COTERRA
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Bindaring Wetland

Concept Plan Development

Revision 1, July 2017

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Concept Plan Development

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This report was prepared by:

Coterra Pty Ltd trading as COTERRA ENVIRONMENT
ABN: 92 143 411 456

Our Ref: TOBBWC01
Author(s): K. Chandler, C. Hopkirk
Reviewer: R. Epworth
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This report was prepared for:

Town of Bassendean
35 Old Perth Road
BASSENDEAN WA 6934

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EXECUTIVE SUMMARY

Bindaring Park is a local public open space located adjacent to the Swan River in the Town of Bassendean. The park is dominated by Bindaring Wetland, a modified wetland of varying conservation value. Bindaring Wetland is considered to predominately be an expression of groundwater, but also receives surface water inflows from the Town of Bassendean stormwater network.

The Town of Bassendean is seeking to improve the ecological and recreational value of Bindaring Park. The objective of this study is to develop three concept design options for the improvement of the water quality, ecological and recreational amenity aspects of the park.

The Town has recently undertaken a number of technical studies to support concept plan development. These studies include;

- A desktop environmental assessment (GHD, 2016),
- A weed management plan (Ecoscape, 2010),
- A revegetation action plan (Natural Area, 2015),
- Hydraulic modelling (GHD, 2016) of the northern portion of the wetland, and
- A preliminary acid sulphate soils investigation (GHD, 2016).

Further studies undertaken as part of this study to further support concept plan development included the following;

- Additional hydraulic modelling (Coterra, 2017) of the middle and southern portions of the wetland,
- Water quality modelling using the UNDO tool (Coterra, 2017),
- A fauna survey (Bamford Consulting Ecologists, 2017),
- A geotechnical investigation (Structerre, 2017) and
- A targeted acid sulphate soils (ASS) investigation (Western Environmental, 2017).

Three concept designs were prepared on the basis of the technical studies, feedback from the Friends of Bindaring Park group, and relevant state and local policies. The concept designs were prepared to meet the following design objectives:

1. Improve water quality within Bindaring Wetland through the improved treatment of urban stormwater runoff at stormwater discharge locations within the Park.

2. Improve ecological and habitat value through removal of weed vegetation, retention of high value trees and rehabilitation planting using with local native species.

3. Improve access, path connectivity and underutilised space within the park for improved recreational amenity.

4. Consider modification of hydraulic controls (e.g. removal of 'the causeway' and Hyland Street).

All three of the concept options prepared incorporated the same measures for weed management, revegetation, fauna habitat retention and ASS management. The following features varied between different options:

- Some recreational features such as boardwalks and community areas vary between concept design options.
- Stormwater quality treatment measures varied between the three concept designs, with each option including a selection of BMPs such as biofilters, swales and floating wetlands. The relative effectiveness of the water quality treatment measures proposed was calculated for each option using Department of Water and Environmental Regulation's UNDO tool.
- The modification of hydraulic controls (i.e. removal of Hyland Street and the causeway) were included in two options (see callout box on options 2 and 3). *Please note*: This element was not introduced until part way through the assessment as such the hydrological assessments in this study have not considered the impact of these structural changes to the hydrology and ecosystem. Further flood investigations and impacts of the changes to hydrology (inundation time and levels), as well as a salinity intrusion assessment would be required to consider their impact on the ecosystem and wetland vegetation.

The key differences between each concept design option, water quality treatment effectiveness and indicative cost is listed in Table E1 below.

Table E1 Summary of Concept Options

Option	Hydraulic Controls	Key landscape features	Water quality treatment	Water quality treatment effectiveness	Indicative Cost (Inc. GST $)*
1	Existing situation: Retention of causeway and Hyland Street	Wetland boardwalks with viewing deck/bird hide	6 biofilters, 3 swales and 1 floating wetland	Most effective – 0.86 kg/ha/yr N and 0.08 kg/ha/yr P removed.	1.64 M
2	Existing situation: Retention of causeway and Hyland Street Optional: Removal of causeway (if land is acquired)	Limited boardwalks	3 biofilters and 6 swales	0.56 kg/ha/yr N and 0.05 kg/ha/yr P removed.	1.40 M
3	Existing situation: Retention of causeway and Hyland Street Optional: Opening of Hyland Street Optional: Removal of causeway (if land is acquired)	Wetland boardwalks with viewing deck/bird hide	9 swales	Least effective – 0.27 kg/ha/yr N and 0.01 kg/ha/yr P removed.	1.45 M

*Engineering works required for the removal of Hyland Street and/or causeway are not included in this cost. Other exclusions are also listed in Section 5.4.2 and Appendix I.

As indicated in Table E1, Option 1 was found to be most effective at nutrient removal but was also the most expensive option overall. Option 2 was found to be the most cost effective option and achieved the second highest rate of nutrient removal, however had limited landscape/community features.

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1.0 INTRODUCTION

1.1 Background

Bindaring Park (the site) is a local Public Open Space (POS) adjacent to the Swan River within the Town of Bassendean (ToB). The Park has been previously subdivided into a number of lots. The Town of Bassendean owns the majority of these lots however a small number are in private ownership. The site boundary is shown in Figure 1 and includes only those lots under council ownership.

The park covers an area of approximately 10 ha and is dominated by natural wetland areas of varying conservation value. The wetlands are considered to be fed by both groundwater and surface water runoff from an urban catchment. Significant portions of the wetland have become degraded as a result of development within the catchment which has led to changes in wetland hydrology, water quality and species composition (GHD, 2016).

The Town of Bassendean are seeking to improve the ecological and recreational value of Bindaring Park. The objectives of this study are to:

- Undertake further technical assessments including geotechnical and acid sulphate soils investigations, fauna survey and hydraulic modelling to further characterise the opportunities and constraints associated with the improvement of Bindaring Park.
- Draw on previous and current technical investigations to develop three concept design options for the improvement of water quality, ecological value and recreational value of the park.
- Provide a comparison of water quality treatment effectiveness and costs for each of the three concept design options.

1.2 Project Area

Various investigations have been undertaken over different areas of the wetland. For ease of reference and consistency with previous studies, the site has been divided into three zones:

- Northern Zone: the wetland area located between Harcourt Street and Anstey Road.
- Middle Zone: the wetland area bound by Anstey Road and Hyland Street.
- Southern Zone: the wetland/park area located between Hyland Street and Bassendean Parade, including a narrow strip of land connecting Bassendean Parade and the Swan River.

These reference zones are shown in Figure 1.

1.2.1 Planning

The site is zoned as Parks and Recreation under the Town of Bassendean Town Planning Scheme No. 4.

It is noted that on the 24th of April 2016, council resolved to acquire some privately owned land bordering the park, including Lot 211 Carnegie Street, part Lot 206 Hyland Street part Lot 113 Hyland Street and part Lot 130 Anstey Road following a land value report related to a land swap between the privately owned Lot 27L (Lot 100) Hyland Street and other land elsewhere within Bassendean.

All of the council owned Public Open Space that comprises the area of Bindaring Park will then be amalgamated into a single title.

1.3 Previous Studies and Investigations

1.3.1 Technical Assessments

As indicated in Section 1.1 a number of technical studies have recently been undertaken to improve understanding of the wetland system. These studies are listed in Table 1 below.

Table 1 Previous Technical Studies

Study	Area covered
Site Feature Survey (GHD, 2016a).	Wetland Northern Zone.
Site Feature Survey (Links Surveying, 2017).	Wetland Middle and Southern Zones.
Bindaring Park Desktop Environmental Assessment (GHD, 2016).	Wetland Northern, Middle and Southern Zones.
Bindaring Park Wetland – Northern Zone Flood Inundation Assessment – Existing Conditions (GHD, 2016a).	Wetland Northern Zone.
Stage 1 Preliminary Acid Sulphate Soil Investigation (GHD, 2016b).	Wetland Northern, Middle and Southern Zones
Bassendean Drainage Assessment: Drainage Review and Assessment (Cardno, 2016).	Entire Town of Bassendean local government area including entire wetland and upstream catchment.
Water and Sediment Quality in the Bassendean Drainage Network (SRT & DoW, 2011).	Bassendean drainage network, including monitoring point in wetland Southern Zone.
Water and Sediment Quality in the Bassendean Drainage Network (SRT & DoW, 2012).	Bassendean drainage network, including monitoring point in wetland Southern Zone.
Water and Sediment Quality in the Bassendean Drainage Network (SRT & DoW, 2013).	Bassendean drainage network, including monitoring point in wetland Southern Zone.
Water and Sediment Quality in the Bassendean Drainage Network (SRT & DoW, 2014).	Bassendean drainage network, including monitoring point in

	wetland Southern Zone.
Water and Sediment Quality in the Bassendean Drainage Network (SRT & DoW, 2015).	Bassendean drainage network, including monitoring points in wetland Northern, Middle and Southern zones.
Water and Sediment Quality in the Bassendean Drainage Network (SRT & DoW, 2016).	Bassendean drainage network, including monitoring points in wetland Northern, Middle and Southern zones.

1.3.2 Concept Design

The following concept designs have previously been prepared for the site:

- Friends of Bindaring Concept Design (2002).
- 2015/16 Action Plan Bindaring Park (Natural Area, 2015).

2.0 EXISTING ENVIRONMENT

The existing environmental conditions at Bindaring Park have been summarised below. For a more detailed description, please refer to the Bindaring Park Desktop Environmental Assessment study prepared by GHD in 2016.

2.1 Topography and Landforms

The site is located within an area of low lying land within the floodplain of the Swan River. Development of the surrounding area has resulted in modification to the original wetland landform through the construction of roads and driveways which have isolated parts of the wetland. Residential areas adjacent to the park are typically elevated at least 1 - 2 m above seasonally inundated wetland areas.

Topography within the park area (outside of the wetland) ranges from 1 to 5 mAHD with overall gradients sloping inwards towards the wetland. A number of shallow linear depressions and small open drains cross the park to channel overland flows towards the wetland core. The topography of the site is shown in Figure 2.

The wetland core consists of a preferential flow channel known as Bindaring Creek, which flows through the wetland from the northern zone to the wetland outlet in the southern zone. Bindaring Creek represents the deepest part of the wetland, with a minimum base level is as low as -0.12 mAHD.

Two recent feature surveys have been undertaken at the site:

- A survey of the northern portion of the wetland was undertaken by GHD in 2016.
- The middle and southern portions of the wetland were surveyed by Links Surveying in 2017.

A copy of these surveys are included in Appendix A.

2.2 Soils

2.2.1 Regional Mapping

Regional soil mapping indicates that the soils at the site are comprised of:

- MS_4 – Alluvium (Qha) – SANDY SILT – light yellow brown, blocky, mottled, some fine to medium-grained sand, soft when moist, variable clay content.

- S_{10} – Thin Bassendean Sand over Guildford Formation (Qpb/Qpa) – SAND – very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz, moderately well sorted of eolian origin.

The site soils are shown in Figure 3.

2.2.2 Site Specific Investigations

The field investigation was carried out in June 2017 and comprised of the following:

- 5 x Electric Friction Cone Penetrometer Tests (EFCPT) to a maximum depth of 4.0m for material assessment and soil profiling;
- 5 x Sample Retrieval Probe (SRP) boreholes to a depth of 3.0m over the site for material assessment and soil profiling;
- 5 x Dynamic Cone Penetrometer (DCP) tests in accordance with AS 1289.6.3.2 (1997) to a depth of 3.2m for evaluation of relative densities of the upper layers.

The EFCPT (CPT01-05), SRP boreholes and DCP test locations (BH01-05) are shown in Figure 3. A geotechnical engineer from Structerre supervised the fieldwork and all fieldwork, interpretation and terminology used in the report are in accordance with the guidelines presented in AS1726-1993 Geotechnical Site Investigations.

The subsurface soil profile presented in Table 2 below was determined from the ground conditions encountered within the boreholes and through the interpretation of the EFCPT and DCP test results.

Table 2 Subsurface Soil Profile

Depth to Base of Strata (m)	Material Description
1.7	FILL: SAND, with gravel, trace silt, generally loose. Locally encountered at the location of BH01.
Not Penetrated (>3.0m)	NATURAL: Clayey SAND, medium plasticity clay, locally trace gravel, firm locally stiff. Overlain locally with sand and silty sand layers.
Not Penetrated (>4.0m)	NATURAL: CLAY, medium plasticity, with sand, firm to stiff locally soft. Locally underlain and or interbedded with silty clay materials.

The soils encountered are consistent with the expected site conditions as predicted from the Environmental Geology Map. It is important to note that there may be pockets of fill on site that are deeper than that encountered by the investigation boreholes.

The full geotechnical investigation is provided in Appendix B.

2.3 Acid Sulphate Soils

DER mapping of acid sulphate soils (ASS) indicates that the site is classified as having a high to moderate risk of ASS occurring within 3 m of the natural surface.

2.3.1 Preliminary Investigation

A preliminary acid sulphate soils (ASS) investigation was undertaken by GHD in 2016 over the entire wetland area. The investigation included sampling and installation of monitoring bores at five locations across the site. Bores were drilled to depths of 3.5 – 8 m, with sampling for ASS undertaken to a maximum depth of 2 m. The test bore locations are shown in Figure 3 (MB01-05).

The results of the investigation indicated the presence of acid sulfate material at one of the locations tested (MB03). Groundwater at MB03 was also found to be acidic during a one-off groundwater quality analysis undertaken in July 2016.

GHD recommended that future concept design options:

- Consider the extent of disturbance/earthworks and propose non-intrusive activities in high risk ASS areas, with the aim of minimising ASS disturbance.
- Limit disturbance to shallow disturbance above the water table and/or within the zone of seasonal fluctuation.
- Maintain in-situ soils in a saturated state (flooded or below the water table).

Further detail is provided in the Preliminary Acid Sulfate Soil Investigation Factual Report (GHD, 2016b).

2.3.2 Targeted Investigation

A targeted ASS investigation was undertaken by Western Environmental in June 2017. The investigation targeted locations identified for disturbance during concept plan development. The investigation targeted 5 key locations across the site and these are shown in Figure 3.

The results of the investigation indicated that ASS has been identified in soils across the site, in natural soils at and below the water table. Peak concentrations of 0.10%S were observed, above the Department of Environment Regulation (DER) action criteria of 0.03%S.

The identification of ASS is not considered to be limiting in terms of proposed development given the likely scale of any ground disturbing works. However; in the event site works will involve excavation of >100m3 of natural soils, or if any dewatering or disturbance of soils beneath the water table is required, an ASS and dewatering management plan will need to be prepared in accordance with DER (2015) ASS guidelines. This plan would document the management and monitoring requirements for the construction phase of the project.

The ASS investigation is provided in Appendix C.

2.4 Contamination

Lot 27 Hyland Street is located in the western portion of the southern wetland zone, but is not included in the site boundary as this land is privately owned. Information relating to contamination in this lot is included in case the Town of Bassendean choose to acquire this land in future. The land has been identified as a contaminated site by the Department of Environment Regulation. The contamination refers to the presence of a built up driveway (known as ‘the causeway’) which was constructed with uncontrolled fill between 1965 and 1974.

Gemec carried out an investigation into the fill material in 2013. The results of this investigation indicated that the fill material is likely to have originated from a foundry source.

The investigation did not identify any potential receptors at risk of adverse exposure as a result of the fill material, other than flora growing on the causeway embankments. The risk to the flora was considered to be negligible given that all flora present was healthy. The fill on the causeway had not resulted in contamination of adjacent sediments and surface waters within the Bindaring Park wetland.

It was noted that fill material from the same source appeared to have been applied to a large area (5,000 to 6,000 m^2) of the Park to the east of the causeway. The potential impact of this fill was not included in the investigation.

Further information on the Lot 27 investigation can be found in the Gemec (2013) report.

2.5 Hydrology

2.5.1 Groundwater

2.5.1.1 Groundwater Levels

Groundwater flows northwest to southeast across the site towards the Swan River. Department of Water and Environmental Regulation's groundwater map (DWER, 2017) indicates maximum groundwater levels of 6 mAHD near the sites north-western boundary and approximately 1.0mAHD in May 2003 (considering the minimum level).

Groundwater monitoring was undertaken in five groundwater monitoring bores during a one-off sampling event in July 2016 (GHD, 2016)(Figure 3). The results of this monitoring indicated that groundwater levels ranged from 1.41 mAHD in the north-west (MB05) to 0.63 mAHD in the most south-eastern bore (MB01). The monitoring locations are shown in Figure 4.

Groundwater monitoring was undertaken in five groundwater monitoring bores during a one-off sampling event in June 2017 (Structerre, 2017)(Figure 3). The results of this monitoring inducted that groundwater was encountered in boreholes BH01 and BH02 during and after drilling, and was established at respective depths of 1.2m and 1.5m below ground level. Groundwater was not detected in boreholes BH03 and BH04 due to holes collapsing to 1.3m and 1.5m deep, respectively. Boreholes BH01-04 were installed in areas with an approximate ground surface level of 1.0-3.0m AHD. Groundwater was not detected in borehole BH05 however it is to be noted that BH05 was carried out on an area with approximate ground surface level of 4.0-5.0m AHD.

The wetland has been identified as being predominately an expression of groundwater (SRT, 2014). This is consistent with the measured groundwater levels at the site, which exceed the wetland base elevation.

2.5.1.2 Groundwater Quality

Groundwater quality monitoring was undertaken as part of a one-off monitoring event in June 2016. The results indicate that the groundwater is neutral to slightly acidic and brackish. The elevated salinity of the groundwater is likely to be a result of interaction with the Swan River.

During the June 2016 sampling event total nitrogen (TN) concentrations exceeded the ANZECC (2000) guidelines for slightly disturbed ecosystems (wetlands) in South-West Australia in one bore (MB05) reaching 8.3 mg/L against a guideline of 1.5 mg/L. Concentrations in bores MB01 – MB04 ranged from 0.4 – 1.3 mg/L.

Total phosphorous concentrations ranged from 0.07 – 0.12 mg/L in two bores (MB01 and MB03), against a guideline value of 0.06 mg/L. Guideline criteria were not exceeded in bores MB02, MB04 and MB05. Metals including Aluminium, Arsenic, Chromium, Copper, Iron, Manganese, Nickel, Selenium and Zinc were detected at bores within the site.

The full groundwater quality results from this event are provided in Appendix D.

2.5.2 Surface Water

2.5.2.1 Swan River

The site is situated entirely within the flood fringe of the Swan River (WA Atlas, 2017). As such, the Swan River has influence on the hydrology of Bindaring wetland during flood events. The floodway and flood fringe are shown in Figure 4.

The Swan River is tidal in its lower reaches, including at the site. Gauging records from the Swan River at Meadow Street Bridge gauge (3.5 km upstream of the site) indicate that tidal fluctuations may range between by approximately 0.4 m.

Gauging records from this site indicate annual maximum daily water levels have ranged from 0.96 to 1.07 mAHD in the last five years. Daily streamflow statistics for the last five years are shown in Table 3 below.

Table 3 Stage levels – Swan River at Meadow Street Bridge

Calendar Year	Max Water level (mAHD)	Average maximum daily water level (mAHD)
2011	1.05	0.46
2012	1.07	0.42
2013	0.96	0.45
2014	1.00	0.36
2015	0.96	0.30

Data source: Water Information Reporting (Department of Water and Environmental Regulation, 2017)

2.5.2.2 Bindaring Wetland

Classification

Bindaring wetland is classified as three separate wetland types under the Department of Biodiversity, conservation and Attractions (DBCA) geomorphic wetland mapping, as outlined below:

- The northern zone of the wetland is classified as Multiple Use Wetland (MUW) (sumpland UFI 8735).
- The middle zone of the wetland and the upper half of the southern zone are classified as Conservation Category Wetland (CCW) (sumpland UFI 8737).
- The remainder of the southern zone is classified as Resource Enhancement Wetland (REW) (floodplain UFI 8690).

The wetland classifications are shown in Figure 5.

Hydrology

The wetland receives inflows from a predominately residential catchment via the Town of Bassendean's stormwater drainage network. The wetland is seasonally inundated with distinct areas that become inundated more regularly than others.

The Local Biodiversity Project (2017) and SRT (2014) have indicated that the wetlands are reliant on a surface expression of groundwater. As outlined in Section 2.5.1.1 above, this is consistent with the measured groundwater levels at the site, which exceed the wetland base elevation.

Stormwater discharges to the wetland at 11 individual locations via culverts. A number of these inflow locations are distant from the portion of the wetland that is regularly inundated (southern zone) and stormwater flows via shallow overland flow paths to the lower elevation, more regularly inundated portions of the wetland.

Within the wetland, water flows from north to south along a main flow channel known as Bindaring Creek. The northern, middle and southern zones of the wetland are intersected by roads, former road connections and driveways. Flows between these portions of wetland are maintained by culverts under the roadways.

Wetland water levels are maintained by a weir in the downstream portion of the southern zone of the wetland. When the weir spillcrest is exceeded the wetland discharges to the Swan River through an open channel adjacent to Pickering Park and culverts beneath Bassendean Parade.

Water Quality

Water quality in Bindaring wetland has been monitored over seven years (2010 – 2016) by Department of Biodiversity, Conservation and Attractions (formerly Swan River Trust) and Department of Water and Environmental Regulation. The monitoring was initially undertaken in only one location (the weir in the southern zone of the wetland). Two additional monitoring sites (Hyland Street Culvert and Lovelock Street Bridge) were also monitored in 2015 and 2016. The monitoring locations are shown in Figure 5. Summary statistics (average and range) for key parameters from this monitoring are listed in Table 4 below.

Table 4 Summary Statistics for Surface Water Monitoring.

Parameter	ANZECC (2000) Wetlands guideline	Bindaring Creek Outlet	Hyland Street Culvert	Lovelock Street Bridge
Temp (°C)	NG	13.8 [9.2 – 22.0]	12.1 [11.6 – 12.6]	12.3 [11.5 – 13.1]
pH	7 -8.5	7.27 [**6.6** – 7.9]	7.04 [**6.9** – 7.2]	7.04 [**6.9** – 7.2]
Electrical Conductivity (mS/cm)	NG	2.94 [0.59 – 6.48]	1.35 [0.55 – 2.15]	0.86 [0.70 – 1.01]
Dissolved oxygen (%)	90-120	**49.3** **[14.5 – 73.2]**	**42.0** **[37.1 – 46.8]**	**33.2** **[21.2-45.2]**
Total nitrogen (mg/L)	1.5	1.25 [0.8 – **2.2**]	1.35 [1.3 – 1.4]	1.44 [0.9 – **2.0**]
Ammonia-N (mg/L)	0.04	**0.18** [0.01 – **0.93**]	**0.22** [0.04 – **0.40**]	0.02 [0.02 – 0.02]
NOx (mg/L)	0.10	0.07 [0.01 – **0.28**]	**0.25** [0.04 – **0.45**]	**0.59** [0.07 – **1.10**]
Total phosphorous (mg/L)	0.06	**0.14** **[0.06 – 0.32]**	**0.08** [**0.07 – 0.09**]	**0.08** [**0.08 – 0.09**]
Soluble reactive phosphorous (mg/L)	NG	0.08 [0.03 – 0.26]	0.05 [0.04 – 0.05]	0.04 [0.03 – 0.05]
Average [Min – Max]	Format. **Bold** indicates result is outside guideline.			
NG	No guideline			

The results of the monitoring indicate that the water within the wetland is typically pH neutral, and fresh to brackish. The elevated salinity is likely to be a result of interaction with brackish groundwater and the Swan River.

Total nitrogen concentrations were typically within the ANZECC (2000) guidelines for wetlands in South West Australia while ammonia concentrations typically exceed this guideline.

Total phosphorous concentrations were elevated above the guideline during all monitoring events.

2.6 Vegetation and Flora

2.6.1 General

The site contains Beads Vegetation association 1009 which is characteristic of medium woodland; marri and river gum, based on regional mapping. Approximately 10-30% of this association remains within the Interim Biogeographic Regionalisation of Australia (IBRA) subregion.

The site lies within two vegetation complexes:

- Guildford Complex: A mixture of open forest to tall open forest of marri (*Corymbia calophylla*), Wandoo (*Eucalyptus wandoo*) and Jarrah (*Eucalyptus marginata)* with a small number of locations fringed by *Eucalyptus rudis-Melaleuca rhaphiophylla* woodlands along streams.

Occasional areas of Eucalyptus lane-poolei are also found within the Guildford complex, now restricted to an area between Cardup and Keysbrook in the Darling System. Other species in this complex include *Banksia grandis, Kingia australia, Xanathorria preissii* and species of Hardenbergia and Hibbertia.

- Bassendean Central and South: Vegetation ranges from woodland of jarrah (E. *marginata), Allacasuarina fraseriana, Banksia attenuata, B. grandis* and *B. menziesii* on the sand dunes to low woodland of *Melaleuca preissiana, B. ilicifolia* and *B. littoralis* and sedgelands on the low-lying moister sites. This area includes the transition of jarrah to coastal blackbutt (*E. todtiana*) in the Perth vicinity and jarrah to marri (*Corymbia calophylla*) on the moister soils. Other plant species include *Kunzea ericifolia, Hypocalymma angustifolium*, *Adenanthos obovatus* and *Verticordia* species. (Heddle et al., 1980).

Approximately 50% of the park consists of remnant vegetation with the other 50% consisting of Parkland and/or open water.

The Local Biodiversity Project (2017) has indicated that the vegetation located within the CCW area is reliant on groundwater as part of the local ecosystem. These remnant bush areas are also Local Natural Areas.

2.6.2 Site Surveys

A Bushland Condition and Land Function Assessment was undertaken at the site by Ecoscape in 2010. The survey concluded that all of the vegetation in Bindaring Park is in 'Degraded' or 'Completely Degraded' condition. Vegetation within the northern zone was considered to be in a poorer condition than the middle and southern zones. Weeds in middle and southern zones were frequent in and adjacent to the water ways and at a greater diversity while in the northern zone weed species were scattered throughout the area (Ecoscape, 2010).

Ecoscape (2010) reported a total of 57 weed species in Bindaring Park, which consisted of:

- 16 species of High Priority weeds.
- 21 species of Moderate Priority weeds.
- 20 species of Low Priority weeds.

Most of the recorded High Priority weed species were grasses and geophytes which dominated the understorey adjacent to the waterway/wetland area (Ecoscape, 2010).

A formal dieback survey has not been undertaken for the Park however, no dieback infestations are currently evident within the area (Ecoscape, 2010).

2.7 Fauna and Habitat

A Level 1 fauna assessment was undertaken by Bamford Consulting Ecologists in April 2017. This assessment included a desktop review and preliminary site inspection. The outcomes of the assessment were:

- The site contains four Vegetation and Substrate Associations (VSA). VSAs describe the combination of vegetation types, soils/substrates and landform that are habitat for fauna. The VSAs identified include:
  - Wetland (VSA1)
  - Exotic Tree plantings (VSA2)
  - Open Flooded Gum Parklands (VSA3)
  - Cleared open space (VSA 4)

  VSA1 and VSA3 may have higher biodiversity considerations then VSA2 and VSA4.

- The Bindaring Park wetland lacks extensive areas of shallow water or mud flats favoured by migratory birds. Based on existing topography and hydrological regime (i.e. seasonally dries during the summer months) the creation of this habitat type is not currently viable.

- Although most of the site has low foraging value the Forest Red-tailed and Carnaby's Black-Cockatoos are regular visitors and have been recorded on site. Chewed pine cones were recorded on site which confirms Black Cockatoo foraging.

- The site also contains 50 potential habitat trees (Flooded Gums) for Black-Cockatoos. This tree species is commonly used for roosting by the Carnaby's Black Cockatoo. Retention and the preservation of these trees are recommended (tree locations are shown on Figures 7-9).
  - Two of these trees contained potential nest hollows of suitable size and inclination.
  - Three of these trees contained potential but marginally suitable (non-preferred) hollows.

- Five feral bee hives were found to be located within the study area. Feral bees provide competition with native bees and are a potential safety issue in active recreation areas. Removal of these hives is recommended.

- Weeds are prevalent throughout the study area. Weeds generally reduce habitat quality, however they can be considered important in disturbed or small fragmented areas where most of the original plant species and vegetation structure is missing. Rehabilitation should be phased to ensure that the diversity of the lower story/fringing habitat environment is still present in some areas during rehab works to support existing species on site.

- The main processes currently affecting the fauna assemblage in the survey area include habitat size and loss, connectivity and feral species (plants and animals), and local hydrology. Proximity and connectivity with the Swan River is important providing some a degree of habitat linkage with this estuarine system.

The fauna assessment report is provided in Appendix E.

2.8 Ecological Linkages

The northern wetland zone has been identified as a local ecological linkage connection to the middle and southern wetland zones which is part of a regional ecological linkage. As discussed by EMRC (2009) local ecological linkages aim to link locally significant natural areas and regional linkages.

Local ecological linkages are important in improving the viability of isolated Local Natural Areas that may be too small or in too poor condition to be viable on their own. The viability of areas is improved by including as many natural areas within each link and maximising the number of connections to each area.

The concept design plans will ensure that the ecological potential within the site is enhanced to incorporate habitat diversity and regeneration opportunities.

2.9 Bush Fire Risk

A significant portion of the site has been identified as bushfire prone areas in the Department of Fire and Emergency Services Map of Bushfire Prone Areas 2016. Refer to Plate 1.

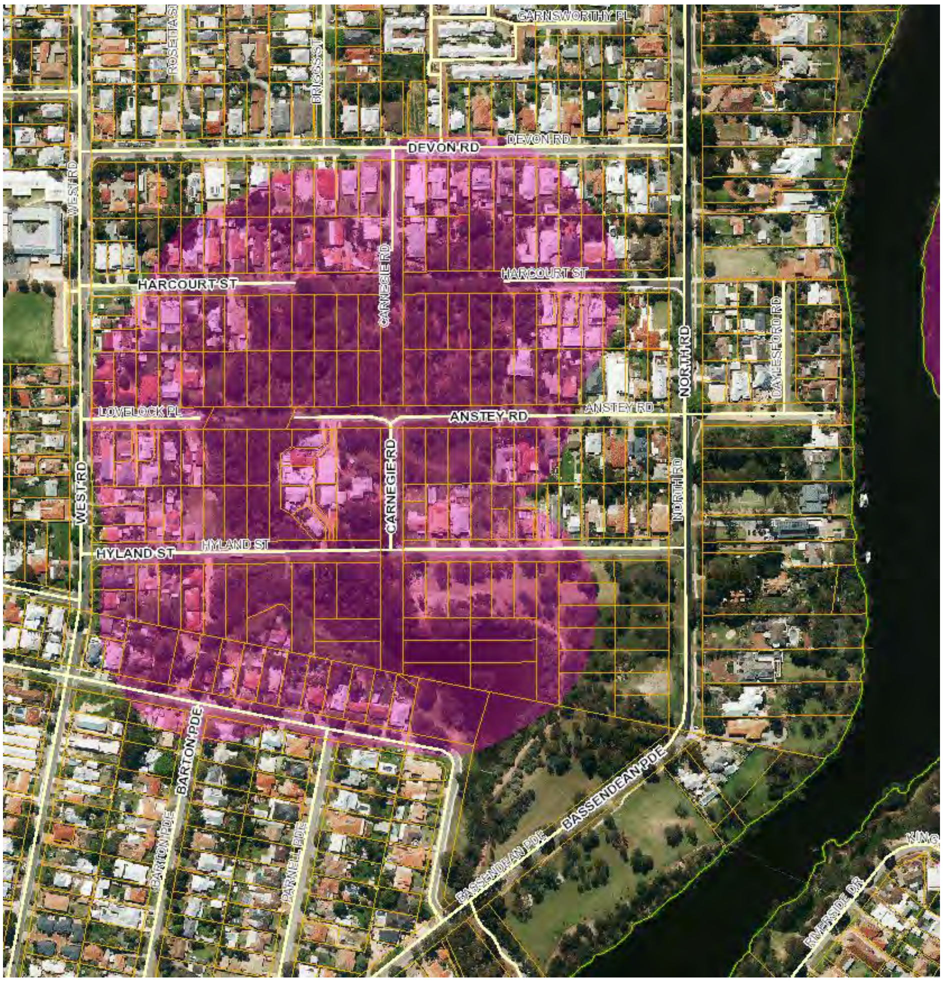

Plate 1 BushFire Prone Areas 2016 (DFES 2016)

It is noted by the WAPC (2016) if public facility buildings are proposed in this area a Bushfire Attack Level (BAL) assessment will need to be undertaken.

2.10 Cultural Heritage

A search of the Aboriginal Heritage Inquiry System indicated that the site is included within the Helena River heritage site (Site ID 3758) which is registered for Ceremonial and Mythological values. The Swan River heritage site (Site ID 3536) is parallel to the southern boundary of the site (Department of Aboriginal Affairs (DAA), 2017).

A search of the Heritage Council/State Heritage Office (2017) database found that there are currently no registered European heritage sites within Bindaring Park.

3.0 HYDRAULIC MODELLING

Hydraulic modelling of Bindaring wetland has been undertaken in order to:

- Improve understanding of the hydraulic function of the wetland during frequent and large storm events.
- Assist with the development of the concept plan for the improvement of the ecological and recreational value of Bindaring Park.

The hydraulic modelling has been undertaken in two phases:

- Phase 1 – hydraulic modelling of the northern wetland zone undertaken by GHD in 2016. A modelling study of the Town of Bassendean stormwater network was also undertaken by Cardno during 2016.
- Phase 2 – hydraulic modelling of the middle and southern wetland zones undertaken by Coterra Environment in 2017.

These studies are summarised briefly below, and are provided in full in Appendix F.

3.1 Town of Bassendean Stormwater Modelling (Cardno, 2016)

A drainage assessment of the entire Town of Bassendean stormwater network was undertaken by Cardno in April 2016. The network was modelled using a fully dynamic 1D/2D hydraulic model in XPSWMM software for various design rainfall events.

3.2 Northern Zone Study (GHD, 2016)

As outlined above, a flood inundation assessment was undertaken by GHD for the northern zone of the wetland in 2016. This study was undertaken using a TUFLOW 2D model for the 5, 10 and 100 year ARI events and a ‘frequent event’ (equivalent to approximately half of the 5 year ARI event). The storm duration used was 18 hours, which is the critical duration of the upstream stormwater catchment (Cardno, 2016).

The modelling was based on survey of the site (also undertaken by GHD) and stormwater inflows to the wetland which were derived from a previous study of the Town of Bassendean stormwater drainage network undertaken by Cardno in 2016.

The results of the modelling were compared to water level data from a continuous water level logger installed at the downstream boundary of the northern zone (footbridge beneath Anstey Road) and the wetland outflows of the Cardno model.

The results of the modelling indicate that a large area of the northern zone is likely to become inundated during frequent events. A centrally located pathway and small culvert were found to represent a barrier to flow during events up to the 10 year ARI event, forming a pool on either side of the pathway. The pathway is overtopped during the 100 year ARI event.

Maximum flood depths within the northern zone range from approximately 0.78 m in frequent events to 0.87 m in the 100 year ARI flood event in the pool to the west of the central pathway.

A conceptual wetland inundation plan was also prepared to separate the northern zone into wetland zones based on frequency of inundation, inundation depth and topographical location to assist with concept plan development. The following zones were developed:

- Deep wetland zone – frequent flooding, water depths greater than 300 mm during minor storm events.
- Wetland zone – inundated with water depths greater than 300 mm during the 100 year ARI event.
- Ephemeral zone – based on the extent of inundation during frequent events with water depths greater than 100 mm.

These areas are shown in Figure 6.

3.3 Middle and Southern Zone Study (Coterra, 2017)

A flood inundation assessment of the middle and southern wetland zones was undertaken by Coterra Environment in 2017. This modelling builds on the modelling undertaken for the northern zone (GHD, 2016) to improve understanding of the hydraulic function of the middle and southern portions of the wetland.

In accordance with the previous modelling undertaken by GHD, the modelling was run for the ‘frequent’, 5, 10 and 100 year ARI storm events. Inflows to the model were derived from the Cardno 2016 and GHD 2016 models. A full description of the model inputs and assumptions is provided in Appendix F.

The results of the modelling indicate that flooding in the middle wetland zone is generally confined to the main channel ‘Bindaring Creek’ during frequent events, but inundates a wider area during larger events (>10 year ARI events).

Flow is discharged from the middle zone to the southern zone through culverts under Hyland Street. Flow through these culverts is unrestricted in ‘frequent’ events, but there is some restriction in the 5, 10 and 100 year ARI events.

Significant inundation occurs within the southern wetland zone to the west of the causeway as a result of a relatively large inflow from the local stormwater network and restricted outflow via a partially blocked culvert under the causeway. Water levels in the centre of this area range from 40 – 60 cm during ‘frequent’ events and exceed 1.2 m during the 100 year ARI event.

Within the remainder of the southern zone, inundation is largely contained within the main body of the wetland during minor events, although some shallow ponding occurs in low points throughout the park. This ponding is predominately contained within trapped low points and the minor drainage channels that traverse the park.

In larger events flooding extends over the wetland bank on all sides with the largest area of flooding occurring in the south east in proximity to the weir. The footpath adjacent to the wetland in this area floods during all storm events simulated.

The results also indicate that the weir is overtopped during ‘frequent’ and large ARI events. Water is discharged from the wetland via an outlet culvert under Bassendean Parade and an open channel that stretches from Bassendean Parade to the Swan River. The discharge was found to be contained within the culvert and outflow channel during all events, with the exception of some overflow of the culverts under the footbridge adjacent to the boat ramp during the 100 year ARI event. Flood extents and depths are provided in Appendix F.

Similarly to the GHD model, a conceptual wetland inundation plan has been prepared to assist with concept development (Figure 6). This plan shows the deep wetland zone, wetland zone and ephemeral zone as described in Section 3.1 above.

4.0 WATER QUALITY MODELLING

4.1 Overview

Department of Water and Environmental Regulation has recently released the Urban Nutrient Decision Outcomes (UNDO) tool, a conceptual decision support tool developed to assess the effectiveness of treatment train options for urban developments. The tool is specific to developments located on the Swan Coastal Plain.

The UNDO tool is suitable for proposed urban developments, or retrofitting of treatment infrastructure in existing urban developments. The tool calculates:

- Total nitrogen and phosphorous input from the development area based on land use.
- Pre-treatment nutrient export based on soil and fill characteristics, groundwater separations and effluent disposal mechanisms.
- Post-treatment nutrient export based on the proposed water quality treatment train. The tool models specific treatment methods only, including constructed wetlands, floating treatment wetlands, biofilters, detention/infiltration basins, swales, living streams, and spiral wrapped filter media.

It is noted that the UNDO modelling undertaken considers the impact of stormwater discharges from upstream urban and commercial catchments to the wetland and does not include the impacts of the developed area on groundwater as a result of stormwater infiltration.

