the tables in the hard copy Gibson *et al.* (1994) report. Gibson *et al.* (1994) utilised the quadrat-based data collected during that survey and PATN was used to sort the quadrat data into a series of FCTs using

specified parameters. To validly compare new data collected for new sites on the southern Swan Coastal Plain, these methods should be repeated.

There are a number of ways the statistical analysis can be done. The new quadrat data can be inserted, the classification rerun and examined with cluster (some minor typological changes might be expected) or ordination techniques. Nearest neighbour distances of the new quadrats to the Gibson *et al*. (1994) or preferably Keighery *et al*. (2012) data can be examined, or some form of multivariate discriminate analysis can be applied, such as CAP - canonical analysis of principal coordinates, in the Primer package. Regardless of the methods used, the most reliable outcomes will be from comparison of adequately sampled quadrat data.

Critical analysis of the logic of the outcomes of analysis is required. For example, the typical habitat features such as soil and landform, and hydrological status of quadrats established for Gibson *et al*. (1994) should be explicitly discussed and compared in reporting. Comparison of 'typical' floristics and structure of the FCTs as defined by Gibson *et al*. (1994) and Keighery *et al*. (2012) may also be relevant. If results of statistical analysis do not indicate a 'logical' outcome in this regard then the reasons for this should be discussed. This may include factors such as vegetation condition, timing of survey, potential presence of previously unsampled FCTs or transitional zones, and issues associated with data quality. The most logical conclusion regarding FCTs present in the new quadrats should be stated and reasoning should be explicit.

2. Use of other methods

Species lists for vegetation units can be collected and analysed using other methods where native species richness is inadequate to provide good quality data for statistical analysis; for example where vegetation is not in suitable condition.

The flora and vegetation can be surveyed along a series of transects or relevés across the site, with species recorded for different vegetation units being compiled in separate lists. Detailed notes should be recorded about the species present, vegetation condition on Bush Forever scales, and soils and landform. Plant species or combinations of taxa that may be particularly significant in differentiating the floristic community types should also be noted.

The species lists for each identified vegetation unit should be compared to full species lists compiled from all quadrats established for Gibson *et al.* (1994) or Keighery *et al*. (2012), for floristic community types considered most likely to occur at the site on the basis of soil and landform characteristics and general species composition. The quadrat data from Gibson *et al.* (1994) and Keighery *et al*. (2012) are available free of charge from Department of Parks and Wildlife. Keighery *et al*. (2012) data occurs at http://naturemap.dpaw.wa.gov.au/default.aspx.

Results should be provided in the form of raw data (species lists) and tables that indicate the alignment (proportional overlap) of species present in each different vegetation unit, with species lists compiled for all quadrats in likely FCTs from Gibson *et al.* (1994) or Keighery *et al*. (2012).

Combinations of plant species that are indicative of particular FCTs should be evaluated from species present in each identified vegetation unit. Lists of taxa that are 'typical' or 'common' to particular FCTs are listed in Gibson *et al*. (1994). In addition, taxa that are indicative of the eastern side of the Swan Coastal Plain (Keighery and Trudgen 1992, Table 4), may be particularly helpful in determining the FCTs present. The eastern side of the Plain is characterized by the presence of a suite of threatened ecological communities (TECs) including three marri communities on heavy soils (floristic community types 3a, 3b and 3c, and three closely allied woodlands and shrublands - type 20a, 20b and 20c – 'the 20 group of floristic community types' as described in Gibson *et al*. (1994)). There are a suite of taxa

listed in Keighery and Trudgen (1992) that are associated with the highly cleared heavier soils on this side of the plain, and that are associated with either or both of these two groups of TECs. These taxa are particularly helpful in distinguishing the presence of these threatened ecological communities.

In addition, information about Reference Sites that provide good examples of specific FCTs in Bush Forever sites is on the Western Australian Local Government Association web site at: http://pbp.walga.asn.au/ProjectPrograms/PerthRegionPlantBiodiversityProject/BushForeverReferenceSites.aspx

The location in question should be compared to these Reference Sites in terms of composition and structure of the vegetation, habitat, and soil and landform.

The logic used to determine the likely FCTs present at the new site should be evident in reporting, (eg soil and landform, patterns of species composition). Table 14 in the Gibson *et al.* (1994) report provides a list of the most frequent landforms on which the FCTs occur, but this is not a definitive list of landforms on which the FCTs were found. Conclusions that certain Priority or threatened ecological communities could not occur because the soil and landform units from which they have been recorded do not occur at the survey site are not conclusive and additional data would need to be presented.

If taxa indicate that vegetation is generally transitional between specific FCTs, then this should be noted and the FCTs to which the vegetation aligns most closely should be identified. The status of each possible FCT should be noted (eg PEC or TEC, and rank).

3. Mapping

The boundaries between vegetation condition classes using Bush Forever scales should be mapped and digitised.

The boundary of the vegetation units (FCTs) identified, should also be mapped and digitised.

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DRAFT

Appendix H – Flora Survey Ecological 2017

Flora, Vegetation and Fauna Survey of Anderson Road Reserve

Prepared for
City of Kalamunda

22 May 2017






DOCUMENT TRACKING

Item	Detail
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Cover photo	[Clockwise from top left] Chewed Marri nuts, *Isotoma hypocrateriformis*, nesting box, *Gazania linearis* © Eco Logical Australia

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Abbreviations

Abbreviation	Description
BAM Act	*Biosecurity and Agriculture Management Act 2007*
BoM	Bureau of Meteorology
DAFWA	Department of Agriculture and Food Western Australia
DBH	Diameter at Breast Height
DEC	Department of Environment Conservation
DER	Department of Environment Regulation
DotEE	Department of the Environment and Energy
DRF	Declared Rare Flora

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Abbreviation	Description
ELA	Eco Logical Australia
EP Act	*Environmental Protection Act 1986*
EPA	Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESA	Environmentally Sensitive Area
FCT	Floristic Community Type
ha	Hectare
IBRA	Interim Biogeographical Regionalisation for Australia
IUCN	International Union for Conservation of Nature
km	Kilometre
LED	Light Emitting Diode
m	Metre
mm	Millimetre
Parks and Wildlife	Department of Parks and Wildlife
PEC	Priority Ecological Community
PMST	Protected Matters Search Tool
RNE	Register of the National Estate
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SLIP	Shared Land Information Platform
SWA	State of Western Australia
TEC	Threatened Ecological Community
The Reserve	Anderson Road Reserve
The City	City of Kalamunda
WA	Western Australia
WAH	Western Australian Herbarium
WAM	Western Australian Museum
WC Act	*Wildlife Conservation Act 1950*
WoNS	Weed of National Significance

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Executive summary

Eco Logical Australia was commissioned by the City of Kalamunda to undertake a flora, vegetation and fauna survey of Anderson Road Reserve to analyse the importance of the Reserve for a range of flora and fauna species, to assist in management and to achieve the best possible environmental outcomes.

A Level 2 flora and vegetation survey was undertaken over two phases during spring (26-27 October 2016) and autumn (4 April 2017). Vegetation communities were described through the establishment of six 10 m x 10 m quadrats. Target weed species and conservation listed flora were recorded and mapped through systematic traverses. A Level 1 fauna survey was conducted on the 26 October 2016 which included opportunistic searches, nocturnal searches, bird census, hand searches, and bat survey.

A total of 180 flora taxa were identified within the study area. This total included 114 native and 66 introduced (weed) taxa. No Threatened or Priority flora species were recorded. Of the weeds recorded, two are listed as Weeds of National Significance: **Opuntia stricta* and **Genista linifolia*. **O. stricta* is also listed as a Declared Pest under the *Biosecurity and Agriculture Management Act 2007*.

Three vegetation types were described within the study area comprising *Corymbia calophylla* open woodland, *Eucalyptus marginata* subsp*. marginata* woodland, and historical planting of *Eucalyptus wandoo* open woodland. The condition of the vegetation across the study area was mostly Very Good to Good condition, in areas of remnant vegetation, with smaller areas in Degraded and Completely Degraded condition. None of the vegetation types were considered to represent conservation listed ecological communities.

One broad fauna habitat type was mapped within the study area comprising mixed Eucalypt woodland. An ephemeral drainage line and sump was also identified as being important for many native fauna species. Black Cockatoo foraging and potential breeding/ night roosting habitat was recorded across the study area.

A total of 28 fauna species were opportunistically observed, or signs of their presence recorded, during the Level 1 fauna survey. This comprised 21 birds (15 native and six non-native), three mammals (one native and two introduced) and four reptiles. Two conservation listed fauna species were recorded: *Calyptorhynchus banksii naso* (Forest Red-tailed Black Cockatoo; listed as Vulnerable) and *Isoodon obesulus fusciventer* (Quenda; listed as Priority 4).

The study area, while containing high diversity and densities of weeds in some areas, still contains a diverse array of native flora and represents a significant area of remnant vegetation in an otherwise built up area in the Perth metropolitan region.

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1 Introduction

1.1 Project background

Anderson Road Reserve (the Reserve) is a bushland reserve located in Forrestfield, within the City of Kalamunda (the City), approximately 18 kilometres (km) east of Perth, Western Australia (**Figure 1**). The City wishes to gain a better understanding of the range of flora and fauna species present within the Reserve, particularly Threatened Black Cockatoos, mammals and reptiles, to assist in management and to achieve the best possible environmental outcomes.

The Reserve provides visual amenity between Lewis Road, Anderson Road and the adjacent housing. The vegetation within the Reserve provides screening from existing infrastructure and allows the local community to connect with the environment in an otherwise built up area. The local community currently use the Reserve to access Forrestfield Schools, shops and bus routes.

The Reserve, to date, has undergone extensive work including weed control, dieback treatment, firebreak maintenance and revegetation, undertaken by the City's environmental team. Additional work, for example installation of nesting boxes, has been made possible by external funding, grants and initiatives such as the Green Army. There is a large community engagement within the Reserve, including a volunteer friends group, that undertake weed removal and assist with revegetation programs. There are Nature Awareness events, night stalks and bird watching, held within the Reserve.

Eco Logical Australia (ELA) was commissioned to undertake a two-phase Level 2 flora survey and a Level 1 fauna survey of the Reserve to identify the ecological values present within the Reserve, as well as to assess for the presence of Threatened or Priority flora, fauna and ecological communities.

1.2 Objectives

The objectives of the flora, vegetation and fauna survey were to:

- Document, describe and map the vegetation communities and Floristic Community Types (FCTs) present, including identification of Threatened Ecological Communities (TECs) and Priority Ecological Communities (PECs).
- Provide a full species inventory, including the establishment and mapping of any *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) listed, *Wildlife Conservation Act 1950* (WC Act) Threatened flora, Priority or other significant flora on site.
- Assess and map vegetation structure, cover and condition, per the Environment Protection Authority (EPA) and Department of Parks and Wildlife (Parks and Wildlife) Technical Guide – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA and Parks and Wildlife 2015).
- Establish the extent of and map target introduced flora (weed) species.
- Establish the occurrence of native and introduced fauna species, including targeted searches for direct (vertebrate fauna seen or heard) or indirect (scats, tracks, burrows etc.) evidence of fauna.
- Describe and map native vertebrate fauna habitat, including a habitat assessment for Threatened Black Cockatoos.
- Make management recommendations to the City to achieve the best possible environmental outcomes.

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1.3 Legislative framework

This survey was undertaken to meet requirements under the Western Australian (WA) *Environmental Protection Act 1986* (EP Act) and the EPBC Act. The survey was consistent with relevant WA EPA guidelines. Specifically, the survey was undertaken in accordance with the following:

- EPA and Parks and Wildlife Technical Guide – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA and Parks and Wildlife 2015).
- No. 51 - Terrestrial Flora Surveys for Environmental Impact Assessment in Western Australia (EPA 2004a).
- EPA Guidance Statement No. 56 - Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA 2004b).
- EPA Guidance Statement EPA and Department of Environment and Conservation (DEC) Technical Guide – Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA and DEC 2010).
- EPA Position Statement No. 3 - Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002).
- EPBC Act referral guidelines for three Threatened Black Cockatoo species (Department of Sustainability, Environment, Water, Population and Communities [SEWPaC] 2012).

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Figure 1: Study area location

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2 Desktop assessment

2.1 Study area

Anderson Road Reserve is a small reserve located in Forrestfield, within the City of Kalamunda, approximately 18 km east of Perth, Western Australia. The Reserve is small, approximately 17 hectares (ha) in size and is an irregular shape. It comprises several land parcels along Anderson Road, and is bound by Anderson Road to the east, Lewis Road to the south, Moira Avenue to the west and housing to the north. The Reserve contains a diverse array of plants and animals, characteristic of the Forrestfield area (Shire of Kalamunda 2015).

2.2 Bioregion

The Interim Biogeographical Regionalisation for Australia (IBRA) Version 7 recognises 89 geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information. The 89 bioregions are further refined into 419 subregions which are more localised and homogenous geomorphological units in each bioregion (Department of the Environment and Energy [DotEE] 2017a).

The study area is located on the eastern edge of the Swan Coastal Plain bioregion as defined by IBRA. The Swan Coastal Plain bioregion has been further subdivided into two subregions: Dandaragan Plateau (SWA1) and Perth (SWA2). The study area falls within the Perth subregion, which is described by Mitchell et al. (2002) as:

- Colluvial and Aeolian sands, alluvial river flats, coastal limestone. Heath and/or Tuart woodlands on limestone, Banksia and Jarrah-Banksia woodlands on Quaternary marine dunes of various ages, Marri on colluvial and alluvials. Includes a complex series of seasonal wetlands. Rainfall ranges between 600 and 1000 mm annually and the climate is Mediterranean.

2.3 Climate

The Perth subregion experiences a warm, Mediterranean climate with hot dry summers and mild wet winters (Mitchell et al. 2002). Based on climatic data from the Bureau of Meteorology (BoM) Maida Vale weather station (station number 9182, rainfall data 1961 – current; located approximately 2.5 km north of the study area), the area receives an annual average rainfall of 804.2 millimetres (mm), with most rainfall occurring during the months of June, July and August (156.7 mm, 159.6 mm and 127.5 mm respectively) (BoM 2017). Based on climatic data from the BoM Perth Airport weather station (station number 9021; temperature data 1991 – current; located approximately 9 km to the north of the study area), mean maximum air temperatures range from 32.0 °C in February to 17.9 °C in July, and mean minimum air temperatures range from 17.5 °C in February to 8.0 °C in July/August (BoM 2017).

2.4 Landform, geology and soils

The study area is situated on the Bassendean Dune system, which is Pleistocene Aeolian heavily leached sands falling from 40 to 80 metres (m) relief in the north of the plain to almost sea level in the south. The study area has extremely low to very low relief dunes with undulating sandplains and discrete sand with deep bleached grey sands sometimes with a pale yellow or a weak iron-organic hardpan at depths generally greater than 2 m (Government of Western Australia 2000).

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2.5 Vegetation

Vegetation across the Perth metropolitan area has been described by Heddle et al. (1980) as vegetation complexes. The vegetation of the study area is mapped as the Forrestfield Complex. This vegetation complex is described as predominantly vegetation ranging from open forest of *Eucalyptus calophylla*, *E. wandoo* and *E. marginata* to open forest of *E. marginata*, *E. calophylla*, *Casuarina fraseriana* and *Banksia* spp. There is also fringing woodland of *E. rudis* in the gullies that dissect this landform (by Heddle et al. 1980).

Vegetation type and extent has been mapped at a regional scale by Beard (1975) who categorised vegetation into broad vegetation associations. Based on Beard's (1975) mapping at a scale of 1:1,000,000, Department of Agriculture and Food Western Australia (DAFWA 2017a) has compiled a list of the types and extent of vegetation associations across WA (Shepherd et al. 2002).

Two broad vegetation associations occur within the study area:

- Vegetation association 3: *Eucalyptus marginata* and *Corymbia calophylla* open forest; and
- Vegetation association 1009: *Corymbia calophylla* and *Eucalyptus rudis* woodland.

The extent of vegetation association 3 remaining within the Perth subregion is 16.70% of its pre-European extent, while the extent of vegetation association 1009 remaining within the Perth subregion is 16.35% of its pre-European extent (Government of Western Australia 2016).

2.6 Conservation areas and National Parks

The study area does not occur within any conservation area or National Park. Lesmurdie Falls National Park lies less than a kilometre east of the study area, which forms part of the greater Mundy Regional Park. Based on Beard's (1975) mapping at a scale of 1:1,000,000, Department of Agriculture and Food Western Australia (DAFWA 2017a) has compiled a list of the types and extent of vegetation associations across WA (Shepherd et al. 2002).

One broad vegetation association occur within Lesmurdie Falls National Park:

- Vegetation association 4: *Corymbia calophylla* and *Eucalyptus wandoo* open woodland.

This vegetation association differs to the association that is present within in the study area.

2.7 Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESAs) are defined in the Environmental Protection (Environmentally Sensitive Areas) Notice 2005 under section 51B of the EP Act. ESAs include areas declared as World Heritage, areas included on the Register of the National Estate (RNE)[1], defined wetlands, vegetation containing rare (Threatened) flora, TECs and Bush Forever sites. The study area does not occur within any ESAs and there are no TECs identified as potentially occurring within the study area.

[1] Note the RNE was closed in 2007 and is no longer a statutory list. The RNE has been replaced by the National Heritage List under the EPBC Act.

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2.8 Priority Ecological Communities

Priority Ecological Communities (PECs) are biological flora or fauna communities that are recognised to be of significance, but do not meet the criteria for a TEC. There are five categories of PECs, none of which are currently protected under legislation (see **Appendix A**).

One PEC occurs within the City of Kalamunda: 'Central Northern Darling Scarp Granite Shrubland Community' (Shire of Kalamunda 2012). This PEC is listed as Priority 4 by the Department of Parks and Wildlife and is described as:

> 'Shrublands and heath on deeper loams and red earths on fragmented granite/quartzite'. Heath species typically consist of the taller shrubs *Xanthorrhoea acanthostachya* and *Allocasuarina humilis* over smaller proteaceous and myrtaceous shrubs, namely *Melaleuca* aff. *scabra*, *Baeckea camphorosmae* and to a lesser extent, the proteaceous shrubs *Banksia armata*, *Hakea incrassata* and *Hakea undulata*. Located in central region of the Northern Darling Scarp near Perth' (Parks and Wildlife 2015).

The closest known occurrence of this PEC is located in Lesmurdie Falls National Park, approximately 600 metres (m) east of the study area. It is considered unlikely to occur because the dominant species commonly found in association with this PEC were not present within the study area.

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3 Methodology

3.1 Desktop review

The following Commonwealth and State databases were searched for information relating to conservation listed ecological communities, flora and fauna in order to compile and summarise existing data to inform the field survey:

- Parks and Wildlife databases for Threatened Flora listed under the latest WA Wildlife Conservation (Rare Flora) Notice and Priority listed flora (Parks and Wildlife 2016a)
- Parks and Wildlife and Western Australian Museum (WAM) NatureMap online flora and fauna database (Parks and Wildlife 2016b)
- Commonwealth EPBC Act Protected Matters Search Tool (PMST) for Threatened species and communities listed under the EPBC Act (DotEE 2017b).

The following databases/information sources were also used to inform the survey and likelihood of occurrence of flora, vegetation and fauna species:

- The International Union for Conservation of Nature (IUCN) red list (IUCN 2017)
- Department of Environment Regulation (DER) ESA database (DER 2017)
- BirdLife Australia (BirdLife Australia 2017)
- Western Australian Organism List (DAFWA 2017b)
- Relevant Landgate databases (Shared Land Information Platform [SLIP] portal) for TECs and PECs (State of Western Australia [SWA] 2017).

Conservation codes, categories and criteria for flora and fauna protected under the EPBC Act and WC Act are provided in **Appendix A**. Results of the NatureMap and PMST database searches are presented in **Appendix B**.

3.1.1 Likelihood of occurrence assessment

Conservation listed flora and fauna species that possibly occur within the survey area were identified from a review of key datasets and literature as described above. An assessment of the likelihood of occurrence of conservation listed flora and fauna was made using existing species records from the database searches and the results of the site inspection.

The following criteria was used to assess likelihood of occurrence:

- Known to occur: Recorded from the study area, through database search results and/or from previous surveys of the study area (<20 years).
- Likely to occur: The study area is within the species current distribution and contains suitable habitat for the species, however;
    - The species utilises seasonal habitat or has a large home range, so is not always present/visible in the study area; and/or
    - Survey limitations identified.
- Potential to occur: The study area is within the species current distribution and contains habitat, however (at least two of below);
    - The study area is located on the edge of the species range or it has a patchy distribution; and/or
    - Survey limitations identified; and/or
    - Habitat is less suitable; and/or

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- Species is cryptic, and/or difficult to record utilising traditional survey methods.

- Unlikely to occur: The study area is within the species current distribution and contains habitat, however; the study area was adequately surveyed (including for seasonal, migratory and cryptic species and fauna species with large home ranges) and did not record the species or; the habitat is modified and not likely to support the species and survey limitations identified.
- Does not occur: The study area is within the species current distribution, and was adequately surveyed (including for seasonal, migratory and cryptic species and fauna species with large home ranges) and did not record the species; or the study area does not contain suitable habitat and there is certainty that the species is not present in the study area.

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3.2 Survey team and timing

The Level 2 flora and vegetation survey was undertaken over two phases by Katrina Zeehandelaar-Adams (Ecologist), Sarah Dalgleish (Botanist) and Jeni Morris (Graduate Ecologist). The first phase was undertaken on 26-27 October 2016 (spring survey) and the second phase on 4 April 2017 (autumn survey). The Level 1 fauna survey was conducted by Nicki Thompson (Ecologist) on the 26 October 2016. The timing of the surveys was optimal for these types of assessment. The survey team's relevant qualifications, experience and licences are provided in **Table 1**.

A total of 354 mm of rainfall was recorded in the three months prior to the fauna survey and the first phase of the flora survey (July to September 2016; BoM 2017). This is below the long-term average for the same period (375.6 mm). A total of 155.5 mm of rainfall was recorded in the three months prior to the second phase of the flora survey (January to March 2017; BoM 2017). This is above the long-term average for the same period (54.6 mm). Despite these discrepancies, the timing was still considered suitable for both surveys.

Table 1: Survey team

Name	Qualification	Relevant experience	Licence numbers
Katrina Zeehandelaar-Adams	BSc (Hons) Conservation Biology and Management	Undertaken numerous flora and fauna surveys throughout WA, with experience in the Perth region.	Flora scientific collection Licence No. SL011844 DRF collection licence No. 11-1617
Sarah Dalgleish	BSc (Hons) Environmental Management	Undertaken numerous flora surveys throughout WA, with experience in the Perth region.	Flora scientific collection licence No. SL011820 Declared Rare Flora (DRF) collection licence No. 12-1617
Jeni Morris	BSc Conservation and Wildlife Biology	Undertaken numerous flora, vegetation and weed surveys and fauna surveys on the Swan Coastal Plain.	Flora scientific collection Licence No. SL011818 DRF collection licence No. 10-1617
Nicki Thompson	BSc (Hons) Zoology	Extensive fauna surveys within the Jarrah Forrest and most WA bioregions. Includes target surveys for relevant conservation listed species, baseline and Level 2 surveys.	N/A for Level 1 fauna survey

3.2.1 Level 2 flora and vegetation survey

The Level 2 flora survey was conducted in accordance with EPA and Parks and Wildlife Technical Guide – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA and Parks and Wildlife 2015) and EPA Guidance Statement 51: Terrestrial Flora and vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA 2004a).

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The number of quadrats established to describe vegetation communities was informed using aerial imagery and previous background survey reports. Dominant vegetation communities were described, including with respect to dominant species, structure and overall condition. The survey involved the use of 10 m x 10 m quadrats, relevés to supplement the data obtained from the quadrats, and opportunistic sampling of species not recorded within the quadrats to inform a species inventory of the study area. EPA and Parks and Wildlife Technical Guide states a minimum of three quadrats per vegetation type are required to be established (EPA and Parks and Wildlife 2015).

Six quadrats and one relevé were installed across the study area (**Figure 2**). Stainless steel fence droppers were used to permanently mark the north-west corner of each quadrat to repeat sampling in phase two of the flora survey. Photos were taken of each quadrat, from the north-west corner showing the marker and quadrat tape. All quadrats and their positions were recorded via an Android tablet.

The following data was recorded as part of the flora and vegetation survey:

- Vegetation structure classes, cover of all species observed in quadrats and dominant species lists for each vegetation type in accordance with Keighery (1994)
- Full species inventory (angiosperm and gymnosperm) of both native and introduced species across the study area
- Vegetation condition was assessed using the Keighery (1994) vegetation condition scale for natural assessment (**Table 2**)
- Other observational data such as landform, soils, time since fire, etc.

Table 2: Keighery (1994) vegetation condition scale for natural area assessment

Condition Rating	Explanation
Pristine	Pristine or nearly so, no obvious signs of disturbance.
Excellent	Vegetation structure intact; disturbance affecting individual species; weeds are non-aggressive species.
Very Good	Vegetation structure altered; obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires; the presence of some more aggressive weeds; dieback; logging; grazing
Good	Vegetation structure significantly altered by obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires; the presence of some very aggressive weeds at high density; partial clearing; dieback; grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires; the presence of very aggressive weeds; partial clearing; dieback; grazing.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

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A targeted survey was completed within the study area for conservation listed flora, communities and weeds including:

- Threatened flora listed under the EPBC Act
- Threatened (Declared Rare) Flora listed under the latest WA Wildlife Conservation (Rare Flora) Notice
- Priority flora recognised by Parks and Wildlife
- Introduced flora (weeds) flora, including Declared Pest plants under the WA Biosecurity and Agriculture Management Act 2007 (BAM Act; Department of Agriculture and Food Western Australia [DAFWA] 2017b) and Weeds of National Significance (WoNS), and weeds of interest to the City (**Table 3**).

Table 3: Target weed species list

Scientific name	Common name	Status
**Acacia dealbata*	Silver Wattle	
**Acacia iteaphylla*	Flinders Range Wattle	
**Acacia longifolia*	Sydney Golden Wattle	
**Acacia podalyriifolia*	Queensland Silver Wattle	
**Arundo donax*	False Bamboo	
**Asparagus asparagoides*	Bridal Creeper	Declared Pest, WoNS
**Cenchrus clandestinus*	Kikuyu Grass	
**Chamaecytisus palmensis*	Tagasaste	
**Chamelaucium uncinatum*	Geraldton Wax	
**Cynodon dactylon*	Couch	
**Ehrharta calycina*	Perennial Veldt Grass	
**Eragrostis curvula*	African Love Grass	
**Freesia alba* x *leichtlinii*	Freesia	
**Genista linifolia*	Flaxleaf Broom	WoNS
**Gladiolus caryophyllaceus*	Wild Gladiolus	
**Gomphocarpus fruticosus*	Narrow Leaf Cotton Bush	Declared Pest
**Leptospermum laevigatum*	Victorian Tea Tree	
**Lupinus angustifolius*	Narrowleaf Lupin	
**Lupinus cosentinii*	Blue Lupin	
**Opuntia stricta*	Common Prickly Pear	Declared Pest, WoNS
**Tribolium uniolae*	Tribolium	
**Watsonia meriana*	Watsonia	

The survey methodology involved personnel walking meandering transects across the study area as well as outside the study area boundary if required. The location of ELA transects and survey effort are shown in **Figure 2**.

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In addition to point locations, the following data were collected for any conservation listed species identified in the study area:

- Number of individuals and/or percent cover (recording a range of coordinates if necessary)
- Estimates were made for groups of individuals within a 20 m radius and for large populations to record a significant area polygon
- Reproductive phase (flowering, fruiting, etc.)
- Description of dominant vegetation unit in which the species is located
- Associated dominant species
- Photograph of the plant *in situ*.

The targeted weed survey was undertaken in conjunction with the conservation listed flora and communities survey. Focus was given to the boundaries of the study area, along tracks and other areas of increased disturbance. When encountered, mapping of weeds was undertaken using 'point' or 'density' mapping, or a combination of both. Where density mapping was used, four density categories were used: <5%, 6–30%, 31–60% and >61% cover for each species.

Except where specifically noted, the field survey was undertaken using an Android Nexus 7 tablet operating the ArcGIS Collector app. These units can have errors of 3-20 m (subject to availability of satellites on the day) with an average of 5 m.

3.2.2 FCT analysis

Species lists for each quadrat were entered into the statistical analysis package Primer (version 6.1.11). The complete dataset of Gibson et al. (1994) was entered into Primer and merged with the ELA dataset to allow comparison of all ELA quadrats against all FCT quadrats of Gibson et al. (1994). The taxonomy of each species was aligned with that used by Gibson et al. (1994) to permit direct comparison between datasets. All data were analysed using presence/absence of each species within each quadrat.

The merged dataset was analysed using hierarchical cluster analysis (Everitt 1980). The Primer routine uses hierarchical agglomerative clustering, which takes a similarity matrix and successively fuses the samples into groups and the groups into larger clusters, starting with the highest mutual similarities then gradually lowering the similarity level at which groups are formed (Clarke and Warwick 2001). The hierarchical clustering is represented by the x-axis representing the full set of samples (in this case, the quadrats sampled by ELA and Gibson et al. [1994] and the y-axis defining a similarity level at which two samples or groups are considered to have fused). The purpose of this analysis was to determine whether the quadrats sampled in the study area were similar in species composition to any of those quadrats sampled by Gibson et al. (1994) and therefore similar to a FCT assigned by Gibson et al. (1994). Hierarchical clustering was performed on similarity matrices computed using the Bray-Curtis coefficient and using the 'group average' cluster mode (Clarke and Warwick 2001).

3.2.3 Specimen identification and nomenclature

Nomenclature used for the flora species within this report follows the WA Plant Census as available on FloraBase (Western Australian Herbarium [WAH]1998-2017). Voucher specimens were collected in the field of all actual or potential conservation listed flora species. Collections were made of other species, if required, that commonly occurred in the habitat of the conservation listed species to enable correct identification. All collections were assigned a unique collecting number.

Specimen identification was undertaken by ELA Senior Botanist Joel Collins and ELA Botanist Sarah Dalgleish. Species identification utilised taxonomic literature and keys with all specimens confirmed using the WAH reference collection.

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3.3 Level 1 Fauna survey

The survey design was aligned with methodology outlined in EPA Guidance Statement No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA 2004b), the principles outlined in EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002), and the Technical Guide – Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA and DEC 2010).

3.3.1 Fauna habitat assessment

An assessment of fauna habitat in terms of its ability to support and sustain populations of fauna, along with an assessment of the likelihood of occurrence of conservation listed fauna species was undertaken during the survey. The habitat characteristic and fauna database records used in assessing likelihood of occurrence for fauna included:

- Vegetation type, structure and condition
- Soil and landform type
- Extent and connectivity of bushland
- Fauna species habitat preferences
- Proximity of conservation listed fauna records
- Signs of species presence.

The habitat assessment included assessing habitat for its potential to support conservation listed species, such as Western Quoll (*Dasyurus geoffroii*) or Quenda (*Isoodon obesulus fusciventer*). This included searches for diggings and evidence of feeding, and nocturnal searches for activity.

Black Cockatoo habitat assessment

An assessment of Black Cockatoo habitat was undertaken in accordance with the EPBC Act referral guidelines (SEWPaC 2012). This involved assessing all tree species known to support breeding for their diameter at breast height (DBH) and their potential to support hollows. Trees with a DBH over 50 cm are defined as suitable for breeding (SEWPaC 2012).

Prior to the survey, aerial imagery was studied to determine the vegetation communities present within the study area and their potential for providing foraging habitat for Black Cockatoos. These values were then ground-truthed during the survey to determine the extent of potential foraging habitat within the study area. This was undertaken in conjunction with the vegetation mapping methodology described in **Section 3.2.1**.

Observations were made of Black Cockatoo foraging activity based on feeding residue such as chewed *Banksia* and eucalypt nuts, and any Black Cockatoo individuals observed foraging within the study area. In addition, the study area was assessed for any Black Cockatoo night roosting or breeding behaviour during the nocturnal/twilight survey.

3.3.2 Sampling methods

The survey was undertaken using a variety of sampling techniques, both systematic and opportunistic. Systematic sampling refers to data methodically collected over a fixed time in a discrete habitat type or location, using an equal or standardised sampling effort across multiple sample locations. This approach provides a range of detection methods that cover the full suite of vertebrate fauna assemblages. Opportunistic sampling includes data collected non-systematically from both fixed sampling sites and as opportunistic records from chance encounters with fauna. This method generally accounts for the majority of bird species and a significant proportion of other fauna groups recorded.

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Direct observation and opportunistic sightings

Direct observations over one day and evening were made. These included visual sightings of active fauna such as reptiles and birds; records of bird calls; and signs of species presence such as tracks, diggings, burrows, scats and any other signs of fauna activity. Searches were also conducted beneath leaf litter, logs and other suitable shelter sites and microhabitats.

Motion camera traps

Motion camera traps were deployed to detect species such as Quenda or introduced predators. Two traps were set over one night. Camera trap locations are shown in **Figure 2**.

Nocturnal/twilight searching

Nocturnal and twilight searching was conducted using Light Emitting Diode (LED) head torches to detect active crepuscular (dusk active) and nocturnal fauna by eye-shine. This method targets crepuscular and nocturnal mammals, owls, frogs and geckos. Searching was conducted by traversing walk tracks whilst spotlighting into adjacent bushland within the study area. The nocturnal and twilight survey occurred over a period of approximately two hours by two ecologists, from 18:30 to 20:30 hours on 26 October 2016.

Bat survey

Sampling for microchiropteran bats was undertaken during the twilight and nocturnal periods on 26 October 2016. A bat detector was deployed to record ultrasonic bat calls, an Anabat SD2 ®, held in the hand while traversing during nocturnal searches. This detector was operating for approximately two hours, from 18:30 to 20:30 hours. Specialised software was used to visualise ultrasonic bat echolocation calls recorded on the bat detector into a corresponding graphical representation for analysis. Most bats species have a unique call which appears as a 'fingerprint' graph output. Bat calls were analysed by comparing recorded calls with reference calls by Alicia Scanlon, an ELA ecologist specialising in bat survey and identification.

3.3.3 Taxonomy and nomenclature

Nomenclature used for the vertebrate fauna species within this report follows the WAM Checklist of the Vertebrates of Western Australia (WAM 2017). Where common names were not stated for certain species, the following references were consulted:

- Amphibians and reptiles: Bush et al. (2010);
- Reptiles: Wilson and Swan (2013);
- Birds: Simpson and Day (2010); and
- Mammals: Menkhorst and Knight (2011).

3.4 Survey limitations

EPA Guidance Statement 51 (EPA 2004a) and EPA Guidance Statement No. 56 (EPA 2004b) recommend including discussion of the constraints and limitations of the survey methods used. Constraints and limitations for the Level 2 flora and vegetation, and Level 1 fauna survey for the study area are summarised in **Table 4**.

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Table 4: Survey limitations of the Anderson Road Reserve flora, vegetation and fauna survey

Factor	Limitations
Sources of information	The Perth subregion has been relatively well surveyed. Numerous flora and fauna surveys have been undertaken in the wider area. Database searches provide adequate information about Threatened and Priority flora and fauna, TECs and PECs.
Scope of works	The scope of works provided adequate detail to achieve the survey objectives.
Completeness of survey	The survey requirements of a Level 2 flora and Level 1 fauna survey including Black Cockatoo assessment were adequately met. Transect sampling was undertaken to effectively search for Threatened and Priority flora, and flora quadrats were established to identify vegetation communities. Habitat assessment was conducted to effectively determine likelihood of occurrence of the relevant conservation listed flora and fauna species.
Intensity of survey	The survey effort was satisfactory for a Level 2 flora, Level 1 fauna and targeted flora survey, and considering the size and location of the study area as per EPA Guidance Statement No. 51 and SEWPaC (2012).
Timing, weather, season, cycle	Phase 1 of the flora survey was undertaken during spring when flora species are flowering and more easily detectable. The timing of the survey was appropriate for a targeted flora survey and in accordance with EPA and Parks and Wildlife Technical Guide and EPA Guidance Statement 51.
Disturbances	There were moderate indications of disturbances within the study area, including human activity and weeds.
Resources	The team members that completed the surveys are suitably qualified in their respective fields to identify specimens, assess habitat, and detect species.
Accessibility	All relevant areas in the study area were easily accessed and surveyed on foot.

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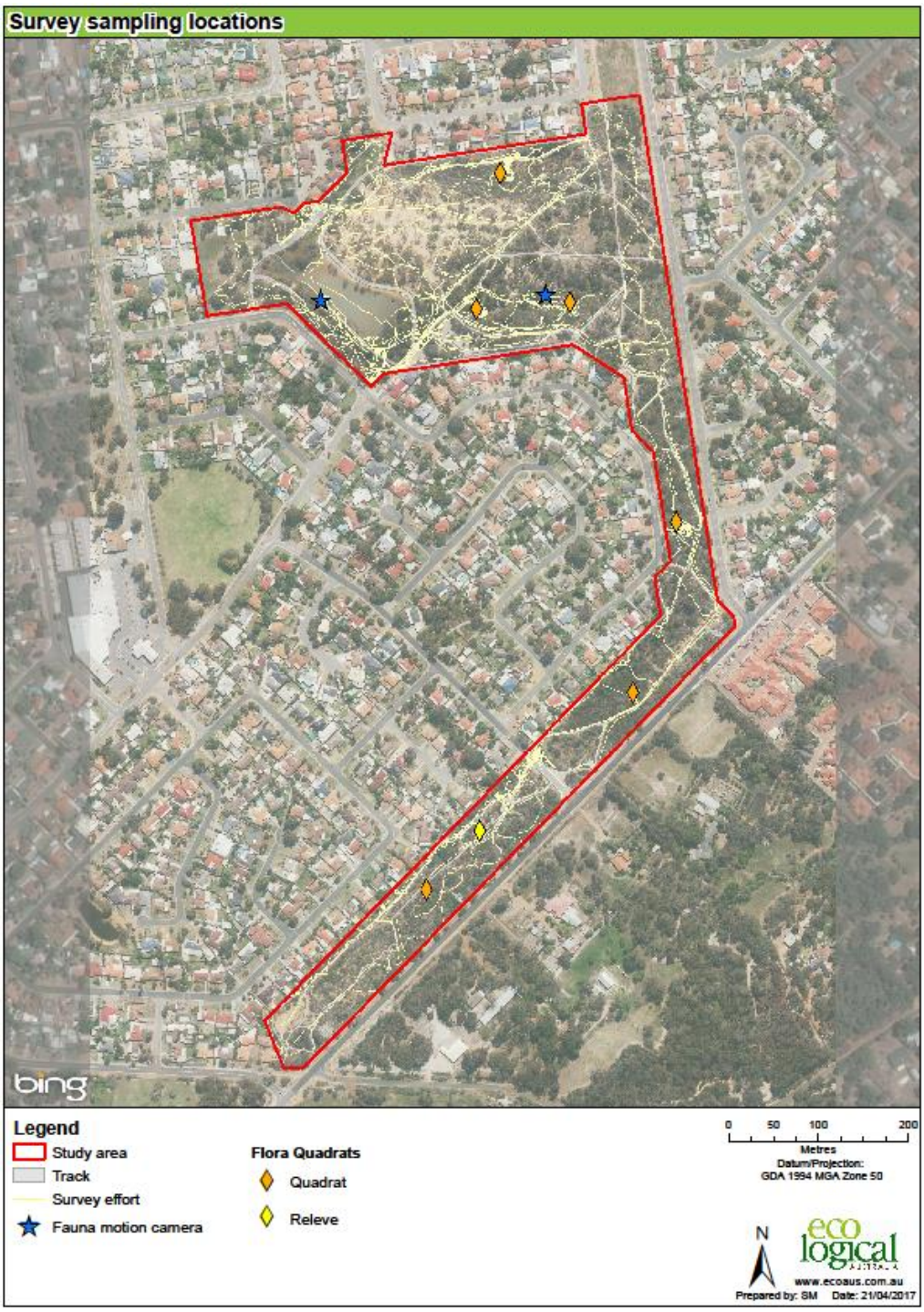


Figure 2: Survey sampling locations

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4 Results

4.1 Flora of the study area

A total of 180 flora taxa were identified within the study area (**Appendix E**). This included 114 native and 66 introduced taxa. The taxa compromised 49 families and 124 genera. The most commonly occurring families were Fabaceae (29 taxa), Myrtaceae (24 taxa) and Proteaceae (19 taxa). *Acacia* (Fabaceae) was the most common genus with 9 taxa recorded in the study area.

The mean native species richness for quadrats sampled was 25.3 species per quadrat (range: 8 – 45 species per quadrat). A flora species matrix is provided in **Appendix F** and floristic quadrat data is provided in **Appendix H**.

4.1.1 Conservation listed flora

A total of 60 conservation listed flora species that possibly occur within the study area were identified from the database searches, based on records of occurrence within a 3 km radius (Parks and Wildlife 2007-2017; Parks and Wildlife 2016; DotEE 2017b). However, no Threatened or Priority listed flora was recorded during the two-phase survey. Additionally, no conservation listed flora has previously been recorded within the study area, and as such, none are considered likely to occur (**Appendix C**).

4.1.2 Introduced flora

Introduced (weed) species represented approximately 37% of the total species recorded, with a total of 66 taxa recorded. This number of weed species is typical for remnant vegetation in Perth and the surrounding metropolitan areas, with many of the species recorded in disturbed areas such as along the edge of tracks, edges of remnant vegetation and in cleared/parkland areas. A full list of weed species recorded from the study area is included in **Appendix G**.

Two weed species recorded during the field survey are listed as WoNS: **Opuntia stricta* and **Genista linifolia*. **O. stricta* is also listed as a Declared Pest under the BAM Act (DAFWA 2017b). * *O. stricta* was recorded from two locations along the south-western border of the study area, and **G. linifolia* was recorded from two locations in the north of the study area (**Figure 3**).

Weed mapping of the remaining target weed species (as listed in **Table 3**) has been separated into the following:

- Bulbous weeds (**Figure 4**)
- Woody weeds (**Figure 5**)
- Grass weeds (**Figure 6**)
- Other weeds (**Figure 7**).

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Figure 3: Weeds of National Significance

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Figure 4: Bulbous weeds

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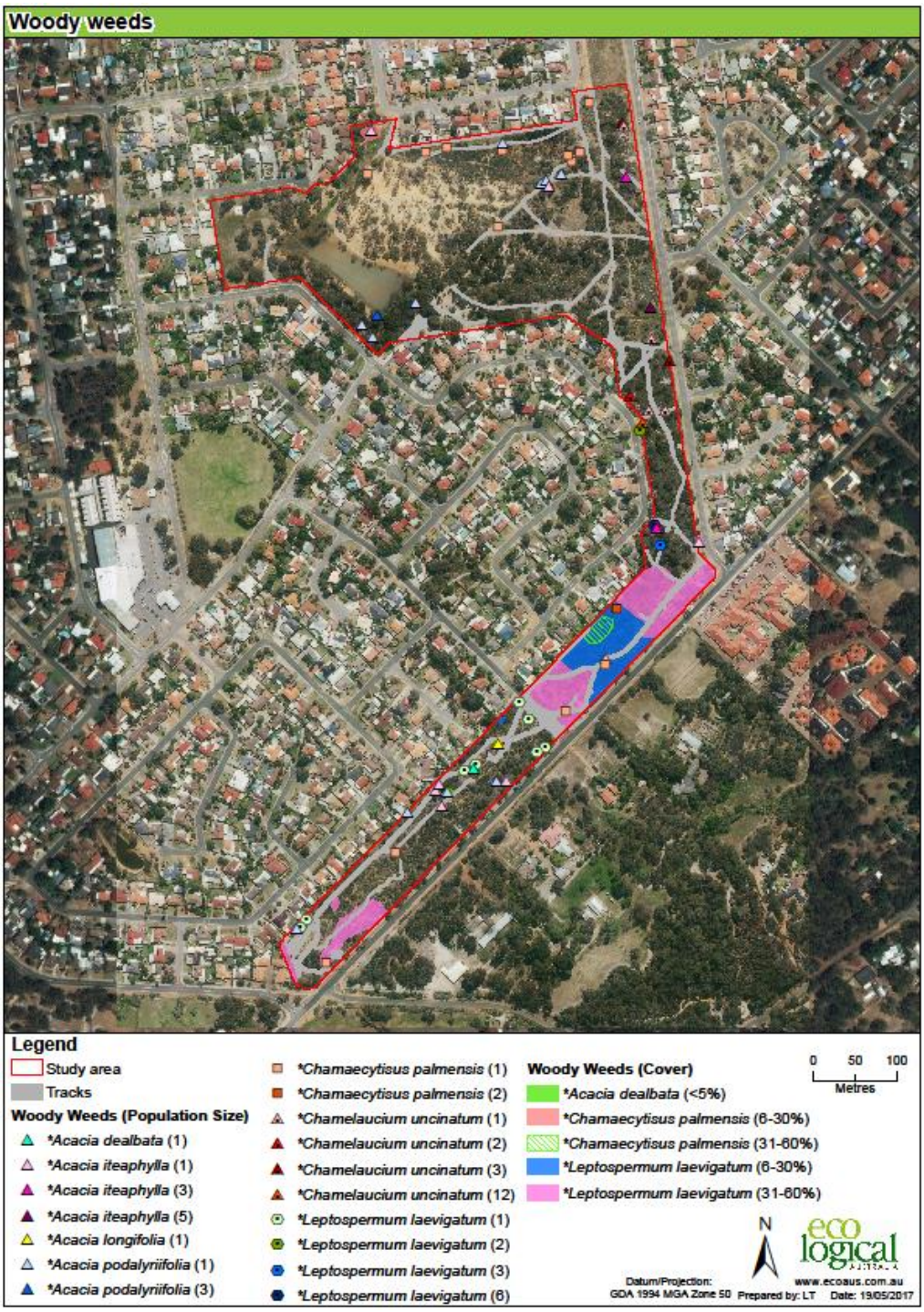


Figure 5: Woody weeds

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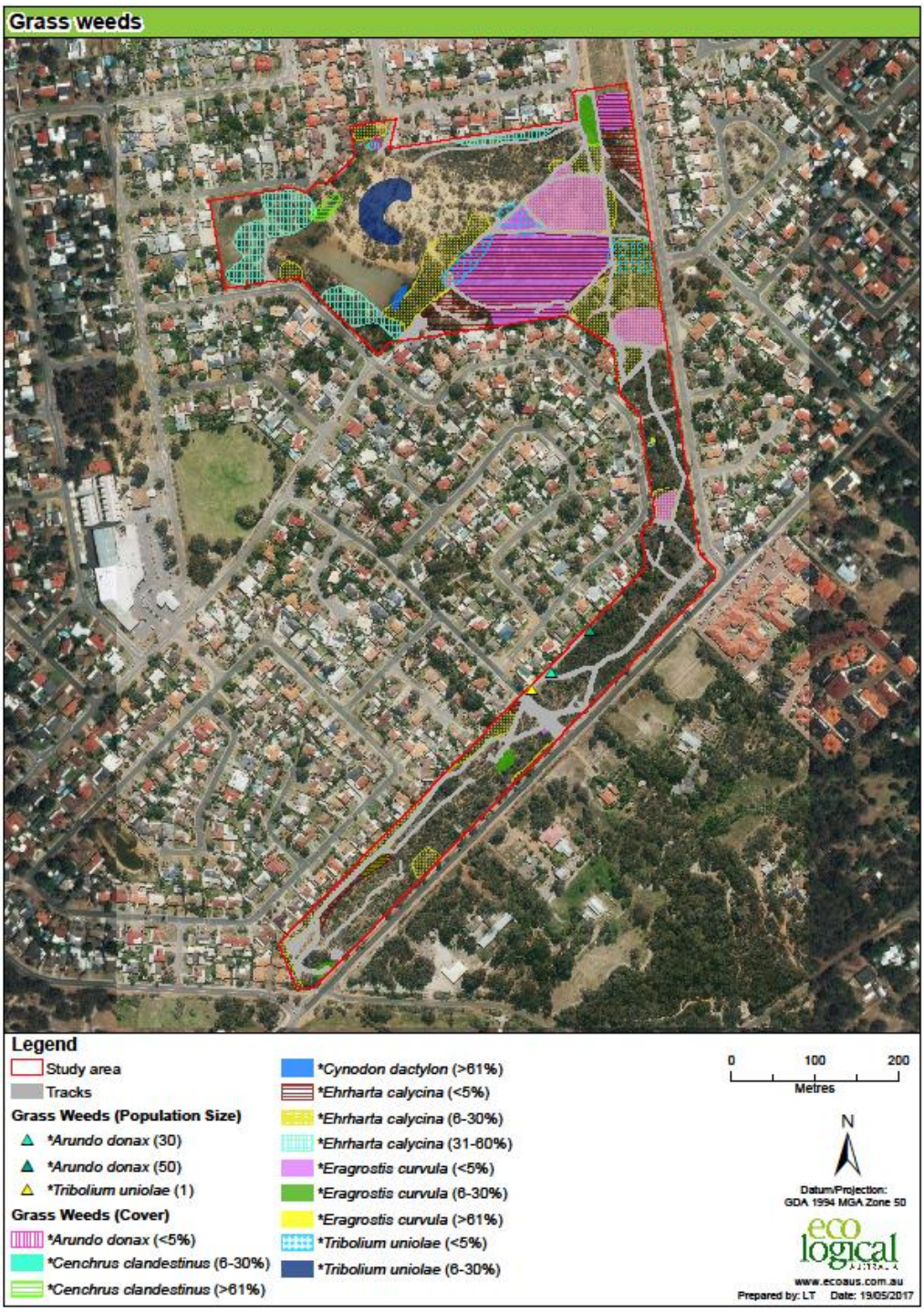


Figure 6: Grass weeds

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Figure 7: Other weeds

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4.2 Vegetation of the study area

4.2.1 Vegetation types

Three vegetation types were mapped in the study area (**Table 5** and **Figure 8**). Vegetation type CcOW was present throughout the southern narrow strip and a small patch in the north of the study area. Vegetation type EmW was the dominant vegetation type in the northern half of the study area, including areas of parkland that have been predominantly cleared. Vegetation type EwOW was present in one patch in the north of the study area and appeared to be historically cleared and planted with *Eucalyptus wandoo*. Recently revegetated areas were not assigned vegetation types, however, species from the Forrestfield Vegetation complex were used for revegetation.

Table 5: Vegetation types within the study area

Vegetation type	Description	ELA quadrats	Condition	Extent within study area (ha)	Portion of study area (%)
CcOW	*Corymbia calophylla* open woodland over *Hakea trifurcata* open shrubland over *Neurachne alopecuroidea, Opercularia vaginata, *Freesia alba* × *leichtlinii* isolated forbs.	ELA_01 ELA_05 ELA_06	Very Good - Degraded	5.07	29.82
EmW	*Eucalyptus marginata* subsp*. marginata* woodland over *Xanthorrhoea preissii*, *Allocasuarina humilis* and *Melaleuca aspalathoides* sparse shrubland over **Briza maxima* and **Ehrharta calycina* isolated grasses.	ELA_02 ELA_03 ELA_04	Very Good - Completely Degraded	6.74	39.66
EwOW	*Eucalyptus wandoo* open woodland over **Briza maxima* and **Ehrharta calycina* isolated grasses (historical planting).	-	Completely Degraded	2.08	12.24
Other	Tracks, revegetation, ephemeral drainage	-	-	3.11	18.29
Total				**17.0**	**100.0**

4.2.2 Conservation listed ecological communities

The vegetation communities of the study area do not represent the 'Banksia Woodlands of the Swan Coastal Plain' TEC based on the absence of key diagnostic species *Banksia attenuata* and *B. menziesii*, either as dominants or sub-dominants (DotEE 2016).

No other TECs or PECs are considered to be represented by the vegetation of the study area.

4.2.3 Vegetation condition

Vegetation condition in the study area ranged from Very Good to Completely Degraded based on the Keighery (1994) scale (**Table 6** and **Figure 9**). The majority of remnant vegetation was in Very Good and Good condition. The study area contained high numbers and densities of weeds, and several areas

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showed obvious signs of edge effects, which is reflected in lower vegetation condition ratings along tracks and roads (**Figure 9**). Other disturbances observed across the study area affecting condition included rubbish and garden waste dumping, historical clearing and revegetation using non-native species.

Other areas such as tracks, revegetation and drainage were not considered in the assessment of vegetation condition. Two areas previously revegetated to the south of the study area were very sparse and lacking in good cover of native plants; however, weed loads in these areas were low (**Figure 9**). The revegetation to the north of the study area appeared to be older and plants were much more mature in this area, consequently vegetation cover was better.

Table 6: Vegetation condition within the study area

Vegetation condition	Total area (ha)	Portion of study area (%)
Pristine	0.0	0.0
Excellent	0.0	0.0
Very Good	4.82	28.34
Good	4.20	24.72
Degraded	2.06	12.15
Completely Degraded	2.81	16.52
Tracks/paths	2.00	11.76
Other (Drainage, revegetation)	1.11	6.52
Total	**17.0**	**100.0**

4.2.4 FCT analysis

Results of the cluster analysis indicated that the ELA quadrats established in the study area clustered together into two separate groupings with various similarities to each other. The first group contained ELA_05 and ELA_01, the most similar at 41%, and ELA_06 joined at 29%, however, they joined a much larger group of Gibson et al. (1994) quadrats at a very low similarity which did not allow a determination of the likely FCT to be made at an appropriate confidence level.

The second group contained ELA_02 and ELA_04 the most similar at 47% and ELA_03 joined at 35%. These ELA quadrats joined two Gibson et al. (1994) quadrats; Card11 and Card4 at 26% similarity, which is classed as FCT 6 'Weed dominated wetlands on heavy soils' (Gibson et al. 1994). The low similarity (26%) is not considered an appropriate confidence level and thus FCT 6 is not considered to occur in the study area.

The reason for these low similarities is most likely due to the fact that Gibson et al. (1994) did not establish any quadrats on the far eastern side of the Swan Coastal Plain where the foothills vegetation grades into the Swan Coastal Plain vegetation, where the study area is located. The absence of any Gibson et al. (1994) quadrats to compare in the statistical analysis resulted in an inconclusive result. As such, the vegetation communities of the study area have not been assigned FCTs.

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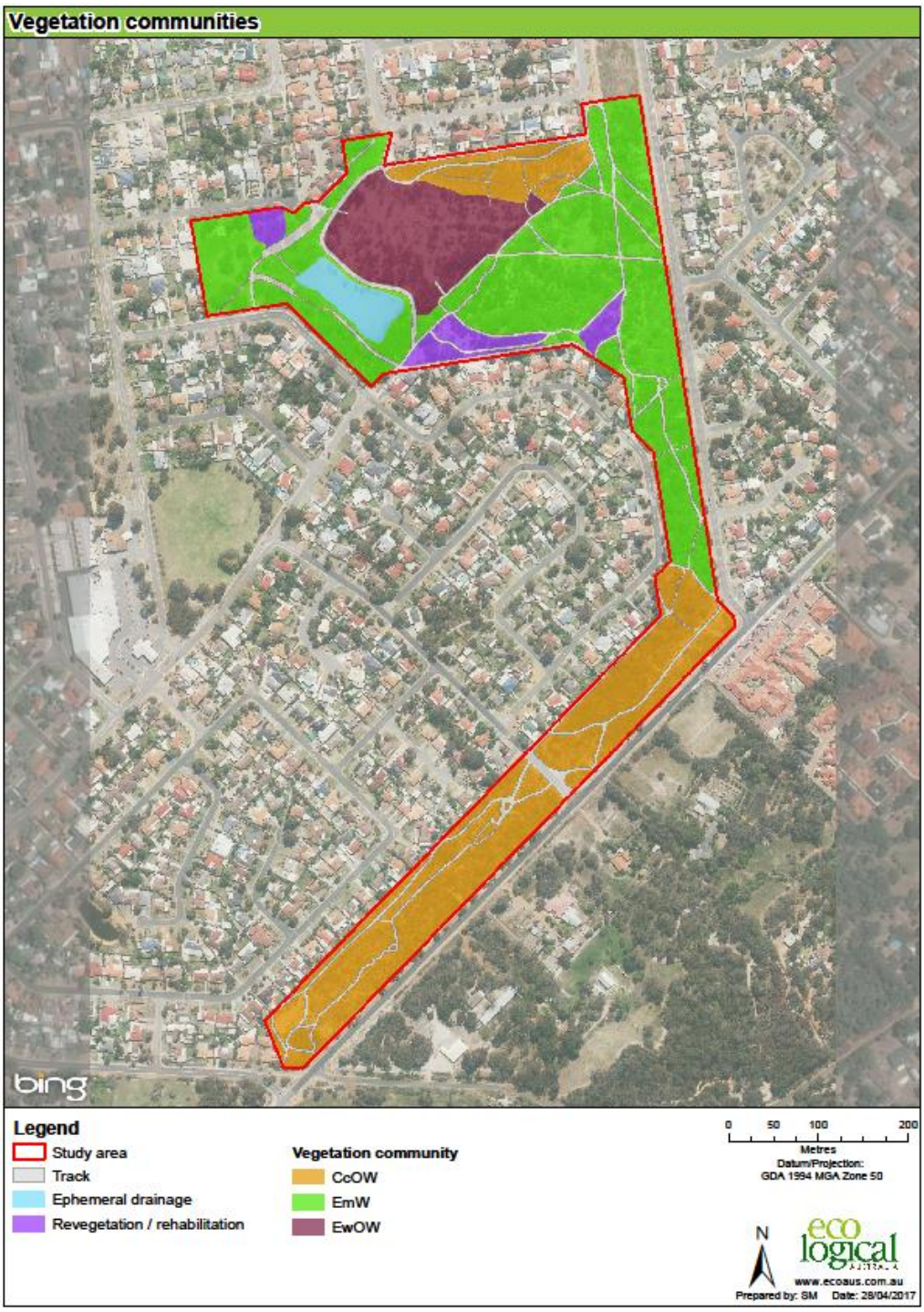


Figure 8: Vegetation types within the study area

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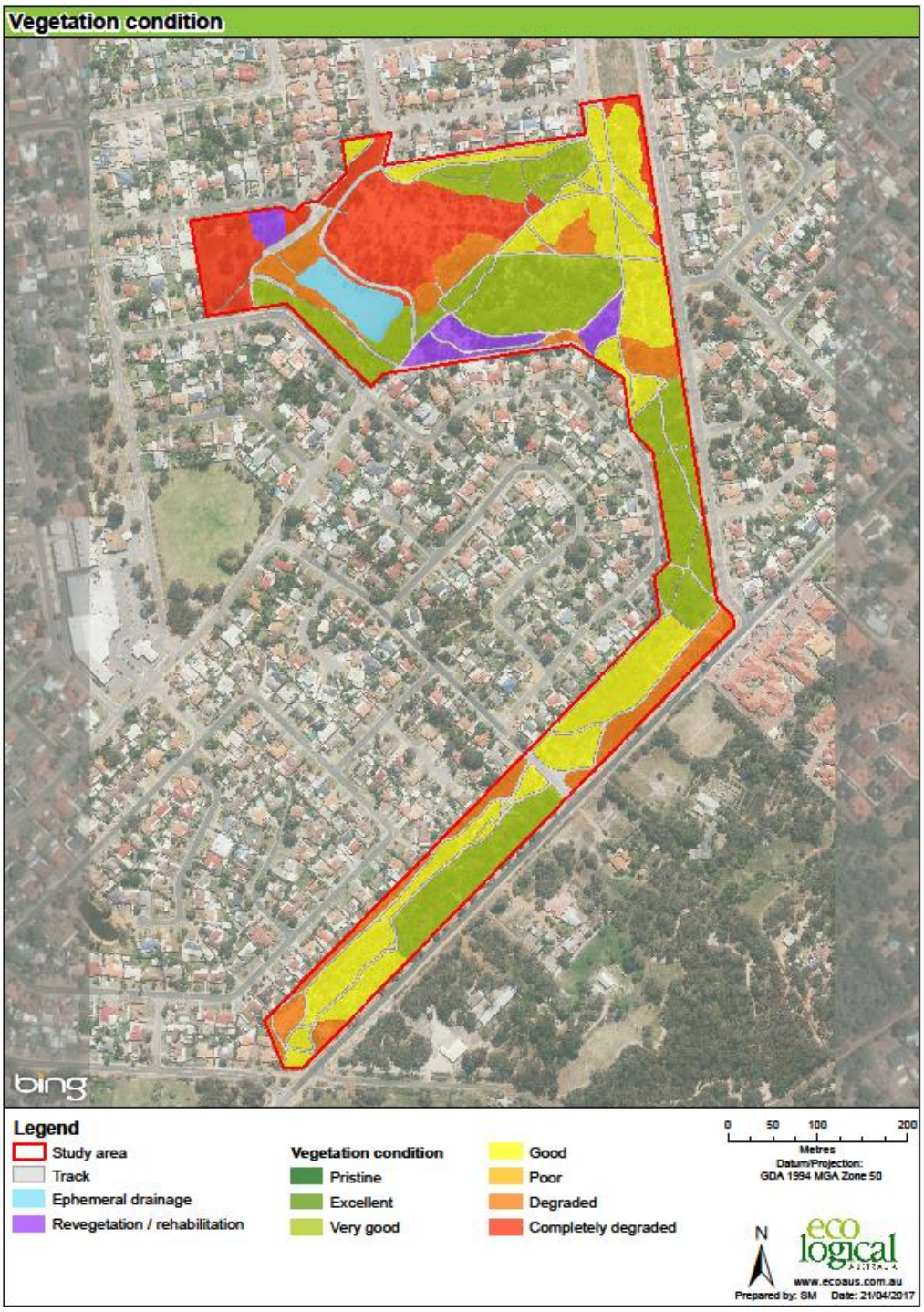


Figure 9: Vegetation condition within the study area

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4.3 Fauna of the study area

4.3.1 Fauna habitats

The vegetation types identified in the study area can be classed as one broad fauna habitat type: mixed Eucalypt woodland. The Eucalypt woodland habitat provides foraging and nesting habitat for a range of shrubland birds, including honeyeaters, wrens and other insectivorous birds; a range of terrestrial and fossorial reptiles, such as skinks, snakes and geckos; and for small mammals such as Quenda. Large *Eucalyptus marginata* (Jarrah) and *Corymbia calophylla* (Marri) trees provide nesting and roosting habitat for a range of larger birds, including Black Cockatoos.

The ephemeral drainage line leading into an artificial drainage sump also provides habitat for fauna when water is present. This provides suitable habitat for a number of common frog species, as well as providing an ephemeral water source for a wide range of fauna.

4.3.2 Black Cockatoo habitat assessment

The study area provides good foraging habitat for Black Cockatoos, such as *Banksia sessilis,* Jarrah, and Marri, which were present across most of the study area. Other species such as *Callistemon* and other eucalypts also provide potential foraging habitat.

Sixty-nine mature or dead Jarrah, Marri and *Eucalyptus wandoo* (Wandoo) trees, with DBH over 50 cm, were recorded throughout the study area (**Figure 12**). These trees provide potential breeding habitat for Black Cockatoos (SEWPaC 2012). Five of these trees had visible hollows; however, it is likely that additional trees within the study area would contain hollows that were not visible from the ground. The 69 potential breeding trees also provide suitable night roosting habitat for Black Cockatoos, as would other tall trees present throughout the study area.

4.3.3 Fauna assemblages

A total of 28 fauna species were opportunistically observed, or signs of their presence recorded, during the Level 1 fauna survey. This comprised 21 birds (15 native and six non-native), three mammals (one native and two introduced) and four reptiles (**Appendix I**).

4.3.4 Conservation listed fauna

A total of 22 conservation listed fauna species that possibly occur within the study area were identified from the database searches, based on records of occurrence within a 3 km radius (Parks and Wildlife 2007-2017; Parks and Wildlife 2016; DotEE 2017b). Of these 22, two were recorded, or signs of their presence recorded, within the study area:

- Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*) – listed as Vulnerable under the EPBC and WC Acts.
- Quenda (*Isoodon obesulus fusciventer*) – listed as Priority 4 by DPaW.

Forest Red-tailed Black Cockatoos were heard calling in the study area during the spring field survey (**Figure 13**). In addition, evidence of Black Cockatoo foraging activity on Marri nuts was recorded in the north of the study area (**Figure 10** and **Appendix K**). It is possible that Carnaby's Cockatoo (*Calyptorhynchus latirostris*) and Baudin's Cockatoo (*C. baudinii*) would also occur in the study area based on the presence of suitable foraging, breeding and night roosting habitat (**Figure 12**). No Black Cockatoo breeding or night roosting activity was observed during the fauna survey. Environmental staff have sighted white tailed cockatoos foraging in the reserve, however these have not been identified as being either Carnaby's Cockatoo or Baudin's Cockatoo (City of Kalamunda pers comm., 26 September 2017).

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Numerous Quenda diggings were observed in the north-eastern section of the study area in remnant vegetation (**Figure 11**, **Figure 13** and **Appendix K**). Majority of diggings were observed in vegetation considered to be in Very Good condition, however a few diggings were also observed in lesser quality vegetation (refer to **Figure 9** for vegetation condition). These areas still retained good coverage in the under storey, which is likely why Quenda are able to persist in the area. The presence of the ephemeral drainage in the north may also provide a water source for Quenda. Motion cameras were set up over one night during the spring survey in areas were Quenda diggings were observed, however no Quenda were recorded via motion camera.

Five additional conservation listed fauna species were considered to have the potential to occur, despite not being recorded, due to their seasonal movement patterns or their wide-ranging occurrence:

- *Apus pacificus* (Fork-tailed Swift)
- *Calyptorhynchus baudinii* (Baudin's Cockatoo)
- *Calyptorhynchus latirostris* (Carnaby's Cockatoo)
- *Dasyurus geoffroii* (Chuditch)
- *Merops ornatus* (Rainbow Bee-eater).

Environmental staff have sighted Rainbow Bee-eaters in the areas and it is known to burrow and breed in Hartfield Park in the sandy soils, adjacent to the study area. It is considered to potentially be present within the reserve. The remaining conservation listed fauna species were considered unlikely to occur either due to lack of habitat or erroneous records (**Appendix D**).



Figure 10**: Marri nuts chewed by Forest Red-tailed Black Cockatoos in the study area**

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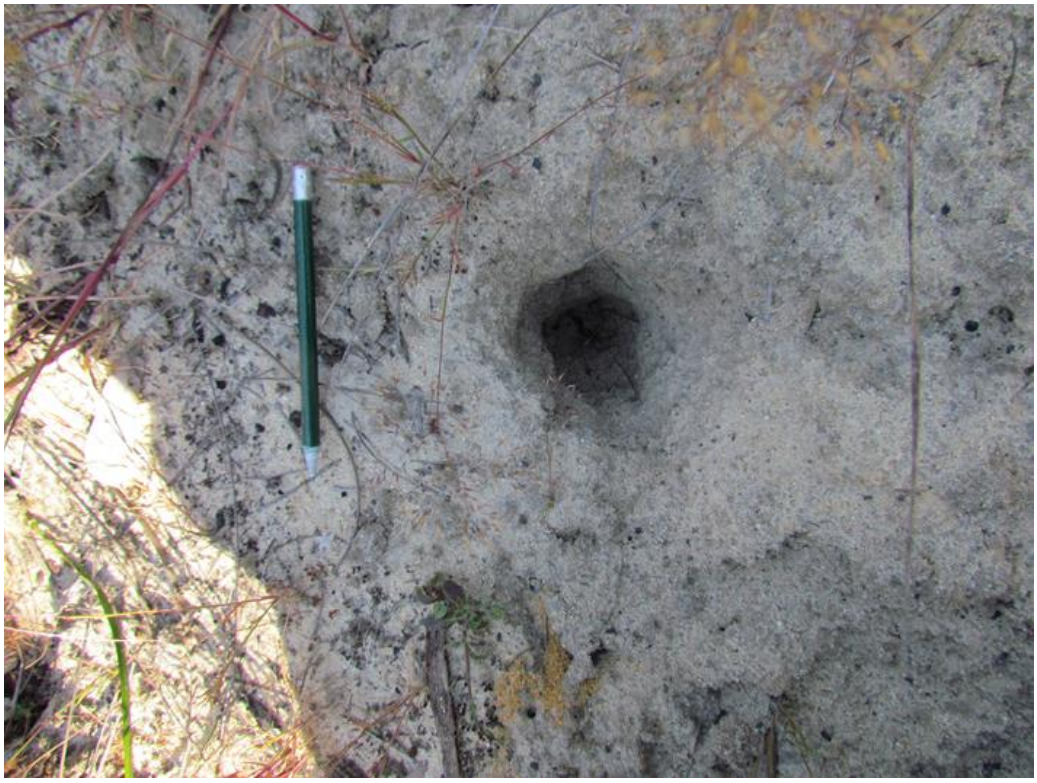


Figure 11: Example of Quenda digging observed in the study area

4.3.5 Introduced fauna

Five pest birds, one introduced bird and two introduced mammals were observed in the study area (**Appendix I**):

- Domestic Cat
- Domestic Pigeon
- European Rabbit
- Galah
- Laughing Dove
- Laughing Kookaburra
- Little Corella
- Rainbow Lorikeet

While pest birds are native to Australia, they are not native to the Perth area, and consequently create problems for native wildlife. This includes competition for nest hollows and food, predation, and the introduction and spread of disease. European Rabbits cause land degradation and competition for food, and Domestic Cats prey on numerous native fauna species.

In additional, several dog walkers were observed throughout the study area. Feral Bees (**Apis mellifera*) were also recorded in nest boxes in the north of the study area (**Figure 14**).

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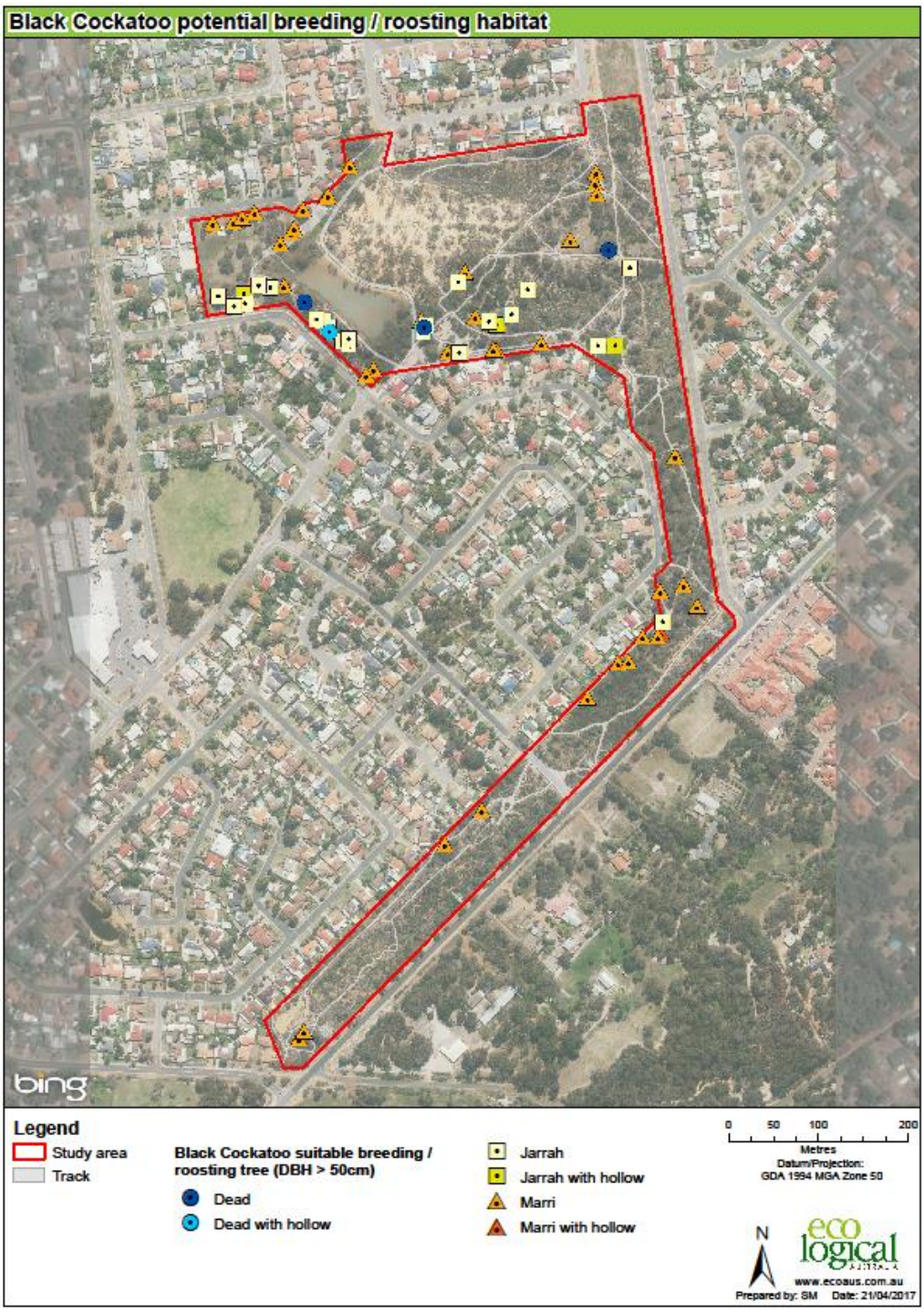


Figure 12: Black cockatoo potential breeding / night roosting habitat

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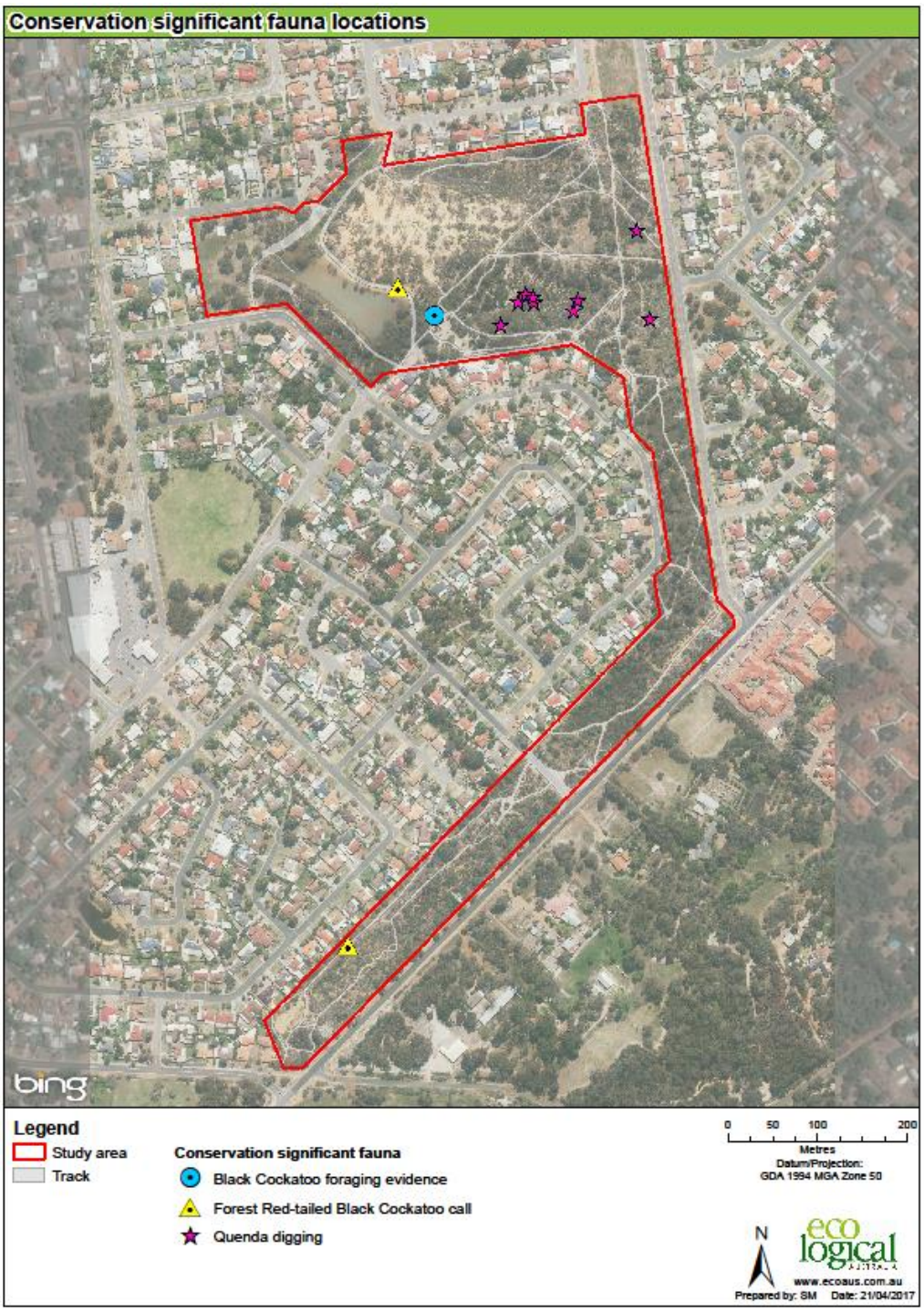


Figure 13: Conservation listed fauna recorded during the survey

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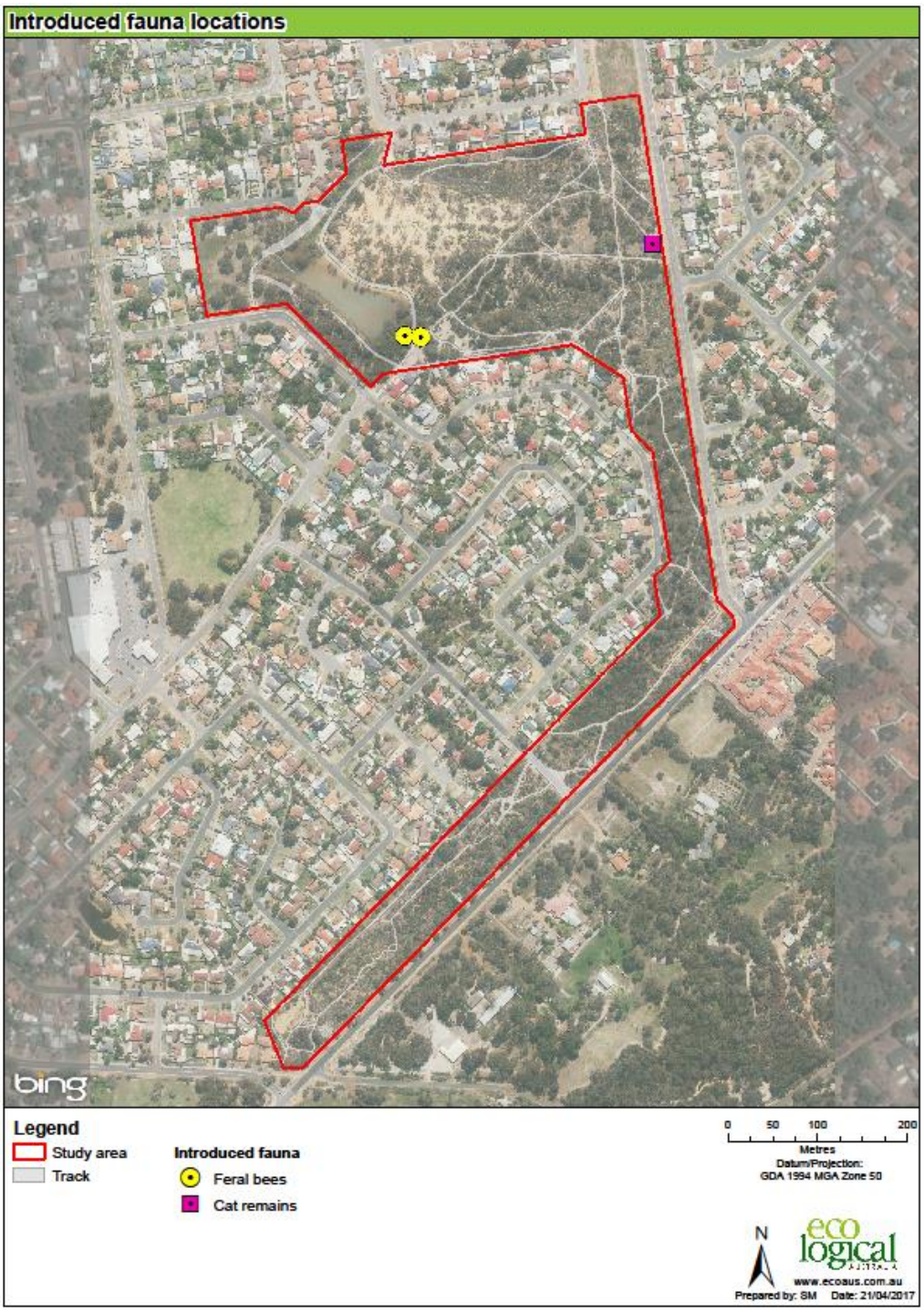


Figure 14: Introduced fauna recorded during the survey

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5 Conclusions and recommendations

5.1 Flora and vegetation

The study area is comprised of three vegetation types, all of which are broadly defined as eucalypt woodlands characterised by the dominant species of eucalypt in each (i.e. Marri, Jarrah and Wandoo). Boundaries between vegetation types are generally discontinuous, with interfaces representing an admixture of multiple vegetation types. However, in some cases the boundaries are more discrete due to a change in soil profile or disturbance (e.g. tracks, firebreaks, clearing etc.). None of these vegetation types represents a conservation significant ecological community which is supported by the FCT analysis undertaken from quadrat data recorded in the study area.

A total of 180 flora taxa were identified within the study area; 114 of which are native. The study area contains a high proportion of weeds, with 66 species (i.e. 37% of the total species recorded) documented during the survey. This level of weed infestation is a significant contributing factor to vegetation condition within the study area which ranged from Very Good to Completely Degraded. Weeds are present throughout the study area; however higher concentrations occur adjacent to cleared areas and in areas which have been subject to disturbance. Two weed species recorded during the field survey are listed as WoNS: **Opuntia stricta* and **Genista linifolia*. **O. stricta* is also listed as a Declared Pest under the BAM Act and was recorded from two locations along the south-western border of the study area. **G. linifolia* was recorded from two locations in the north of the study area.

A total of 60 conservation listed flora species that possibly occur within the study area were identified from the database searches, however no Threatened or Priority listed flora was recorded during the survey. Additionally, no conservation listed flora has previously been recorded within the study area, and as such, none are considered likely to occur.

5.2 Fauna

The fauna species recorded during the survey represent a snapshot of the fauna actually occurring within the study area, and it is therefore likely that many more species occur than were observed. A total of 294 vertebrate fauna taxa (native and introduced) were identified as possibly occurring based on NatureMap database search, including 10 amphibians, 51 reptiles, 212 birds and 21 mammals (Parks and Wildlife 2007 – 2017).

The study area provides an important area of remnant fauna habitat within the City of Kalamunda. The vegetation and habitat resources it contains are likely to support a diverse and species-rich assemblage of native birds and reptiles, and the bushland is considered to have high local conservation value. Several areas of large, intact remnant native vegetation occur on the Darling Scarp: Lesmurdie Falls National Park to the east and Mundy Regional Park to the north-east. However, few areas of remnant vegetation occur in close proximity on the Swan Coastal Plain. In addition, the study area is fragmented by roads and housing, which would limit the dispersal of many reptiles, mammals and amphibians.

The study area provides habitat and connectivity for many bird species and is important for the continued presence of a range of local reptile species. The occurrence of Forest Red-tailed Black Cockatoos highlights the foraging and potential breeding value of the study area for avifauna. It is also an important site for the Priority listed Quenda, which may be locally restricted to the area given the fragmented nature of the study area.

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Despite the certainty of introduced fauna preying on and competing with native fauna, the fact that Quenda are persisting in the study area is a positive indication that it represents a refuge for a range of native fauna. Feral animal control could potentially increase numbers of Quenda, other small mammals and a wide range of reptiles within the study area.

5.3 Recommendations

The following is recommended to continue to conserve and protect the environmental values of Anderson Road Reserve:

- Undertake a dieback survey to determine presence of *Phytophthora* Dieback in the reserve and to inform future management of the pathogen.
- Undertake a feasibility study to determine opportunities to create habitat linkages between Hartfield Park, Mundy Regional Park, Lesmurdie Falls and Woodlupine Brook.
- Continue weed management, particularly in areas adjacent to housing. Priorities include treatment and removal of WoNS (**Figure 3**).
- Undertake targeted weed control to minimise the spread of weeds in the areas of 'very good' vegetation condition.
- Remove dumped rubbish as soon as practicable and consider barrier or fencing options to prevent unauthorised access.
- Rationalise the existing pathways for passive recreational use.
- Undertake regular feral bee control within nest boxes and tree hollows across the study area.
- Consider infill planting and ongoing monitoring/management of revegetated areas.
- Continue implementation of *Anderson Road Reserve Action Plan 2015-2017* (Shire of Kalamunda 2015), update accordingly and recruit new volunteers.

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Appendix A Framework for conservation listed flora and fauna in Western Australia

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CATEGORIES OF THREATENED SPECIES UNDER THE *ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999* (EPBC ACT)

Threatened fauna and flora may be listed in any one of the following categories as defined in Section 179 of the EPBC Act. Species listed as 'conservation dependent' and 'extinct' are not Matters of National Environmental Significance and therefore do not trigger the EPBC Act.

Category	Definition
Extinct (EX)	There is no reasonable doubt that the last member of the species has died.
Extinct in the Wild (EW)	Taxa known to survive only in captivity or as a naturalised population well outside its past range; or taxa has not been recorded in its known and/or expected habitat at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
Critically Endangered (CE)	Taxa considered to be facing an extremely high risk of extinction in the wild.
Endangered (EN)	Taxa considered to be facing a very high risk of extinction in the wild.
Vulnerable (VU)	Taxa considered to be facing a high risk of extinction in the wild.
Near Threatened (NT)	Taxa has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Least Concern (LC)	Taxa has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.
Data Deficient (DD)	There is inadequate information to make a direct, or indirect, assessment of taxa's risk extinction based on its distribution and/or population status.
Not Evaluated (NE)	Taxa has not yet been evaluated against the criteria.
Migratory (M)	Not an IUCN category. Species are defined as migratory if they are listed in an international agreement approved by the Commonwealth Environment Minister, including: • the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animal) for which Australia is a range state; • the agreement between the Government of Australian and the Government of the People's Republic of China for the Protection of Migratory Birds and their environment (CAMBA); • the agreement between the Government of Japan and the Government of Australia for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment (JAMBA); or • the agreement between Australia and the Republic of Korea to develop a bilateral migratory bird agreement similar to the JAMBA and CAMBA in respect to migratory bird conservation and provides a basis for collaboration on the protection of migratory shorebirds and their habitat (ROKAMBA).

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CONSERVATION CODES FOR WESTERN AUSTRALIA FLORA AND FAUNA

Specially protected fauna or flora are species which have been adequately searched for and are deemed to be, in the wild, either rare, at risk of extinction, or otherwise in need of special protection, and have been gazetted as such.

Threatened species (T)
Published as Specially Protected under the Wildlife Conservation Act 1950, and listed under Schedules 1 to 4 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora (which may also be referred to as Declared Rare Flora).

Threatened fauna is that subset of 'Specially Protected Fauna' declared to be 'likely to become extinct' pursuant to section 14(4) of the Wildlife Conservation Act.

Threatened flora is 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(2) of the Wildlife Conservation Act.

The assessment of the conservation status of these species is based on their national extent and ranked according to their level of threat using IUCN Red List categories and criteria as detailed below.

Schedule	Code	Description
Schedule 1 Critically Endangered species	S1 (CR)	Threatened species considered to be facing an extremely high risk of extinction in the wild. Published as Specially Protected under the Wildlife Conservation Act 1950, in Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.
Schedule 2 Endangered species	S2 (EN)	Threatened species considered to be facing a very high risk of extinction in the wild. Published as Specially Protected under the Wildlife Conservation Act 1950, in Schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.
Schedule 3 Vulnerable species	S3 (VU)	Threatened species considered to be facing a high risk of extinction in the wild. Published as Specially Protected under the Wildlife Conservation Act 1950, in Schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.
Schedule 4 Presumed extinct species	S4 (EX)	Species which have been adequately searched for and there is no reasonable doubt that the last individual has died. Published as Specially Protected under the Wildlife Conservation Act 1950, in Schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice for Presumed Extinct Fauna and Wildlife Conservation (Rare Flora) Notice for Presumed Extinct Flora.

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Schedule	Code	Description
Schedule 5 Migratory birds protected under an international agreement	S5 (IA)	Birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and the Bonn Convention, relating to the protection of migratory birds. Published as Specially Protected under the Wildlife Conservation Act 1950, in Schedule 5 of the Wildlife Conservation (Specially Protected Fauna) Notice.
Schedule 6 Conservation dependent fauna	S6 (CD)	Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as threatened. Published as Specially Protected under the Wildlife Conservation Act 1950, in Schedule 6 of the Wildlife Conservation (Specially Protected Fauna) Notice.
Schedule 7 Other specially protected fauna	S7 (OS)	Fauna otherwise in need of special protection to ensure their conservation. Published as Specially Protected under the Wildlife Conservation Act 1950, in Schedule 7 of the Wildlife Conservation (Specially Protected Fauna) Notice.

Priority species (P)

Possibly threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened flora or fauna.

Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring.

Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.

Category	Code	Definition
Priority 1	P1	*Poorly-known species* 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.
Priority 2	P2	*Poorly-known species* 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

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Category	Code	Definition
		requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.
Priority 3	P3	*Poorly-known species* 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.
Priority 4	P4	*Rare, Near Threatened and other species in need of monitoring* (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. (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. (c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

DEFINITIONS, CATEGORIES AND CRITERIA FOR THREATENED AND PRIORITY ECOLOGICAL COMMUNITIES

An Ecological Community is described as “a naturally occurring biological assemblage that occurs in a particular type of habitat”.

A threatened ecological community (TEC) is one which is found to fit into one of the following categories; “presumed totally destroyed”, “critically endangered”, “endangered” or “vulnerable”.

Possible TECs that do not meet survey criteria are added to DPaW’s Priority Ecological Community Lists under Priorities 1, 2 and 3. Ecological Communities that are adequately known, are rare but not threatened, or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation Dependent ecological communities are placed in Priority 5.

Definitions and Criteria for Presumed Totally Destroyed, Critically Endangered, Endangered and Vulnerable Ecological Communities

Presumed Totally Destroyed (PD)

An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be totally destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future.

An ecological community will be listed as presumed totally destroyed if there are no recent records of the community being extant and either of the following applies (A or B):

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A) Records within the last 50 years have not been confirmed despite thorough searches of known or likely habitats,

B) All occurrences recorded within the last 50 years have since been destroyed.

Critically Endangered (CR)

An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated.

An ecological community will be listed as Critically Endangered when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria (A, B or C):

A) The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and either or both of the following apply (i or ii):

i) geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within approximately 10 years);

ii) modification throughout its range is continuing such that in the immediate future (within approximately 10 years) the c

B) Current distribution is limited, and one or more of the following apply (i, ii or iii):

i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 20 years);

ii) there are few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes;

iii) there may be many occurrences but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes.

C) The ecological community exists only as very modified occurrences that may be capable of being substantially restored or rehabilitated if such work begins in the short-term future (within approximately 20 years).

Endangered (EN)

An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future.

An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. This will be

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determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B, or C):

A) The geographic range, and/or total area occupied, and/or number of discrete occurrences have been reduced by at least 70% since European settlement and either or both of the following apply (i or ii):

i) the estimated geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is likely in the short term future (within approximately 20 years);

ii) modification throughout its range is continuing such that in the short term future (within approximately 20 years) the community is unlikely to be capable of being substantially restored or rehabilitated.

B) Current distribution is limited, and one or more of the following apply (i, ii or iii):

i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 20 years);

ii) there are few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes;

iii) there may be many occurrences but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes.

C) The ecological community exists only as very modified occurrences that may be capable of being substantially restored or rehabilitated if such work begins in the short-term future (within approximately 20 years).

Vulnerable (VU)

An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range.

An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing a high risk of total destruction or significant modification in the medium to long-term future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B or C):

A) The ecological community exists largely as modified occurrences that are likely to be capable of being substantially restored or rehabilitated.

B) The ecological community may already be modified and would be vulnerable to threatening processes, is restricted in area and/or range and/or is only found at a few locations.

C) The ecological community may be still widespread but is believed likely to move into a category of higher threat in the medium to long term future because of existing or impending threatening processes.

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Definitions and Criteria for Priority Ecological Communities

Possible threatened ecological communities that do not meet survey criteria or that are not adequately defined are added to the Priority Ecological Community List under priorities 1, 2 and 3. These three categories are ranked in order of priority for survey and/or definition of the community, and evaluation of conservation status, so that consideration can be given to their declaration as threatened ecological communities. Ecological communities that are adequately known, and are rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation Dependent ecological communities are placed in Priority 5.

Priority One: Poorly-known ecological communities

Ecological communities that are known from very few occurrences with a very restricted distribution (generally ≤5 occurrences or a total area of ≤ 100ha). Occurrences are believed to be under threat either due to limited extent, or being on lands under immediate threat (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) or for which current threats exist. May include communities with occurrences on protected lands. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range.

Priority Two: Poorly-known ecological communities

Communities that are known from few occurrences with a restricted distribution (generally ≤10 occurrences or a total area of ≤200ha). At least some occurrences are not believed to be under immediate threat of destruction or degradation. Communities may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under threat from known threatening processes.

Priority Three: Poorly known ecological communities

(i) Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation or:

(ii) communities known from a few widespread occurrences, which are either large or with significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat, or;

(iii) communities made up of large, and/or widespread occurrences, that may or may not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes.

Communities may be included if they are comparatively well known from several localities but do not meet adequacy of survey requirements and/or are not well defined, and known threatening processes exist that could affect them.

Priority Four: Ecological communities that are adequately known, rare but not threatened or meet criteria for Near Threatened or that have been recently removed from the threatened list. These communities require regular monitoring.

(i) Rare. Ecological communities known from few occurrences that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently

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threatened or in need of special protection, but could be if present circumstances change. These communities are usually represented on conservation lands.

(ii) Near Threatened. Ecological communities that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable.

(iii) Ecological communities that have been removed from the list of threatened communities during the past five years.

Priority Five: Conservation Dependent ecological communities

Ecological communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.

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Appendix B Database search results

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NatureMap
Mapping Western Australia's biodiversity

NatureMap Species Report

Created By Guest user on 25/10/2016

Kingdom Plantae
Conservation Status Conservation Taxon (T, X, IA, S, P1-P5)
Current Names Only Yes
Core Datasets Only Yes
Method 'By Circle'
Centre 116° 01' 05" E,31° 59' 40" S
Buffer 3km

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
1.	3219	*Acacia anomala (Grass Wattle)*		T	
2.	14131	*Acacia oncinophylla subsp. patulifolia*		P4	
3.	32211	*Banksia mimica (Summer Honeypot)*		T	
4.	32138	*Banksia pteridifolia subsp. vernalis*		P3	
5.	4444	*Boronia tenuis (Blue Boronia)*		P4	
6.	3178	*Byblis gigantea (Rainbow Plant)*		P3	
7.	13999	*Conospermum undulatum*		T	
8.	5505	*Darwinia apiculata (Scarp Darwinia)*		T	
9.	19630	*Grevillea bipinnatifida subsp. pagna*		P1	
10.	13439	*Grevillea thelemanniana subsp. thelemanniana (Spider Net Grevillea)*		T	
11.	1469	*Haemodorum loratum*		P3	
12.	5133	*Hibbertia helianthemoides*		P4	
13.	2228	*Isopogon drummondii*		P3	
14.	5025	*Lasiopetalum bracteatum (Helena Velvet Bush)*		P4	
15.	45081	*Lasiopetalum glutinosum subsp. glutinosum*		P3	
16.	37683	*Melaleuca viminalis*		P2	
17.	8163	*Pithocarpa corymbulosa (Corymbose Pithocarpa)*		P3	
18.	8212	*Senecio leucoglossus*		P4	
19.	7803	*Stylidium striatum (Fan-leaved Triggerplant)*		P4	
20.	8244	*Taraxacum cygnorum*		X	
21.	14333	*Tetratheca sp. Granite (S. Patrick SP1224)*		P3	
22.	20729	*Thelymitra magnifica (Crystal Brook Star Orchid)*		P1	
23.	10862	*Thelymitra stellata (Star Orchid)*		T	
24.	14714	*Verticordia lindleyi subsp. lindleyi*		P4	

Conservation Codes
T - Rare or likely to become extinct
X - Presumed extinct
IA - Protected under international agreement
S - Other specially protected fauna
1 - Priority 1
2 - Priority 2
3 - Priority 3
4 - Priority 4
5 - Priority 5

[1] For NatureMap's purposes, species flagged as endemic are those whose records are wholely contained within the search area. Note that only those records complying with the search criterion are included in the calculation. For example, if you limit records to those from a specific datasource, only records from that datasource are used to determine if a species is restricted to the query area.

NatureMap is a collaborative project of the Department of Parks and Wildlife and the Western Australian Museum.
Department of Parks and Wildlife
museum

NatureMap
Mapping Western Australia's biodiversity

NatureMap Species Report

Created By Guest user on 12/04/2017

Kingdom	Animalia
Conservation Status	Conservation Taxon (T, X, IA, S, P1-P5)
Current Names Only	Yes
Core Datasets Only	Yes
Method	'By Circle'
Centre	116° 01' 05" E,31° 59' 40" S
Buffer	3km

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
1.	24162	*Bettongia penicillata subsp. ogilbyi (Woylie, Brush-tailed Bettong)*		T	
2.	24731	*Calyptorhynchus banksii subsp. naso (Forest Red-tailed Black-Cockatoo)*		T	
3.	24734	*Calyptorhynchus latirostris (Carnaby's Cockatoo (short-billed black-cockatoo), Carnaby's Cockatoo)*		T	
4.	24092	*Dasyurus geoffroii (Chuditch, Western Quoll)*		T	
5.	24215	*Hydromys chrysogaster (Water-rat, Rakali)*		P4	
6.	25478	*Isoodon obesulus (Southern Brown Bandicoot)*		P4	
7.	24153	*Isoodon obesulus subsp. fusciventer (Quenda, Southern Brown Bandicoot)*		P4	
8.	24133	*Macropus irma (Western Brush Wallaby)*		P4	
9.	24598	*Merops ornatus (Rainbow Bee-eater)*		IA	
10.	25249	*Neelaps calonotos (Black-striped Snake)*		P3	
11.	24328	*Oxyura australis (Blue-billed Duck)*		P4	

Conservation Codes
T - Rare or likely to become extinct
X - Presumed extinct
IA - Protected under international agreement
S - Other specially protected fauna
1 - Priority 1
2 - Priority 2
3 - Priority 3
4 - Priority 4
5 - Priority 5

[1] For NatureMap's purposes, species flagged as endemic are those whose records are wholely contained within the search area. Note that only those records complying with the search criterion are included in the calculation. For example, if you limit records to those from a specific datasource, only records from that datasource are used to determine if a species is restricted to the query area.

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

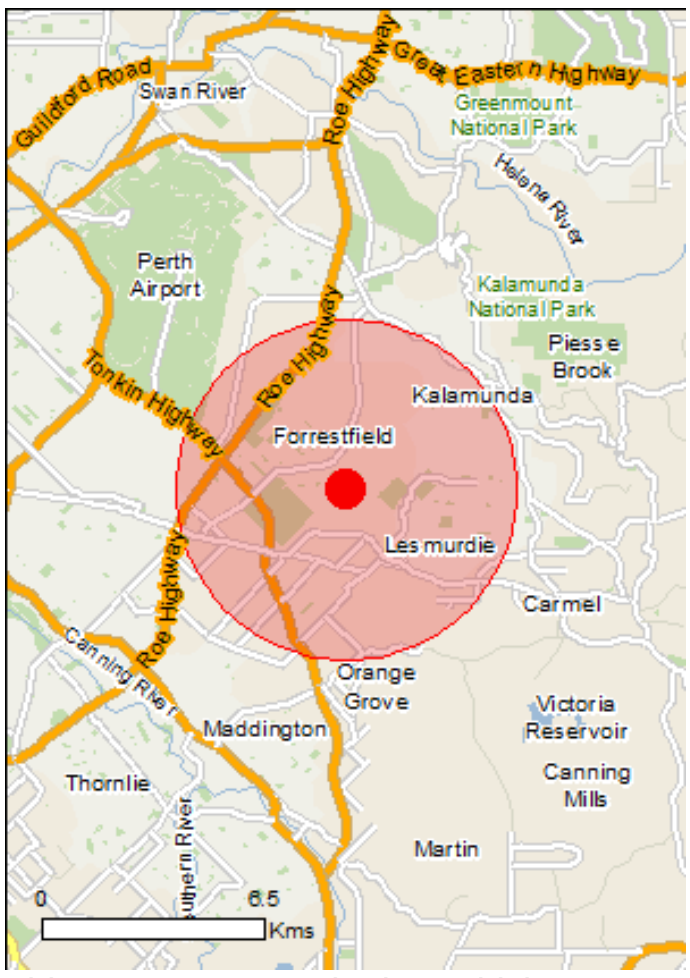
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 20/10/16 14:15:26

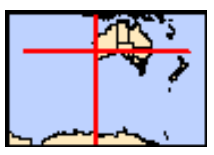
Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements



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Coordinates
Buffer: 5.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	3
Listed Threatened Species:	36
Listed Migratory Species:	6

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	12
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	7
Regional Forest Agreements:	1
Invasive Species:	43
Nationally Important Wetlands:	1
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Banksia Woodlands of the Swan Coastal Plain	Endangered	Community likely to occur within area
Claypans of the Swan Coastal Plain	Critically Endangered	Community likely to occur within area
Corymbia calophylla - Kingia australis woodlands on heavy soils of the Swan Coastal Plain	Endangered	Community known to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calyptorhynchus banksii naso Forest Red-tailed Black-Cockatoo, Karrak [67034]	Vulnerable	Species or species habitat known to occur within area
Calyptorhynchus baudinii Baudin's Cockatoo, Baudin's Black-Cockatoo, Long-billed Black-Cockatoo [769]	Vulnerable	Roosting known to occur within area
Calyptorhynchus latirostris Carnaby's Black-Cockatoo, Short-billed Black-Cockatoo [59523]	Endangered	Species or species habitat known to occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Mammals		
Bettongia penicillata Brush-tailed Bettong, Woylie [213]	Endangered	Species or species habitat may occur within area
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat known to occur

Name	Status	Type of Presence
		within area
Pseudocheirus occidentalis Western Ringtail Possum, Ngwayir, Womp, Woder, Ngoor, Ngoolangit [25911]	Vulnerable	Species or species habitat may occur within area
Setonix brachyurus Quokka [229]	Vulnerable	Species or species habitat likely to occur within area
Plants		
Acacia anomala Grass Wattle, Chittering Grass Wattle [8153]	Vulnerable	Species or species habitat known to occur within area
Andersonia gracilis Slender Andersonia [14470]	Endangered	Species or species habitat known to occur within area
Anthocercis gracilis Slender Tailflower [11103]	Vulnerable	Species or species habitat likely to occur within area
Banksia mimica Summer Honeypot [82765]	Endangered	Species or species habitat likely to occur within area
Caladenia huegelii King Spider-orchid, Grand Spider-orchid, Rusty Spider-orchid [7309]	Endangered	Species or species habitat likely to occur within area
Calytrix breviseta subsp. breviseta Swamp Starflower [23879]	Endangered	Species or species habitat known to occur within area
Chamelaucium sp. Gingin (N.G.Marchant s.n., 4/11/1988) Gingin Wax [64649]	Endangered	Species or species habitat may occur within area
Conospermum undulatum Wavy-leaved Smokebush [24435]	Vulnerable	Species or species habitat likely to occur within area
Darwinia apiculata Scarp Darwinia [8763]	Endangered	Species or species habitat likely to occur within area
Diuris drummondii Tall Donkey Orchid [4365]	Vulnerable	Species or species habitat likely to occur within area
Diuris micrantha Dwarf Bee-orchid [55082]	Vulnerable	Species or species habitat likely to occur within area
Diuris purdiei Purdie's Donkey-orchid [12950]	Endangered	Species or species habitat known to occur within area
Drakaea elastica Glossy-leafed Hammer Orchid, Glossy-leaved Hammer Orchid, Warty Hammer Orchid [16753]	Endangered	Species or species habitat likely to occur within area
Drakaea micrantha Dwarf Hammer-orchid [56755]	Vulnerable	Species or species habitat may occur within area
Eleocharis keigheryi Keighery's Eleocharis [64893]	Vulnerable	Species or species habitat likely to occur within area
Eucalyptus balanites Cadda Road Mallee, Cadda Mallee [24264]	Endangered	Species or species habitat may occur within

Name	Status	Type of Presence
		area
Grevillea curviloba subsp. incurva Narrow curved-leaf Grevillea [64909]	Endangered	Species or species habitat may occur within area
Lasiopetalum pterocarpum Wing-fruited Lasiopetalum [64922]	Endangered	Species or species habitat may occur within area
Lepidosperma rostratum Beaked Lepidosperma [14152]	Endangered	Species or species habitat likely to occur within area
Macarthuria keigheryi Keighery's Macarthuria [64930]	Endangered	Species or species habitat likely to occur within area
Ptilotus pyramidatus Pyramid Mulla-mulla [18216]	Critically Endangered	Species or species habitat known to occur within area
Synaphea sp. Fairbridge Farm (D.Papenfus 696) Selena's Synaphea [82881]	Critically Endangered	Species or species habitat likely to occur within area
Thelymitra dedmaniarum Cinnamon Sun Orchid [65105]	Endangered	Species or species habitat likely to occur within area
Thelymitra stellata Star Sun-orchid [7060]	Endangered	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Migratory Wetlands Species		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name

Commonwealth Land -

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Thinornis rubricollis Hooded Plover [59510]		Species or species habitat may occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Kenwick Wetlands	WA
Korung	WA
Lesmurdie Falls	WA
Unnamed WA23076	WA
Unnamed WA24657	WA
Unnamed WA29815	WA
Unnamed WA37997	WA

Regional Forest Agreements [Resource Information]

Note that all areas with completed RFAs have been included.

Name	State
South West WA RFA	Western Australia

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Acridotheres tristis Common Myna, Indian Myna [387]		Species or species habitat likely to occur within area
Anas platyrhynchos Mallard [974]		Species or species habitat likely to occur within area
Carduelis carduelis European Goldfinch [403]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Streptopelia senegalensis Laughing Turtle-dove, Laughing Dove [781]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Turdus merula Common Blackbird, Eurasian Blackbird [596]		Species or species habitat likely to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Feral deer Feral deer species in Australia [85733]		Species or species habitat likely to occur within area
Funambulus pennantii Northern Palm Squirrel, Five-striped Palm Squirrel [129]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus norvegicus Brown Rat, Norway Rat [83]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Anredera cordifolia Madeira Vine, Jalap, Lamb's-tail, Mignonette Vine, Anredera, Gulf Madeiravine, Heartleaf Madeiravine, Potato Vine [2643]		Species or species habitat likely to occur within area
Asparagus asparagoides Bridal Creeper, Bridal Veil Creeper, Smilax, Florist's Smilax, Smilax Asparagus [22473]		Species or species habitat likely to occur within area
Brachiaria mutica Para Grass [5879]		Species or species habitat may occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat may occur within area
Chrysanthemoides monilifera Bitou Bush, Boneseed [18983]		Species or species habitat may occur within area
Chrysanthemoides monilifera subsp. monilifera Boneseed [16905]		Species or species habitat likely to occur within area
Eichhornia crassipes Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Genista linifolia Flax-leaved Broom, Mediterranean Broom, Flax Broom [2800]		Species or species habitat likely to occur within area
Genista monspessulana Montpellier Broom, Cape Broom, Canary Broom, Common Broom, French Broom, Soft Broom [20126]		Species or species habitat likely to occur within area
Genista sp. X Genista monspessulana Broom [67538]		Species or species habitat may occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		Species or species habitat likely to occur within area
Olea europaea Olive, Common Olive [9160]		Species or species habitat may occur within area
Pinus radiata Radiata Pine Monterey Pine, Insignis Pine, Wilding Pine [20780]		Species or species habitat may occur within area
Rubus fruticosus aggregate Blackberry, European Blackberry [68406]		Species or species habitat likely to occur within area
Sagittaria platyphylla Delta Arrowhead, Arrowhead, Slender Arrowhead [68483]		Species or species habitat likely to occur within area
Salix spp. except S.babylonica, S.x calodendron & S.x reichardtii Willows except Weeping Willow, Pussy Willow and Sterile Pussy Willow [68497]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Tamarix aphylla Athel Pine, Athel Tree, Tamarisk, Athel Tamarisk, Athel Tamarix, Desert Tamarisk, Flowering Cypress, Salt Cedar [16018]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area
Ramphotyphlops braminus Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat likely to occur within area

Nationally Important Wetlands	[Resource Information]
Name	State
Brixton Street Swamps	WA

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-31.99444 116.01806

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Parks and Wildlife Commission NT, Northern Territory Government
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Appendix C Flora likelihood of occurrence assessment

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Species	Conservation status[1]			Source[2]				Likelihood assessment
	EPBC Act	WC Act	Parks and Wildlife	NatureMap	PMST	WAHerb	TPFL	
Acacia anomala	VU	S3	T	X	X	X	X	Unlikely
Acacia aphylla	VU	S3	T	-	-	X	X	Unlikely
Acacia oncinophylla subsp. *patulifolia*	-	-	P4	X	-	X	X	Unlikely
Amanita kalamundae	-	-	P3	-	-	X	-	Unlikely
Andersonia gracilis	EN	S3	T	-	X	X	X	Unlikely
Anthocercis gracilis	VU	S3	T	-	X	X	X	Unlikely
Austrostipa bronwenae	-	S2	T	-	-	X	X	Unlikely
Babingtonia urbana	-	-	P3	-	-	-	X	Unlikely
Banksia mimica	EN	S3	T	X	X	X	X	Unlikely
Banksia pteridifolia subsp. *vernalis*	-	-	P3	X	-	X	-	Unlikely
Boronia humifusa	-	-	P1	-	-	X	X	Unlikely
Boronia tenuis	-	-	P4	X	-	X	X	Unlikely
Byblis gigantea	-	-	P3	X	-	X	X	Unlikely
Caladenia huegelii	EN	S1	T	-	X	-	-	Unlikely
Calandrinia sp. Piawaning (A.C. Beauglehole 12257)	-	-	P1	-	-	X	-	Unlikely
Calytrix breviseta subsp. *breviseta*	EN	S1	T	-	X	X	X	Unlikely
Centrolepis caespitosa	-	-	P4	-	-	X	-	Unlikely
Chamelaucium sp. Gingin (N.G. Marchant 6)	EN	S3	T	-	X	-	-	Unlikely
Comesperma rhadinocarpum	-	-	P2	-	-	-	X	Unlikely

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Species	Conservation status[1]			Source[2]				Likelihood assessment
	EPBC Act	WC Act	Parks and Wildlife	NatureMap	PMST	WAHerb	TPFL	
Conospermum undulatum	VU	S3	T	X	X	X	X	Unlikely
Darwinia apiculata	EN	S2	T	X	X	X	X	Unlikely
Diuris drummondii	VU	S3	T	-	X	-	-	Unlikely
Diuris micrantha	VU	S3	T	-	X	-	-	Unlikely
Diuris purdiei	EN	S2	T	-	X	-	X	Unlikely
Drakaea elastica	EN	S1	T	-	X	-	-	Unlikely
Drakaea micrantha	VU	S2	T	-	X	-	-	Unlikely
Drosera occidentalis subsp. *occidentalis*	-	-	P4	-	-	X	X	Unlikely
Eleocharis keigheryi	VU	S3	T	-	X	-	-	Unlikely
Eremophila glabra subsp. *chlorella*	-	S2	T	-	-	X	X	Unlikely
Eucalyptus x *balanites*	EN	S1	T	-	X	-	-	Unlikely
Grevillea bipinnatifida subsp. *pagna*	-	-	P1	X	-	-	-	Unlikely
Grevillea curviloba subsp. *incurva*	EN	S1	T	-	X	-	-	Unlikely
Grevillea thelemanniana subsp. *thelemanniana*	-	-	P1	X	-	X	X	Unlikely
Haemodorum loratum	-	-	P3	X	-	X	X	Unlikely
Halgania corymbosa	-	-	P4	-	-	X	-	Unlikely
Hibbertia helianthemoides	-	-	P4	X	-	-	-	Unlikely
Hibbertia montana	-	-	P4	-	-	X	-	Unlikely
Hypocalymma sp. Cataby (G.J. Keighery 5151)	-	-	P2	-	-	-	X	Unlikely

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Species	Conservation status[1]			Source[2]				Likelihood assessment
	EPBC Act	WC Act	Parks and Wildlife	NatureMap	PMST	WAHerb	TPFL	
Isopogon drummondii	-	-	P3	X	-	X	-	Unlikely
Lasiopetalum bracteatum	-	-	P4	X	-	X	-	Unlikely
Lasiopetalum glutinosum subsp. *glutinosum*	-	-	P3	X	-	X	-	Unlikely
Lasiopetalum pterocarpum	EN	S1	T	-	X	-	-	Unlikely
Lepidosperma rostratum	EN	S2	T	-	X	X	X	Unlikely
Macarthuria keigheryi	EN	S2	T	-	X	X	X	Unlikely
Melaleuca viminalis	-	-	P2	X	-	X	-	Unlikely
Myriophyllum echinatum	-	-	P3	-	-	X	-	Unlikely
Ornduffia submersa	-	-	P4	-	-	X	-	Unlikely
Pithocarpa corymbulosa	-	-	P3	X	-	X	X	Unlikely
Platysace ramosissima	-	-	P3	-	-	X	X	Unlikely
Ptilotus pyramidatus	CR	S1	T	-	X	-	-	Unlikely
Schoenus pennisetis	-	-	P3	-	-	X	X	Unlikely
Senecio leucoglossus	-	-	P4	X	-	X	X	Unlikely
Stylidium striatum	-	-	P4	X	-	X	-	Unlikely
Synaphea sp. Fairbridge Farm (D. Papenfus 696)	CR	S1	T	-	X	-	X	Unlikely
Tetratheca sp. Granite (S. Patrick SP1224)	-	-	P3	X	-	X	X	Unlikely
Thelymitra dedmaniarum	EN	S1	T	-	X	-	-	Unlikely
Thelymitra magnifica	-	-	P1	X	-	X	X	Unlikely

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Species	Conservation status[1]			Source[2]				Likelihood assessment
	EPBC Act	WC Act	Parks and Wildlife	NatureMap	PMST	WAHerb	TPFL	
Thelymitra stellata	EN	S2	T	X	X	X	X	Unlikely
Thysanotus anceps	-	-	P3	-	-	X	-	Unlikely
Verticordia lindleyi subsp. *lindleyi*	-	-	P4	X	-	X	X	Unlikely

[1]CR = listed as Critically Endangered under the EPBC Act.