The tool is currently available for use to determine the relative effectiveness of different treatment options. DWER has advised that targets for maximum nutrient export concentrations will be released in the future however targets are not currently available.

In this study, the UNDO tool has been applied to compare water quality treatment effectiveness of three water quality concept designs for Bindaring Park. The three options are outlined in Table 5 below.

Table 5 Water Quality Concept Design Options

	Water quality treatment
Option 1	Biofilters at all major inflows. Swales at minor inflows. Floating wetland within open water of Bindaring Wetland.
Option 2	Biofilter at largest catchment inflow (catchment A). Swales at all other inflows.
Option 3	Swales at all inflows.

4.2 Modelling Results

The modelling inputs and assumptions are detailed in Appendix H.

4.2.1 Treatment

Water quality treatment is provided for each stormwater inflow location to Bindaring Park except inflow E (see figure H1 in Appendix H). Inflow E was found to have no/very minor inflow during the hydraulic modelling (described in Appendix D). As such, water quality treatment is not considered to be required.

All water quality treatment areas were sized at approximately 2% of the sub-region road reserve area, excluding sub-region A where the total treatment size was limited to 500 m^2 to manage cost and space constraints.

The treatment type and sizing for each option is listed in Table 6 below. A detailed description of the treatment types are provided in Appendix H.

Table 6 Treatments Applied – Water Quality Concept Options 1 to 3.

Option 1			Option 2		Option 3	
Inflow	**BMP**	**Treatment area (m^2)**	**BMP**	**Treatment area (m^2)**	**BMP**	**Treatment area (m^2)**
A1	Biofilter	421	Biofilter	421	Swale	421
A2	Biofilter	24	Biofilter	24	Swale	24
A3	Biofilter	55	Biofilter	55	Swale	55
B	Biofilter	483*	Swale	483*	Swale	483*
C	Biofilter	122	Swale	122	Swale	122
D	Swale	60	Swale	60	Swale	60
E	-	-	-	-	-	-
F	Biofilter	113	Swale	113	Swale	113
G	Swale	25	Swale	25	Swale	25
H	Swale	56	Swale	56	Swale	56
All	Floating wetland	200	-	-	-	-

*An existing swale (460 m^2) is installed upstream in the catchment. As such only an additional 23 m^2 of treatment is required in this catchment.

4.2.2 Pre-Treatment Export

The results of the UNDO modelling indicate that pre-treatment nutrient export from stormwater discharges to Bindaring wetland equate to approximately 1.70 kg/ha/yr of nitrogen and 0.19 kg/ha/yr of phosphorous.

It is noted that these values represent the nutrients discharged from the urban stormwater network to Bindaring Park and do not include the export of nutrients from the existing urban development to groundwater via infiltration on lots (e.g. soakwells). As such, the total nutrient export from the developed area to the environment is likely to exceed the values presented above.

As mentioned previously, Department of Water and Environmental Regulation have not released guidance on appropriate levels of nutrient export from urban development to date. As such, the results have been compared to levels derived from the ANZECC (2000) guidelines for reference. These values suggest that an export of 1 – 2 kg/ha/yr of nitrogen and 0.2 -0.3 kg/ha/yr of phosphorous may be appropriate. This indicative value may differ from the future guidance released by Department of Water and Environmental Regulation.

4.2.3 Post-Treatment Export

Post-treatment nutrient export was assessed for the three concept design options summarised in Tables 1 and 2. The results of this analysis are provided in Table 3 below.

Post-treatment nutrient concentrations range from 0.84 – 1.43 kg/ha/yr of nitrogen and 0.11- 0.18 kg/ha/yr of phosphorous across the three concept options. All options fall within the reference criteria of 1 – 2 kg/ha/yr of nitrogen and 0.2 - 0.3 kg/ha/yr of phosphorous.

Nutrient removal was highest in concept option 1 which included biofilters all at major inflow points and swales at minor inflow points. A floating wetland installed within the open water of Bindaring Wetland also contributed to the high level of nutrient removal. Export rates were approximately half that of the pre-treatment rates.

Nutrient removal was significantly decreased in concept options 2 and 3 where biofilters were replaced with swales to varying degrees and the floating wetland was excluded. Option 2 resulted in an approximate reduction of 30% nutrient export in comparison to pre-treatment export rates. Option 3 (no biofilters) only provided a slight improvement to pre-treatment export rates. The effectiveness is detailed in Table 7 below.

Table 7 Water Quality Treatment Effectiveness

		Total treatment areas (m^2)				Pre-treatment export (kg/ha/yr)		Total nutrient removed (kg/ha/yr)		Post-treatment export (kg/ha/yr)		Rank*
Concept	Treatment method	Biofilter	Swale	Floating wetland	Total	N	P	N	P	N	P	
Indicative maximum export criteria										1-2	0.2-0.3	
Option 1	Biofilter at major inflows. Swale at minor inflows. Floating Wetland. Gross pollutant trap at largest inflow.	785	141	200	1126	1.70	0.19	0.86	0.08	0.84	0.11	1
Option 2	Biofilter for inflows from the largest catchment. Swales at all other inflows. Gross pollutant trap at largest inflow.	500	426	0	926	1.70	0.19	0.56	0.05	1.13	0.14	2
Option 3	Swales at all inflows. Gross pollutant trap at largest inflow.	0	926	0	926	1.70	0.19	0.27	0.01	1.43	0.18	3

*Where a rank of 1 represents the greatest improvement in water quality.

5.0 CONCEPT DESIGN OBJECTIVES

5.1 Design Objectives

Town of Bassendean seek to improve the ecological and recreational value of Bindaring wetland and its surrounding parkland. As described in the sections above, a number of technical studies have been undertaken to assist with the development of a concept design for Bindaring Park that both adequately considers the environmental constraints of site and improves ecological outcomes.

The following specific objectives have been set for concept plan development. These objectives have been determined based on feedback from the Friends of Bindaring Group during the site meeting on the 14th of March 2017, and the key guidance documents listed in Section 4.2 below.

1. Improve water quality within Bindaring Wetland through the improved treatment of urban stormwater runoff at stormwater discharge locations within the Park.

2. Improve ecological and habitat value through removal of weed vegetation, retention of high value trees and rehabilitation planting using with local native species.

3. Improve access, path connectivity and underutilised space within the park for improved recreational amenity.

4. Consider modification of wetland hydraulic controls such as Hyland Street and the causeway (if this land is acquired). *Please Note*: As previously identified, this aspect of the design objectives was raised during the Friends of Bindaring site visit. The scope for the investigations had been set at this point and as such, further hydrological and environmental investigations required to adequately assess the impact these objectives would have on the wetland hydrology and ecosystem would need to be assessed as part of a separate scope. The flood levels represented on the concept options are indicative of the current hydraulic controls and existing topography only.

5.2 Key Guidance Documents

The following guidance documents have been considered during concept design development.

5.2.1 Environmental Policies and Reports

5.2.1.1 <u>EPA Guidance Statement No. 33 – Environmental Guidance for Land Development</u>

EPA Guidance Statement No. 33 (EPA, 2008) outlines the environmental protection process and provides the EPA's advice on a range of environmental factors in order to assist in the protection, conservation and enhancement of the environment during the land planning and development process.

5.2.1.2 SRT Planning for Stormwater Management affecting the Swan Canning Development Control Area

The objective of this policy is to ensure land use, development, and other permitted works, acts and activities that comprise, include or use stormwater management systems in or affecting the Swan Canning Development Control Area (DCA):

- Do not result in further water quality degradation of the Swan Canning river system, and where possible, improve the situation, and
- Protect and enhance the ecological health, community benefits and amenity of the river system (SRT, 2016).

5.2.2 Planning Policies and Reports

5.2.2.1 State Planning Policy 2.9 Water Resources

The objectives of this policy are to:

- Protect, conserve and enhance water resources that are identified as having significant economic, social, cultural and/or environmental values.
- Assist in ensuring the availability of suitable water resources to maintain essential requirements for human and all other biological life with attention to maintaining or improving the quality and quantity of water resources.
- Promote and assist in the management and sustainable use of water resources.

The outcomes of the policy are:

- Environmental repair and rehabilitation of the water resource;
- Improved water quality;
- Reduction in nutrient export to receiving waters to a level lower than existing;
- Restoration of natural flow regimes and variability; and
- Use of site works such as fencing, revegetation or water monitoring.

5.2.2.2 State Planning Policy 2.10 Swan Canning River System

The policy objective relevant to the site includes *“ensure that activities, land use and development maintain and enhance the health, amenity and landscape values of the river, including its recreational and scenic values*”.

Further to the above the SPP 2.10 provides guiding principles which are to be considered for the concept plan, these include (but not limited to):

- Maintaining the river and its setting as a community resource.
- Securing public access to the river.
- Maintaining a sense of place.

- Providing opportunities for water transport.
- Protecting the natural environment (including fringing vegetation).
- Implementing responsible stormwater management practices.
- Conserving the cultural and natural heritage of the river and its setting.
- Promoting sensitive design and built form to complement the river landscape.
- Creating linkages and natural vegetation corridors.

5.2.2.3 Local Planning Policy No. 4 - Floodplain Management and Development

The purpose of this policy is:

- To reduce loss of life and property due to floods.
- To conserve the floodplain environment.
- To guide residential development which permits access to residences in times of flooding.
- To ensure that proposed development is compatible with flood hazard in order to minimise the risks of damage and impacts of flooding.
- To encourage development which maintains or enhances the physical and visual amenity of the floodplain.
- To provide guidelines for the use and development of the floodplain.

5.2.2.4 Local Planning Policy No. 18- Landscaping with Local Plants

The objective of this policy includes:

- Provide development applicants with guidance as to the standard of landscaping expected by Council.
- Build pride in the Town of Bassendean's natural environment and foster a 'sense of place' in the community through appropriate landscaping.
- Reduce threats to biodiversity by avoiding plant selection that may lead to future environmental weed problems.
- Create visual stimulus and contrast between natural and built features.
- Soften the impact of the built form.
- Maintain and further promote the amenity and resultant quality of life provided for residents of the Town of Bassendean.
- Promote better utilisation of water resources and the development of practices which conserve water.
- Minimise the extent of fertilisers leaching into drains and waterways, and in turn maintaining water quality within the Town.

The application of these policies (where relevant) are discussed in the following sections.

6.0 CONCEPT DESIGN OPTIONS

Three concept designs have been developed for the improvement of ecological and recreational values at Bindaring Park. The concept designs have been developed to meet the design objectives outlined in Section 5.1.

The design elements listed below are common to all three concept designs.

Weed Management:

- Removal of all high priority weeds. High priority weed species are invasive and dominant in a wetland environment. A weed management strategy for priority weeds is provided in Ecoscape (2010) (Appendix G).

Revegetation:

- Revegetation along the western banks of the southern wetland zone, within water quality treatment areas and indicated areas throughout the northern, middle and southern wetland zones.

Fauna and habitat:

- Retention of 50 potential black cockatoo habitat trees.
- Removal of 5 feral bee hives.

Access and Paths:

- Installation of 800 m of asphalt cycleway connecting the Harcourt Street cul-de-sacs.
- Installation of formalised limestone paths away from existing properties.
- Boardwalks across wetland areas for pedestrian access (although location and extent of boardwalks vary between concepts).
- Footpath connection along Carnegie Road.
- Path connection towards Pickering Park and Swan River.
- 3 m wide stabilised limestone access track to Water Corporation sewer manhole.

Passive recreation opportunities:

- Installation of seating nodes and lookouts over the wetland.

- Retained open parkland space for passive recreation.

The design elements that vary between the various concept options are described in the sections below.

As described in Section 4 above, water quality treatment BMPs used within the various concept designs include biofilters, swales and floating wetlands. These BMPs are described in Appendix H.

6.1 Concept Design - Option One

Concept Option One has been designed to meet design objectives 1-3 and encompasses improvements to water quality, ecological and habitat value and recreational amenity. No changes to the existing hydraulic controls (e.g. Hyland Street culvert or the causeway) are proposed.

This option achieves the highest level of water quality treatment of the three options proposed.

The concept plan for Option One is provided in Figure 7 and is outlined in Table 8.

Table 8 Concept Design Option One

Objective	Measures proposed
1. Improve quality of stormwater discharged to wetland	Stormwater is discharged to Bindaring wetland at 11 inflow locations from 8 broad urban catchments. Stormwater inflows from the 4 largest catchments (Catchment A, B, C, F) will receive water quality treatment within biofilters. Remaining inflows will receive water quality treatment within swales. A floating wetland will be installed within the open water in the southern wetland to further improve water quality treatment. A gross pollutant trap is also proposed at one of the larger inflow points (catchment C) due to the high volume of litter observed during the site visit in March 2017.
2. Improve ecological and habitat value	Extensive weed control to be undertaken throughout the wetland, focusing on high priority invasive weeds. 50 potential black cockatoo habitat trees to be retained. Removal of 5 feral bee hives. Rehabilitation planting is proposed to improve habitat value.
3. Improve recreational Amenity	Additional paths and boardwalks proposed to increase access, connectivity and circulation through the wetland. Occasional seating opportunities are provided along the edge of the wetland. A boardwalk and bird hide across the main open water area of wetland in the southern zone is proposed.
4. Hydraulic Controls	No changes to the existing hydraulic controls (Hyland Street and the causeway) are presented in this option.

6.2 Concept Design - Option Two

Concept Option Two has also been designed to meet objectives 1-4 and encompasses improvements to water quality, ecological and habitat value and recreational amenity. The removal of the causeway has been included as possible future option (see callout box on Figure 8) if the city acquires the relevant land in the future. The impact of the removal of the causeway on the wetland hydrology and flood levels has not been assessed in this scope.

The concept plan for Option Two is provided in Figure 8 and is outlined in Table 9.

Table 9 Concept Design Option Two

Objective	Measures proposed
1. Improve quality of stormwater discharged to wetland	Stormwater inflows from the largest catchment (Catchment A) will receive water quality treatment within biofilters. Remaining inflows will receive water quality treatment within swales. A gross pollutant trap is also proposed at one of the larger inflow points (catchment C) due to the high volume of litter

Objective	Measures proposed
	observed during the site visit in March 2017.
2. Improve ecological and habitat value	Extensive weed control to be undertaken throughout the wetland, focusing on high priority invasive weeds. 50 potential black cockatoo habitat trees to be retained. Removal of 5 feral bee hives. Rehabilitation planting is proposed to improve habitat value.
3. Improve recreational Amenity	Additional paths and boardwalks proposed to increase access, connectivity and circulation through the wetland. Picnic and playspace areas are proposed in underutilised park areas. Occasional seating opportunities are provided along the edge of the wetland.
4. Hydraulic Controls	No changes to the existing hydraulic controls are proposed in this option. However, the removal of the causeway may be considered as a possible future option if the land is acquired by the Town as outlined in Section 6.2.1 below. No changes to Hyland Street are proposed.

6.2.1 Optional addition to Concept Design 2

As shown in the callout box on Figure 8, removal of the causeway is included as a possible future option addition to concept design 2. Removal of the causeway has been designated as a possible future option addition as the land is currently under private ownership and would need to be acquired by Town of Bassendean.

Table 10 Concept Design Option Two – Optional Extra Items

Additional measure proposed	Explanation
Removal of causeway (if land is acquired by Town of Bassendean)	Removal of the causeway to hydraulically connect the western portion of the wetland and the remainder of the southern wetland zone. The causeway would be replaced with a pedestrian boardwalk crossing across the wetland to facilitate connectivity. No changes to Hyland Street are proposed. Note: It is noted that the northern half of the southern zone is currently classified as Conservation Category Wetland by Department of Biodiversity, Conservation and Attractions / Department of Water and Environmental Regulation. This category of wetland has the highest ecological value and level of protection. The existing vegetation in this area is likely to be suited to the existing hydraulic regime due to the age of the hydraulic controls. Disruption of the hydraulic regime in this area is likely to require approval from the Department of Biodiversity, Conservation and Attractions. Further technical studies will likely be required to determine the potential impact of the removal of the hydraulic control on the existing wetland vegetation. As the hydraulic modelling undertaken for this investigation assumes that the hydraulic controls are in place, it is not valid if these controls are removed.

Additional measure proposed	Explanation
	The impact of the removal of the causeway on the wetland hydrology and flood levels has not been assessed in this scope.

6.3 Concept Design - Option Three

Concept Option Three has been designed to meet objectives 1-4 and encompasses improvements to water quality, ecological and habitat value and recreational amenity. This concept option includes the removal of Hyland Street and the causeway as a possible future option (see Section 6.3.1 below) to reconnect areas of wetland that have historically been intersected by built up roads and driveways. The impact of the removal of the road and causeway on the wetland hydrology and flood levels has not been assessed in this scope.

The concept plan for Option Three is provided in Figure 9 and is outlined in Table 11 below.

Table 11 Concept Design Option Three

Objective	Measures proposed
1. Improve quality of stormwater discharged to wetland	All stormwater inflows will receive water quality treatment within swales. A gross pollutant trap is also proposed at one of the larger inflow points (catchment C) due to the high volume of litter observed during the site visit in March 2017.
2. Improve ecological and habitat value	Extensive weed control to be undertaken throughout the wetland, focusing on high priority invasive weeds. 50 potential black cockatoo habitat trees to be retained. Removal of 5 feral bee hives. Rehabilitation planting is proposed to improve habitat value.
3. Improve recreational Amenity	Additional paths and boardwalks proposed to increase access, connectivity and circulation through the wetland. Picnic and playspace areas are proposed in underutilised park areas. Occasional seating opportunities are provided along the edge of the wetland. A boardwalk and bird hide across the main open water area of wetland in the southern zone is proposed.
4. Hydraulic Controls	No changes to hydraulic controls are proposed, however the removal of the causeway and Hyland Street are provided as a possible future option in Section 6.3.1 below.

6.3.1 Optional addition to Concept Design 3

As shown in the callout box on Figure 9, removal of the causeway and Hyland Street are included as a possible future option addition to concept design 3. Removal of these hydraulic controls have been designated as an optional addition as the land is currently under private ownership and would need to be acquired by Town of Bassendean.

The reconfiguration of Hyland Street would involve formation of a cul-de-sac with a pedestrian path and boardwalk constructed across the restored wetland.

Table 12 **Concept Design Option Three – Optional Extra Items**

Additional measure proposed	Explanation
Removal of causeway (if land is acquired by Town of Bassendean) and removal of a portion of Hyland Street.	Removal of the causeway and dwelling on Lot 27 to open this portion of the wetland up to the remainder of the southern zone. Removal of a section of Hyland Street to reconnect to middle and southern wetland zones. Removal of house on 27 Hyland Street. Note: It is noted that the middle zone and northern half of the southern zone are currently classified as Conservation Category Wetland by Department of Biodiversity, Conservation and Attractions. This category of wetland has the highest ecological value and level of protection. The existing vegetation in these areas is likely to be suited to the existing hydraulic regime due to the age of the hydraulic controls. Disruption of the hydraulic regime in this area is likely to require approval from the Department of Biodiversity, Conservation and Attractions / Department of Water and Environmental Regulation. Further technical studies may be required to determine the potential impact of the removal of the hydraulic controls on the existing wetland vegetation. As the hydraulic modelling undertaken for this investigation assumes that the hydraulic controls are in place, it is not valid if these controls are removed. Given this option removes both the causeway and the road this option is likely to have to most impact to the current hydraulic regime of the wetland.

It is noted that Hyland Street is a major bus route (bus route 55) within the Town. A traffic assessment including modelling and consultation with Department of Transport would be required to support removal of the street. Consultation with residents and other stakeholders will also be required.

It is also noted that Hyland Street is likely to contain a number of services within the road reserve such as power, water, sewer, gas, Telstra etc. Removal of this portion of Hyland Street may mean that these services need to be re-routed.

6.4 Cost Comparison of Options

An indicative cost for each concept option is provided in Table 13 below to assist with the comparison of concept options. A full breakdown of costs is provided in Appendix I.

Table 13 Concept Design Options – Indicative Cost Estimates

	Option 1	Option 2	Option 3
Preliminaries	$15,000	$15,000	$15,000
Site preparation	$27,625	$27,625	$27,625
Hardscape works	$361,500	$361,500	$316,150
Built elements and furniture	$822,000	$734,000	$797,000
Softworks	$74,900	$74,900	$77,700
Drainage inflow landscape treatments	$155,530	$26,500	$9,000
Provisional sums (Arborist works)	$60,000	$60,000	$60,000
Contingency	$20,000	$20,000	$20,000
Total (ex. GST)	**$1,491,205**	**$1,274,175**	**$1,322,475**
Total (inc. GST)	**$1,640,326**	**$1,401,593**	**$1,454,723**

It is noted that these costs are indicative only, and do not include:

- Works related to the removal of the causeway, or removal or modification to the existing dwelling at Lot 27 Hyland Street. Works are likely to include but not be limited to engineering, structural, and contamination work.
  It is noted that Syrinx Environmental (2015) provided an estimate of $27,250 for the removal of the causeway including:
  - Area survey
  - Material landfill classification
  - Rehabilitation and remedial action plan
  - Closure reporting

  A rough order of magnitude cost of up to $236,200 was also provided, which included:
  - Preliminaries
  - Earthworks, remediation and validation
  - Revegetation

  However it was noted by Syrinx that these costs could not be confirmed until the initial survey and material landfill classification is undertaken.

- Works relating to the modification of Hyland Street. Works are likely to include but not be limited to engineering and structural. Modifications to Hyland Street are expected to have implications on traffic and services (e.g. water, sewer, power, gas, Telstra etc.). The cost of investigating the impact of the removal of Hyland Street on traffic and these services is not included.
- General road and carpark modifications, including design.
- Civil services and drainage infrastructure (other than water quality treatment areas). E.g. pipework.
- Dewatering, acid sulphate soil management or subsurface drainage.
- Pickering Park improvements.

- Maintenance, ongoing weeding and replacement planting (except floating wetland where nominated price includes 1 year of maintenance by suppliers).
- Lighting and electrical.
- Tree survey and assessment.
- Irrigation bore and irrigation works.
- Upgrades to private property boundary walls or fencing.
- Pest control.
- Design and Consultancy Fees including flood modelling refinements.
- Environmental assessments and approvals.
- Multiple site mobilisations (assumes all work completed as one contract).

6.5 Staging

Prioritisation of tasks have been provided in Tables 14 to 16 below to assist and provide guidance to the Town of Bassendean on possible staging of works. It is noted that the budget estimates provided however, include one stage of mobilisation. The staging tasks below do not include any future approval requirements or future assessments required.

Table 14 Prioritisation of Task - Option 1

Tasks (in order of priority)	**Comment**
Option 1	
1. Weed management and feral bee hive removal	Weed management should be undertaken 12 months prior to revegetation works. Feral bee hives should be removed as soon as possible to ensure public safety.
2. Installation of biofilters at major inflow locations (A1, A2, A3, C, F) and gross pollutant trap at inflow C.	Take note of future path locations when installing connection to pipe outlets.
3. Installation of floating wetland	This item was given a high priority as improvement of water quality was a key objective of this study. However, the floating wetlands can be easily be installed at any time.
4. Construct key strategic paths	Particularly the 'loop' path and boardwalk in the southern portion of the wetland.
5. Installation of biofilter at inflow B, and construction/planting of swales at inflows D, G and H.	
6. Rehabilitation planting throughout wetland	Take note of future path locations when planting.
7. Construct amenity paths and water corporation access tracks	
8. Install minor nature play area, seating, lookouts and signage.	

Table 15 Prioritisation of Task - Option 2.

Tasks (in order of priority)	Comment
Option 2	
1. Weed management and feral bee hive removal	Weed management should be undertaken 12 months prior to revegetation works. Feral bee hives should be removed as soon as possible to ensure public safety.
2. Installation of biofilters at major inflow locations (A1, A2, A3) and gross pollutant trap at inflow C. Construction/planting of swales at inflows C and F.	Take note of future path locations when installing connection to pipe outlets.
3. Removal and rehabilitation of the causeway. Removal of house on 27 Hyland St.	*If the land is acquired.*
4. Construct key strategic paths	Particularly around southern portion of the wetland, and the boardwalk across the former causeway location (if this land is acquired).
5. Construction/planting of swales at inflows B, D, G and H.	
6. Rehabilitation planting throughout wetland	Take note of future path locations when planting.
7. Construct amenity paths and water corporation access tracks	
8. Install minor nature play area, seating, lookouts and signage.	

Table 16 Prioritisation of Task - Option 3.

Tasks (in order of priority)	Comment
Option 3	
1. Weed management and feral bee hive removal	Weed management should be undertaken 12 months prior to revegetation works. Feral bee hives should be removed as soon as possible to ensure public safety.
2. Installation of swales at major inflow locations (A1, A2, A3, C and F) and gross pollutant trap at inflow C.	Take note of future path locations when installing connection to pipe outlets.
3. Removal and rehabilitation of the causeway. Removal of house on 27 Hyland St.	*If the land is acquired.*
4. Removal of Hyland Street	
5. Construct key strategic paths	Particularly around southern portion of the wetland, and the boardwalk across the former causeway location (if this land is acquired).
6. Construction/planting of swales at inflows B, D, G and H.	
7. Rehabilitation planting	Take note of future path locations when

Tasks (in order of priority)	Comment
throughout wetland	planting.
8. Construct amenity paths and water corporation access tracks	
9. Install minor nature play area, seating, lookouts and signage.	

7.0 REFERENCES

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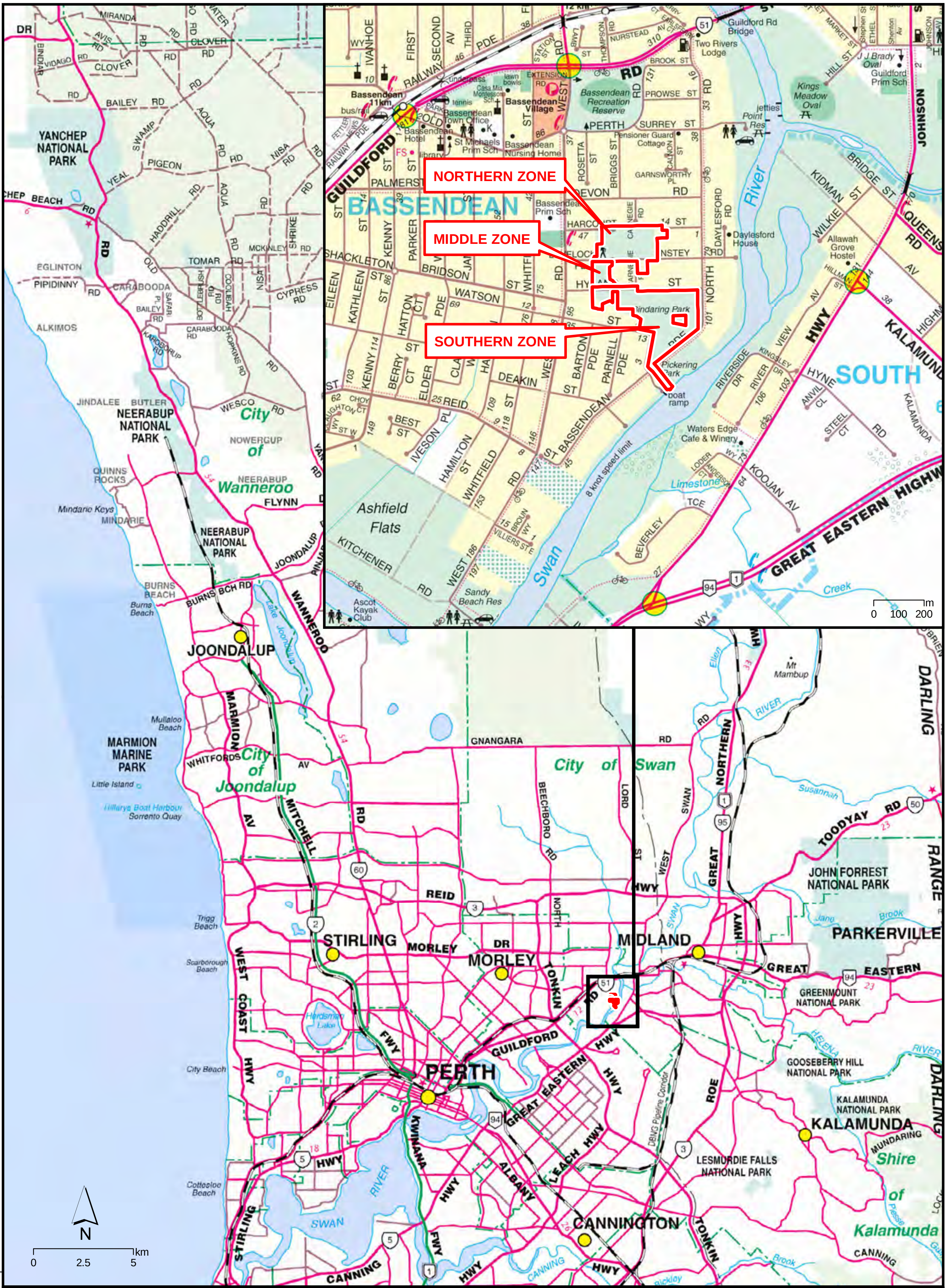
FIGURES



COTERRA ENVIRONMENT

Job: TOBBWC01
Doc: 001
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

Town of Bassendean
BINDARING WETLAND CONCEPT PLAN
BINDARING WETLAND, BASSENDEAN

SITE LOCATION

Figure 1

ENVIRONMAPS
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www.environmaps.com.au

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Source: Cadastre - Landgate, 2017
Orthophoto - NearMaps, 24.04.17
Topography - DoW, 2015

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Job: TOBBWC01
Doc: 001
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

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TOPOGRAPHY

Figure 2

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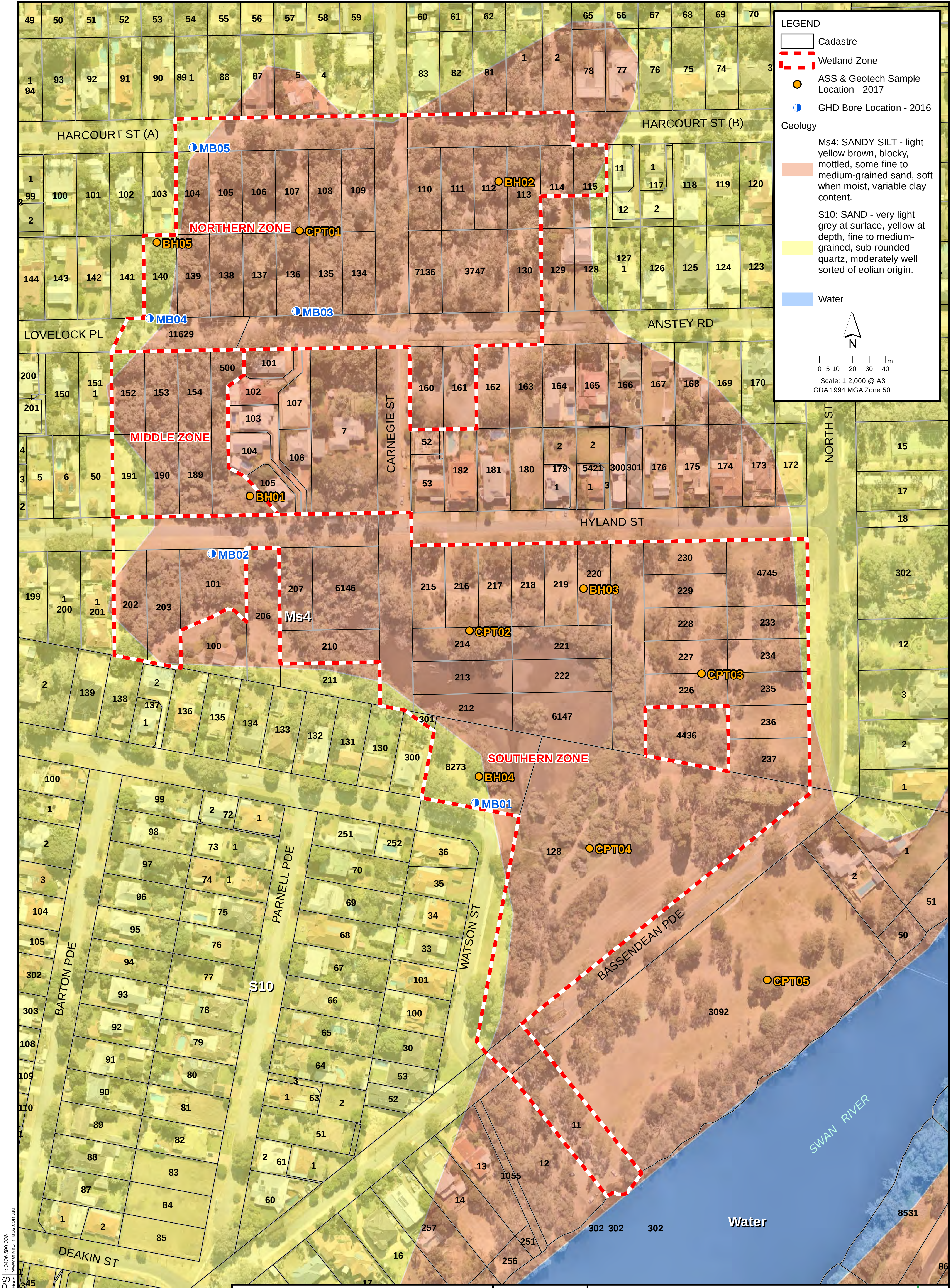

Source: Cadastre - Landgate, 2017
Orthophoto - NearMaps, 24.04.17
Geology - DoIR: Geological Survey of W.A., 1999

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Job: TOBBWC01
Doc: 003
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

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GEOLOGY, SOILS AND SAMPLE LOCATIONS

Figure 3

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Source: Cadastre - Landgate, 2017
Orthophoto - NearMaps, 24.04.17
Floodway Mapping - DoW, 2013

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Doc: 004
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

Town of Bassendean
BINDARING WETLAND CONCEPT PLAN
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HYDROLOGY

Figure 4

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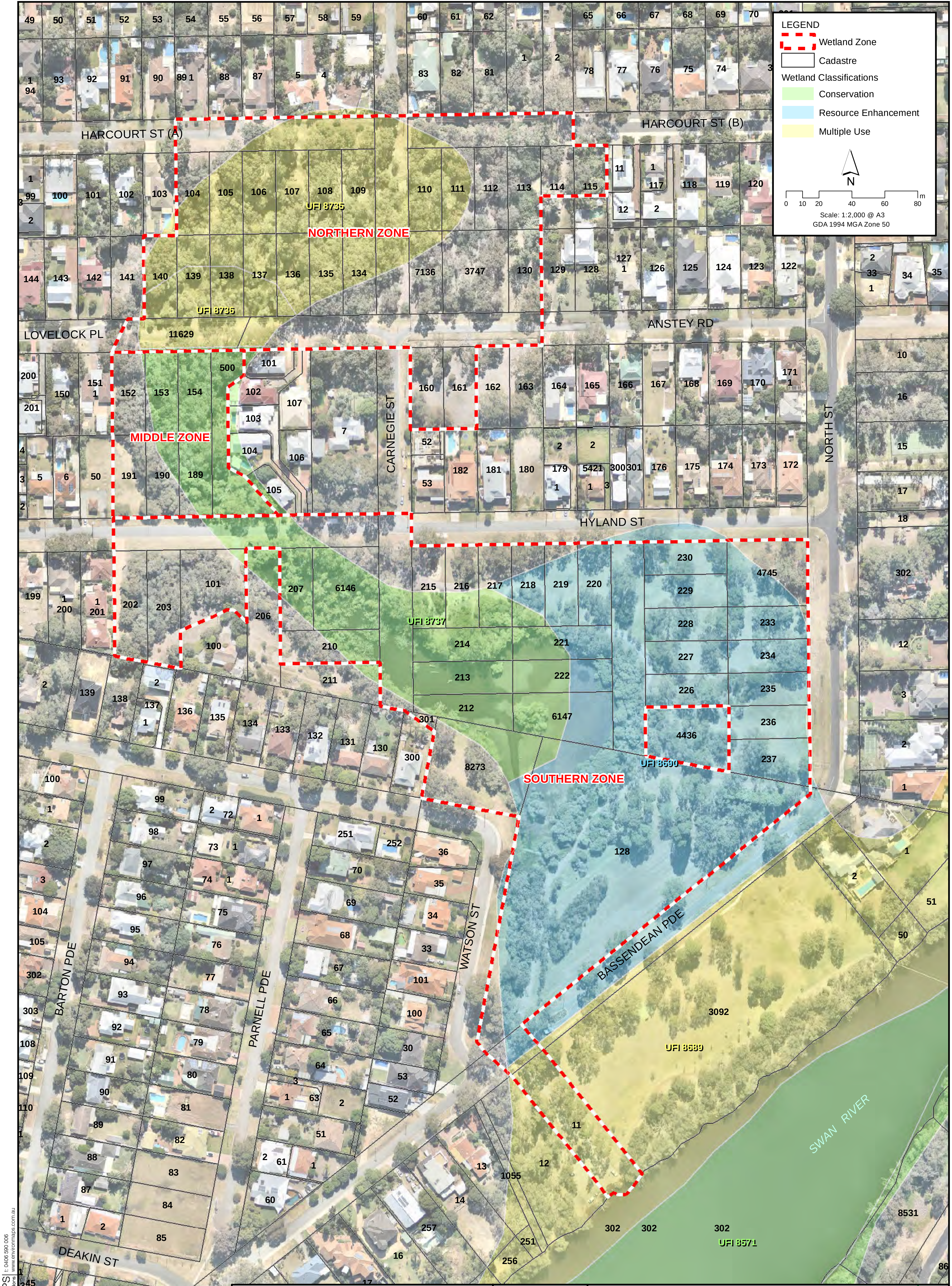

Source: Cadastre - Landgate, 2017
Orthophoto - NearMaps, 24.04.17
Wetlands - DPaW, 31.03.17

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Job: TOBBWC01
Doc: 005
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