EN = listed as Endangered under the EPBC Act.

VU = listed as Vulnerable under the EPBC Act.

S1 = Schedule 1: Flora that are considered likely to become extinct or rare, as critically endangered flora (CR) under the WC Act.

S2 = Schedule 2: Flora that are considered likely to become extinct or rare, as endangered flora (EN) under the WC Act.

S3 = Schedule 3: Flora that are considered likely to become extinct or rare, as vulnerable flora (VU) under the WC Act.

T = Threatened species: flora that has been declared likely to become extinct or is rare, or otherwise in need of special protection, pursuant to section 23F(2) of the WC Act.

P1 = Priority 1: poorly known species that are known from one or a few locations which are potentially at risk, and are in urgent need of further survey. Listed by Department of Parks and Wildlife.

P2 = Priority 2: poorly known species known from one or a few locations, some of which are on lands managed primarily for nature conservation, and are in urgent need of further survey. Listed by Department of Parks and Wildlife.

P3 = Priority 3: poorly-known species known from several specimens or records but not under imminent threat, and need further survey. Listed by Department of Parks and Wildlife.

P4 = Priority 4: Rare, Near Threatened and other species in need of monitoring but not currently threatened; could become threatened if present circumstances change. Listed by Department of Parks and Wildlife.

[2]NatureMap = NatureMap database search (Parks and Wildlife 2007 - 2017); PMST = EPBC Act Protected Matters Report (DotEE 2017b); WAHerb = Western Australian Herbarium; TPFL = Threatened and Priority Flora database (Parks and Wildlife 2016a)

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Appendix D Fauna likelihood of occurrence assessment

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Species	Conservation status[1]			Source[2]		Likelihood assessment
	EPBC Act	Parks and Wildlife	WC Act	NatureMap	PMST	
Apus pacificus (Fork-tailed Swift)	M	-	S5	-	X	Potential
Bettongia penicillata (Brush-tailed Bettong, Woylie)	EN	-	S1	X	X	Unlikely
Botaurus poiciloptilus (Australasian Bittern)	EN	-	S2	-	X	Unlikely
Calidris ferruginea (Curlew Sandpiper)	CR, M	-	S3	-	X	Unlikely
Calyptorhynchus banksii naso (Forest Red-tailed Black-Cockatoo)	VU	-	S3	X	-	Known
Calyptorhynchus baudinii (Baudin's Cockatoo)	VU	-	S2	-	X	Potential
Calyptorhynchus latirostris (Carnaby's Cockatoo)	EN	-	S2	X	-	Potential
Dasyurus geoffroii (Chuditch)	VU	-	S3	X	-	Potential
Hydromys chrysogaster (Water-rat)	-	P4	-	X	-	Unlikely
Isoodon obesulus fusciventer (Southern Brown Bandicoot, Quenda)	-	P4	-	X	-	Known
Leipoa ocellata (Malleefowl)	VU	-	S3	-	X	Unlikely
Macropus irma (Western Brush Wallaby)	-	P4	-	X	-	Unlikely
Merops ornatus (Rainbow Bee-eater)	M		S5	X	-	Potential
Motacilla cinerea (Grey Wagtail)	M	-	S5	-	X	Unlikely
Neelaps calonotos (Black-striped Snake)	-	P3	-	X	-	Unlikely
Numenius madagascariensis (Eastern Curlew)	CR	-	S3	-	X	Unlikely
Oxyura australis (Blue-billed Duck)	-	P4	-	X	-	Unlikely
Pandion haliaetus (Osprey)	M	-	S5	-	X	Unlikely

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Species	Conservation status[1]			Source[2]		Likelihood assessment
	EPBC Act	Parks and Wildlife	WC Act	NatureMap	PMST	
Pseudocheirus occidentalis (Western Ring-tailed Possum)	VU	-	S1	-	X	Unlikely
Rostratula australis (Australian Painted Snipe)	EN	-	S2	-	X	Unlikely
Setonix brachyurus (Quokka)	VU	-	S3	-	X	Unlikely
Tringa nebularia (Common Greenshank)	M	-	S5	-	X	Unlikely

[1]CR = listed as Critically Endangered under the EPBC Act.

EN = listed as Endangered under the EPBC Act.

VU = listed as Vulnerable under the EPBC Act.

M = listed as Migratory species under the EPBC Act.

S1 = Schedule 1: Fauna that is rare or is likely to become extinct as critically endangered fauna (CR) under the WC Act.

S2 = Schedule 2: Fauna that is rare or likely to become extinct as endangered fauna (EN) under the WC Act.

S3 = Schedule 3: Fauna that is rare or likely to become extinct as vulnerable fauna (VU) under the WC Act.

S5 = Schedule 5: Migratory birds protected under an international agreement (IA) under the WC Act.

P3 = Priority 3: poorly-known species known from several specimens or records but not under imminent threat, and need further survey. Listed by Department of Parks and Wildlife.

P4 = Priority 4: Rare, Near Threatened and other species in need of monitoring but not currently threatened; could become threatened if present circumstances change. Listed by Department of Parks and Wildlife.

[2]NatureMap = NatureMap database search (Parks and Wildlife 2007 - 2017); PMST = EPBC Act Protected Matters Report (DotEE 2017b).

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Appendix E Flora species list

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Family	Species
Arecaceae	**Washingtonia filifera*
Asparagaceae	**Agave americana*
	Laxmannia ramosa subsp. *ramosa*
	Lomandra preissii
	Thysanotus manglesianus
	Thysanotus sparteus
	Thysanotus tenellus
Asteraceae	**Arctotheca calendula*
	**Gazania linearis*
	**Hypochaeris glabra*
	**Lactuca serriola*
	**Osteospermum ecklonis*
	**Taraxacum khatoonae*
	**Ursinia anthemoides*
	Pterochaeta paniculata
Brassicaceae	**Raphanus raphanistrum*
Cactaceae	**Opuntia stricta*
Campanulaceae	**Wahlenbergia capensis*
	Isotoma hypocrateriformis
Caprifoliaceae	**Centranthus macrosiphon*
Caryophyllaceae	**Silene gallica*
Casuarinaceae	*Allocasuarina huegeliana*
	Allocasuarina humilis
Colchicaceae	*Burchardia congesta*
Convolvulaceae	**Ipomoea cairica*
Crassulaceae	*Crassula colorata* var. *colorata*
Cyperaceae	*Mesomelaena pseudostygia*
	Mesomelaena tetragona
	Schoenus sp.
Dasypogonaceae	*Dasypogon bromeliifolius*
Dilleniaceae	*Hibbertia hypericoides*
	Hibbertia huegelii

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Family	Species
Droseraceae	*Drosera* sp.
	Drosera erythrorhiza
	Drosera glanduligera
	Drosera macrantha
	Drosera pallida
Elaeocarpaceae	*Tetratheca nuda*
Euphorbiaceae	**Euphorbia peplus*
Fabaceae	**Acacia dealbata*
	**Acacia iteaphylla*
	**Acacia longifolia*
	**Acacia podalyriifolia*
	**Acacia* sp. (Eastern States)
	**Chamaecytisus palmensis*
	**Genista linifolia*
	**Lotus angustissimus*
	**Lotus subbiflorus*
	**Lupinus angustifolius*
	**Lupinus cosentinii*
	**Trifolium campestre*
	**Trifolium angustifolium*
	**Trifolium arvense*
	**Vicia sativa*
	Acacia pulchella
	Acacia nervosa
	Acacia pulchella var. *pulchella*
	Acacia saligna
	Bossiaea eriocarpa
	Daviesia decurrens subsp. *decurrens*
	Daviesia nudiflora subsp. *nudiflora*
	Gastrolobium retusum
	Gompholobium sp.
	Gompholobium knightianum

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Family	Species
	Gompholobium marginatum
	Jacksonia lehmannii
	Kennedia prostrata
	Sphaerolobium linophyllum
Geraniaceae	**Erodium botrys*
Goodeniaceae	*Dampiera linearis*
	Lechenaultia biloba
	Scaevola repens var. *repens*
Haemodoraceae	*Anigozanthos humilis* subsp. *humilis*
	Anigozanthos manglesii subsp. *manglesii*
	Conostylis candicans
	Conostylis setosa
	Haemodorum sp.
	Haemodorum discolor
Hemerocallidaceae	*Agrostocrinum hirsutum*
	Caesia micrantha
	Tricoryne elatior
Iridaceae	**Freesia alba × leichtlinii*
	**Gladiolus undulatus*
	**Gladiolus ?angustus*
	**Gladiolus caryophyllaceus*
	**Hesperantha falcata*
	**Romulea rosea*
	**Watsonia meriana*
	Patersonia occidentalis
	Patersonia umbrosa var. *xanthina*
Lamiaceae	**Lavandula dentata*
	Hemiphora bartlingii
Lauraceae	*Cassytha racemosa*
Linaceae	**Linum trigynum*
Loranthaceae	*Nuytsia floribunda*
Meliaceae	**Melia azedarach*

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Family	Species
Myrtaceae	**Angophora costata* subsp. *costata* (planted)
	**Callistemon* sp. (cultivar planted)
	**Chamelaucium uncinatum*
	**Leptospermum laevigatum*
	Babingtonia camphorosmae
	Beaufortia squarrosa
	Calothamnus quadrifidus
	Calothamnus torulosus
	Calytrix glutinosa
	Corymbia calophylla
	Eremaea pauciflora
	Eremaea pauciflora var. *pauciflora*
	Eucalyptus sp. (seedling)
	Eucalyptus camaldulensis
	Eucalyptus lane-poolei
	Eucalyptus marginata subsp. *marginata*
	Eucalyptus utilis
	Eucalyptus wandoo subsp. *wandoo*
	Kunzea glabrescens
	Melaleuca aspalathoides
	Melaleuca radula
	Pericalymma ellipticum var. *ellipticum*
	Verticordia densiflora var. *densiflora*
	Verticordia plumosa
Onagraceae	**Oenothera stricta*
Orchidaceae	*Caladenia flava*
	Pterostylis sanguinea
Orobanchaceae	**Orobanche minor*
Oxalidaceae	**Oxalis pes-caprae*
Papaveraceae	**Fumaria capreolata*
Phyllanthaceae	*Poranthera microphylla*
Poaceae	**Arundo donax*

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Family	Species
	**Avena barbata*
	**Briza maxima*
	**Briza minor*
	**Bromus diandrus*
	**Bromus hordeaceus*
	**Cenchrus clandestinus*
	**Cynodon dactylon*
	**Ehrharta calycina*
	**Eragrostis curvula*
	**Pentameris airoides*
	**Tribolium uniolae*
	**Vulpia bromoides*
	Austrostipa elegantissima
	Neurachne alopecuroidea
	Rytidosperma setaceum
	Themeda triandra
Primulaceae	**Lysimachia arvensis*
Proteaceae	*Banksia grandis*
	Banksia sessilis
	Banksia dallanneyi var. *dallanneyi*
	Banksia menziesii
	Grevillea bipinnatifida subsp. *bipinnatifida*
	Grevillea preissii subsp. *preissii*
	Hakea trifurcata
	Hakea conchifolia
	Hakea laurina
	Hakea trifurcata
	Hakea undulata
	Isopogon divergens
	Lambertia multiflora
	Lambertia multiflora var. *darlingensis*
	Petrophile linearis

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Family	Species
	Petrophile striata
	Stirlingia latifolia
	Synaphea gracillima
	Synaphea spinulosa
Pteridaceae	*Cheilanthes sieberi* subsp. *sieberi*
Restionaceae	*Desmocladus fasciculatus*
Rhamnaceae	*Trymalium odoratissimum* subsp. *odoratissimum*
Rubiaceae	*Opercularia vaginata*
Rutaceae	*Boronia* sp.
Stylidiaceae	*Levenhookia pusilla*
	Levenhookia stipitata
	Stylidium brunonianum
	Stylidium piliferum
	Stylidium repens
Thymelaeaceae	*Pimelea imbricata*
	Pimelea lehmanniana
Tropaeolaceae	**Tropaeolum majus*
Violaceae	*Hybanthus* sp.
Xanthorrhoeaceae	*Xanthorrhoea preissii*

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Appendix F Flora species matrix

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Species	ELA01	ELA02	ELA03	ELA04	ELA05	ELA06	Releve
**Arctotheca calendula*	0	0	1	0	0	0	0
**Briza maxima*	1	1	1	1	1	0	0
**Briza minor*	0	0	1	0	1	0	0
**Bromus hordeaceus*	0	0	0	0	0	1	0
**Cynodon dactylon*	0	0	0	1	0	0	0
**Ehrharta calycina*	0	1	1	1	1	0	0
**Eragrostis curvula*	0	1	0	0	0	1	0
**Freesia alba × leichtlinii*	1	1	0	1	1	1	0
**Gladiolus ?angustus*	0	0	0	0	0	1	0
**Gladiolus caryophyllaceus*	0	1	0	1	0	0	0
**Hypochaeris glabra*	0	1	0	1	0	0	0
**Lactuca serriola*	0	0	0	0	1	0	0
**Leptospermum laevigatum*	0	0	0	0	1	0	0
**Linum trigynum*	0	0	0	0	0	1	0
**Lysimachia arvensis*	0	0	1	0	0	0	0
**Pentameris airoides*	0	0	1	0	0	0	0
**Romulea rosea*	0	1	0	0	0	1	0
**Silene gallica*	0	0	1	0	0	0	0
**Taraxacum khatoonae*	0	0	1	0	0	0	0
**Trifolium campestre*	0	0	0	0	1	0	0
**Trifolium angustifolium*	0	0	0	0	0	1	0
**Trifolium angustifolium* var. *angustifolium*	0	0	0	0	0	1	0
**Trifolium campestre* var. *campestre*	1	0	0	0	0	0	0
**Ursinia anthemoides*	1	1	1	1	0	0	0
Acacia nervosa	1	0	0	0	0	0	0
Acacia pulchella var. *pulchella*	0	0	0	0	0	1	0
Acacia saligna	0	0	1	0	0	0	0
Allocasuarina huegeliana	0	0	1	0	0	0	1
Allocasuarina humilis	0	1	1	1	0	0	0
Anigozanthos humilis subsp. *humilis*	0	1	0	0	0	0	0
Austrostipa elegantissima	0	0	0	1	1	1	0
Babingtonia camphorosmae	0	0	0	1	0	0	0

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Species	ELA01	ELA02	ELA03	ELA04	ELA05	ELA06	Releve
Banksia sessilis	0	0	0	0	0	1	1
Banksia dallanneyi var. *dallanneyi*	0	1	0	1	0	0	0
Boronia sp.	1	0	0	0	0	0	0
Bossiaea eriocarpa	0	0	0	1	0	0	0
Burchardia congesta	0	1	1	1	0	0	0
Caesia micrantha	0	0	0	1	0	0	0
Calothamnus torulosus	0	0	0	0	0	0	1
Calytrix glutinosa	0	0	0	0	0	1	0
Cassytha racemosa	0	0	0	1	1	0	0
Conostylis candicans	0	0	0	0	1	0	0
Conostylis setosa	0	1	0	1	0	0	0
Corymbia calophylla	1	0	0	1	1	1	0
Crassula colorata var. *colorata*	0	1	0	0	0	0	0
Dampiera linearis	1	0	0	1	0	0	0
Dasypogon bromeliifolius	0	0	1	0	0	0	0
Daviesia decurrens subsp. *decurrens*	0	1	0	0	1	0	0
Daviesia nudiflora subsp. *nudiflora*	0	0	1	1	0	0	0
Desmocladus fasciculatus	1	0	0	0	1	0	0
Drosera erythrorhiza	0	0	0	1	0	0	0
Drosera glanduligera	0	0	1	0	0	0	0
Drosera macrantha	1	0	0	0	0	0	0
Drosera pallida	0	0	0	1	0	0	0
Eremaea pauciflora	0	1	0	0	0	0	0
Eremaea pauciflora var. *pauciflora*	0	1	0	0	0	0	0
Eucalyptus sp. (seedling)	1	0	0	0	0	0	0
Eucalyptus marginata subsp. *marginata*	0	1	0	1	0	0	0
Gastrolobium retusum	1	0	0	1	0	0	0
Gompholobium sp.	0	0	0	0	0	1	0
Gompholobium knightianum	0	0	0	0	1	0	0
Gompholobium marginatum	1	0	0	0	0	0	0
Grevillea bipinnatifida subsp. *bipinnatifida*	0	1	0	0	0	0	0
Haemodorum sp.	1	0	0	0	0	0	0

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Species	ELA01	ELA02	ELA03	ELA04	ELA05	ELA06	Releve
Haemodorum discolor	0	0	0	1	0	0	0
Hakea trifurcata	1	0	0	0	1	1	1
Hakea conchifolia	0	0	0	1	0	0	0
Hakea laurina	0	0	0	0	0	1	1
Hakea trifurcata	0	1	0	0	0	0	0
Hibbertia hypericoides	0	1	1	1	0	1	0
Hibbertia huegelii	0	0	0	0	1	0	0
Hybanthus sp.	0	0	0	0	0	1	0
Isotoma hypocrateriformis	0	0	1	0	0	0	0
Jacksonia lehmannii	0	1	0	1	0	0	0
Kunzea glabrescens	0	1	0	0	0	0	0
Lambertia multiflora var. *darlingensis*	0	0	0	1	0	0	0
Lechenaultia biloba	0	0	1	1	1	0	0
Leptospermum laevigatum	0	0	0	0	0	0	1
Levenhookia pusilla	0	0	0	1	0	0	0
Levenhookia stipitata	0	0	0	1	0	0	0
Lomandra preissii	0	1	0	0	0	0	0
Melaleuca aspalathoides	0	1	1	1	0	0	0
Melaleuca radula	0	0	0	0	0	0	1
Mesomelaena pseudostygia	0	1	0	1	0	0	0
Mesomelaena tetragona	1	0	0	0	0	0	0
Neurachne alopecuroidea	1	0	0	1	1	1	0
Nuytsia floribunda	0	0	1	0	0	0	0
Opercularia vaginata	0	0	0	0	1	1	0
Patersonia occidentalis	0	0	1	0	0	0	0
Patersonia umbrosa var. *xanthina*	1	0	0	0	0	0	0
Pericalymma ellipticum var. *ellipticum*	1	0	0	0	0	0	0
Petrophile linearis	0	1	0	0	0	0	0
Petrophile striata	0	0	1	1	1	0	0
Pimelea lehmanniana	0	0	0	1	0	0	0
Poranthera microphylla	0	0	0	0	1	0	0
Pterochaeta paniculata	1	0	0	0	0	0	0

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Species	ELA01	ELA02	ELA03	ELA04	ELA05	ELA06	Releve
Pterostylis sanguinea	0	1	0	0	0	0	0
Rytidosperma setaceum	0	0	0	1	0	0	0
Scaevola repens var. *repens*	0	1	1	0	0	0	0
Schoenus sp.	0	0	1	1	1	0	1
Sphaerolobium linophyllum	0	0	0	1	0	0	0
Stylidium brunonianum	1	0	0	1	0	0	0
Stylidium piliferum	0	0	0	1	0	0	0
Stylidium repens	1	0	0	0	1	0	0
Synaphea gracillima	0	0	0	1	0	0	0
Themeda triandra	1	0	0	0	0	0	0
Thysanotus sparteus	0	0	0	1	0	0	0
Thysanotus tenellus	1	0	0	0	0	0	0
Tricoryne elatior	0	1	1	1	0	0	0
Verticordia densiflora var. *densiflora*	1	0	0	0	0	0	0
Xanthorrhoea preissii	0	1	1	1	0	0	0

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Appendix G Introduced flora (weed) species list

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Family	Species
Arecaceae	**Washingtonia filifera*
Asparagaceae	**Agave americana*
Asteraceae	**Arctotheca calendula*
	**Dimorphotheca ecklonis*
	**Gazania linearis*
	**Hypochaeris glabra*
	**Lactuca serriola*
	**Osteospermum ecklonis*
	**Taraxacum khatoonae*
	**Ursinia anthemoides*
Brassicaceae	**Raphanus raphanistrum*
Cactaceae	**Opuntia stricta*
Campanulaceae	**Wahlenbergia capensis*
Caprifoliaceae	**Centranthus macrosiphon*
Caryophyllaceae	**Silene gallica*
Convolvulaceae	**Ipomoea cairica*
Euphorbiaceae	**Euphorbia peplus*
Fabaceae	**Acacia dealbata*
	**Acacia iteaphylla*
	**Acacia longifolia*
	**Acacia podalyriifolia*
	**Acacia* sp. (Eastern States)
	**Chamaecytisus palmensis*
	**Genista linifolia*
	**Lotus angustissimus*
	**Lotus subbiflorus*
	**Lupinus angustifolius*
	**Lupinus cosentinii*
	**Trifolium campestre*
	**Trifolium angustifolium*
	**Trifolium arvense*
	**Vicia sativa*

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Family	Species
Geraniaceae	**Erodium botrys*
Iridaceae	**Freesia alba × leichtlinii*
	**Gladiolus undulatus*
	**Gladiolus ?angustus*
	**Gladiolus caryophyllaceus*
	**Hesperantha falcata*
	**Romulea rosea*
	**Watsonia meriana*
Lamiaceae	**Lavandula dentata*
Linaceae	**Linum trigynum*
Meliaceae	**Melia azedarach*
Myrtaceae	**Angophora costata* subsp. *costata* (planted)
	**Callistemon* sp. (cultivar planted)
	**Chamelaucium uncinatum*
	**Leptospermum laevigatum*
Onagraceae	**Oenothera stricta*
Orobanchaceae	**Orobanche minor*
Oxalidaceae	**Oxalis pes-caprae*
Papaveraceae	**Fumaria capreolata*
Poaceae	**Arundo donax*
	**Avena barbata*
	**Briza maxima*
	**Briza minor*
	**Bromus diandrus*
	**Bromus hordeaceus*
	**Cenchrus clandestinus*
	**Cynodon dactylon*
	**Ehrharta calycina*
	**Eragrostis curvula*
	**Pentameris airoides*
	**Tribolium uniolae*
	**Vulpia bromoides*

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Family	Species
Primulaceae	**Lysimachia arvensis*
Tropaeolaceae	**Tropaeolum majus*

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Appendix H Quadrat data

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Site number	Date	Site type	Observer
ELA01	26/10/2016	Quadrat 10x10 m	KZA, SD & JM
Habitat description	Landform unit	Easting	Northing
Flat, foothills	Flat	407044	6460177
Rock type	Soil type	Soil texture	Soil colour
Gravelly	Clay loam	Fine	Grey-brown
Condition	Geology	Disturbance	Time since fire (years)
Very Good	Laterite	Weeds	10 – 20



Taxon	Cover (%)	Stratum*	Sub-Stratum
Corymbia calophylla	8	U	Trees over 30 m
Hakea trifurcata	20	M	Shrubs 1 – 2 m
Pericalymma ellipticum var. *ellipticum*	15	M	Shrubs 1 – 2 m
Verticordia densiflora var. *densiflora*	1	M	Shrubs 1 – 2 m
Gastrolobium retusum	0.1	M	Shrubs 1 – 2 m
Acacia nervosa	0.1	M	Shrubs under 1 m
Boronia sp.	0.1	M	Shrubs under 1 m
Gompholobium marginatum	0.1	M	Shrubs under 1 m
Eucalyptus sp. (seedling)	0.1	M	Shrubs under 1 m

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Taxon	Cover (%)	Stratum*	Sub-Stratum
Mesomelaena tetragona	15	L	Grasses
**Briza maxima*	0.1	L	Grasses
**Ursinia anthemoides*	0.1	L	Grasses
Neurachne alopecuroidea	10	L	Herbs
Stylidium repens	2	L	Herbs
Dampiera linearis	0.1	L	Herbs
Desmocladus fasciculatus	0.1	L	Herbs
Drosera macrantha	0.1	L	Herbs
**Freesia alba* × *leichtlinii*	0.1	L	Herbs
Haemodorum sp.	0.1	L	Herbs
Patersonia umbrosa var. *xanthina*	0.1	L	Herbs
Pterochaeta paniculata	0.1	L	Herbs
Stylidium brunonianum	0.1	L	Herbs
Themeda triandra	0.1	L	Herbs
Thysanotus tenellus	0.1	L	Herbs
**Trifolium campestre* var. *campestre*	0.1	L	Herbs

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Site number	Date	Site type	Observer
ELA02	26/10/2016	Quadrat 10x10 m	KZA, SD & JM
Habitat description	Landform unit	Easting	Northing
Flat, foothills, close to drainage	Flat	407018	6460036
Rock type	Soil type	Soil texture	Soil colour
Gravelly	Loam	Fine	Grey-yellow
Condition	Geology	Disturbance	Time since fire (years)
Good	Laterite	Weeds	1-10



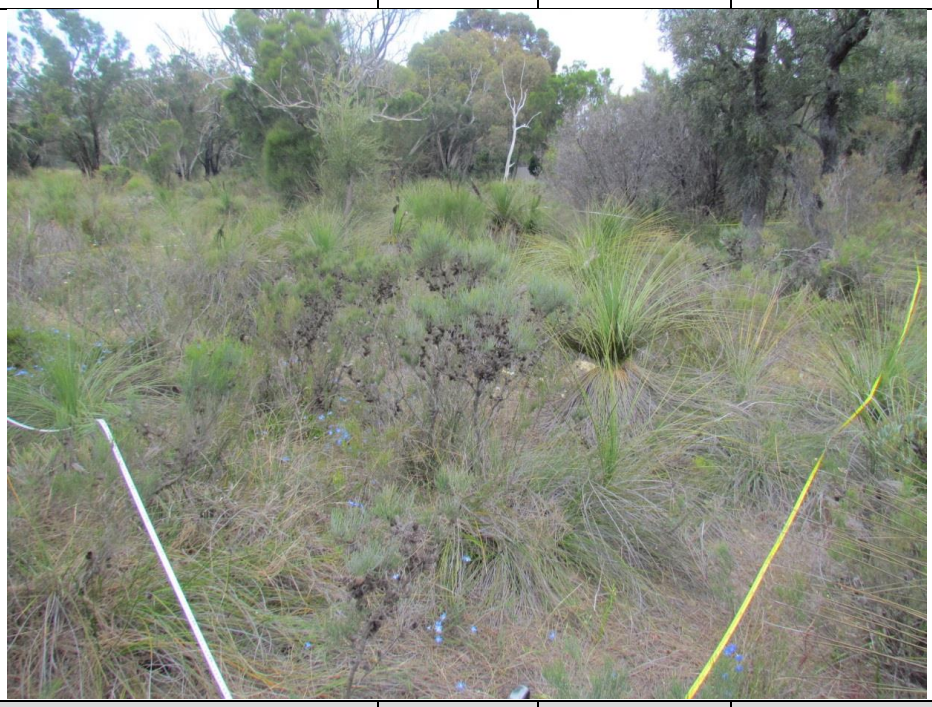
Taxon	Cover (%)	Stratum*	Sub-Stratum
Eucalyptus marginata subsp. *marginata*	5	U	Trees over 30 m
Eremaea pauciflora var. *pauciflora*	0.1	U	Trees 10 – 30 m
Banksia dallanneyi var. *dallanneyi*	0.1	U	Trees under 30 m
Xanthorrhoea preissii	5	M	Shrubs over 2 m
Eremaea pauciflora	0.1	M	Shrubs over 2 m
Allocasuarina humilis	10	M	Shrubs 1 – 2 m
Hakea trifurcata	2	M	Shrubs 1 – 2 m
Kunzea glabrescens	0.1	M	Shrubs 1 – 2 m
Melaleuca aspalathoides	0.1	M	Shrubs 1 – 2 m

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Taxon	Cover (%)	Stratum*	Sub-Stratum
Hibbertia hypericoides	1	M	Shrubs under 1 m
Daviesia decurrens subsp. *decurrens*	0.1	M	Shrubs under 1 m
Grevillea bipinnatifida subsp. *bipinnatifida*	0.1	M	Shrubs under 1 m
Jacksonia lehmannii	0.1	M	Shrubs under 1 m
Petrophile linearis	0.1	M	Shrubs under 1 m
Scaevola repens var. *repens*	0.1	M	Shrubs under 1 m
**Ehrharta calycina*	5	L	Grasses
**Eragrostis curvula*	1	L	Grasses
**Briza maxima*	0.1	L	Grasses
Mesomelaena pseudostygia	0.1	L	Grasses
Lomandra preissii	2	L	Herbs
Anigozanthos humilis subsp. *humilis*	0.1	L	Herbs
Burchardia congesta	0.1	L	Herbs
Conostylis setosa	0.1	L	Herbs
Crassula colorata var. *colorata*	0.1	L	Herbs
**Freesia alba × leichtlinii*	0.1	L	Herbs
**Gladiolus caryophyllaceus*	0.1	L	Herbs
**Hypochaeris glabra*	0.1	L	Herbs
Pterostylis sanguinea	0.1	L	Herbs
**Romulea rosea*	0.1	L	Herbs
Tricoryne elatior	0.1	L	Herbs
**Ursinia anthemoides*	0.1	L	Herbs

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Site number	Date	Site type	Observer
ELA03	26/10/2016	Quadrat 10x10 m	KZA, SD & JM
Habitat description	Landform unit	Easting	Northing
Flat, foothills	Flat	407122	6460033
Rock type	Soil type	Soil texture	Soil colour
Gravelly	Loam	Fine	Grey-brown
Condition	Geology	Disturbance	Time since fire (years)
Very Good	Laterite	Weeds	10 – 20



Taxon	Cover (%)	Stratum*	Sub-Stratum
Nuytsia floribunda	5	U	Trees under 10 m
Allocasuarina huegeliana	2	U	Trees under 10 m
Xanthorrhoea preissii	20	M	Shrubs over 2 m
Acacia saligna	0.1	M	Shrubs over 2 m
Allocasuarina humilis	15	M	Shrubs 1 – 2 m
Daviesia nudiflora subsp. *nudiflora*	1	M	Shrubs 1 – 2 m
Melaleuca aspalathoides	1	M	Shrubs 1 – 2 m
Lechenaultia biloba	2	M	Shrubs under 1 m
Hibbertia hypericoides	1	M	Shrubs under 1 m

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Taxon	Cover (%)	Stratum*	Sub-Stratum
Isotoma hypocrateriformis	0.1	M	Shrubs under 1 m
Petrophile striata	0.1	M	Shrubs under 1 m
Scaevola repens var. *repens*	0.1	M	Shrubs under 1 m
**Briza maxima*	1	L	Grasses
**Briza minor*	1	L	Grasses
**Ehrharta calycina*	1	L	Grasses
**Taraxacum khatoonae*	0.1	L	Grasses
Schoenus sp.	5	L	Herbs
Dasypogon bromeliifolius	2	L	Herbs
Isotoma hypocrateriformis	2	L	Herbs
Patersonia occidentalis	1	L	Herbs
**Ursinia anthemoides*	1	L	Herbs
**Arctotheca calendula*	0.1	L	Herbs
Burchardia congesta	0.1	L	Herbs
Drosera glanduligera	0.1	L	Herbs
**Lysimachia arvensis*	0.1	L	Herbs
**Pentameris airoides*	0.1	L	Herbs
**Silene gallica*	0.1	L	Herbs
Tricoryne elatior	0.1	L	Herbs

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Site number	Date	Site type	Observer
ELA04	26/10/2016	Quadrat 10x10 m	KZA, SD & JM
Habitat description	Landform unit	Easting	Northing
Flat, foothills	Flat	407240	6459789
Rock type	Soil type	Soil texture	Soil colour
Gravelly	Sandy loam	Fine	Brown
Condition	Geology	Disturbance	Time since fire (years)
Very Good	Laterite	Weeds	10 – 20



Taxon	Cover (%)	Stratum*	Sub-Stratum
Corymbia calophylla	2	U	Trees over 30 m
Conostylis setosa	0.1	U	Trees over 30 m
Eucalyptus marginata subsp. *marginata*	20	U	Trees 10 – 30 m
Banksia dallanneyi var. *dallanneyi*	2	U	Trees under 10 m
Lechenaultia biloba	0.1	U	Trees under 10 m
Xanthorrhoea preissii	5	M	Shrubs over 2 m
Drosera pallida	0.1	M	Shrubs over 2 m
Allocasuarina humilis	2	M	Shrubs 1 – 2 m
Haemodorum discolor	2	M	Shrubs 1 – 2 m

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Taxon	Cover (%)	Stratum*	Sub-Stratum
Lambertia multiflora var. *darlingensis*	2	M	Shrubs 1 – 2 m
Melaleuca aspalathoides	2	M	Shrubs 1 – 2 m
Hibbertia hypericoides	15	M	Shrubs under 1 m
Petrophile striata	2	M	Shrubs under 1 m
Babingtonia camphorosmae	1	M	Shrubs under 1 m
Gastrolobium retusum	1	M	Shrubs under 1 m
Lechenaultia biloba	1	M	Shrubs under 1 m
Synaphea gracillima	1	M	Shrubs under 1 m
Bossiaea eriocarpa	0.1	M	Shrubs under 1 m
Hakea conchifolia	0.1	M	Shrubs under 1 m
Jacksonia lehmannii	0.1	M	Shrubs under 1 m
Pimelea lehmanniana	0.1	M	Shrubs under 1 m
Sphaerolobium linophyllum	0.1	M	Shrubs under 1 m
Mesomelaena pseudostygia	5	L	Grasses
**Briza maxima*	1	L	Grasses
Austrostipa elegantissima	0.1	L	Grasses
**Cynodon dactylon*	0.1	L	Grasses
**Ehrharta calycina*	0.1	L	Grasses
Schoenus sp.	2	L	Herbs
Burchardia congesta	1	L	Herbs
Dampiera linearis	1	L	Herbs
Daviesia nudiflora subsp. *nudiflora*	1	L	Herbs
Stylidium brunonianum	1	L	Herbs
Tricoryne elatior	1	L	Herbs
Caesia micrantha	0.1	L	Herbs
Cassytha racemosa	0.1	L	Herbs
Drosera erythrorhiza	0.1	L	Herbs
**Freesia alba × leichtlinii*	0.1	L	Herbs
**Gladiolus caryophyllaceus*	0.1	L	Herbs
**Hypochaeris glabra*	0.1	L	Herbs
Levenhookia pusilla	0.1	L	Herbs
Levenhookia stipitata	0.1	L	Herbs

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Taxon	Cover (%)	Stratum*	Sub-Stratum
Neurachne alopecuroidea	0.1	L	Herbs
Rytidosperma setaceum	0.1	L	Herbs
Stylidium piliferum	0.1	L	Herbs
Thysanotus sparteus	0.1	L	Herbs
**Ursinia anthemoides*	0.1	L	Herbs

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Site number	Date	Site type	Observer
ELA05	26/10/2016	Quadrat 10x10 m	KZA, SD & JM
Habitat description	Landform unit	Easting	Northing
Flat, foothills	Flat	407192	6459599
Rock type	Soil type	Soil texture	Soil colour
Gravelly	Sandy loam	Fine	Brown
Condition	Geology	Disturbance	Time since fire (years)
Good	Laterite	Weeds, clearing	10 – 20



Taxon	Cover (%)	Stratum*	Sub-Stratum
Corymbia calophylla	2	U	Trees over 30 m
**Leptospermum laevigatum*	5	M	Shrubs over 2 m
Hakea trifurcata	25	M	Shrubs 1 – 2 m
Daviesia decurrens subsp. *decurrens*	0.1	M	Shrubs 1 – 2 m
Hibbertia huegelii	1	M	Shrubs under 1 m
Petrophile striata	1	M	Shrubs under 1 m
Gompholobium knightianum	0.1	M	Shrubs under 1 m
Lechenaultia biloba	0.1	M	Shrubs under 1 m
**Briza maxima*	5	L	Grasses

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Taxon	Cover (%)	Stratum*	Sub-Stratum
**Ehrharta calycina*	2	L	Grasses
Austrostipa elegantissima	0.1	L	Grasses
**Briza minor*	0.1	L	Grasses
Schoenus sp.	5	L	Herbs
Conostylis candicans	1	L	Herbs
Desmocladus fasciculatus	1	L	Herbs
**Freesia alba × leichtlinii*	1	L	Herbs
Neurachne alopecuroidea	1	L	Herbs
Opercularia vaginata	1	L	Herbs
Cassytha racemosa	0.1	L	Herbs
**Lactuca serriola*	0.1	L	Herbs
Poranthera microphylla	0.1	L	Herbs
Stylidium repens	0.1	L	Herbs
**Trifolium campestre*	0.1	L	Herbs

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Site number	Date	Site type	Observer
ELA06	26/10/2016	Quadrat 10x10 m	KZA, SD & JM
Habitat description	Landform unit	Easting	Northing
Flat, foothills	Flat	406963	6459380
Rock type	Soil type	Soil texture	Soil colour
Gravelly	Loam	Fine	Brown
Condition	Geology	Disturbance	Time since fire (years)
Very Good	Laterite	Weeds	10 – 20



Taxon	Cover (%)	Stratum*	Sub-Stratum
Corymbia calophylla	2	U	Trees over 30 m
Banksia sessilis	15	U	Trees under 10 m
Hakea laurina	3	U	Trees under 10 m
Acacia pulchella var. *pulchella*	1	M	Shrubs over 2 m
Hakea trifurcata	15	M	Shrubs 1 – 2 m
Hybanthus sp.	1	M	Shrubs 1 – 2 m
Austrostipa elegantissima	0.1	M	Shrubs under 1 m
Gompholobium sp.	0.1	M	Shrubs under 1 m
Hibbertia hypericoides	0.1	M	Shrubs under 1 m

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Taxon	Cover (%)	Stratum*	Sub-Stratum
**Eragrostis curvula*	2	L	Grasses
**Bromus hordeaceus*	0.1	L	Grasses
Calytrix glutinosa	5	L	Herbs
**Freesia alba × leichtlinii*	2	L	Herbs
Opercularia vaginata	2	L	Herbs
**Gladiolus ?angustus*	1	L	Herbs
**Trifolium angustifolium*	1	L	Herbs
**Linum trigynum*	0.1	L	Herbs
Neurachne alopecuroidea	0.1	L	Herbs
**Romulea rosea*	0.1	L	Herbs
**Trifolium angustifolium* var. *angustifolium*	0.1	L	Herbs

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Site number	Date	Site type	Observer
Releve	26/10/2016	Quadrat 10x10 m	KZA, SD & JM
Habitat description	Landform unit	Easting	Northing
Flat, foothills	Flat	407022	6459445
Rock type	Soil type	Soil texture	Soil colour
Gravelly	Sandy gravelly loam	Fine	Grey-brown
Condition	Geology	Disturbance	Time since fire (years)
Very Good	Laterite	Weeds	10 – 20



Taxon	Cover (%)	Stratum*	Sub-Stratum
Banksia sessilis	15	U	Trees under 10 m
Hakea laurina	0.1	U	Trees under 10 m
Melaleuca radula	25	M	Shrubs 1 – 2 m
Hakea laurina	5	M	Shrubs 1 – 2 m
Allocasuarina huegeliana	0.1	M	Shrubs 1 – 2 m
Hakea trifurcata	7	M	Shrubs under 1 m
Calothamnus torulosus	0.1	M	Shrubs under 1 m
**Leptospermum laevigatum*	2	L	Herbs

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Schoenus sp.	1	L	Herbs

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Appendix I Fauna species list

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Common name	Species	Notes
Birds		
Australian Magpie	*Cracticus tibicen*	Observed
Australian Raven	*Corvus coronoides*	Observed
Australian Ringneck Parrot	*Barnardius zonarius*	Observed
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	Observed
Brown Honeyeater	*Lichmera indistincta*	Observed
Common Bronzewing	*Phaps chalcoptera*	Observed
Domestic Pigeon	**Columba livia*	Observed
Galah	**Eolophus roseicapilla*	Observed
Grey Butcherbird	*Cracticus torquatus*	Observed
Laughing Dove	**Spilopelia senegalensis*	Observed
Laughing Kookaburra	**Dacelo novaeguineae*	Observed
Little Corella	**Cacatua sanguinea*	Observed
Magpie-lark	*Grallina cyanoleuca*	Observed
New Holland Honeyeater	*Phylidonyris novaehollandiae*	Observed
Rainbow Lorikeet	**Trichoglossus moluccanus*	Observed
Red Wattlebird	*Anthochaera carunculata*	Observed
Red-tailed Black Cockatoo	*Calyptorhynchus banksii naso*	Calls heard, foraging evidence
Scarlet Robin	*Petroica boodang*	Observed
Singing Honeyeater	*Lichenostomus virescens*	Observed
Weebill	*Smicrornis brevirostris*	Observed
Willie Wagtail	*Rhipidura leucophrys*	Observed
Mammals		
Domestic Cat	**Felis catus*	Remains
European Rabbit	**Oryctolagus cuniculus*	Diggings
Quenda	*Isoodon obesulus fusciventer*	Diggings
Reptiles		
Bobtail	*Tiliqua rugosa rugosa*	Observed
Buchanan's Snake-eyed Skink	*Cryptoblepharus buchananii*	Observed
Burton's Legless Lizard	*Lialis burtonis*	Observed
Southwestern Earless Skink	*Hemiergis quadrilineata*	Observed

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Appendix J Black Cockatoo potential breeding trees

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Tree species	DBH (cm)	Co-ordinates	
		Northing	Easting
Marri	86	6460137	406825.5
Marri	58	6460151	406851.1
Marri	50	6460153	406853.2
Marri	50	6460186	406877.6
Marri	85	6460179	407151.3
Marri	50	6460166	407150.1
Marri	50	6460154	407152.3
Marri	50	6460014	406956.6
Dead	50	6460006	406960.4
Jarrah	50	6460008	406962.8
Jarrah	68	6460001	406959.4
Marri (with nest box)	75	6459960	406903.6
Marri	50	6459953	406895.6
Jarrah	70	6459988	406876.2
Jarrah	90	6459990	406869.5
Jarrah	50	6459993	406876.9
Dead (hollows present)	90	6460001	406855.1
Jarrah	50	6460013	406848
Jarrah	50	6460006	406853.8
Jarrah	60	6460015	406840.6
Dead	90	6460033	406827.4
Marri	50	6460052	406804.3
Jarrah	50	6460050	406789.7
Jarrah	50	6460052	406776.5
Jarrah (hollows present)	100	6460043	406760.2
Jarrah	50	6460032	406761.3
Jarrah	55	6460029	406749.2
Jarrah	200	6460041	406731.6
Marri	60	6460122	406724.9
Marri	65	6460123	406748
Marri	70	6460128	406757.5
Marri	75	6460134	406771.4
Marri	50	6460111	406811.9
Marri	100	6460099	406799.9
Marri	50	6460116	406815.5
Jarrah	70	6460072	407189.6
Wandoo	50	6460079	407176.1
Dead	60	6460092	407165.5

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Tree species	DBH (cm)	Co-ordinates	
		Northing	Easting
Marri	60	6460103	407122.5
Marri	80	6460067	407005.3
Jarrah	60	6460056	406998.5
Marri	60	6460018	407016.8
Jarrah	70	6460012	407032.6
Jarrah (hollows present)	75	6460009	407041.1
Jarrah	70	6460020	407057.7
Jarrah	50	6460048	407076
Jarrah (hollows present)	60	6459986	407173.4
Jarrah	50	6459986	407153.8
Marri	50	6459988	407090.1
Marri	60	6459980	407041.2
Marri	50	6459981	407037.1
Wandoo	50	6459989	407028.5
Jarrah	60	6459978	406999.5
Marri	50	6459978	406986.1
Marri	60	6459863	407239
Marri	70	6459696	407263.7
marri	60	6459719	407248.9
Jarrah	50	6459678	407226
Marri (hollows present)	95	6459665	407224
Marri	90	6459469	407024.1
Marri	50	6459431	406983.1
Marri	50	6459214	406820.6
Marri	50	6459223	406826.6
Marri	50	6459594	407141.8
Marri	180	6459632	407175.7
Marri	50	6459634	407187.5
Marri	70	6459662	407203
Marri	85	6459662	407220
Marri	80	6459712	407222.6

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Appendix K Fauna locations

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Fauna locations	Northing	Easting
Conservation significant fauna locations		
Quenda digging	6460114	407197
Quenda digging	6460008	407046
Quenda digging	6460042	407074
Quenda digging	6460040	407082
Quenda digging	6460036	407132
Forest Red-tailed Black Cockatoo foraging evidence	6460019	406972
Forest Red-tailed Black Cockatoos heard calling	6460050	406931
Forest Red-tailed Black Cockatoos heard calling	6459318	406876
Introduced fauna locations		
Feral Bee hive	406957	6459995
Feral Bee hive	406939	6459997
Cat remains observed	407215	6460098

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bsi. ISO 14001 Environmental Management

bsi. AS/NZS 4801:2001 Occupational Health and Safety Management

bsi. ISO 9001 Quality Management

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Appendix I – Environmental Management Strategy

CAMBRIDGE RESERVE

ENVIRONMENTAL MANAGEMENT STRATEGY

Prepared for:	City of Kalamunda
Report Date:	28 May 2020
Version:	2
Report No.	2020-512



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Figure 2: Concept Plan Overlain on Vegetation Condition

Figure 3: Concept Plan Overlain on Threatened Ecological Communities

Appendices

Appendix 1: Concept Plan

1 INTRODUCTION

1.1 Background

Cambridge Reserve is an area of local open space of around 9ha located in Forrestfield in the City of Kalamunda, (Figure 1).

The Reserve is used by local residents for passive recreation and currently consists of native vegetation, planted trees, grassed areas, play equipment and a large constructed stormwater drainage basin.

In 2019 the City of Kalamunda Council adopted a Concept Plan to redevelop part of the Reserve for residential and an Aged Care/Retirement Village and to improve the open space facilities in the balance of the Reserve for the local community. Comments on the plan by government agencies indicated that the Concept Plan may have an adverse impact on conservation significant plant communities. As a result, the City of Kalamunda undertook further environmental and hydrological studies of the Reserve and have revised the Concept Plan to avoid impacting on the important plant communities present on the site.

The revised Concept Plan is included as Appendix 1 and is described in Section 3 of this report.

1.2 Purpose of this Report

The revised Concept Plan includes areas of retained native bushland that will be protected in local open space.

The purpose of this Vegetation Management Strategy is to outline the City of Kalamunda's objectives for the retained bushland areas once the Concept Plan has been adopted and the site rezoned to allow for future development.

2 EXISTING ENVIRONMENT

2.1 Site Location

Cambridge Reserve consists of the following Lots:

- 12 Cambridge Road, Forrestfield (Lots 7876 and 3677) (Reserve 27559)
- 17 York Street, Forrestfield (Lot 2346) (Reserve 31348)
- 71 Moira Avenue, Forrestfield (Lots 2850, 3059, 3097 and 3487) (Reserve 34364)
- Lot 9835 Mallow Way (Reserve 34364)

The total combined area is 8.9596ha.

The Reserve is generally bound by Mallow Way, Cambridge Road, York Street and Anderson Road. Residential houses directly abut the reserve on the northern, southern and western boundaries. A 60m wide vegetated powerline easement directly abuts the eastern end of the reserve.

2.2 Land Use

The Reserve has a history of land use that has resulted in the current mix of natural bushland, regenerated vegetation, cleared areas and a large drainage basin.

The Reserve was already highly disturbed with large sections cleared as early as 1953. By 1977 the Reserve was almost completely cleared. The large drainage basin was constructed in the early 1980s to accommodate stormwater drainage from nearby residential areas and roads. Some planting of previously cleared parts of the Reserve was undertaken when the stormwater drain was constructed.

Since the 1980s the natural vegetation and the replanted areas have regrown substantially to their present condition.

The network of informal trails in the Reserve is used by local residents for passive recreation including walking dogs. People also pass through the Reserve on route to other areas.

2.3 Landform and Soils

The Reserve is mostly located on the Forrestfield landform system which is described as the laterised undulating foot slopes of the Darling and Whicher Scarps. The soils are mapped as duplex sandy gravels, pale deep sands and grey deep sandy duplexes (DPIRD, 2019). Geotechnical studies on the Reserve confirmed the soils to be Sandy Clay, Gravelly Sand and some areas of shall Sand over heavier soils (Urbaqua, 2020).

The soils are mapped as having no known risk of acid sulfate soils within 3m of the surface (DWER, 2019).

There is no recorded contamination on the Reserve and no evidence that there is any current material on site contributing to contamination.

2.4 Topography

The Reserve is relatively flat apart from the large drainage basin. There is a gentle slope down from the east at approximately 50m Australian Height Datum (AHD) to 42mAHD at the western end.

2.5 Hydrology

Minimum groundwater under the Reserve is at approximately 17mAHD (DWER, 2019), which is between 25m and 33m below ground level. Groundwater flow is generally from the north-east to the south-west.

There are no natural surface water features such as wetlands on the site. However, there is a large drainage basin located in the western part of the reserve. The basin is connected to the upstream catchment by an open constructed drain as well as piped drainage and sheet flow.

The drain outflow is via piped drainage and overland flow to York Street in the south-west end of the Reserve.

Soil infiltration rates are relatively low which is indicative of the gravelly duplex soil type.

2.6 Flora and Vegetation

2.6.1 Flora

Three flora and vegetation surveys of the Reserve have been conducted for the City of Kalamunda (Plantecology, 2012; EcoLogical, 2017; PGV Environmental, 2020).

A total of 154 plant species have been recorded in the Reserve, including 97 native and 57 introduced species. The high percentage of introduced species (37%) reflects the high level of disturbance to the site in the past.

A species list for the areas of bushland retained in the Concept Plan has not been prepared. However, it is expected that almost all of the native species recorded in the three surveys on the whole Reserve would occur in the areas of retained bushland.

None of the native species in the Reserve is a Threatened or Priority species at State or Commonwealth level.

2.6.2 Introduced Species

None of the introduced species is a Declared Plant under the *Biosecurity and Agriculture Management Act 2007*. However, many of the introduced species are grasses (Poaceae) which are invasive and have the capacity to spread further into the areas of remnant native vegetation. These species include Perennial Veldtgrass (*Ehrharta calycina*), African Lovegrass (*Eragrostis curvula*), Tambookie Grass (*Hyparrhenia hirta*) and Tribolium (*Tribolium uniolae*) (Plate 1).

Flaxleaf Broom (*Genista linifolia*) is a Weed of National Significance and has been recorded in the Reserve. Other common weed species present in the retained areas of bushland include Gladiolus (*Gladiolus caryophyllaceus*), Queensland Silver Wattle (*Acacia podalyriifolia*) and Tree Lucerne (*Chamaecytisus palmensis*).

Plate 1: *Tribolium uniolae* common in Cambridge Reserve bushland (FloraBase)



A number of non-local Australian tree species have been planted in the Reserve including Rose Gum (*Eucalyptus grandis*), Spotted Gum (*Corymbia maculata*), Bushy Yate (*Eucalyptus conferruminata*), Silver Leaved Mountain Gum (*Eucalyptus pulverulenta*) and Sydney Red Gum (*Angophora costata*).

Some of these planted non-local tree species occur within the retained areas of bushland in the Concept Plan.

2.6.3 Vegetation

Three areas of native bushland have been retained in the Concept Plan; in the south-west, south-east and north-east areas (Figure 2). The vegetation in each area is described as follows:

- **South-west Area and south-east Area** – Open Woodland of *Eucalyptus marginata* (Jarrah) and *Allocasuarina fraseriana* (Sheoak) over an open shrubland of *Xanthorrhoea preissii* over a sedgeland of *Mesomelaena tetragona, Mesomelaena pseudostygia* and *Dasypogon bromeliifolius* (Plate 2).
- **North-East Area (Zone 5)** – Open Heath of *Hakea trifurcata* and *Leptospermum erubescens* over a sedgeland of *Mesomelaena tetragona* (Plate 3).

Plate 2: Jarrah/Sheoak Open Woodland



Plate 3: Hakea trifurcata and Leptospermum erubescens Open Heath



2.6.4 Vegetation Condition

The condition of the retained bushland is mostly in Excellent to Very Good condition. Some parts around the areas of excellent vegetation are rated as Degraded due to the absence or low density of native species and prevalence of weeds and non-native plant species.

The presence of several invasive weed species in the retained bushland areas, including grasses and woody weeds (*Acacia* species) is described in Section 2.6.2.

2.6.5 Threatened Ecological Communities

The native vegetation in the Reserve has conservation significance as one of two different types of Threatened Ecological Communities (TECs). The vegetation in the south-east part of the site is part of the TEC called FCT 20a '*Banksia attenuata* woodlands over species rich dense shrublands'. The vegetation in the north-east and south-west areas of the Reserve is part of the TEC called FCT 3c '*Corymbia calophylla – Xanthorrhoea preissii* woodlands and shrublands'. The TECs are listed under the State *Biodiversity Conservation Act 2016* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

The areas of Threatened Ecological Communities in the Reserve are all retained in the Concept Plan.

2.7 Fauna

The native woodland and heath vegetation retained in the Concept Plan provides habitat for a range of birds, reptiles and small mammals such as Quenda (EcoLogical 2017).

The Jarrah, Sheoak, Marri trees and Parrot Bush (*Banksia sessilis*) shrubs provide foraging habitat for Black Cockatoos. The Jarrah, Marri and planted Wandoo trees provide future potential breeding habitat for Black Cockatoos although no current breeding occurs on the site. The abundant tall trees on the site provide suitable roosting habitat for Black Cockatoos, although the Reserve is not known as a current roosting site.

Quenda are expected to be numerous in the retained areas of bushland, particularly in the south-east bushland area (EcoLogical, 2017).

Introduced fauna have been recorded in the Reserve including domestic cats, rabbits and several bird species. Foxes were not recorded in the Reserve in the EcoLogical study (2017). Feral Bees have invaded some nest boxes installed in tall trees in the south-west bushland area.

2.8 Ecological Linkages

The native bushland in the Reserve is directly connected to native vegetation in the powerline easement that abuts the eastern boundary of the Reserve. There is no fence separating the Reserve from the easement. The native vegetation in the powerline easement is around 60m wide and continues for approximately 1km further south where it stops at Hartfield Road. Treed areas continue further south, including the Hartfield Golf Course.

The vegetation in the Reserve is about 600m from the vegetated foothills below the Lesmurdie townsite which is itself connected to the extensive vegetation of the Darling Scarp.

The bushland areas in the Reserve provide some local and regional ecological linkage function in particular for birds and bats as well as ground-dwelling fauna such as Quenda.

3 Concept Plan

3.1 Description

The Concept Plan includes the following proposed land uses:

- An Aged Care facility in the northern central part;
- Residential Lots ranging in size from 225-642m^2;
- A re-designed stormwater drainage basin to include a linear swale, pond and basin that contains water for 12 months of the year;
- An internal road network linking to Mallow Way and Cambridge Road to the north;
- Three areas of retained vegetation; and
- A picnic shelter and playground area.

3.2 Environmental Impact

3.2.1 Flora and Vegetation

The three areas of retained vegetation retain all the areas of native vegetation in Very Good to Excellent condition in the Reserve including all areas of Threatened Ecological Communities (Figures 2 and 3).

The retained areas of vegetation are likely to include nearly all the native plant species that have been recorded in the Reserve.

There will be further opportunities to improve areas of native vegetation in less than Very Good condition through weed control and revegetation through the implementation of a Vegetation Management Plan likely to be required as a condition of subdivision (see Section 4.3).

The re-designed stormwater drainage basin will retain existing vegetation along the southern side of the existing basin and allow revegetation of the newly created banks with native wetland species.

3.2.2 Fauna

Woodland and heath fauna habitats are included in the retained bushland areas. The drainage basin will be re-designed and revegetated with fringing wetland species to improve habitat for wetland fauna species.

The areas of retained vegetation on site will be connected by landscaped road verges and Public Access Ways to maintain the connection on site. The bushland areas will continue to function as an ecological linkage to the vegetation in the power line easement to the east.

3.3 Bushfire Management

A key consideration in the re-development of the Reserve will be to manage the threat of bushfire that the areas of retained vegetation pose for existing and future residents while not having an adverse impact on the areas of Very Good and Excellent quality TEC vegetation.

An initial bushfire assessment by Smith Bushfire Consultants has indicated that the areas of retained vegetation will need to be separated from existing and future residential areas by 'managed or low threat vegetation'. Managed or Low threat vegetation includes a sparse understorey cover with vegetation less than 100mm in height and a low tree canopy cover.

The requirement for low threat vegetation will not allow full revegetation of the areas adjoining the high quality TEC vegetation. Revegetation of managed or low threat vegetation areas can be with locally native shrub species that are typically 100mm high or less. Species could include *Amphipogon turbinatus, Banksia dallanneyi, Conostylis setigera, Dasypogon bromeliifolius, Desmocladus fascicularis, Lechenaultia biloba, Lomandra hermaphrodita, Scaevola repens,* and *Tricoryne elatior* subject to availability.

Removing some of the introduced trees in the retained vegetation areas will reduce the bushfire risk level of the bushland areas.

4 Management Strategy

4.1 Vision

The vision for the re-development of Cambridge Reserve as stated in the Cambridge Reserve Community Enhancement Project Concept Plan Report (April 2020) is as follows:

> *"Cambridge Reserve will be a transformative project that re-engages with this wonderful community asset and formalises many of the existing activities on the site. The inclusion of an aged care or retirement living on the site will provide additional activation and uplift as well as provide much needed housing opportunities for this sector of the community.*
>
> *The clear delineation and retention of established native vegetation and the adaption of the detention basin on site will provide a manageable asset for the community both existing and future.*
>
> *The provision of walking trails and regular activity nodes across the site will contribute to the wider engagement of the community and provide a formalisation of the existing informal trails. A new playground and active area is available to the wider community and provides a place to gather and play. This is targeted to a range of age groups ensuring use by the entire cross section of the community. This also provides a location for aged care residents to visit with their grandchildren and visitors."*

4.2 Environmental Management Plan

A Vegetation Management Plan will be prepared following endorsement of the Concept Plan by the Council and Government agencies and rezoning of the Reserve to enable the Concept Plan to be developed.

The Vegetation Management Plan will likely be a condition of subdivision of the Reserve.

Table 1 outlines the objectives and issues to be addressed in a future Management Plan to meet the vision for the Reserve's re-development.

Table 1 Management Strategies

Factor	Objective	Issues to be addressed in future management plan
Native Vegetation	To protect and enhance areas of native vegetation including TECs	1. Prepare a rehabilitation plan for areas in Good condition or worse (subject to bushfire requirements) 2. Map the areas of invasive weed species 3. Prepare a weed management plan for invasive weed species 4. Fence off areas of TEC and allow for fauna movement between areas of retained vegetation, eg chain-mesh fence with 150mm opening at the base. 5. Monitor and manage areas of vegetation on an ongoing basis (eg annual, bi-annual) 6. Prepare disease control measures for any access to the areas of retained vegetation 7. Consider re-use of any native plant material (logs, mulch, translocated plants) elsewhere in the development or other City sites.
Fauna	To protect and enhance fauna habitat	8. Consider use of artificial and natural hollow logs as fauna habitat on the ground and installed in trees 9. Revegetate stormwater drain batters with species suitable as wetland fauna habitat 10. Educate local residents with regards to the control of cats and dogs
Fire Management	Manage Bushfire Attack Levels to protect existing and future residents	11. Implement the Bushfire Management Plan (when approved), (eg firebreaks, low threat planting, signage) 12. Consider the requirement for internal firebreaks and emergency vehicle access gates 13. Fire hazard reduction measures not to impact on TEC vegetation
Public Recreation	To promote the use of the areas of retained vegetation for local residents	14. Install or upgrade walking trails 15. No paths to encroach into TEC areas 16. Paths will also function as a firebreak 17. Install seating 18. Install educational signage 19. Remove any rubbish including old asbestos sheet fencing

5 Conclusion

This Environmental Management Strategy summarises the environmental features of Cambridge Reserve and describes how the areas of ecological importance including all areas of Threatened Ecological Communities and their flora and fauna values have been retained in the Concept Plan.

The Strategy outlines how the areas of retained bushland will be managed in the future to enable the vision for the Reserve to be achieved.

6 References

Department of Primary Industries and Regional Development (DPIRD) (2019) Natural Resource Information. Accessed September 2019 http://maps.agric.wa.gov.au/nrm-info/ Government of Western Australia, Perth.

Department of Water and Environmental Regulation (DWER) (2019) *Perth Groundwater Map.* Accessed September 2019 https://maps.water.wa.gov.au/#/webmap/gwm Government of Western Australia, Perth.

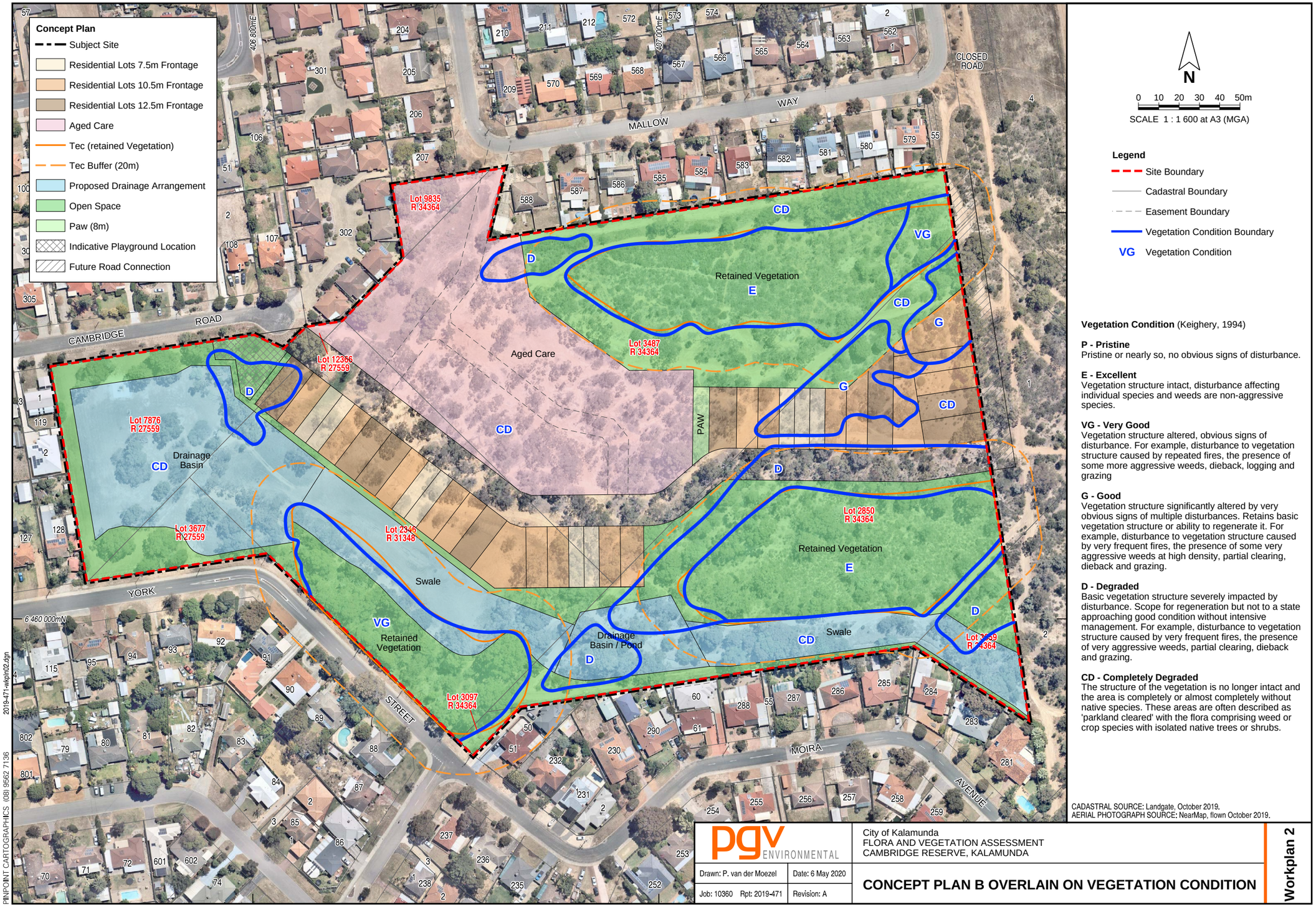
EcoLogical (2017). *Flora, Vegetation and Fauna Survey of Anderson Road Reserve.* Prepared for the City of Kalamunda, 22 May 2017.

PG Environmental (2020). *Cambridge Reserve, Kalamunda Flora and Vegetation Assessment.* Prepared for the City of Kalamunda, January 2020.

Plantecology (2012). *York Road Reserve Forrestfield Level 2 Flora and Vegetation Survey.* Report 2019-471, Prepared for the City of Kalamunda, December 2012.

Urbaqua (2020) *Modelling Report for Cambridge Reserve*. Letter Report prepared for the City of Kalamunda. 4 March 2020.

FIGURES



Vegetation Condition (Keighery, 1994)

P - Pristine
Pristine or nearly so, no obvious signs of disturbance.

E - Excellent
Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.

VG - Very Good
Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing

G - Good
Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.

D - Degraded
Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.

CD - Completely Degraded
The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

CADASTRAL SOURCE: Landgate, October 2019.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown October 2019.

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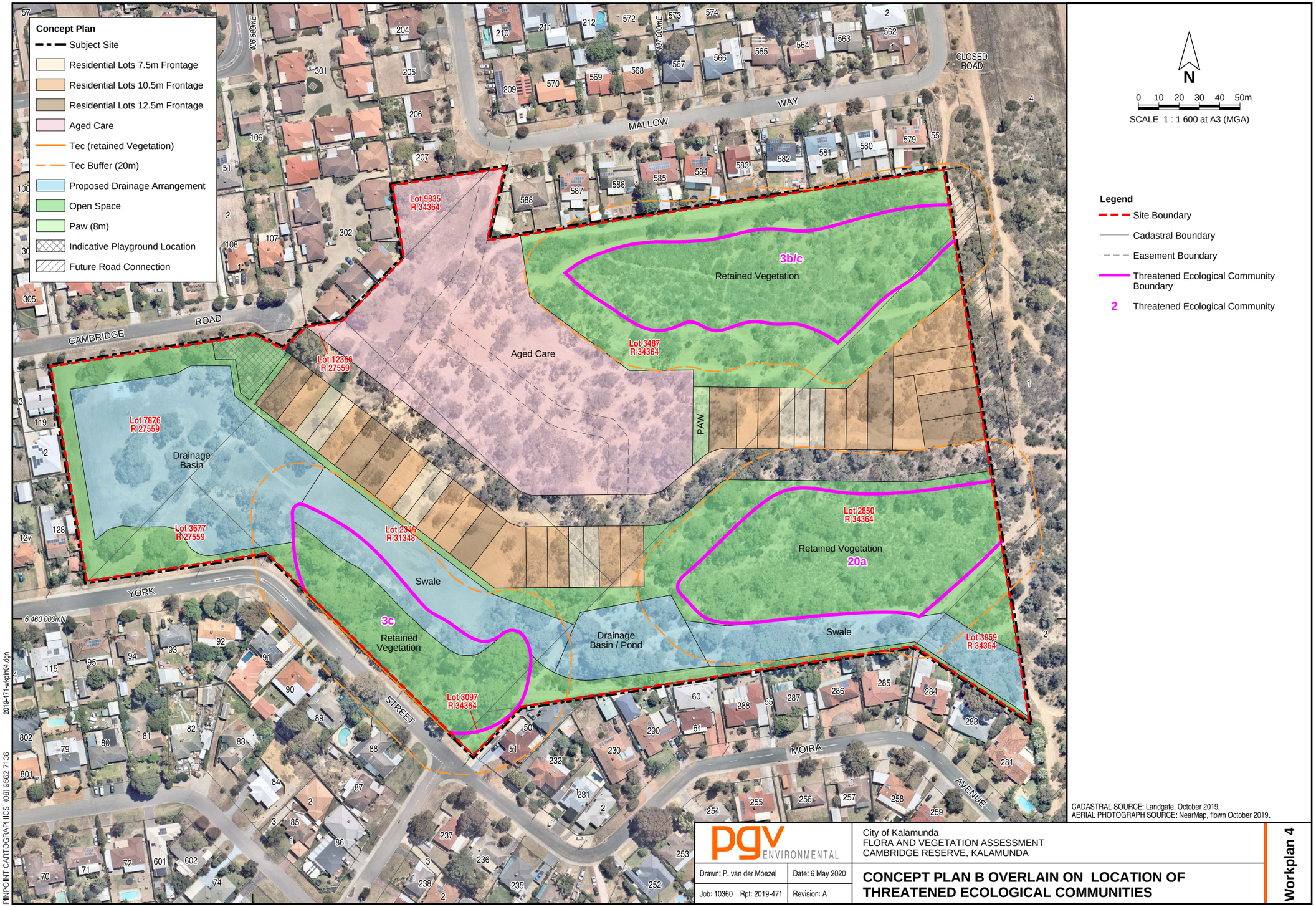
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City of Kalamunda
FLORA AND VEGETATION ASSESSMENT
CAMBRIDGE RESERVE, KALAMUNDA

Drawn: P. van der Moezel | Date: 6 May 2020
Job: 10360 Rpt: 2019-471 | Revision: A

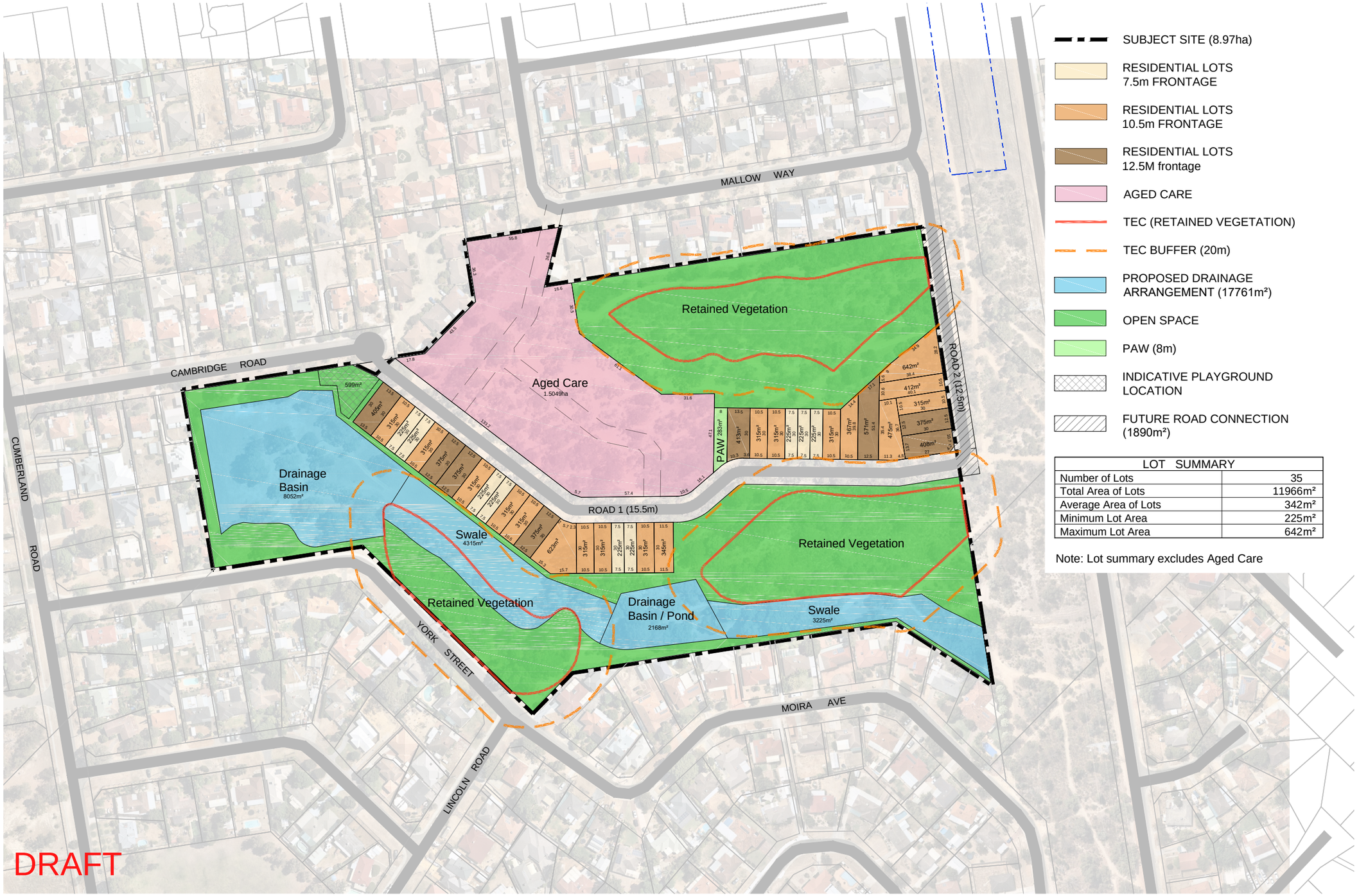
CONCEPT PLAN B OVERLAIN ON VEGETATION CONDITION

Workplan 2


Concept Plan
Subject Site
Residential Lots 7.5m Frontage
Residential Lots 10.5m Frontage
Residential Lots 12.5m Frontage
Aged Care
Tec (retained Vegetation)
Tec Buffer (20m)
Proposed Drainage Arrangement
Open Space
Paw (8m)
Indicative Playground Location
Future Road Connection
406 800mE
407 000mE
6 460 000mN
CAMBRIDGE ROAD
MALLOW WAY
CLOSED ROAD
YORK STREET
MOIRA AVENUE
PAW
Lot 9835 R 34364
Lot 12366 R 27559
Lot 7876 R 27559
Lot 3677 R 27559
Lot 2346 R 31348
Lot 3487 R 34364
Lot 2850 R 34364
Lot 3659 R 34364
Lot 3097 R 34364
Aged Care
Retained Vegetation
3b/c
Drainage Basin
Swale
3c
Retained Vegetation
Drainage Basin / Pond
Swale
Retained Vegetation
20a
N
0 10 20 30 40 50m
SCALE 1 : 1 600 at A3 (MGA)
Legend
Site Boundary
Cadastral Boundary
Easement Boundary
Threatened Ecological Community Boundary
2 Threatened Ecological Community
CADASTRAL SOURCE: Landgate, October 2019.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown October 2019.
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City of Kalamunda
FLORA AND VEGETATION ASSESSMENT
CAMBRIDGE RESERVE, KALAMUNDA
Drawn: P. van der Moezel
Date: 6 May 2020
Job: 10360 Rpt: 2019-471
Revision: A
CONCEPT PLAN B OVERLAIN ON LOCATION OF THREATENED ECOLOGICAL COMMUNITIES
Workplan 4

APPENDIX 1

Concept Plan



SUBJECT SITE (8.97ha)

RESIDENTIAL LOTS
7.5m FRONTAGE

RESIDENTIAL LOTS
10.5m FRONTAGE

RESIDENTIAL LOTS
12.5M frontage

AGED CARE

TEC (RETAINED VEGETATION)

TEC BUFFER (20m)

PROPOSED DRAINAGE
ARRANGEMENT (17761m²)

OPEN SPACE

PAW (8m)

INDICATIVE PLAYGROUND
LOCATION

FUTURE ROAD CONNECTION
(1890m²)

LOT SUMMARY	
Number of Lots	35
Total Area of Lots	11966m²
Average Area of Lots	342m²
Minimum Lot Area	225m²
Maximum Lot Area	642m²

Note: Lot summary excludes Aged Care

URBIS

Concept Plan
Cambridge Reserve

Level 14, The Quadrant, 1 William Street | Perth WA 6000 Australia | +61 8 9346 0500 | URBIS Pty Ltd | ABN 50 105 256 228

DATA SOURCE
Landgate

PROJECTION
MGA Zone 50

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CLIENT
City Of Kalamunda

1:2,000 @ A3
0 10 20 30 40 50m

PROJECT NO. P0011135
DATE 08.04.2020
DRAWING NO. 01
REVISION B

Appendix J – Water Modelling and Local Water Management Strategy

urbaqua
land and water solutions

24 April 2020

Stephanie Brokenshire
City of Kalamunda
2 Railway Road
Kalamunda, WA 6076

Dear Stephanie,

Re: Modelling Report for Cambridge Reserve

This letter is prepared in support of the Cambridge Reserve Community Enhancement Project and to satisfy the requirements of Better Urban Water Management (WAPC, 2008). It outlines water management strategies to address key water management considerations for the site, consistent with the principles of Water Sensitive Urban Design (WSUD).

The Study Area is an approximately 11 ha local open space reserve located in Forrestfield. It located between Anderson Road, Mallow Way, Cambridge Road and York Street (Figure 1 attached). Cambridge Reserve is being investigated for residential development whilst preserving the existing environmental value of the site. A draft Concept Plan was prepared and included following key features (Urbis, 2020):

- Activity hub – including half-court basketball, seating areas and playground;
- Retained bushland;
- Improved landscape around the drainage sump;
- Formalised walking trails;
- Aged care development site; and
- Residential development.

The key water management considerations for the site include:

- Understanding the performance and capacity of the existing drainage basin onsite;
- Configuring drainage (and site layout) to account for the presence of the TEC; and,
- Implement WSUD to improve the function and aesthetics of the sump, whilst improving water quality treatment and flood protection.

This letter provides a summary of site conditions, stormwater modelling results, recommendations for the water management for review of the concept plan. The report incorporates complementary investigates of the TEC and geotechnical conditions onsite.

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Site Conditions

The following environmental characterisation is based on a desktop assessment of regional and local data sets and field investigations. The site contains a large basin (Figure 2), which receives drainage from the surrounding area. The site is underlain mostly with Pebbly Silt (Mgs_1) and Gravelly Silt (Mgs_2), with infiltration rates investigated by Urbaqua (July 2019) and Structerre Consulting (January 2020). The following rates were identified within the basin:

- Urbaqua: infiltration rates between 0.4 m/day and 0.9 m/day; and,
- Structerre: infiltration rates between 0.5 m/day and 1.3 m/day;

These infiltrations rates are comparatively low compared within sandy soils in the Perth Metropolitan Area, and runoff from the surrounding catchment is retained and slowly infiltrated, or discharges downstream (discussed further in *Stormwater Modelling*)

The general site conditions are summarised in Table 1 below.

Table 1: Site Conditions

Category	Site Characteristic
Topography	• The topography ranges between 41 mAHD and 53 mAHD; • Generally slopes down towards the north-west, with a local low point (the basin) present to the south-west of the site.
Land Use	• Local open space reserve, surrounded largely by residential areas, with small areas of industrial and commercial north and west of the site; • High voltage transmission lines are located east of the site along Anderson Road.
Geotechnical	• Regional soil mapping indicates that the site is underlain mostly with Pebbly Silt (Mgs_1) and Gravelly Silt (Mgs_2). A small portion of the study area near York Road is underlain with Sand (S10). • Structerre identified Sandy Clay (within the basin) and Gravelly Sand or Sand across the remainder of the site, though all tests were impenetrable at depths of only 0.7 m; • Infiltration across the site (outside of the basin) was generally less than 1.4 m/day, apart from one site (BH10) near the transmission lines which was 4.0 m/day (note that a nearby test at BH7 was 0.7 m/day).
Groundwater	• The DWER regional groundwater mapping (DWER, 2019) indicates that the minimum groundwater level is approximately 17 mAHD; • Depth to groundwater ranges from approximately 24.5 m to 35.5 m; and, • Groundwater flows generally from northeast to southwest.

Surface Water	• Within Cambridge Reserve there is an existing basin, connected upstream via a constructed drain (southern boundary) and sheetflow;
	• Outflow from the basin occurs via an existing pipe connection and overland flow to York Street;
	• According to the Surface Water Management Areas map, the study area is located within the Middle Canning surface water management area (DWER, 2020);
	• Surface water quality sampling and analysis was conducted for the surface water in the sump (Strategen, 2014). According to the results:
	  ○ total nitrogen concentrations were between 0.43 and 1.40 mg/L;
	  ○ total phosphorus concentrations were between 0.09 and 0.36 mg/L.

Category	Site Characteristic
Water Resources	• The site is located within the Shire of Kalamunda subarea of the Perth Catchment groundwater management area; • Groundwater allocation is available in the superficial aquifer (DWER, 2020), with 12,748 kL/yr currently available for allocation (the aquifer is 99.57% allocated).
Vegetation	• No threatened species occur on the site (PVG, 2019); and, • Two areas (north east and south east of the site) have been assessed as having vegetation in Excellent condition, and an area of Very Good condition between the basin and York St.
Wetlands	• No wetlands are registered within or near the Reserve (DBCA, 2019).
General Environment	• The site is mapped with no known risk of acid sulfate soils occurring within 3 m of the surface (DWER, 2019); • A search of the DWER Contaminated Sites Database (DWER, 2019) indicates that there are no contaminated sites located within the study area.

Stormwater Modelling

Hydrological and hydraulic modelling has been undertaken to determine the following:

1. Existing performance of the basin;
2. Impact of the concept plan on basin performance;
3. Assessment of alternative storage locations; and,
4. Revised basin sizing and location.

Modelling was undertaken with modelling package XP-Storm, consistent with Australian Rainfall & Runoff 2019 protocol, including multi-storm analysis to determine the critical duration event that produces the largest stormwater volume. The model is based on the 2016 design rainfall Intensity- Frequency-Durations (IFDs) and Ensembles approaches (ARR, 2016).

The existing basin was constructed in the late 1970s and no design information was available for interrogation. The basin sites between 2 and 3 m below the surrounding landscape, with an invert of 41.0 mAHD. Owing to the informal nature of the basin, there is varying side slopes between approximately 1:2 and 1:4, with some areas as flat at 1:8. Slopes greater than 1:6 generally require fencing to restrict access. The basin has minimal vegetation, though surrounding vegetation to west and south has been graded as Very Good. The stage/area dimensions for the basin are provided in Table 2, noting that the footprint of the basin is larger than the actual capacity due to the outlet.

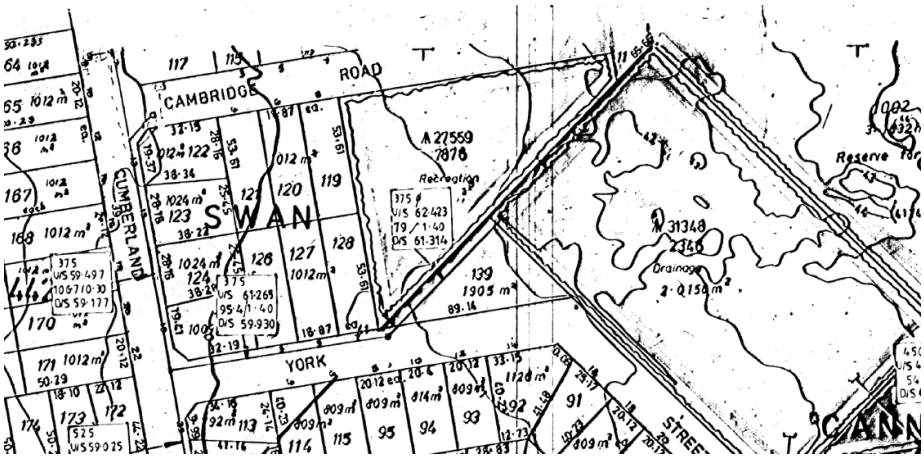
Table 2: Basin Stage/Area

Stage (mAHD)	Area (ha)	Stage (mAHD)	Area (ha)
41.0	0.015	42.2	1.02
41.2	0.55	42.4*	1.10
41.4	0.74	42.6*	1.24
41.6	0.83	42.8*	1.34
41.8	0.90	43.0*	1.48
42.0	0.96	43.2*	1.60

** Above the overland flow outlet*

Runoff from the surrounding catchment flows into the basin through a combination of formal and informal pathways. Three formal pipe outlets were noted during field inspections, with rock pitching preventing erosion at some inlets. There is an informal drain along the southern boundary that conveys overland flow into the basin, along with general sheet flow through the site.

There is a connection to the downstream stormwater system on York Street as shown in the image below, with a 375 mm pipe connection. The invert of this outlet (based on aerial imagery and elevation data) is assumed to be 41.8 mAHD. The existing surface at 42.2 mAHD provides an overland route for any additional overflow in the system. Based on LIDAR data, this overflow continues down York Street towards Cumberland Road and ultimately toward Yule Brook.



The surrounding catchment is shown in Figure 1. The assumed runoff rates for the respective land uses are provided in Table 3.

Table 3: Runoff parameters

Land Use	Initial Loss (mm)	Runoff Rate
Road Reserve	3	80%
Residential Lots	8	50%
Industrial / Commercial Lots	3	70%
Undeveloped / POS	5	25%

As per the Structerre Geotechnical Report (2020), infiltration within the basin was assumed to be 1.0 m/day (measured range of 0.5 m/day and 1.3 m/day).

Scenario 1: Baseline Conditions

The baseline model was established to assess the current capacity of the system based on available data, and in the absence of original design information. Larger storm events (10% AEP and 1% AEP) were assessed with varying duration to determine the performance of the system. The results for this scenario are provided in Table 4, based on the catchment parameters and existing basin configuration.

Table 4: Existing basin capacity results

AEP Event	Duration	Total Rainfall	Maximum Water Level	Surface flow to York Street
10% AEP	1 hr	28.1 mm	41.78 mAHD	No
10% AEP	3 hrs	42.0 mm	42.03 mAHD	No
10% AEP	6 hrs	54.8 mm	42.16 mAHD	No
10% AEP	**9 hrs**	**64.0 mm**	**42.22 mAHD**	**Yes**
10% AEP	**12 hrs**	**71.2 mm**	**42.21 mAHD**	**Yes**
10% AEP	18 hrs	82.2 mm	42.20 mAHD	No
10% AEP	24 hrs	90.3 mm	42.18 mAHD	No
1% AEP	1 hr	43.0 mm	42.12 mAHD	No
1% AEP	**3 hrs**	**67.1 mm**	**42.40 mAHD**	**Yes**
1% AEP	**6 hrs**	**90.1 mm**	**42.43 mAHD**	**Yes**
1% AEP	**9 hrs**	**106 mm**	**42.45 mAHD**	**Yes**
1% AEP	**12 hrs**	**118 mm**	**42.42 mAHD**	**Yes**
1% AEP	**18 hrs**	**134 mm**	**42.39 mAHD**	**Yes**
1% AEP	**24 hrs**	**145 mm**	**42.38 mAHD**	**Yes**

Results of this assessment demonstrate that the basin in its existing configuration has insufficient capacity for a 1% AEP event given the 10% AEP (9 and 12 hours) event discharges via overland flow. Therefore with development of the structure plan area, water levels (and consequently flows downstream) should not increase above the levels in Table 4, and preferably the capacity of the basin is increased to allow for improved flood storage.

Scenario 2: Post-development

The second scenario considered was assessment of the impact on the basin from the proposed development. This assessment was made on an older version of the development layout, as shown in Figure 2, though the total proposed land uses are comparable with the final layout, and the findings are consistent. The proposed development results in an increase in impervious area and additional runoff from the local catchment. The proposed development includes additional road reserves, residential lots and an aged care facility. In order to minimise the increase in water level in the basin, runoff from the new development need to be managed locally wherever possible.

Applying runoff rates adapted from the rest of the catchment results in an increase in basin water levels of approximately 0.08 m and 0.02 m for the 10% AEP and 1% AEP events respectively. Mitigation of runoff from the new development areas can be achieved be adopting the following strategies.

Consistent with the *Decision process for stormwater management in Western Australia* (DWER, 2017), the first 15 mm of rainfall should be managed at source. This approach is required to improve water quality downstream, but also provides a marginal improvement to flood management. Although the soil conditions (and measured infiltration rates) aren't as effective as sandy soils on the Swan Coastal Plain, the use of soakwells at the front of lots (with a grated overflow to the road) provides a retention and detention function that will assist with the downstream volumes. An alternative approach is the use of above ground garden beds (positioned beneath downpipes) to retain and infiltrate roof runoff on each lot.

For roads, installation of raingardens in non-active verges will provide management of the 15 mm rainfall event.

Results from management of this runoff are presented in Table 5. There is a requirement for further management to maintain the predevelopment water levels and overflow downstream as the increase in water level is between 0.07 m and 0.02 m for the 10% AEP and 1% AEP events respectively.

Table 5: Post-development basin capacity with 15 mm management

AEP Event	Duration	Total Rainfall	Pre-dev Max Water Level	Maximum Water Level	Surface flow to York Street
10% AEP	1 hr	28.1 mm	41.78 mAHD	41.80 mAHD	No
10% AEP	3 hrs	42.0 mm	42.03 mAHD	42.09 mAHD	No
10% AEP	**6 hrs**	**54.8 mm**	**42.16 mAHD**	**42.23 mAHD**	**Yes**
10% AEP	**9 hrs**	**64.0 mm**	**42.22 mAHD**	**42.28 mAHD**	**Yes**
10% AEP	**12 hrs**	**71.2 mm**	**42.21 mAHD**	**42.27 mAHD**	**Yes**
10% AEP	**18 hrs**	**82.2 mm**	**42.20 mAHD**	**42.27 mAHD**	**Yes**
10% AEP	**24 hrs**	**90.3 mm**	**42.18 mAHD**	**42.25 mAHD**	**Yes**
1% AEP	1 hr	43.0 mm	42.12 mAHD	42.15 mAHD	No
1% AEP	**3 hrs**	**67.1 mm**	**42.40 mAHD**	**42.42 mAHD**	**Yes**
1% AEP	**6 hrs**	**90.1 mm**	**42.43 mAHD**	**42.45 mAHD**	**Yes**
1% AEP	**9 hrs**	**106 mm**	**42.45 mAHD**	**42.47 mAHD**	**Yes**
1% AEP	**12 hrs**	**118 mm**	**42.42 mAHD**	**42.44 mAHD**	**Yes**
1% AEP	**18 hrs**	**134 mm**	**42.39 mAHD**	**42.41 mAHD**	**Yes**
1% AEP	**24 hrs**	**145 mm**	**42.38 mAHD**	**42.40 mAHD**	**Yes**

To maintain the pre-development conditions, a number of options are available, namely;

- Increase the basin overflow level to 42.3 mAHD (detaining all 10% AEP events);
- Require the aced care facility site to manage up to the 10% AEP onsite (not just the first 15 mm);
- Increase storage within the new development area, to manage larger events that the first 15 mm (most likely by the use of underground storage as not to limit developable areas;
- Increase storage elsewhere in the catchment; and/or,
- Reconfigure the basin to maximise storage within the existing footprint.

Increasing the basin outlet level is a relatively simple approach and requires a minimum 100 mm bund construction on the downstream side of the basin to increase the outlet level. This allows detention of the 10% AEP event (all durations) which is a slight improvement on pre-development conditions. The presence of *Excellent* condition vegetation may limit this approach near York Street.

Management of larger events, whether in the aged care facility or elsewhere in the new development is a potentially expensive and inefficient approach. As discussed above, the soils feature relatively low infiltration rates and any underground storage (that relies of disposal through infiltration) becomes larger than equivalent systems on the Swan Coastal Plain. Therefore the cost of installing these systems becomes prohibitive relative to other proposed

systems. Within the aged care facility, above ground storage could be considered (in the form of a basin), however this will result in the loss of developable land.

The remaining two approaches (increasing storage elsewhere in the catchment and reconfiguring the basin) also provides the opportunity to also potentially manage the 1% AEP event and reduce the pressure on downstream system. These two approaches have been considered further in the following sections.

Scenario 3: Alternative Storage

Along Anderson Road, there are opportunities to install additional drainage basins to offset the impact of additional runoff from development and improve the overall performance of the system by increasing 1% AEP storage. As shown in Figure 3, two basins are proposed (based on the superseded development layout), north east and south east of Cambridge Reserve. Both locations would be beneath the Western Power transmission lines and will require approval, though it is noted this has been done recently elsewhere in Forrestfield. The northern basin has limited existing vegetation, though some clearing would be required in the south.

The reserve where the basins are located are up to 50 m wide, through a more conservative 32 m basin width is assumed to allow for other uses (services, paths etc.). A 1:6 side slopes is also assumed, with a depth up to 1.0 m. The full dimensions are provided in Table 6, with modelling results (for the central basin in Cambridge Reserve) provided in Table 7.

Table 6: Alternative basin details

Invert	Depth	Base Area	Top Area	Side Slopes	Volume
51.0 mAHD	1.0 m	0.24 ha	0.42 ha	1:6	3,290 m^3

Table 7: Post-development basin capacity with alternative basins

AEP Event	Duration	Total Rainfall	Pre-dev Max Water Level	Maximum Water Level	Surface flow to York Street
10% AEP	1 hr	28.1 mm	41.78 mAHD	41.68 mAHD	No
10% AEP	3 hrs	42.0 mm	42.03 mAHD	41.72 mAHD	No
10% AEP	6 hrs	54.8 mm	42.16 mAHD	41.74 mAHD	No
10% AEP	9 hrs	64.0 mm	42.22 mAHD	41.76 mAHD	No
10% AEP	12 hrs	71.2 mm	42.21 mAHD	41.67 mAHD	No
10% AEP	18 hrs	82.2 mm	42.20 mAHD	41.45 mAHD	No
10% AEP	24 hrs	90.3 mm	42.18 mAHD	41.60 mAHD	No
1% AEP	1 hr	43.0 mm	42.12 mAHD	41.66 mAHD	No
1% AEP	3 hrs	67.1 mm	42.40 mAHD	42.04 mAHD	No
1% AEP	**6 hrs**	**90.1 mm**	**42.43 mAHD**	**42.28 mAHD**	**Yes**
1% AEP	**9 hrs**	**106 mm**	**42.45 mAHD**	**42.32 mAHD**	**Yes**
1% AEP	**12 hrs**	**118 mm**	**42.42 mAHD**	**42.33 mAHD**	**Yes**
1% AEP	**18 hrs**	**134 mm**	**42.39 mAHD**	**42.30 mAHD**	**Yes**
1% AEP	**24 hrs**	**145 mm**	**42.38 mAHD**	**42.29 mAHD**	**Yes**

The northern basin is sized to contain the majority of the runoff from the catchment east of Anderson Road. Only the larger 1% events overflow to the central basin. The southern basin overflows in a 10% AEP event and could potentially be increased in size, noting that there are restrictions with the existing vegetation and power pole locations.

Further discussions with the City indicated that the southern basin was not feasible owing to the presence of existing vegetation. However the results of this scenario demonstrate the effectiveness of these basins in reducing the water levels within the central basin. There is still the overflow to York Street in the 1% AEP event with the current basin form. The cost for the northern basin is roughly estimated at $76,000 based on earthwork requirements.

Scenario 4: Revised Basin Configuration

The approach to a revised basin configuration is to provide conditions that are suitable for community interaction, increase storage and minimising footprint increase (maintain developable areas and minimise impact on existing vegetation). The scenario here is presented in (a) the reconfigured basin alone and (b) the reconfigured basin with the alternative storage in Scenario 3. Results (based on the superseded development layout) presented below are in the form of a rectangular basin, and it is assumed that the final form will be further modified by landscaping design to tie in with the surrounding amenities.

Revised configuration (no storage upstream)

Revising the basin configuration alone, the model was run for a basin with a 1:6 side slope (no surrounding fencing), assuming management of the first 15 mm within the new development areas. The objective was to prevent overland flow out of the system in a 1% AEP event, with the only discharge via the existing pipe connection downstream. The proposed basin dimensions are provided in Table 8, with the modelling results in Table 9.

Table 8: Reconfigured basin details (no upstream storage)

Invert	Depth	Base Area	Top Area	Side Slopes	Volume
41.0 mAHD	1.2 m	1.28 ha	1.63 ha	1:6	17,413m^3

Table 9: Reconfigured basin results (no upstream storage)

AEP Event	Duration	Total Rainfall	Pre-dev Max Water Level	Maximum Water Level	Surface flow to York Street
1% AEP	1 hr	43.0 mm	42.12 mAHD	41.55 mAHD	No
1% AEP	3 hrs	67.1 mm	42.40 mAHD	41.88 mAHD	No
1% AEP	6 hrs	90.1 mm	42.43 mAHD	42.07 mAHD	No
1% AEP	9 hrs	106 mm	42.45 mAHD	42.19 mAHD	No
1% AEP	12 hrs	118 mm	42.42 mAHD	42.20 mAHD	No
1% AEP	18 hrs	134 mm	42.39 mAHD	42.20 mAHD	No
1% AEP	24 hrs	145 mm	42.38 mAHD	42.18 mAHD	No

The top water level area (basin footprint) is shown in Figure 4, noting this shape will need to be refined with landscaping design. A preliminary costing suggests this option will cost approximately $228,500 associated with the basic earthworks. Further costs associated with the landscaping improvements are required.

It should be noted that this approach increases the basin footprint to 1.63 ha from 1.03 ha. If the side slope is increase to 1:3; the top area can be reduced to 1.55 ha whilst containing the 1% AEP event, though this may require fencing or landscaping to control and/or prevent community access.

Scenario 5: Combined Approach (Proposed Development Concept)

Scenarios 3 and 4 presented above, whilst based on superseded layouts, demonstrate that the solution for the site is a combination of upstream storage and an alternative basin configuration. Following discussions between the project team, the preferred solution for the basin was the western portion of the site, which provides the following benefits:

- A relatively flat area of the site to maximise basin footprint (whilst protecting established trees);
- Protection of the TEC on York Street; and,
- Increased development potential within the "core" area of the site.

In order for this configuration to meet the site design requirements, additional storage was required in the eastern and southern portion of the site. The northern basin under the Western Power Transmission Lines (Scenario 3) was considered suitable and is included within this assessment.

The existing drain along the southern boundary has also been utilised to generate additional stormwater storage. Modifying the drain into a series of small basins that fill up and overtop, creates a cascading system that detains flows towards the basin. These basins are generally a maximum of 20 m wide (to fit within the corridor between the site boundary and southern TEC), 1.2 m deep and 1:6 side slopes for safety considerations. A larger "pond" area is utilised to increase storage in land that would be difficult to incorporate into the layout.

The additional storage and revised basin configuration were assessed against the proposed development layout in Figure 5 (Scenario 5a). This configuration was modelled iteratively to determine the suitable infrastructure size, with results outlined in Table 10 and Table 11.

Table 10: Proposed basin details

Invert	Depth	Base Area	Top Area	Side Slopes	Volume
41.0 mAHD	1.2 m	0.56 ha	0.81 ha	1:6	8,150 m^3

Table 11: Proposed basin results

AEP Event	Duration	Total Rainfall	Maximum Water Level	Surface flow to York Street
1% AEP	1 hr	43.0 mm	41.38 mAHD	No
1% AEP	3 hrs	67.1 mm	41.78 mAHD	No
1% AEP	6 hrs	90.1 mm	42.05 mAHD	No
1% AEP	9 hrs	106 mm	42.17 mAHD	No
1% AEP	12 hrs	118 mm	42.18 mAHD	No
1% AEP	18 hrs	134 mm	42.16 mAHD	No
1% AEP	24 hrs	145 mm	42.13 mAHD	No

This basin with this configuration is able to meet the design requirements (no overland flow discharge to the York Street), improves community safety (1:6 side slopes, maximum 1.2 m depth) and maximise developable area on the site. The estimated cost to construct this configuration is $495,000, mainly associated with earthworks to construct the new basin and fill the old basin.

In order for this system to function correctly within the proposed site layout, drainage easements are required to connect drainage from Mallow Way (north of the site) through the Aged Care Site. A combination of pit/pipe drainage (modification of the existing pipework) and overland flow path is required to ensure drainage can reach the basin system. A potential easement location is shown in Figure 5, though internal roads within the Aged Care Site are a suitable alternative and could be determined during detailed design. Flow paths to connect the internal drainage to the basin system are also shown in Figure 5.

Along with the layout provided in Figure 5, an alternative layout concept is being considered by the City. This layout is shown in Figure 6 (Scenario 5b) and includes a reduction in the Aged Care Site, and the addition of a public road and residential lots. The runoff from this alternative configuration is slightly less than the Aged Care Facility as private lots have greater potential for pervious areas such as gardens). The proposed basin configuration is therefore suitable for either development concept.

Water Management Recommendation

The Local Water Management Strategy (LWMS) for Cambridge Reserve will address the requirements of Better Urban Water Management (WAPC, 2008). Table 12 outlines the key water management strategies to be achieved for the proposed development of the site.

Table 12: Water Management Recommendations

Design Objective
Water sustainability • Provide alternative water sources for non-drinking water demands, potentially including groundwater abstraction for irrigation; and • Minimise ex-house water demand through waterwise landscaping and promotion of passive irrigation with stormwater runoff wherever possible.
Groundwater management • No active management of groundwater is required on this site (owing to the depth).
Surface water management – new development area • Reduce risks to downstream water quality by managing small (up to 15 mm) rainfall events within the site using vegetated systems (preferred), soakwells and/or underground storage; • Provide an acceptable standard of amenity in roads, laneways and to properties during minor (20% AEP) rainfall events (pit and pipe system); and • Provide a minimum floor level within properties at least 500 mm above the 1% AEP water levels within the central basin to ensure appropriate level of protection from flooding
Surface water management – Cambridge Reserve • Modification of the basin is required to maintain existing performance of the system and not increase the flooding risk to downstream properties; • The simplest approach to maintaining the current performance is to construct a 100 mm bund around the southern and western portions of the site; • Improvement to the system to detain larger storm events, with no overland flow to York Street can be achieved by;

Design Objective
○ Installing additional basins east of the reserve under the transmission lines (partial detention of the 1% AEP); ○ Modifying the existing basin only (full detention of the 1% AEP); and, ○ A combination of additional basins and modifying the existing basin (full detention of the 1% AEP). • A combination of additional basins and modification/relocation of the current basin is recommended as it provides improved performance (detention of the 1% AEP) and allows for a design with 1:6 side slopes and community access.
Surface water management – other • The existing drain along the southern boundary should be modified to increase storage within the system. Landscaping of these areas should be considered to improve amenity in the site.
Other WSUD • Retain existing trees where possible (and replace any removed through development), consistent with the City of Kalamunda's Environmental Initiative; and • Provide for passive watering of trees and green spaces by directing small rainfall events towards verges and street trees (15 mm management).

Please do not hesitate to contact me on (08) 9328 4663 or at ross@urbaqua.org.au should you have any questions on this report.

Yours sincerely,

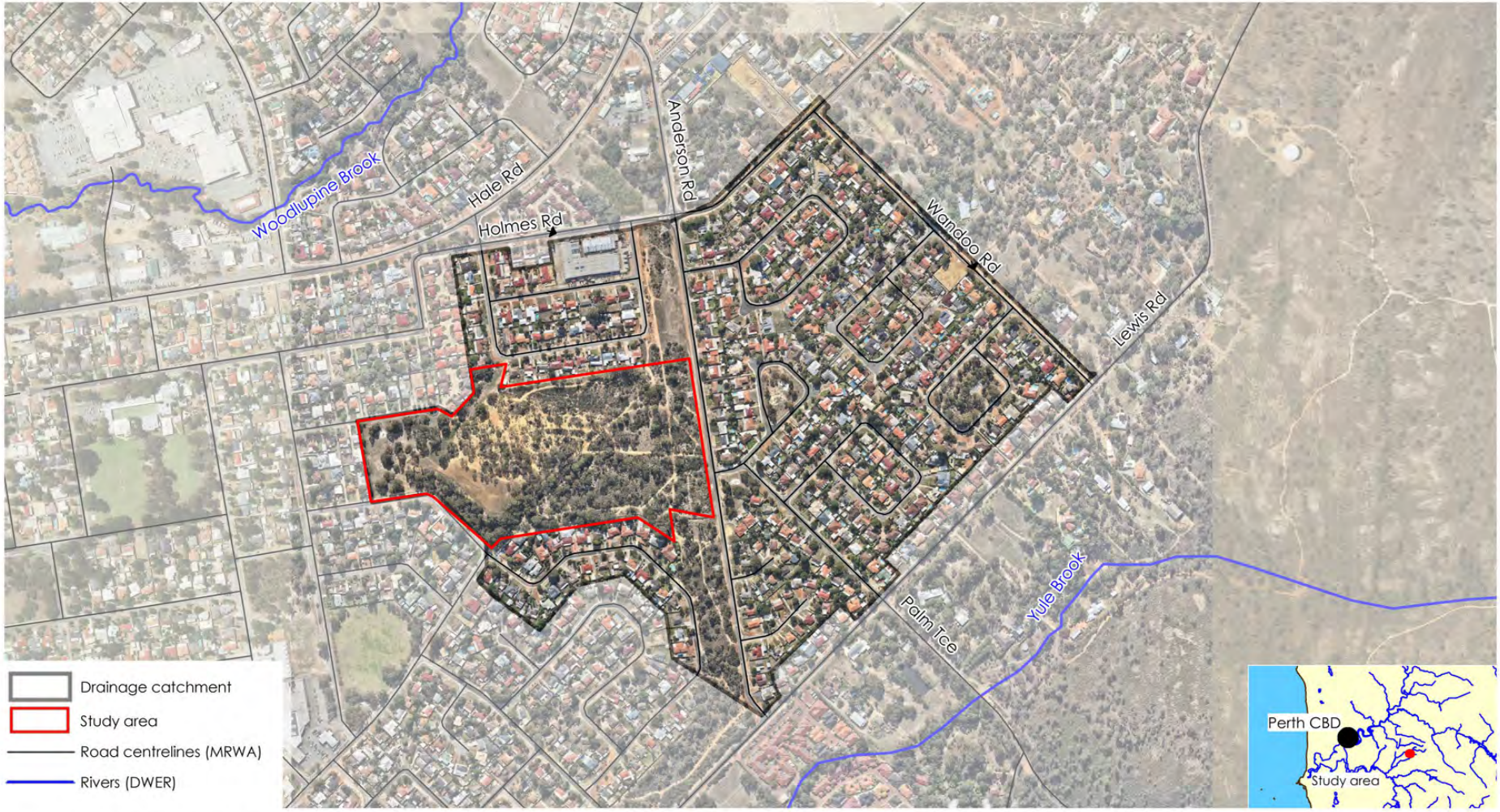


Ross Perrigo
SENIOR ENGINEER
URBAQUA

Attachment:

- Figure 1 – Study Area
- Figure 2 – Subdivision Plan
- Figure 3 – Additional basins upstream (Scenario 3)
- Figure 4 – Reconfigured basin only (Scenario 4)
- Figure 5 – Combined approach (Scenario 5a)
- Figure 6 – Combined approach (Scenario 5b)

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Figure 1 - Study Area

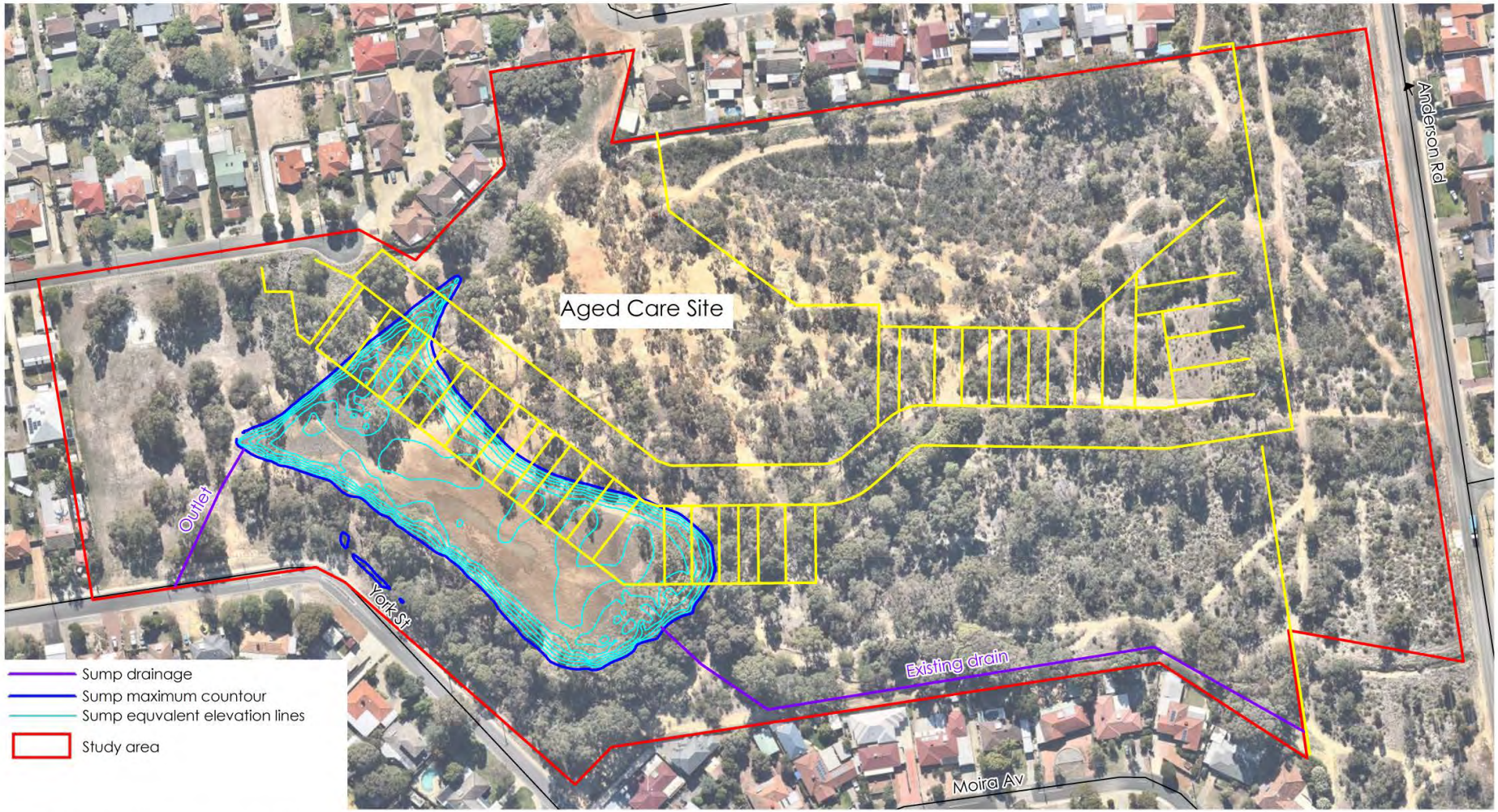


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Figure 2 - Subdivision Plan

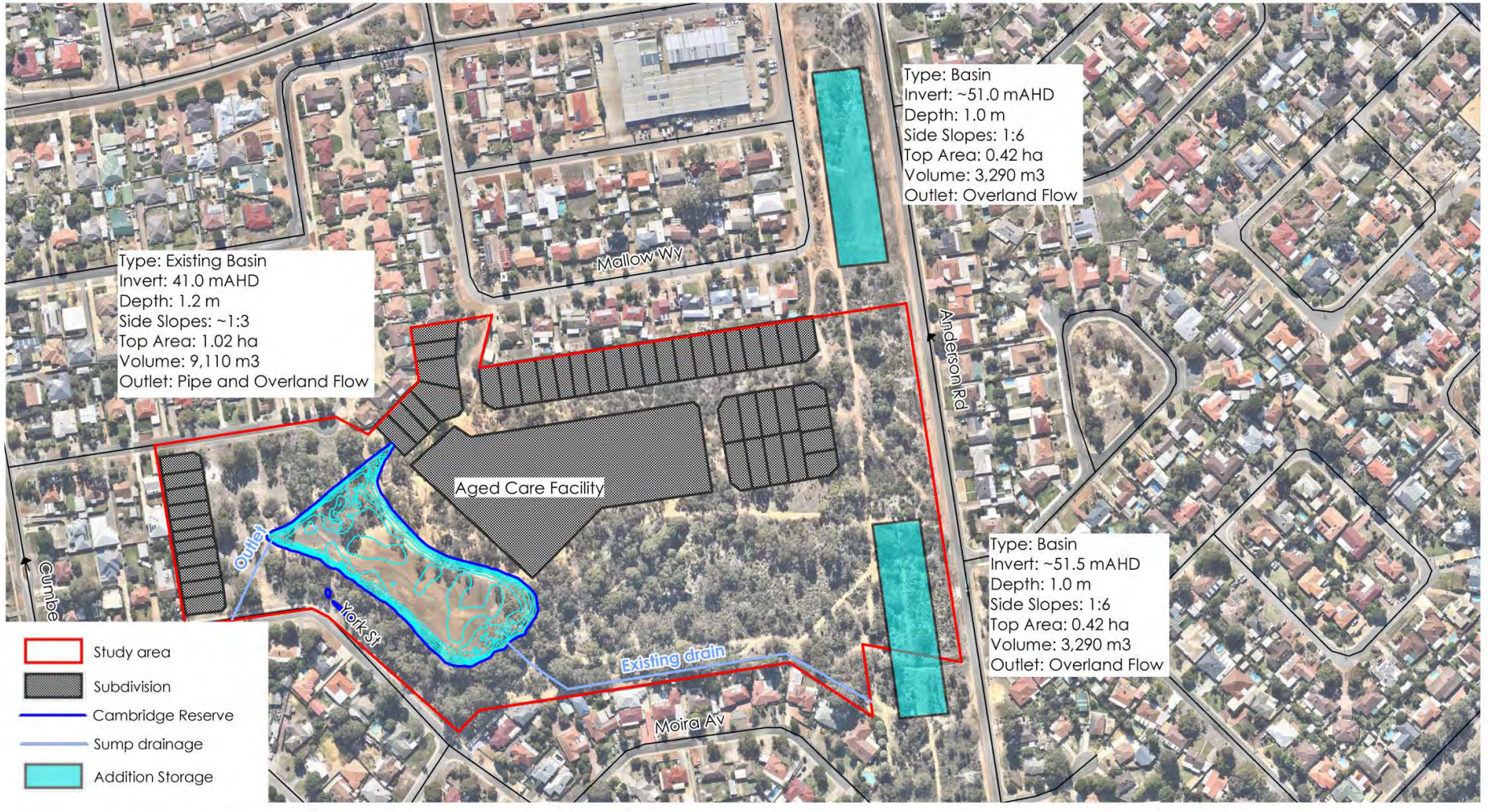


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Figure 3 - Addition Storage Upstream