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WETLAND CLASSIFICATIONS

Figure 5

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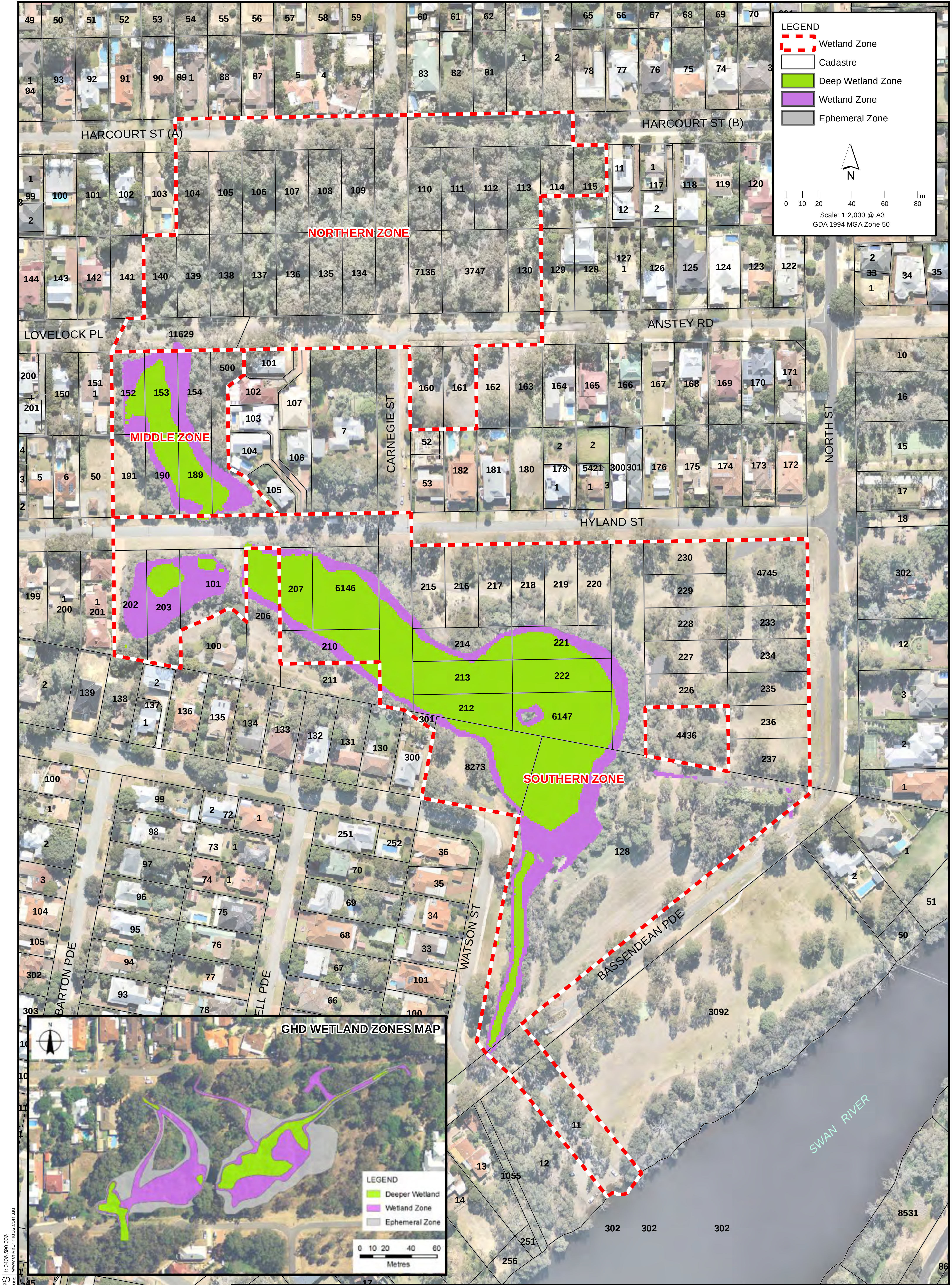

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Source: Cadastre - Landgate, 2017
Orthophoto - NearMaps, 24.04.17

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Job: TOBBWC01
Doc: 006
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

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BINDARING WETLAND CONCEPT PLAN
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WETLAND ZONES

Figure 6

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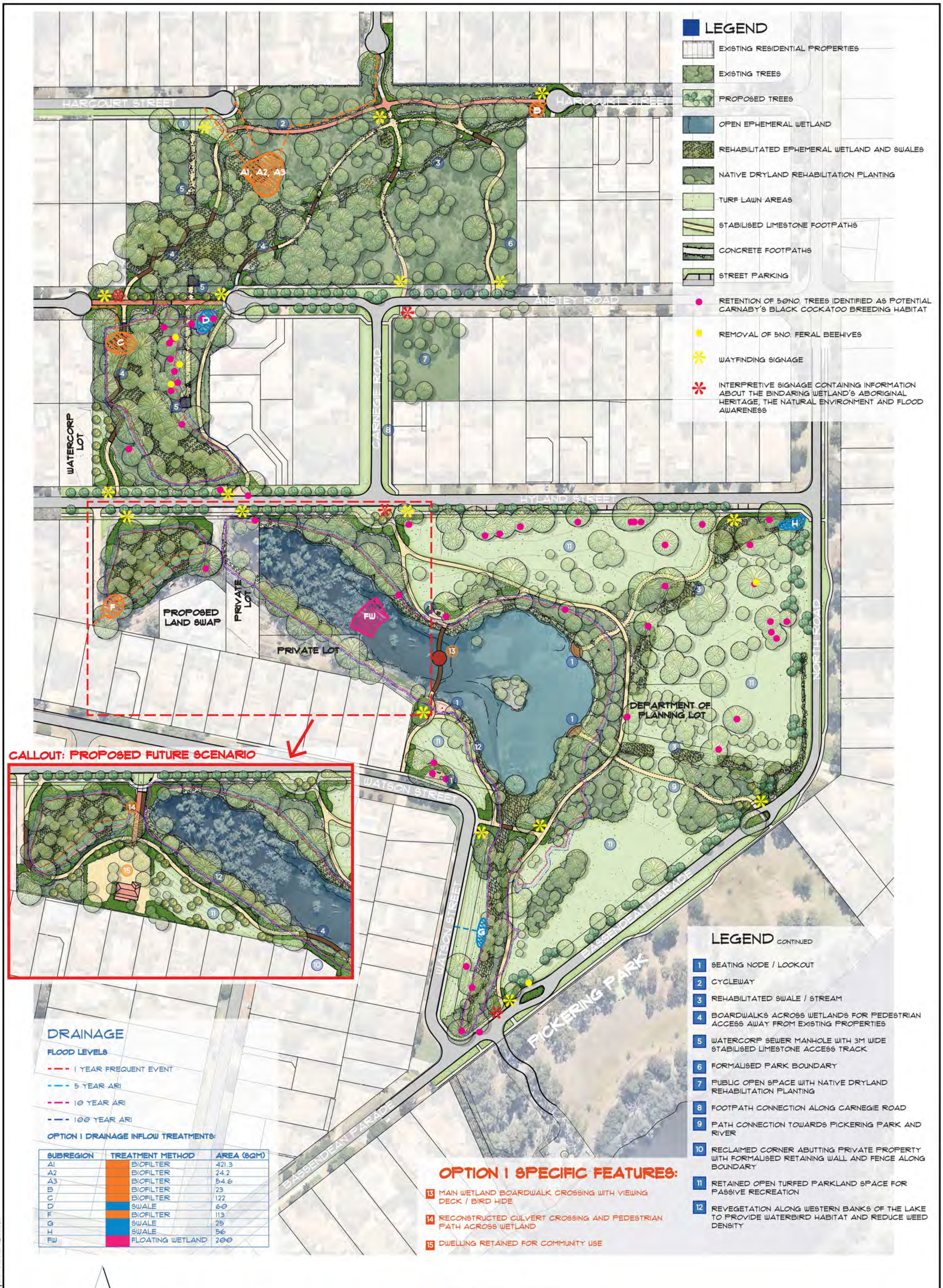

LEGEND

- ▨ EXISTING RESIDENTIAL PROPERTIES
- EXISTING TREES
- PROPOSED TREES
- OPEN EPHEMERAL WETLAND
- REHABILITATED EPHEMERAL WETLAND AND SWALES
- NATIVE DRYLAND REHABILITATION PLANTING
- TURF LAWN AREAS
- STABILISED LIMESTONE FOOTPATHS
- CONCRETE FOOTPATHS
- STREET PARKING
- ● RETENTION OF 50NO. TREES IDENTIFIED AS POTENTIAL CARNABY'S BLACK COCKATOO BREEDING HABITAT
- ● REMOVAL OF 5NO. FERAL BEEHIVES
- ✳ WAYFINDING SIGNAGE
- ✳ INTERPRETIVE SIGNAGE CONTAINING INFORMATION ABOUT THE BINDARING WETLAND'S ABORIGINAL HERITAGE, THE NATURAL ENVIRONMENT AND FLOOD AWARENESS

LEGEND CONTINUED

1 SEATING NODE / LOOKOUT
2 CYCLEWAY
3 REHABILITATED SWALE / STREAM
4 BOARDWALKS ACROSS WETLANDS FOR PEDESTRIAN ACCESS AWAY FROM EXISTING PROPERTIES
5 WATERCORP SEWER MANHOLE WITH 3M WIDE STABILISED LIMESTONE ACCESS TRACK
6 FORMALISED PARK BOUNDARY
7 PUBLIC OPEN SPACE WITH NATIVE DRYLAND REHABILITATION PLANTING
8 FOOTPATH CONNECTION ALONG CARNEGIE ROAD
9 PATH CONNECTION TOWARDS PICKERING PARK AND RIVER
10 RECLAIMED CORNER ABUTTING PRIVATE PROPERTY WITH FORMALISED RETAINING WALL AND FENCE ALONG BOUNDARY
11 RETAINED OPEN TURFED PARKLAND SPACE FOR PASSIVE RECREATION
12 REVEGETATION ALONG WESTERN BANKS OF THE LAKE TO PROVIDE WATERBIRD HABITAT AND REDUCE WEED DENSITY

OPTION 1 SPECIFIC FEATURES:

13 MAIN WETLAND BOARDWALK CROSSING WITH VIEWING DECK / BIRD HIDE
14 RECONSTRUCTED CULVERT CROSSING AND PEDESTRIAN PATH ACROSS WETLAND
15 DWELLING RETAINED FOR COMMUNITY USE

DRAINAGE

FLOOD LEVELS

- - - 1 YEAR FREQUENT EVENT
- - - 5 YEAR ARI
- - - 10 YEAR ARI
- - - 100 YEAR ARI

OPTION 1 DRAINAGE INFLOW TREATMENTS:

SUBREGION	TREATMENT METHOD	AREA (SQM)
A1	🟧 BIOFILTER	421.3
A2	🟧 BIOFILTER	24.2
A3	🟧 BIOFILTER	54.6
B	🟧 BIOFILTER	23
C	🟧 BIOFILTER	122
D	🟦 SWALE	60
F	🟧 BIOFILTER	113
G	🟦 SWALE	25
H	🟦 SWALE	56
FW	🟪 FLOATING WETLAND	200

Source: Concept Plan - EPCAD, 26.07.17

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Environmental Mapping Solutions t: 0406 590 006 e: simoncrofts74@me.com

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ENVIRONMENT

Job: TOBBWC01
Doc: 007
Date: 27.07.17
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

Town of Bassendean
BINDARING WETLAND CONCEPT PLAN
BINDARING WETLAND, BASSENDEAN

LANDSCAPE CONCEPT MASTERPLAN
OPTION 1

Figure 7

CALLOUT: PROPOSED FUTURE SCENARIO

DISCLAIMER: THE FLOOD MODELLING AND INUNDATION AREAS DEPICTED ON THIS CONCEPT PLAN ARE BASED ON THE EXISTING SITE TOPOGRAPHY AND CONDITIONS, AS PER THE SCOPE. PLEASE NOTE THAT THESE AREAS HAVE THEREFORE NOT TAKEN INTO ACCOUNT THE REMOVAL OF THE CAUSEWAY AS SHOWN PICTORIALLY AND ARE NOT INDICATIVE OF THE FLOOD INUNDATION IN THAT SCENARIO. FURTHER MODELLING WOULD BE REQUIRED TO REFINE THE FLOOD LEVELS AND AREAS SHOULD THIS OPTION BE PROGRESSED.

LEGEND

- EXISTING RESIDENTIAL PROPERTIES
- EXISTING TREES
- PROPOSED TREES
- OPEN EPHEMERAL WETLAND
- REHABILITATED EPHEMERAL WETLAND AND SWALES
- NATIVE DRYLAND REHABILITATION PLANTING
- TURF LAWN AREAS
- STABILISED LIMESTONE FOOTPATHS
- CONCRETE FOOTPATHS
- STREET PARKING
- ● RETENTION OF 50NO. TREES IDENTIFIED AS POTENTIAL CARNABY'S BLACK COCKATOO BREEDING HABITAT
- ● REMOVAL OF 5NO. FERAL BEEHIVES
- ✳ WAYFINDING SIGNAGE
- ✳ INTERPRETIVE SIGNAGE CONTAINING INFORMATION ABOUT THE BINDARING WETLAND'S ABORIGINAL HERITAGE, THE NATURAL ENVIRONMENT AND FLOOD AWARENESS

LEGEND CONTINUED

1. SEATING NODE / LOOKOUT
2. CYCLEWAY
3. REHABILITATED SWALE / STREAM
4. BOARDWALKS ACROSS WETLANDS FOR PEDESTRIAN ACCESS AWAY FROM EXISTING PROPERTIES
5. WATERCORP SEWER MANHOLE WITH 3M WIDE STABILISED LIMESTONE ACCESS TRACK
6. FORMALISED PARK BOUNDARY
7. PUBLIC OPEN SPACE WITH NATIVE DRYLAND REHABILITATION PLANTING
8. FOOTPATH CONNECTION ALONG CARNEGIE ROAD
9. PATH CONNECTION TOWARDS PICKERING PARK AND RIVER
10. RECLAIMED CORNER ABUTTING PRIVATE PROPERTY WITH FORMALISED RETAINING WALL AND FENCE ALONG BOUNDARY
11. RETAINED OPEN TURFED PARKLAND SPACE FOR PASSIVE RECREATION
12. REVEGETATION ALONG WESTERN BANKS OF THE LAKE TO PROVIDE WATERBIRD HABITAT AND REDUCE WEED DENSITY

OPTION 2 SPECIFIC FEATURES:

13. CAUSEWAY DEMOLISHED AND PEDESTRIAN BOARDWALK CROSSING CONSTRUCTED
14. DWELLING RETAINED FOR COMMUNITY USE

DRAINAGE

FLOOD LEVELS

- 1 YEAR FREQUENT EVENT
- 5 YEAR ARI
- 10 YEAR ARI
- 100 YEAR ARI

OPTION 2 DRAINAGE INFLOW TREATMENTS:

SUBREGION	TREATMENT METHOD		AREA (SQM)
A1	🟧	BIOFILTER	421.3
A2	🟧	BIOFILTER	24.2
A3	🟧	BIOFILTER	54.6
B	🟦	SWALE	23
C	🟦	SWALE	122
D	🟦	SWALE	60
F	🟦	SWALE	113
G	🟦	SWALE	25
H	🟦	SWALE	56

Source: Concept Plan - EPCAD, 26.07.17

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Job: TOBBWC01
Doc: 008
Date: 27.07.17
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

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BINDARING WETLAND CONCEPT PLAN
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LANDSCAPE CONCEPT MASTERPLAN OPTION 2

Figure 8

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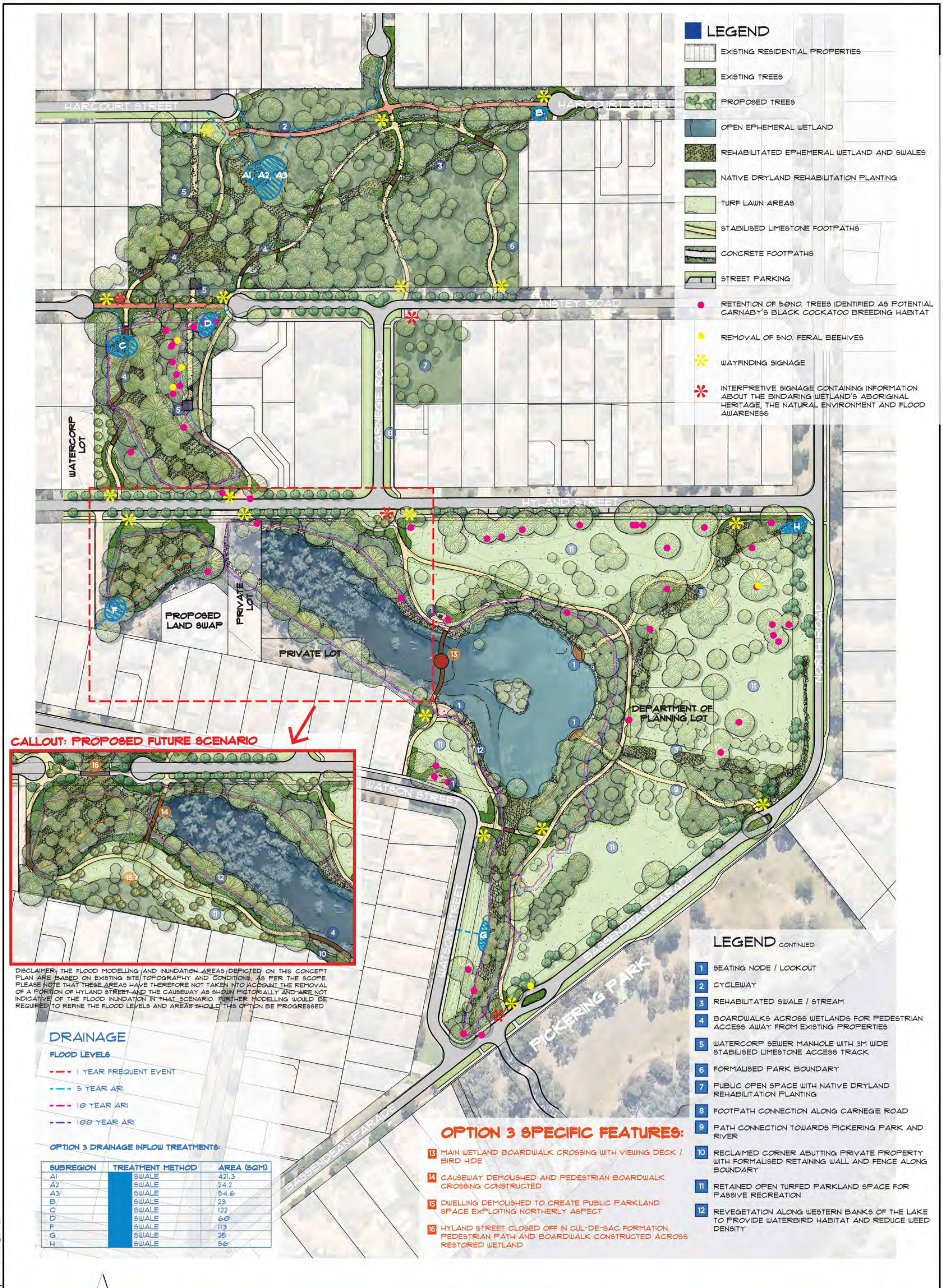

LEGEND

- ▨ EXISTING RESIDENTIAL PROPERTIES
- EXISTING TREES
- PROPOSED TREES
- OPEN EPHEMERAL WETLAND
- REHABILITATED EPHEMERAL WETLAND AND SWALES
- NATIVE DRYLAND REHABILITATION PLANTING
- TURF LAWN AREAS
- STABILISED LIMESTONE FOOTPATHS
- CONCRETE FOOTPATHS
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- ● REMOVAL OF 5NO. FERAL BEEHIVES
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CALLOUT: PROPOSED FUTURE SCENARIO

DISCLAIMER: THE FLOOD MODELLING AND INUNDATION AREAS DEPICTED ON THIS CONCEPT PLAN ARE BASED ON EXISTING SITE TOPOGRAPHY AND CONDITIONS, AS PER THE SCOPE. PLEASE NOTE THAT THESE AREAS HAVE THEREFORE NOT TAKEN INTO ACCOUNT THE REMOVAL OF A PORTION OF HYLAND STREET AND THE CAUSEWAY AS SHOWN PICTORIALLY AND ARE NOT INDICATIVE OF THE FLOOD INUNDATION IN THAT SCENARIO. FURTHER MODELLING WOULD BE REQUIRED TO REFINE THE FLOOD LEVELS AND AREAS SHOULD THIS OPTION BE PROGRESSED.

DRAINAGE

FLOOD LEVELS

- 1 YEAR FREQUENT EVENT
- 5 YEAR ARI
- 10 YEAR ARI
- 100 YEAR ARI

OPTION 3 DRAINAGE INFLOW TREATMENTS:

SUBREGION	TREATMENT METHOD	AREA (SQM)
A1	SWALE	421.3
A2	SWALE	24.2
A3	SWALE	54.6
B	SWALE	23
C	SWALE	122
D	SWALE	60
F	SWALE	113
G	SWALE	25
H	SWALE	56

OPTION 3 SPECIFIC FEATURES:

13 MAIN WETLAND BOARDWALK CROSSING WITH VIEWING DECK / BIRD HIDE
14 CAUSEWAY DEMOLISHED AND PEDESTRIAN BOARDWALK CROSSING CONSTRUCTED
15 DWELLING DEMOLISHED TO CREATE PUBLIC PARKLAND SPACE EXPLOITING NORTHERLY ASPECT
16 HYLAND STREET CLOSED OFF IN CUL-DE-SAC FORMATION. PEDESTRIAN PATH AND BOARDWALK CONSTRUCTED ACROSS RESTORED WETLAND

LEGEND CONTINUED

1 SEATING NODE / LOOKOUT
2 CYCLEWAY
3 REHABILITATED SWALE / STREAM
4 BOARDWALKS ACROSS WETLANDS FOR PEDESTRIAN ACCESS AWAY FROM EXISTING PROPERTIES
5 WATERCORP SEWER MANHOLE WITH 3M WIDE STABILISED LIMESTONE ACCESS TRACK
6 FORMALISED PARK BOUNDARY
7 PUBLIC OPEN SPACE WITH NATIVE DRYLAND REHABILITATION PLANTING
8 FOOTPATH CONNECTION ALONG CARNEGIE ROAD
9 PATH CONNECTION TOWARDS PICKERING PARK AND RIVER
10 RECLAIMED CORNER ABUTTING PRIVATE PROPERTY WITH FORMALISED RETAINING WALL AND FENCE ALONG BOUNDARY
11 RETAINED OPEN TURFED PARKLAND SPACE FOR PASSIVE RECREATION
12 REVEGETATION ALONG WESTERN BANKS OF THE LAKE TO PROVIDE WATERBIRD HABITAT AND REDUCE WEED DENSITY

N

0 25 50 75 100 m

Source: Concept Plan - EPCAD, 26.07.17

ENVIROMAP Environmental Mapping Solutions t: 0406 590 006 e: simoncrofts74@me.com

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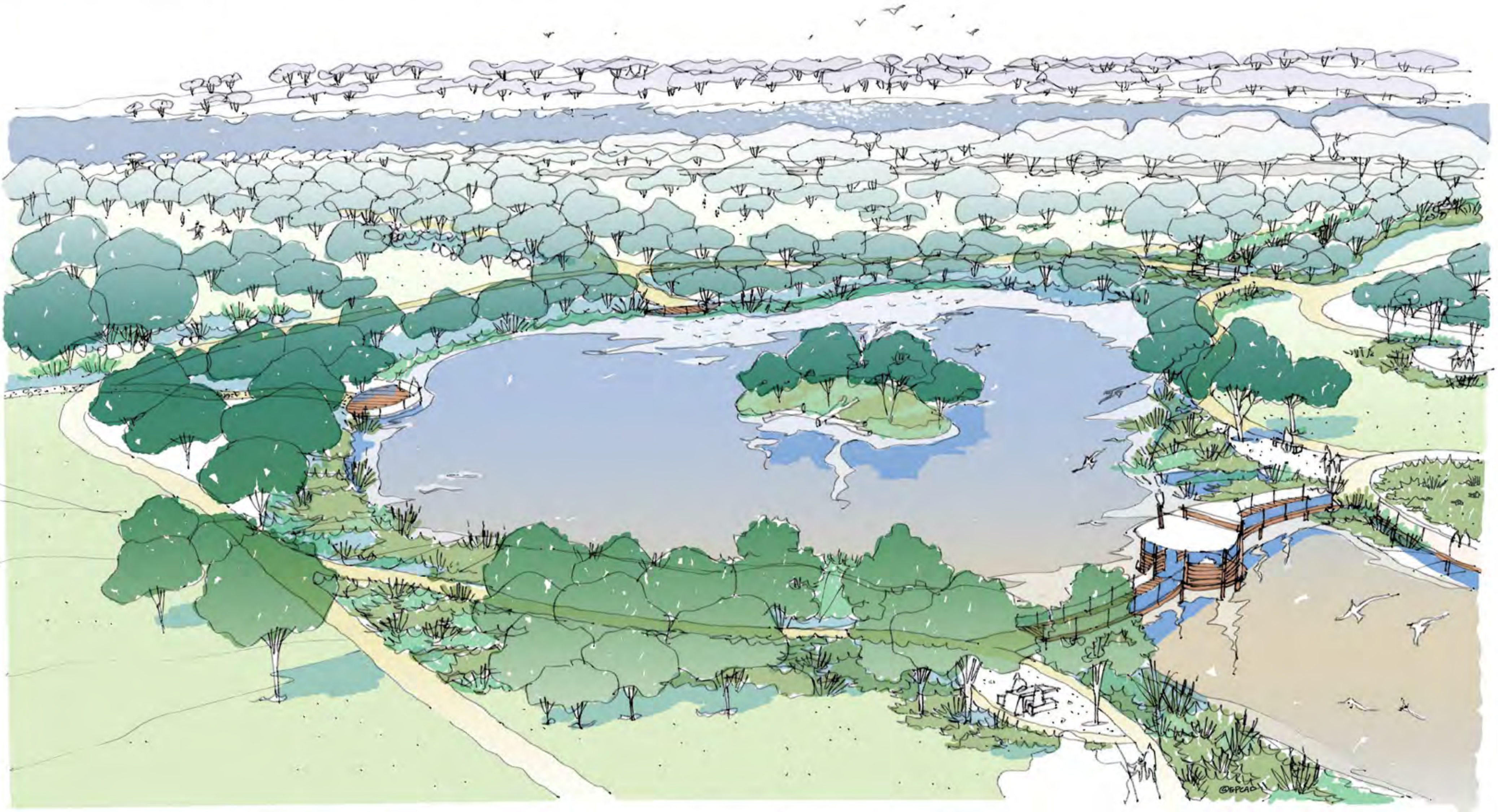
Job: TOBBWC01
Doc: 009
Date: 27.07.17
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

Town of Bassendean
BINDARING WETLAND CONCEPT PLAN
BINDARING WETLAND, BASSENDEAN

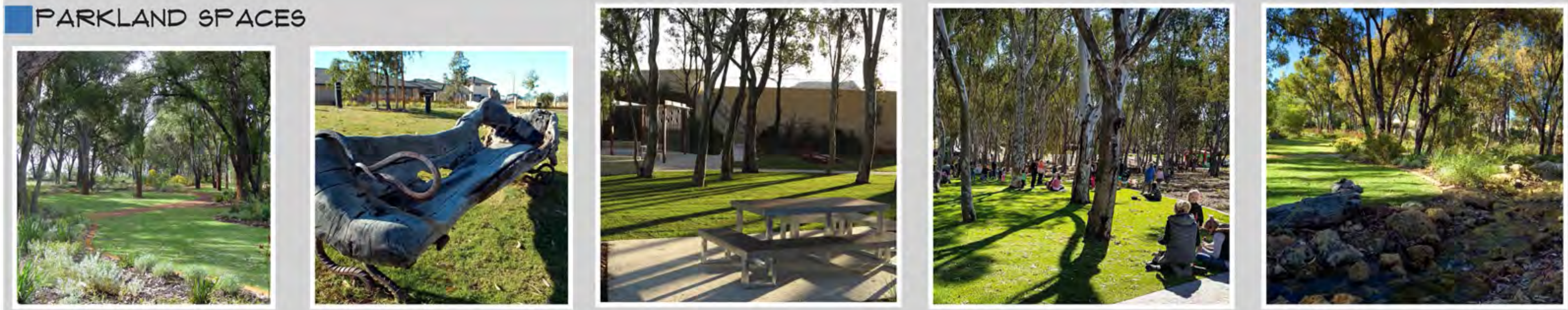
**LANDSCAPE CONCEPT MASTERPLAN
OPTION 3**

Figure 9

BIRDS EYE PERSPECTIVE: LOOKING SOUTH TOWARDS THE CENTRAL LAKE WITH VIEWING DECKS AND PICNIC SPACES



PARKLAND SPACES



SWALES AND BIOFILTERS

BOARDWALKS

COTERRA
ENVIRONMENT

Job: TOBBWC01
Doc: 010
Date: 27.07.17
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

Town of Bassendean
BINDARING WETLAND CONCEPT PLAN
BINDARING WETLAND, BASSENDEAN

LANDSCAPE MASTERPLAN SKETCHES AND IMAGERY

Figure 10

Source: Concept Plan - EPCAD, 27.07.17

ENVIROMAP
Environmental Mapping Solutions
t: 0406 590 006
e: simoncrofts74@me.com

APPENDIX A – Survey surveys


N
0 5000 10000 15000 20000 25000mm
SCALE 1:500 AT ORIGINAL SIZE

SERVICE LEGEND

POWER

CONSUMER POLE	CP
POWER POLE	PP
LIGHT POLE	LP
STAY POLE	SP
S. WIRE ANCHOR	SWA
U/G CABLE BOX	
CABLE M/H	☒
CABLE DOME	

GAS

GAS MARKER	G
GAS METER	GM
GAS VALVE	GV

SEWERAGE

SEWER MANHOLE	○
INSPECT. SHAFT	IS
INSPECT. OPENING	IO
HOUSE CONNECTION	HC

TELSTRA

TELSTRA MARKER	T
TELSTRA PIT	TEL
TELSTRA M/H	⊞

DRAINAGE

SW MANHOLE	DMH
GRATE	
SIDE ENTRY PIT	

WATER

STOP VALVE	SV
HYDRANT	HY
FLUSH POINT	FP
WATER TAP	TP
WATER MARKER	W
WATER METER	M

SURVEY

PEG FOUND	PF
PEG DISTURBED	PD
PEG GONE	PG
CONTROL POINT	△
DATUM	✦

LOT RECORDS

STATUS / LOT SERVICE	LOCATED	AVAILABLE	NO SERVICE	CONFIRM
WATER	✓			
SEWERAGE	✓			
GAS		✓		✓
TELSTRA	✓			
DRAINAGE	✓			
POWER U/G				✓
O/H	✓			

AREA: -

COASTAL DISTANCE >1.5Km

LOT: -
AREA: -

AHD:

SERVICES MARKED CONFIRM REQUIRE BUILDER / CLIENT TO CONFIRM POSITION & / OR AVAILABILITY ON SITE. AHD CONNECTION OBSERVED FROM LANDGATE'S GEODETIC RECORDS.

N

HORIZONTAL DATUM : PCG - 94
VERTICAL DATUM : AHD

TITLE : FEATURE SURVEY
CLIENT : WESTERN ENVIRONMENTAL PTY LTD
BUILDER :

AREA : BINDARING WETLAND
SUBURB : BASSENDEAN
AUTHORITY : TOWN OF BASSENDEAN
C/T :
UBD REF : 251 A 9
GPS : S 31.91160° E 115.95844°

5 0 2.5 5 10 15

LINKS SURVEYING
P: (08) 9354 8511
W: www.linkssurveying.com.au
E: info@linkssurveying.com.au

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SHEET	BUILDER'S REF	SURVEYED	SCALE @ A0	DWG No	REV
2 of 5		14/03/17	1: 200	31124005	A

SERVICE LEGEND

POWER

CONSUMER POLE	CP
POWER POLE	PP
LIGHT POLE	LP
STAY POLE	SP
S. WIRE ANCHOR	SWA
U/G CABLE BOX	
CABLE M/H	☒
CABLE DOME	

GAS

GAS MARKER	G
GAS METER	GM
GAS VALVE	GV

SEWERAGE

SEWER MANHOLE	
INSPECT. SHAFT	IS
INSPECT. OPENING	IO
HOUSE CONNECTION	HC

TELSTRA

TELSTRA MARKER	T
TELSTRA PIT	TEL
TELSTRA M/H	

DRAINAGE

SW MANHOLE	DMH
GRATE	
SIDE ENTRY PIT	

WATER

STOP VALVE	SV
HYDRANT	HY
FLUSH POINT	FP
WATER TAP	TP
WATER MARKER	W
WATER METER	M

SURVEY

PEG FOUND	PF
PEG DISTURBED	PD
PEG GONE	PG
CONTROL POINT	△
DATUM	✦

LOT RECORDS

STATUS / LOT SERVICE	LOCATED	AVAILABLE	NO SERVICE	CONFIRM
WATER	✓			
SEWERAGE	✓			
GAS		✓		✓
TELSTRA	✓			
DRAINAGE	✓			
POWER U/G				✓
POWER O/H	✓			

AREA: -

COASTAL DISTANCE >1.5Km

LOT: -
AREA: -

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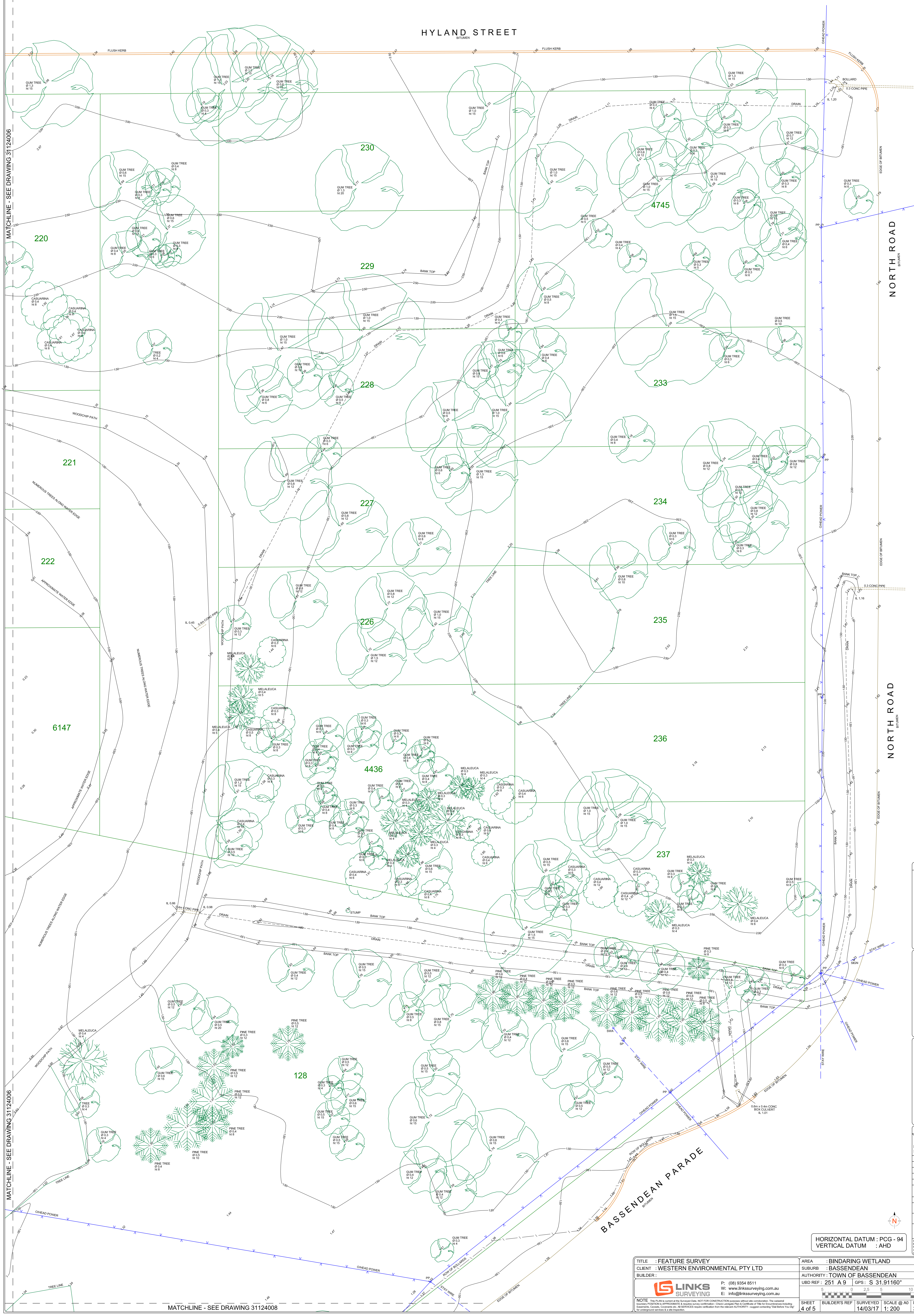
5 0 2.5 5 10 15

SHEET	BUILDER'S REF	SURVEYED	SCALE @ A0	DWG No	REV
3 of 5		14/03/17	1: 200	31124006	A



SERVICE LEGEND

POWER

CONSUMER POLE	CP
POWER POLE	PP
LIGHT POLE	LP
STAY POLE	SP
S. WIRE ANCHOR	SWA
U/G CABLE BOX	
CABLE M/H	☒
CABLE DOME	

GAS

GAS MARKER	G
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GAS VALVE	GV

SEWERAGE

SEWER MANHOLE	
INSPECT. SHAFT	IS
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HOUSE CONNECTION	HC

TELSTRA

TELSTRA MARKER	T
TELSTRA PIT	TEL
TELSTRA M/H	

DRAINAGE

SW MANHOLE	DMH
GRATE	
SIDE ENTRY PIT	

WATER

STOP VALVE	SV
HYDRANT	HY
FLUSH POINT	FP
WATER TAP	TP
WATER MARKER	W
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SURVEY

PEG FOUND	PF
PEG DISTURBED	PD
PEG GONE	PG
CONTROL POINT	△
DATUM	✦

LOT RECORDS

STATUS / LOT SERVICE	LOCATED	AVAILABLE	NO SERVICE	CONFIRM
WATER	✓			
SEWERAGE	✓			
GAS		✓		✓
TELSTRA	✓			
DRAINAGE	✓			
POWER U/G				✓
O/H	✓			

AREA: -

COASTAL DISTANCE >1.5Km

LOT: -
AREA: -

AHD:

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5 0 2.5 5 10 15

SHEET	BUILDER'S REF	SURVEYED	SCALE @ A0	DWG No	REV
4 of 5		14/03/17	1: 200	31124007	A

SERVICE LEGEND

POWER	
CONSUMER POLE	CP
POWER POLE	PP
LIGHT POLE	LP
STAY POLE	SP
S. WIRE ANCHOR	SWA
U/G CABLE BOX	
CABLE M/H	☒
CABLE DOME	
GAS	
GAS MARKER	G
GAS METER	GM
GAS VALVE	GV
SEWERAGE	
SEWER MANHOLE	
INSPECT. SHAFT	IS
INSPECT. OPENING	IO
HOUSE CONNECTION	HC
TELSTRA	
TELSTRA MARKER	T
TELSTRA PIT	TEL
TELSTRA M/H	
DRAINAGE	
SW MANHOLE	DMH
GRATE	
SIDE ENTRY PIT	
WATER	
STOP VALVE	SV
HYDRANT	HY
FLUSH POINT	FP
WATER TAP	TP
WATER MARKER	W
WATER METER	M
SURVEY	
PEG FOUND	PF
PEG DISTURBED	PD
PEG GONE	PG
CONTROL POINT	△
DATUM	✦

LOT RECORDS

STATUS / LOT SERVICE	LOCATED	AVAILABLE	NO SERVICE	CONFIRM
WATER	✓			
SEWERAGE	✓			
GAS		✓		✓
TELSTRA	✓			
DRAINAGE	✓			
POWER U/G				✓
O/H	✓			

AREA: -

COASTAL DISTANCE >1.5Km

LOT: -
AREA: -

AHD:

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SHEET	BUILDER'S REF	SURVEYED	SCALE @ A0	DWG No	REV
5 of 5		14/03/17	1: 200	31124008	A

APPENDIX B – Geotechnical Investigation

WA | QLD | NSW | VIC

GE2.3.001

GEOTECHNICAL INVESTIGATION

For: Town of Bassendean c/o Western Environmental

Project Address: Bindaring Wetlands – Bassendean Parade, Bassendean

Project Number: D168468

Job Number: J180065

Revision Number: 0

Author: Prasudi Atmajaya

Date: 4/7/2017

Structerre Consulting Engineers
(+618) 9205 4500
1 Erindale Road, Balcatta WA 6021
wageotecheng@structerre.com.au
www.structerre.com.au

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1. PROJECT DETAILS

1.1. Introduction

At the request of James Gibson of Western Environmental (The Client), Structerre Consulting Engineers (Structerre) have conducted a Geotechnical Investigation at Bindaring Wetlands, Bassendean. The purpose of the investigation was to provide the following for improvement of the existing site:

- Desk top study including a summary of geology, groundwater and site history (obtained from historical photographs)
- Summary of encountered ground and groundwater conditions
- Discussion of geotechnical issues including site preparation requirements (earthworks), including site traffic, excavation, reuse of materials and batter slopes
- Geotechnical design parameters
- California Bearing Ratio (CBR) values determined from penetrometer results, ground conditions encountered and laboratory testing

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, 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 Engineers proposal reference Q66712 (dated 22 December 2016), which was submitted to and accepted by The Client.

1.2. Site Description & Proposed Development

The site is located at Bindaring Wetlands in Bassendean, Town of Bassendean. It extends from the south of Harcourt Street to the north of Bassendean Parade and includes the existing Bindaring Park and Pickering Park; the latter lies immediate to Swan River.

The site could be allotted into 4 areas based on the streets separating them; site plan in appendix 1 refers. These areas generally lie on lower elevations than the surrounding topography, with the exception of Pickering Park on the south where the ground is sloping towards the river.

At the time of the field investigation the site was a reserve area with trees, grass and a locally encountered water body.

We understand that it is proposed to enhance the wetland ecological values and to improve amenities at site with an end goal of improving water quality discharge into the Swan River.

1.3. Field Investigation – Scope of Works

The field investigation was carried out on 30 June 2017 and comprised:

- 5 x Electric Friction Cone Penetrometer Tests (EFCPT) to a maximum depth of 4.0m for material assessment and soil profiling;
- 5 x Sample Retrieval Probe (SRP) boreholes to a depth of 3.0m over the site for material assessment and soil profiling;
- 5 x Dynamic Cone Penetrometer (DCP) tests in accordance with AS 1289.6.3.2 (1997) to a depth of 3.2m for evaluation of relative densities of the upper layers.

The EFCPT, borehole and DCP test locations are shown on the attached site plan in Appendix 1.

A geotechnical engineer from Structerre supervised the fieldwork and all fieldwork, interpretation and terminology used in this report are in accordance with the guidelines presented in AS1726-1993 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:

- SANDY SILT (Ms_4) – cream to pale brown alluvium, clayey in part, fine to medium-grained sand, of alluvial origin (Alluvium, Qha);
- SAND (S_{10}) – very light grey at surface, yellow at depth, fine to medium grained, sub-rounded, quartz, moderately sorted of eolian origin (Bassendean Sand Qpb overlying Guildford Formation Qpa).

2.2. Ground Surface and Groundwater Level

The Perth Groundwater Atlas (Waters & Rivers Commission) indicates the ground surface level at this site was approximately 1.0-5.0m Australian Height Datum (AHD).

The May 2003 groundwater level at the site was approximately 1.0m AHD and the historical maximum was indicated to be approximately 6.0m. 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. Site History

Historical aerial photographs dating back to 1953 are publically available through Landgate Map Viewer were assessed and a summary is presented in Table 1.

Table 1 – Historical Site Information

Date	Description
1953	The wetlands have taken the current form. Residential properties have been built surrounding the site.
1965	Hyland Street was extended through the site.
1965-2015	Site remains relatively unchanged to the current day. Water Body within Bindaring Park was understood to fluctuate with times.

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 EFCPT and DCP test results:

Table 2 – Subsurface Soil Profile

Depth to Base of Strata (m)	Material Description
1.7	FILL: SAND, with gravel, trace silt, generally loose. Locally encountered at the location of BH01.
Not Penetrated (>3.0m)	NATURAL: Clayey SAND, medium plasticity clay, locally trace gravel, firm locally stiff. Overlain locally with sand and silty sand layers.
Not Penetrated (>4.0m)	NATURAL: CLAY, medium plasticity, with sand, firm to stiff locally soft. Locally underlain and or interbedded with silty clay materials.

The soils encountered are consistent with the expected site conditions as predicted from the Environmental Geology Map. It is important to note that there may be pockets of fill on site that are deeper than that encountered by the investigation boreholes. The subsurface soil conditions encountered are presented in the bore logs, within Appendix 3.

3.2. Groundwater

Groundwater was encountered in boreholes BH01 and BH02 during and after drilling, and was established at respective depths of 1.2m and 1.5m. Groundwater was not detected in boreholes BH03 and BH04 due to holes collapsing to 1.3m and 1.5m deep, respectively. Boreholes BH01-04 were undertaken on areas with approximate ground surface levels of 1.0-3.0m AHD.

Groundwater was not detected in borehole BH05 however it is to be noted that BH05 was carried out on an area with approximate ground surface level of 4.0-5.0m AHD.

3.3. Laboratory Test Results

Selected representative soil samples were tested by Structerre's in-house NATA accredited laboratory for Atterberg Limits including shrink-swell index, organic content and soil compaction. The results are attached in Appendix 4.

3.3.1. Atterberg Limits

Atterberg Limits were tested by Structerre's in-house NATA accredited laboratory. Results of the testing are summarised below:

Table 3 – Atterberg Limits Test Results

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
BH02	0.7 - 1.3	CLAY with Sand	43	17	26	9.5
BH04	0.2 - 0.6	Sandy CLAY	34	16	18	7

Test results indicate that the natural clay material has moderate shrink swell capacity or degree of expansion, and low to moderate plasticity.

3.3.2. Organic Content Testing

Results for organic content tests of representative selected samples are summarised below, with test certificate presented in Appendix 4.

Table 4 – Organic Content Test Results

Test Hole	Depth (m)	Average Organic Content (%)	Moisture Content (%)
BH04	0.1 - 0.3	3.2	21.7
BH05	0.1 - 0.3	2.6	10.4

Based on the above result limited blending would be required to achieve suitable structural fill (i.e. <2% organics).

3.3.3. California Bearing Ratio (CBR)

Representative sample was tested for CBR by the Mining and Civil Geotest's NATA accredited laboratory in accordance with AS1289.5.2.1 (2003). The test certificates are presented in Appendix 4 and are summarised in Table 5.

Table 5 – California Bearing Ratio

Test Hole	Depth (m)	Soil Description	Optimum Moisture Content %	Maximum Dry Density t/m^3	CBR at 2.5mm Penetration (%)
BH01	0.1 - 0.5	SAND with Gravel	8.5	2.14	40

Based on the above results a soaked CBR of 40% would be recommended.

4. GEOTECHNICAL CONSTRUCTION CONSIDERATIONS

4.1. Earthworks

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 loose fill, topsoil, deleterious and organic materials.
- It is considered that the near surface loose sand requires improvement. Therefore, it is proposed to excavate and stockpile the materials for reuse, provided it is free from clay/silt (i.e. <5%), deleterious and organic materials. The depth of excavation may vary depending on conditions encountered 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 or deeper, it is recommended that this office be contacted for retaining design.
- Proof compact the exposed base. The compaction requirements are set out in Table 6, as per AS 3798-2007:

Table 6 – Compaction Requirements

Item	Application	Minimum relative compaction, %	
		Minimum density ratio (Standard Compaction Effort) (Cohesive soils)	**Minimum density index (Cohesionless soils)**
1	Commercial – fills to support minor loadings, including floor loading of up to 20kPa and isolated pad or strip footings to 100kPa	98	75
2	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 is to be inspected 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.

- The ground level should be built up to design levels with the 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 its is recommended that this be verified with appropriate laboratory testing.
- A minimum 0.6m of non-reactive cover (sand) is required on top of reactive materials i.e. clayey or clay, for the site to be classified as an equivalent Class "S" with an expected surface movement y_s = 15mm in accordance with AS 2870 (2011) Residential Slabs and Footings.
- After remedial earthworks have been completed, the earthworks should be inspected 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.

The material encountered on site can be deemed as 'easy' to 'hard' to excavate with medium sized earthwork equipment (i.e. a 20t excavator). A deeper excavation if undertaken might encounter the stiff clay layers, and might require localised use of a ripper. It is recommended that any excavation technique adopted consider reducing the transmission of vibrations to adjoining structures.

Should water be encountered during excavations, it is recommended that the excavation works be stopped and allow the water to dissipate before continuing. If the groundwater does not dissipate, appropriate remedial measures should be undertaken to stop the water from entering the excavation.

4.2. Geotechnical Design Parameters

Based on the on site observations and the site investigation results, the interpreted geotechnical soil parameters of the encountered materials are presented in Table 7:

Table 7 – Soil Parameters

Soil Type	Friction Angle Ø' (^{0})	Cohesion c' (kPa)	Density Y (t/m^3)	Elastic Modulus E (MPa)
SAND	27	0	1.70	5
Clayey SAND	30	5	1.90	15
CLAY – Silty CLAY	25	5	1.70	8

It is recommended that for design purposes, the soil parameters be crosschecked with the profiles shown in the borehole logs, relevant to the location of the structure.

5. CONCLUSIONS

A site investigation was carried out at the subject 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 subsurface soil profile encountered comprised sand fill to a depth of 1.7m, underlain with clayey sand with clay of medium plasticity, and clay (medium plasticity) locally silty clay materials to the investigated depth of 4.0m.
- The water table was encountered at the depths of 1.2-1.5m below the existing ground.
- The site can be classified as an equivalent Class “S” in accordance with AS 2870-2011 provided the recommended earthworks are undertaken, and a minimum of 0.6m deep non-reactive covers are provided on top of reactive materials.
- The recommended soaked CBR value is 40%.
- Recommended earthworks include stripping of unsuitable materials, excavation of loose materials, proof compaction of the base, placement of engineered fill and compaction to final level.

6. LIMITATION OF FIELD INVESTIGATIONS

This report has been prepared in accordance with generally accepted consulting practice for The Client 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 ENGINEERS

Author: Prasudi Atmajaya
Title: Geotechnical Engineer
Credentials: BE Civil & Construction (Hons), MIEAust

Disclaimer
This report is at the request of the addressee and no liability is accepted by Structerre Consulting Engineers 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
J180065	0	PA

7. REFERENCES

Department of Water – Perth Groundwater Atlas

Geological Survey of Western Australia 1:250,000 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 1289.5.2.1-2003 Methods of testing soils for engineering purposes – Soil compaction and density tests – Determination of the dry density/moisture content relation of a soil using modified compactive effort

AS 1289.6.1.1-2014 Methods of testing soils for engineering purposes – Soil strength and consolidation tests - Determination of the California Bearing Ratio of a soil – Standard laboratory method for a remoulded specimen

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

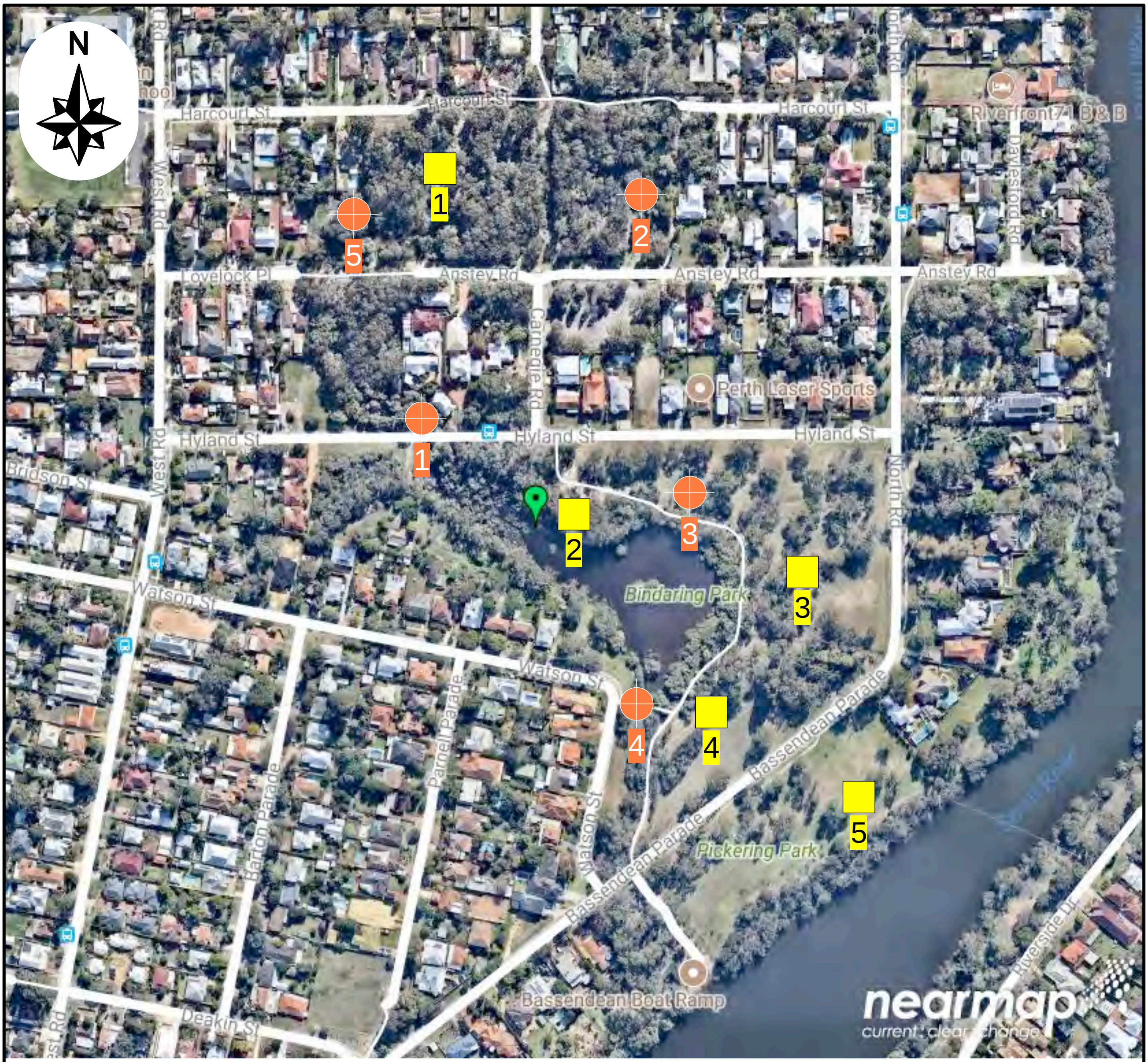
AS 1726-1993 Geotechnical site investigation

AS 2870-2011 Residential slabs and footings

AS 3798-2007 Guidelines on earthworks for commercial and residential developments

ASTM D 2974 Standard test methods for moisture, ash, and organic matter of peat and other organic soils

APPENDIX 1 – GEOTECHNICAL INVESTIGATION SITE PLAN



LEGEND:

⊕	SRP: DCP:	Sample Retrieval Probe Dynamic Cone Penetrometer Test
🟨	EFCPT:	Electric Friction Cone Penetration Test

STRUCterre consulting engineers

PROJECT: Bindaring Wetlands, BASSENDEAN

PROJECT #: D168468

JOB #: J180065

CLIENT: **Town of Bassendean c/- Western Environmental**

SCALE: NTS

TITLE: Geotechnical Investigation Site Plan

DATE: 30 Jun '17

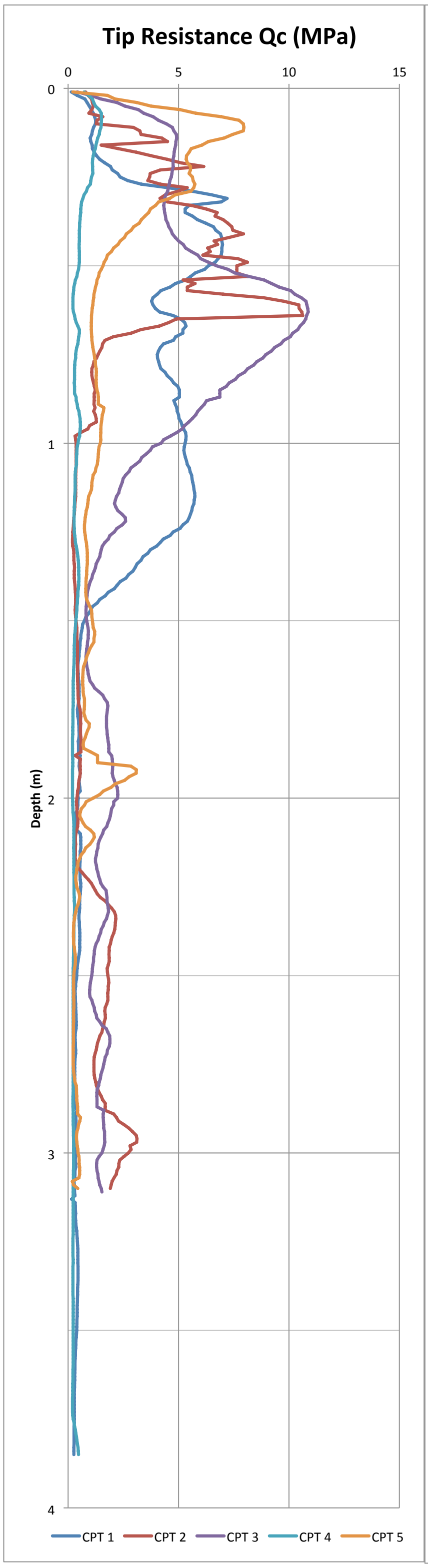
DRAWN BY: PA

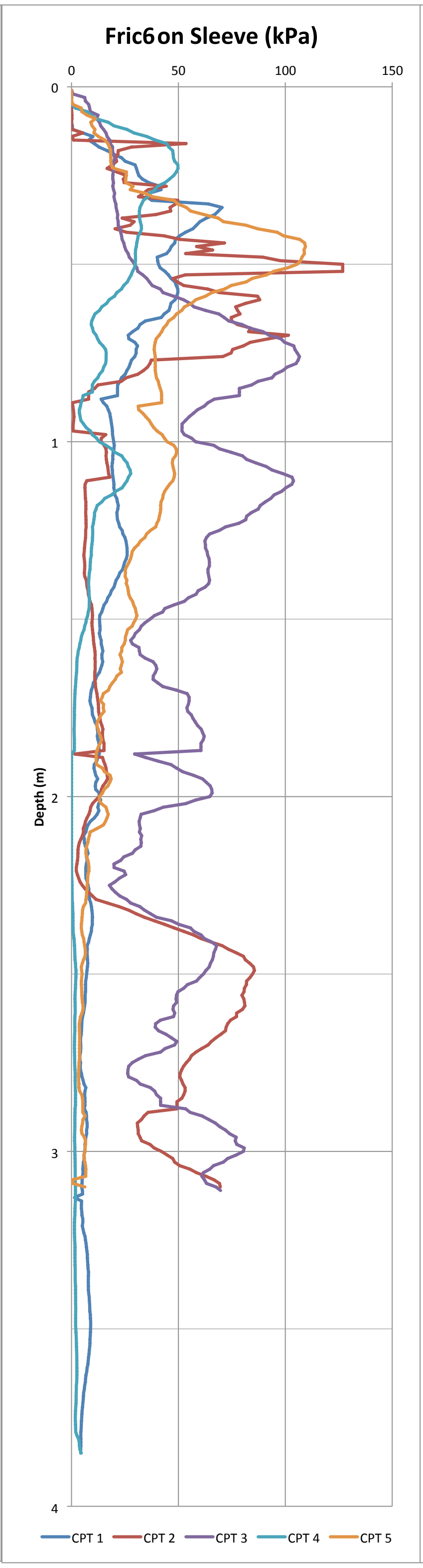
Zemla Pty Ltd (ABN 71 349 772 837) ATF the Young Purich and Higham
Unit Trust trading as Structerre Consulting Engineers

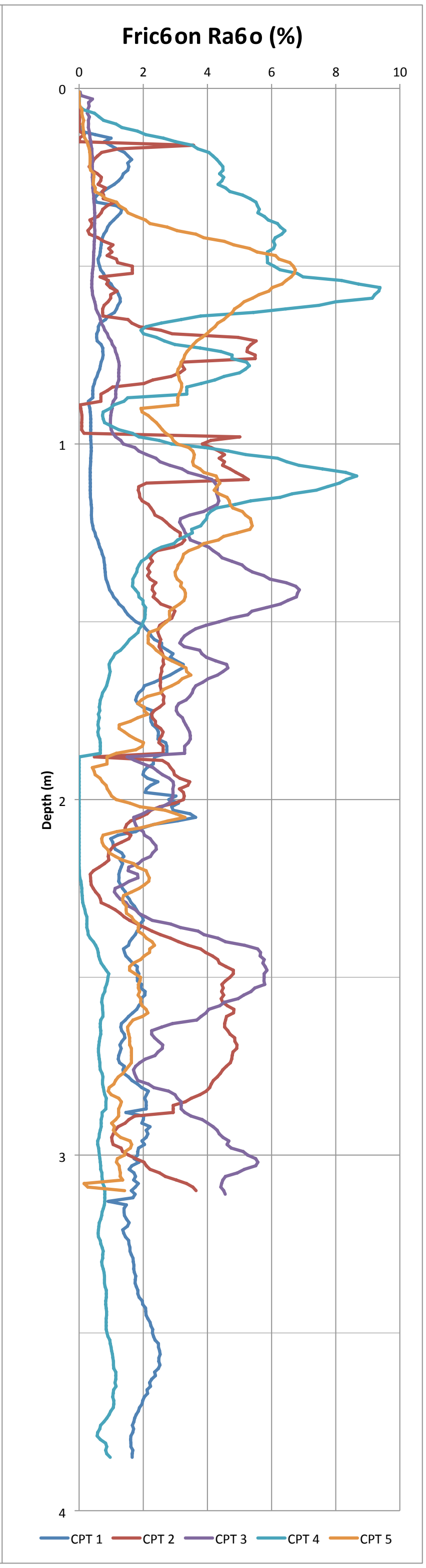
1 ERINDALE ROAD, BALCATTA, WA 6021
TEL 9205 4500 FAX 9205 4501 EMAIL: wageotecheng@structerre.com.au

APPENDIX 2 – EFCPT TRACES

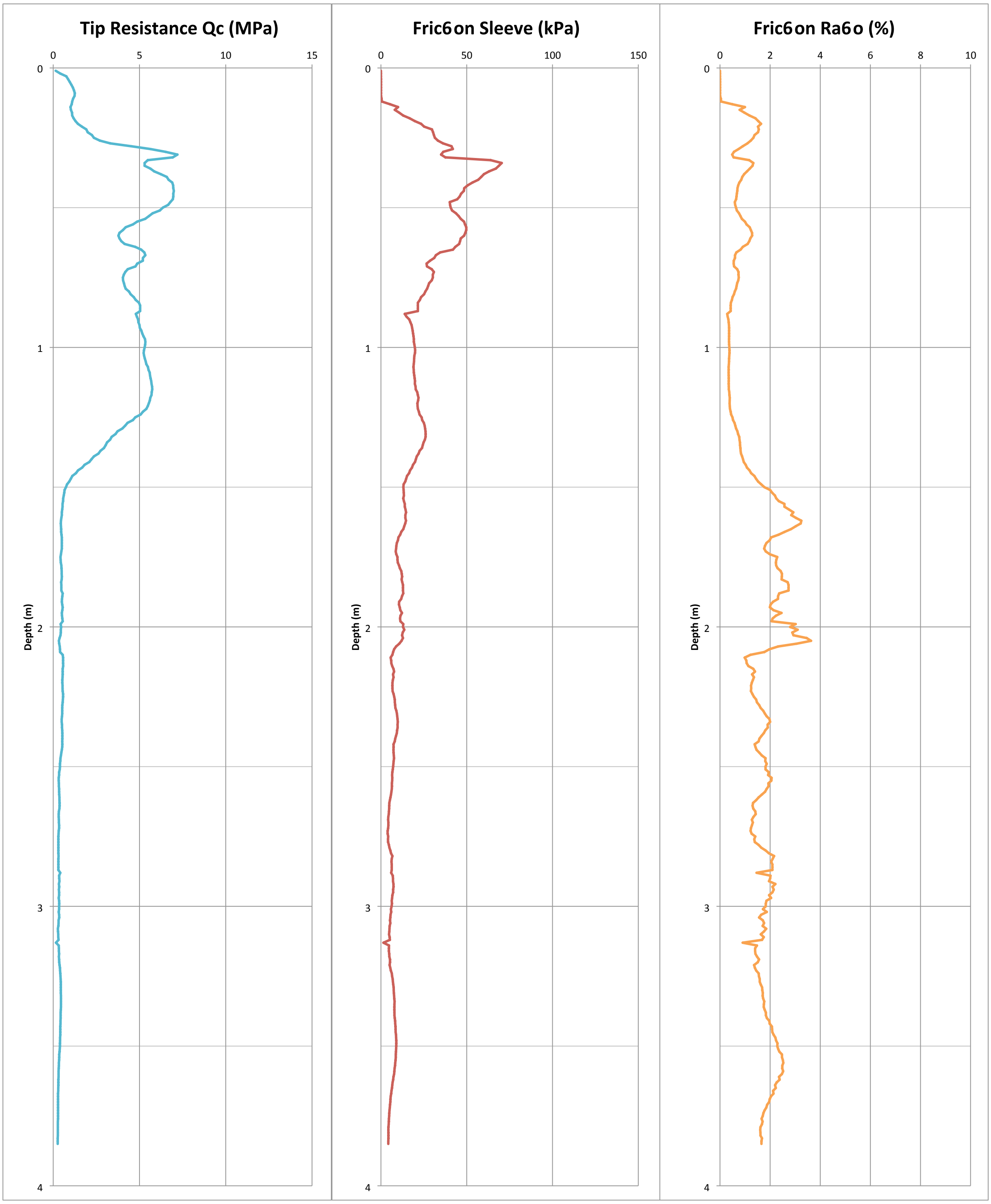
Client:	Western Environmental			Project:	J180065/D168468
Project:	Bindaring Wetlands, Bassendean			GPS:	
Probe No:	ALL	Test Date:	8/06/17	Tested By:	D.SMITH


Tip Resistance Qc (MPa)


Friction Sleeve (kPa)

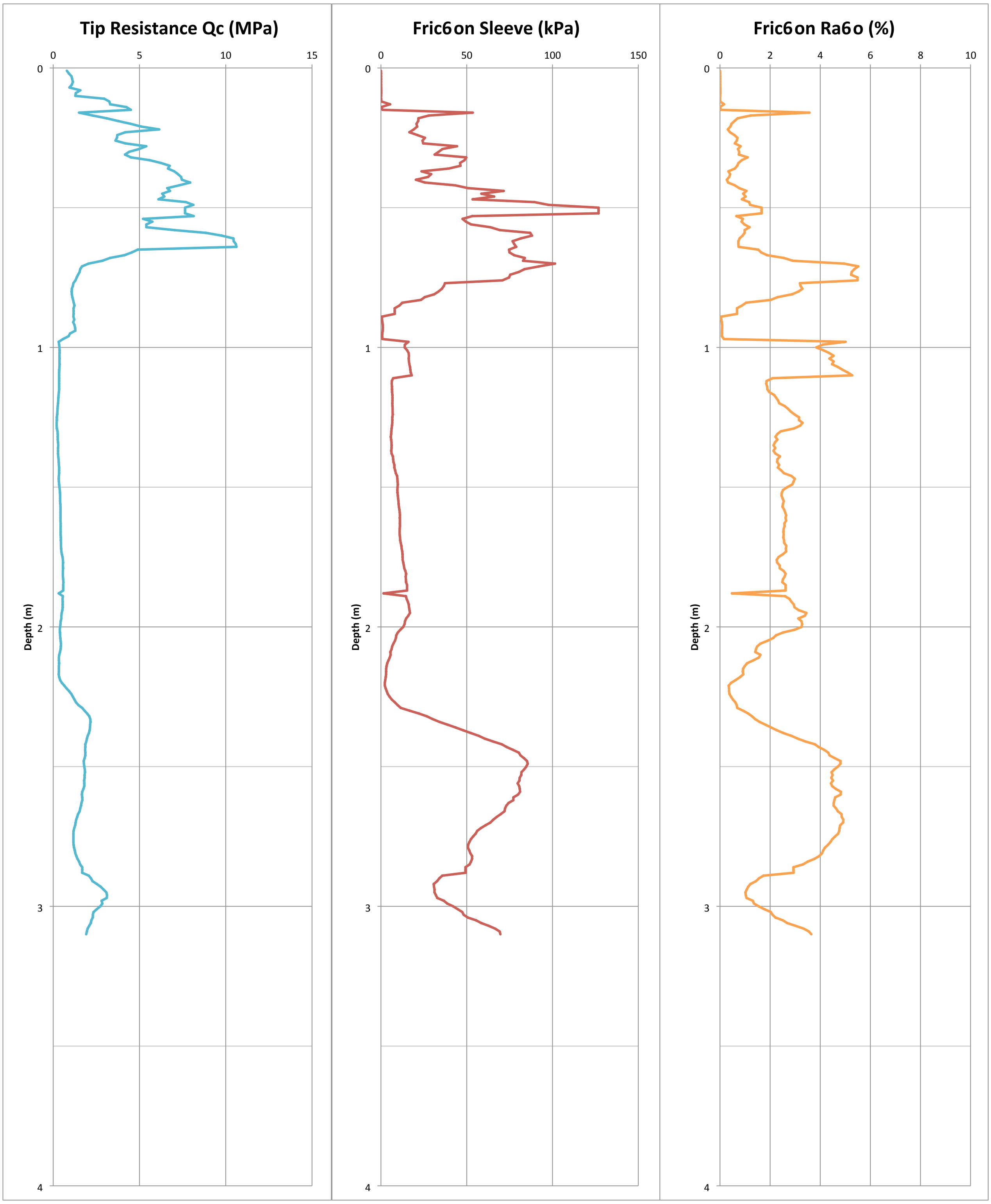

Friction Ratio (%)

Client:	Western Environmental			Project:	J180065/D168468
Project:	Bindaring Wetlands, Bassendean			GPS:	6469233N 401335E
Probe No:	CPT1	Test Date:	8/06/17	Tested By:	D.SMITH



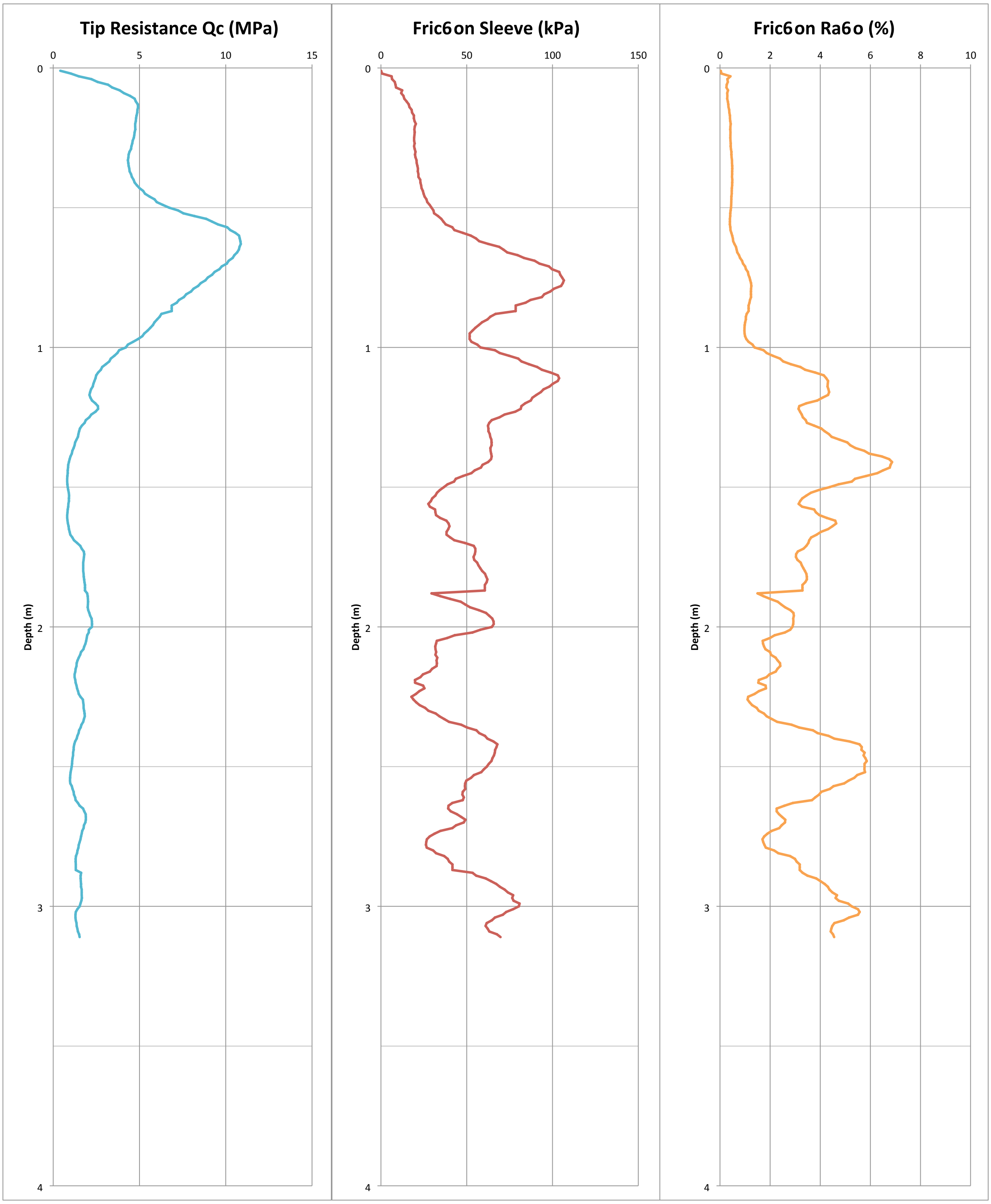
Water (m)	-	Max Depth	3.85	Termination Reason	Target Depth

Client:	Western Environmental		Project:	J180065/D168468
Project:	Bindaring Wetlands, Bassendean		GPS:	6468990N 401438E
Probe No:	CPT2	Test Date: 8/06/17	Tested By:	D.SMITH



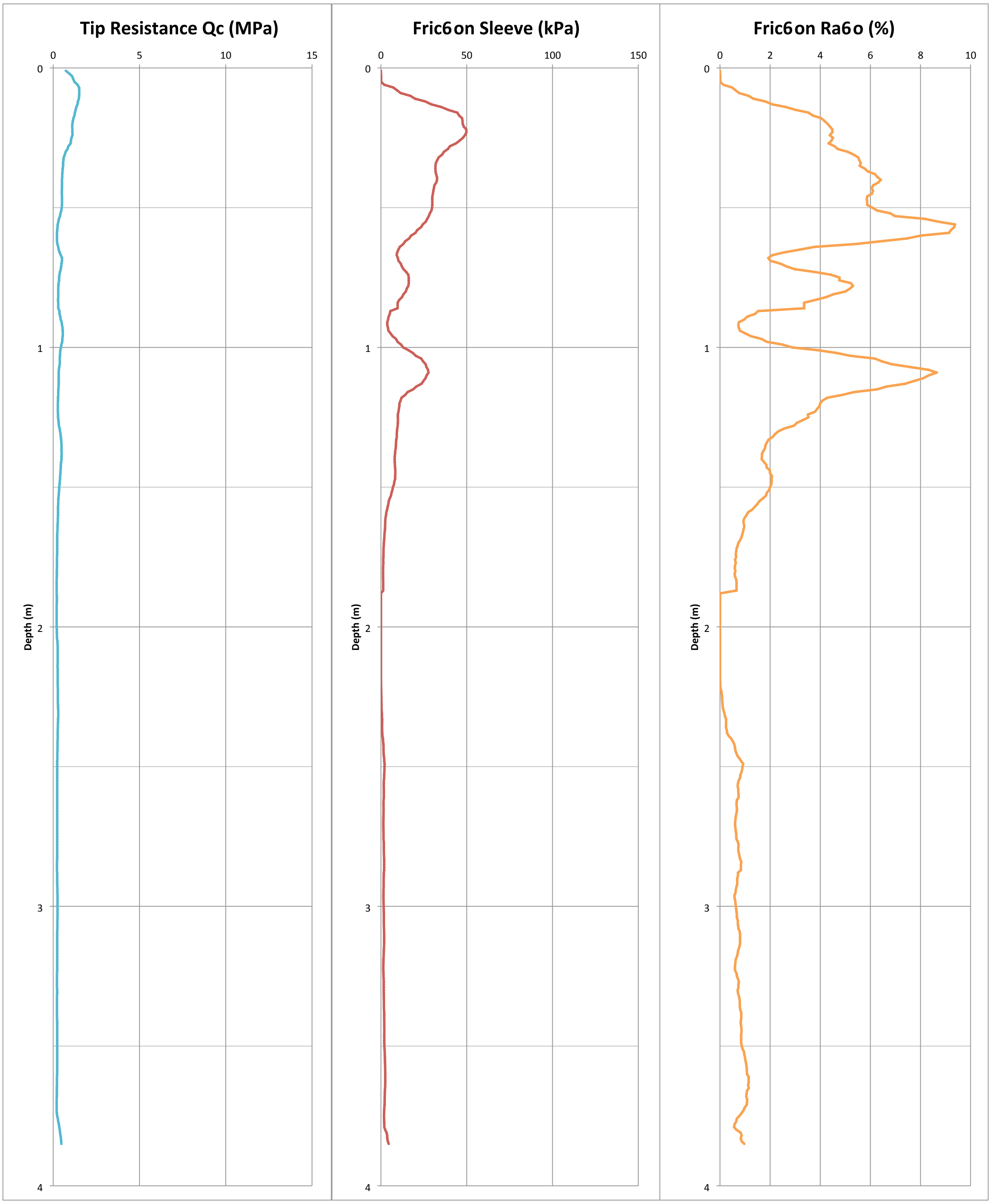
Water (m)	-	Max Depth	3.1	Termination Reason	Target Depth		