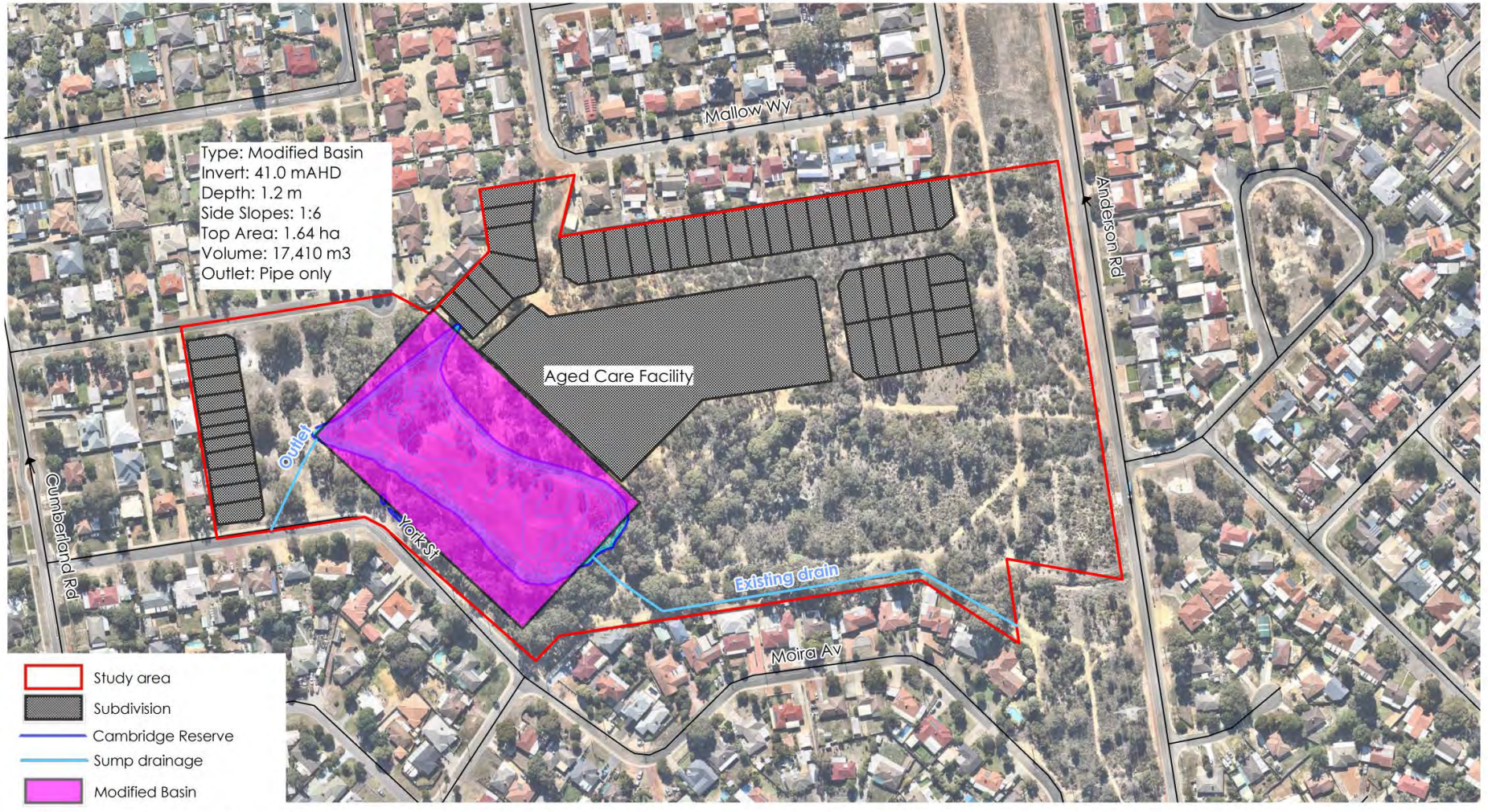


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Figure 4 - Reconfigured Basin Only



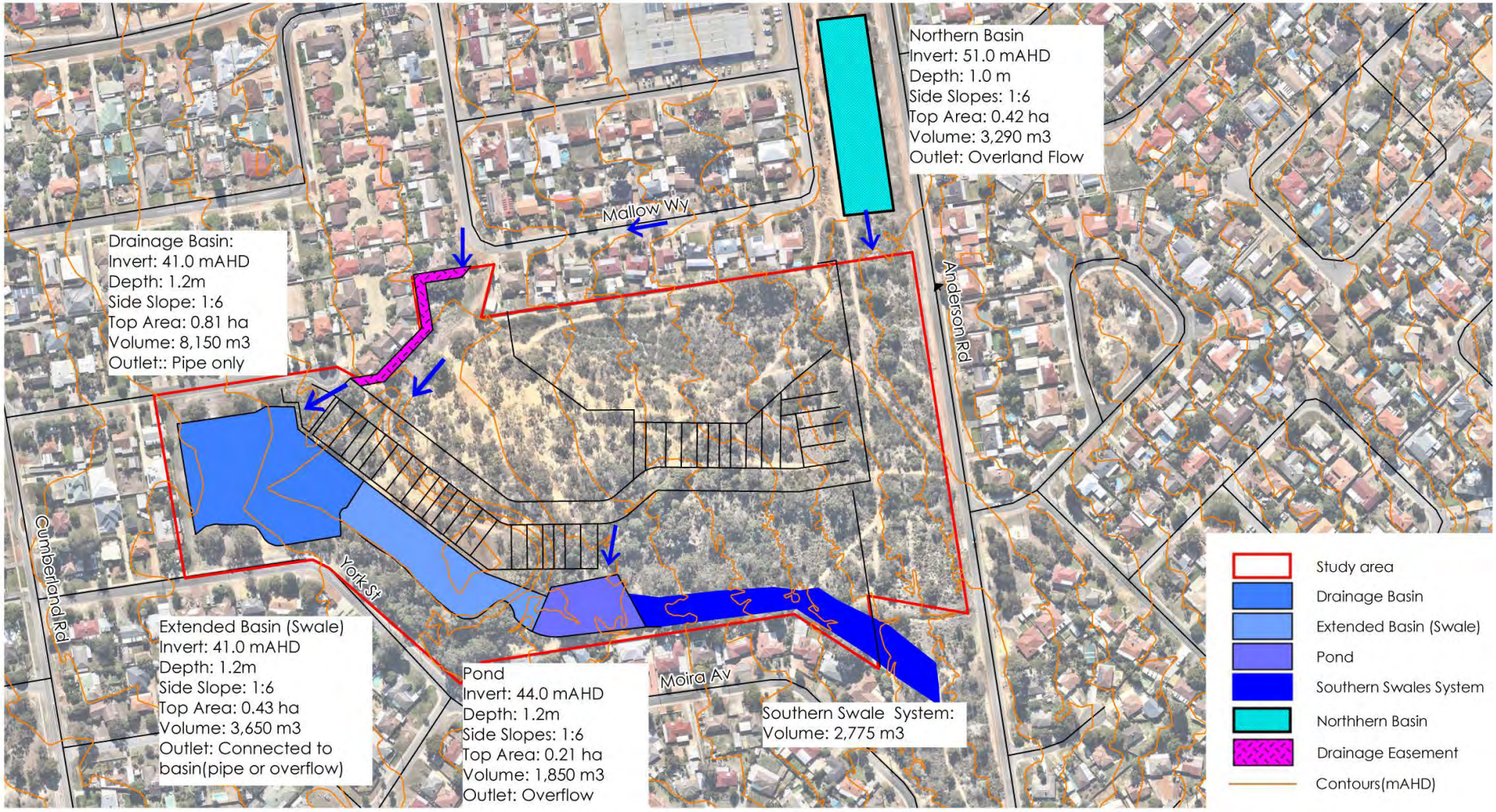
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Figure 5 - Drainage System for Concept Plan



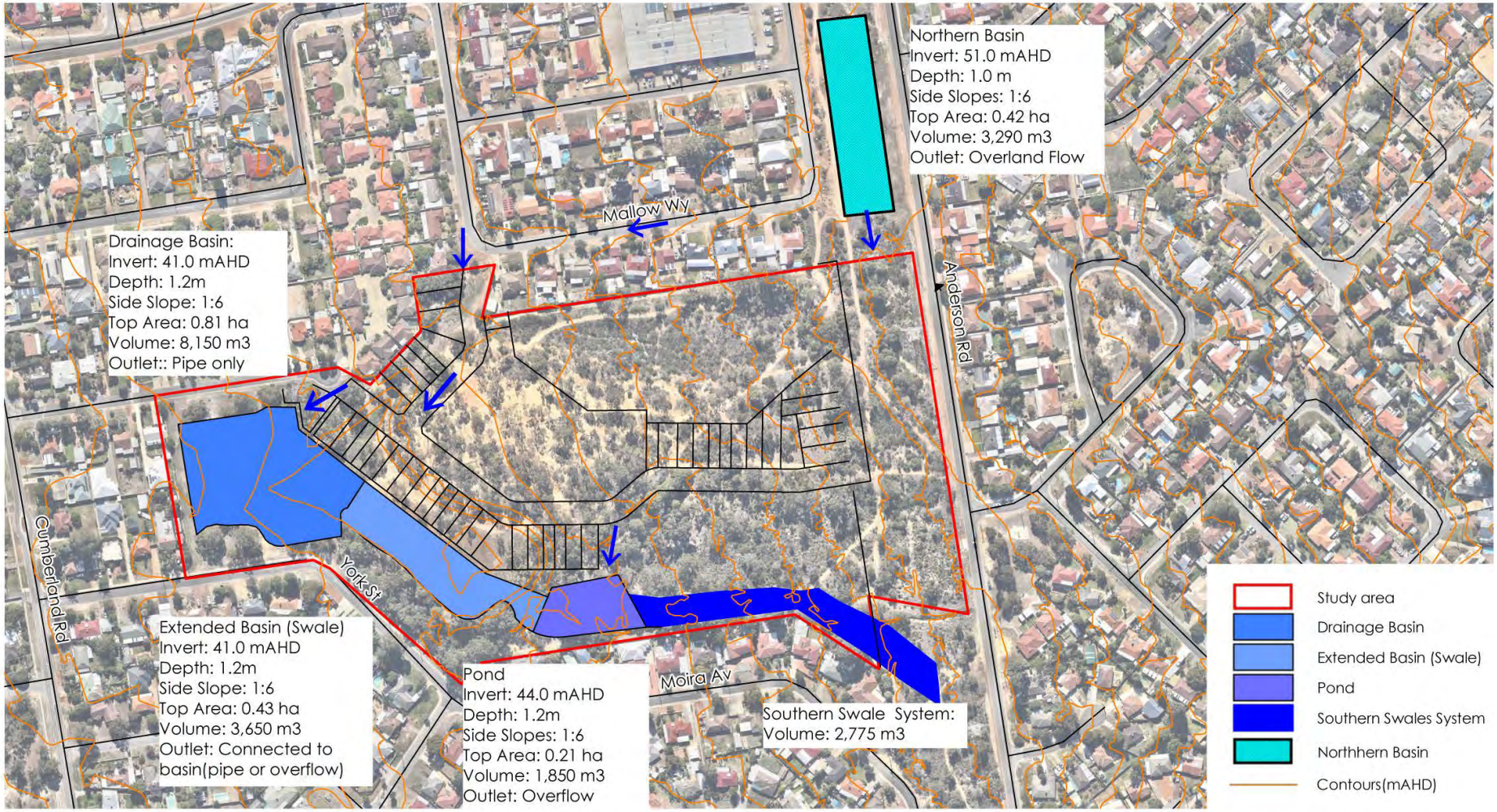
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Figure 6 - Drainage System for Alternative Concept Plan



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Cambridge Reserve, Forrestfield

Local Water Management Strategy

Prepared for City of Kalamunda

By Urbaqua

May 2020

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1 INTRODUCTION

Urbaqua has been commissioned by the City of Kalamunda to prepare this Local Water Management Strategy (LWMS) in support of the Local Structure Plan for Cambridge Reserve, Forrestfield (herein referred to as Study Area). The Study Area is located approximately 13 km east of the Perth CBD. The site is 9.2 hectares in size and is bound by:

- High voltage transmission and Anderson Road to the east;
- York Street and Cambridge Road to the west; and,
- Residential properties to the south and north.

The Study Area is currently classified local open space in the City of Kalamunda Local Planning Scheme No. 3. The site features a combination of drainage infrastructure, native vegetation and informal walking tracks. The vision is to redevelop the Study Area into a residential precinct with residential lots, an aged care facility and public open space. The LWMS is prepared to support the planning process and guide sustainable water management during redevelopment.

1.1 Principles and design objectives

Consistent with *State Planning Policy 2.9: Water Resources* (WAPC, 2006) and *Better Urban Water Management* (WAPC, 2008) a local water management strategy (LWMS) is required to be submitted to support any rezoning of land in a Local Planning Scheme or adoption of a Local Structure Plan to ensure that appropriate water management strategies are identified. The position of this document within the state government planning framework is defined in *Better Urban Water Management* (WAPC, 2008) and is outlined in Figure 1.

The LWMS has been prepared in accordance with the Department of Water and Environmental Regulation's (DWER) *Interim: Developing a Local Water Management Strategy* (DoW, 2008a) and demonstrates:

- How the key principles and strategies of this plan have been addressed;
- How the urban structure will address water use and management;
- Existing and required water management infrastructure; and,
- Detailed land requirements for water management.

The principles and strategies contained within Section 5 of this LWMS will be implemented as part of detailed land use planning and development requirements and are consistent with the framework and requirements in *Better Urban Water Management* (WAPC, 2008) as demonstrated in Appendix 1.

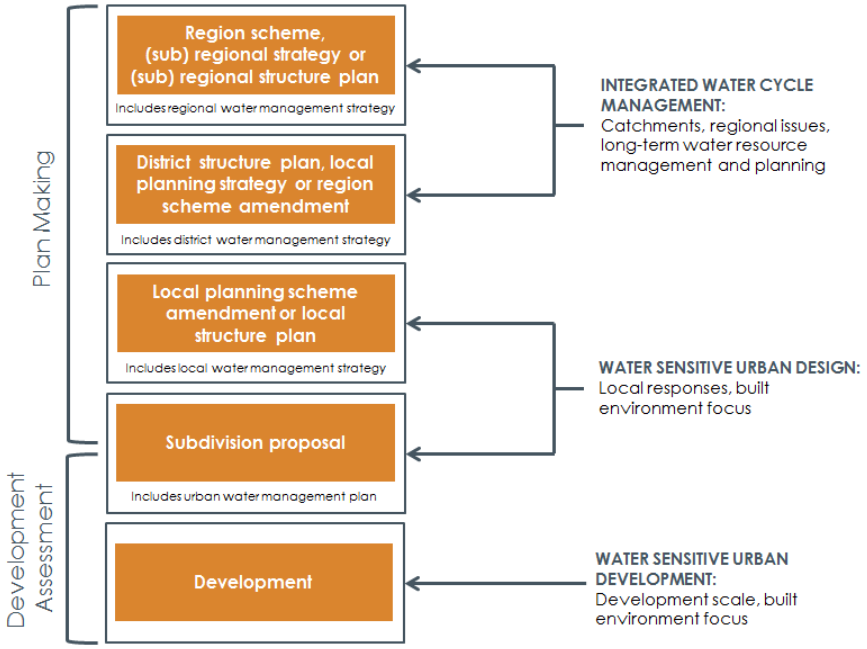


Figure 1: Integrating water planning with land planning processes (WAPC, 2008)

1.2 Planning background

The site is currently zoned as 'Urban' under the Metropolitan Regional Scheme and as 'Regional Open Space' under the City's Local Planning Scheme No. 3. This LWMS is being submitted to support the scheme amendment process.

1.3 Guiding documents

A number of guiding documents have been considered that are relevant to the Study Area. In addition to State Planning Policy 2.9, these documents inform the strategies and management principles contained within this Local Water Management Strategy:

- Developing a Local Water Management Strategy (DoW, 2008a);
- Stormwater Management Manual for Western Australia (DoW, 2004-09);
- Better Urban Water Management (WAPC, 2008a); and,
- Decision Process for Stormwater Management in Western Australia (DWER, 2017).

2 PROPOSED DEVELOPMENT

Development of the Study Area to create a residential development that provides opportunities to incorporate water sensitive urban design and protect existing environmental values. This section outlines the key elements of the current land use and proposed re-development that influence water management.

2.1 Previous land use

The site has been cleared since prior to the 1950s and the existing drainage basin on site was constructed in the 1970s, accompanying establishment of surrounding residential areas. Since the 1980s remnant and planted vegetation has regrown substantially (PGV, 2019).

2.2 Development

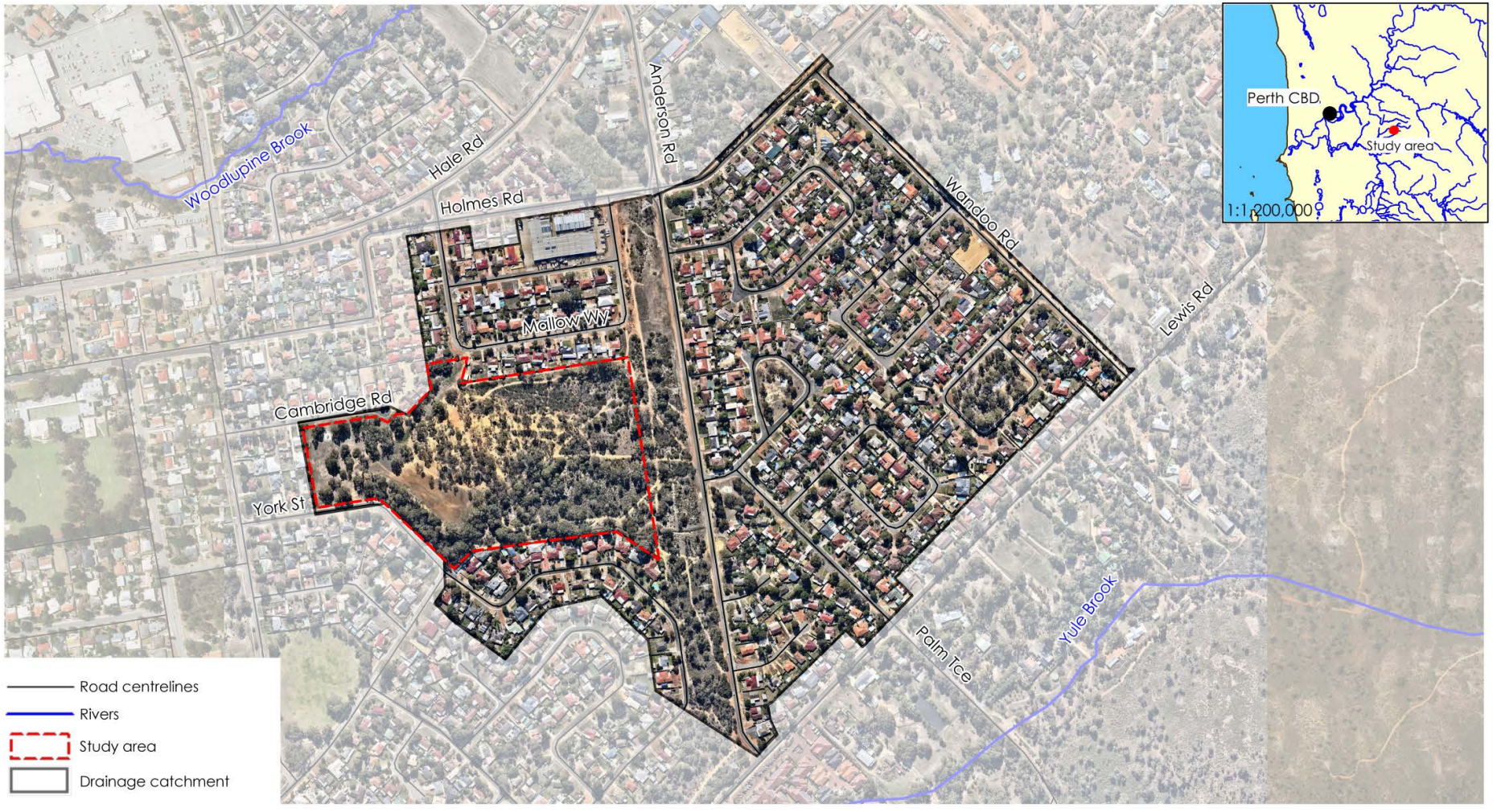
The local structure plan amendment will guide the future urban regeneration of the study area. Proposed development will feature:

- Residential lots and road reserves;
- An aged care facility in the north;
- Fenced off areas to protect existing threatened ecological communities; and,
- Stormwater infrastructure.

The concept design is presented in Figure 3 and included in Appendix 2.

Development will increase impervious areas and increase stormwater runoff. There is however, an opportunity to integrate water sensitive urban design into the development and provide improved water quality and sustainability outcomes.

City of Kalamunda - Cambridge Reserve Local Water Management Strategy
Figure 2 - Study Area

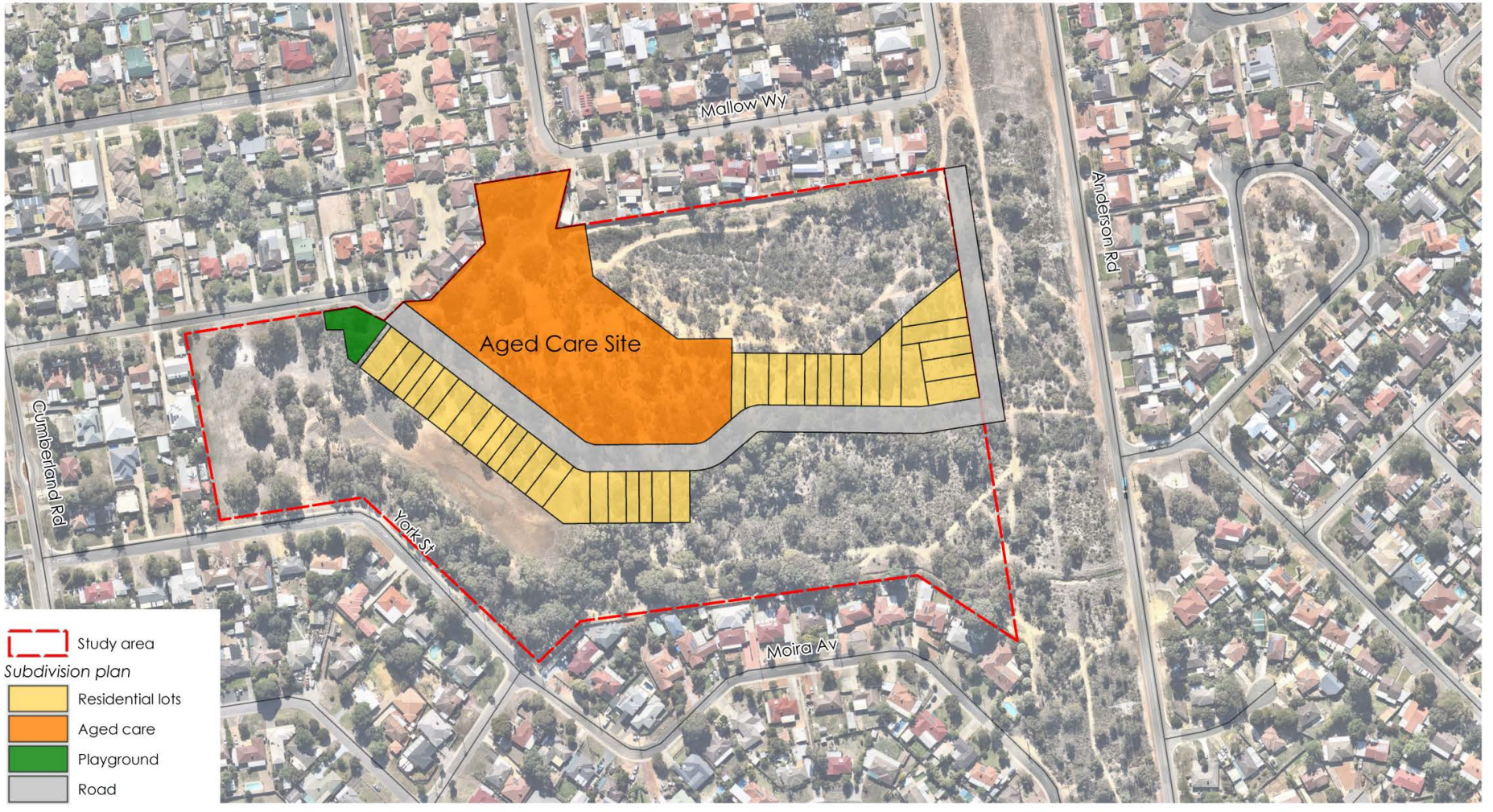


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Figure 3 - Concept Plan



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3 DESIGN CRITERIA

Table 1 outlines the key design objectives to be achieved within the Study Area.

Table 1: Design criteria

Design Element	Criteria
Water sustainability	• Reach a target for domestic scheme water use of 100kL/year per person; and • Provide alternative water sources for domestic irrigation and in-house domestic non-drinking water demands.
Surface water management	• The first 15mm of rainfall is to be retained within all lots through a combination of raingardens, water tanks or soakwell systems (DWER, 2017); • Minor event runoff from events larger than 15 mm total depth are to be managed to provide serviceability requirements; • Roads and public open spaces are to be designed to cater for the surface overflow for more severe storm events with habitable floors at least 0.3 m above the 1% AEP flood or storage level at any location; • Water quality treatment systems and stormwater management structures should be designed in accordance with the Stormwater Management Manual for Western Australia (Department of Water, 2004-07) and Australian Runoff Quality: A guide to water sensitive urban design (Engineers Australia, 2006).
Groundwater management	• Provide an appropriate separation distance between finished lot levels and groundwater to maintain the expected level of amenity with all soakwell devices designed with a minimum of 0.3 m separation from the maximum groundwater level.
Management of disease vectors and nuisance insects	• Limit the creation of new sites for breeding of nuisance insects; • Prevent standing water in drainage infrastructure (infiltration within 96hrs); and • Improve water quality throughout the development.
Implementation	• Provide a framework to implement water management strategies outlined in the LWMS; • Water management measures during construction to prevent damage to existing infrastructure and receiving environments.

4 EXISTING SITE CHARACTERISTICS

A summary of the existing environmental conditions in the Study Area are provided in this section, including determination of the opportunities and constraints for water management.

4.1 Climate

The climate is typical of the south western region of Western Australia and is characterised by the Koppen Climate Classification as Dry Subtropical featuring mild winters and hot to very hot summers. The dominate rainfall mechanisms are frontal systems caused by cold fronts associated with low pressure systems that extend across southern Australian between May and October. During the summer months, thunderstorms and ex-tropical cyclones can bring intense rainfall.

Average annual rainfall recorded at the nearest long term Bureau of Meteorology (BoM) weather station (Perth Airport (no. 9021) approximately 5 km northwest of the Study Area) since 1944 is 762 mm (Figure 4). Since 2000, the average annual rainfall is 667 mm, an approximately 12.5% decrease.

The significant decrease in annual rainfall is associated with a decrease in winter rainfall. Rainfall in the June and July has decreased by approximately 20%. There has been an increase in summer rainfall associated with thunderstorms and ex-tropical cyclones, but this rainfall is often intense occurs over a short duration and does not affect the loss of winter rainfall.

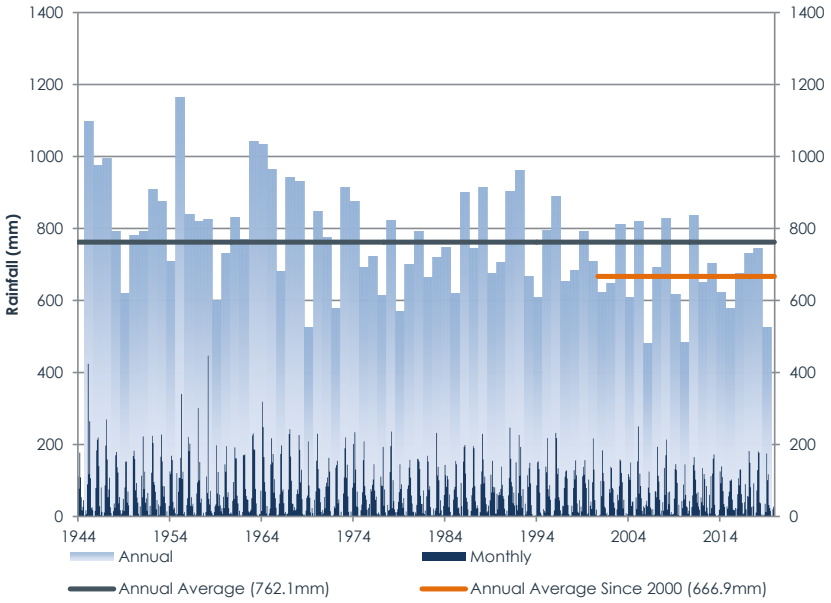


Figure 4: Rainfall summary data (Perth Airport, BoM, 2020)

Temperatures recorded at the Perth Airport (BoM station 9021) show that the average monthly maximum temperatures range between 18.0°C in July and 32.0°C in February, while average monthly minimum temperatures range between 8.0°C in July and 17.5°C in February.

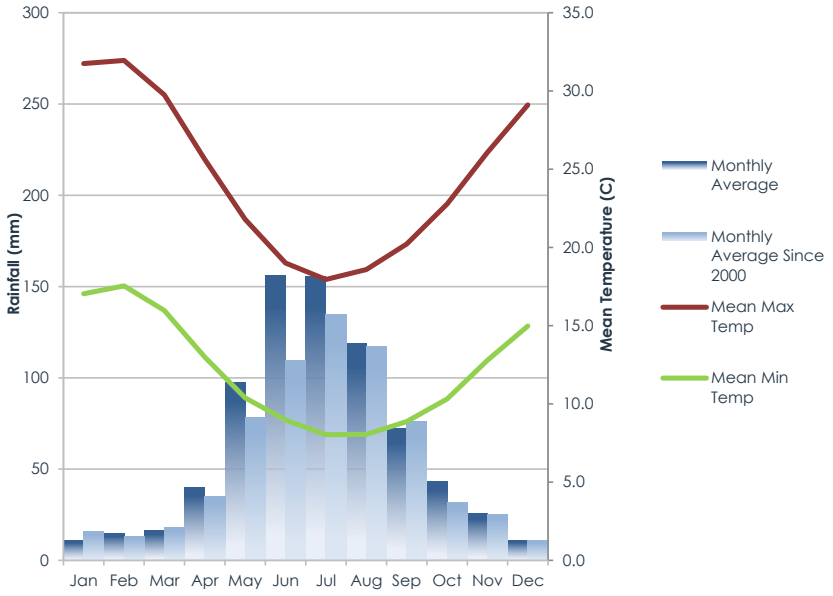


Figure 5: Climate summary data (Perth Airport, BoM, 2020)

4.2 Topography

Elevations with the Study Area range between 41 mAHD and 53 mAHD (Figure 6). The site generally slopes down towards the west, with a local low point within the existing drainage basin in the southwest of the site.

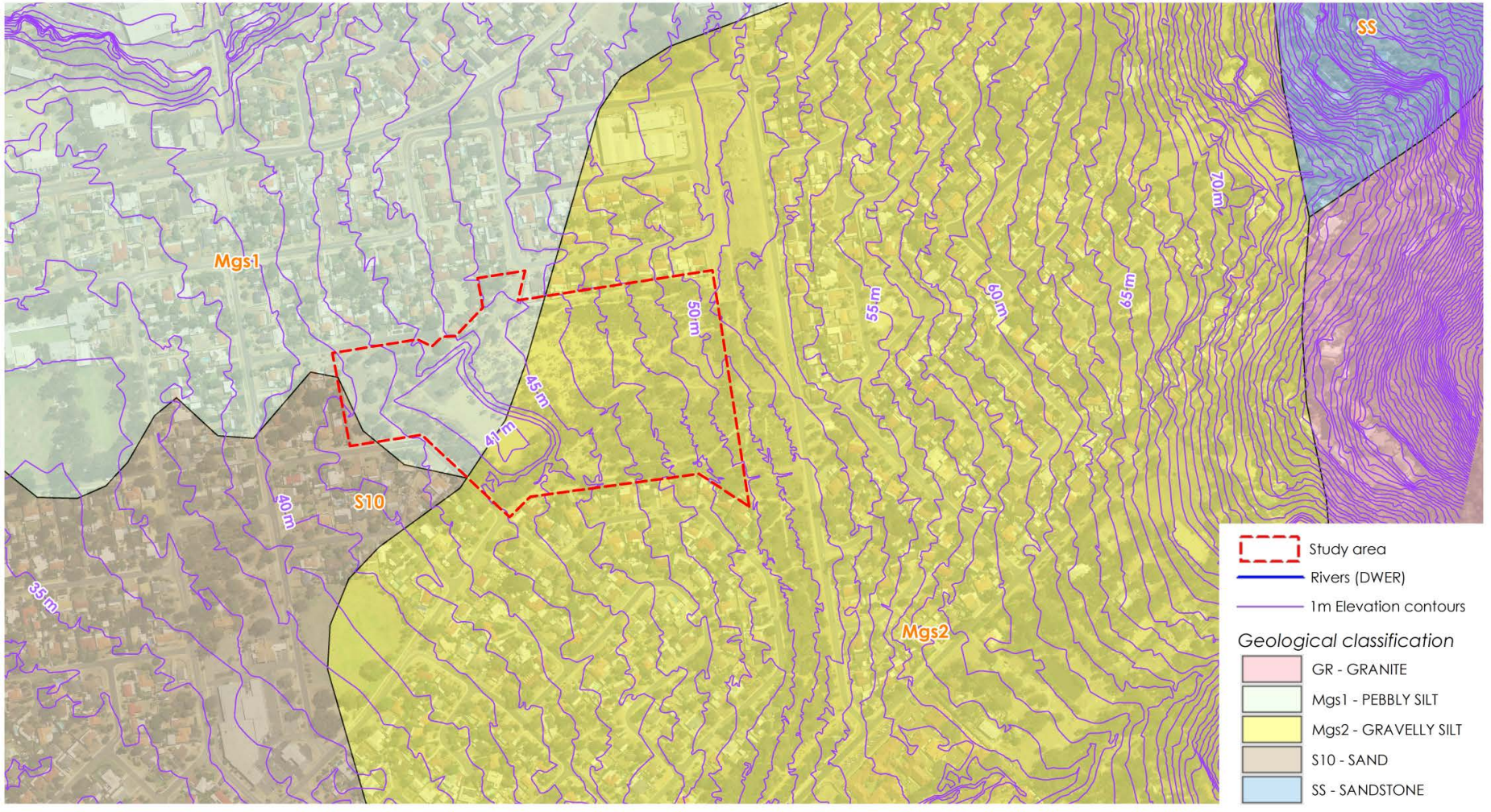
4.3 Geology and soils

Stormwater management is influenced by the soils of the Study Area and their ability to retain and infiltrate runoff.

4.3.1 Surface geology and soils

Regional surface geological mapping indicates that the site is underlain mostly with Pebbly Silt (Mgs1) and Gravelly Silt (Mgs2). A small portion of the study area near York Road is underlain with Sand (S10) (Figure 6). A geotechnical assessment was undertaken by Structerre in January 2020 (Appendix 3). The investigation identified Sandy Clay (within the basin) and Gravelly Sand or Sand across the remainder of the site, though all tests were impenetrable at depths of only 0.7 m. Infiltration across the site (outside of the basin) was generally less than 1.4 m/day, apart from one site (BH10) near the transmission lines which was 4.0 m/day (note that a nearby test at BH7 was 0.7 m/day). All infiltration results are provided in Table 2.

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Figure 6 - Soil and topography



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Table 2: In-situ percolation test results (Structerre, 2020)

Test location	Testing depth	Soil Type	Permeability
BH02	0 – 1.1m	Sandy CLAY	0.5 m/day
BH03	0 – 1.1m	Sandy CLAY	1.3 m/day
BH05	0 – 0.7m	Gravelly SAND	0.6 m/day
BH07	0 – 0.9m	Sandy CLAY	0.8 m/day
BH08	0 – 0.7m	SAND to Gravelly SAND	1.1 m/day
BH09	0 – 0.6m	Gravelly SAND	1.4 m/day
BH10	0 – 0.6m	Gravelly SAND	4.0 m/day

4.3.2 *Acid sulfate soils*

A review of the Department of Water and Environment Regulation Acid Sulfate Soils (ASS) risk mapping (DWER, 2020a) identifies the Study Area as having no known risk of ASS occurring within 3 m of the surface.

4.4 Groundwater resources

Determining the groundwater depth, quality and availability are crucial for forming total cycle water management strategies. These components are outlined below.

4.4.1 *Public Drinking Water Source Area*

There are no Public Drinking Water Source Areas within the Study Area.

4.4.2 *Groundwater allocation*

The Study Area is located within the Shire of Kalamunda Subarea. The Department of Water and Environmental Regulation's Water Register (DWER, 2020b) shows that there is limited groundwater available for allocation from the Superficial Aquifer within the Study Area. An Aquifer Allocation Report was requested from DWER in February 2020 and the details are shown in Table 3. There is currently no existing groundwater Licence within the Study Area.

Table 3: Groundwater resource allocation availability (as of June 2019)

Mgmt Area	Mgmt Sub Area	Allocation Limit	Allocated	Remaining
Perth	Shire of Kalamunda	2,986,500 kL	2,973,752 kL	12,748 kL

4.4.3 *Groundwater levels*

The DWER regional groundwater mapping (DWER, 2020c) indicates that the minimum groundwater level is approximately 17 mAHD (Figure 7). Maximum groundwater levels are anticipated to be within 3 m of minimum levels. The depth to groundwater is therefore at least 20 m across the site. The regional mapping is supported by the geotechnical investigation that did not encounter groundwater (Structerre, 2020). The low infiltration rates also demonstrate that the site is dominated by surface runoff over local recharge.

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Figure 7 - Groundwater Levels



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4.5 Surface water resources

Existing surface water features within and adjacent to the Study Area may require protection from redevelopment or provide opportunities for modification to deliver the community an asset with social and ecological benefits. The surface water features are outlined below.

4.5.1 Natural Water Resources

Within the Study Area there are no natural water bodies. The main feature surface water feature is a large drainage basin constructed in the 1970s that collects drainage from surrounding areas. The performance of this basin is discussed further in Section 4.5.2. Construction of this basin is shown in Figure 8.



Figure 8: Aerial imagery from 1977 (Landgate, 2020)

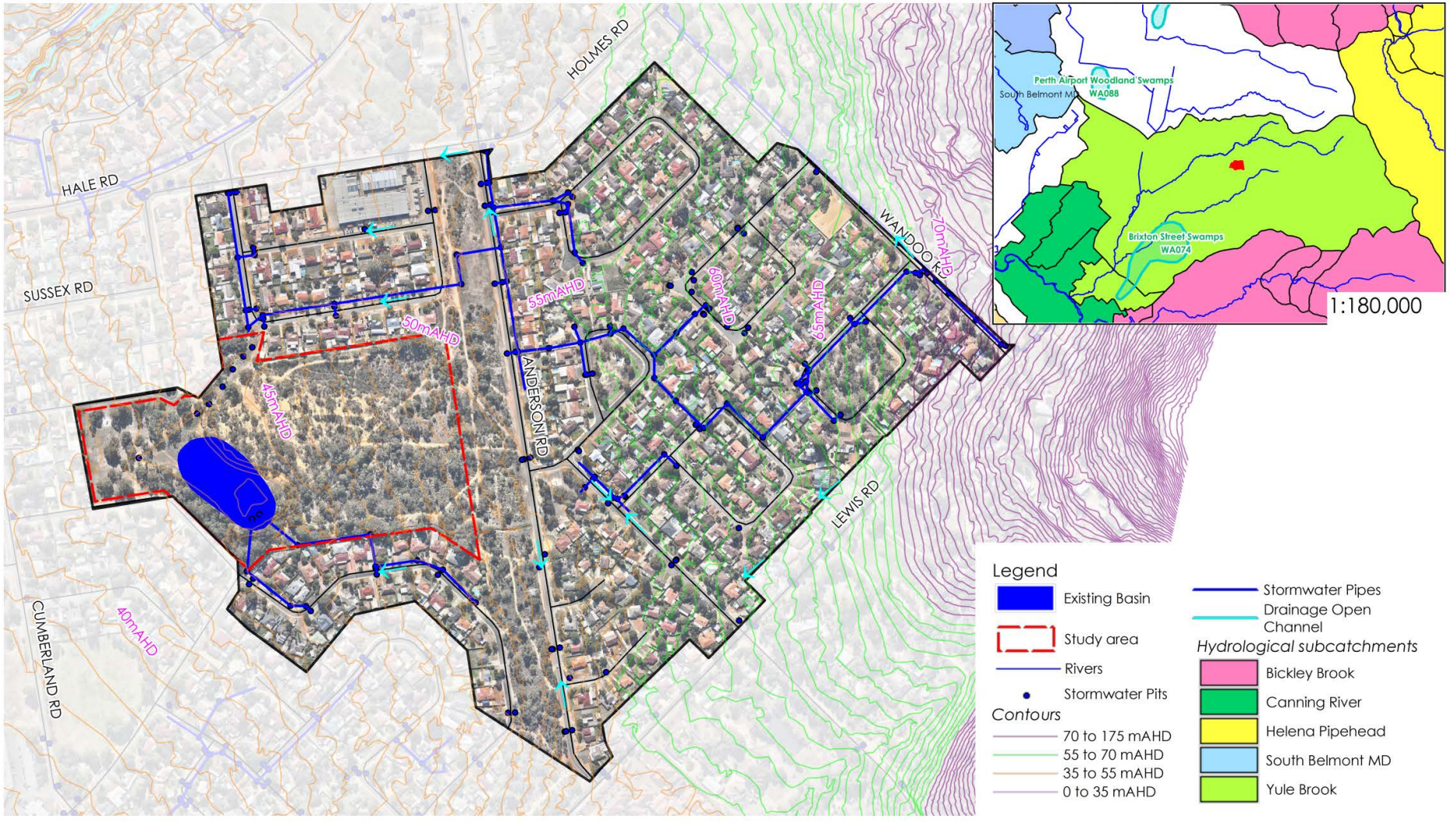
The Study Area is located within the Yule Brook catchment as shown in Figure 9. The site ultimately discharges to Yule Brook to the south.

4.5.2 Existing Drainage

Existing drainage within the Study Area is dominated by the basin that was constructed in the 1970s. Runoff from the surrounding catchment (Figure 9) flows into the basin through a combination of formal and informal pathways. Three formal pipe outlets were noted during field inspections, with rock pitching preventing erosion at some inlets. There is an informal drain along the southern boundary that conveys overland flow into the basin, along with general sheet flow through the site.

The basin sites between 2 and 3 m below the surrounding landscape, with an invert of 41.0 mAHD. Owing to the informal nature of the basin, there is varying side slopes between approximately 1:2 and 1:4, with some areas as flat at 1:8. The basin has minimal vegetation, though surrounding vegetation to west and south has been graded as Very Good (Section 4.6).

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Figure 9 - Surface Water Features



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The basin features a pipe outlet to the downstream stormwater system on York Street as shown in the image below, with a 375 mm pipe connection. The invert of this outlet (based on aerial imagery and elevation data) is assumed to be 41.8 mAHD. The existing surface at 42.2 mAHD provides an overland route (sheetflow) for any additional overflow in the system. Based on LIDAR data, this overflow continues down York Street towards Cumberland Road and ultimately toward Yule Brook.



Figure 10: Basin outlet drawing (City of Kalamunda)

The stage/area dimensions for the basin are provided in Table 4, noting that footprint of the basin is larger than the actual capacity. The original earthworks for the basin have created banks on the eastern edge that are higher than overland flow out levels on the western edge (York Street). As shown in Table 4, the overflow occurs at 42.2 mAHD.

Table 4: Basin stage/area

Stage (mAHD)	Area (ha)	Stage (mAHD)	Area (ha)
41.0	0.015	42.2	1.02
41.2	0.55	42.4*	1.10
41.4	0.74	42.6*	1.24
41.6	0.83	42.8*	1.34
41.8	0.90	43.0*	1.48
42.0	0.96	43.2*	1.60

** Above the overland flow outlet*

In the absence of any design information for the basin, the system was modelled to determine the existing capacity and performance. The assumed runoff rates for the respective land uses are provided in Table 5. As per the Structerre Geotechnical Report (2020), infiltration within the basin was assumed to be 1.0 m/day (measured range of 0.5 m/day and 1.3 m/day).

Table 5: Runoff parameters

Land Use	Initial Loss (mm)	Runoff Rate
Road Reserve	3	80%
Residential Lots	8	50%
Industrial / Commercial Lots	3	70%
Undeveloped / POS	5	25%

In order to determine the requirements for the capacity and performance of the basin, the hydrological and hydraulic model XP-Storm was utilised. The model was run with the latest ARR 2016 IFD to confirm the critical storm durations for the site between 1 hour and 24 hours and determine peak water levels within the basin for larger storm events (10% AEP and 1% AEP). The results of this modelling are provided in Table 6.

Table 6: Existing basin modelling results

AEP Event	Duration	Total Rainfall	Maximum Water Level	Surface flow to York Street
10% AEP	1 hr	28.1 mm	41.78 mAHD	No
10% AEP	3 hrs	42.0 mm	42.03 mAHD	No
10% AEP	6 hrs	54.8 mm	42.16 mAHD	No
10% AEP	**9 hrs**	**64.0 mm**	**42.22 mAHD**	**Yes**
10% AEP	**12 hrs**	**71.2 mm**	**42.21 mAHD**	**Yes**
10% AEP	18 hrs	82.2 mm	42.20 mAHD	No
10% AEP	24 hrs	90.3 mm	42.18 mAHD	No
1% AEP	1 hr	43.0 mm	42.12 mAHD	No
1% AEP	**3 hrs**	**67.1 mm**	**42.40 mAHD**	**Yes**
1% AEP	**6 hrs**	**90.1 mm**	**42.43 mAHD**	**Yes**
1% AEP	**9 hrs**	**106 mm**	**42.45 mAHD**	**Yes**
1% AEP	**12 hrs**	**118 mm**	**42.42 mAHD**	**Yes**
1% AEP	**18 hrs**	**134 mm**	**42.39 mAHD**	**Yes**
1% AEP	**24 hrs**	**145 mm**	**42.38 mAHD**	**Yes**

Results of this assessment demonstrate that the basin in its existing configuration has insufficient capacity for a 1% AEP event given the 10% AEP event (9 and 12 hour duration) discharges via overland flow to York Street. This flow represents a potential risk to existing properties along York Street and development of the site presents an opportunity to improve stormwater management in this area by increasing flood storage.

4.5.3 Wetlands

There are no existing wetland areas mapped within or near the Study Area (DBCA, 2020).

4.6 General Environment and Social

A search of the DWER Contaminated Sites Database (DWER, 2020d) indicates that there are no contaminated sites located within the Study Area.

The existing vegetation on site (Figure 2) was assessed to determine the significant and requirements for protection. PGV Environmental (2019) completed a Flora and Vegetation Assessment to determine the conservation significance of the existing native vegetation to ensure protection during residential development. Two areas of vegetation in excellent condition were noted, and another in very good condition. The remainder of the site was noted as degraded or completely degraded, depending on the presence of native trees or shrubs among weeds or cleared areas. Three Threatened Ecological Communities (TECs) were mapped based on the assessment and are shown in Figure 11.

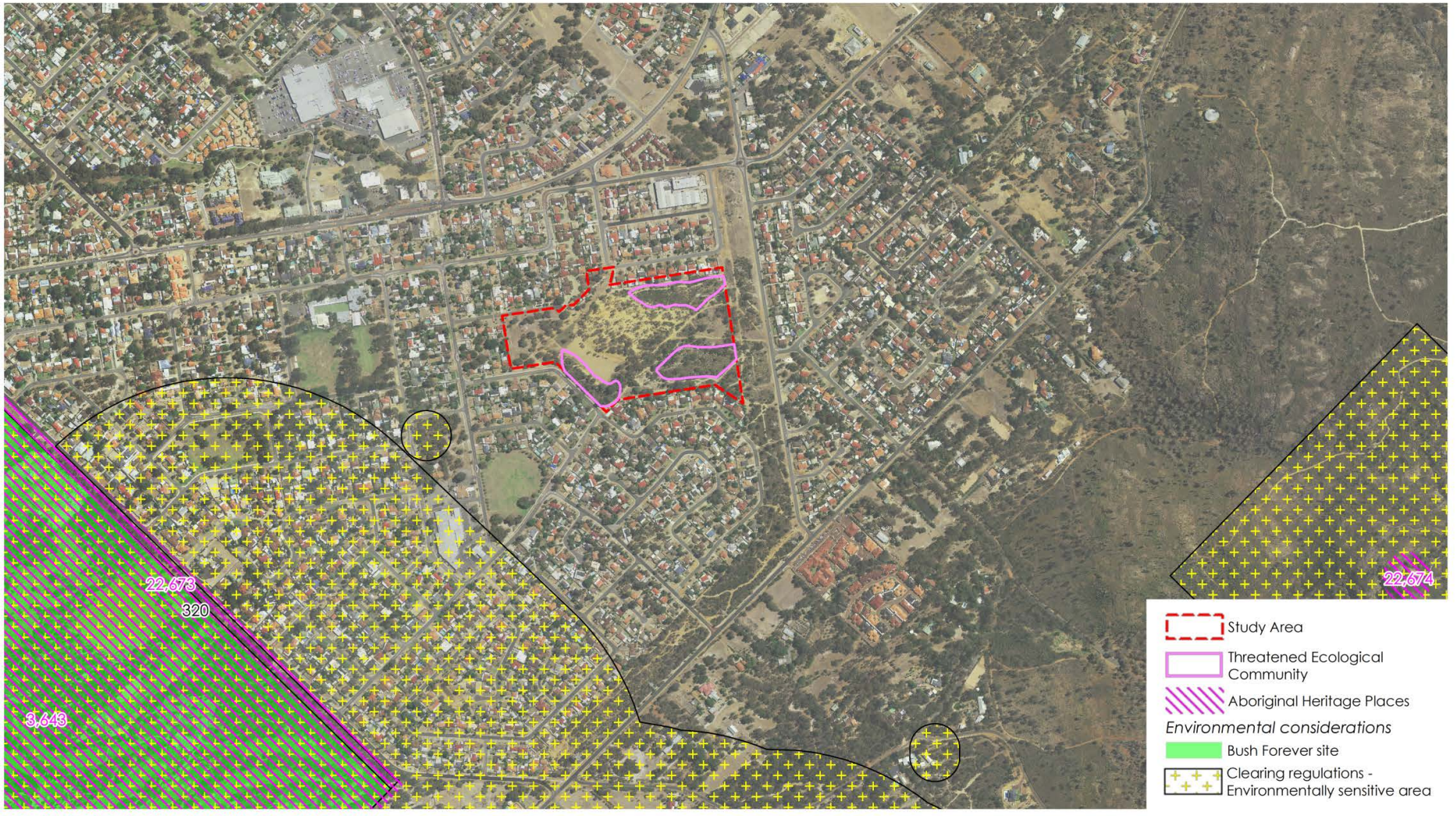
The Aboriginal Heritage Sites database (Department of Aboriginal Affairs) indicates that the Study Area is not a registered heritage site.

4.7 Summary

Based on the review of geological, hydrological and environmental information for the Study Area, the key considerations for water management are as follows:

- Soils feature low permeability and therefore favour surface runoff over infiltration;
- The site features an existing basin constructed in the 1970s to collect runoff from surrounding residential areas;
- Modelling identified that the existing basin overflows to residential streets during a 10% AEP event and additional capacity should be considered to improve flood protection;
- Onsite vegetation assessments identified three TEC areas that require protection during development; and
- Groundwater is deep and is not a significant issue to constrain development.

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Figure 11 - Environmental and Heritage Features



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5 WATER MANAGEMENT STRATEGY

Water management strategies for the Study Area have been prepared in accordance with the guiding documents, policies and strategies (Section1), the development concept (Section 2) and the site considerations (Section 4). Strategies for water sustainability, stormwater, groundwater, and water quality improvement are outlined in this Section.

5.1 Water sustainability initiatives

The key objectives for water sustainability are:

- Ensure the efficient use of all water resources in the redeveloped urban form and aim to achieve highest value use of fit-for-purpose water; and
- Maintain opportunities for future generations by using water more efficiently.

5.1.1 Water supply

The Study Area is located in an area served by the Water Corporation's integrated water supply scheme. Potable water will be supplied to the proposed development as an extension of the existing infrastructure.

The total POS area that will be irrigated (area surrounding the playground and minor basin portion of the drainage system described in Section 5.3.2) is 0.5 ha which requires a total water of 3,750 kL/yr for irrigation, based on the DWER standard irrigation rate of 7,500 kL/ha/yr for POS. A portion of the City's existing licence allocation will be used to irrigate this area.

5.1.2 Wastewater treatment and disposal

The Study Area is located in an area served by the Water Corporation's integrated sewerage scheme and will be connected to a reticulated sewerage network.

5.1.3 Water conservation and efficiency measures

To reduce the consumption of scheme water newly constructed houses will be recommended to meet the Water Corporation's Waterwise homes and gardens criteria. That is:

- All showerheads installed will be better than the minimum WELS 3 Star rating;
- All taps installed will be better than the minimum WELS 4 Star rating;
- All toilets will be duel flush and exceed the minimum WELS 4 Star rating; and
- All water using appliances installed are rated WELS 4 Star or above.

Landscaping of public open space will contribute to water efficiency by using waterwise native plantings outside of playing fields. Water sensitive irrigation designs will be applied throughout all POS areas.

5.2 Groundwater management

The key objectives for groundwater management are:

- Protecting infrastructure and assets from flooding and inundation by high seasonal groundwater levels, perching and/or soil moisture; and,
- Protecting groundwater dependent ecosystems from the impacts of urban runoff

The following planning measures are adopted to achieve the above objectives:

- Use of bio-retention areas within raingardens, tree pits and swales to improve runoff quality compared with the existing conditions.

The clearance between the existing surface and groundwater across the Study Area is estimated to be at least 20 m (Section 4.4.3). Direct management of groundwater, including importation of fill or installation of subsoil drainage is therefore not required. Any fill imported on site should be clean, free draining sand, consistent with the geotechnical recommendations (Appendix 3).

Localised subsoil drainage for retaining walls and roads will be considered during the construction phase. Areas of shallow or perched groundwater are not anticipated however subsoil drainage may be required to alleviate any problematic soil moisture. Where these conditions are identified short length subsoil drains will be installed. To be cost effective and free draining, these drains will be connected to the nearest road drainage system, with water quality treatment provided downstream.

5.3 Stormwater management

The key objectives for surface water management are:

- Protection of the receiving environments from the impacts of urban runoff; and,
- Protection of infrastructure and assets from flooding and inundation.

The following planning measures are adopted to achieve the above objectives:

- Residential habitable floor levels in proposed areas must have their floor levels elevated 300 mm above the 1% AEP flood level in the local drainage system and 500 mm above the 1% AEP flood level in basins/sumps (where there is no overflow relief) (DWER, 2017);
- Runoff from up to the 20% AEP (approx. 5 yr ARI) event in residential lots are to be managed in accordance with the serviceability requirements of the *Decision Process for Stormwater Management in WA* (DWER, 2017) minor/major system;
- The design of the urban areas will incorporate current best practice in water-sensitive urban design to mitigate the potential impacts on regional water quantity and quality from development within the catchment;
- Manage the first 15mm of rainfall through retention/detention and treatment within the Study Area boundaries; and,
- Modification of the existing local drainage systems to suit the urban form; and,

The post-development stormwater system includes basins, swales and easements to manage runoff onsite. These features account for site constraints including the location of TECs and existing infrastructure. Further detail on the sizing and location of the respective components is provided in the following Sections.