Client:	Western Environmental			Project:	J180065/D168468
Project:	Bindaring Wetlands, Bassendean			GPS:	6468964N 401579E
Probe No:	CPT3	Test Date:	8/06/17	Tested By:	D.SMITH



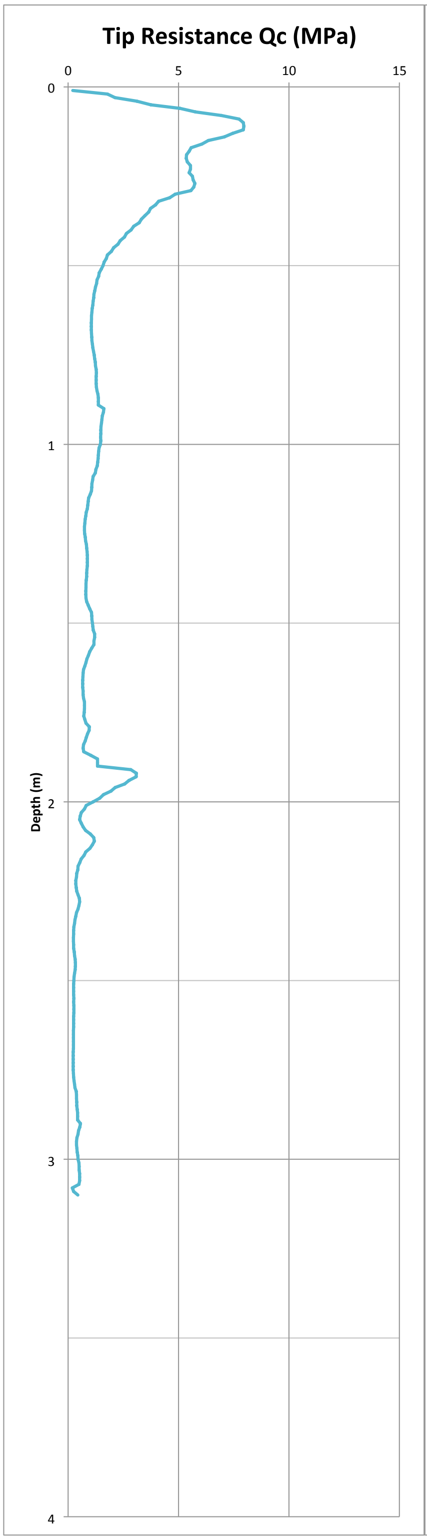
Water (m)	-	Max Depth	3.11	Termination Reason	Target Depth

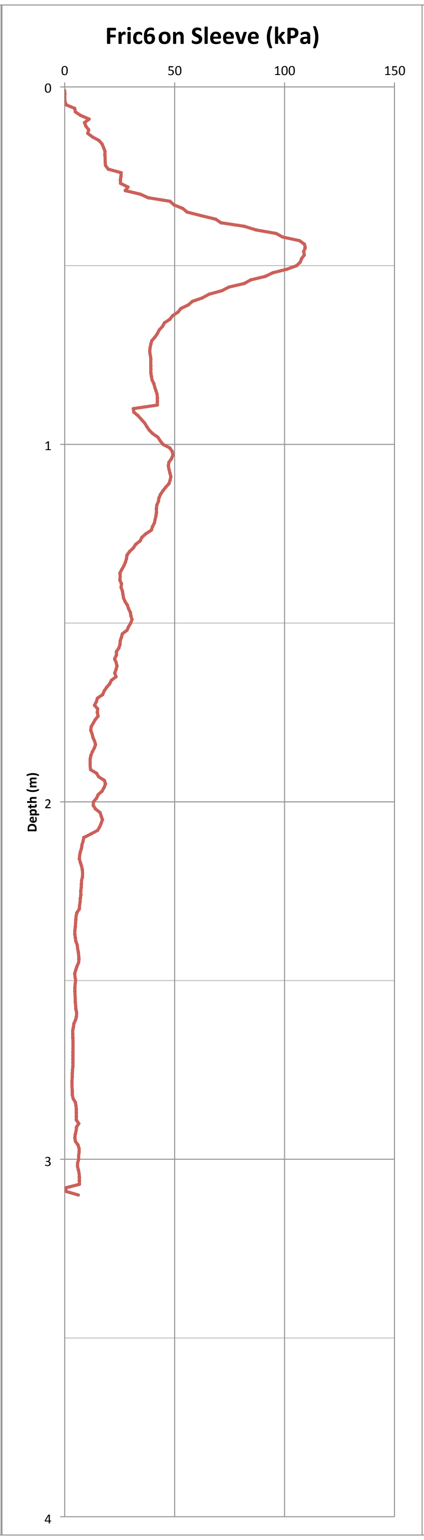
Client:	Western Environmental	Project:	J180065/D168468
Project:	Bindaring Wetlands, Bassendean	GPS:	6468858N 401511E
Probe No:	CPT4 Test Date: 8/06/17	Tested By:	D.SMITH

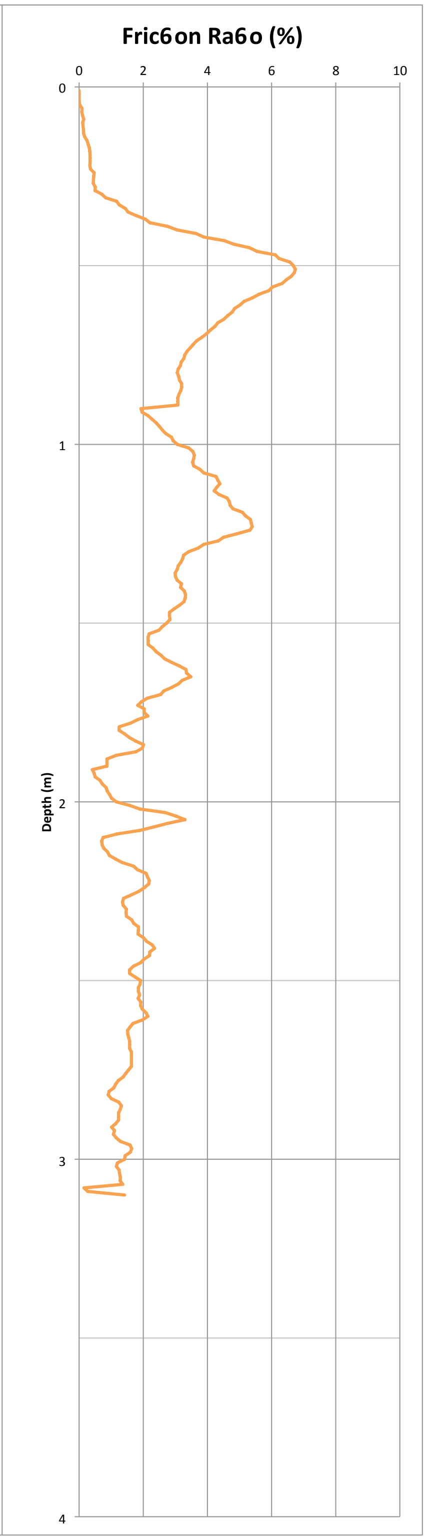


Water (m)	0.4	Max Depth	3.85	Termination Reason	Target Depth

Client:	Western Environmental			Project:	J180065/D168468
Project:	Bindaring Wetlands, Bassendean			GPS:	6468778N 401619E
Probe No:	CPT5	Test Date:	8/06/17	Tested By:	D.SMITH


Tip Resistance Qc (MPa)


Friction Sleeve (kPa)


Friction Ratio (%)

Water (m)	-	Max Depth	3.1	Termination Reason	Target Depth

APPENDIX 3 – BOREHOLE LOGS & TERMINOLOGY

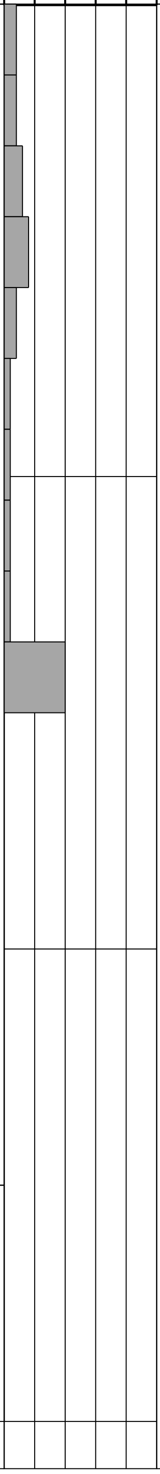
Project Bindaring Wetlands - Bassendean Parade, Bassendean

Client Town of Bassendean c/o Western Environmental

Test No.
BH01

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401304
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469063

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm 5 10 15 20	Samples Depth	Samples Type	Moisture	Water Level
1		SP: SAND: fine to medium grained, non-plastic, with gravel, trace silt, grey/brown (FILL)	L				D to M	▼
2		SP: SAND: fine to medium grained, non-plastic, with silt, grey (Alluvium)					S	
		CI: CLAY: medium plasticity, with sand, grey (Alluvium)	S					
3		Terminated at 3.00 m						



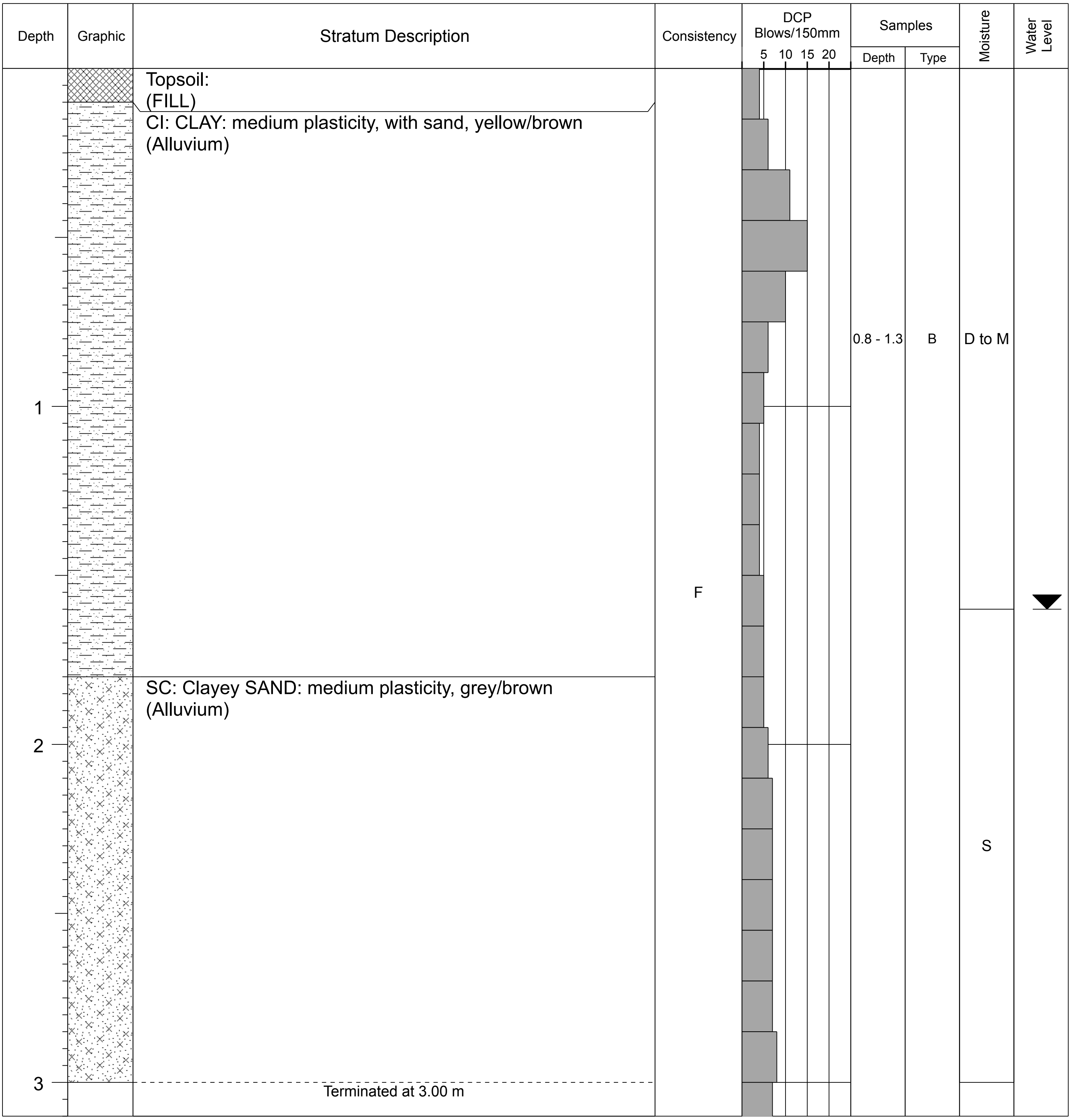
Remarks
1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: None
4. Co-ordinate system: WGS 84

Project Bindaring Wetlands - Bassendean Parade, Bassendean

Client Town of Bassendean c/o Western Environmental

Test No.
BH02

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401463
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469242



Topsoil:
(FILL)

CI: CLAY: medium plasticity, with sand, yellow/brown
(Alluvium)

SC: Clayey SAND: medium plasticity, grey/brown
(Alluvium)

Terminated at 3.00 m

Consistency	Samples Depth	Samples Type	Moisture
F	0.8 - 1.3	B	D to M
			S

Continued on next sheet

Remarks
1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: As indicated
4. Co-ordinate system: WGS 84

Project Bindaring Wetlands - Bassendean Parade, Bassendean

Client Town of Bassendean c/o Western Environmental

Test No.
BH02

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401463
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469242

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm 5 10 15 20	Samples		Moisture	Water Level
					Depth	Type		
				▨				
4								
5								
6								

Remarks
1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: As indicated
4. Co-ordinate system: WGS 84

Project Bindaring Wetlands - Bassendean Parade, Bassendean

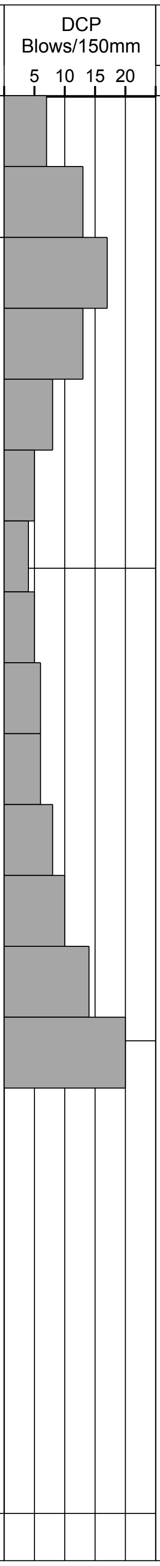
Client Town of Bassendean c/o Western Environmental

Test No.

BH03

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401518
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469002

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm	Samples		Moisture	Water Level
					Depth	Type		
		Topsoil: (FILL)	D				D to M	
		SM: Silty SAND: low to medium plasticity, trace organic material (fine roots), grey/brown (Alluvium)						
1		SC: Clayey SAND: medium plasticity, trace gravel, pale grey (Alluvium)	F				M	
2		CI: CLAY: medium plasticity, with sand, grey/brown (Alluvium)						
3		Terminated at 3.00 m						



Remarks

1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: None
4. Co-ordinate system: WGS 84

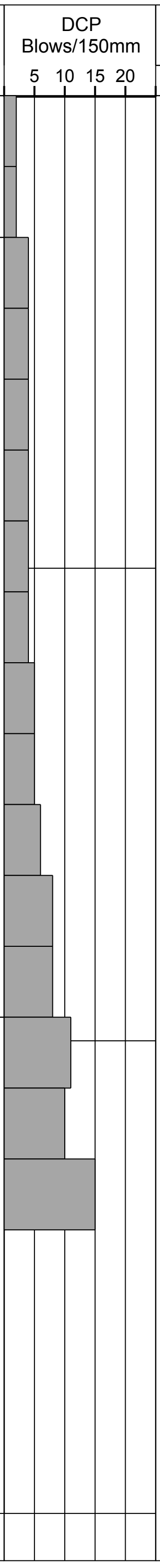
Project Bindaring Wetlands - Bassendean Parade, Bassendean

Client Town of Bassendean c/o Western Environmental

Test No.
BH04

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401448
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6468896

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm 5 10 15 20	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil: (FILL)	S				D to M	
		CI: Sandy CLAY: low plasticity, grey/brown (Alluvium)	F					
1		SC: Clayey SAND: medium plasticity, pale grey (Alluvium)					M	
2			F-St					
3		Terminated at 3.00 m						



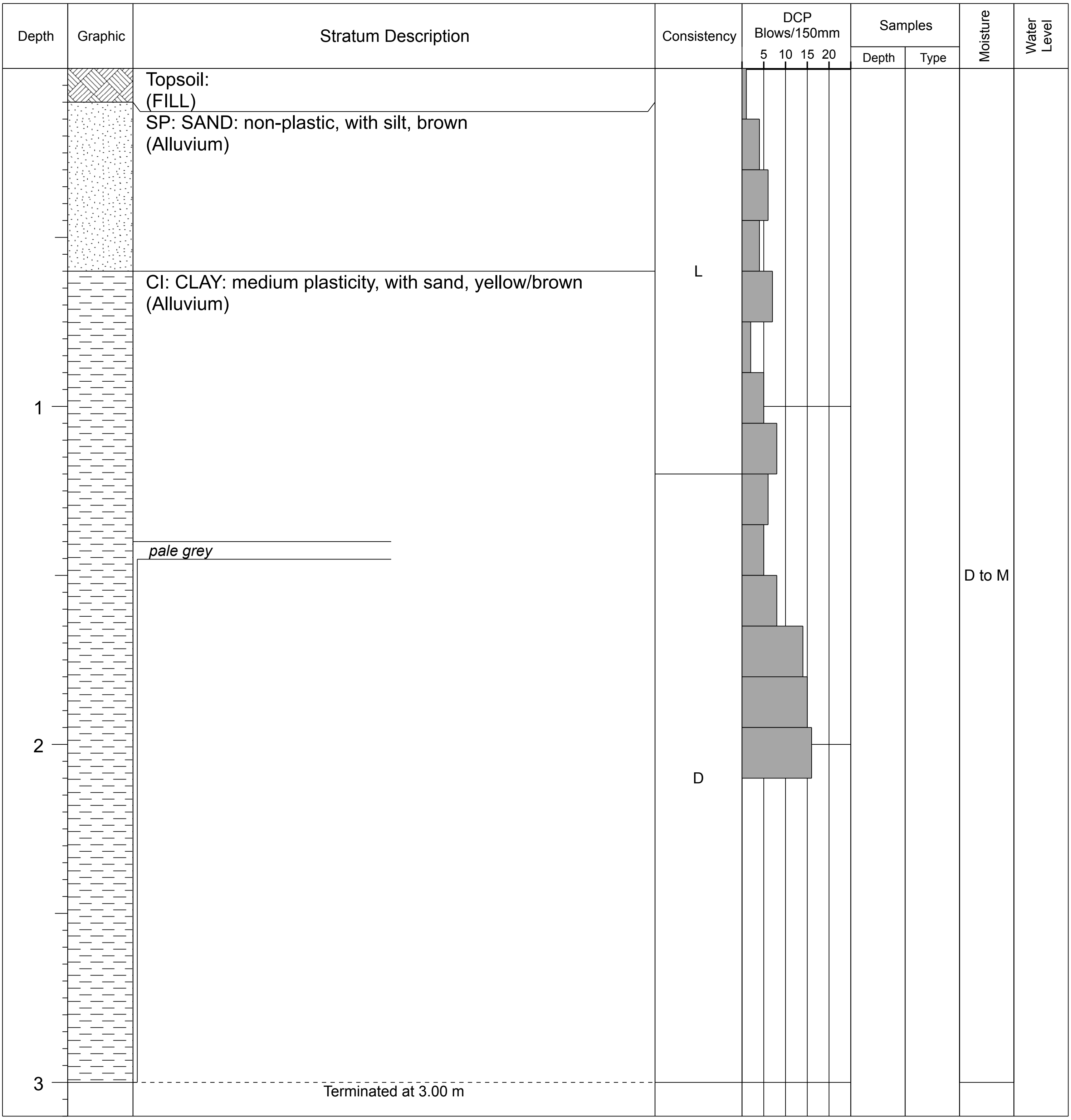
Remarks
1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: None
4. Co-ordinate system: WGS 84

Project Bindaring Wetlands - Bassendean Parade, Bassendean

Client Town of Bassendean c/o Western Environmental

Test No. **BH05**

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401246
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469220



Topsoil: (FILL)

SP: SAND: non-plastic, with silt, brown (Alluvium)

CI: CLAY: medium plasticity, with sand, yellow/brown (Alluvium)

pale grey

Terminated at 3.00 m

Remarks

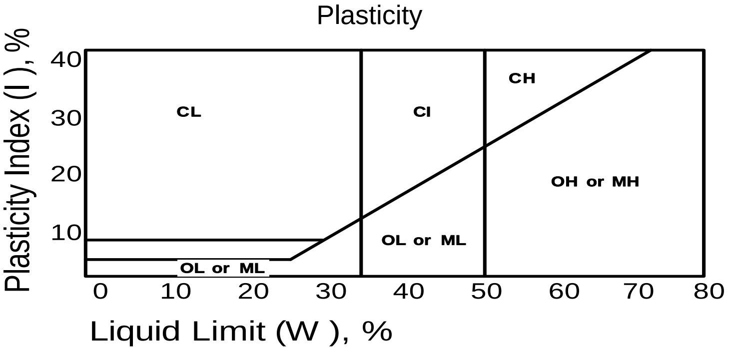
1. Termination reason: Target depth
2. Hole stability: Hole stable
3. Samples taken: None
4. Co-ordinate system: WGS 84

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 2.2.3

APPENDIX 4 – LABORATORY TEST RESULTS

Sample No.	**29824**	**Client**	Geotechnical
Job No.	J180065	**Project**	Bindaring Wetlands, Bassendean

SAMPLE DETAILS

BH No. / Depth : 4 0.2-0.6m Sampling Method Client
Sample History : Air Dried ☐ 50⁰C Oven Dried ☒ Sample Preparation AS 1289 1.1

ATTERBERG LIMITS

Description	Method	Result (%)
Liquid Limit	AS 1289.3.1.2	34
Plastic Limit	AS 1289.3.2.1	16
Plasticity Index	AS 1289.3.3.1	18
Linear Shrinkage	AS 1289.3.4.1	7
Nature of Shrinkage		Flat

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	100
0.425	94
0.075	52

Material Description: Sandy CLAY of Low Plasticity
AS 1726 Appendix A Section A2: CL

Accredited for compliance with ISO/IEC 17025

NATA

WORLD RECOGNISED ACCREDITATION
STRUCTERRE CONSULTING ENGINEERS
BALCATTA LABORATORY
ACCREDITATION NUMBER 18742

Wayne Rozmianiec
Authorised Signatory

Date: 14-Jun-17

Sample No.	**29825**	**Client**	Geotechnical
Job No.	J180065	**Project**	Bindaring Wetlands, Bassendean

SAMPLE DETAILS

BH No. / Depth : 2 0.7-1.3m
Sample History : Air Dried ☐ 50⁰C Oven Dried ☒

Sampling Method Client
Sample Preparation AS 1289 1.1

ATTERBERG LIMITS

Description	Method	Result (%)
Liquid Limit	AS 1289.3.1.2	43
Plastic Limit	AS 1289.3.2.1	17
Plasticity Index	AS 1289.3.3.1	26
Linear Shrinkage	AS 1289.3.4.1	9.5
Nature of Shrinkage		Flat

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	100
0.425	99
0.075	74

Material Description: CLAY of Intermediate Plasticity with sand
AS 1726 Appendix A Section A2: CI

Accredited for compliance with ISO/IEC 17025
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WORLD RECOGNISED ACCREDITATION
STRUCTERRE CONSULTING ENGINEERS
BALCATTA LABORATORY
ACCREDITATION NUMBER 18742

Wayne Rozmianiec
Authorised Signatory

Date: 14-Jun-17

Material Test Certificate

ASTM D 2974 Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils

Report Number	S846710-A Issue 1	**Client**	Western Environmental
Site Office Job Number	S846710	**Project**	Bindaring Wetlands - BASSENDEAN PDE BASSENDEAN

Sample Details

			Date tested	23 June 2017	
Sample ID	-				
Proposed Use	-			**Layer Thickness**	-
Material Description	Clayey sand			**Test Depth**	-
Sampling Method	AS 1289.1.2.1	**Site Selection Method**		AS 1289.1.4.1	

ASTM D 2974 Method C

Laboratory Number	S846710-A-1	S846710-A-2			
Chainage	BH 04	BH 05			
Offset	0.1-0.3m	0.1-0.3m			
Elevation					
Sample					
Moisture content %	21.7	10.4			
Average organic content %	3.2	2.6			
Average ash content %	96.8	97.4			

Laboratory Number					
Chainage					
Offset					
Elevation					
Sample					
Moisture content %					
Average organic content %					
Average ash content %					

Remarks:

Furnace Temperature 440 °C

Date 30 June 2017

Authorised Signatory

Wayne Rozmianiec
Laboratory Manager

Material Test Certificate

AS 1289.5.2.1 Determination of the dry density/moisture content relation of a soil using modified compactive effort

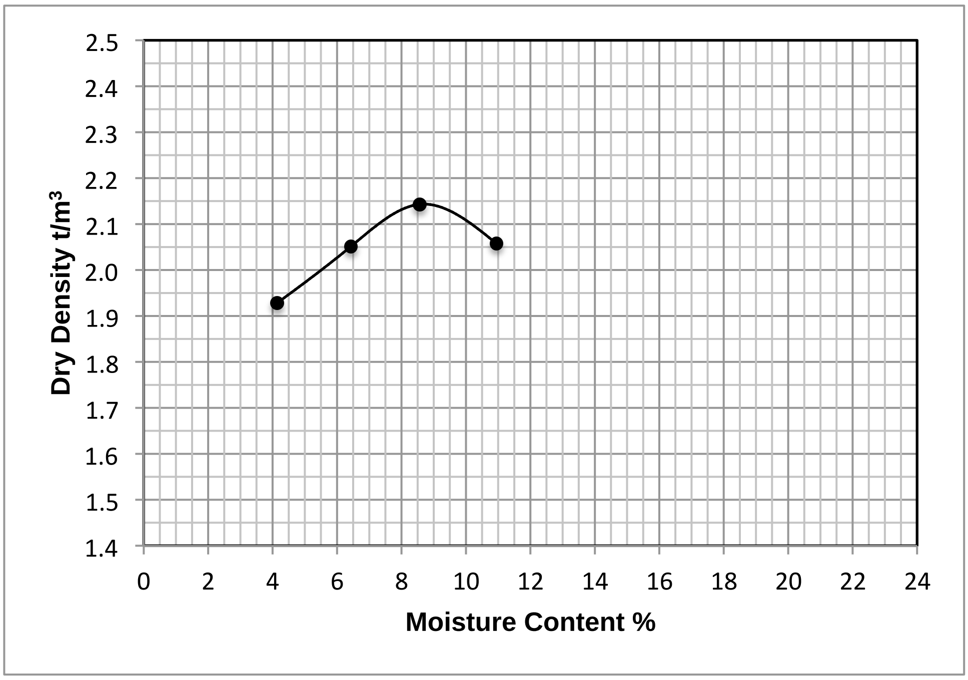
Report Number	S846710-A Issue 1	**Client**	Western Environmental
Job Number	S846710	**Project**	Bindaring Wetlands - BASSENDEAN PDE BASSENDEAN

Sample Details

Laboratory Number	S846710-A-1	**Date tested**	23 June 2017
Sample ID	BH01_0.1-0.5m		
Proposed Use	-		
Material Description	Sand		
Sampling Method	AS 1289.1.2.1	**Site Selection Method**	AS 1289.1.4.1

AS 1289.2.1.1 Determination of the moisture content of a soil - Oven drying method (standard method)

Maximum Dry Density t/m^3	2.14	**Optimum Moisture Content %**	8.5
% Retained 19mm Sieve	2	**% Retained 37.5mm Sieve**	1
Curing Time (hrs)	2	**Method used to determine LL**	Visual/Tactile



Remarks

Accredited for compliance with ISO/IEC 17025 - Testing

NATA
WORLD RECOGNISED ACCREDITATION
STRUCTERRE CONSULTING ENGINEERS
BALCATTA LABORATORY
ACCREDITATION NUMBER 18742

Authorised Signatory

Date 30 June 2017

Wayne Rozmianiec
Laboratory Manager

Material Test Certificate

ASTM D 2974 Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils

Report Number	S846710-A Issue 1	**Client**	Western Environmental
Site Office Job Number	S846710	**Project**	Bindaring Wetlands - BASSENDEAN PDE BASSENDEAN

Sample Details

		Date tested	23 June 2017		
Sample ID	-				
Proposed Use	-		**Layer Thickness**		-
Material Description	Clayey sand		**Test Depth**		-
Sampling Method	AS 1289.1.2.1	**Site Selection Method**	AS 1289.1.4.1		

ASTM D 2974 Method C

Laboratory Number	S846710-A-1	S846710-A-2			
Chainage	BH 04	BH 05			
Offset	0.1-0.3m	0.1-0.3m			
Elevation					
Sample					
Moisture content %	21.7	10.4			
Average organic content %	3.2	2.6			
Average ash content %	96.8	97.4			

Laboratory Number					
Chainage					
Offset					
Elevation					
Sample					
Moisture content %					
Average organic content %					
Average ash content %					

Remarks:

Furnace Temperature 440 °C

Date 30 June 2017

Authorised Signatory

Wayne Rozmianiec
Laboratory Manager
Page 1 of 1

Maximum Dry Density (AS 1289.5.2.1) &
California Bearing Ratio (AS 1289.6.1.1)
Test Report

**Mining & Civil
Geotest Pty Ltd**

9 Lerista Court, Bibra Lake WA 6164
Ph: (08) 9418 1873
Email: lab@mcgeotest.com.au

Client:	Structerre Consulting Engineers	**Job No:**	60069
Project:	Western Environmental	**Sample No:**	P17/2149
Location:	Bindaring Wetlands, Bassendean Parade, Bassendean	**Issued Date:**	05-Jul-17
Sample ID:	S846710-A-1	**Report No:**	60069-P17/2149

Maximum Dry Density t/m3	2.14	**Conditions at Test**	
Optimum Moisture Content %:	8.7	Soaking Period (Days)	4
Desired Conditions: MDD/OMC	95/100	Surcharge (kg)	4.5
Retained on 19.0mm %		Entire Moisture Content %	10.6
Compactive Effort		Entire Moisture Ratio %	122.0
Mass of hammer kg	4.9	Top 30mm Moisture Content %	11.6
Number of layers	5	Top 30mm Moisture Ratio %	133.0
Number of blows/layer	15	Swell %	0.0
Conditions after Compaction		C.B.R. at 5.0 mm Penetration %	40
Dry Density t/m3	2.03	**Conditions after Soaking**	
Moisture Content %	9.0	Dry Density t/m3	2.03
Density Ratio %	94.5	Moisture Content %	11.3
Moisture Ratio %	104.0	Dry Density Ratio %	94.5
Soaked / Unsoaked	Soaked	Moisture Ratio %	130.5

Comments:

MDD & OMC data provided by client, Sample No S846710-A-1

Client Address: 1 Erindale Road, Balcatta WA 6021

Approved Signature

Kevin M Jones

APPENDIX C – Acid Sulphate Soils Investigation

WESTERN
ENVIRONMENTAL

Stage 2 Bindaring Wetland Development Proposal

Acid Sulfate Soil Investigation Report

Western Environmental Pty Ltd
(08) 6162 8980
PO Box 437, Leederville, WA 6903
enquiries@westernenvironmental.com.au
westernenvironmental.com.au

Stage 2 Bindaring Wetland Concept Plan Development Proposal

Acid Sulfate Soil Investigation Report

Report No:
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Prepared for:
Coterra Environment
3/25 Prowse St
West Perth WA 6005

Prepared By:
Western Environmental Pty Ltd
Level 3, 25 Prowse Street
West Perth WA 6005
www.westernenvironmental.com.au

Internal Review

AUTHOR	REVIEWED BY	APPROVED BY
BLockley	P.C Brand	James Gibson
Bianca Lockley Environmental Scientist	**Phillip Brand** Senior Environmental Scientist	**James Gibson** Principal Environmental Scientist
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Executive Summary

Background

Western Environmental Pty Ltd (WEPL) has been commissioned by Coterra Environment to undertake an Acid Sulfate Soil (ASS) investigation of Bindaring Wetland, Bassendean (the site). The proposed concept development plan for the site is not subject to any Town of Bassendean planning conditions or other instruments that necessitate formal review/approval of the investigation by the Department of Environment Regulation (DER).

This report documents the investigation undertaken at the site, prepared in compliance with relevant DER (2015) guidelines.

Objectives of the Investigation

The objective of this report is as follows:

- To provide an ASS investigation report for Bindaring Wetlands that is consistent with the most recently issued DER (2015) ASS guidelines.

Analytical Results

Summary of analytical results are as follows:

- Soil results indicate that there is Potential Acid Sulfate Soils (PASS) above adopted assessment criteria (up to 0.17% S above the 0.03% S criterion), occurring across the site.

Conclusions and Recommendations

Conclusions and recommendations are as follows:

- The results of the investigation show ASS is present at the site above the DER action criteria, including areas that will likely require dewatering for any construction works;
- There is a requirement for an ASS Management Plan to be developed and submitted to DER to obtain approval for any proposed (dewatering and soil disturbance) works;
- The installation of groundwater monitoring wells, and undertaking of groundwater and surface water monitoring to ascertain current groundwater and surface water conditions prior to works commencing; and
- Direct consultation with project engineers and related parties to discuss site constraints so that these can be factored into the final stages of design with a goal to minimise the scale of works (i.e. ASS disturbance) required.

1 Introduction

1.1 Regulatory and Approvals Context

Western Environmental Pty Ltd (WEPL) has been commissioned by Coterra Environment to undertake an Acid Sulfate Soil (ASS) investigation of Bindaring Wetland, Bassendean (the site) (Figure 1, Figure 2). The proposed concept development plan for the site is not subject to any Town of Bassendean planning conditions or other instruments that necessitate formal review/approval of the investigation by the Department of Environment Regulation (DER).

This report documents the investigation undertaken at the site, prepared in compliance with relevant DER (2015) guidelines.

1.2 Objectives

The objective of this report is as follows:

- To provide an ASS investigation report for Bindaring Wetlands that is consistent with the most recently issued DER (2015) ASS guidelines.

1.3 Scope of Work

The scope of work comprised the following investigations:

- Installation of five (5) soil boreholes to depths of up to 3.0 metres below ground level (mbgl);
- Collection of soil samples as per DER (2015) guidelines for field testing and laboratory analysis; and
- Review and interpretation of analysis results and preparation of an investigation report.

2 Background

2.1 Site Identification

The site comprises the Bindaring Wetland in the Town of Bassendean (ToB). The site is located approximately 12 km northeast of the Perth Central Business District and is bordered by Harcourt St to the north; North Road to the east; the Swan River to the south and West Road to the west (Figure 1).

Summary details identifying the site are provided in Table A.

Table A: Site Identification

Common name	Bindaring Wetlands
Local Government Authority	Town of Bassendean (ToB)
Metropolitan Region Scheme Zoning	Urban
ToB Local Planning Scheme No. 10	Parks and Recreation
Site Northern GDA 94 Co-ordinates	Z: 50 N: 6 469 332 E: 401 391
Site SW Corner GDA 94 Co-ordinates	Z: 50 N: 6 468 781 E: 401 509

2.2 Details of Site Concept Plan

2.2.1 Proposed Concept Plan

The Town of Bassendean is currently undertaking the process to gather environmental and technical information to complete water quality treatment design options for Stage 2 to enhance the ecological values and improve the amenity of the whole park (Stage 1 and 2). This will be proposed through the development of three (3) concept plan options.

The concept plan includes the installation of boardwalks, bridges, pathways and seating/picnic areas to improve amenities within the wetland; and modifications to water courses and installation of drainage channels to maintain or improve water quality within the wetlands.

The site is bordered by residential lots and public open space. The draft concept plan options for the site are provided in Appendix A and the site layout is outlined in Figure 2.

2.3 Site Conditions

2.3.1 Topography

The topography of the wetland area is generally flat with a gentle slope to the south towards the Swan River. The natural surface level as reported in the Perth Groundwater Atlas is 3.3 m Australian Height Datum (mAHD) at the northern edge of the site and 1.0 mAHD at the southern end.

2.3.2 Surface Water

Bindaring Wetland is a natural, seasonally inundated wetland system with surface water generally present during and just after winter. The wetland receives surface water runoff from the residential catchment. The wetland is also subject to potential tidal influence over some of its area.

2.3.3 Local Sensitive Environments

The DER Geomorphic Wetlands Swan Coastal Plain dataset identifies wetland or sumpland areas categorised as Conservation, Resource Enhancement or Multiple Use as well as wetland areas which have not been assessed or are not applicable. Mapped wetland areas located within the site and within a 1 km radius of the site are identified in Figure 3 and summarised as follows:

- Bindaring Wetland is comprised of the following geomorphic wetlands:
    - UFI8735 Multiple use floodplain (northern section)
    - UFI8737 Conservation sumpland (central section)
    - UFI8690 Resource enhancement floodplain (Bindaring Park, southern section)
    - UFI8689 Multiple use floodplain (southern section)
- The Swan River (UFI8571) is classified as a Conservation Estuary-Waterbody and is located immediately south of the site; further south is the Swan River conservation and resource enhancement floodplains (UFI15048, UFI8091, UFI8093 and UFI 13399) and a multiple use dampland (UFI15264).
- Ashfields Flats (UFI15040) is a multiple use estuary-peripheral wetland located 900 m to the south-west of the site; the area includes UFI8739 (a multiple use estuary-peripheral) and UFI8576 (a conservation estuary-peripheral).
- Point Reserve (UFI8715), a conservation floodplain is located 300 m to the east and north-east of the site; while a conservation (UFI8826) and multiple use (UFI15047) floodplain is located further to the east and north-east.