Small event management

The development will retain the first 15 mm of rainfall on-site within lots and streets. Residential lots will be required to install soakwells with grated lids within the front setback, which will be graded to allow for runoff into the street when the capacity of soakwells is exceeded. The use of soakwells is dependent on final earthwork and geotechnical assessment as the existing geotechnical report suggests soakwells are not suitable (in current condition) (Structerre, 2020). Should soakwells be deemed unsuitable during further design, direct lot connections may be provided for residential lots. This approach does not impact on water levels in the basin system during larger storm events.

Road reserves will provide for on-site retention through roadside raingardens, tree-pits and swales. These systems (e.g. see Figure 12 and Figure 13) will be installed with at least 0.5 m of amended soil. The soil profile will be in accordance with Adoption Guidelines for Stormwater Bio-filtration (CRC, 2015). These systems are expected to provide treatment and infiltration of the first 15 mm of rainfall. Planting of these raingardens will meet the soil profiles, noting that ongoing irrigation is unlikely. Preferably trees will be installed to prevent urban heating impacts.

Smaller roadside swales may be installed to connect road reserves with the larger flood storage system to provide water quality treatment and conveyance. The potential locations are shown in Figure 14.

Within the Aged Care retention of runoff within lots will be achieved through a combination of raingardens, water tanks or soakwell systems. Rainfall captured from roof areas is suitable for non-potable reuse in-house (toilets, laundry) and ex-house (garden areas), and will assist in future achieving the water sustainability objectives. The suitability of a roof runoff capture and reuse system (tank) will be determined during detailed design of each building. Where these systems are not viable, roof runoff will be captured and infiltrated in underground infiltration systems (soakwells) within the lot boundaries. These types of systems will be at the discretion of the owner to design, install and manage.

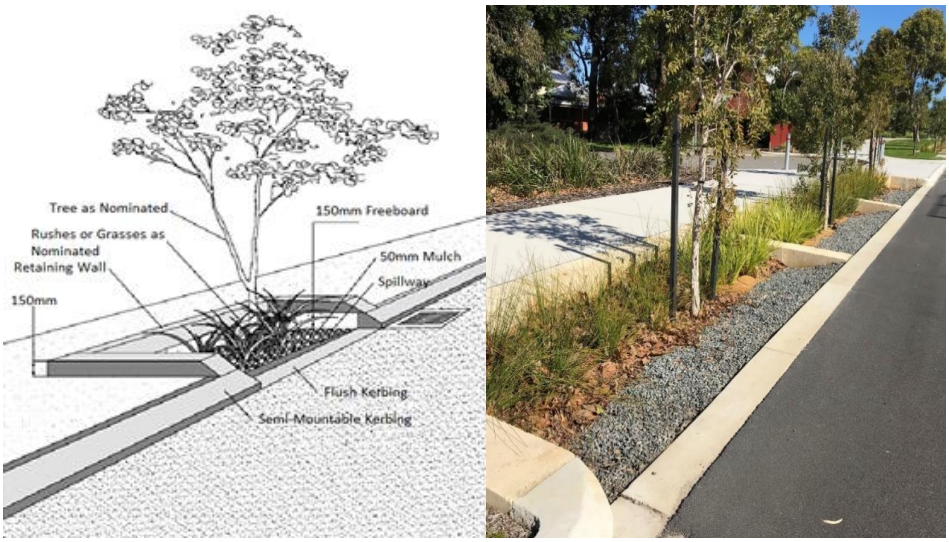


Figure 12: Typical roadside tree pit or raingarden

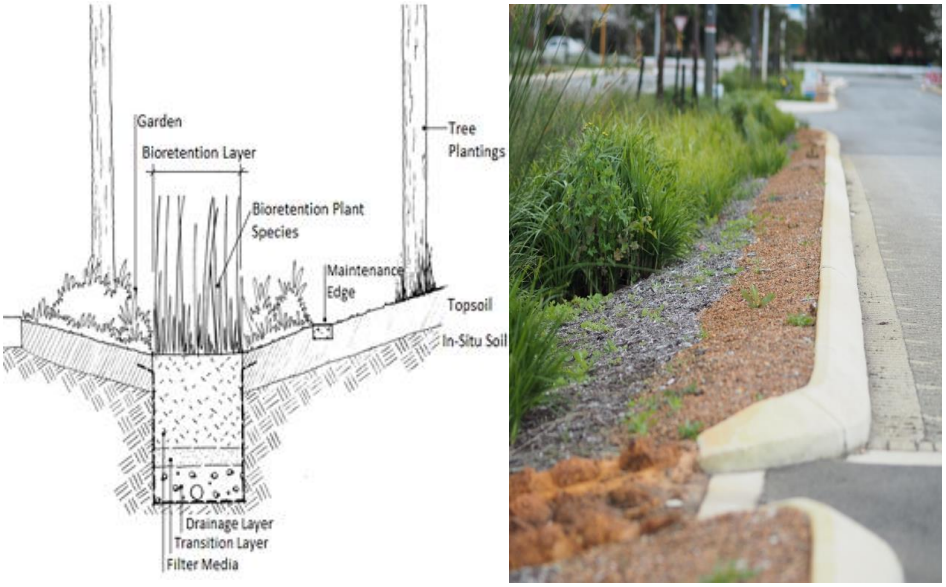


Figure 13: Typical roadside swale

5.3.1 Minor event management

Runoff from up to the 20% AEP (~5yr ARI) event which is in excess of the capacity of on-site retention systems will be conveyed through a combination of piped drainage and swales into POS and drainage areas to provide an acceptable standard of amenity in roads and to properties. Surface conveyance will be used wherever possible, though piped drainage will be required to ensure the continuity of existing piped systems that discharge to the basin (Figure 14 and Figure 15).

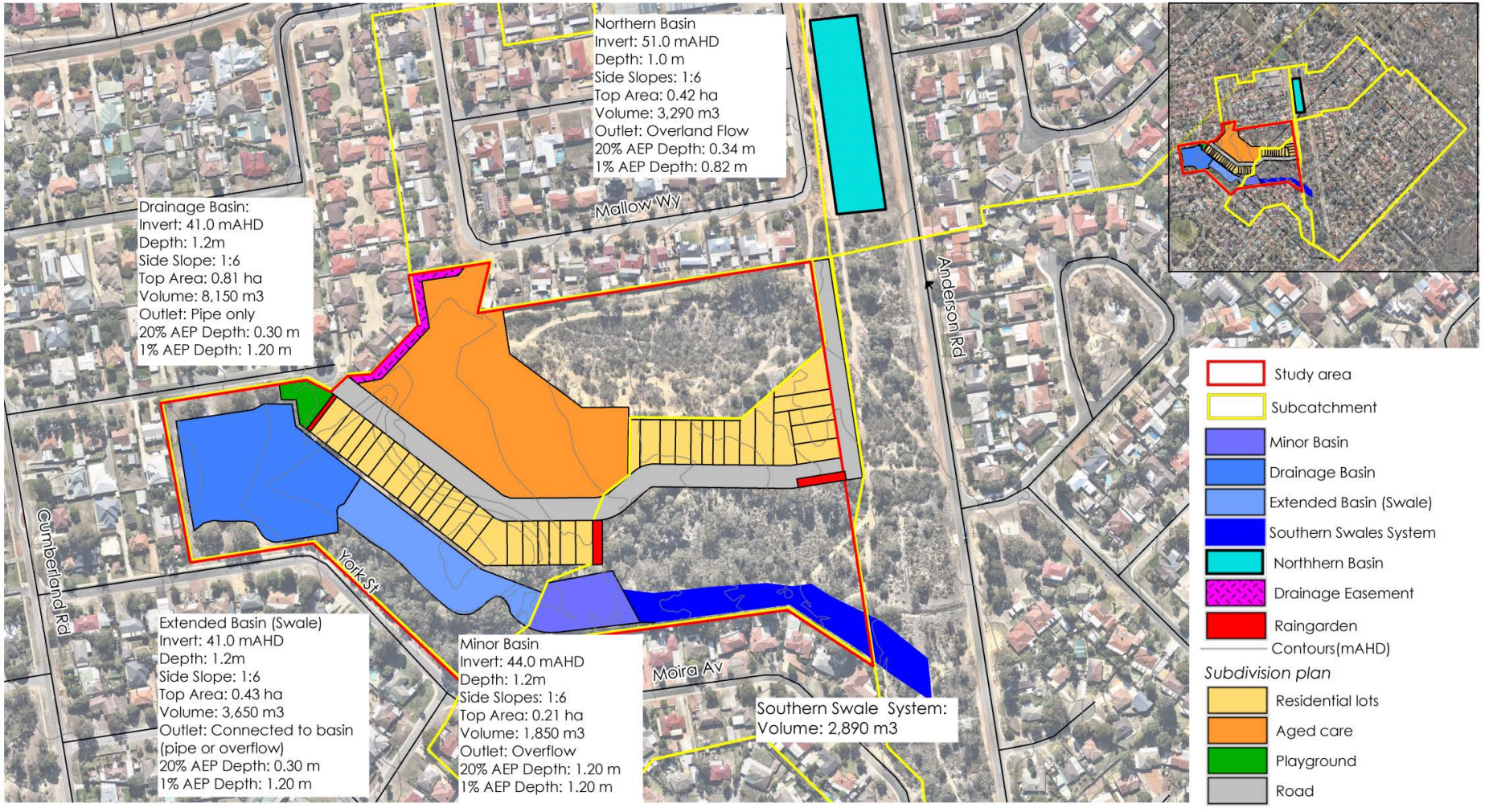
5.3.2 Major event management

Major flood runoff (1% AEP) will be conveyed via overland flow within the Study Area prior to discharge to drainage areas throughout the development.

As outlined in Section 4.5.2, the site features a large basin that was constructed in the 1970s and manages major rainfall events for the Study Area and surrounding catchment. Modelling indicates that the existing basin overtops to York Street during a 10% AEP event. Discussions with the City of Kalamunda determined that discharge from the basin during a 1% AEP should be limited to flow through the existing 375 mm pipe connection to York Street. This approach provides improved flood protection to downstream properties.

Having determined that the existing basin has insufficient capacity without the additional residential development, options were considered to provide additional storage. These options are summarised in Table 7 and discussed in further detail in Appendix 4.

City of Kalamunda - Cambridge Reserve Local Water Management Strategy
Figure 14 - Stormwater Management System Layout

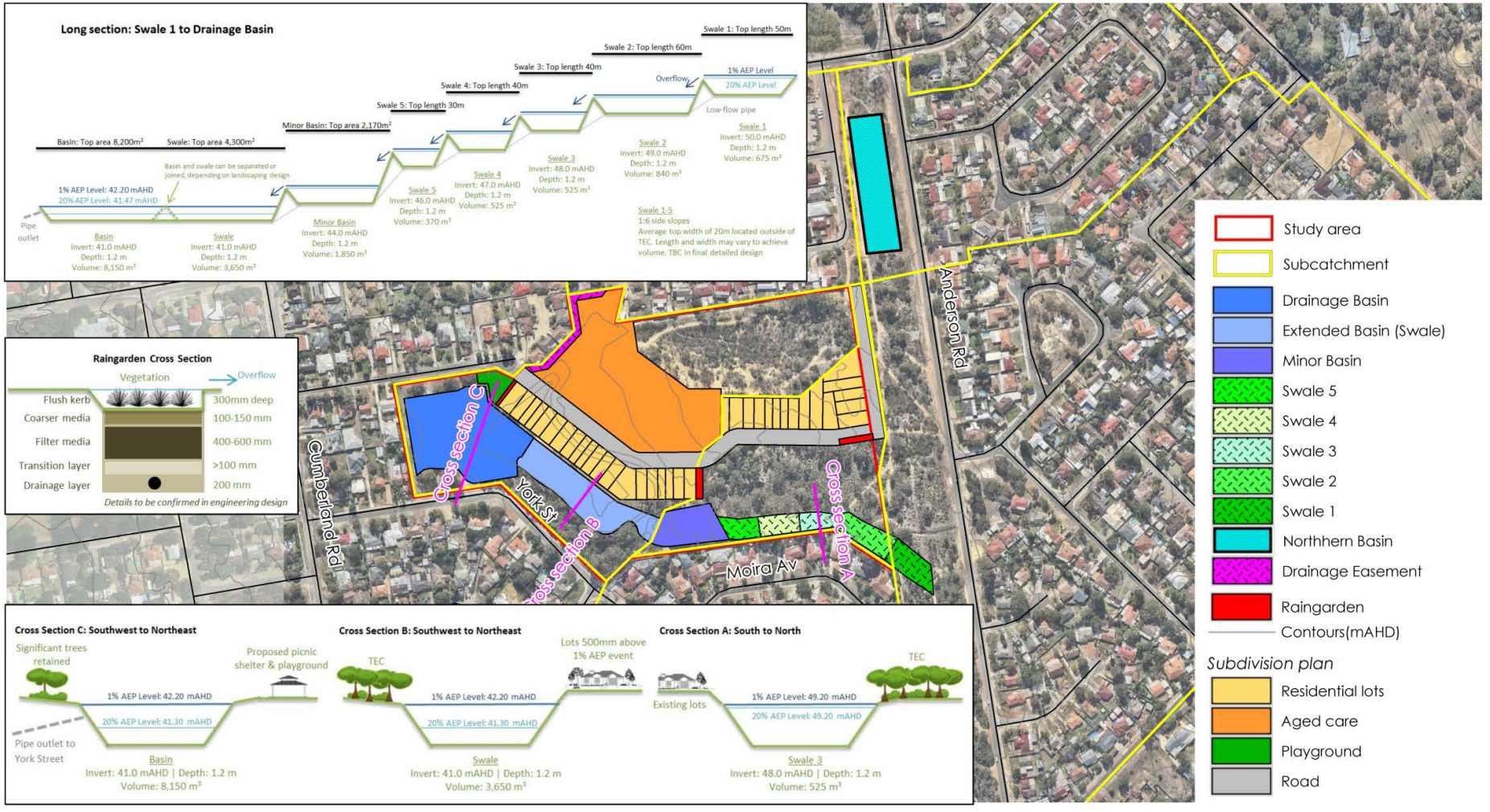


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Figure 15 - Stormwater Management System Sections



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Table 7: Basin configuration options

Option	Description	Comment
A	Additional basin northeast within the transmission easement	The intent of this basin is to capture runoff from east of Anderson Road. They would be located beneath the high voltage lines, requiring approval from Western Power
B	Additional basin southeast within the transmission easement	
C	Increased basin size	Within the current location, widen the basin to increase the volume to meet the requirements
D	Bunds	Install 200 – 300 mm bunds around the basin to restrict runoff to York Street, designed with earthworks suitable for small scale dams
E	Basin relocation	Relocate the basin elsewhere in the site to provide sufficient volume

Each option presented limitations to achieve the design objective. Expansion of the current basin in the existing location and installation of bunds is difficult owing to the presence of the TEC to the south, and developable land to the north. Similarly relocation of the basin was limited by the desire to retain significant trees onsite. The additional upstream basin in the southeast is not possible due to existing vegetation whereas the northeast basin can be installed but provides limited benefit owing to the portion of the catchment that drains to it.

The configuration adopted for the post-development site is a combination of the viable options outlined above including;

- Relocation of the main basin further west, but shaped to avoid significant trees;
- Retention of a portion of the existing basin;
- Expansion of the southern drain to provide online storage; and,
- Inclusion of the northwest basin within the transmission easement.

The alignment and location of these features are provided in Figure 14.

Main Basin

The majority of the flood storage is provided in the swale and basin system along the southern and eastern portions of the sites. The basin is relocated to the western portion of the site which is relatively flat and away from TECs on site. The shape of the basin is limited by the retention of significant trees near York Street and Cambridge Road. The area available for a basin with 1:6 side slopes and 1.2 m depth is insufficient alone for the 1% AEP event, however additional volume is attained by retaining a portion of the existing basin. This feature is labelled as a swale in Figure 14 as it conveys flows from upstream and will be modified to feature 1:6 side slopes and 1.2 m depth. These systems have been considered as separate structures (connected via culverts) though practically they could be combined in further design.

These features were sized (along with the southern swale and northeast basin) using XP-Storm, applying the same parameters outlined in Section 4.5.2 and accounting for the proposed development within the site. The respective volumes and areas for these systems and modelling results are provided in Table 8.

Table 8: 1% AEP basin flood levels

Parameters	Basin	Swale
Side Slopes	1:6	1:6
Base Elevation	41.0 mAHD	41.0 mAHD
Base Area	0.56 ha	0.18 ha
Top Area	0.82 ha	0.43 ha
Total Volume	8,150 m^3	3,650 m^3
Total Depth	1.2 m	1.2 m
20% AEP Event Depth	0.30 m	0.30 m
20% AEP Event Area	0.62 ha	0.24 ha
20% AEP Event Volume	1,760 m^3	600 m^3
20% Emptying Time (24 hr duration)	31 hrs	31 hrs
1% AEP Event Depth	1.2 m	1.2 m
1% AEP Event Area	0.82 ha	0.43 m^2
1% AEP Event Volume	8,150 m^3	3,650 m^3
Critical Duration	12 hrs	12 hrs
1% Emptying Time (48 hr duration)	54 hrs	54 hrs

The modelling results demonstrate that the 1% AEP event can be detained on site within the proposed configuration. Similarly, the minimum habitable floor level within the adjoining residential lots will be at least 42.7 mAHD, providing 500 mm of clearance above the 1% AEP flood levels. To ensure protection of existing lots on York Street and Cambridge Road in extreme events, an overflow for the basin to either road is recommended. The location and the design of this overflow will be confirmed during detail engineering design.

Southern Swale

The swale is a modification of the existing drain along the southern boundary to provide improved flood storage and amenity. This portion of the site is steeper than the main basin location, so flood storage is achieved by creating a series of cascading basins. These basins fill and overtop to the next component of the system. These basins are generally a maximum of 20 m wide (to fit within the corridor between the site boundary and southern TEC), 1.2 m deep and 1:6 side slopes for safety considerations. To prevent standing water, a small low-flow pipe may also be installed to connect the basin downstream. Planting of this system will also improve amenity and water quality treatment compared with the existing eroded drain.

The final basin within this configuration is labelled as "minor basin" in Figure 14. This area is utilised to increase storage in land that would be difficult to incorporate into the development layout and also provides the opportunity for alternative landscaping design compared with the remainder of the system. It is not intended to contain permanent water due to safety and mosquito risks.

Table 9: 1% AEP swale flood levels

Parameters	1	2	3	4	5	Minor Basin
Invert	50.0 mAHD	49.0 mAHD	48.0 mAHD	47.0 mAHD	46.0 mAHD	44.0 mAHD
Side Slopes	1:6	1:6	1:6	1:6	1:6	1:6
Base Width	5.6 m	5.6 m	5.6 m	5.6 m	5.6 m	-
Base Area	200 m^2	255 m^2	140 m^2	140 m^2	90 m^2	970 m^2
Top Area	1,000 m^2	1,200 m^2	800 m^2	800 m^2	600 m^2	2,170 m^2
Total Volume	675 m^3	840 m^3	525 m^3	525 m^3	370 m^3	1,850 m^3
Total Depth	1.2 m	1.2 m	1.2 m	1.2 m	1.2 m	1.2 m
20% AEP Event Depth	1.2 m	1.2 m	1.2 m	1.2 m	1.2 m	1.2 m
1% AEP Event Depth	1.2 m	1.2 m	1.2 m	1.2 m	1.2 m	1.2 m

Northeast Basin

The proposed basin northeast of the Study Area is shown in Figure 14. The aim of this basin is to intercept drainage from established residential areas east of the Anderson Road that would otherwise flow into the main basin. The proposed basin has sufficient capacity to retain and infiltrate up to the 1% AEP event in the proposed configuration. The placement of the basin within the transmission easement will require agreement with Western Power, though it is understood that this has been agreed for other residential developments within the City of Kalamunda. The dimensions of the basin are provided in Table 10.

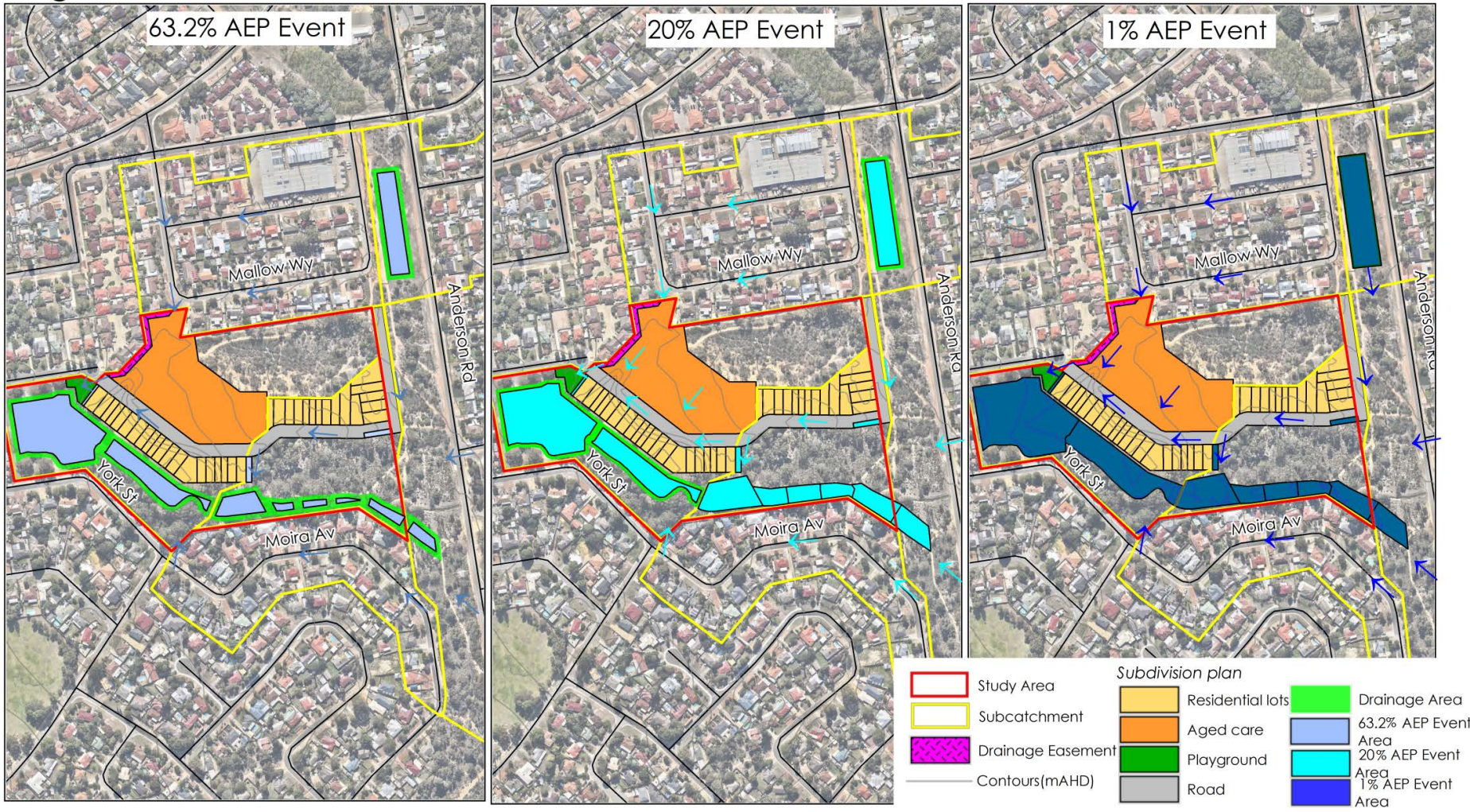
Table 10: Northeast basin details

Invert	Depth	Base Area	Top Area	Side Slopes	Total Volume	20% AEP Depth	20% AEP Volume	20% AEP Depth	1 % AEP Volume
51.0 mAHD	1.0 m	0.24 ha	0.42 ha	1:6	3,290 m^3	0.34 m	915 m^3	0.82 m	2,560 m^3

Easement

In order for this system to function correctly within the proposed site layout, drainage easements are required to connect drainage from Mallow Way (north of the site) through the Aged Care Site. A combination of pit/pipe drainage (modification of the existing pipework) and overland flow path is required to ensure drainage can reach the basin system. A potential easement location is shown in Figure 14, though internal roads within the Aged Care Site are a suitable alternative and could be determined during detailed design. Flow paths for the drainage system are provided in Figure 16.

City of Kalamunda - Cambridge Reserve Local Water Management Strategy
Figure 16 - Stormwater Event Plan



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Data source: MRWA, Landgate. Created by: YY. Projection: MGA: zone 50.

0 500
meters
Scale 1:6,000@A4

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5.4 Water quality management

Site specific targets have been proposed for estuarine catchments of the Swan Coastal Plain as a part of background work undertaken by DWER during the development of the UNDO water quality modelling tool. The targets were developed based on consideration of the sensitivity of the receiving water body and the proximity of the development site. Applying this approach, the Study Area would lie outside the suggested 'proximity zones' of the estuarine portion (>1000 m). This would indicate that the following targets could be applied:

- 3.6 kg/ hectare / year of Nitrogen
- 0.2 kg/ hectare / year of Phosphorous

UNDO (Urban Nutrient Decision Outcomes) is a simple empirical decision support model with a flexible framework that evaluates nutrient reduction decisions for new urban developments on the Swan Coastal Plain. It has been developed by the Department of Water to provide urban development proponents with an easy to use tool for assessment by local and state government authorities.

An UNDO model has been developed for the Study Area and was run for existing conditions and the proposed development scenario. For both scenarios, the Study Area is assumed to be located within the Forrestfield area with over 20 m clearance to groundwater.

Results of UNDO modelling, in the form of a report which is generated by the software containing details of all assumptions and inputs, are provided in Appendix 5 (existing conditions) and Appendix 6 (proposed development). The outcomes of UNDO modelling indicate that on-site retention of the frequent rainfall event within raingardens and soakwells on lots will provide discharge loads of:

- 3.93 kg/ hectare / year of total nitrogen
- 0.01 kg/ hectare / year of total phosphorous

These loads are well within the recommended targets for developments within the Swan Coastal Plain that have been prepared for a discussion paper in support of the UNDO modelling tool by the Department of Water and Environmental Regulation.

5.5 Management of disease vectors and nuisance insects

The construction of above ground water quality treatment systems (raingardens and roadside swales) is proposed within the Study Area. These systems will drain by infiltration through sandy soil with relatively high infiltration rate which minimise standing water times.

Standing water was observed within the sump on Cristata Terrace and has the potential for mosquitoes and midges to breed. As part of upgrades for this sump, the base on the sump will be raised and fine sediment removed to improve infiltration performance and prevent standing water for mosquito breeding.

Physical, chemical and biological control methods can be used to manage mosquito populations. Methods which may to be employed (and their order of priority) include:

- Improving water quality, minimising nutrient loads and thereby reducing potential for algal blooms and fish kills; and,
- Should Mosquitos and Chironomid Midges become a nuisance, pesticides (larvicides and/or adulticides) will be used as required to kill mosquito larvae in breeding sites.

6 IMPLEMENTATION

The success of the water management strategies outlined in this document depends on their implementation through further planning, detailed design, construction and maintenance.

6.1 Urban Water Management Plans

Urban Water Management Plans (UWMPs) are the final water management documents within the state government planning framework outlined in Section 1.1. These documents are prepared as a condition of the subdivision (in support of local development plans) to demonstrate that designs achieve the objectives, strategies and design criteria outlined in this LWMS. Specifically, UWMPs include detailed engineering and landscaping designs and design of bio-retention systems and non-structural controls measures to manage impacts from construction.

UWMPs are assessed and approved by Local Governments under the BUWM framework. As the proponent is the City of Kalamunda in this instance, preparation of an UWMP is considered unnecessary. Detailed design of stormwater infrastructure and associated landscaping will be overseen by the City during preparation, with corresponding documentation. The LWMS is considered sufficient to guide the respective design for this site.

6.2 Monitoring

Pre and post-development monitoring is discussed below.

6.2.1 Pre-development monitoring

It is considered that there is no value in groundwater level monitoring prior to construction. Monitoring data is collected as part of further geotechnical investigation is considered sufficient to characterise the groundwater characteristics.

6.2.2 Post-development monitoring

Similarly owing to the depth to groundwater pre- and post-development, groundwater monitoring following development is not considered necessary. As demonstrated above, water quality treatment will occur throughout the development in the form or raingardens and swales.

6.3 Dieback Management

A Dieback Management Plan should be prepared during the subdivision stage. This document should consider drainage infrastructure construction and planting, with measures introduced to limit spread, including construction during dry conditions to control water movement, limiting access to areas of the site, and undertaking appropriate vehicle washdowns.

6.4 Construction

Construction activities have the potential to directly and indirectly impact local water resources and water management measures are required.

6.4.1 *Licencing*

Water will be required for construction activities such as dust suppression. Water for construction purposes could be sourced from groundwater allocation sought in Section 5.1.1

6.4.2 *Construction Management*

To ensure downstream waterways are protected, developers, builders and landscapers must implement best management practices to control erosion and sedimentation. Contractors and staff should be notified of specific construction management requirements including appropriate disposal of waste material, erosion control and dust suppression.

6.5 Roles and responsibilities

Key tasks, roles and responsibilities relating to delivery of urban water management objectives are outlined in Table 11.

Table 11: Summary of roles and responsibilities

Task	Responsibility	Planning stage
Potable water supply planning and connection to main distribution network	Water Corporation	Subdivision
Design of wastewater reticulation networks	City of Kalamunda	Subdivision
Design of drainage networks including design of water quality treatment areas	City of Kalamunda	Subdivision
Development of detailed Landscaping plan incorporating stormwater management strategies	City of Kalamunda	Subdivision
Preparation of a Dieback Management Plan	City of Kalamunda	Subdivision
Confirmation of ongoing management and maintenance requirements	City of Kalamunda	Subdivision

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APPENDIX 1 – LWMS CHECKLIST

Local water management strategy Item	Deliverable	☑	Comments
Executive summary			
Summary of the development design strategy, outlining how the design objectives are proposed to be met	Table 1: Design elements & requirements for BMPs and critical control points	☑	
Introduction			
Total water cycle management – principles & objectives Planning background Previous studies		☑	
Proposed development			
Structure plan, zoning and land use. Key landscape features Previous land use	Site context plan Structure plan	☑ ☑	
Landscape – proposed POS areas, POS credits, water source, bore(s), lake details (if applicable)	Landscape Plan	☑	
Design criteria			
Agreed design objectives		☑	
Pre-development environment			
Existing information and more detailed assessments (monitoring). How do the site characteristics affect the design?		☑	
Site Conditions – existing topography/ contours, aerial photo underlay, major physical features	Site condition plan	☑	
Geotechnical – topography, soils including acid sulphate soils and infiltration capacity, test pit locations	Geotechnical plan	☑	
Environmental – areas of significant vegetation, wetlands and buffers, waterways and buffers, contaminated sites	Environmental Plan plus supporting data where appropriate	☑	
Surface Water – topography, 100 year floodways and flood fringe areas, water quality of flows entering and leaving (if applicable)	Surface Water Plan	☑	
Groundwater – topography, pre development groundwater levels and water quality, test bore locations	Groundwater Plan plus details of groundwater monitoring and testing	☑	
Water sustainability initiatives			
Water supply & efficiency measures – private and public open spaces		☑	
Fit-for-purpose strategy and agreed actions. If non-potable supply, support with water balance		☑	
Wastewater management		☑	
Stormwater management strategy			
Flood protection – peak flow rates, volumes and top water levels at control points,100 year flow paths and100 year detentions storage areas	major event Plan Long section of critical points	☑	
Manage serviceability – storage and retention required for the critical 5 year ARI storm events Minor roads should be passable in the 5 year ARI event	minor event Plan	☑	

Local water management strategy Item	Deliverable	☑	Comments
Protect ecology – detention areas for the 1 yr 1 hr ARI event, areas for water quality treatment and types of (including indicative locations for) agreed structural and non-structural best management practices and treatment trains. Protection of waterways, wetlands (and their buffers), remnant vegetation and ecological linkages	small event Plan Typical cross sections	☑	
Groundwater management strategy			
Post development groundwater levels and fill requirements (including existing and likely final surface levels), outlet controls, and any subsoils	Groundwater/subsoil Plan	☑	
Actions to address acid sulfate soils or contamination		☑	
The next stage – subdivision and urban water management plans			
Content and coverage of future urban water management plans to be completed at subdivision. Include areas where further investigations are required prior to detailed design.		☑	
Monitoring			
Recommended future monitoring plan including timing, frequency, locations and parameters, together with arrangements for ongoing actions		☑	
Implementation			
Developer commitments		☑	
Roles, responsibilities, funding for implementation		☑	
Review		☑	

APPENDIX 2 – CONCEPT PLAN



- SUBJECT SITE (8.97ha)
- RESIDENTIAL LOTS 7.5m FRONTAGE
- RESIDENTIAL LOTS 10.5m FRONTAGE
- RESIDENTIAL LOTS 12.5M frontage
- AGED CARE
- TEC (TO BE REHABILITATED & REVEGETATED)
- TEC BUFFER (20m)
- EXISTING DRAINAGE BASIN EXTENTS
- PROPOSED DRAINAGE ARRANGEMENT (17761m²)
- OPEN SPACE
- PAW (8m)
- INDICATIVE PLAYGROUND LOCATION
- ROAD CONNECTION (1890m²)

LOT SUMMARY	
Number of Lots	42
Total Area of Lots	14510m²
Average Area of Lots	345m²
Minimum Lot Area	225m²
Maximum Lot Area	642m²

Note:

- Lot summary excludes Aged Care

URBIS

Concept Plan

Cambridge Reserve

Level 14, The Quadrant, 1 William Street | Perth WA 6000 Australia | +61 8 9346 0500 | URBIS Pty Ltd | ABN 50 105 256 228

DATA SOURCE
Landgate

PROJECTION
MGA Zone 50

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CLIENT
City Of Kalamunda

1:2,000 @ A3
0 10 20 30 40 50m

PROJECT NO.
P0011135

DATE
27.05.2020

DRAWING NO.
01

REVISION
D

APPENDIX 3 – GEOTECHNICAL ASSESSMENT DARCH (STRUCTERRE, 2020)

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Doc GE2.2.1

GEOTECHNICAL INVESTIGATION

For: City of Kalamunda

Project Address: Cambridge Reserve - Cambridge Road, Forrestfield

Project Number: D230816

Job Number: J339742

Revision Number: 0

Date: 7/2/2020

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1. PROJECT DETAILS

1.1. Introduction

At the request of Stephanie Brokenshire of City of Kalamunda, Structerre Consulting (Structerre) have conducted a Geotechnical Investigation at Cambridge Reserve - Cambridge Road, Forrestfield. The purpose of the investigation was to provide the following:

- Desk top study including a summary of geology, groundwater, site history (obtained from historical photographs) and potential presence of Acid Sulfate Soils (ASS);
- Summary of encountered ground and groundwater conditions;
- Site Classification in accordance with AS2870;
- Earthquake site factor in accordance with AS1170.4;
- Recommendations for stormwater drainage design;
- Site preparation requirements (earthworks), including site traffic, excavation, reuse of materials and batter slopes; and
- Preliminary pavement design parameter, indicative California Bearing Ratio (CBR) values determined from penetrometer results and ground conditions encountered.

This report details the scope of the geotechnical investigation, presents an interpretation of ground conditions and material properties across the site, provides geotechnical design parameters for the design of the proposed infrastructure, and evaluates the suitability of materials for use in earthworks. Interpretation of site conditions is based on the subsurface lithology revealed during the investigation programme, visual assessments of the in-situ materials and the results of in situ field tests.

Terms of reference for this investigation were presented in a Structerre Consulting proposal reference Q83690 (dated 20 December 2019), which was submitted to and accepted by City of Kalamunda.

1.2. Site Description & Proposed Development

The site is located at Cambridge Reserve - Cambridge Road, Forrestfield, City of Kalamunda. Cambridge Road lies to the northwest of the site, York Street to the southwest, with Anderson Road to the east and residential properties to the north and south.

The site is slopes up towards the eastern boundary. At the time of the field investigation, the site was covered in vegetation with small to medium sized trees.

We understand that the site is to be used for the construction of a mixture of residential development, public open space (feature parks) and reserve vegetation areas.

1.3. Field Investigation – Scope of Works

The field investigation was carried out on 14 January and 7 February 2020 and comprised:

- 10 x Sample Retrieval Probe boreholes to a depth of 1.1m (refusal) over the site for material assessment and soil profiling;
- 7 x In-situ percolation tests to determine the permeability of the materials within the upper 1.0m; and
- 9 x Dynamic Cone Penetrometer (DCP) tests in accordance with AS 1289.6.3.2 (1997) to a depth of 0.45m (refusal) for evaluation of relative densities of the upper layers.

The borehole, percolation and DCP test locations are shown on the attached site plan in Appendix 1.

Suitably qualified geotechnical personnel from Structerre supervised the fieldwork and all fieldwork, interpretation and terminology used in this report are in accordance with the guidelines presented in AS1726-2017 Geotechnical Site Investigations.

2. DESK STUDY

2.1. Geological Setting

The Perth sheet 1: 50,000 Environmental Geology Series (Part Sheets 2034 III and 2134 III, 1986) prepared by the Geological Survey of Western Australia indicates that the following geological layers underlie the site:

- Mgs2 - GRAVELLY SILT – strong brown, tough with common pebbles of fine to coarse-grained, sub-rounded granite, some dolerite and rare sandstone (SS) variable sand content (Colluvium Qc).

2.2. Ground Surface and Groundwater Level

The Perth Groundwater Atlas (Waters & Rivers Commission) indicates the ground surface level at this site was approximately 41.0m – 52.0m Australian Height Datum (AHD).

The May 2003 groundwater level at the site was approximately 17.0m AHD. It should be noted that the groundwater levels can vary significantly due to seasonal variation and the data from the recorded maximum levels should be used only as a guide.

2.3. Acid Sulfate Soils

Information from publicly available Landgate website indicates that the site lies within a zone of no known risk of ASS occurring within 3m of natural surface.

2.4. Site History

Historical aerial photographs dating back to 1953 are publicly available through Landgate Map Viewer were assessed and a summary is presented in Table 1.

Table 1 – Historical Site Information

Date	Description
1953	The site is bushland
1965	Anderson Road on the east boundary was developed
1974	York Street and Lincoln Road on the southwest boundary was developed and more houses built.
1977	Part of the reserve park was cleared
2019	Site remains relatively unchanged to the current day

3. RESULTS OF THE INVESTIGATION

3.1. Subsurface Soil Profile

The subsurface soil profile presented below was determined from the ground conditions encountered within the boreholes and through the interpretation of the DCP test results:

Table 2 – Subsurface Soil Profile BH02, BH03 and BH07

Depth to Base of Strata (m)	Material Description
0.1	Topsoil
Not Penetrated (>1.1m)	NATURAL: Sandy CLAY (fine to medium grained), medium plasticity, with gravel, very stiff

Table 3 – Subsurface Soil Profile BH04, BH05, BH06, BH09 and BH10

Depth to Base of Strata (m)	Material Description
0.1	Topsoil
Not Penetrated (>0.7m)	NATURAL: Gravelly SAND (fine to medium grained), non-plastic, trace clay, very dense

Table 4 – Subsurface Soil Profile BH01 and BH08

Depth to Base of Strata (m)	Material Description
0.1	Topsoil
0.3	NATURAL: SAND (fine to medium grained), non-plastic, dense grading to very dense
Not Penetrated (>0.7m)	NATURAL: Gravelly SAND (fine to medium grained), non-plastic, trace clay, very dense

Table 5 – Subsurface Soil Profile BH10

Depth to Base of Strata (m)	Material Description
Not Penetrated (>0.6m)	NATURAL: Gravelly SAND (fine to medium grained), non-plastic, very dense

The soils encountered are consistent with the expected site conditions as predicted from the Environmental Geology Map. All boreholes refused on “hard ground” typically cemented gravels and stiff clays at depths of between 0.5m and 1.1m.

It is important to note that there may be pockets of fill on site that were not encountered within the investigation borehole locations.

The subsurface soil conditions encountered are presented in the bore logs, within Appendix 3.

3.2. Groundwater

Groundwater was not encountered in any of the boreholes during or immediately after drilling. However, perched groundwater is expected to be encountered approximately 0.1m below the existing ground level above the more cohesive (clay) materials.

3.3. Percolation Testing

Percolation testing of the in-situ soils was undertaken in five locations. Results of the testing are summarised below:

Table 5 – In Situ Percolation Test Results

Test Location	Testing Depth	Soil Type	Permeability
BH02	0 - 1.1m	Sandy CLAY	0.5m/day
BH03	0 - 1.1m	Sandy CLAY	1.3m/day
BH05	0 – 0.7m	Gravelly SAND	0.6m/day
BH07	0 – 0.9m	Sandy CLAY	0.8m/day
BH08	0 – 0.7m	SAND to Gravelly SAND	1.1m/day
BH09	0 – 0.6m	Gravelly SAND	1.4m/day
BH10	0 – 0.6m	Gravelly SAND	4.0m/day

3.4. Laboratory Test Results

Selected representative soil samples were tested by Structerre's in-house NATA accredited laboratory for Atterberg Limits. The results are attached in Appendix 4.

3.4.1. Atterberg Limits

Atterberg Limits were tested by Structerre's in-house NATA accredited laboratory. Results of the testing are summarised below:

Table 6 – Atterberg Limit Test Results

Sample	Test Hole	Depth (m)	Soil Description	Liquid Limit % AS1289 3.1.2	Plastic Limit % AS1289 3.2.1	Plasticity Index % AS1289 3.3.1	Linear Shrinkage % AS1289 3.4.1
1	BH02	0.7-1.1	Sandy CLAY with gravel	39	19	20	9.5

Test results indicate that the natural Sandy CLAY with gravel has moderate shrink swell capacity or degree of expansion.

A copy of the laboratory results is presented in Appendix 4.

4. GEOTECHNICAL CONSTRUCTION CONSIDERATIONS

4.1. Site Classification

AS 2870-2011 Residential Slabs and Footings provides guidance on site classification for residential slabs and footing design based on the expected ground surface movement and depth of expected moisture changes.

Based on results of this investigation the site can be classified as a Class "S" provided that all unsuitable materials are removed and replaced with engineer-controlled sand fill materials in accordance with earthwork recommendations outlined in Section 4.3 in this report.

4.2. Drainage

The existing ground conditions are not suitable for on-site disposal of stormwater runoff through the use of soakwells.

The design of the drainage system, is unknown at this time, but may include:

- Rainwater Tanks;
- Dams / Compensation basin;
- Overland flow paths; and
- Soakwells, if permeable (sand) cover is significantly increased and / or designs are appropriate.

Sub soil drainage may be required to control groundwater perching in the upper soil layers within the building footprint.

4.3. Seismic Site Subsoil Class

The seismic subsoil site class has been assessed in accordance with AS 1170.4-2007, using the results of this investigation and published information.

Table 7 – Summary of Seismic Parameters

Hazard Factor	Site Sub-soil Class
0.09	Class Ce –shallow soil site

4.4. Earthworks (Residential and Structural Areas)

All earthworks shall be undertaken in accordance with AS 3798-2007 Guidelines on Earthworks for Commercial and Residential Developments and are to include the following:

- All unsuitable materials to be stripped and removed from the site. Unsuitable materials include topsoil, uncontrolled fills, deleterious and organic materials.
- It is considered that the near surface materials require improvement. Therefore, it is proposed to excavate and stockpile the materials for reuse, provided it is dry, free from clay/silt (i.e. <5%), organic and deleterious materials. The depth of excavation may vary depending on conditions encountered (i.e. groundwater) and is subject to inspection. Excavations should not exceed 2.0m and / or undermine surrounding structures. A 1V:2H slope should be maintained for temporary excavations. If excavation is required closer than the 1V:2H slope would allow, it is recommended that this office be contacted for retaining design.

- Proof compact the exposed base. The compaction requirements are set out in Table 8 below, as per AS 3798-2007:

Table 8 – Compaction Requirements

Item	Application	Minimum relative compaction, %	
		Minimum density ratio (Standard Compaction Effort) (Cohesive soils)	Minimum density index (Cohesionless soils)
1	Residential - lot, fill, house, sites	95	70
2	Commercial – fills to support minor loadings, including floor loading of up to 20kPa and isolated pad or strip footings to 100kPa	98	75
3	Fill to support pavements a) General fill b) Subgrade (to a depth of 0.3m)	 95 98	 70 75

- After excavation and proof compaction, the excavated base should be assessed and approved by a representative from this office prior to backfilling. At this stage it can be assessed whether any further materials need to be removed or whether further compaction of the base is required.
- It is recommended a minimum of 0.6m sand cover is to be placed above the reactive material in order to achieve a Class "S" site with y_s = <10mm.
- The ground level should be built up to design levels with any stockpiled sand materials and imported fill. If required, the imported fill should consist of free draining sand with not more than 5% passing a 75µm sieve and be free of organic matter and other deleterious materials. The fill sand materials should be placed in layers not exceeding 300mm loose thickness and compacted to achieve the values stated in the table above. As a guide a minimum of 8 PSP blows over the interval 150 – 450mm, 9 PSP blows over the interval 450 – 750mm and 11 PSP blows over the interval 750 – 1050mm should be achieved, however it is recommended that this be verified with appropriate laboratory testing.
- After remedial earthworks have been completed, the earthworks should be assessed and approved by a representative from this office.

It is considered that standard small to medium sized earthmoving equipment would be appropriate for the proposed development. The near surface ground was generally competent and should not pose an issue to site traffic movements in the drier months of the year. Earthworks in the wetter months of year may be problematic and earthworks trafficking may cause softening of clayey subgrades, therefore should be accounted if any works are conducted during the wet months of the year.

The material encountered on site can be deemed as 'easy' to excavate with medium sized earthwork equipment (i.e. a 20t excavator).

4.5. Indicative California Bearing Ratio (CBR)

The indicative California Bearing Ratio (CBR) value of the subgrade material, following earthworks can be estimated from the site investigation results and would be appropriate for preliminary design purposes. The indicative value is shown in the below table:

Table 9– Indicative CBR Values

Material	Indicative CBR (%)	Compaction
SAND (In situ or Imported Fill)	12	95% of MMDD*
SANDY CLAY (NATURAL)	<5	92% of MMDD*

* Implies the maximum dry density ratio using Modified compaction in accordance with AS 1289 5.2.1-2003.

For detailed design and construction of the pavements, it is recommended that the CBR values be verified with laboratory Soaked CBR testing on the anticipated subgrade material.

5. CONCLUSIONS

A site investigation was carried out at the proposed commercial development site to assess the geotechnical conditions. Parameter and design recommendations are incorporated in the body of the report. The following conclusions have been drawn from the site investigation:

- The average subsurface soil profile encountered comprised topsoil to 0.1m, variable sand to gravelly sand from 0.1m up to 0.7m, underlain by sandy CLAY with gravel to the investigated depth of 1.1m.
- Groundwater or perched water was not encountered across the site to the depth of 1.1m, however would be anticipated to perch above the reactive clay soils in the wetter months of the year.
- It is considered that the site is not suitable for on-site drainage via soakwells in its current condition.
- The site can be classified as Class "S" in accordance with AS 2870-2011 due to presence of moderately reactive sandy CLAY deposits within the proposed building areas, provided that the recommended earthworks are undertaken.
- The full scope of the recommended earthworks is presented in Section 4.3, but generally comprises:
    - Stripping of topsoil and unsuitable materials
    - Proof compaction of the base
    - Placement of a minimum 0.6m sand fill to required level
    - Compaction to final level

6. LIMITATION OF FIELD INVESTIGATIONS

This report has been prepared in accordance with generally accepted consulting practice for City of Kalamunda using information supplied at the time and for the project specific requirements as understood by Structerre. To the best of our knowledge the information contained in this report is accurate at the date of issue, however it should be emphasised that any changes to ground conditions and/or the proposed structures may invalidate the recommendations given herein.

The conclusions and recommendations in this report are based on the site conditions revealed through selective point sampling, representing the conditions of the site in total, although the area investigated represents only a small portion of the site. The actual characteristics may vary significantly between successive test locations and sample intervals other than where observations, explorations and investigations have been made.

The materials and their geotechnical properties presented in this report may not represent the full range of materials and strengths that actually exist on site and the recommendations should be regarded as preliminary in nature. Allowances should be made for variability in ground conditions and any consequent impact on the development. Structerre accepts no responsibility and shall not be liable for any consequence of variations in ground conditions.

If ground conditions encountered during construction are different to that described in this report, this office should be notified immediately.

For and behalf of

STRUCTERRE CONSULTING



Margie Mortera
Geotechnical Assistant



Checked By: David Harding
Employee Title: Geotechnical Supervisor



Authorised By: Mel Castle
Employee Title: Division Manager - Geotechnical

Disclaimer
This report is at the request of the addressee and no liability is accepted by Structerre Consulting to any third person reading or relying upon the report, not withstanding any rule of law and/or equity to the contrary and that this report is strictly confidential and intended to be read and relied upon only be the addressee.

Job #	Revision	Authored	Checked	Authorised
J339742	0	MM	DH	MC

7. REFERENCES

Department of Water – Perth Groundwater Atlas

Geological Survey of Western Australia 1:50,000 Environmental Geology Series

AS 1170.4-2007 Structural design actions – Earthquake actions in Australia

AS 1289.3.1.2-2009 Methods of testing soils for engineering purposes – Soil classification tests – Determination of the liquid limit of a soil

AS 1289.3.2.1-2009 Methods of testing soils for engineering purposes – Soil classification tests – Determination of the plastic limit of a soil

AS 1289.3.3.1-2009 Methods of testing soils for engineering purposes – Soil classification tests – Calculation of the plasticity index of a soil

AS 1289.3.4.1-2009 Methods of testing soils for engineering purposes – Soil classification tests – Determination of the linear shrinkage of a soil

AS 1289.6.3.2-1997 Methods of testing soils for engineering purposes – Soil strength and consolidation tests – Determination of the penetration resistance of a soil – 9kg dynamic cone penetrometer test

AS 1726-2017 Geotechnical site investigation

AS 2870-2011 Residential slabs and footings

AS 3798-2007 Guidelines on earthworks for commercial and residential developments

APPENDIX 1 – SITE LOCATION MAP



Note: Showing approximate test locations only

LEGEND

BH Borehole

STRUCterre consulting

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PROJECT:	Cambridge Reserve - Cambridge Road, Forrestfield
PROJECT #:	D230816
JOB #:	J339742
CLIENT:	City of Kalamunda
SCALE:	NTS
TITLE:	Geotechnical Investigation Site Plan
DATE:	14 Jan '20
DRAWN BY:	MM
CHECKED BY:	DH

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APPENDIX 2 – SITE PHOTOS



Alder Way - East Facing Anderson Road



Existing Parkland Clearing

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PROJECT:	Cambridge Reserve - Cambridge Road, Forrestfield
PROJECT #: D230816	CLIENT: City of Kalamunda
JOB #: J339742	
SCALE: NTS	TITLE: Site Photographs
DATE: 14 Jan '20	DRAWN BY: MM / CHECKED BY: DH

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Central Clearing



Sample taken at BH01

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PROJECT:	Cambridge Reserve - Cambridge Road, Forrestfield
PROJECT #:	D230816
JOB #:	J339742
CLIENT:	City of Kalamunda
SCALE:	NTS
TITLE:	Site Photographs
DATE:	14 Jan '20
DRAWN BY:	MM
CHECKED BY:	DH

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APPENDIX 3 – BORELOGS

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Project Cambridge Reserve - Cambridge Road, Forrestfield

Client City of Kalamunda

Test No. **BH01**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**	Soil Retrieval Probe	**Easting**	406737
Job No.	J339742	**Date**	14/01/2020	**Hole Dia.**	65mm	**Northing**	6460071

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm (5 10 15 20)	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil:	D - VD				D	
		SP: SAND: fine to medium grained, non-plastic, brown (Colluvium)						
		GP: Gravelly SAND: fine to medium grained, non-plastic, trace clay, brown						
		Terminated at 0.60 m						
1								
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on dense gravel
2. Hole stability:
3. Samples taken: None
4. Co-ordinate system: WGS 84

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Project Cambridge Reserve - Cambridge Road, Forrestfield

Client City of Kalamunda

Test No. **BH02**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**	Soil Retrieval Probe	**Easting**	406878
Job No.	J339742	**Date**	14/01/2020	**Hole Dia.**	65mm	**Northing**	6460065

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm (5 10 15 20)	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil:			0.0 - 1.1	T		
		Cl: Sandy CLAY: fine to medium grained, medium plasticity, with gravel, brown (Colluvium)	VSt				D	
1		Terminated at 1.10 m						
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on stiff clay
2. Hole stability:
3. Samples taken: As indicated
4. Co-ordinate system: WGS 84

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Project Cambridge Reserve - Cambridge Road, Forrestfield

Client City of Kalamunda

Test No. **BH03**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**	Soil Retrieval Probe	**Easting**	406867
Job No.	J339742	**Date**	14/01/2020	**Hole Dia.**	65mm	**Northing**	6459977

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm (5 10 15 20)	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil:						
		Cl: Sandy CLAY: fine to medium grained, medium plasticity, with gravel, brown (Colluvium)	VSt				D	
1		Terminated at 1.10 m						
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on stiff clay
2. Hole stability:
3. Samples taken: None
4. Co-ordinate system: WGS 84

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Project Cambridge Reserve - Cambridge Road, Forrestfield

Client City of Kalamunda

Test No. **BH04**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**	Soil Retrieval Probe	**Easting**	406906
Job No.	J339742	**Date**	14/01/2020	**Hole Dia.**	65mm	**Northing**	6460132

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm (5 10 15 20)	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil:						
		GP: Gravelly SAND: fine to medium grained, non-plastic, trace clay, brown (Colluvium)	VD				D	
		Terminated at 0.50 m						
1								
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on dense gravel
2. Hole stability:
3. Samples taken: None
4. Co-ordinate system: WGS 84

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Client City of Kalamunda

Test No. **BH05**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**		**Easting**	407049
Job No.	J339742	**Date**	14/01/2020	**Hole Dia.**	65mm	**Northing**	6460134

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm (5 10 15 20)	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil:						
		GP: Gravelly SAND: fine to medium grained, non-plastic, trace clay, brown (Colluvium)	VD				D	
		Terminated at 0.70 m						
1								
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on dense gravel
2. Hole stability:
3. Samples taken: None
4. Co-ordinate system: WGS 84

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Project Cambridge Reserve - Cambridge Road, Forrestfield

Client City of Kalamunda

Test No. **BH06**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**	Soil Retrieval Probe	**Easting**	407044
Job No.	J339742	**Date**	14/01/2020	**Hole Dia.**	65mm	**Northing**	6460145

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm (5 10 15 20)	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil:						
		GP: Gravelly SAND: fine to medium grained, non-plastic, trace clay, brown (Colluvium)	VD				D	
		Terminated at 0.70 m						
1								
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on dense gravel
2. Hole stability:
3. Samples taken: None
4. Co-ordinate system: WGS 84

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Project Cambridge Reserve - Cambridge Road, Forrestfield

Client City of Kalamunda

Test No. **BH07**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**	Soil Retrieval Probe	**Easting**	407156
Job No.	J339742	**Date**	14/01/2020	**Hole Dia.**	65mm	**Northing**	6460289

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm (5 10 15 20)	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil:						
		Cl: Sandy CLAY: fine to medium grained, medium plasticity, with gravel, brown (Colluvium)	VSt				D	
1		Terminated at 0.90 m						
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on stiff clay
2. Hole stability:
3. Samples taken: None
4. Co-ordinate system: WGS 84

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Project Cambridge Reserve - Cambridge Road, Forrestfield

Client City of Kalamunda

Test No. **BH08**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**	Soil Retrieval Probe	**Easting**	407229
Job No.	J339742	**Date**	14/01/2020	**Hole Dia.**	65mm	**Northing**	6459905

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm (5 10 15 20)	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil:						
		SP: SAND: fine to medium grained, non-plastic, brown (Colluvium)	VD					
		GP: Gravelly SAND: fine to medium grained, non-plastic, trace clay, brown					D	
		Terminated at 0.70 m						
1								
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on dense gravel
2. Hole stability:
3. Samples taken: None
4. Co-ordinate system: WGS 84

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Client City of Kalamunda

Test No. **BH09**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**	Soil Retrieval Probe	**Easting**	
Job No.	J339742	**Date**	14/01/2020	**Hole Dia.**	65mm	**Northing**	

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm (5 10 15 20)	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil:						
		GP: Gravelly SAND: fine to medium grained, non-plastic, trace clay, brown (Colluvium)	VD				D	
		Terminated at 0.60 m						
1								
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on dense gravel
2. Hole stability:
3. Samples taken: None
4. Co-ordinate system: WGS 84

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Project Cambridge Reserve - Cambridge Road, Forrestfield

Client City of Kalamunda

Test No. **BH10**

Project No.	D230816	**Logged By**	Tony Broadway	**Machine**	Soil Retrieval Probe	**Easting**	407147
Job No.	J339742	**Date**	07/02/2020	**Hole Dia.**	65mm	**Northing**	6460190

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm 5 10 15 20	Samples Depth	Samples Type	Moisture	Water Level
		GP: Gravelly SAND: fine to medium grained, non-plastic, brown (Colluvium)					D	
		Terminated at 0.60 m						
1								
2								
3								

Remarks

1. Termination reason: Refusal - interpreted on dense gravel
2. Hole stability:
3. Samples taken: None
4. Co-ordinate system: WGS 84

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APPENDIX 4 – LABORATORY TEST RESULTS

Sample No.	**33276**	**Client**	Geotechnical
Job No.	J339742	**Project**	Cambridge Rd, Forrestfield

Laboratory testing carried out at Balcatta Laboratory 1 Erindale Rd, Balcatta WA 6021

SAMPLE DETAILS

BH No. / Depth : BH2 0.7-1.1m
Sample History : 50°C Oven Dried

Sampling Method Client
Sample Preparation AS 1289 1.1

ATTERBERG LIMITS

Description	Method	Result (%)
Liquid Limit	AS 1289.3.1.2	39
Plastic Limit	AS 1289.3.2.1	19
Plasticity Index	AS 1289.3.3.1	20
Linear Shrinkage	AS 1289.3.4.1	9.5
Nature of Shrinkage		Cracked

PARTICLE SIZE DISTRIBUTION

Method: AS 1289.3.6.1
Description: Particle size distribution by sieve analysis

Sieve Size (mm)	% Passing
19.0	100
2.36	84
0.425	68
0.075	38

AS 1726:2017 Clause 6.1
Material Description: Sandy CLAY with gravel
AS Group Symbol: Cl or Ol

Accredited for compliance with ISO/IEC 17025
NATA
WORLD RECOGNISED ACCREDITATION
STRUCTERRE CONSULTING ENGINEERS BALCATTA LABORATORY ACCREDITATION NUMBER 18742

Wayne Rozmianiec
Laboratory Manager

Date: 21-Jan-20

Soils Analysis Workbook V3.28 11-Nov-19

AS 1289.3.6.1 Report Feb 18

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APPENDIX 5 – BORELOG TERMINOLOGY

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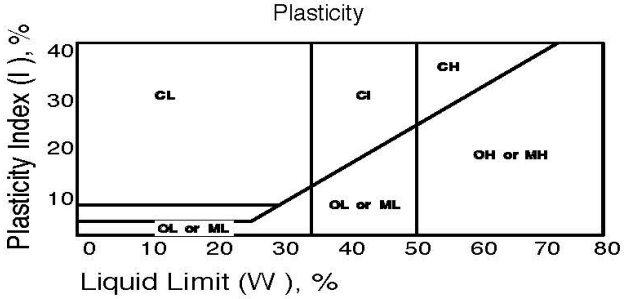
Residential Geotechnical Commercial & Infrastructure
Inspect & Investigate Energy Assessment Environmental

BORELOG TERMINOLOGY

Particle Size Distribution

Major Division	Subdivision	Size
Boulders		>200mm
Cobbles		200 - 63mm
Gravel	Coarse	63 - 20mm
	Medium	20- 6mm
	Fine	6 - 2.36mm
Sand	Coarse	2.36 - 0.6mm
	Medium	0.6 - 0.2mm
	Fine	0.2 - 0.075mm

Plasticity



Consistency of Cohesive Soils

Term	Undrained Strength Su (kPa)	Field Guide
Very Soft	< 12	Exudes between the fingers when squeezed in hand
Soft	12 - 25	Can be moulded by light finger pressure
Firm	25 - 50	Can be moulded by strong finger pressure
Stiff	50 - 100	Cannot be moulded by Fingers. Can be indented by thumb.
Very Stiff	100 - 200	Can be indented by thumb nail
Hard	> 200	Can be indented with difficulty by thumb nail.
Friable	-	Crumbles or powders when scraped by thumbnail

Consistency/Density of Non-Cohesive Soils

Term	Density Index (%)	SPT "N" Value Comparison
Very Loose	< 15	0 - 4
Loose	15 - 35	4 - 10
Medium Dense	35 - 65	10 - 30
Dense	65 - 85	30 - 50
Very Dense	> 85	> 50

Moisture Content

D	Dry
M	Moist
W	Wet
S	Saturated

Minor Components

Term	Assessment Guide	Proportion of Minor Component In:
Trace	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component	Coarse grained soils: < 5 % Fine grained soils: <15%
With	Presence easily detected by feel or eye, soil properties little different to general properties of primary component	Coarse grained soils: 5 - 12 % Fine grained soils: 15 - 30%

Soil Legend

FILL	CLAY	GRAVEL	CONCRETE
TOPSOIL	SILT	LIMESTONE	COMBINATIONS
PEAT	SAND	BEDROCK	eg: Clay, Silty, Sandy

USCS

GW	Well graded gravel	SC	Clayey sand	OL	Organic low plasticity silt	CL	Low plasticity clay
GP	Poorly graded gravel	SM	Silty sand	ML	Low plasticity silt	CI	Intermediate plasticity clay
SW	Well graded sand			MH	High plasticity silt	CH	High plasticity clay
SP	Poorly graded sand			OH	Organic high plasticity silt	PT	Peat

DOC:GE:3.003

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APPENDIX 4 – MODELLING REPORT (URBAQUA, 2020)

urbaqua
land and water solutions

24 April 2020

Stephanie Brokenshire
City of Kalamunda
2 Railway Road
Kalamunda, WA 6076

Dear Stephanie,

Re: Modelling Report for Cambridge Reserve

This letter is prepared in support of the Cambridge Reserve Community Enhancement Project and to satisfy the requirements of Better Urban Water Management (WAPC, 2008). It outlines water management strategies to address key water management considerations for the site, consistent with the principles of Water Sensitive Urban Design (WSUD).

The Study Area is an approximately 11 ha local open space reserve located in Forrestfield. It located between Anderson Road, Mallow Way, Cambridge Road and York Street (Figure 1 attached). Cambridge Reserve is being investigated for residential development whilst preserving the existing environmental value of the site. A draft Concept Plan was prepared and included following key features (Urbis, 2020):

- Activity hub – including half-court basketball, seating areas and playground;
- Retained bushland;
- Improved landscape around the drainage sump;
- Formalised walking trails;
- Aged care development site; and
- Residential development.

The key water management considerations for the site include:

- Understanding the performance and capacity of the existing drainage basin onsite;
- Configuring drainage (and site layout) to account for the presence of the TEC; and,
- Implement WSUD to improve the function and aesthetics of the sump, whilst improving water quality treatment and flood protection.

This letter provides a summary of site conditions, stormwater modelling results, recommendations for the water management for review of the concept plan. The report incorporates complementary investigates of the TEC and geotechnical conditions onsite.

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Site Conditions

The following environmental characterisation is based on a desktop assessment of regional and local data sets and field investigations. The site contains a large basin (Figure 2), which receives drainage from the surrounding area. The site is underlain mostly with Pebbly Silt (Mgs_1) and Gravelly Silt (Mgs_2), with infiltration rates investigated by Urbaqua (July 2019) and Structerre Consulting (January 2020). The following rates were identified within the basin:

- Urbaqua: infiltration rates between 0.4 m/day and 0.9 m/day; and,
- Structerre: infiltration rates between 0.5 m/day and 1.3 m/day;

These infiltrations rates are comparatively low compared within sandy soils in the Perth Metropolitan Area, and runoff from the surrounding catchment is retained and slowly infiltrated, or discharges downstream (discussed further in *Stormwater Modelling*)

The general site conditions are summarised in Table 1 below.

Table 1: Site Conditions

Category	Site Characteristic
Topography	• The topography ranges between 41 mAHD and 53 mAHD; • Generally slopes down towards the north-west, with a local low point (the basin) present to the south-west of the site.
Land Use	• Local open space reserve, surrounded largely by residential areas, with small areas of industrial and commercial north and west of the site; • High voltage transmission lines are located east of the site along Anderson Road.
Geotechnical	• Regional soil mapping indicates that the site is underlain mostly with Pebbly Silt (Mgs_1) and Gravelly Silt (Mgs_2). A small portion of the study area near York Road is underlain with Sand (S10). • Structerre identified Sandy Clay (within the basin) and Gravelly Sand or Sand across the remainder of the site, though all tests were impenetrable at depths of only 0.7 m; • Infiltration across the site (outside of the basin) was generally less than 1.4 m/day, apart from one site (BH10) near the transmission lines which was 4.0 m/day (note that a nearby test at BH7 was 0.7 m/day).
Groundwater	• The DWER regional groundwater mapping (DWER, 2019) indicates that the minimum groundwater level is approximately 17 mAHD; • Depth to groundwater ranges from approximately 24.5 m to 35.5 m; and, • Groundwater flows generally from northeast to southwest.

Surface Water	• Within Cambridge Reserve there is an existing basin, connected upstream via a constructed drain (southern boundary) and sheetflow;
	• Outflow from the basin occurs via an existing pipe connection and overland flow to York Street;
	• According to the Surface Water Management Areas map, the study area is located within the Middle Canning surface water management area (DWER, 2020);
	• Surface water quality sampling and analysis was conducted for the surface water in the sump (Strategen, 2014). According to the results:
	  ○ total nitrogen concentrations were between 0.43 and 1.40 mg/L;
	  ○ total phosphorus concentrations were between 0.09 and 0.36 mg/L.

Category	Site Characteristic
Water Resources	• The site is located within the Shire of Kalamunda subarea of the Perth Catchment groundwater management area; • Groundwater allocation is available in the superficial aquifer (DWER, 2020), with 12,748 kL/yr currently available for allocation (the aquifer is 99.57% allocated).
Vegetation	• No threatened species occur on the site (PVG, 2019); and, • Two areas (north east and south east of the site) have been assessed as having vegetation in Excellent condition, and an area of Very Good condition between the basin and York St.
Wetlands	• No wetlands are registered within or near the Reserve (DBCA, 2019).
General Environment	• The site is mapped with no known risk of acid sulfate soils occurring within 3 m of the surface (DWER, 2019); • A search of the DWER Contaminated Sites Database (DWER, 2019) indicates that there are no contaminated sites located within the study area.

Stormwater Modelling

Hydrological and hydraulic modelling has been undertaken to determine the following:

1. Existing performance of the basin;
2. Impact of the concept plan on basin performance;
3. Assessment of alternative storage locations; and,
4. Revised basin sizing and location.

Modelling was undertaken with modelling package XP-Storm, consistent with Australian Rainfall & Runoff 2019 protocol, including multi-storm analysis to determine the critical duration event that produces the largest stormwater volume. The model is based on the 2016 design rainfall Intensity- Frequency-Durations (IFDs) and Ensembles approaches (ARR, 2016).

The existing basin was constructed in the late 1970s and no design information was available for interrogation. The basin sites between 2 and 3 m below the surrounding landscape, with an invert of 41.0 mAHD. Owing to the informal nature of the basin, there is varying side slopes between approximately 1:2 and 1:4, with some areas as flat at 1:8. Slopes greater than 1:6 generally require fencing to restrict access. The basin has minimal vegetation, though surrounding vegetation to west and south has been graded as Very Good. The stage/area dimensions for the basin are provided in Table 2, noting that the footprint of the basin is larger than the actual capacity due to the outlet.

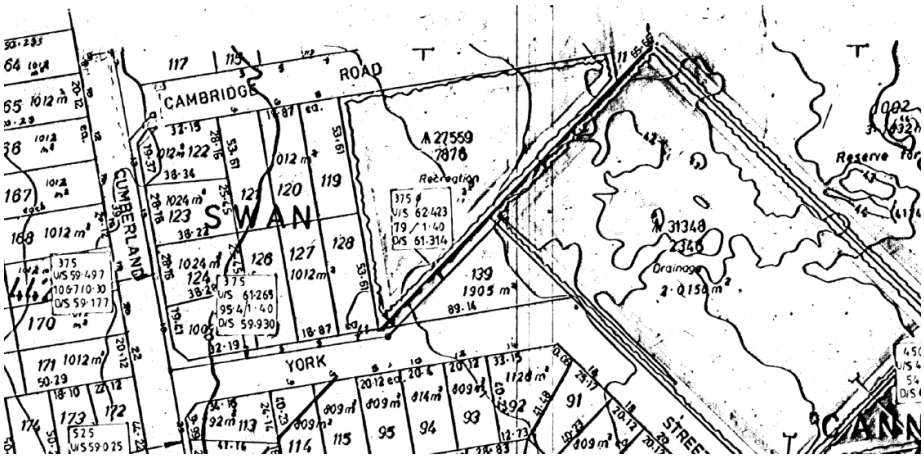
Table 2: Basin Stage/Area

Stage (mAHD)	Area (ha)	Stage (mAHD)	Area (ha)
41.0	0.015	42.2	1.02
41.2	0.55	42.4*	1.10
41.4	0.74	42.6*	1.24
41.6	0.83	42.8*	1.34
41.8	0.90	43.0*	1.48
42.0	0.96	43.2*	1.60

** Above the overland flow outlet*

Runoff from the surrounding catchment flows into the basin through a combination of formal and informal pathways. Three formal pipe outlets were noted during field inspections, with rock pitching preventing erosion at some inlets. There is an informal drain along the southern boundary that conveys overland flow into the basin, along with general sheet flow through the site.

There is a connection to the downstream stormwater system on York Street as shown in the image below, with a 375 mm pipe connection. The invert of this outlet (based on aerial imagery and elevation data) is assumed to be 41.8 mAHD. The existing surface at 42.2 mAHD provides an overland route for any additional overflow in the system. Based on LIDAR data, this overflow continues down York Street towards Cumberland Road and ultimately toward Yule Brook.



The surrounding catchment is shown in Figure 1. The assumed runoff rates for the respective land uses are provided in Table 3.

Table 3: Runoff parameters

Land Use	Initial Loss (mm)	Runoff Rate
Road Reserve	3	80%
Residential Lots	8	50%
Industrial / Commercial Lots	3	70%
Undeveloped / POS	5	25%

As per the Structerre Geotechnical Report (2020), infiltration within the basin was assumed to be 1.0 m/day (measured range of 0.5 m/day and 1.3 m/day).

Scenario 1: Baseline Conditions

The baseline model was established to assess the current capacity of the system based on available data, and in the absence of original design information. Larger storm events (10% AEP and 1% AEP) were assessed with varying duration to determine the performance of the system. The results for this scenario are provided in Table 4, based on the catchment parameters and existing basin configuration.

Table 4: Existing basin capacity results

AEP Event	Duration	Total Rainfall	Maximum Water Level	Surface flow to York Street
10% AEP	1 hr	28.1 mm	41.78 mAHD	No
10% AEP	3 hrs	42.0 mm	42.03 mAHD	No
10% AEP	6 hrs	54.8 mm	42.16 mAHD	No
10% AEP	**9 hrs**	**64.0 mm**	**42.22 mAHD**	**Yes**
10% AEP	**12 hrs**	**71.2 mm**	**42.21 mAHD**	**Yes**
10% AEP	18 hrs	82.2 mm	42.20 mAHD	No
10% AEP	24 hrs	90.3 mm	42.18 mAHD	No
1% AEP	1 hr	43.0 mm	42.12 mAHD	No
1% AEP	**3 hrs**	**67.1 mm**	**42.40 mAHD**	**Yes**
1% AEP	**6 hrs**	**90.1 mm**	**42.43 mAHD**	**Yes**
1% AEP	**9 hrs**	**106 mm**	**42.45 mAHD**	**Yes**
1% AEP	**12 hrs**	**118 mm**	**42.42 mAHD**	**Yes**
1% AEP	**18 hrs**	**134 mm**	**42.39 mAHD**	**Yes**
1% AEP	**24 hrs**	**145 mm**	**42.38 mAHD**	**Yes**

Results of this assessment demonstrate that the basin in its existing configuration has insufficient capacity for a 1% AEP event given the 10% AEP (9 and 12 hours) event discharges via overland flow. Therefore with development of the structure plan area, water levels (and consequently flows downstream) should not increase above the levels in Table 4, and preferably the capacity of the basin is increased to allow for improved flood storage.

Scenario 2: Post-development

The second scenario considered was assessment of the impact on the basin from the proposed development. This assessment was made on an older version of the development layout, as shown in Figure 2, though the total proposed land uses are comparable with the final layout, and the findings are consistent. The proposed development results in an increase in impervious area and additional runoff from the local catchment. The proposed development includes additional road reserves, residential lots and an aged care facility. In order to minimise the increase in water level in the basin, runoff from the new development need to be managed locally wherever possible.

Applying runoff rates adapted from the rest of the catchment results in an increase in basin water levels of approximately 0.08 m and 0.02 m for the 10% AEP and 1% AEP events respectively. Mitigation of runoff from the new development areas can be achieved be adopting the following strategies.

Consistent with the *Decision process for stormwater management in Western Australia* (DWER, 2017), the first 15 mm of rainfall should be managed at source. This approach is required to improve water quality downstream, but also provides a marginal improvement to flood management. Although the soil conditions (and measured infiltration rates) aren't as effective as sandy soils on the Swan Coastal Plain, the use of soakwells at the front of lots (with a grated overflow to the road) provides a retention and detention function that will assist with the downstream volumes. An alternative approach is the use of above ground garden beds (positioned beneath downpipes) to retain and infiltrate roof runoff on each lot.

For roads, installation of raingardens in non-active verges will provide management of the 15 mm rainfall event.

Results from management of this runoff are presented in Table 5. There is a requirement for further management to maintain the predevelopment water levels and overflow downstream as the increase in water level is between 0.07 m and 0.02 m for the 10% AEP and 1% AEP events respectively.

Table 5: Post-development basin capacity with 15 mm management

AEP Event	Duration	Total Rainfall	Pre-dev Max Water Level	Maximum Water Level	Surface flow to York Street
10% AEP	1 hr	28.1 mm	41.78 mAHD	41.80 mAHD	No
10% AEP	3 hrs	42.0 mm	42.03 mAHD	42.09 mAHD	No
10% AEP	**6 hrs**	**54.8 mm**	**42.16 mAHD**	**42.23 mAHD**	**Yes**
10% AEP	**9 hrs**	**64.0 mm**	**42.22 mAHD**	**42.28 mAHD**	**Yes**
10% AEP	**12 hrs**	**71.2 mm**	**42.21 mAHD**	**42.27 mAHD**	**Yes**
10% AEP	**18 hrs**	**82.2 mm**	**42.20 mAHD**	**42.27 mAHD**	**Yes**
10% AEP	**24 hrs**	**90.3 mm**	**42.18 mAHD**	**42.25 mAHD**	**Yes**
1% AEP	1 hr	43.0 mm	42.12 mAHD	42.15 mAHD	No
1% AEP	**3 hrs**	**67.1 mm**	**42.40 mAHD**	**42.42 mAHD**	**Yes**
1% AEP	**6 hrs**	**90.1 mm**	**42.43 mAHD**	**42.45 mAHD**	**Yes**
1% AEP	**9 hrs**	**106 mm**	**42.45 mAHD**	**42.47 mAHD**	**Yes**
1% AEP	**12 hrs**	**118 mm**	**42.42 mAHD**	**42.44 mAHD**	**Yes**
1% AEP	**18 hrs**	**134 mm**	**42.39 mAHD**	**42.41 mAHD**	**Yes**
1% AEP	**24 hrs**	**145 mm**	**42.38 mAHD**	**42.40 mAHD**	**Yes**

To maintain the pre-development conditions, a number of options are available, namely;

- Increase the basin overflow level to 42.3 mAHD (detaining all 10% AEP events);
- Require the aced care facility site to manage up to the 10% AEP onsite (not just the first 15 mm);
- Increase storage within the new development area, to manage larger events that the first 15 mm (most likely by the use of underground storage as not to limit developable areas;
- Increase storage elsewhere in the catchment; and/or,
- Reconfigure the basin to maximise storage within the existing footprint.

Increasing the basin outlet level is a relatively simple approach and requires a minimum 100 mm bund construction on the downstream side of the basin to increase the outlet level. This allows detention of the 10% AEP event (all durations) which is a slight improvement on pre-development conditions. The presence of *Excellent* condition vegetation may limit this approach near York Street.

Management of larger events, whether in the aged care facility or elsewhere in the new development is a potentially expensive and inefficient approach. As discussed above, the soils feature relatively low infiltration rates and any underground storage (that relies of disposal through infiltration) becomes larger than equivalent systems on the Swan Coastal Plain. Therefore the cost of installing these systems becomes prohibitive relative to other proposed

systems. Within the aged care facility, above ground storage could be considered (in the form of a basin), however this will result in the loss of developable land.

The remaining two approaches (increasing storage elsewhere in the catchment and reconfiguring the basin) also provides the opportunity to also potentially manage the 1% AEP event and reduce the pressure on downstream system. These two approaches have been considered further in the following sections.

Scenario 3: Alternative Storage

Along Anderson Road, there are opportunities to install additional drainage basins to offset the impact of additional runoff from development and improve the overall performance of the system by increasing 1% AEP storage. As shown in Figure 3, two basins are proposed (based on the superseded development layout), north east and south east of Cambridge Reserve. Both locations would be beneath the Western Power transmission lines and will require approval, though it is noted this has been done recently elsewhere in Forrestfield. The northern basin has limited existing vegetation, though some clearing would be required in the south.

The reserve where the basins are located are up to 50 m wide, through a more conservative 32 m basin width is assumed to allow for other uses (services, paths etc.). A 1:6 side slopes is also assumed, with a depth up to 1.0 m. The full dimensions are provided in Table 6, with modelling results (for the central basin in Cambridge Reserve) provided in Table 7.

Table 6: Alternative basin details

Invert	Depth	Base Area	Top Area	Side Slopes	Volume
51.0 mAHD	1.0 m	0.24 ha	0.42 ha	1:6	3,290 m^3

Table 7: Post-development basin capacity with alternative basins

AEP Event	Duration	Total Rainfall	Pre-dev Max Water Level	Maximum Water Level	Surface flow to York Street
10% AEP	1 hr	28.1 mm	41.78 mAHD	41.68 mAHD	No
10% AEP	3 hrs	42.0 mm	42.03 mAHD	41.72 mAHD	No
10% AEP	6 hrs	54.8 mm	42.16 mAHD	41.74 mAHD	No
10% AEP	9 hrs	64.0 mm	42.22 mAHD	41.76 mAHD	No
10% AEP	12 hrs	71.2 mm	42.21 mAHD	41.67 mAHD	No
10% AEP	18 hrs	82.2 mm	42.20 mAHD	41.45 mAHD	No
10% AEP	24 hrs	90.3 mm	42.18 mAHD	41.60 mAHD	No
1% AEP	1 hr	43.0 mm	42.12 mAHD	41.66 mAHD	No
1% AEP	3 hrs	67.1 mm	42.40 mAHD	42.04 mAHD	No
1% AEP	**6 hrs**	**90.1 mm**	**42.43 mAHD**	**42.28 mAHD**	**Yes**
1% AEP	**9 hrs**	**106 mm**	**42.45 mAHD**	**42.32 mAHD**	**Yes**
1% AEP	**12 hrs**	**118 mm**	**42.42 mAHD**	**42.33 mAHD**	**Yes**
1% AEP	**18 hrs**	**134 mm**	**42.39 mAHD**	**42.30 mAHD**	**Yes**
1% AEP	**24 hrs**	**145 mm**	**42.38 mAHD**	**42.29 mAHD**	**Yes**

The northern basin is sized to contain the majority of the runoff from the catchment east of Anderson Road. Only the larger 1% events overflow to the central basin. The southern basin overflows in a 10% AEP event and could potentially be increased in size, noting that there are restrictions with the existing vegetation and power pole locations.

Further discussions with the City indicated that the southern basin was not feasible owing to the presence of existing vegetation. However the results of this scenario demonstrate the effectiveness of these basins in reducing the water levels within the central basin. There is still the overflow to York Street in the 1% AEP event with the current basin form. The cost for the northern basin is roughly estimated at $76,000 based on earthwork requirements.

Scenario 4: Revised Basin Configuration

The approach to a revised basin configuration is to provide conditions that are suitable for community interaction, increase storage and minimising footprint increase (maintain developable areas and minimise impact on existing vegetation). The scenario here is presented in (a) the reconfigured basin alone and (b) the reconfigured basin with the alternative storage in Scenario 3. Results (based on the superseded development layout) presented below are in the form of a rectangular basin, and it is assumed that the final form will be further modified by landscaping design to tie in with the surrounding amenities.

Revised configuration (no storage upstream)

Revising the basin configuration alone, the model was run for a basin with a 1:6 side slope (no surrounding fencing), assuming management of the first 15 mm within the new development areas. The objective was to prevent overland flow out of the system in a 1% AEP event, with the only discharge via the existing pipe connection downstream. The proposed basin dimensions are provided in Table 8, with the modelling results in Table 9.

Table 8: Reconfigured basin details (no upstream storage)

Invert	Depth	Base Area	Top Area	Side Slopes	Volume
41.0 mAHD	1.2 m	1.28 ha	1.63 ha	1:6	17,413m^3

Table 9: Reconfigured basin results (no upstream storage)

AEP Event	Duration	Total Rainfall	Pre-dev Max Water Level	Maximum Water Level	Surface flow to York Street
1% AEP	1 hr	43.0 mm	42.12 mAHD	41.55 mAHD	No
1% AEP	3 hrs	67.1 mm	42.40 mAHD	41.88 mAHD	No
1% AEP	6 hrs	90.1 mm	42.43 mAHD	42.07 mAHD	No
1% AEP	9 hrs	106 mm	42.45 mAHD	42.19 mAHD	No
1% AEP	12 hrs	118 mm	42.42 mAHD	42.20 mAHD	No
1% AEP	18 hrs	134 mm	42.39 mAHD	42.20 mAHD	No
1% AEP	24 hrs	145 mm	42.38 mAHD	42.18 mAHD	No

The top water level area (basin footprint) is shown in Figure 4, noting this shape will need to be refined with landscaping design. A preliminary costing suggests this option will cost approximately $228,500 associated with the basic earthworks. Further costs associated with the landscaping improvements are required.

It should be noted that this approach increases the basin footprint to 1.63 ha from 1.03 ha. If the side slope is increase to 1:3; the top area can be reduced to 1.55 ha whilst containing the 1% AEP event, though this may require fencing or landscaping to control and/or prevent community access.

Scenario 5: Combined Approach (Proposed Development Concept)

Scenarios 3 and 4 presented above, whilst based on superseded layouts, demonstrate that the solution for the site is a combination of upstream storage and an alternative basin configuration. Following discussions between the project team, the preferred solution for the basin was the western portion of the site, which provides the following benefits:

- A relatively flat area of the site to maximise basin footprint (whilst protecting established trees);
- Protection of the TEC on York Street; and,
- Increased development potential within the "core" area of the site.

In order for this configuration to meet the site design requirements, additional storage was required in the eastern and southern portion of the site. The northern basin under the Western Power Transmission Lines (Scenario 3) was considered suitable and is included within this assessment.

The existing drain along the southern boundary has also been utilised to generate additional stormwater storage. Modifying the drain into a series of small basins that fill up and overtop, creates a cascading system that detains flows towards the basin. These basins are generally a maximum of 20 m wide (to fit within the corridor between the site boundary and southern TEC), 1.2 m deep and 1:6 side slopes for safety considerations. A larger "pond" area is utilised to increase storage in land that would be difficult to incorporate into the layout.

The additional storage and revised basin configuration were assessed against the proposed development layout in Figure 5 (Scenario 5a). This configuration was modelled iteratively to determine the suitable infrastructure size, with results outlined in Table 10 and Table 11.

Table 10: Proposed basin details

Invert	Depth	Base Area	Top Area	Side Slopes	Volume
41.0 mAHD	1.2 m	0.56 ha	0.81 ha	1:6	8,150 m^3

Table 11: Proposed basin results

AEP Event	Duration	Total Rainfall	Maximum Water Level	Surface flow to York Street
1% AEP	1 hr	43.0 mm	41.38 mAHD	No
1% AEP	3 hrs	67.1 mm	41.78 mAHD	No
1% AEP	6 hrs	90.1 mm	42.05 mAHD	No
1% AEP	9 hrs	106 mm	42.17 mAHD	No
1% AEP	12 hrs	118 mm	42.18 mAHD	No
1% AEP	18 hrs	134 mm	42.16 mAHD	No
1% AEP	24 hrs	145 mm	42.13 mAHD	No

This basin with this configuration is able to meet the design requirements (no overland flow discharge to the York Street), improves community safety (1:6 side slopes, maximum 1.2 m depth) and maximise developable area on the site. The estimated cost to construct this configuration is $495,000, mainly associated with earthworks to construct the new basin and fill the old basin.

In order for this system to function correctly within the proposed site layout, drainage easements are required to connect drainage from Mallow Way (north of the site) through the Aged Care Site. A combination of pit/pipe drainage (modification of the existing pipework) and overland flow path is required to ensure drainage can reach the basin system. A potential easement location is shown in Figure 5, though internal roads within the Aged Care Site are a suitable alternative and could be determined during detailed design. Flow paths to connect the internal drainage to the basin system are also shown in Figure 5.

Along with the layout provided in Figure 5, an alternative layout concept is being considered by the City. This layout is shown in Figure 6 (Scenario 5b) and includes a reduction in the Aged Care Site, and the addition of a public road and residential lots. The runoff from this alternative configuration is slightly less than the Aged Care Facility as private lots have greater potential for pervious areas such as gardens). The proposed basin configuration is therefore suitable for either development concept.

Water Management Recommendation

The Local Water Management Strategy (LWMS) for Cambridge Reserve will address the requirements of Better Urban Water Management (WAPC, 2008). Table 12 outlines the key water management strategies to be achieved for the proposed development of the site.

Table 12: Water Management Recommendations

Design Objective
Water sustainability • Provide alternative water sources for non-drinking water demands, potentially including groundwater abstraction for irrigation; and • Minimise ex-house water demand through waterwise landscaping and promotion of passive irrigation with stormwater runoff wherever possible.
Groundwater management • No active management of groundwater is required on this site (owing to the depth).
Surface water management – new development area • Reduce risks to downstream water quality by managing small (up to 15 mm) rainfall events within the site using vegetated systems (preferred), soakwells and/or underground storage; • Provide an acceptable standard of amenity in roads, laneways and to properties during minor (20% AEP) rainfall events (pit and pipe system); and • Provide a minimum floor level within properties at least 500 mm above the 1% AEP water levels within the central basin to ensure appropriate level of protection from flooding
Surface water management – Cambridge Reserve • Modification of the basin is required to maintain existing performance of the system and not increase the flooding risk to downstream properties; • The simplest approach to maintaining the current performance is to construct a 100 mm bund around the southern and western portions of the site; • Improvement to the system to detain larger storm events, with no overland flow to York Street can be achieved by;

Design Objective
○ Installing additional basins east of the reserve under the transmission lines (partial detention of the 1% AEP); ○ Modifying the existing basin only (full detention of the 1% AEP); and, ○ A combination of additional basins and modifying the existing basin (full detention of the 1% AEP). • A combination of additional basins and modification/relocation of the current basin is recommended as it provides improved performance (detention of the 1% AEP) and allows for a design with 1:6 side slopes and community access.
Surface water management – other • The existing drain along the southern boundary should be modified to increase storage within the system. Landscaping of these areas should be considered to improve amenity in the site.
Other WSUD • Retain existing trees where possible (and replace any removed through development), consistent with the City of Kalamunda's Environmental Initiative; and • Provide for passive watering of trees and green spaces by directing small rainfall events towards verges and street trees (15 mm management).

Please do not hesitate to contact me on (08) 9328 4663 or at ross@urbaqua.org.au should you have any questions on this report.

Yours sincerely,

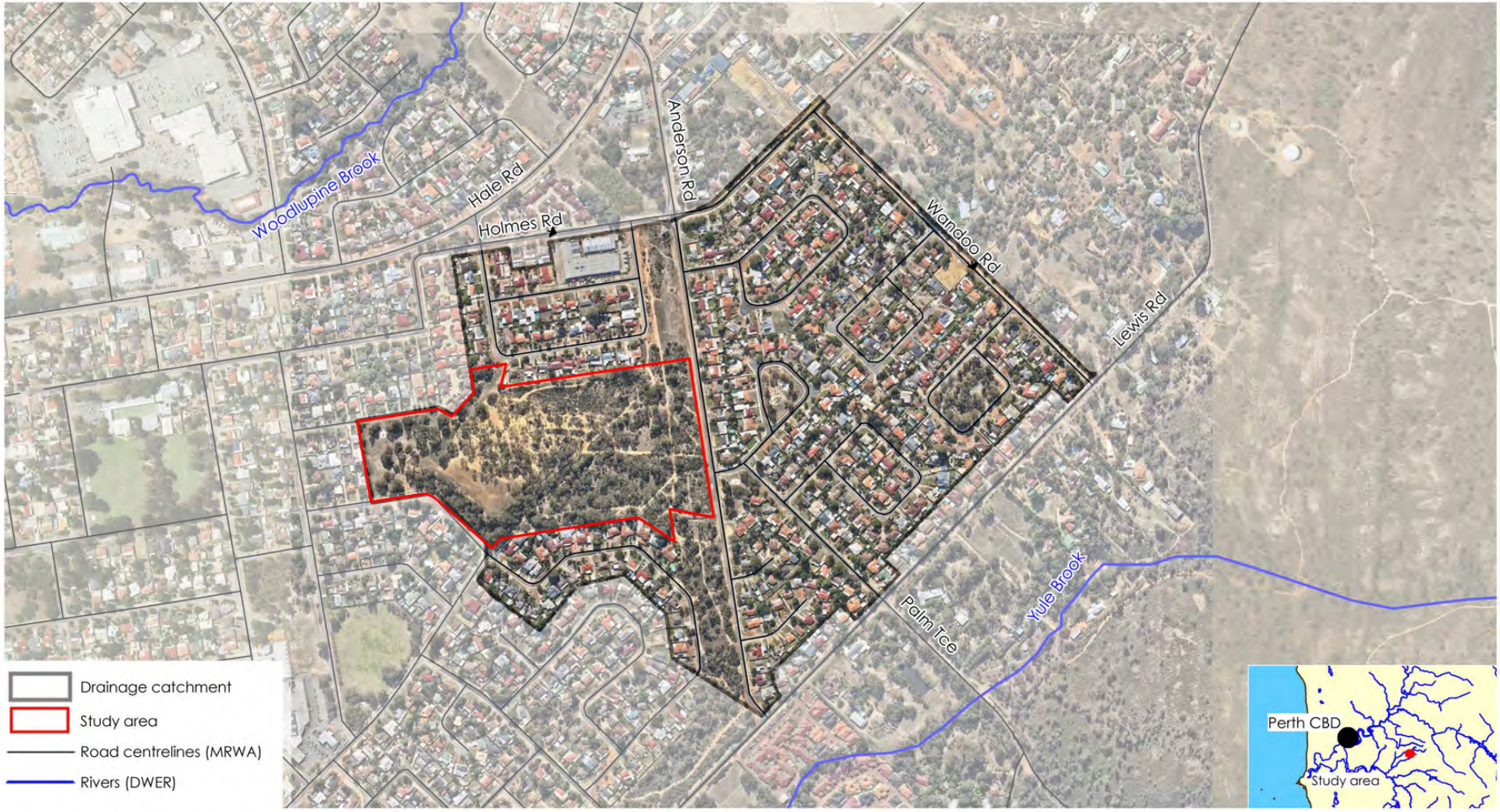


Ross Perrigo
SENIOR ENGINEER
URBAQUA

Attachment:

- Figure 1 – Study Area
- Figure 2 – Subdivision Plan
- Figure 3 – Additional basins upstream (Scenario 3)
- Figure 4 – Reconfigured basin only (Scenario 4)
- Figure 5 – Combined approach (Scenario 5a)
- Figure 6 – Combined approach (Scenario 5b)

City of Kalamunda - Modelling Report for Cambridge Reserve, Forrestfield
Figure 1 - Study Area

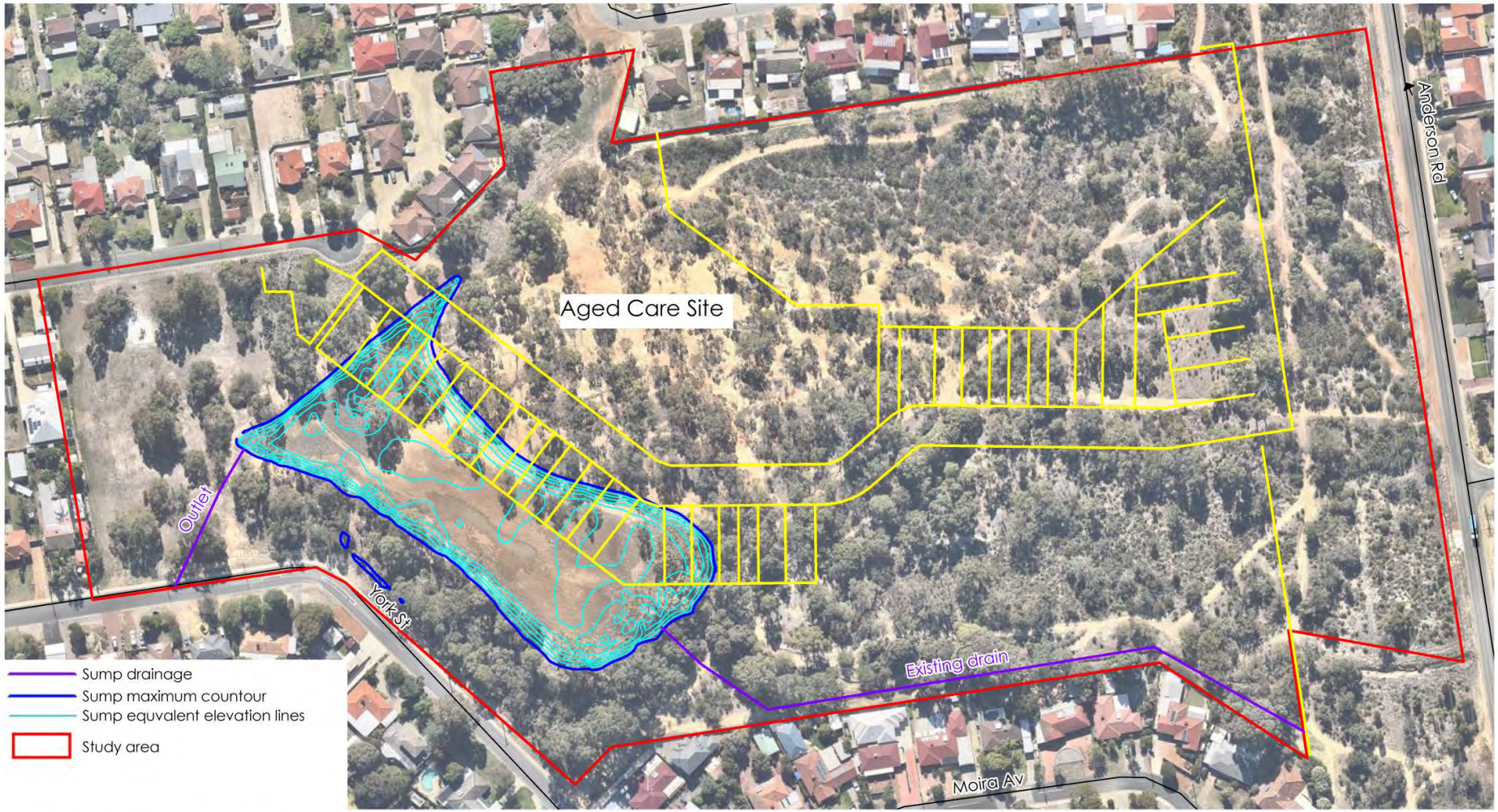


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City of Kalamunda - Modelling Report for Cambridge Reserve, Forrestfield
Figure 2 - Subdivision Plan

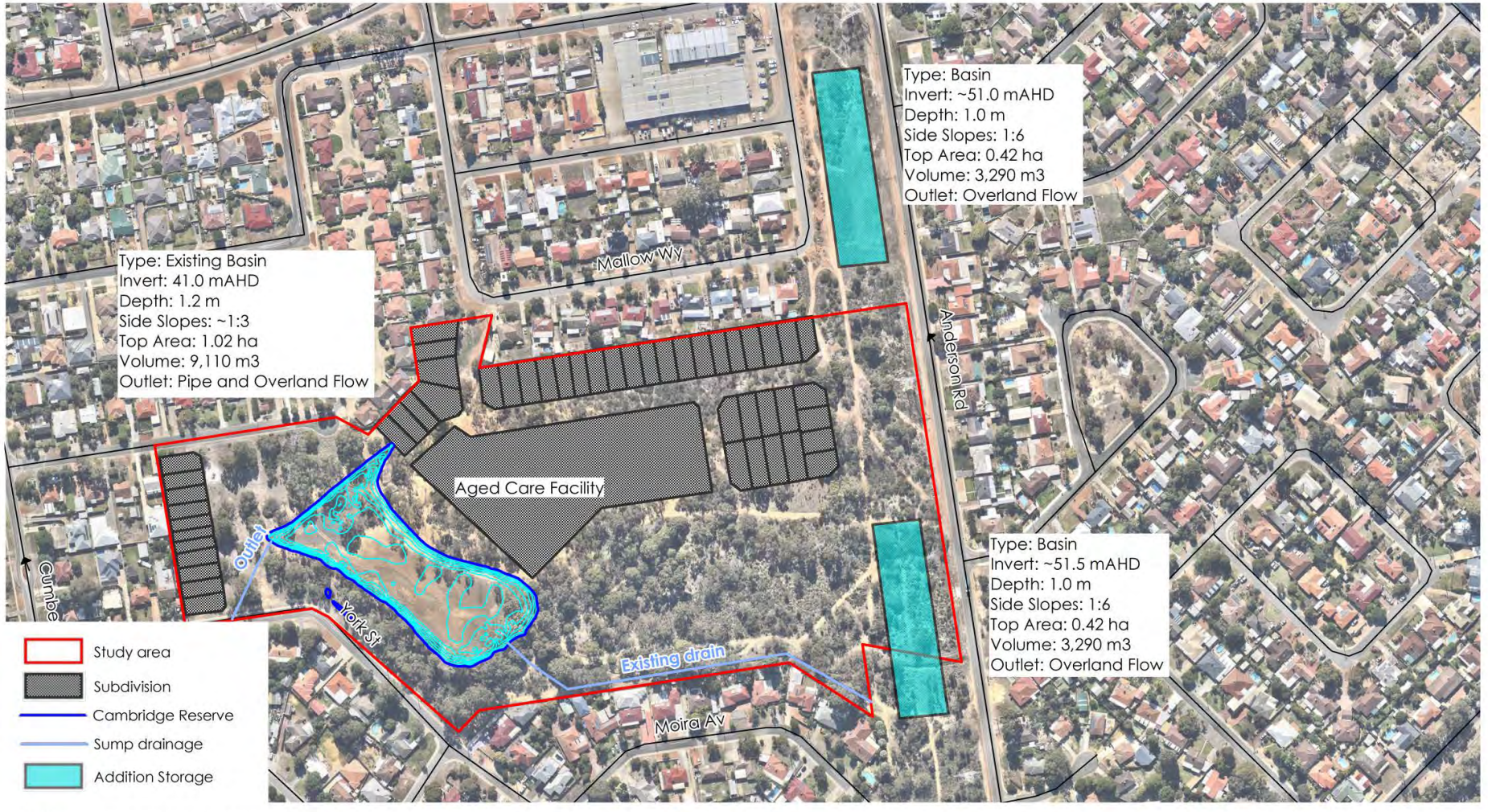


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Data source: MRWA, Landgate. Created by: RV. Projection: MGA: zone 50.

0 150
meters
Scale 1:2,000 @ A4

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City of Kalamunda - Modelling Report for Cambridge Reserve, Forrestfield
Figure 3 - Addition Storage Upstream

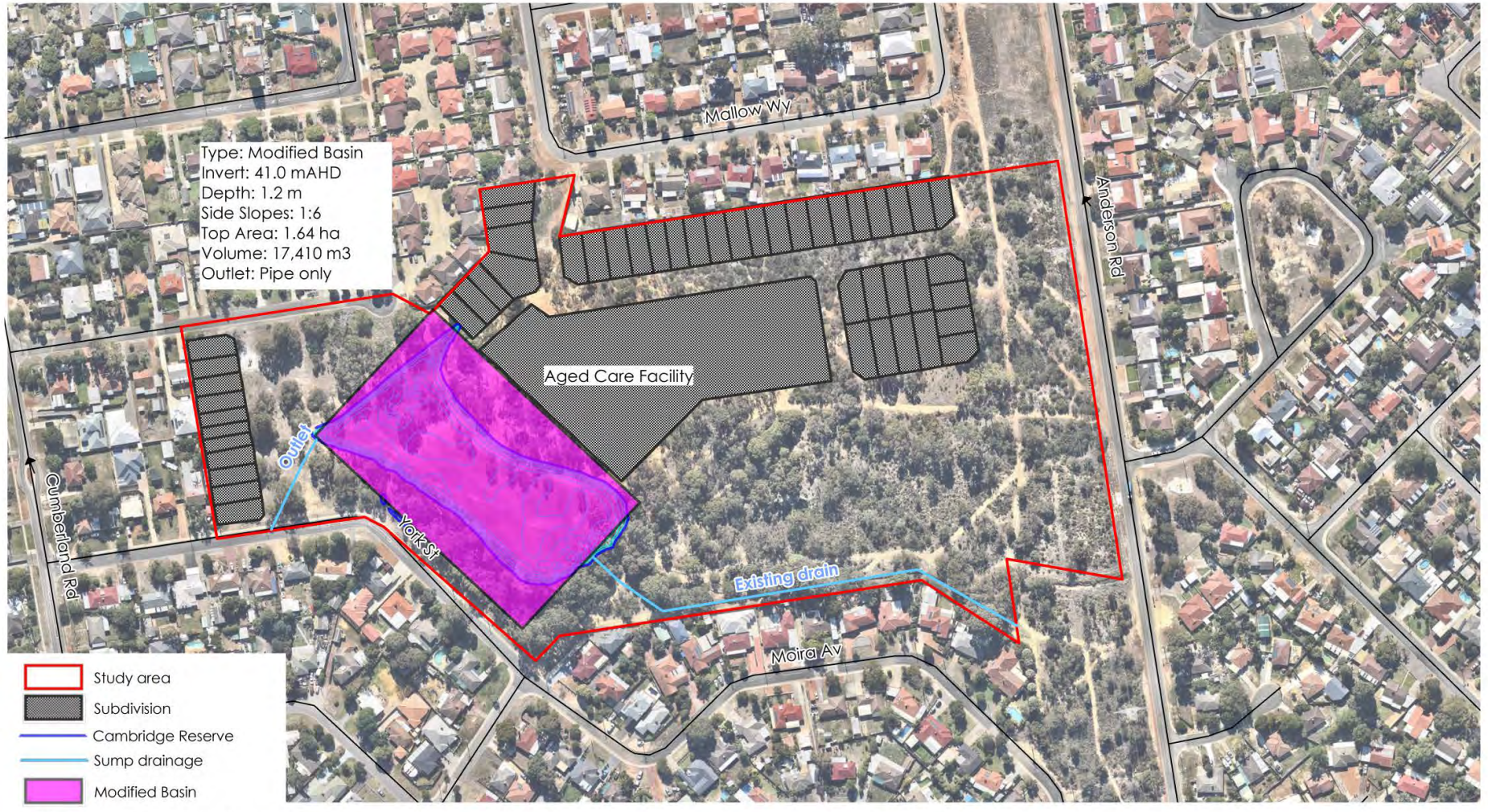


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Data source: MRWA, Landgate. Created by: RV. Projection: MGA: zone 50.

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meters
Scale 1:3,500 @A4

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City of Kalamunda - Modelling Report for Cambridge Reserve, Forrestfield
Figure 4 - Reconfigured Basin Only



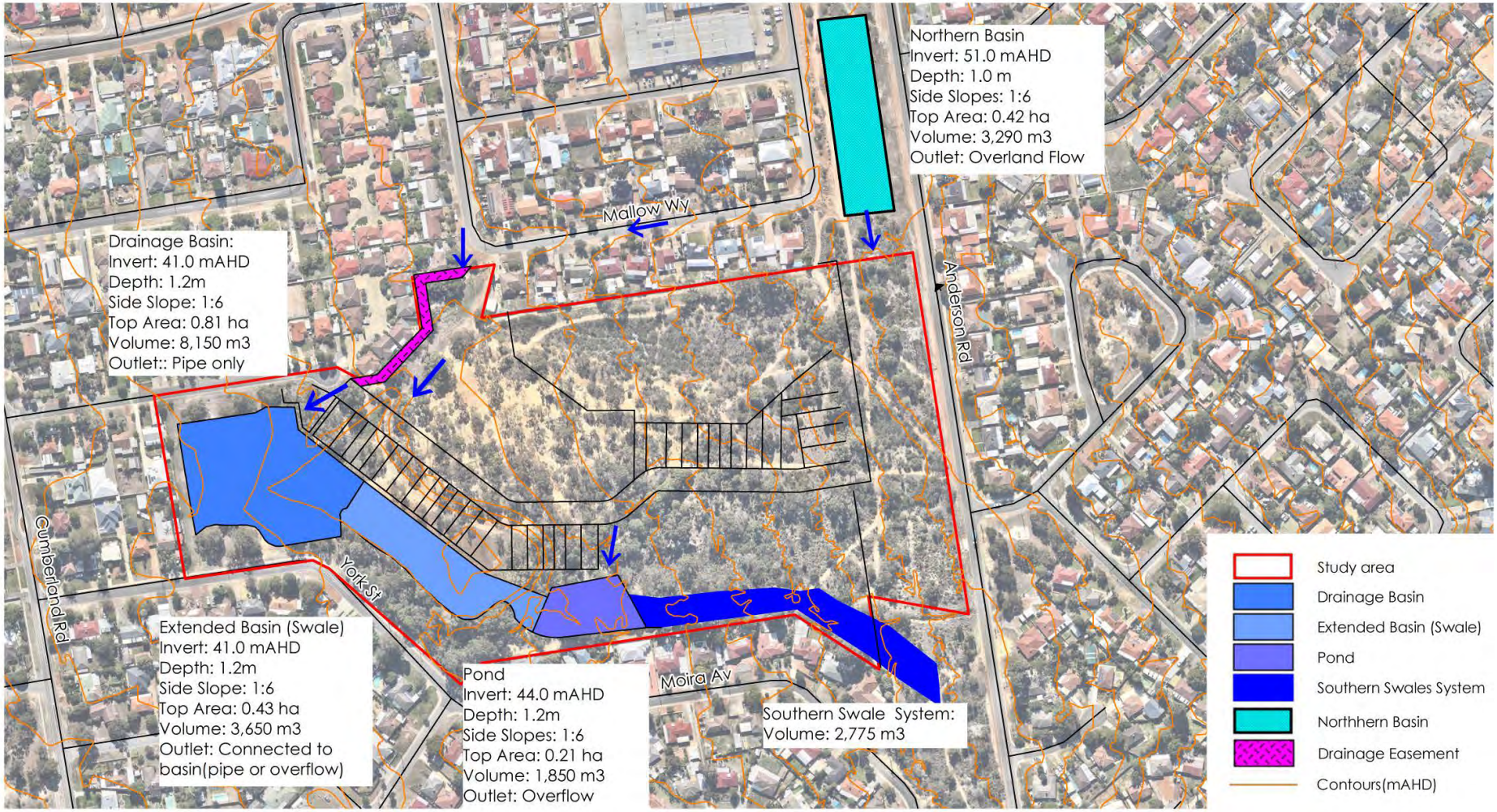
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Data source: MRWA, Landgate. Created by: RV. Projection: MGA: zone 50.

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Scale 1:3,000@A4

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City of Kalamunda - Modelling Report for Cambridge Reserve, Forrestfield

Figure 5 - Drainage System for Concept Plan



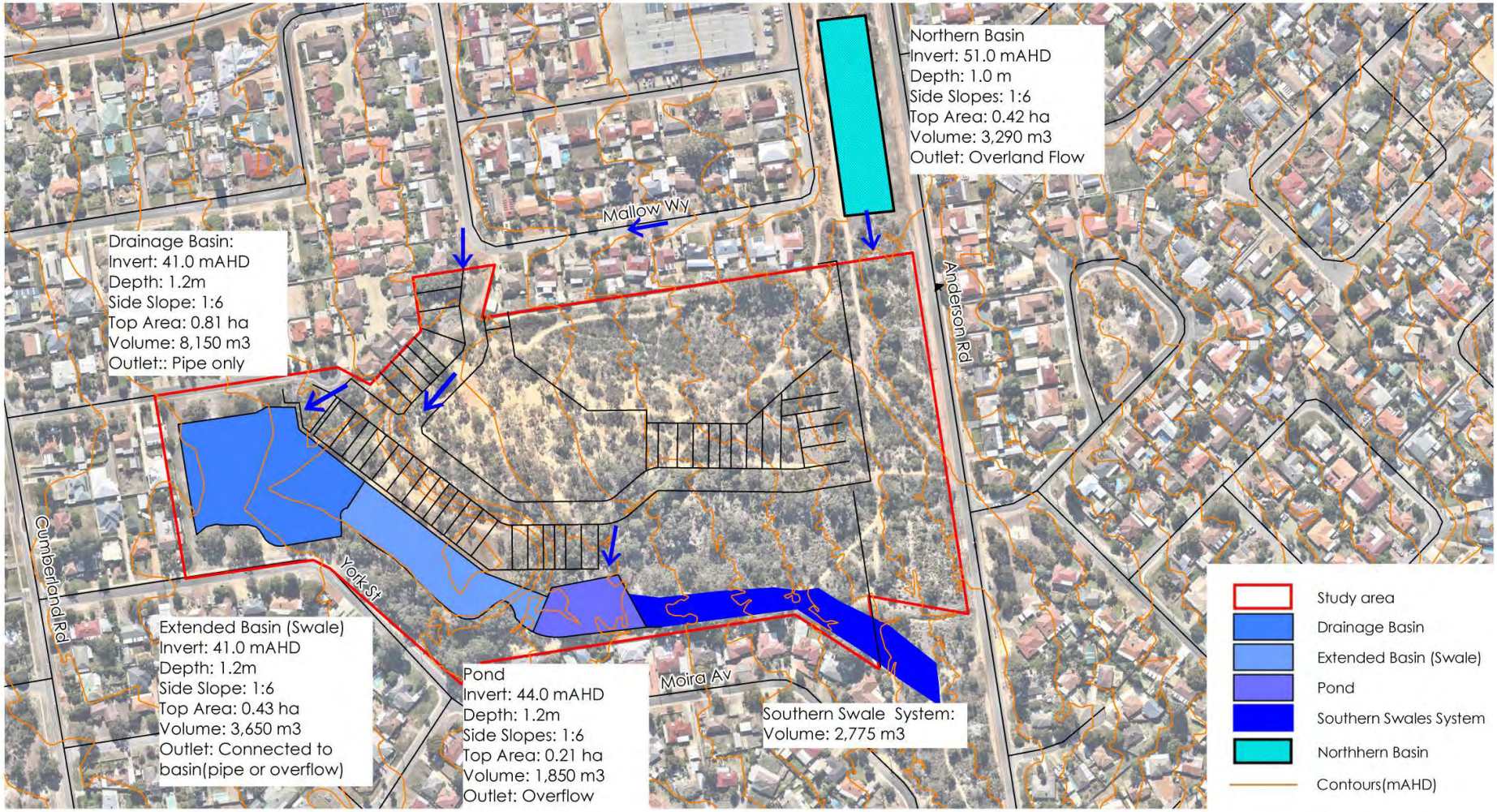
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Data source: MRWA, Landgate. Created by: RV. Projection: MGA: zone 50.

0 200
meters
Scale 1:3,500 @A4

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Figure 6 - Drainage System for Alternative Concept Plan



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Data source: MRWA, Landgate. Created by: RV. Projection: MGA: zone 50.

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meters
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APPENDIX 5 – UNDO RESULTS PRE-DEVELOPMENT

Government of Western Australia
Department of Water

Project: Cambridge Pre-Dev

Date: 08-May-20

Version: Version 1.1.0.16333

Subregion name: Subregion 1

Landuse	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Input load Phosphorus (kg)
Residential	0	0.00	0.00	0.00
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	100	9.00	0.00	0.00
Road reserve	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
9.00	100

Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
5.23	0.15

Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
0.35	0.00

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	100	9.00
Nature	0	0.00
Sport	0	0.00
Recreation	0	0.00
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
9.00	100

Nitrogen input (kg)	Phosphorus input (kg)
0.00	0.00

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Forrestfield**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**20**		
Groundwater slope (%)	**0.5**		
Soil PRI	**18.7**		

Note: Please attach the results of soil tests to this report when submitting.