2.3.4 Surrounding Land Use

Based on the review of different information sources (aerial photography, street directory, Google maps and the Metropolitan Regional Scheme) the land uses surrounding the site, as shown in Figure 4, are summarised below.

- North– Urban residential;
- East – Urban residential, Parkland, Swan River;
- South – Swan River, Parks and Recreation; and
- West –Urban residential.

2.3.5 Site Photographs

Photographs of the site layout and surrounding landscape are included in Appendix B.

2.3.6 Characteristic Indicators of AASS and/or PASS

A log of each of the soil bores is included in Appendix C. There were no obvious signs of ASS such as Coffee Rock; however, there was a slight sulfidic odour noted in soils retrieved from below the water table indicating the presence of ASS.

2.4 Geology

The geology of the site is described by the Geological Survey of Western Australia (GSWA, 1986) in the Perth Map Sheet as comprising of sandy silt surrounded by sand.

The geological units associated with the site, shown in Figure 5, are:

- Ms_4 – SANDY SILT – light yellow brown, blocky, mottled, some find to medium-grained sand, soft when moist, variable clay content.
- S8 – SAND: very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz, moderately well-sorted of eolian origin.

2.5 Preliminary Acid Sulfate Soil Assessment

Acid Sulfate Soil is naturally occurring soil containing iron sulphides, which when oxidised, can lead to acidification of soils and groundwater and, consequently, extensive environmental damage. According to DER Swan Coastal Plain ASS Risk Map, the site is classified as having a high to moderate risk of ASS occurring within 3 m of the natural soils surface as shown in Figure 6.

It is noted that the DER mapping is based on regional reinterpretation of existing geological, topographic and other data sets. The margins and extent of the mapped units are therefore indicative only.

2.6 Groundwater

2.6.1 Groundwater Level

Local groundwater levels at the end of summer, as reported by the Perth Groundwater Map (DoW, 2004), vary from approximately 3.3 mbgl at the northern end of the wetland to 0.3 mbgl at the southern end of the wetland.

Insufficient hydrographic data was available to estimate the seasonal groundwater level variations, although variations of ±0.5 m are expected (DoW, 2004).

The depth of the base of the superficial formation (aquifer) is approximately -20 mAHD (DoW, 2004).

Groundwater below the site is expected to flow south towards Swan River (DoW, 2004).

2.6.2 Groundwater Discharge Locations

The site and the Swan River are the likely discharge locations for localised groundwater based on the site surface contours, site groundwater contours, the perennial water body within the site and the proximity of the site to Swan River.

3 Soil Investigation Methodology

3.1 General

Soil sampling was undertaken on the 8th June 2017. All works (drilling and soil sampling) were carried out by a qualified field scientist from Structerre, using Structerre's SRP rig.

Sampling involved the collection of duplicate samples as required and decontamination procedures were adhered to between each sampling location.

In addition to the above, the following guidelines and standards were adhered to during the investigation:

- DER (2015). *Identification and Investigation of acid sulfate soils and acidic landscapes*, Department of Environment and Conservation, Government of Western Australia, Acid Sulfate Soils Guideline Series, June 2015;
- Standards Australia (2005), *AS 4482.1:2005, Guide to the Investigation and Sampling of Sites with Potentially Contaminated Soil, Part 1: Non Volatile and Semi Volatile Compounds*, Committee EV/9, Sampling and Analysis of Soils and Biota, Council of Standards Australia, 02 November 2005.

3.2 Soil Investigation

3.2.1 Location of Boreholes

Five sampling boreholes (BH01-BH05) were drilled to 3.0 mbgl at representative locations across the site and sampled for ASS down the soil profile (Figure 7).

3.2.2 Density of the Sampling Program

The number of boreholes drilled onsite was selected on the basis of characterising the substrate with a high degree of accuracy and also general conformance with *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DER, 2015). The location of boreholes was based on the following considerations:

- The sampling pattern for the boreholes was designed to assess subsurface conditions within the area of planned developments (i.e. installation of bridges and/or bunds), with a sampling density as recommended for non-linear excavations (Table 6, DER 2015); and
- The boreholes were also located to allow an effective interpretation of the underlying substrate across the site.

The bore installation logs including a grid reference of each bore location using the World Geodetic System 84 (WGS 84) are presented in Appendix C.

3.2.3 Testing for Field pH (pH_{FIELD}) and Peroxide pH (pH_{FOX})

Soil samples were recovered at 0.25 m intervals at all five locations (BH01–BH05) from 0.00 mbgl to termination depth at 3.0 mbgl. Samples were sealed in zip-lock bags, chilled and transported to the ALS laboratory for same-day field testing. Field testing was undertaken by ALS in accordance with DER (2015) guidelines.

3.2.4 Selection of Samples for Laboratory Analysis

Representative samples, reflective of a broad range of field observed conditions, were selected for further laboratory analysis based on:

- The interpretation of soil logs; and
- The results of field testing.

All samples were analysed using the Suspension Peroxide Oxidation Combined Acidity Sulfur (SPOCAS) suite according to the guideline requirements (DER, 2015). Analyses of samples and duplicates were conducted at the National Association of Testing Authorities (NATA)-accredited ALS Laboratory, Malaga.

Samples selected for SPOCAS testing were BH01 (at 1.5 m and 3.0 m), BH02 (at 0.25 m and 2.5 m), BH03 (1.25 m and 2.0 m), BH04 (at 0.5 m and 2.5 m) and BH05 (at 0.25 m and 2.25 m).

Samples were also selected for metals testing as follows: BH01-3.0, BH02-1.5, BH03-1.25, BH04-2.5 and BH05-0.25

3.2.5 Quality Assurance and Quality Control

The field investigation was designed by a WEPL Environmental Scientist qualified and experienced in the assessment of ASS, and was executed by a Structerre field scientist.

All sampling procedures were in accordance with relevant Australian Standards for soil sampling (AS 4482.1-2005 and AS 4482.2-1999). ASS soil samples were placed in zip-lock sealed soil bags and retained in an iced esky prior to and during field testing and up until dispatch to the laboratory for analysis.

Laboratory analysis was undertaken by a NATA - accredited laboratory, under recognised Chain of Custody procedures, with QA/QC sample results presented in Section 5.4.

4 Basis for Adoption of Assessment Criteria

4.1 Field Testing Indicative Criteria

Field testing only provides an indication whether the tested soil exhibits Actual Acid Sulfate Soil (AASS), Potential Acid Sulfate Soil (PASS) or no ASS characteristics. The criteria for classifying the ASS potential from field testing results are presented in Appendix 2 of the ASS guidelines (DER, 2015). In summary:

- pH_F Value (from Field pH Test). pH_{FIELD} <4 indicates very acidic conditions and the presence of AASS and that oxidation of sulfides has probably occurred in the past. pH_{FIELD} < 4.5 indicates very acidic conditions, most likely due to pyrite oxidation but may have resulted from highly organic or heavily fertilised soils. pH_{FIELD} 4.5 – 5.5 indicates acidic soil, but it is not conclusive that the pH is due to pyrite oxidation;

- pH_{FOX} - Reaction Strength with Hydrogen Peroxide. The strength of the reaction with peroxide is a useful indicator but cannot be used alone. Reaction should be rated, e.g. L = Low reaction, M = Medium reaction, H = High reaction, X = Extreme and V = Volcanic. Organic matter, coffee rock and other soil constituents such as manganese oxides can also cause a strong but 'false positive' reaction and care should be exercised in interpreting a reaction where these constituents are present in the soil profile;

- pH_{FOX} Value (from pH_{FOX} Test). If the pH_{FOX} <3, and a significant reaction occurred, then it strongly indicates PASS. The more the pH_{FOX} drops below 3, the more positive the presence of inorganic sulfides; and

- pH_{FOX} << pH_{FIELD}. The lower the final pH_{FOX} value and the greater the difference between the pH_{FOX} compared to the pH_{FIELD}, the more indicative the presence of PASS. This difference may not be as great if starting with an already very acid pH_{FIELD} (close to 4), but if the starting pH is neutral or alkaline then a larger change in pH should be expected. Where fine shell, coral or carbonate, is present the change in pH may not be as large due to buffering. The 'fizz test' (effervescence with 1 M HCl) should be used to test for carbonates and shell.

4.2 Soil Laboratory Results Criteria

The action criteria based on laboratory results are identified in DER (2015). As clay content generally increases soil's natural pH buffering capacity, the action criteria are grouped by three broad texture categories – coarse, medium and fine. These textures are not to be confused with sand grain size categories, and are as follows.

- Coarse – Texture sands to loamy sands (<5% clay content).

- Medium – Sandy loams to light clays (5-40% clay content).

- Fine – Fine texture medium to heavy clays and silty clays (>40% clay content).

For projects that disturb 1,000 tonnes of ASS or more, the action criteria for existing and potential acidity are equal to those set for a coarse texture, regardless of the actual texture category encountered on the site.

4.2.1 Site Specific Criteria

The soils at the site are primarily comprised of SAND, Clayey SAND and CLAY, and hence are considered to have a coarse–fine texture. Based on the texture (coarse), in accordance with the DER guidelines the action limits selected for this investigation are: 0.03% w/w %S or 18.7 mol H+/tonne. Henceforth, analytical results will be referred to in w/w %S units. This criterion is compared to the Net Acidity criterion applied in DER (2015), which equates to combined Potential and Actual acidity (without subtraction of any value for Acid Neutralising Capacity).

5 Results

5.1 Soil Profile

Soil boreholes were installed on 8 June 2017. Logging details of each bore are included as log sheets in Appendix C.

The soil profile was relatively consistent across the site with topsoil/fill sand in the first 0.5 m of the soil profile (with the exception of BH01 in which fill sand extended to 1.75 mbgl) overlaying a Sandy CLAY layer of the Guildford Formation approximately 0.75-1.5 m deep and a CLAY or Sandy CLAY layer extending from 1.5mbgl to termination at 3.0 mbgl. These observations are consistent with the expected geology of the site.

5.2 Soil Field Testing

Field test results are reported in Table 1 and are summarised as follows:

- pH_F values ranged from 6.0 to 8.90 with the lowest pH_F reading reported from BH01 (at 3 mbgl) and BH02 (at 0 mbgl).
- Samples from all bores reported a pH_{FOX} value of 4 or less, specifically BH01 (at surface, 1.5 mbgl and at depths >1.75 mbgl); BH02 (at surface and depths >2 mbgl); BH03 (at surface); BH04 (at depths >2.25 mbgl) and BH05 (at surface).
- Most samples showed a moderate to extreme reaction to the addition of hydrogen peroxide.
- Most samples had ΔpH values of >1 across the entirety of the soil profile.

5.3 Soil Laboratory Analysis Results

Chain of Custody forms and Certificates of Analysis are presented in Appendix D. Complete results are presented in Table 1 and 2.

Four out of the ten primary samples that were submitted for SPOCAS laboratory analysis had a Net Acidity that exceeded the assessment criteria as follows; BH01-1.5 (0.03 %S), BH01-3.0 (0.10 %S), BH02-2.5 (0.10 %S) and BH04 (0.17 %S). The remaining six samples had a Net Acidity between 0.01 %S and 0.02 %S.

No exceedances of NEPM (2013) Health Investigation Levels (HILs) or Environmental Investigation Levels (EILs) were reported for the five primary samples submitted for metals testing (aluminium, arsenic, cadmium, chromium, iron, lead, molybdenum, nickel, selenium and zinc); however, high levels of aluminium and iron indicate the presence of ASS.

5.4 Soil QA/QC Results

Of the 4 duplicate soil samples subject to pH field testing and the one duplicate sample that was submitted for SPOCAS analysis, RPD analysis of these identified no exceedances of acceptable criteria (>30%) for all samples and analytes excluding the following exceptions:

- BH03-1.25/ DUP3 – the RPD for pH_{FOX} is 56%
- BH03-1.25/ DUP3 – the RPD for ΔpH is 163%
- BH04-1.25/ DUP4 – the RPD for ΔpH is 91%.

These RPD exceedances are considered insignificant and do not raise any uncertainty of the investigation findings. QA/QC results demonstrate the investigation these results are be reliable, accurate, and suitable for use in the decision making process.

One duplicate sample (DUP2) was submitted for metals analysis. The RPD analysis identified four of the analytes (aluminium, chromium, lead and nickel) exceeded the acceptable criteria (>30%). This may be attributed to the primary and duplicate sample not being mixed thoroughly before being separated due to the clay content of the soil, resulting in a lack of homogeneity between the primary and duplicate sample. The results are still considered to be suitable for use in this investigation and do not impact the assessment outcome.

6 Discussion

The site is classified as having a high to moderate risk of ASS occurring within 3 m of the surface according to the DER ASS risk mapping (Figure 6). ASS was identified in FILL SAND, Clayey SAND and CLAY across the site, with soil at 3 of 5 investigation localities exceeding the DER Action Criteria. Field indicators and laboratory results are consistent in their identification of ASS.

6.1.1 Field Results

The field test results show an adequate level of consistency between samples taken from different locations in the same lithological units. ASS was suspected to be present across the soil profile at all five bore locations based on the field test results with most samples reporting a ΔpH value of >1 while multiple samples from each borehole had pH_{FOX} values <4.0.

Field testing results cannot be considered as a conclusive determination of the presence or absence of AASS or PASS within the soil profile. An assessment of field test results in conjunction with laboratory analysis results is required in order to adequately assess the ASS characteristics of the site.

6.1.2 Laboratory Results

Eleven out of 69 soil samples (~16%), including one duplicate sample, underwent SPOCAS laboratory analysis. Exceedances of the DER Action Criteria (0.03% S) based on Net Acidity (NA) were noted in four of the ten primary samples collected from across the site. The exceedances were reported in soil samples collected at three of the five investigation localities.

Six out of the 69 soil samples (~8%), including one duplicate sample, were sent for metals laboratory analysis. No exceedances of NEPM HILs or EILs were reported; however, levels of aluminium and iron indicate the presence of ASS at the site.

The distribution of ASS across the site is considered to be reasonably consistent with NA levels slightly below or above the 0.03% S DER Action Criteria guideline observed at all locations.

All material below the water table (or below 1.5 mbgl) at the site should be considered ASS and requires management in accordance with DER (2015) guidelines.

6.2 Discrepancies Between Field Observations and Laboratory Results

The results from the laboratory and field investigations were largely consistent with the laboratory results confirming the presence of ASS within the clayey soils below the water table at the site.

7 Conclusions and Recommendations

7.1 Summary of Findings

The results of investigations have demonstrated that ASS is present at the site above DER action criteria, including areas that will likely require dewatering for any construction works. An ASS Management Plan (ASSMP) will be required for any site works based on these results.

The primary activities that will require management will be:

- The dewatering for any construction works including ensuring drawdown is kept to a minimum and dewatering effluent is treated and monitored.
- Treatment and validation of excavated soils when ASS material is intercepted at the site.
- Monitoring of surface water (wetlands) at the site to ensure there are no adverse environmental impacts as a result of site works.

7.2 Statement for Proposed Development

From the findings of this investigation it can be stated that future development at the site will result in disturbance of ASS, but will remain viable provided soil disturbance and dewatering activities during construction are managed appropriately.

7.3 Recommendations

This ASS investigation report has outlined the requirement for an ASSMP to be developed and submitted to DER to obtain approval for any proposed works. WEPL recommends the following:

- That an ASSMP be developed prior to any site works;
- The installation of groundwater monitoring wells, and undertaking of groundwater and surface water monitoring to ascertain current groundwater and surface water conditions prior to works commencing; and
- Direct consultation with project engineers and related parties to discuss site constraints so that these can be factored into the final stages of design with a goal to minimise the scale of works (i.e. ASS disturbance) required.

8 References

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Urban Bushland Council WA Inc 2017, Bush Forever. http://www.bushlandperth.org.au/bush-forever-overview

Figures

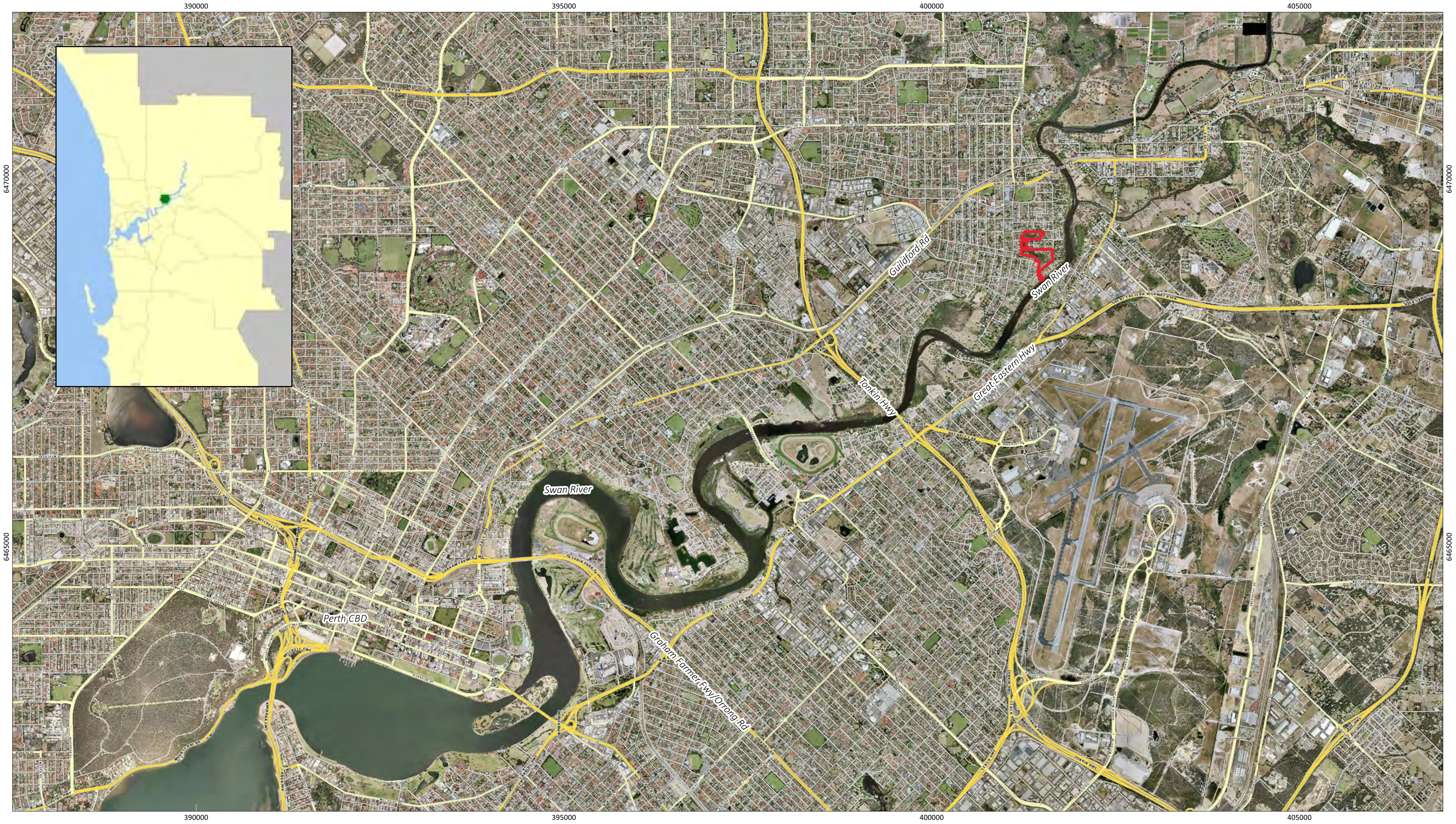


Figure 1: Site Location

N

0 500 1000 1500 2000 m

CLIENT
COTERRA ENVIRONMENT

PROJECT
ASS INVESTIGATION

SCALE
1:50,000

SHEET SIZE
A3

PROJECT NUMBER
16.200

COORDINATE REFERENCE SYSTEM
GDA94 / MGA ZONE 50

DRAWN BY
BL

DATE
12/06/2017

DATA SOURCE
LANDGATE IMAGERY Metro Central 2006

REVIEWED BY
PB

DATE
12/06/2017

Legend

🟥 Site Boundary

WESTERN
ENVIRONMENTAL

Figure 2: Site Layout

N

0 20 40 60 80 m

CLIENT
COTERRA ENVIRONMENT

PROJECT
ASS INVESTIGATION

SCALE
1:2,500

SHEET SIZE
A3

PROJECT NUMBER
16.200

COORDINATE REFERENCE SYSTEM
GDA94 / MGA ZONE 50

DRAWN BY
BL

DATE
12/06/2017

DATA SOURCE
LANDGATE IMAGERY Perth Central 2006

REVIEWED BY
PB

DATE
12/06/2017

Legend

🟥 Site Boundary

WESTERN
ENVIRONMENTAL

Figure 3: Local Sensitive Environments

N

0 100 200 300 400 m

CLIENT	COTERRA ENVIRONMENT
PROJECT	ASS INVESTIGATION
SCALE	1:7,500
SHEET SIZE	A3
PROJECT NUMBER	16.200
COORDINATE REFERENCE SYSTEM	GDA94 / MGA ZONE 50
DRAWN BY	BL
DATE	12/06/2017
DATA SOURCE	LANDGATE IMAGERY Metro Central 2006
REVIEWED BY	PB
DATE	12/06/2017

Legend

- □ Site Boundary
- 🟩 Conservation
- 🟩 Resource Enhancement
- 🟦 Multiple Use

WESTERN ENVIRONMENTAL

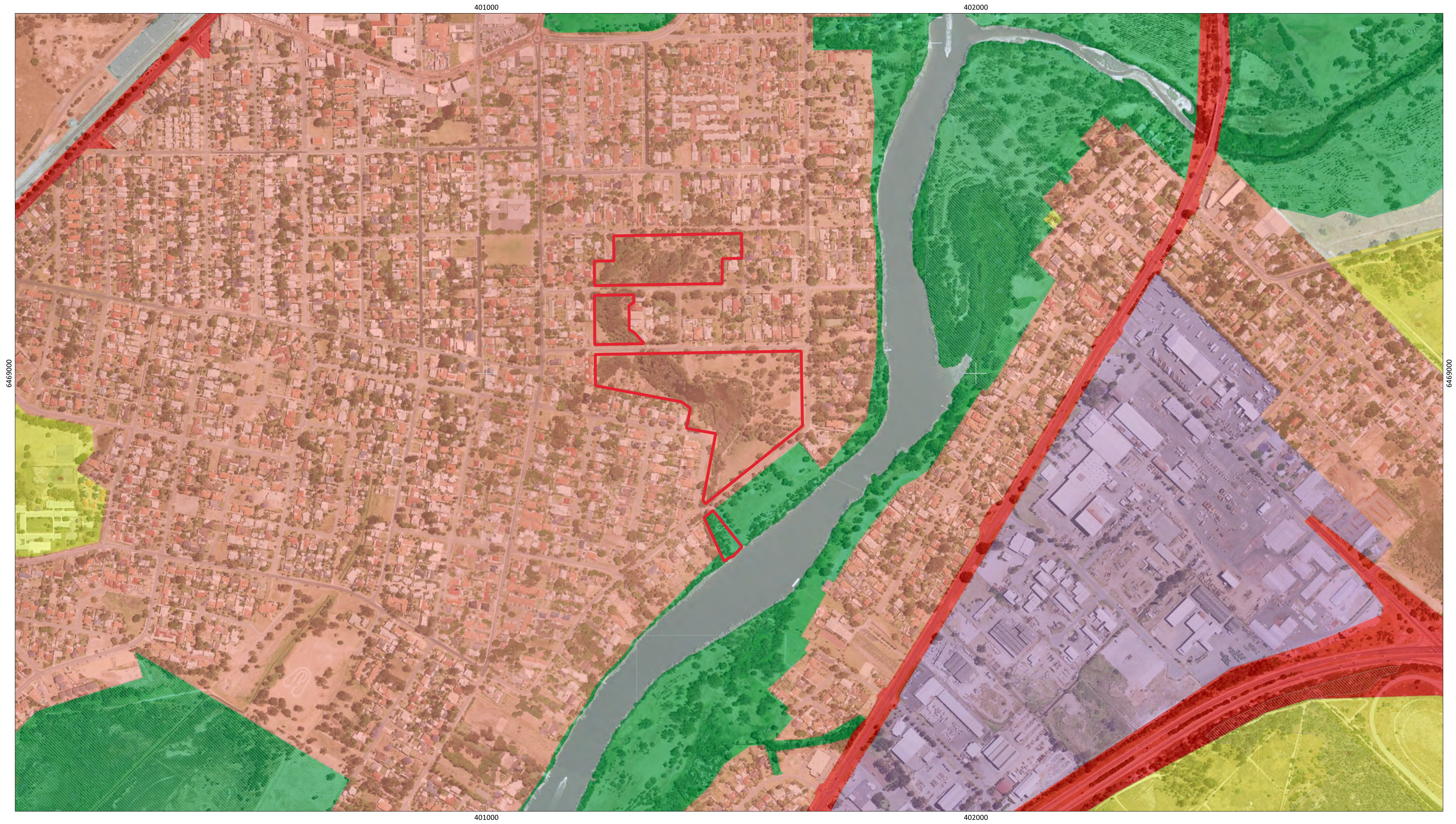


Figure 4: Surrounding Land Use

N

0 100 200 300 400 m

CLIENT
COTERRA ENVIRONMENT

PROJECT
ASS INVESTIGATION

SCALE
1:7,500

SHEET SIZE
A3

PROJECT NUMBER
16.200

COORDINATE REFERENCE SYSTEM
GDA94 / MGA ZONE 50

DRAWN BY
BL

DATE
12/06/2017

DATA SOURCE
LANDGATE IMAGERY Metro Central 2006

REVIEWED BY
PB

DATE
12/06/2017

Legend

☐	Site Boundary	🟩	Parks and Recreation
🟧	Urban	🟥	Primary Regional Roads
🟪	Industrial	🟨	Public Purposes
		▨	Bush Forever Areas

WESTERN
ENVIRONMENTAL

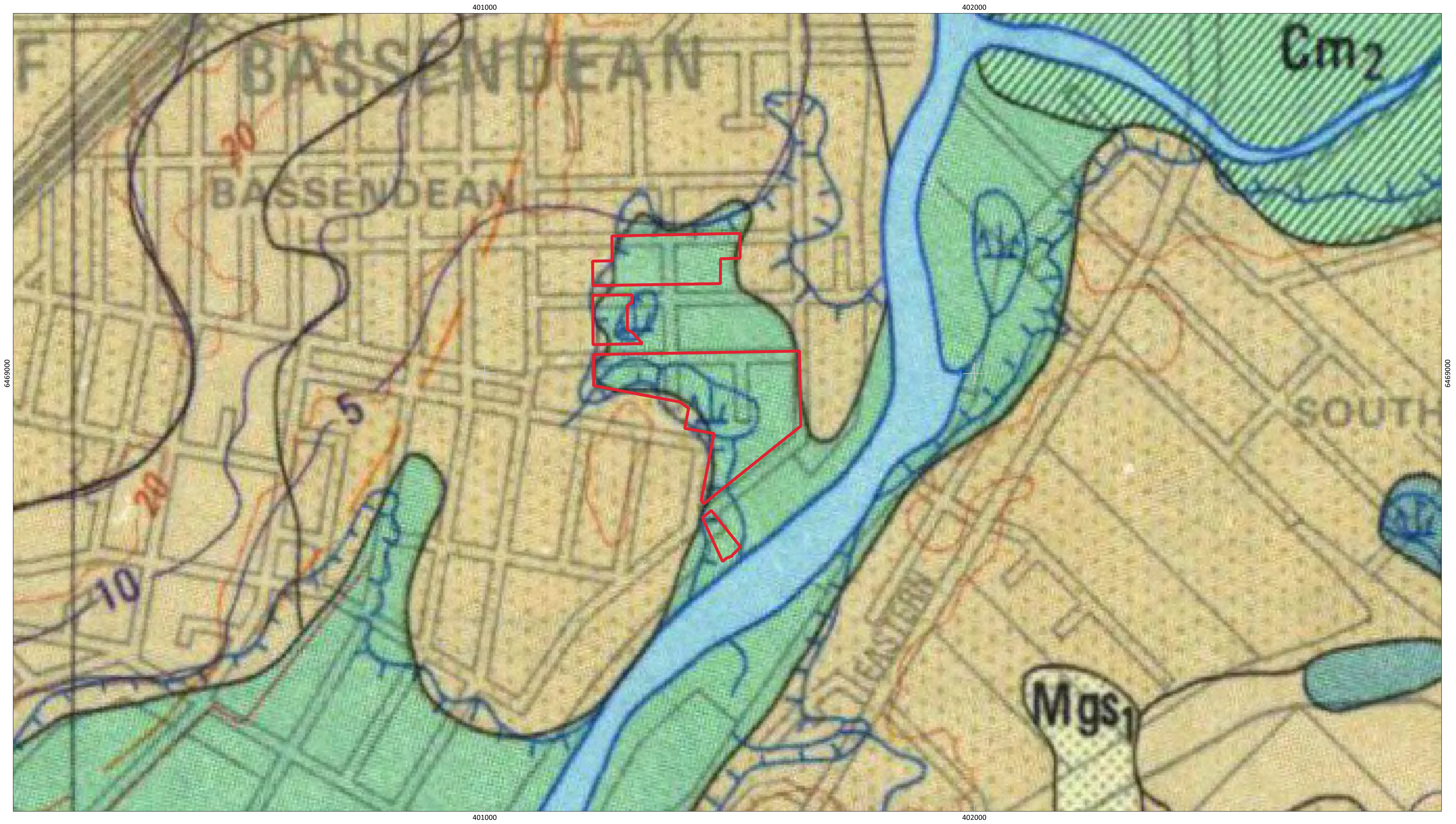


Figure 5: Regional Geology

N

0 100 200 300 400 m

SCALE
1:7,500

SHEET SIZE
A3

COORDINATE REFERENCE SYSTEM
GDA94 / MGA ZONE 50

DATA SOURCE
GSWA 1986, PERTH SHEET

CLIENT
COTERRA ENVIRONMENT

PROJECT
ASS INVESTIGATION

PROJECT NUMBER
16.200

DRAWN BY
BL

DATE
12/06/2017

REVIEWED BY
PB

DATE
12/06/2017

Legend

- 🟥 Site Boundary
- ▨ Sand - S8
- 🟩 Sandy Silt - Ms4
- ▨ Pebbly Silt - Msg1
- ▨ Swan River
- Lake
- Marsh
- 🟩 Clay - Cm2

WESTERN
ENVIRONMENTAL

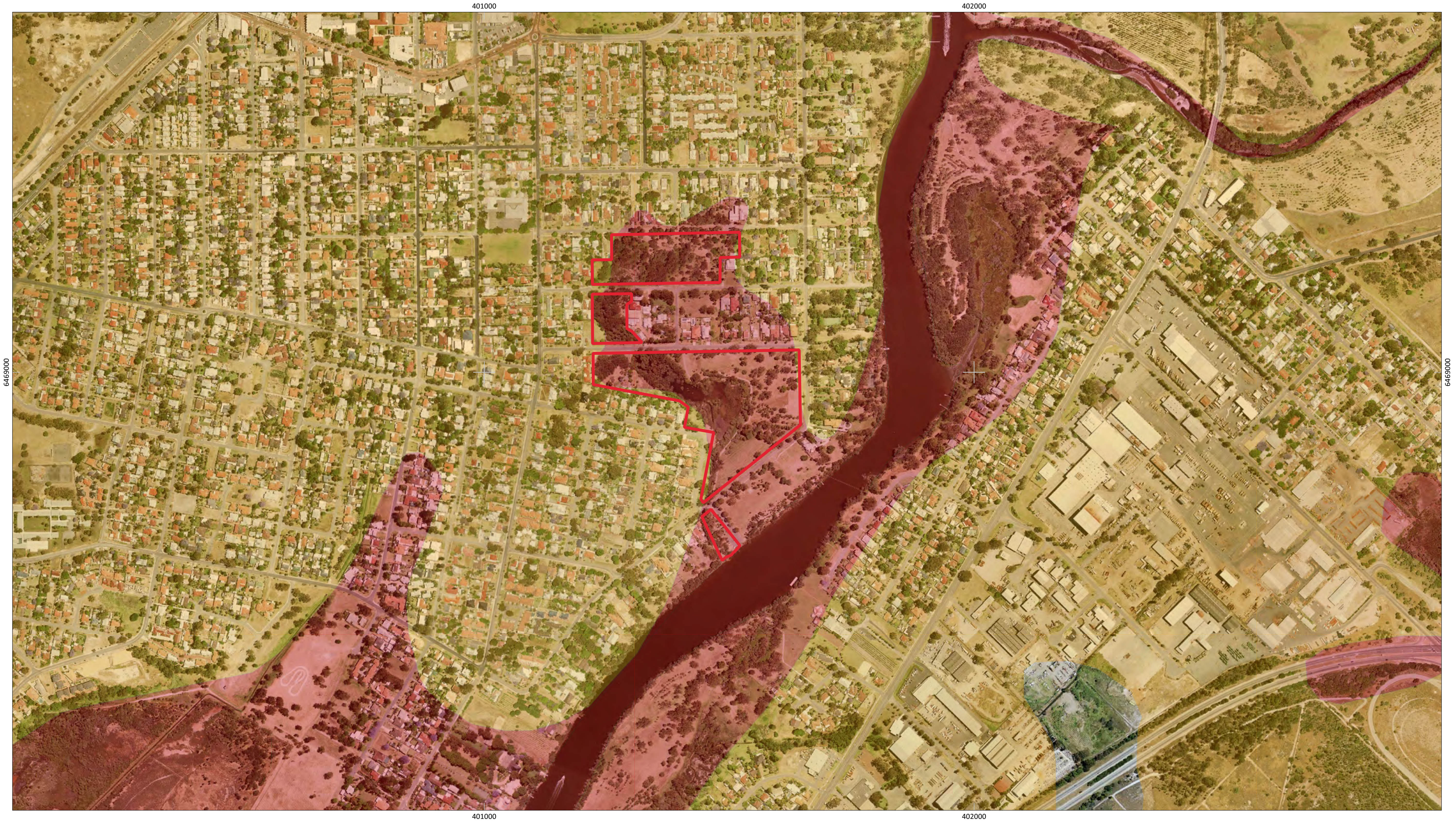


Figure 6: ASS Risk Map

N
0 100 200 300 400 m

CLIENT	COTERRA ENVIRONMENT
PROJECT	ASS INVESTIGATION
SCALE	1:7,500
SHEET SIZE	A3
PROJECT NUMBER	16.200
COORDINATE REFERENCE SYSTEM	GDA94 / MGA ZONE 50
DRAWN BY	BL
DATE	12/06/2017
DATA SOURCE	LANDGATE IMAGERY Metro Central 2006
REVIEWED BY	PB
DATE	12/06/2017

Legend

▭	Site Boundary
🟥	Class 1- High to moderate risk
🟧	Class 2- Moderate to low risk

WESTERN
ENVIRONMENTAL

Figure 7: Sample Locations

N

0 20 40 60 80 m

CLIENT
COTERRA ENVIRONMENT

PROJECT
ASS INVESTIGATION

SCALE 1:2,500	SHEET SIZE A3	PROJECT NUMBER 16.200	
COORDINATE REFERENCE SYSTEM GDA94 / MGA ZONE 50		DRAWN BY BL	DATE 12/06/2017
DATA SOURCE LANDGATE IMAGERY Perth Central 2006		REVIEWED BY PB	DATE 12/06/2017

Legend

🟥	Site Boundary
●	ASS Soil Sample Locations

WESTERN
ENVIRONMENTAL

Tables

Table 1 - Field Test and SPOCAS Laboratory Results

Field observations					Field Test				Lab pH		SPOCAS					
Sample ID			Soil Description*	Depth to ground-water	pH F	pH Fox	pHf - pH Fox	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	SPOS	ANCE	Net Acidity (SPOCAS)
Location	Depth/mBGL From	To		mBGL	pH Units	pH Units	pH Units	LMHXV	pH Units	pH Units	%S	%S	%S	%S	%S	%S
LOR					0.1	0.1	-	1	0.1	0.1	0.005	0.005	0.005	0.005	-	-
Assessment Criteria					<4	<4	>1	NV	NV	NV	**0.03**	**0.03**	NV	**0.03**	NV	**0.03**
BH01	0.00	0.00	SAND (FILL)	1.25	6.4	**3.8**	**2.60**	Moderate								
	0.00	0.25		1.00	6.7	4.5	**2.20**	Extreme								
	0.25	0.50		0.75	6.9	4.8	**2.10**	Moderate								
	0.50	0.75		0.50	6.9	5	**1.90**	Moderate								
	0.75	1.00		0.25	7	5.5	**1.50**	Moderate								
	1.00	1.25		0.00	7.1	4.7	**2.40**	Moderate								
	1.25	1.50		-0.25	6.8	**3.6**	**3.20**	Moderate	6.4	7.5	<0.005	<0.005	<0.005	0.023	0.0325	**0.03**
	DUP1			-0.25	6.8	**3.9**	**2.90**	Moderate	6.5	7.6	<0.005	<0.005	<0.005	0.021	0.0365	0.02
	RPD				0	8	-10	-	2	1	#	#	#	-9	12	-8.16
	1.50	1.75		-0.50	7.3	5.6	**1.70**	Moderate								
	1.75	2.00	SAND (GUILDFORD FORMATION)	-0.75	6.7	**3.1**	**3.60**	Moderate								
	2.00	2.25		-1.00	6.4	**3.1**	**3.30**	Moderate								
	2.25	2.50		-1.25	6.5	**3.5**	**3.00**	Moderate								
	2.50	2.75	CLAY	-1.50	6.4	**3.6**	**2.80**	Moderate								
	2.75	3.00		-1.75	6	**3.2**	**2.80**	Strong	5.4	4.4	**0.041**	**0.211**	0.17	**0.057**	0.0115	**0.10**
BH02	0.00	0.00	TOPSOIL (FILL)	1.75	6	**3**	**3.00**	Moderate								
	0.00	0.25	Sandy CLAY (GUIDLFORD FORMATION)	1.50	6.3	**4**	**2.30**	Moderate	5.5	5.5	0.002	<0.005	<0.005	0.006	0.005	0.01
	0.25	0.50		1.25	7.8	6	**1.80**	Moderate								
	0.50	0.75		1.00	8.7	7.2	**1.50**	Moderate								
	0.75	1.00		0.75	8.9	7.8	**1.10**	Moderate								
	1.00	1.25		0.50	8.7	7.5	**1.20**	Moderate								
	1.25	1.50		0.25	8.3	7.1	**1.20**	Moderate								
	DUP2				8.3	7.4	0.90	Moderate								
	RPD				0	4	-29	-								
	1.50	1.75		0.00	7.7	5.1	**2.60**	Moderate								
	1.75	2.00	Clayey SAND	-0.25	8	6.5	**1.50**	Moderate								
	2.00	2.25		-0.50	7.9	**2.6**	**5.30**	Moderate								
	2.25	2.50		-0.75	7.8	**2.5**	**5.30**	Moderate	6.4	4.2	<0.005	**0.06**	0.055	**0.098**	0.005	**0.10**
	2.50	2.75		-1.00	7.5	**2.5**	**5.00**	Slight								
	2.75	3.00		-1.25	7.4	7.4	0.00	Extreme								
BH03	0.00	0.00	TOPSOIL (FILL)		6.3	**3.1**	**3.20**	Moderate								
	0.00	0.25	Silty SAND		6.9	**3.7**	**3.20**	Strong								
	0.25	0.50	Clayey SAND (GUILDFORD FORMATION		7	4.3	**2.70**	Strong								
	0.50	0.75			7.7	5	**2.70**	Moderate								
	0.75	1.00			8.2	6.5	**1.70**	Strong								
	1.00	1.25			8.2	7.8	0.40	Strong	9.1	7.8	<0.005	<0.005	<0.005	<0.005	0.044	0.01
	DUP3				8.3	4.4	**3.90**	Moderate								
	RPD				1	**56**	**163**	-								
	1.25	1.50	CLAY		7.8	6.9	0.90	Slight								
	1.50	1.75			8	6.7	**1.30**	Moderate								
	1.75	2.00			8.5	7	**1.50**	Moderate	6	6.9	0.006	<0.005	<0.005	0.009	0.005	0.02
	2.00	2.25			8.5	7.9	0.60	Moderate								
	2.25	2.50			8.5	8.2	0.30	Extreme								
	2.50	2.75			8.5	8	0.50	Extreme								
	2.75	3.00			8	8.1	-0.10	Extreme								

Table 1 - Field Test and SPOCAS Laboratory Results

Field observations					Field Test				Lab pH		SPOCAS					
Sample ID			Soil Description*	Depth to ground-water	pH F	pH Fox	pHf - pH Fox	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	SPOS	ANCE	Net Acidity (SPOCAS)
Location	Depth/mBGL From	To		mBGL	pH Units	pH Units	pH Units	LMHXV	pH Units	pH Units	%S	%S	%S	%S	%S	%S
LOR					0.1	0.1	-	1	0.1	0.1	0.005	0.005	0.005	0.005	-	-
Assessment Criteria					<4	<4	>1	NV	NV	NV	**0.03**	**0.03**	NV	**0.03**	NV	**0.03**
BH04	0.00	0.00	TOPSOIL (FILL)		7.4	5	**2.40**	Moderate								
	0.00	0.25	Sandy CLAY (GUIDLFORD FORMATION)		8	6.4	**1.60**	Moderate								
	0.25	0.50			8	6.4	**1.60**	Moderate	7	6.8	<0.005	<0.005	<0.005	0.006	0.022	0.01
	0.50	0.75			8.1	7.3	0.80	Moderate								
	0.75	1.00			8.1	6.9	**1.20**	Moderate								
	1.00	1.25	Clayey SAND		7.8	7.5	0.30	Slight								
	DUP4				8.2	7.4	0.80	Slight								
	RPD				5	1	**91**	-								
	1.25	1.50			7.7	7.9	-0.20	Moderate								
	1.50	1.75			7.8	7.7	0.10	Moderate								
	1.75	2.00			8.2	7.6	0.60	Moderate								
	2.00	2.25			8	**2.8**	**5.20**	Extreme								
	2.25	2.50			7.8	**2.7**	**5.10**	Extreme	6	4.1	<0.005	**0.10**	0.098	**0.165**	0.0075	**0.17**
	2.50	2.75			7.7	**3.2**	**4.50**	Extreme								
	2.75	3.00			7.9	7.8	0.10	Extreme								
BH05	0.00	0.00	TOPSOIL (FILL)		6.8	**3.5**	**3.30**	Moderate								
	0.00	0.25	SAND		6.7	**3.8**	**2.90**	Moderate	5.9	5.2	0.006	<0.005	<0.005	0.011	0.005	0.02
	0.25	0.50			6.6	4.2	**2.40**	Moderate								
	0.50	0.75	Clayey SAND (GUILDFORD FORMATION		6.2	4.3	**1.90**	Moderate								
	0.75	1.00			6.8	5.2	**1.60**	Moderate								
	1.00	1.25			7.2	5.8	**1.40**	Moderate								
	1.25	1.50			7.8	6	**1.80**	Moderate								
	1.50	1.75	CLAY		7.8	6.8	**1.00**	Slight								
	1.75	2.00			7.6	6.6	**1.00**	Slight								
	2.00	2.25			7.6	6.4	**1.20**	Slight	5.7	6.8	0.008	<0.005	<0.005	<0.005	0.0105	0.01
	2.25	2.50			7.7	6.4	**1.30**	Slight								
	2.50	2.75			7.5	6.4	**1.10**	Slight								
	2.75	3.00			7.6	6.6	**1.00**	Moderate								

Notes	
0.05	Result is above DER assessment criteria value
85.71	RPD% exceedence
NV	No Value
LMHXV	Low, Medium, High, Extreme and Volcanic Reaction Rates
n/a	Acid Neutralising capacity, reached before this analysis began. No need to analysis, below LOR.