Summary: Nutrient stripping devices

Treatment Name	Size (m²)	Treated area (ha)	Treating	N removed (kg/ha/yr)	P removed (kg/ha/yr)
Load removed				**0.00**	**0.00**
Net export				**0.35**	**0.00**

Summary: Nutrient load exports

Region	Area (ha)	P export (kg/ha/yr)	N export (kg/ha/yr)
Subregion 1	9.00	0.00	0.35

PRE-TREATMENT LOAD (kg/ha/yr)		LOAD REMOVED (kg/ha/yr)		NET LOAD EXPORT (kg/ha/yr)	
NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS
0.35	**0.00**	**0.00**	**0.00**	**0.35**	**0.00**

APPENDIX 6 – UNDO RESULTS POST-DEVELOPMENT

Government of Western Australia
Department of Water

Project: Cambridge Post-Dev

Date: 08-May-20

Version: Version 1.1.0.16333

Subregion name: Development

Landuse	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Input load Phosphorus (kg)
Residential	76	2.67	58.87	17.60
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	0	0.00	0.00	0.00
Road reserve	24	0.84	17.69	2.01

Total area (ha)	Total percent (%)
3.51	39

Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
27.04	5.74

Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
2.12	0.04

Residential

Size (m²)	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Input load Phosphorus (kg)
<400	43	1.15	26.95	7.89
400-500 m²	0	0.00	0.00	0.00
501-600 m²	0	0.00	0.00	0.00
601-730 m²	0	0.00	0.00	0.00
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	57	1.52	31.92	9.70

Total area (ha)	Total percent (%)
2.6676	76

Nitrogen input (kg)	Phosphorus input (kg)
58.87	17.60

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	70	0.59
Road reserve - impervious	0	0.00
Road reserve - native garden	15	0.13
Road reserve - non-native garden	0	0.00
Road reserve - turf	15	0.13
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
0.8424	24

Nitrogen input (kg)	Phosphorus input (kg)
17.69	17.69

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**Yes**
Soil type	**Forrestfield**	Type of fill imported	**Yellow sand (Spearwood)**
Depth to groundwater (m)	**20**	Fill depth (m)	**2**
Groundwater slope (%)	**0.5**	Approximate PRI of imported fill	**11**
Soil PRI	**17.9**	**Does subregion contain onsite sewage diposal system?**	**No**

Note: Please attach the results of soil tests to this report when submitting.

Subregion name: POS

Landuse	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Input load Phosphorus (kg)
Residential	0	0.00	0.00	0.00
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	100	5.49	0.00	0.00
Road reserve	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
5.49	61

Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
5.23	0.15

Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
0.38	0.00

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	100	5.49
Nature	0	0.00
Sport	0	0.00
Recreation	0	0.00
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
5.49	100

Nitrogen input (kg)	Phosphorus input (kg)
0.00	0.00

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Forrestfield**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**20**		
Groundwater slope (%)	**0.5**		
Soil PRI	**18.7**		

Note: Please attach the results of soil tests to this report when submitting.

Summary: Nutrient stripping devices

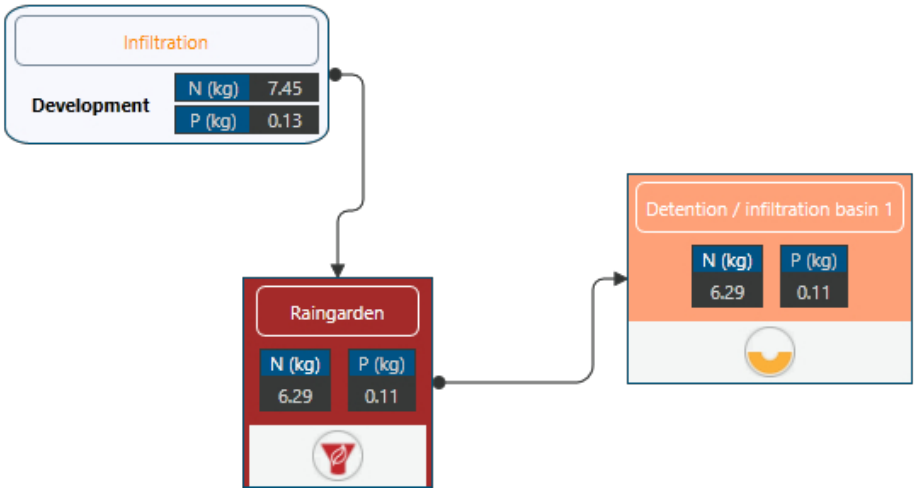
Treatment	Name	Size (m²)	Treated area (ha)	Treating	N removed (kg/ha/yr)	P removed (kg/ha/yr)
Detention / infiltration basin	Detention / infiltration basin 1	0.00	3.51		0.00	0.00
Biofilter	Raingarden	124.00	3.51	Sandy soils – Runoff only (infiltration on lots)	0.33	0.01
Load removed					**0.13**	**0.00**
Net export					**0.93**	**0.01**

Summary: Nutrient load exports

Region	Area (ha)	P export (kg/ha/yr)	N export (kg/ha/yr)
Development	3.51	0.04	2.12
POS	5.49	0.00	0.38

PRE-TREATMENT LOAD (kg/ha/yr)		LOAD REMOVED (kg/ha/yr)		NET LOAD EXPORT (kg/ha/yr)	
NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS
1.06	0.02	0.13	0.00	0.93	0.01

Treatment diagram



Client: City of Kalamunda

Report	Version	Prepared by	Reviewed by	Submitted to Client	
				Copies	Date
Draft	V1	RP / YY	HB	Electronic	May 2020
City of Kalamunda review	V2	RP / YY	HB	Electronic	May 2020

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e: info@urbaqua.org.au
www.urbaqua.org.auL

Appendix K – Bushfire Management Plan

SMITH BUSHIRE CONSULTANTS Pty Ltd

BUSHFIRE MANAGEMENT PLAN

Cambridge Reserve, Cambridge Road, Forrestfield

City of Kalamunda

Prepared by Ralph Smith
BPAD 27541
smith.consulting@bigpond.com
0458 292 280

Site visited 22 April 2020; Report completed 26 May 2020

Bushfire management plan/Statement addressing the Bushfire Protection Criteria coversheet

Site address: Cambridge Reserve, Cambridge Road, Forrestfield

Site visit: Yes ☑ No ☐

Date of site visit (if applicable): Day 22 Month April Year 2020

Report author: Ralph Smith

WA BPAD accreditation level (please circle):

Not accredited ☐ Level 1 BAL assessor ☐ Level 2 practitioner ☑ Level 3 practitioner ☐

If accredited please provide the following.

BPAD accreditation number: 27541 Accreditation expiry: Month August Year 2020

Bushfire management plan version number: 3.2

Bushfire management plan date: Day 26 Month May Year 2020

Client/business name: City of Kalamunda

	Yes	No
Has the BAL been calculated by a method other than method 1 as outlined in AS3959 (tick no if AS3959 method 1 has been used to calculate the BAL)?		✓
Have any of the bushfire protection criteria elements been addressed through the use of a performance principle (tick no if only acceptable solutions have been used to address all of the bushfire protection criteria elements)?		✓

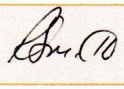
Is the proposal any of the following (see SPP 3.7 for definitions)?	Yes	No
Unavoidable development (in BAL-40 or BAL-FZ)		✓
Strategic planning proposal (including rezoning applications)		✓
Minor development (in BAL-40 or BAL-FZ)		✓
High risk land-use		✓
Vulnerable land-use		✓

None of the above ☐

Note: Only if one (or more) of the above answers in the tables is yes should the decision maker (e.g. local government or the WAPC) refer the proposal to DFES for comment.

Why has it been given one of the above listed classifications (E.g. Considered vulnerable land-use as the development is for accommodation of the elderly, etc.)?

The information provided within this bushfire management plan to the best of my knowledge is true and correct:

Signature of report author  Date 26/05/2020

NOTE

This Bushfire Management Plan has been developed by Smith Bushfire Consultants Pty Ltd for the exclusive use of the client, City of Kalamunda and their agents.

The plan has been compiled using the standard methodologies required by Western Australian government departments and agencies. It is based on the following:

- *State Planning Policy 3.7 Planning in Bushfire Prone Areas (SPP 3.7)*, December 2015
- *Guidelines for Planning in Bushfire Prone Areas*, December 2017
- *Australian Standard 3959 – Construction of buildings in bushfire-prone areas*, November 2018
- Standard fuel load field data collection methods and conversion to a fuel load applicable for the appropriate fire spread models.

The techniques described in the above publications have been applied in the appropriate areas and circumstances for the development of this document.

Where there was no public access the interpretation is based on photographic and satellite imagery, and a laser distance meter was used to measure slope and distances and Nearmap aerial photographs for the effective slope.

It is recommended that this Bushfire Management Plan be revised every five years to ensure that it remains relevant and in-line with current requirements. This will optimise protection. It is proposed that the property owners undertake the review.

DISCLAIMER

This Bushfire Management Plan has been prepared in good faith. It is derived from sources believed to be reliable and accurate at the time of publication. Nevertheless, this plan is distributed on the terms and understanding that the author is not responsible for results of any actions taken based on information in this publication or for any error or omission from this publication.

Smith Bushfire Consultants Pty Ltd has exercised due and customary care in the preparation of this Bushfire Management Plan and has not, unless specifically stated, independently verified information provided by others.

Any recommendations, opinions or findings stated in this report are based on circumstances and facts as they existed at the time Smith Bushfire Consultants Pty Ltd performed the work. Any changes in such circumstances and facts upon which this document is based may adversely affect any recommendations, opinions or findings contained in this plan.

Document control

Report Version	Purpose	Author/reviewer and accreditation details	Date Submitted
1	Support document for the development	Ralph Smith	26 April 2019
2	Revised BMP with modified layouts	Ralph Smith	4 May 2020
3	Revised BMP with modified layouts	Ralph Smith	25 May 2020
3.1	Minor text changes	Ralph Smith	25 May 2020
3.2	Minor text changes	Ralph Smith	26 May 2020

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Section 1: Proposal Details

The City of Kalamunda has undertaken a number community engagements which sought feedback from the community on how they would like to see Cambridge Reserve improved.

The initial concept plan was endorsed by the Council in February 2019 for the purposes of progressing further technical studies, consultation with the State Government authorities and preparing for the land administration process and Local Planning Scheme amendment to support the proposed improvements. During consultation with State Government agencies in 2019,it became evident that further investigation was required to identify and protect environmental values on the site prior to progressing the concept. This process identified required modifications to the concept plan to protect Threatened Ecological Communities and provided an opportunity to reconsider modifications to the drainage basin to improve amenity, environmental and recreational outcomes. In late 2019 / early 2020, the City completed technical studies to support a modified concept plan.[1]

As a result of the technical studies a revised concept design was produced with two options. Both options are shown within this BMP.

[1] Source: Urbis, 2020, Cambridge Reserve Community enhancement Project Concept Plan Report



Figure 1. A copy of the site plan (Option1).



Figure 2. A copy of the site plan (Option2).

The Cambridge Reserve site is declared as bushfire prone. This development site may be partially cleared ready for the construction of homes and associated infrastructure. The related infrastructure includes car parks and active playgrounds. Other portions of the site will be fenced and revegetated utilising native species.

The active playgrounds, associated public open spaces (POS) and 'Fire Hazard Reduction Zones' will all be developed as 'low threat vegetation' to ensure appropriate public amenity and not add as a bushfire threat.



Figure 3. Aerial photo of the bushfire prone area for the subject site.

Section 2: Environmental Considerations

Subsection 2.1: Native Vegetation – modification and clearing

The site will be partially cleared as a component of this development. There are a number of native species overstorey species and there are a number of the tree overstorey species that are introduced species. The indicative development and Landscape Concept Plan demonstrates the potential impact of the subdivision on the environment. There is a significant southern portion of the site that will be fenced, being the 'good' bushland and the bushland revegetation and other portions of the bush revegetation. These areas are identified on the Vegetation Types Plan as areas 3, 5 and 7 respectively[2] and on the Concept Plan as 'Retained Vegetation'.

Subsection 2.2: Re-vegetation/Landscape Plans

The active playgrounds and public open spaces (POS) being the activity hub, open managed parkland and the drainage basin and swales will all be developed as 'low threat vegetation' to ensure appropriate public amenity and not contribute as a bushfire threat.

[2] From the PGV Environmental Flora and Vegetation Assessment.

Section 3: Bushfire assessment results

Subsection 3.1: Assessment Inputs

Vegetation Classification Map (Pre-development)

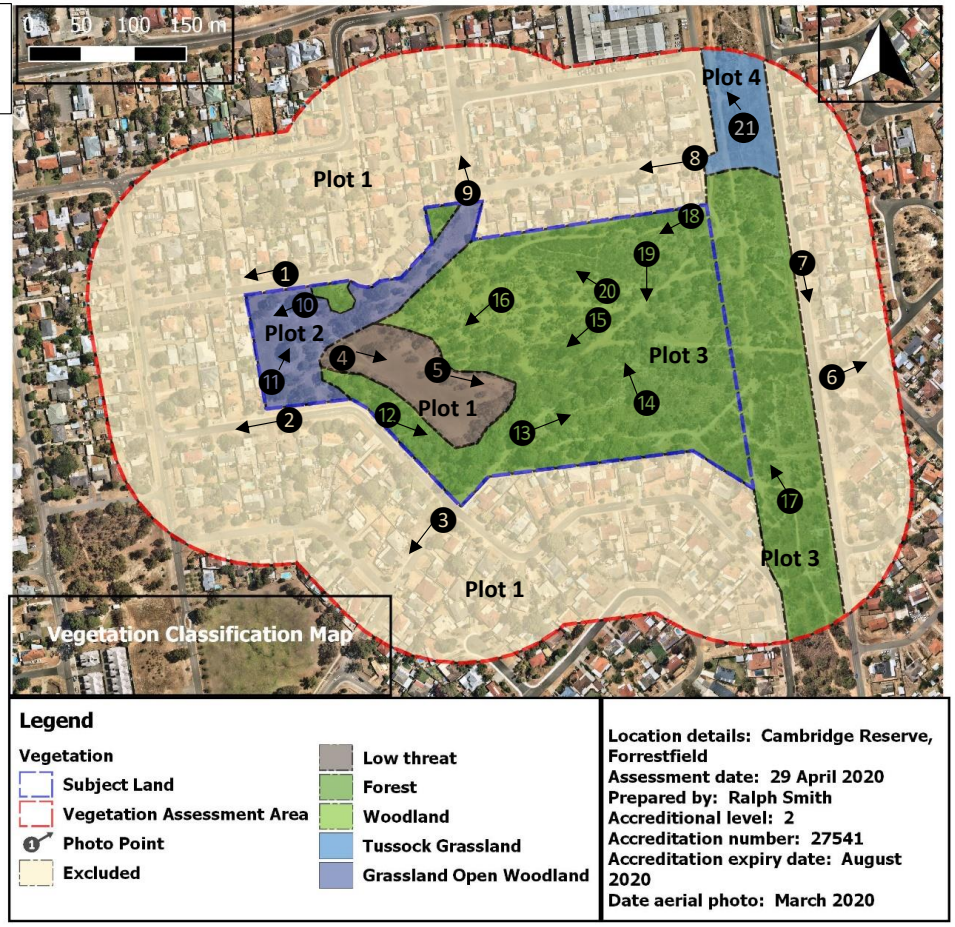


Figure 4. Vegetation classification map pre-development.



Figure 5. Vegetation classification map post-development.

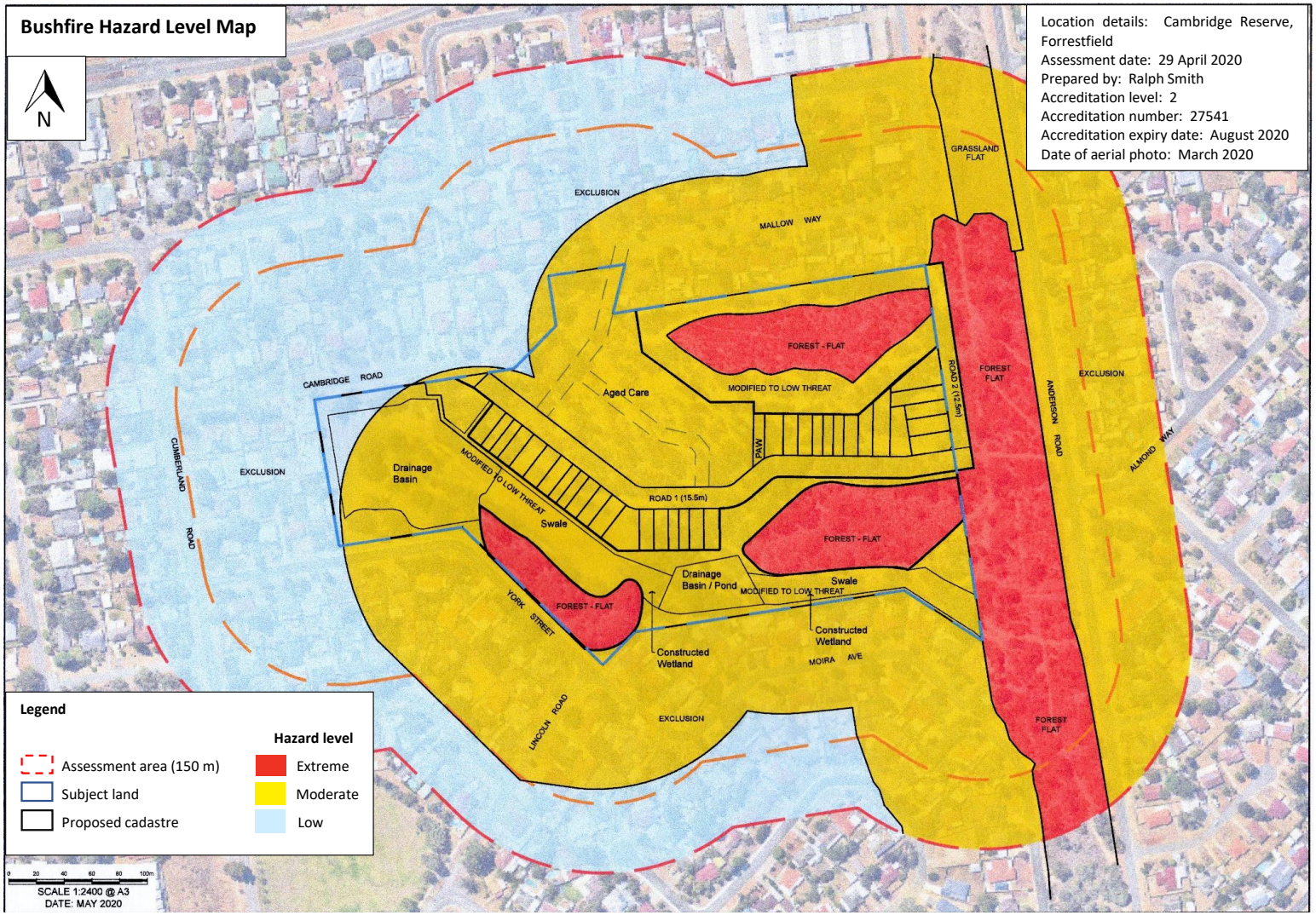


Figure 6. Bushfire hazard level map for Option 1.

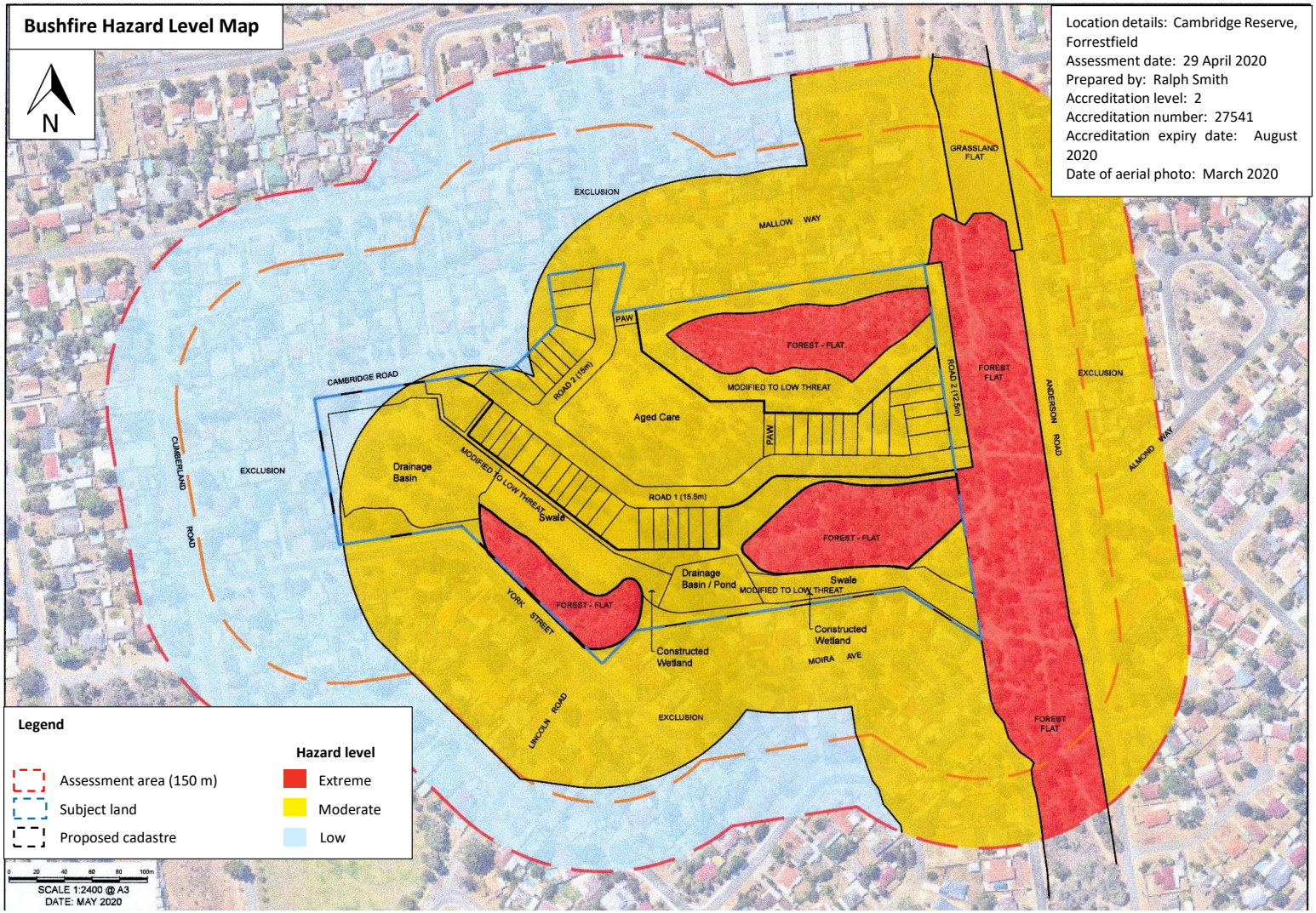


Figure 7. Bushfire hazard level map for Option 2.

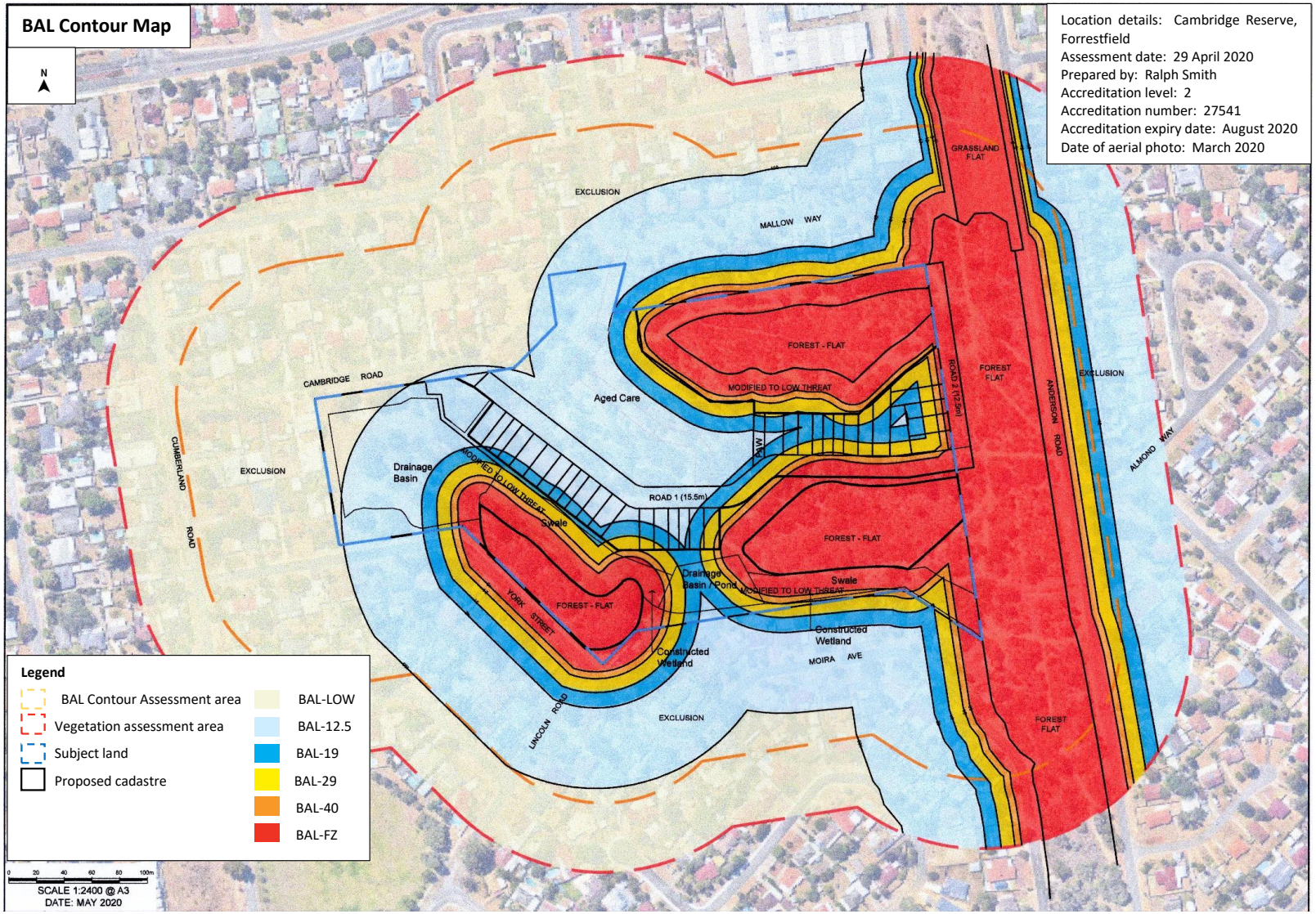


Figure 8. BAL contour map (Option 1).

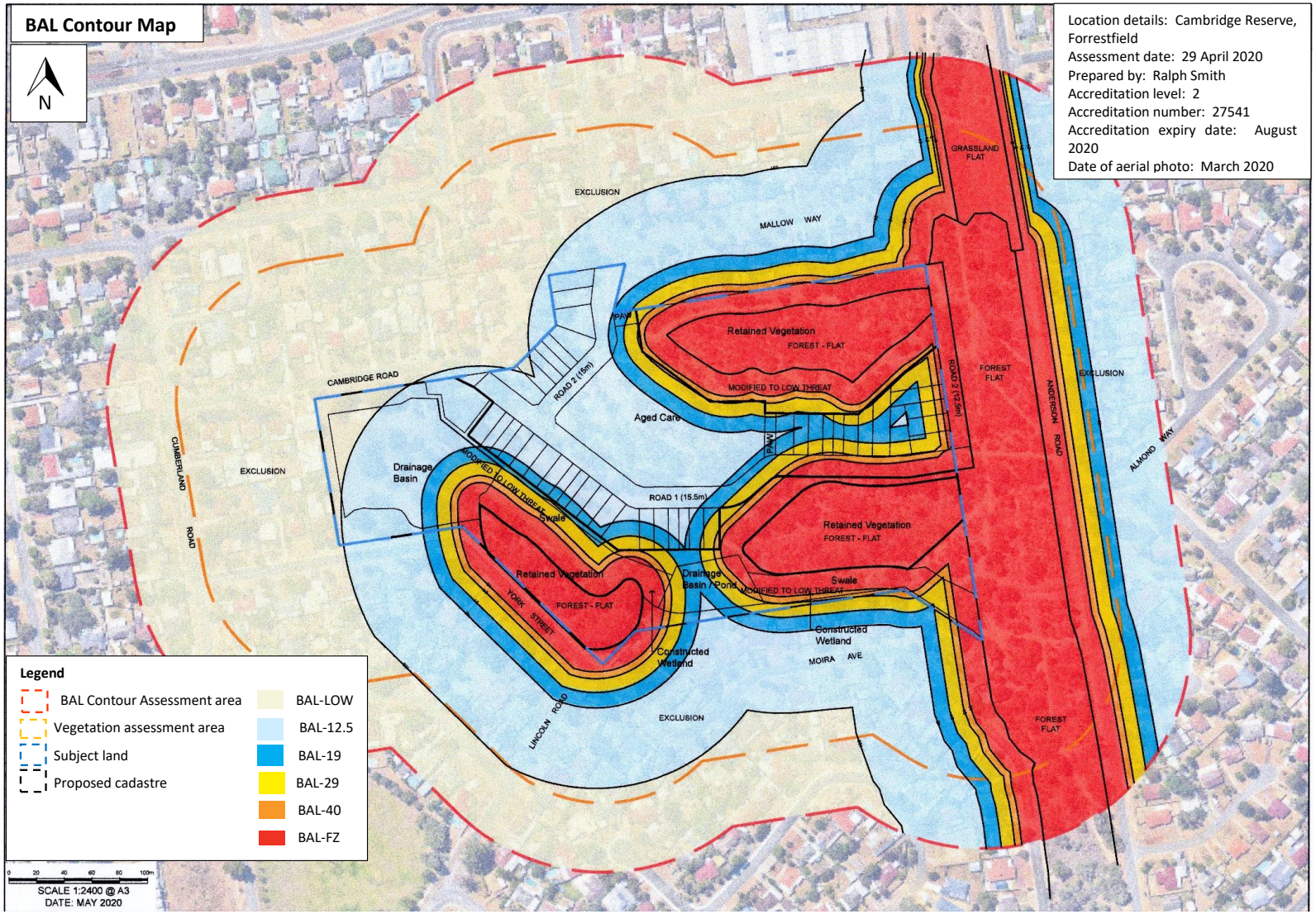


Figure 9. BAL contour map (Option 2).

Plot 1
Exclusion
Clause 2.2.3.3 (e) and (f)



Photo ID: Photo 1 The road infrastructure and established houses and gardens.



Photo ID: Photo 2 The developed housing and infrastructure adjacent to the site.



Photo ID: Photo 3 The developed housing and infrastructure south of the site.



Photo ID: Photo 4 The cleared area which acts as a drainage basin.



Photo ID: Photo 5 The cleared area which acts as a drainage basin.



Photo ID: Photo 6 The infrastructure and dwellings east of the development site.



Photo ID: Photo 7 The infrastructure and dwellings east of the development site.



Photo ID: Photo 8 The infrastructure and dwellings north of the development site.



Photo ID: Photo 9 The infrastructure and dwellings north of the development site.

Plot 2

Class G – Grassland under an open canopy (AS 3959 vegetation classification G – 06)



Photo ID: Photo 10 The grass under an open woodland in the western portion of the development site.



Photo ID: Photo 11 The grass under an open woodland and children's play facilities.

Plot 3
Class A – Forest (AS 3959 vegetation classification A – 03)



Photo ID: Photo 12 The woodland vegetation in the southern area of the development site.



Photo ID: Photo 13 The woodland vegetation in the central portion of the development site.



Photo ID: Photo 14 The woodland vegetation in the central portion of the development site.



Photo ID: Photo 15 The woodland revegetation in the northern portion of the development site.



Photo ID: Photo 16 The modified woodland vegetation with an absence of understorey.



Photo ID: Photo 17 The forest vegetation under the powerline east of the development site.



Photo ID: Photo 18 The forest revegetation plantings and scrub understorey.



Photo ID: Photo 19 The forest revegetation plantings and scrub understorey.



Photo ID: Photo 20 The scrub vegetation in the foreground and tree overstorey cover in the background.

Plot 4

Class G – Grassland (AS 3959 vegetation classification G – 21)



Photo ID: Photo 21 The grassland north of the development site.

Notes to Accompany Vegetation Classification

1. Plot 1
Exclusion – Low threat vegetation and non-vegetated areas
Clause 2.2.3.2 (e) (f)

This plot comprises the houses, sheds, gardens and infrastructure around the development site. The site is within an established suburb with all of the amenities such as roads, reticulation scheme water and power.

2. Plot 2
Class G – Grassland under an open woodland (AS 3959 classification – G – 06).

This plot comprises the grass under a sparse overstorey coverage across the western side of the development site. This plot also includes the current playground equipment.

3. Plot 3
Class A – Forest (AS 3959 classification – A – 03).

The forest plot shows the classic forest vegetation structure, which includes a multi-tiered scrub understorey in a number of locations, but not all. There has been some overstorey revegetation in a number of the forest areas, in particular, over the open heath. This revegetation is poorly developed at this stage, but by applying the required precautionary principle, the revegetation is assessed as being capable of developing into a well-established tree overstorey.

There are three areas which have been determined to be threatened ecological communities. These are shown in Appendix 3. The botanical vegetation classification and the AS 3959 (2018) vegetation classification do not perfectly align. The greatest threat vegetation to a building has been applied within the BMP.

4. Plot 4
Class G – Grassland (AS 3959 classification – G – 21).

The plot shows the grassland vegetation which is located north of the development site and under the major powerline.

Slope
The yellow lines on the two metre contour lines and the orange lines on the slope aerials (Nearmap) show the surface slope, and the blue line the vegetation and buildings above the surface.

The land surrounding the development site is an established suburb with no vacant land that is vegetated except the forest and grassland under the powerline to the east and north-east.



Figure 10. Two metre contour lines.

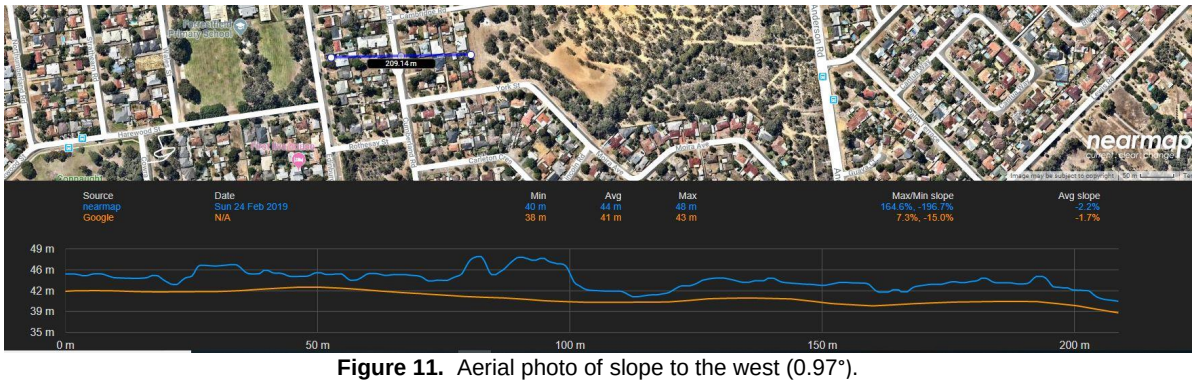


Figure 11. Aerial photo of slope to the west (0.97°).



Figure 12. Aerial photo of slope to the north (0.57°).



Figure 13. Aerial photo of slope to the east (1.95°).

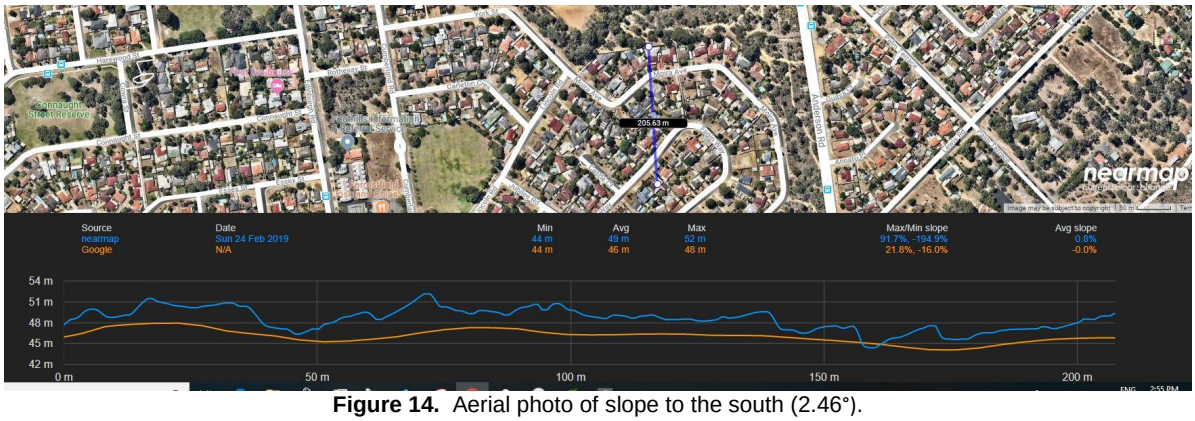


Figure 14. Aerial photo of slope to the south (2.46°).

Subsection 3.2: Assessment outputs

Method 1 BAL Determination				
Vegetation Area/Plot	Applied Vegetation Classification	Effective Slope Under the Classified Vegetation (degrees)	Separation Distance to the Classified Vegetation (metres)	Bushfire Attack Level
1	Exclusion	Not applicable	Not applicable	LOW
2	Grassland with an open woodland	Not applicable	25	12.5
3	Forest	Not applicable	21	40
4	Grassland	Not applicable	21	12.5
			Determined Bushfire Attack Level	12.5

The above information is based on the proposed vegetation pre-development. The vegetation post development is shown in the Concept Plan. The BAL ratings may drop as the vegetation management and clearing for development progresses. The lots should have specific BAL assessments completed prior to building permits being issued. This is particularly relevant with the land and vegetation adjacent to the subdivision components of the site, which are planned to be Retained Vegetation and the forest vegetation to the east of the site. The actual separation between the dwelling and the threat vegetation needs to be determined on a case-by-case basis.

Section 4: Identification of bushfire hazard issues

The principle bushfire hazard is the Retained Vegetation within the development site, and east of the development site, including the land beneath the powerline. The Retained Vegetation will present an ongoing bushfire threat to the buildings within the development site. The development of the public open spaces and Fire Hazard Reduction Zone to 'low threat vegetation' status will also contribute to reduce any potential bushfire threat, and create a separation of the buildings and bushfire fuel to minimise the bushfire threat to future dwellings.

Section 5: Assessment against the Bushfire Protection Criteria

Subsection 5.1: Compliance

Bushfire protection criteria	Method of Compliance Acceptable solutions	Proposed bushfire management strategies
Element 1: Location	A1.1 Development location	This development will be developed in such a manner that on completion all lots will be able to have dwellings located on the lots at BAL–29 or lower. The area that will contain future buildings will be rated as a moderate or low level hazard when the Concept Plan is implemented.
Element 2: Siting and design	A2.1 Asset Protection Zone (APZ)	There will not be any APZ requirements on these lots.
Element 3: Vehicular access	A3.1 Two access routes	There are multiple access options that facilitate movement to a range of alternative locations and directions of travel.
	A3.2 Public road	All public roads will be constructed to the appropriate standards as required in the Guidelines.
	A3.3 Cul-de-sac (including a dead-end-road)	There will be no new dead-end roads in the development that exceed the requirements in the Guidelines.
	A3.4 Battle-axe	Not applicable.
	A3.5 Private driveway longer than 50 m	Not applicable.
	A3.6 Emergency access way	Not applicable.
	A3.7 Fire service access routes (perimeter roads)	Not applicable.
	A3.8 Firebreak width	Firebreaks will be established and maintained in accordance with the City's firebreak and fuel load notice where appropriate.
Element 4: Water	A4.1 Reticulated areas	The site will be serviced with reticulated mains water in accordance with the State Government requirements.
	A4.2 Non-reticulated areas	Not applicable.
	A4.3 Individual lots within non-reticulated areas (Only for use if creating 1 additional lot and cannot be applied cumulatively)	Not applicable.

Subsection 5.2: Additional management strategies



Legend

1. Subject land
2. Cadastre
3. Access roads

Notes

1. AS 3959 construction standards apply to the areas within the declared bushfire prone areas and where a lot is BAL rated at BAL–12.5 or above.
2. The site will have reticulated mains water supply.
3. Forest to the south and east, and grassland to the north-east of the proposed buildings are the primary vegetation plots that provides an ongoing bushfire threat.
4. The site will be partially cleared during the development.
5. The POS will all be developed as 'low threat vegetation'.
6. The drainage basin and swales will be revegetated to 'low threat vegetation'.

Location details: Cambridge Reserve
Local government area: City of Kalamunda
Assessment date: 25 May 2020
Prepared by: Ralph Smith
Accreditation level: 2
Accreditation number: 27541
Accreditation Expiry Date: August 2020
Date of Aerial photo: March 2020
Version No: 3

Figure 15. Spatial representation of bushfire management strategies.

Section 6: Responsibilities for Implementation and Management of the Bushfire Measures

DEVELOPER/LANDOWNER – PRIOR TO SALE OR OCCUPANCY	
No.	**Implementation Action**
1	Install the access ways, and associated signs to the standards stated in the Guidelines.
2	Establishing the water reticulation system and associated infrastructure, including hydrants at the prescribed standard
3	Ensuring that any new domestic dwellings to be built on the property are designed and constructed in full compliance with the requirements of the City of Kalamunda and as detailed in *Australian Standard 3959 – Construction of buildings in bushfire-prone areas*
4	Develop the drainage basin, swale and pond vegetation and public open space including the 'Fire hazard reduction zone' as 'low threat vegetation.'
5	Place a notification on title pursuant to *section 165A of the Planning and Development Act 2005* stating *"This land is within a bushfire prone area as designated by an Order made by the Fire and Emergency Services Commissioner and may be subject to a Bushfire Management Plan. Additional planning and building requirements may apply to development on this land".*

LANDOWNER/OCCUPIER – ONGOING MANAGEMENT	
No.	**Management Action**
1	Comply with the relevant local government annual firebreak notice issued under s33 of the Bush Fires Act 1954.

Appendix 1

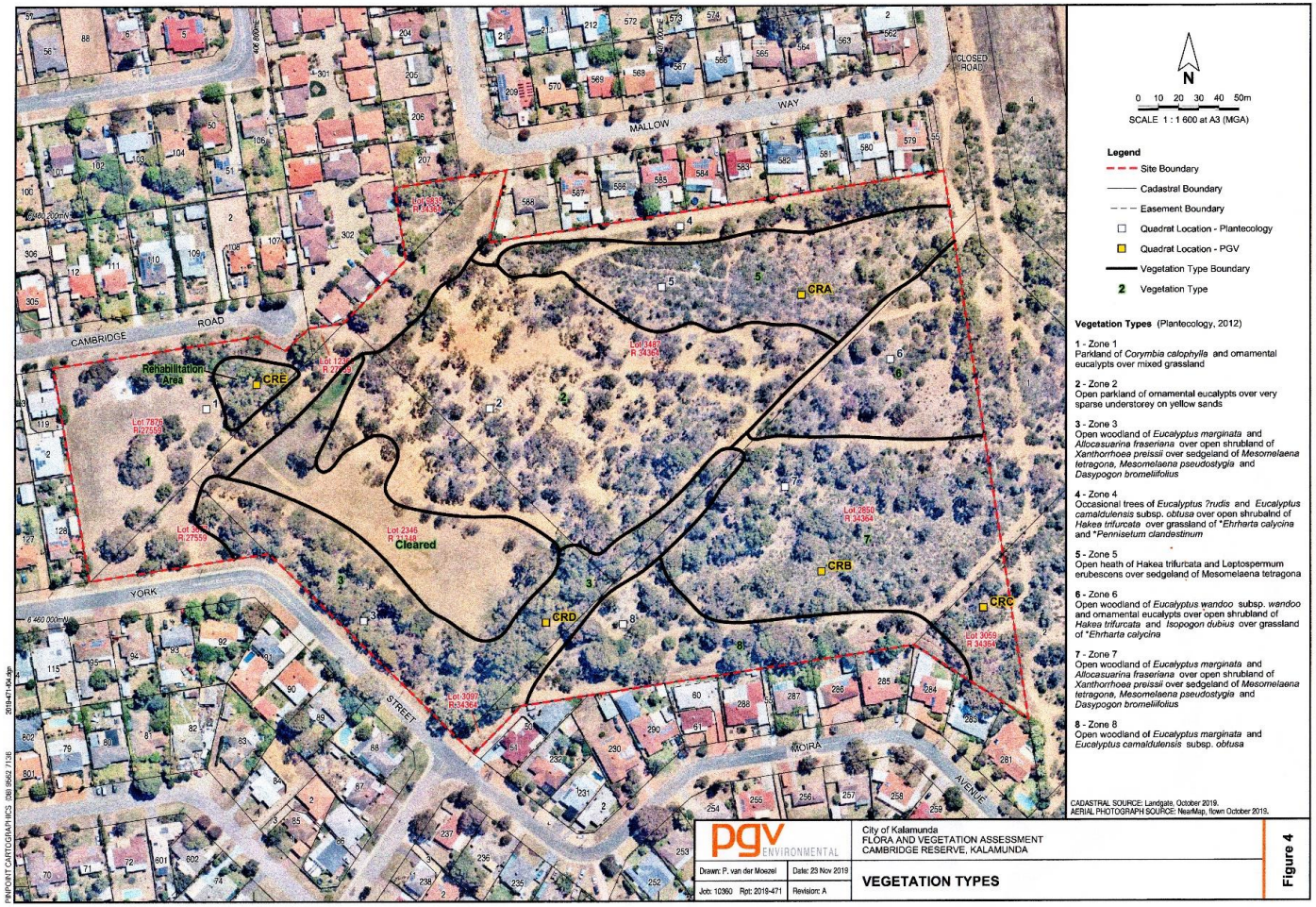
Vehicle technical requirements extracted from the Guidelines (page 68).

Table 4: Vehicular access technical requirements

TECHNICAL REQUIREMENTS	1 Public road	2 Cul-de-sac	3 Private driveway	4 Emergency access way	5 Fire service access routes
Minimum trafficable surface (m)	6*	6	4	6*	6*
Horizontal clearance (m)	6	6	6	6	6
Vertical clearance (m)	4.5	N/A	4.5	4.5	4.5
Maximum grade <50 metres	1 in 10	1 in 10	1 in 10	1 in 10	1 in 10
Minimum weight capacity (t)	15	15	15	15	15
Maximum crossfall	1 in 33	1 in 33	1 in 33	1 in 33	1 in 33
Curves minimum inner radius (m)	8.5	8.5	8.5	8.5	8.5
*Refer to E3.2 Public roads: Trafficable surface					

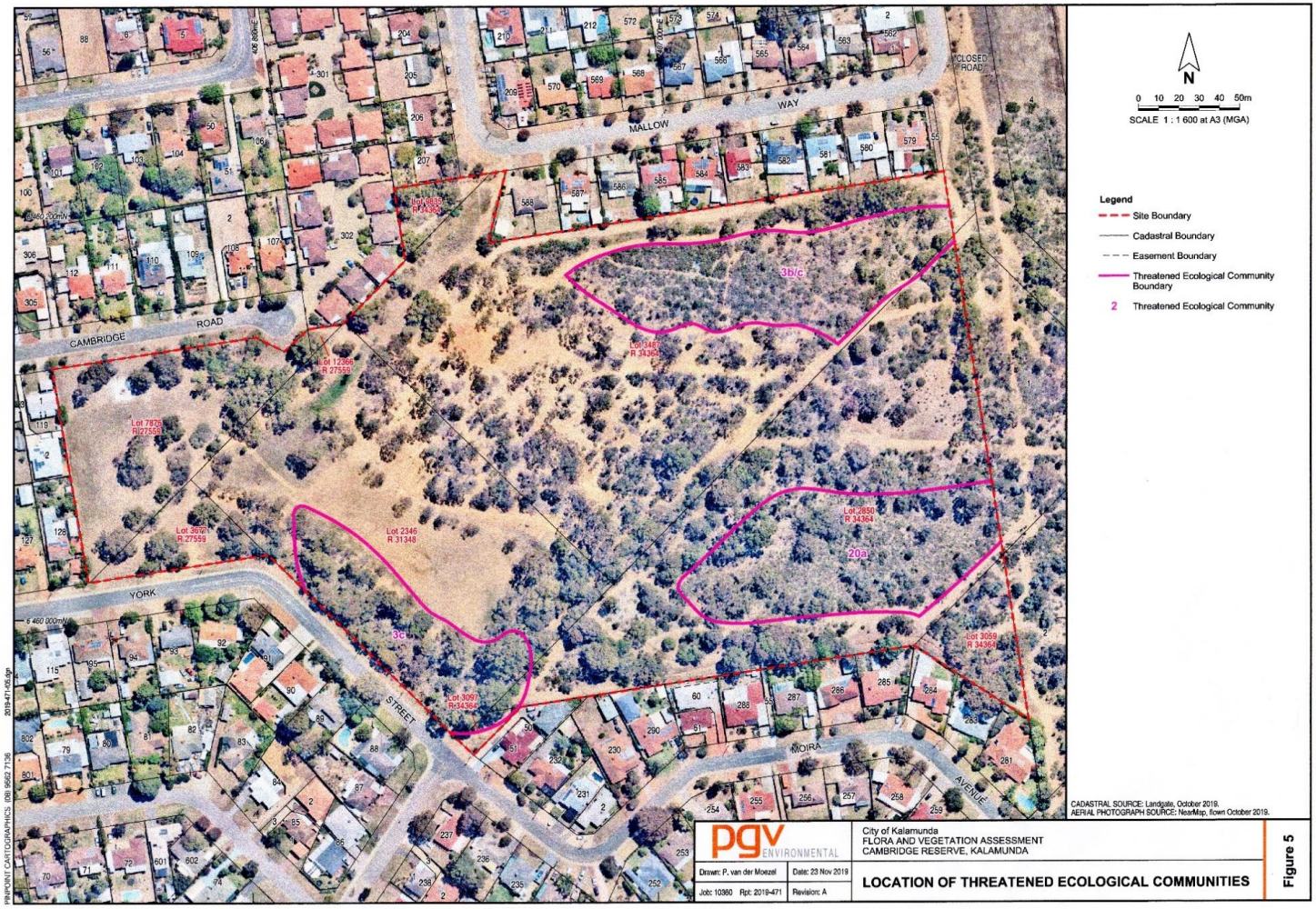
Appendix 2

Map of the vegetation types classified by a botanist, 23 November 2019. Source: City of Kalamunda.



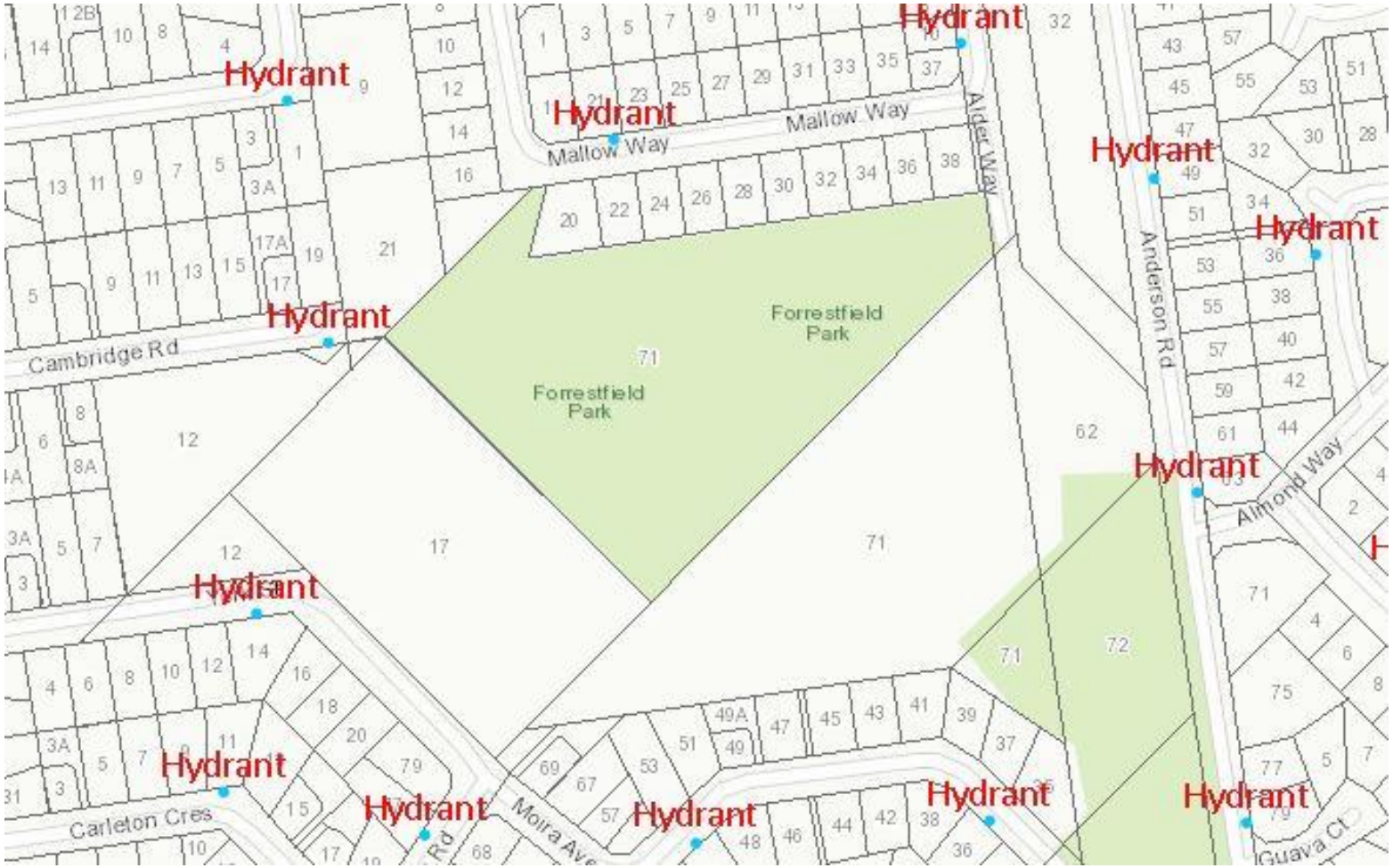
Appendix 3

Map of the threatened ecological community vegetation types classified by a botanist, 23 November 2019. Source: City of Kalamunda.



Appendix 4

Maps of the current fire hydrants and water meters.




Laurel St
Mallow Way
Alder Way
Anderson Rd
Forrestfield Park
Cambridge Rd
Cumberland Rd
York St
Rothesay St
Carleton Cres
Moira Ave
Almond Way
Guava Ct

Appendix 5

State Government hydrant standards.

2.2.1.5 Appurtenances

(b) Hydrants

Hydrants shall be screw-down hydrant with built-in isolation valve and installed only on DN100 or larger pipes. Hydrants shall be located:

- so that the maximum distance between a hydrant and the rear of a building envelope, (or in the absence of a building envelope the rear of the lot) shall be 120m and the hydrants shall be no more than 200m apart;
- a maximum of 100m spacing in Industrial and Commercial areas;
- hydrant spacing in rural residential areas where minimum site areas per dwelling is 10,000 m^2 (1ha), a maximum 400m hydrant spacing be applied. If area is further subdivided to land parcels less than 1ha, then the residential standard (200m) is to be applied;
- centrally along the frontage of a lot to avoid being under driveways;
- where appropriate at the truncation of road junctions or intersections so that they can serve more than one street and can be readily located;
- on both sides of the major roads at staggered intervals where there are mains on both sides of the road;
- at major intersections on dual multi-lane roads, where two hydrants are to be sited on diagonally opposite corners;
- hydrants should be located at least 20m from traffic calming devices i.e. median slow points or chokers, chicanes, mini traffic circles, and intersection 'pop-outs' to ensure traffic is not impeded;
- in a position not less than 10m from any high voltage main electrical distribution equipment such as transformers and distribution boards. AS 2419.1-2005
- hydrants with washout bends shall be used only in cul-de-sac situations.

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Near map from http://maps.au.nearmap.com/

Slope percentage to degrees conversion from https://www.calcunation.com/calculator/slope-percent-conversion.php

Contour map from https://maps.agric.wa.gov.au/nrm-info/

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