Table 2: Soils Metals Laboratory Analysis

								Sample ID	BH01-3.0	BH02-1.5	DUP2	RPD %	BH03-1.25	BH04-2.5	BH05-0.25
								Date	08/06/2017	08/06/2017	08/06/2017		08/06/2017	08/06/2017	08/06/2017
								Lab Report No.	EP1705782037	EP1705782038	EP1705782039		EP1705782040	EP1705782046	EP1705782047
			HILs (NEPM, 2013)				EILs (NEPM, 2013)								
ChemName	**Units**	**EQL**	**HIL-A**	**HIL-B**	**HIL-C**	**HIL-D**	**EIL - Residential/ POS**	**EIL - Commercial/ Industrial**							
Metals															
Aluminium	mg/kg	50							**4640**	**6240**	**3420**	58	**4100**	**2650**	**3170**
Arsenic	mg/kg	5	**100**	**500**	**300**	**3,000**	**100**	**160**	<5	<5	<5	#	<5	<5	<5
Cadmium	mg/kg	1	**20**	**150**	**90**	**900**			<1	<1	<1	#	**1**	<1	<1
Chromium (III+VI)	mg/kg	2	**100***	**500***	**300***	**3,600***			**12**	**31**	**19**	48	**31**	**17**	**11**
Iron	mg/kg	50							**13800**	**12300**	**9180**	29	**17500**	**6630**	**6550**
Lead	mg/kg	5	**300**	**1,200**	**600**	**1,500**	**1,100**	**1,800**	**7**	**14**	**8**	55	**7**	**9**	**16**
Molybdenum	mg/kg	2							**3**	<2	<2	#	<2	<2	<2
Nickel	mg/kg	2	**400**	**1,200**	**1,200**	**6,000**	**30$^{\#}$**	**55$^{\#}$**	<2	**11**	**5**	75	**7**	**4**	<2
Selenium	mg/kg	5	**200**	**1,400**	**700**	**10,000**			<5	<5	<5	#	<5	<5	<5
Zinc	mg/kg	5	**7,400**	**60,000**	**30,000**	**400,000**	**70$^{\#}$**	**110$^{\#}$**	**37**	**9**	<5	#	**8**	**6**	**28**

Comments

$^{\#}$ Values dependent on soil charecteristics; most conservative parameters applied (pH = 4, %Clay = 1, CEC = 5 cmol/kg).

* Chromium VI value utilised

** Inorganic Mercury value utilised

0.012 Analyte concentration that exceeds applied assesment criterea

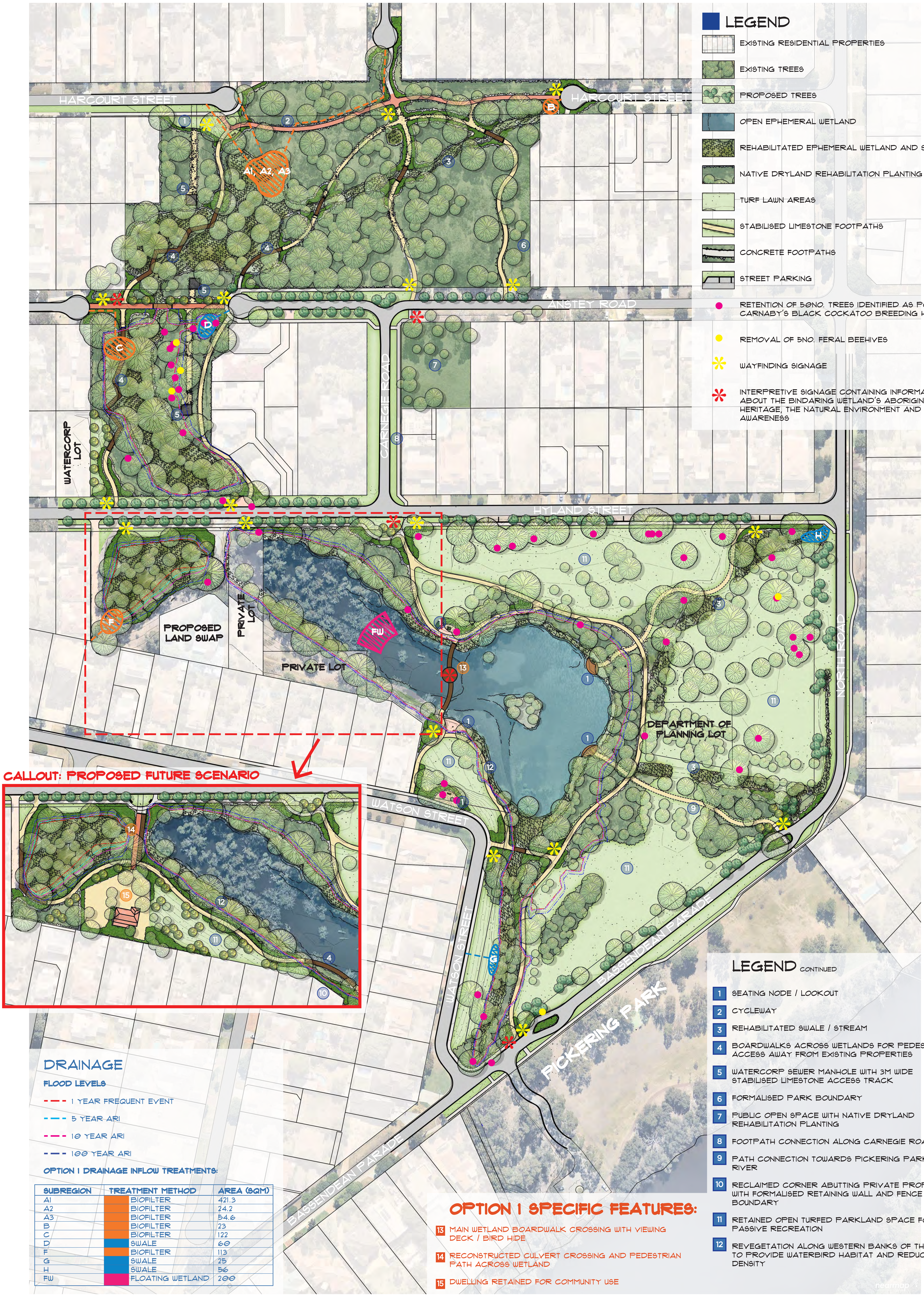
< Indicates analyte concentration less than Effective Quantification Limit (EQL)/ Limit of Reporting (LOR)

Bold font indicates results above the LOR

Red font indicates RPD > 30%

Appendix A

Bindaring Wetland Preliminary Sketch Concept Nodes and Circulation



LEGEND

- Existing residential properties
- Existing trees
- Proposed trees
- Open ephemeral wetland
- Rehabilitated ephemeral wetland and swales
- Native dryland rehabilitation planting
- Turf lawn areas
- Stabilised limestone footpaths
- Concrete footpaths
- Street parking
- ● Retention of 50no. trees identified as potential Carnaby's black cockatoo breeding habitat
- ● Removal of 5no. feral beehives
- ✳ Wayfinding signage
- ✳ Interpretive signage containing information about the Bindaring Wetland's aboriginal heritage, the natural environment and flood awareness

CALLOUT: PROPOSED FUTURE SCENARIO

LEGEND CONTINUED

1 SEATING NODE / LOOKOUT
2 CYCLEWAY
3 REHABILITATED SWALE / STREAM
4 BOARDWALKS ACROSS WETLANDS FOR PEDESTRIAN ACCESS AWAY FROM EXISTING PROPERTIES
5 WATERCORP SEWER MANHOLE WITH 3M WIDE STABILISED LIMESTONE ACCESS TRACK
6 FORMALISED PARK BOUNDARY
7 PUBLIC OPEN SPACE WITH NATIVE DRYLAND REHABILITATION PLANTING
8 FOOTPATH CONNECTION ALONG CARNEGIE ROAD
9 PATH CONNECTION TOWARDS PICKERING PARK AND RIVER
10 RECLAIMED CORNER ABUTTING PRIVATE PROPERTY WITH FORMALISED RETAINING WALL AND FENCE ALONG BOUNDARY
11 RETAINED OPEN TURFED PARKLAND SPACE FOR PASSIVE RECREATION
12 REVEGETATION ALONG WESTERN BANKS OF THE LAKE TO PROVIDE WATERBIRD HABITAT AND REDUCE WEED DENSITY

DRAINAGE

FLOOD LEVELS

- - - 1 YEAR FREQUENT EVENT
- - - 5 YEAR ARI
- - - 10 YEAR ARI
- - - 100 YEAR ARI

OPTION 1 DRAINAGE INFLOW TREATMENTS:

SUBREGION	TREATMENT METHOD	AREA (SQM)
A1	🟧 BIOFILTER	421.3
A2	🟧 BIOFILTER	24.2
A3	🟧 BIOFILTER	54.6
B	🟧 BIOFILTER	23
C	🟧 BIOFILTER	122
D	🟦 SWALE	60
F	🟧 BIOFILTER	113
G	🟦 SWALE	25
H	🟦 SWALE	56
FW	🟪 FLOATING WETLAND	200

OPTION 1 SPECIFIC FEATURES:

13 MAIN WETLAND BOARDWALK CROSSING WITH VIEWING DECK / BIRD HIDE
14 RECONSTRUCTED CULVERT CROSSING AND PEDESTRIAN PATH ACROSS WETLAND
15 DWELLING RETAINED FOR COMMUNITY USE

LANDSCAPE CONCEPT MASTERPLAN

BINDARING WETLAND

SHEET 1 - OPTION 1 REV C

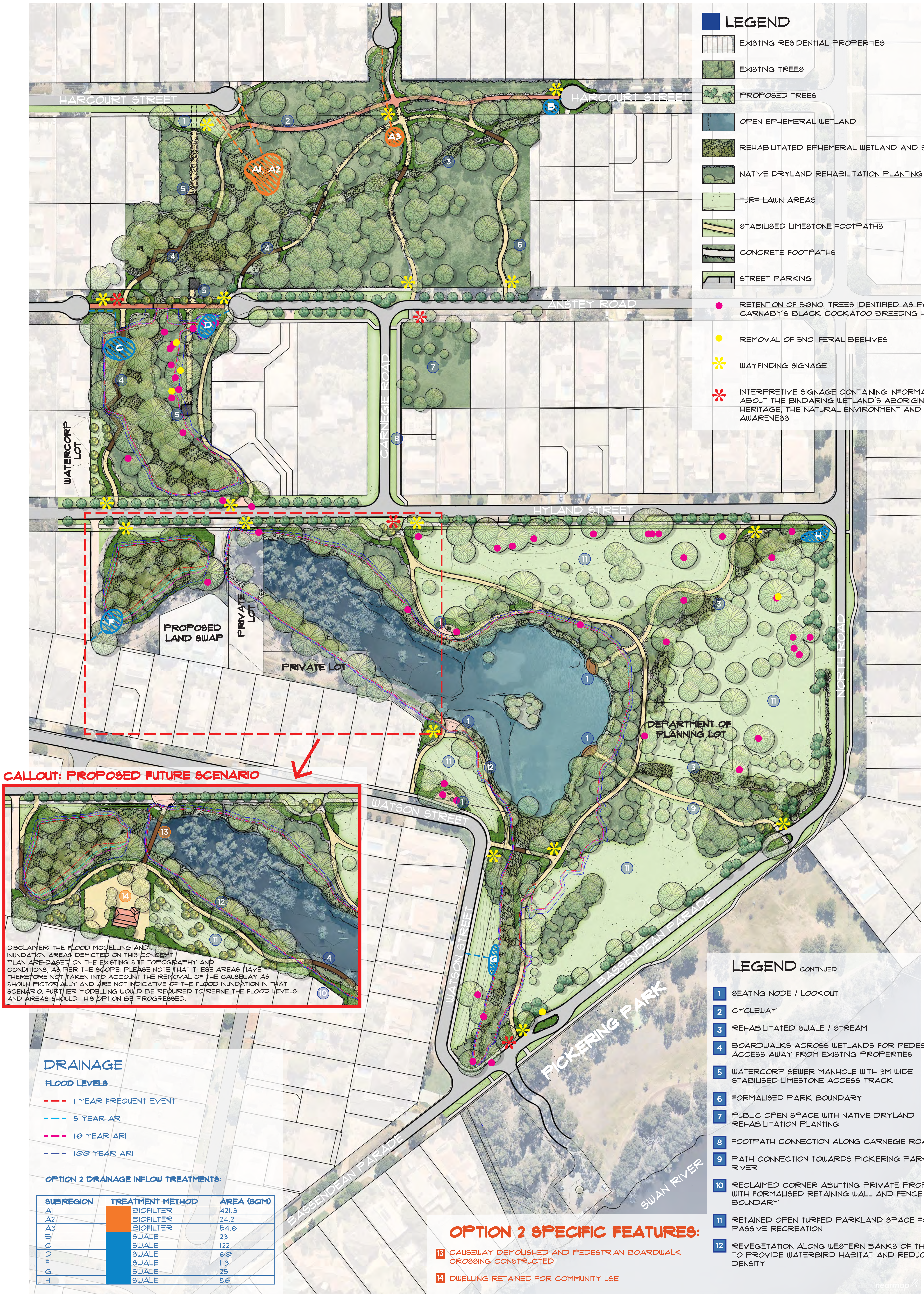
0 10 20
SCALE 1:1000 M on A1

SCALE 1:1000 @ A1 DATE : 26TH JULY 2017

EPCAD Pty Ltd ACN 093 476 334 ABN 26 093 476 334
28-30 Mayfair Street, West Perth, WA 6005. PO Box 1233, West Perth WA
☎+61 8 9481 4410 ✉ epcad@epcad.com.au

EPCAD

epcad.com.au



LEGEND

- ▥ EXISTING RESIDENTIAL PROPERTIES
- 🟩 EXISTING TREES
- 🟩 PROPOSED TREES
- 🟦 OPEN EPHEMERAL WETLAND
- 🟩 REHABILITATED EPHEMERAL WETLAND AND SWALES
- 🟩 NATIVE DRYLAND REHABILITATION PLANTING
- 🟩 TURF LAWN AREAS
- ▨ STABILISED LIMESTONE FOOTPATHS
- ▨ CONCRETE FOOTPATHS
- ▭ STREET PARKING
- ● RETENTION OF 50NO. TREES IDENTIFIED AS POTENTIAL CARNABY'S BLACK COCKATOO BREEDING HABITAT
- ● REMOVAL OF 5NO. FERAL BEEHIVES
- ✳ WAYFINDING SIGNAGE
- ✳ INTERPRETIVE SIGNAGE CONTAINING INFORMATION ABOUT THE BINDARING WETLAND'S ABORIGINAL HERITAGE, THE NATURAL ENVIRONMENT AND FLOOD AWARENESS

LEGEND CONTINUED

1. SEATING NODE / LOOKOUT
2. CYCLEWAY
3. REHABILITATED SWALE / STREAM
4. BOARDWALKS ACROSS WETLANDS FOR PEDESTRIAN ACCESS AWAY FROM EXISTING PROPERTIES
5. WATERCORP SEWER MANHOLE WITH 3M WIDE STABILISED LIMESTONE ACCESS TRACK
6. FORMALISED PARK BOUNDARY
7. PUBLIC OPEN SPACE WITH NATIVE DRYLAND REHABILITATION PLANTING
8. FOOTPATH CONNECTION ALONG CARNEGIE ROAD
9. PATH CONNECTION TOWARDS PICKERING PARK AND RIVER
10. RECLAIMED CORNER ABUTTING PRIVATE PROPERTY WITH FORMALISED RETAINING WALL AND FENCE ALONG BOUNDARY
11. RETAINED OPEN TURFED PARKLAND SPACE FOR PASSIVE RECREATION
12. REVEGETATION ALONG WESTERN BANKS OF THE LAKE TO PROVIDE WATERBIRD HABITAT AND REDUCE WEED DENSITY

CALLOUT: PROPOSED FUTURE SCENARIO

DISCLAIMER: THE FLOOD MODELLING AND INUNDATION AREAS DEPICTED ON THIS CONCEPT PLAN ARE BASED ON THE EXISTING SITE TOPOGRAPHY AND CONDITIONS, AS PER THE SCOPE. PLEASE NOTE THAT THESE AREAS HAVE THEREFORE NOT TAKEN INTO ACCOUNT THE REMOVAL OF THE CAUSEWAY AS SHOWN PICTORIALLY AND ARE NOT INDICATIVE OF THE FLOOD INUNDATION IN THAT SCENARIO. FURTHER MODELLING WOULD BE REQUIRED TO REFINE THE FLOOD LEVELS AND AREAS SHOULD THIS OPTION BE PROGRESSED.

DRAINAGE

FLOOD LEVELS

- 1 YEAR FREQUENT EVENT
- 5 YEAR ARI
- 10 YEAR ARI
- 100 YEAR ARI

OPTION 2 DRAINAGE INFLOW TREATMENTS:

SUBREGION	TREATMENT METHOD		AREA (SQM)
A1	🟧	BIOFILTER	421.3
A2	🟧	BIOFILTER	24.2
A3	🟧	BIOFILTER	54.6
B	🟦	SWALE	23
C	🟦	SWALE	122
D	🟦	SWALE	60
F	🟦	SWALE	113
G	🟦	SWALE	25
H	🟦	SWALE	56

OPTION 2 SPECIFIC FEATURES:

13. CAUSEWAY DEMOLISHED AND PEDESTRIAN BOARDWALK CROSSING CONSTRUCTED
14. DWELLING RETAINED FOR COMMUNITY USE

LANDSCAPE CONCEPT MASTERPLAN

BINDARING WETLAND

SHEET 1 - OPTION 2 REV C

SCALE 1:1000 M on A1

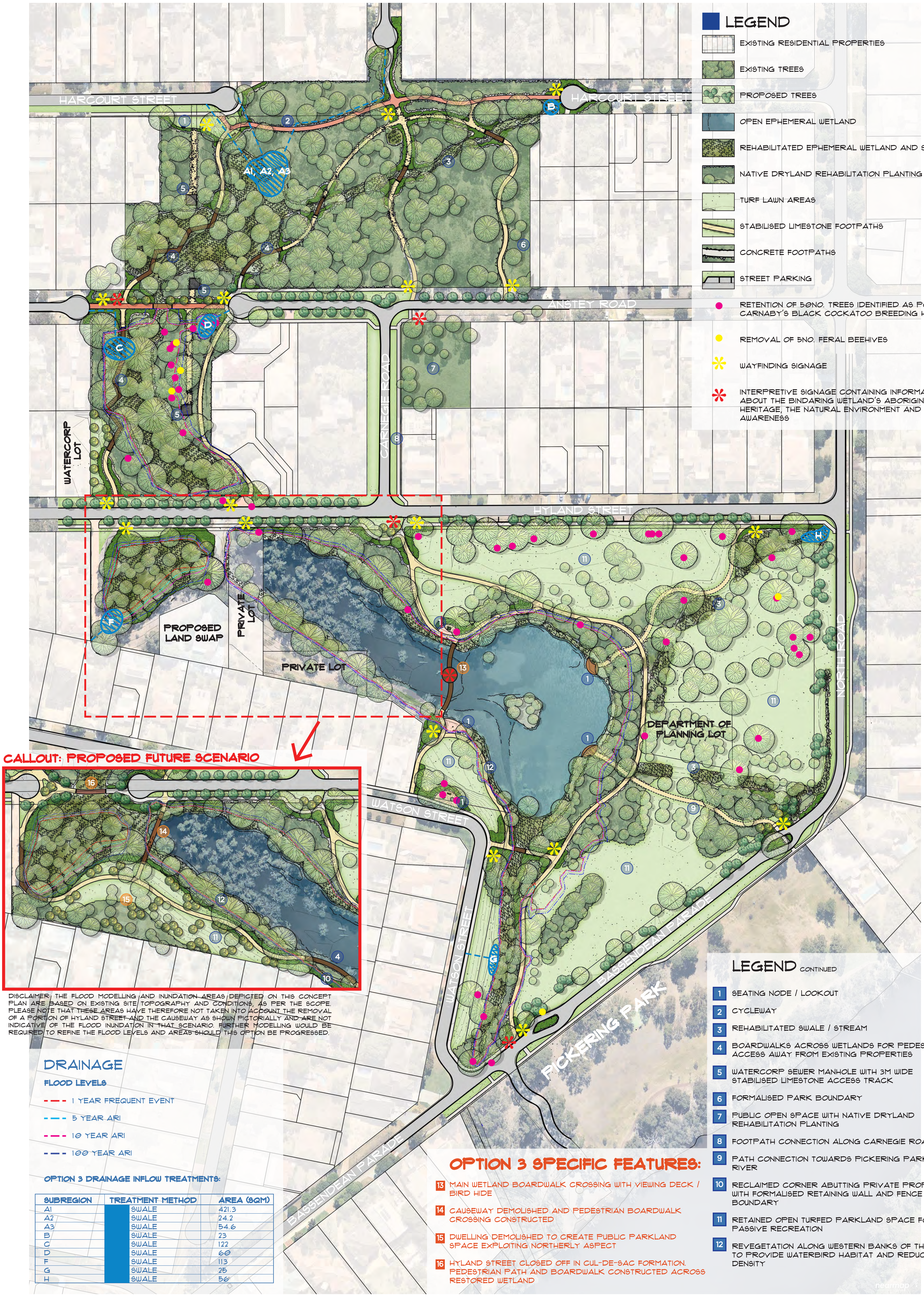
SCALE1:1000 @ A1

DATE : 26TH JULY 2017

EPCAD Pty Ltd ACN 093 476 334 ABN 26 093 476 334
28-30 Mayfair Street, West Perth, WA 6005. PO Box 1233, West Perth WA
☎ +61 8 9481 4410 ✉ epcad@epcad.com.au

EPCAD

epcad.com.au



LEGEND

▥	EXISTING RESIDENTIAL PROPERTIES
🟩	EXISTING TREES
🟩	PROPOSED TREES
🟦	OPEN EPHEMERAL WETLAND
🟩	REHABILITATED EPHEMERAL WETLAND AND SWALES
🟩	NATIVE DRYLAND REHABILITATION PLANTING
🟩	TURF LAWN AREAS
▨	STABILISED LIMESTONE FOOTPATHS
▨	CONCRETE FOOTPATHS
▨	STREET PARKING
●	RETENTION OF 50NO. TREES IDENTIFIED AS POTENTIAL CARNABY'S BLACK COCKATOO BREEDING HABITAT
●	REMOVAL OF 5NO. FERAL BEEHIVES
✳	WAYFINDING SIGNAGE
✳	INTERPRETIVE SIGNAGE CONTAINING INFORMATION ABOUT THE BINDARING WETLAND'S ABORIGINAL HERITAGE, THE NATURAL ENVIRONMENT AND FLOOD AWARENESS

CALLOUT: PROPOSED FUTURE SCENARIO

DISCLAIMER: THE FLOOD MODELLING AND INUNDATION AREAS DEPICTED ON THIS CONCEPT PLAN ARE BASED ON EXISTING SITE TOPOGRAPHY AND CONDITIONS, AS PER THE SCOPE. PLEASE NOTE THAT THESE AREAS HAVE THEREFORE NOT TAKEN INTO ACCOUNT THE REMOVAL OF A PORTION OF HYLAND STREET AND THE CAUSEWAY AS SHOWN PICTORIALLY AND ARE NOT INDICATIVE OF THE FLOOD INUNDATION IN THAT SCENARIO. FURTHER MODELLING WOULD BE REQUIRED TO REFINE THE FLOOD LEVELS AND AREAS SHOULD THIS OPTION BE PROGRESSED.

DRAINAGE

FLOOD LEVELS

- - - 1 YEAR FREQUENT EVENT

- - - 5 YEAR ARI

- - - 10 YEAR ARI

- - - 100 YEAR ARI

OPTION 3 DRAINAGE INFLOW TREATMENTS:

SUBREGION	TREATMENT METHOD	AREA (SQM)
A1	SWALE	421.3
A2	SWALE	24.2
A3	SWALE	54.6
B	SWALE	23
C	SWALE	122
D	SWALE	60
F	SWALE	113
G	SWALE	25
H	SWALE	56

OPTION 3 SPECIFIC FEATURES:

13	MAIN WETLAND BOARDWALK CROSSING WITH VIEWING DECK / BIRD HIDE
14	CAUSEWAY DEMOLISHED AND PEDESTRIAN BOARDWALK CROSSING CONSTRUCTED
15	DWELLING DEMOLISHED TO CREATE PUBLIC PARKLAND SPACE EXPLOITING NORTHERLY ASPECT
16	HYLAND STREET CLOSED OFF IN CUL-DE-SAC FORMATION. PEDESTRIAN PATH AND BOARDWALK CONSTRUCTED ACROSS RESTORED WETLAND

LEGEND CONTINUED

1	SEATING NODE / LOOKOUT
2	CYCLEWAY
3	REHABILITATED SWALE / STREAM
4	BOARDWALKS ACROSS WETLANDS FOR PEDESTRIAN ACCESS AWAY FROM EXISTING PROPERTIES
5	WATERCORP SEWER MANHOLE WITH 3M WIDE STABILISED LIMESTONE ACCESS TRACK
6	FORMALISED PARK BOUNDARY
7	PUBLIC OPEN SPACE WITH NATIVE DRYLAND REHABILITATION PLANTING
8	FOOTPATH CONNECTION ALONG CARNEGIE ROAD
9	PATH CONNECTION TOWARDS PICKERING PARK AND RIVER
10	RECLAIMED CORNER ABUTTING PRIVATE PROPERTY WITH FORMALISED RETAINING WALL AND FENCE ALONG BOUNDARY
11	RETAINED OPEN TURFED PARKLAND SPACE FOR PASSIVE RECREATION
12	REVEGETATION ALONG WESTERN BANKS OF THE LAKE TO PROVIDE WATERBIRD HABITAT AND REDUCE WEED DENSITY

LANDSCAPE CONCEPT MASTERPLAN

BINDARING WETLAND

SHEET 1 - OPTION 3 REV C

0 10 20
SCALE 1:1000 M on A1

SCALE 1:1000 @ A1

DATE : 26TH JULY 2017

N

EPCAD Pty Ltd ACN 093 476 334 ABN 26 093 476 334
28-30 Mayfair Street, West Perth, WA 6005. PO Box 1233, West Perth WA
☎+61 8 9481 4410 ✉ epcad@epcad.com.au

epcad.com.au

EPCAD

Appendix B

Site Photographs

Photo 1	
Description	Drilling soil bore BH01
Details	Taken by Structerre 08/06/2017

Photo 2	
Description	Soils from BH01
Details	Taken by Structerre 08/06/2017

Photo 3	
Description	Drilling soil bore BH02
Details	Taken by Structerre 08/06/2017

Photo 4	
Description	Soils from BH02
Details	Taken by Structerre 08/06/2017

Photo 5	
Description	Drilling soil bore BH03
Details	Taken by Structerre 08/06/2017

Photo 6	
Description	Soils from BH03
Details	Taken by Structerre 08/06/2017

Photo 7	
Description	Soil bore BH04 located near to lake
Details	Taken by Structerre 08/06/2017

Photo 8	
Description	Soils from BH04
Details	Taken by Structerre 08/06/2017

Photo 9	
Description	Drilling soil bore BH05
Details	Taken by Structerre 08/06/2017

Photo 10	
Description	Soils from BH05
Details	Taken by Structerre 08/06/2017

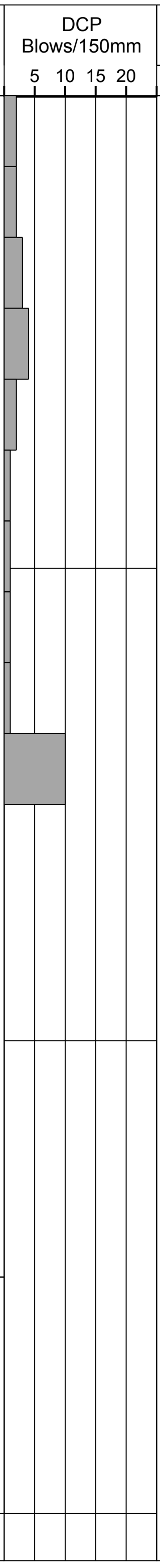
Appendix C

Borehole Logs

Project	Bindaring Wetlands - Bassendean Parade, Bassendean	**Test No.**	**BH01**
Client	Town of Bassendean c/o Western Environmental		

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401304
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469063

Depth	Stratum Description	Consistency	Moisture
	SP: SAND: fine to medium grained, non-plastic, with gravel, trace silt, grey/brown (FILL)	L	D to M
1			
			S
	SP: SAND: fine to medium grained, non-plastic, with silt, grey (Alluvium)		
2			
	CI: CLAY: medium plasticity, with sand, grey (Alluvium)	S	
3	Terminated at 3.00 m		



Samples: Depth, Type — none recorded.

Water Level ▼

Remarks

1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: None
4. Co-ordinate system: WGS 84

Project Bindaring Wetlands - Bassendean Parade, Bassendean

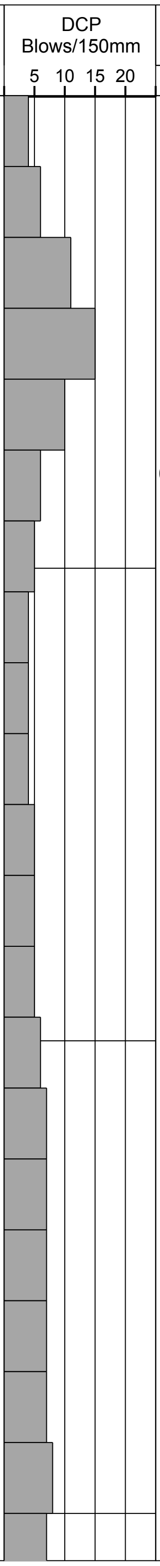
Client Town of Bassendean c/o Western Environmental

Test No. **BH02**

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401463
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469242

Depth	Stratum Description	Consistency	Samples Depth	Samples Type	Moisture	Water Level
	Topsoil: (FILL)					
1	CI: CLAY: medium plasticity, with sand, yellow/brown (Alluvium)	F	0.8 - 1.3	B	D to M	▼
2	SC: Clayey SAND: medium plasticity, grey/brown (Alluvium)				S	
3	Terminated at 3.00 m					

DCP Blows/150mm



Continued on next sheet

Remarks

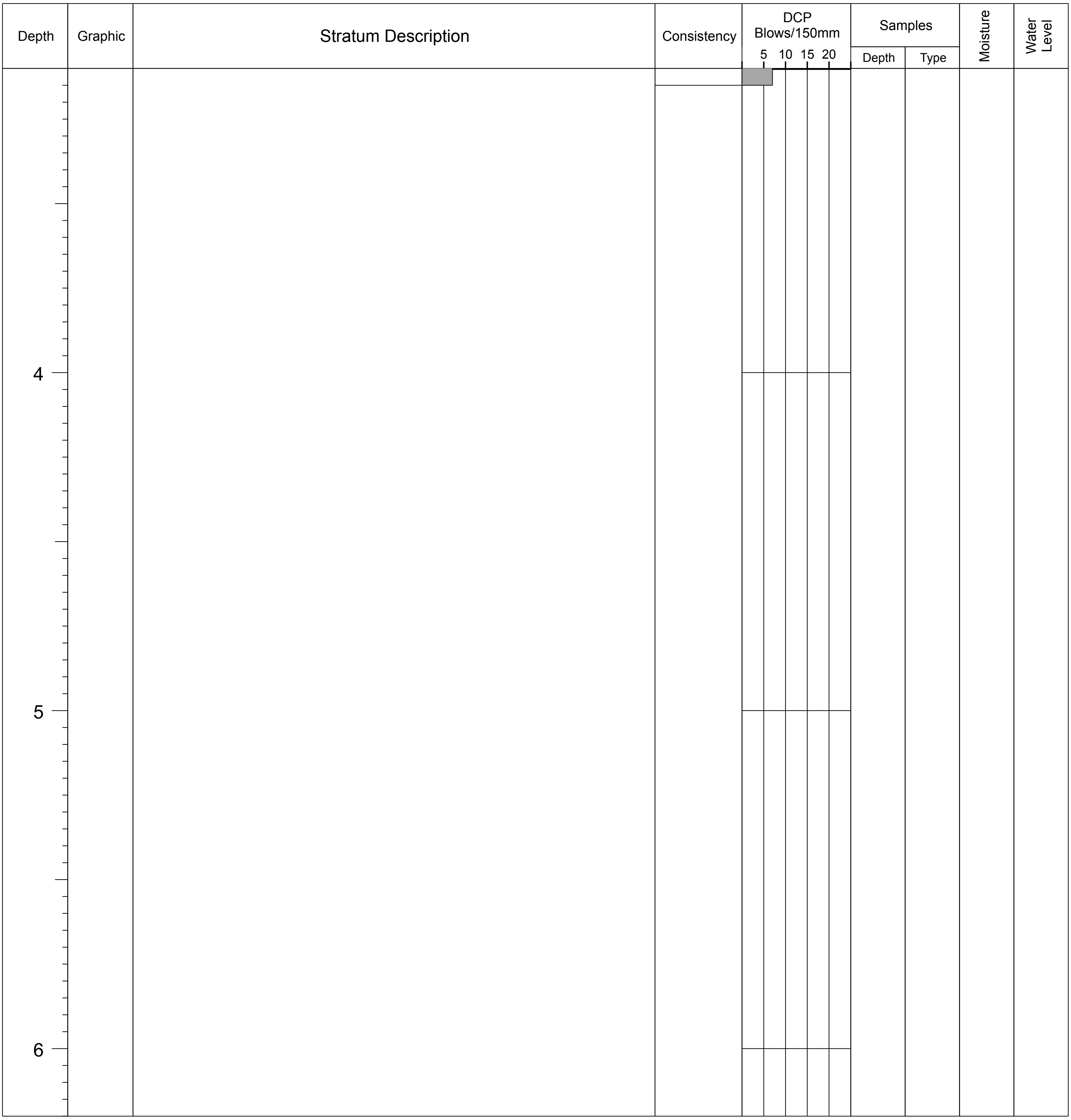
1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: As indicated
4. Co-ordinate system: WGS 84

Project Bindaring Wetlands - Bassendean Parade, Bassendean

Client Town of Bassendean c/o Western Environmental

Test No.
BH02

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401463
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469242

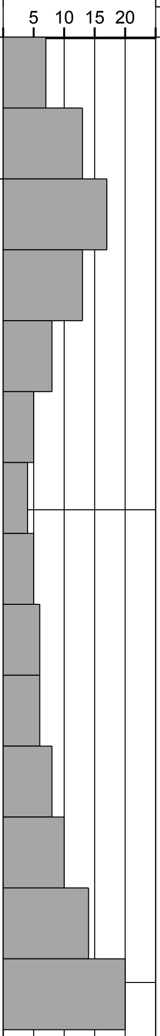


Remarks
1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: As indicated
4. Co-ordinate system: WGS 84

Project	Bindaring Wetlands - Bassendean Parade, Bassendean
Client	Town of Bassendean c/o Western Environmental

Test No.
BH03

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401518
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469002

Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm	Samples		Moisture	Water Level
					Depth	Type		
	▩	Topsoil: (FILL)	D				D to M	
		SM: Silty SAND: low to medium plasticity, trace organic material (fine roots), grey/brown (Alluvium)						
1		SC: Clayey SAND: medium plasticity, trace gravel, pale grey (Alluvium)	F				M	
2		CI: CLAY: medium plasticity, with sand, grey/brown (Alluvium)						
3		Terminated at 3.00 m						

Remarks

1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: None
4. Co-ordinate system: WGS 84

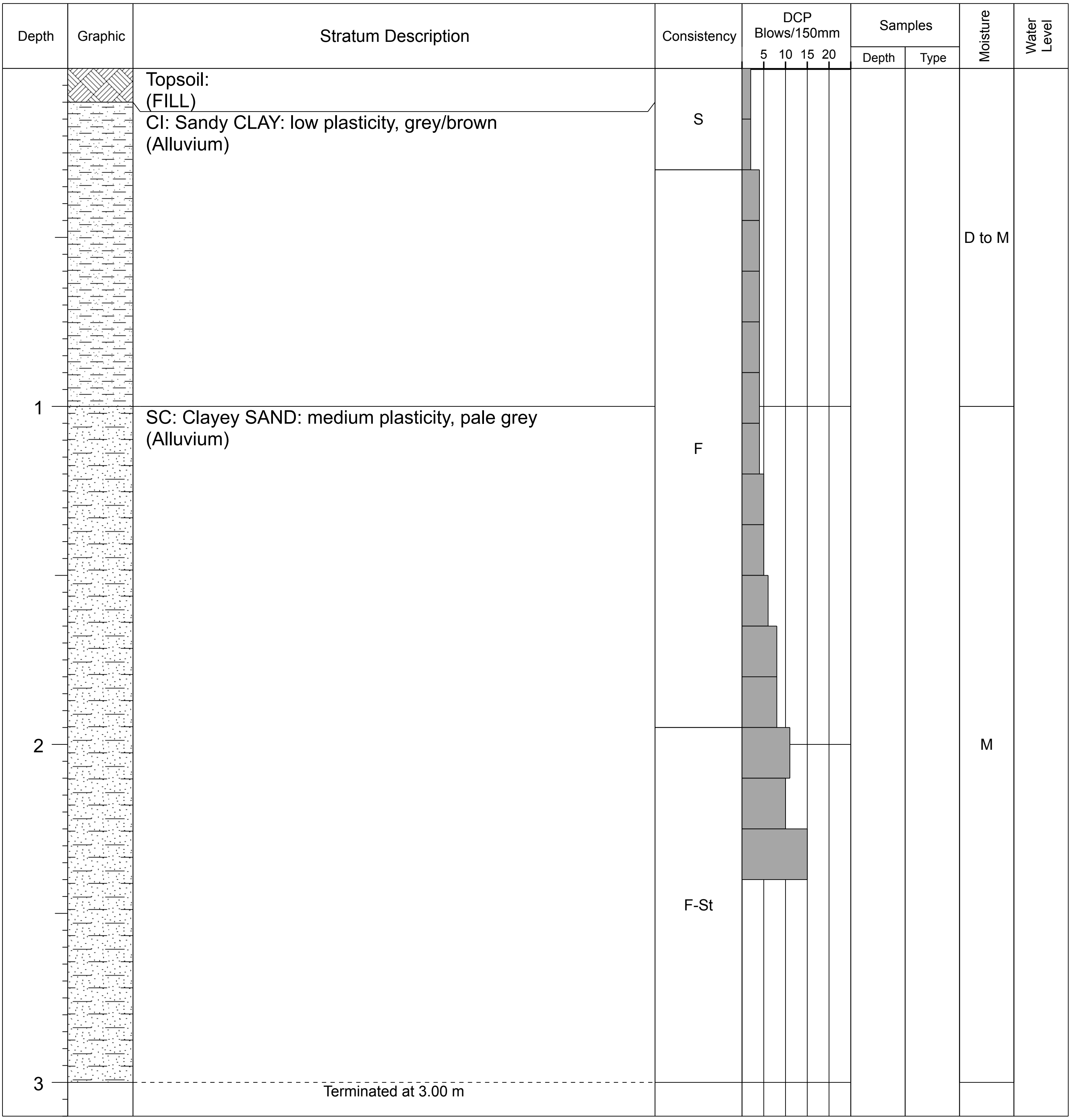
STRUCterre consulting engineers

Project Bindaring Wetlands - Bassendean Parade, Bassendean

Client Town of Bassendean c/o Western Environmental

Test No.
BH04

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401448
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6468896



Topsoil:
(FILL)

CI: Sandy CLAY: low plasticity, grey/brown
(Alluvium)

SC: Clayey SAND: medium plasticity, pale grey
(Alluvium)

Terminated at 3.00 m

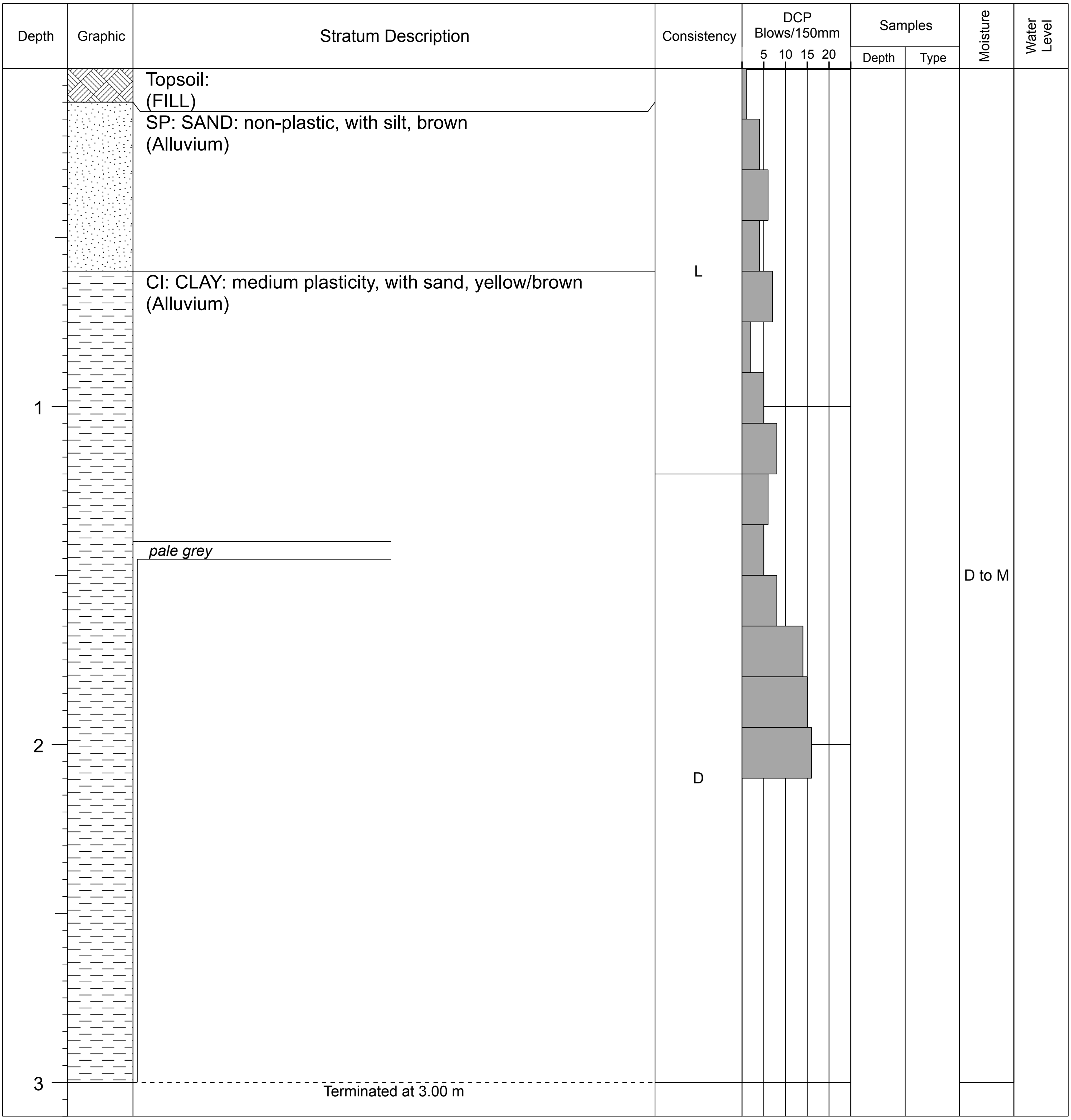
Remarks
1. Termination reason: Target depth
2. Hole stability: Hole partially stable
3. Samples taken: None
4. Co-ordinate system: WGS 84

Project Bindaring Wetlands - Bassendean Parade, Bassendean

Client Town of Bassendean c/o Western Environmental

Test No.
BH05

Project No.	D168468	**Logged By**	Cheyne Quesnel	**Machine**	Soil Retrieval Probe	**Easting**	401246
Job No.	J180065	**Date**	08/06/2017	**Hole Dia.**	65mm	**Northing**	6469220



Depth	Graphic	Stratum Description	Consistency	DCP Blows/150mm	Samples Depth	Samples Type	Moisture	Water Level
		Topsoil: (FILL)						
		SP: SAND: non-plastic, with silt, brown (Alluvium)						
		CI: CLAY: medium plasticity, with sand, yellow/brown (Alluvium)	L					
1								
		pale grey	D				D to M	
2								
3		Terminated at 3.00 m						

Remarks
1. Termination reason: Target depth
2. Hole stability: Hole stable
3. Samples taken: None
4. Co-ordinate system: WGS 84

Appendix D

Soil Chain of Custody and Certificates of Analysis

WESTERN ENVIRONMENTAL

CHAIN OF CUSTODY RECORD

Page 1 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD
Contact Name : Bianca Lockley
Purchase Order :
CoC Number :

Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005
Project Manager : Phil Brand
Project Number : 16.200
Quote ID : EP-100-16

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens

Email: Brandon.Ovens@alsglobal.com

Email for results : bianca.lockley@westernenvironmental.com.au
Courier Consignment # :

Special Directions & Comments :
retain all samples for subsequent SPOCAS analysis

#	Sample ID	Sample Date	Matrix	Analytes											Container							
				ASS Field TESTING	HOLD										ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	Glass Jar
1	BH01-0.00	8.6.17	SOIL	X																		
2	BH01-0.25	8.6.17	SOIL	X																		
3	BH01-0.50	8.6.17	SOIL	X																		
4	BH01-0.75	8.6.17	SOIL	X																		
5	BH01-1.00	8.6.17	SOIL	X																		
6	BH01-1.25	8.6.17	SOIL	X																		
7	BH01-1.50	8.6.17	SOIL	X																		
8	BH01-1.75	8.6.17	SOIL	X																		
9	BH01-2.00	8.6.17	SOIL	X																		
10	BH01-2.25	8.6.17	SOIL	X																		
11	BH01-2.50	8.6.17	SOIL	X																		
12	BH01-2.75	8.6.17	SOIL	X																		
13	BH01-3.00	8.6.17	SOIL	X																		
14	BH02-0.00	8.6.17	SOIL	X																		
15	BH02-0.25	8.6.17	SOIL	X																		

Environmental Division
Perth
Work Order Reference
EP1706052

Telephone : + 61-8-9209 7655

Relinquished By: ____________________

Date & Time : ____________________

Signature: ____________________

Received By: Nicole

Date & Time : 8-6-17 1630

Signature:

Report Number :

Turn around Time :
3 Days

Comments :

Method Of Shipment :

☐ Courier
☑ Hand Delivered
☐ Postal

WESTERN
ENVIRONMENTAL

CHAIN OF CUSTODY RECORD

Page 2 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD

Contact Name : Bianca Lockley

Purchase Order :

CoC Number :

Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005

Project Manager : Phil Brand

Project Number : 16.200

Quote ID : EP-100-16

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens

Email: Brandon.Ovens@alsglobal.com

Email for results : bianca.lockley@westernenvironmental.com.au

Courier Consignment # :

Special Directions & Comments :

retain all samples for subsequent SPOCAS analysis

Analytes

#	Sample ID	Sample Date	Matrix	ASS Field TESTING	HOLD										Container							Glass Jar
															ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	
16	BH02-0.50	8.6.17	SOIL	X																		
17	BH02-0.75	8.6.17	SOIL	X																		
18	BH02-1.00	8.6.17	SOIL	X																		
19	BH02-1.25	8.6.17	SOIL	X																		
20	BH02-1.50	8.6.17	SOIL	X																		
21	BH02-1.75	8.6.17	SOIL	X																		
22	BH02-2.00	8.6.17	SOIL	X																		
23	BH02-2.25	8.6.17	SOIL	X																		
24	BH02-2.50	8.6.17	SOIL	X																		
25	BH02-2.75	8.6.17	SOIL	X																		
26	BH02-3.00	8.6.17	SOIL	X																		
27	BH03-0.00	8.6.17	SOIL	X																		
28	BH03-0.25	8.6.17	SOIL	X																		
29	BH03-0.50	8.6.17	SOIL	X																		
30	BH03-0.75	8.6.17	SOIL	X																		

Relinquished By: ____________________

Date & Time : ____________________

Signature: ____________________

Received By: ____________________

Date & Time : ____________________

Signature: ____________________

Report Number : ____________________

Turn around Time :

3 Days

Comments :

Method Of Shipment :

☐ Courier

☐ Hand Delivered

☐ Postal

WESTERN

CHAIN OF CUSTODY RECORD

Page 3 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD	Contact Name : Bianca Lockley	Purchase Order :	CoC Number :
Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005	Project Manager : Phil Brand	Project Number : 16.200	Quote ID : EP-100-16
	Email for results : bianca.lockley@westernenvironmental.com.au		Courier Consignment # :

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens

Email: Brandon.Ovens@alsglobal.com

Special Directions & Comments :
retain all samples for subsequent SPOCAS analysis

#	Sample ID	Sample Date	Matrix	Analytes											Container							
				ASS Field TESTING	HOLD										ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	Glass Jar
31	BH03-1.00	8.6.17	SOIL	X																		
32	BH03-1.25	8.6.17	SOIL	X																		
33	BH03-1.50	8.6.17	SOIL	X																		
34	BH03-1.75	8.6.17	SOIL	X																		
35	BH03-2.00	8.6.17	SOIL	X																		
36	BH03-2.25	8.6.17	SOIL	X																		
37	BH03-2.50	8.6.17	SOIL	X																		
38	BH03-2.75	8.6.17	SOIL	X																		
39	BH03-3.00	8.6.17	SOIL	X																		
40	BH04-0.25	8.6.17	SOIL	X																		
41	BH04-0.50	8.6.17	SOIL	X																		
42	BH04-0.75	8.6.17	SOIL	X																		
43	BH04-1.00	8.6.17	SOIL	X																		
44	BH04-1.25	8.6.17	SOIL	X																		
45	BH04-1.50	8.6.17	SOIL	X																		

Relinquished By: ______________________

Date & Time : ______________________

Signature: ______________________

Received By: ______________________

Date & Time : ______________________

Signature: ______________________

Report Number : ______________________

Turn around Time :

3 Days

Comments :

Method Of Shipment :

☐ Courier

☐ Hand Delivered

☐ Postal

WESTERN ENVIRONMENTAL

CHAIN OF CUSTODY RECORD

Page 4 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD

Contact Name : Phil Brand

Purchase Order :

CoC Number :

Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005

Project Manager : Bianca Lockley

Project Number : 16.200

Quote ID : EP-100-16

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens

Email: Brandon.Ovens@alsglobal.com

Email for results : bianca.lockley@westernenvironmental.com.au

Courier Consignment # :

Special Directions & Comments :
retain all samples for subsequent SPOCAS analysis

				Analytes											Container							
#	Sample ID	Sample Date	Matrix	ASS Field TESTING	HOLD										ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	Glass Jar
46	BH04-1.75	8.6.17	SOIL	X																		
47	BH04-2.00	8.6.17	SOIL	X																		
48	BH04-2.25	8.6.17	SOIL	X																		
49	BH04-2.50	8.6.17	SOIL	X																		
50	BH04-2.75	8.6.17	SOIL	X																		
51	BH04-3.00	8.6.17	SOIL	X																		
52	BH05-0.00	8.6.17	SOIL	X																		
53	BH05-0.25	8.6.17	SOIL	X																		
54	BH05-0.50	8.6.17	SOIL	X																		
55	BH05-0.75	8.6.17	SOIL	X																		
56	BH05-1.00	8.6.17	SOIL	X																		
57	BH05-1.25	8.6.17	SOIL	X																		
58	BH05-1.50	8.6.17	SOIL	X																		
59	BH05-1.75	8.6.17	SOIL	X																		
60	BH05-2.00	8.6.17	SOIL	X																		

Relinquished By: ______________________

Date & Time : ______________________

Signature: ______________________

Received By: ______________________

Date & Time : ______________________

Signature: ______________________

Report Number : ______________________

Turn around Time :
3 Days

Comments :

Method Of Shipment :
☐ Courier
☐ Hand Delivered
☐ Postal

WESTERN ENVIRONMENTAL

CHAIN OF CUSTODY RECORD

Page 5 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD
Contact Name : Phil Brand
Purchase Order :
CoC Number :

Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005
Project Manager : Bianca Lockley
Project Number : 16.200
Quote ID : EP-100-16

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens

Email: Brandon.Ovens@alsglobal.com

Email for results : bianca.lockley@westernenvironmental.com.au

Courier Consignment # :

Special Directions & Comments :
retain all samples for subsequent SPOCAS analysis

				Analytes											Container							
#	Sample ID	Sample Date	Matrix	ASS Field TESTING	HOLD										ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	Glass Jar
61	BH05-2.25	8.6.17	SOIL	X																		
62	BH05-2.50	8.6.17	SOIL	X																		
63	BH05-2.75	8.6.17	SOIL	X																		
64	BH05-3.00	8.6.17	SOIL	X																		
65	DUP1	8.6.17	SOIL	X																		
66	DUP2	8.6.17	SOIL	X																		
67	DUP3	8.6.17	SOIL	X																		
68	DUP4	8.6.17	SOIL	X																		
69	BH04-0.00	8.6.17	SOIL	X																		
70		8.6.17	SOIL	X																		
71		8.6.17	SOIL	X																		
72		8.6.17	SOIL	X																		
73		8.6.17	SOIL	X																		
74		8.6.17	SOIL	X																		
75		8.6.17	SOIL	X																		

Relinquished By: ______________________

Date & Time : ______________________

Signature: ______________________

Received By: ______________________

Date & Time : ______________________

Signature: ______________________

Report Number : ______________________

Turn around Time : 3 Days

Comments :

Method Of Shipment :
☐ Courier
☐ Hand Delivered
☐ Postal

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order : **EP1706052**
Client : **WESTERN ENVIRONMENTAL P/L**
Contact : PHILIP BRAND
Address : Level 3, Prowse St
West Perth
Telephone : 08 6162 8980
Project : 16.200
Order number : ----
C-O-C number : ----
Sampler : Bianca Lockley
Site : ----
Quote number : EPBQ/100/16
No. of samples received : 69
No. of samples analysed : 69

Page : 1 of 16
Laboratory : Environmental Division Perth
Contact : Brandon Ovens
Address : 10 Hod Way Malaga WA Australia 6090
Telephone : 08 9209 7655
Date Samples Received : 09-Jun-2017 16:30
Date Analysis Commenced : 09-Jun-2017
Issue Date : 12-Jun-2017 12:40

ilac-MRA NATA
Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Daniel Fisher	Inorganics Analyst	Perth ASS, Malaga, WA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ASS: EA037 (Rapid Field and F(ox) screening): pH F(ox) Reaction Rate: 1 - Slight; 2 - Moderate; 3 - Strong; 4 - Extreme
- EA037 ASS Field Screening: NATA accreditation does not cover performance of this service.

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**BH01-0.00**	**BH01-0.25**	**BH01-0.50**	**BH01-0.75**	**BH01-1.00**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1706052-001**	**EP1706052-002**	**EP1706052-003**	**EP1706052-004**	**EP1706052-005**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**6.4**	**6.7**	**6.9**	**6.9**	**7.0**
pH (Fox)	----	0.1	pH Unit	**3.8**	**4.5**	**4.8**	**5.0**	**5.5**
Reaction Rate	----	1	-	**Moderate**	**Extreme**	**Moderate**	**Moderate**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			Client sample ID	**BH01-1.25**	**BH01-1.50**	**BH01-1.75**	**BH01-2.00**	**BH01-2.25**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706052-006**	**EP1706052-007**	**EP1706052-008**	**EP1706052-009**	**EP1706052-010**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.1**	**6.8**	**7.3**	**6.7**	**6.4**
pH (Fox)	----	0.1	pH Unit	**4.7**	**3.6**	**5.6**	**3.1**	**3.1**
Reaction Rate	----	1	-	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			Client sample ID	**BH01-2.50**	**BH01-2.75**	**BH01-3.00**	**BH02-0.00**	**BH02-0.25**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706052-011**	**EP1706052-012**	**EP1706052-013**	**EP1706052-014**	**EP1706052-015**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**6.5**	**6.4**	**6.0**	**6.0**	**6.3**
pH (Fox)	----	0.1	pH Unit	**3.5**	**3.6**	**3.2**	**3.0**	**4.0**
Reaction Rate	----	1	-	**Moderate**	**Moderate**	**Strong**	**Moderate**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			Client sample ID	**BH02-0.50**	**BH02-0.75**	**BH02-1.00**	**BH02-1.25**	**BH02-1.50**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706052-016**	**EP1706052-017**	**EP1706052-018**	**EP1706052-019**	**EP1706052-020**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.8**	**8.7**	**8.9**	**8.7**	**8.3**
pH (Fox)	----	0.1	pH Unit	**6.0**	**7.2**	**7.8**	**7.5**	**7.1**
Reaction Rate	----	1	-	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			*Client sample ID*	**BH02-1.75**	**BH02-2.00**	**BH02-2.25**	**BH02-2.50**	**BH02-2.75**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1706052-021**	**EP1706052-022**	**EP1706052-023**	**EP1706052-024**	**EP1706052-025**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.7**	**8.0**	**7.9**	**7.8**	**7.5**
pH (Fox)	----	0.1	pH Unit	**5.1**	**6.5**	**2.6**	**2.5**	**2.5**
Reaction Rate	----	1	-	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Slight**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**BH02-3.00**	**BH03-0.00**	**BH03-0.25**	**BH03-0.50**	**BH03-0.75**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1706052-026**	**EP1706052-027**	**EP1706052-028**	**EP1706052-029**	**EP1706052-030**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.4**	**6.3**	**6.9**	**7.0**	**7.7**
pH (Fox)	----	0.1	pH Unit	**7.4**	**3.1**	**3.7**	**4.3**	**5.0**
Reaction Rate	----	1	-	**Extreme**	**Moderate**	**Strong**	**Strong**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			*Client sample ID*	**BH03-1.00**	**BH03-1.25**	**BH03-1.50**	**BH03-1.75**	**BH03-2.00**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1706052-031**	**EP1706052-032**	**EP1706052-033**	**EP1706052-034**	**EP1706052-035**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.2**	**8.2**	**7.8**	**8.0**	**8.5**
pH (Fox)	----	0.1	pH Unit	**6.5**	**7.8**	**6.9**	**6.7**	**7.0**
Reaction Rate	----	1	-	**Strong**	**Strong**	**Slight**	**Moderate**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			Client sample ID	**BH03-2.25**	**BH03-2.50**	**BH03-2.75**	**BH03-3.00**	**BH04-0.25**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706052-036**	**EP1706052-037**	**EP1706052-038**	**EP1706052-039**	**EP1706052-040**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.5**	**8.5**	**8.5**	**8.0**	**8.0**
pH (Fox)	----	0.1	pH Unit	**7.9**	**8.2**	**8.0**	**8.1**	**6.4**
Reaction Rate	----	1	-	**Moderate**	**Extreme**	**Extreme**	**Extreme**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			Client sample ID	**BH04-0.50**	**BH04-0.75**	**BH04-1.00**	**BH04-1.25**	**BH04-1.50**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706052-041**	**EP1706052-042**	**EP1706052-043**	**EP1706052-044**	**EP1706052-045**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.0**	**8.1**	**8.1**	**7.8**	**7.7**
pH (Fox)	----	0.1	pH Unit	**6.4**	**7.3**	**6.9**	**7.5**	**7.9**
Reaction Rate	----	1	-	**Moderate**	**Moderate**	**Moderate**	**Slight**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL)**

			Client sample ID	**BH04-1.75**	**BH04-2.00**	**BH04-2.25**	**BH04-2.50**	**BH04-2.75**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706052-046**	**EP1706052-047**	**EP1706052-048**	**EP1706052-049**	**EP1706052-050**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.8**	**8.2**	**8.0**	**7.8**	**7.7**
pH (Fox)	----	0.1	pH Unit	**7.7**	**7.6**	**2.8**	**2.7**	**3.2**
Reaction Rate	----	1	-	**Moderate**	**Moderate**	**Extreme**	**Extreme**	**Extreme**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL)**

			Client sample ID	**BH04-3.00**	**BH05-0.00**	**BH05-0.25**	**BH05-0.50**	**BH05-0.75**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706052-051**	**EP1706052-052**	**EP1706052-053**	**EP1706052-054**	**EP1706052-055**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.9**	**6.8**	**6.7**	**6.6**	**6.2**
pH (Fox)	----	0.1	pH Unit	**7.8**	**3.5**	**3.8**	**4.2**	**4.3**
Reaction Rate	----	1	-	**Extreme**	**Moderate**	**Moderate**	**Moderate**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			Client sample ID	**BH05-1.00**	**BH05-1.25**	**BH05-1.50**	**BH05-1.75**	**BH05-2.00**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706052-056**	**EP1706052-057**	**EP1706052-058**	**EP1706052-059**	**EP1706052-060**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**6.8**	**7.2**	**7.8**	**7.8**	**7.6**
pH (Fox)	----	0.1	pH Unit	**5.2**	**5.8**	**6.0**	**6.8**	**6.6**
Reaction Rate	----	1	-	**Moderate**	**Moderate**	**Moderate**	**Slight**	**Slight**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			Client sample ID	**BH05-2.25**	**BH05-2.50**	**BH05-2.75**	**BH05-3.00**	**DUP1**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706052-061**	**EP1706052-062**	**EP1706052-063**	**EP1706052-064**	**EP1706052-065**
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.6**	**7.7**	**7.5**	**7.6**	**6.8**
pH (Fox)	----	0.1	pH Unit	**6.4**	**6.4**	**6.4**	**6.6**	**3.9**
Reaction Rate	----	1	-	**Slight**	**Slight**	**Slight**	**Moderate**	**Moderate**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			Client sample ID	**DUP2**	**DUP3**	**DUP4**	**BH04-0.00**	**----**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	----
Compound	CAS Number	LOR	Unit	**EP1706052-066**	**EP1706052-067**	**EP1706052-068**	**EP1706052-069**	**--------**
				Result	Result	Result	Result	----
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.3**	**8.3**	**8.2**	**7.4**	**----**
pH (Fox)	----	0.1	pH Unit	**7.4**	**4.4**	**7.4**	**5.0**	**----**
Reaction Rate	----	1	-	**Moderate**	**Moderate**	**Slight**	**Moderate**	**----**

Alicia Manning A.M. 15·6·17 11:08am

From: Brandon Ovens
Sent: Thursday, 15 June 2017 11:08 AM
To: Samples Perth
Subject: FW: Re-batch EP1706052 (Our ref 16.200)

Follow Up Flag: Follow up
Flag Status: Flagged

Categories: Rebatch

Hi guys,

Can you please rebatch the below for Bianca.
Thanks

Kind Regards,

Brandon Ovens
Business Development Officer - WA

Environmental

Environmental Division
Perth
Work Order Reference
EP1706333

Telephone : + 61-8-9209 7655

T +61 8 9209 7605
M +61 4 2793 4085
F +61 8 9209 7600
brandon.ovens@alsglobal.com
10 Hod Way
Malaga WA 6090
AUSTRALIA

From: Bianca Lockley [mailto:bianca.lockley@westernenvironmental.com.au]
Sent: Thursday, 15 June 2017 9:38 AM
To: Brandon Ovens <Brandon.Ovens@alsglobal.com>
Cc: 'Philip Brand' <philip.brand@westernenvironmental.com.au>; James Gibson <james.gibson@westernenvironmental.com.au>
Subject: Re-batch EP1706052 (Our ref 16.200)

Hi Brandon

Can you please rebatch EP1706052 as follows. TAT of 5 days please.

SPOCAS Suite – Complete EA029

BH01 1.5

11 DUP1
2 BH01-3.0

3 BH02-0.25
4 BH02-2.5

5 BH03-1.25
6 BH03-2.0

7 BH04-0.5
8 BH04-2.5

9 BH05-0.25
10 BH05-2.25

<u>Metals (Al, As, Cd, Cr, Fe, Pb, Mo, Ni, Se, Zn)</u>
12 BH01-3.0
13 BH02-1.5
14 DUP2
15 BH03-1.25
16 BH04-2.5
17 BH05-0.25

Thank you in advance
Bianca

Environmental Scientist
Western Environmental Pty Ltd | Level 3, 25 Prowse Street, West Perth WA 6005
p: 6162 8980 | m: 0403 937 056 | w: www.westernenvironmental.com.au

WESTERN
ENVIRONMENTAL

WESTERN ENVIRONMENTAL

CHAIN OF CUSTODY RECORD

Page 1 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD	Contact Name : Bianca Lockley	Purchase Order :	CoC Number :
Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005	Project Manager : Phil Brand	Project Number : 16.200	Quote ID : EP-100-16
	Email for results : bianca.lockley@westernenvironmental.com.au		Courier Consignment # :

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens

Email: Brandon.Ovens@alsglobal.com

Special Directions & Comments :
retain all samples for subsequent SPOCAS analysis

				Analytes											Container							
#	Sample ID	Sample Date	Matrix	ASS Field TESTING	HOLD										ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	Glass Jar
1	BH01-0.00	8.6.17	SOIL	X																		
2	BH01-0.25	8.6.17	SOIL	X																		
3	BH01-0.50	8.6.17	SOIL	X																		
4	BH01-0.75	8.6.17	SOIL	X																		
5	BH01-1.00	8.6.17	SOIL	X																		
6	BH01-1.25	8.6.17	SOIL	X																		
7	BH01-1.50	8.6.17	SOIL	X																		
8	BH01-1.75	8.6.17	SOIL	X																		
9	BH01-2.00	8.6.17	SOIL	X																		
10	BH01-2.25	8.6.17	SOIL	X																		
11	BH01-2.50	8.6.17	SOIL	X																		
12	BH01-2.75	8.6.17	SOIL	X																		
13	BH01-3.00	8.6.17	SOIL	X																		
14	BH02-0.00	8.6.17	SOIL	X																		
15	BH02-0.25	8.6.17	SOIL	X																		

1
12 → 2
3

Environmental Division
Perth
Work Order Reference
EP1706052

Relinquished By:
Date & Time :
Signature:

Received By: Nicole
Date & Time : 8·6·17 1630
Signature:
Report Number :

Turn around Time : 3 Days

Comments :

☑ Hand Delivered
☐ Postal

WESTERN ENVIRONMENTAL

CHAIN OF CUSTODY RECORD

Page 2 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD	Contact Name : Bianca Lockley	Purchase Order :	CoC Number :
Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005	Project Manager : Phil Brand	Project Number : 16.200	Quote ID : EP-100-16
	Email for results : bianca.lockley@westernenvironmental.com.au		Courier Consignment # :

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens

Email: Brandon.Ovens@alsglobal.com

Special Directions & Comments :
retain all samples for subsequent SPOCAS analysis

#	Sample ID	Sample Date	Matrix	Analytes											Container							
				ASS Field TESTING	HOLD										ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	Glass Jar
16	BH02-0.50	8.6.17	SOIL	X																		
17	BH02-0.75	8.6.17	SOIL	X																		
18	BH02-1.00	8.6.17	SOIL	X																		
19	BH02-1.25	8.6.17	SOIL	X																		
20	BH02-1.50	8.6.17	SOIL	X																		
21	BH02-1.75	8.6.17	SOIL	X																		
22	BH02-2.00	8.6.17	SOIL	X																		
23	BH02-2.25	8.6.17	SOIL	X																		
24	BH02-2.50	8.6.17	SOIL	X																		
25	BH02-2.75	8.6.17	SOIL	X																		
26	BH02-3.00	8.6.17	SOIL	X																		
27	BH03-0.00	8.6.17	SOIL	X																		
28	BH03-0.25	8.6.17	SOIL	X																		
29	BH03-0.50	8.6.17	SOIL	X																		
30	BH03-0.75	8.6.17	SOIL	X																		

13

4

Relinquished By: ____________

Date & Time : ____________

Signature: ____________

Received By: ____________

Date & Time : ____________

Signature: ____________

Report Number : ____________

Turn around Time :

3 Days

Comments :

Method Of Shipment :

☐ Courier

☐ Hand Delivered

☐ Postal

CHAIN OF CUSTODY RECORD

Page 3 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD	Contact Name : Bianca Lockley	Purchase Order :	CoC Number :
Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005	Project Manager : Phil Brand	Project Number : 16.200	Quote ID : EP-100-16
	Email for results : bianca.lockley@westernenvironmental.com.au		Courier Consignment # :

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens

Email: Brandon.Ovens@alsglobal.com

Special Directions & Comments :
retain all samples for subsequent SPOCAS analysis

					Analytes											Container							
	#	Sample ID	Sample Date	Matrix	ASS Field TESTING	HOLD										ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	Glass Jar
	31	BH03-1.00	8.6.17	SOIL	X																		
15+5	32	BH03-1.25	8.6.17	SOIL	X																		
	33	BH03-1.50	8.6.17	SOIL	X																		
	34	BH03-1.75	8.6.17	SOIL	X																		
6	35	BH03-2.00	8.6.17	SOIL	X																		
	36	BH03-2.25	8.6.17	SOIL	X																		
	37	BH03-2.50	8.6.17	SOIL	X																		
	38	BH03-2.75	8.6.17	SOIL	X																		
	39	BH03-3.00	8.6.17	SOIL	X																		
	40	BH04-0.25	8.6.17	SOIL	X																		
7	41	BH04-0.50	8.6.17	SOIL	X																		
	42	BH04-0.75	8.6.17	SOIL	X																		
	43	BH04-1.00	8.6.17	SOIL	X																		
	44	BH04-1.25	8.6.17	SOIL	X																		
	45	BH04-1.50	8.6.17	SOIL	X																		

Relinquished By: ______

Date & Time : ______

Signature: ______

Received By: ______

Date & Time : ______

Signature: ______

Report Number : ______

Turn around Time :
3 Days

Comments :

Method Of Shipment :
☐ Courier
☐ Hand Delivered
☐ Postal

WESTERN ENVIRONMENTAL

CHAIN OF CUSTODY RECORD

Page 4 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD	Contact Name : Phil Brand	Purchase Order :	CoC Number :
Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005	Project Manager : Blanca Lockley	Project Number : 16.200	Quote ID : EP-100-16
	Email for results : bianca.lockley@westernenvironmental.com.au		Courier Consignment # :

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens
Email: Brandon.Ovens@alsglobal.com

Special Directions & Comments :
retain all samples for subsequent SPOCAS analysis

				Analytes											Container							
#	Sample ID	Sample Date	Matrix	ASS Field TESTING	HOLD										ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	Glass Jar
46	BH04-1.75	8.6.17	SOIL	X																		
47	BH04-2.00	8.6.17	SOIL	X																		
48	BH04-2.25	8.6.17	SOIL	X																		
49	BH04-2.50	8.6.17	SOIL	X																		
50	BH04-2.75	8.6.17	SOIL	X																		
51	BH04-3.00	8.6.17	SOIL	X																		
52	BH05-0.00	8.6.17	SOIL	X																		
53	BH05-0.25	8.6.17	SOIL	X																		
54	BH05-0.50	8.6.17	SOIL	X																		
55	BH05-0.75	8.6.17	SOIL	X																		
56	BH05-1.00	8.6.17	SOIL	X																		
57	BH05-1.25	8.6.17	SOIL	X																		
58	BH05-1.50	8.6.17	SOIL	X																		
59	BH05-1.75	8.6.17	SOIL	X																		
60	BH05-2.00	8.6.17	SOIL	X																		

16+8

17+9

Relinquished By: ____________
Date & Time : ____________
Signature: ____________

Received By: ____________
Date & Time : ____________
Signature: ____________
Report Number : ____________

Turn around Time :
3 Days
Comments :

Method Of Shipment :
☐ Courier
☐ Hand Delivered
☐ Postal

CHAIN OF CUSTODY RECORD

Page 5 of 5

Company Name : WESTERN ENVIRONMENTAL PTY LTD	Contact Name : Phil Brand	Purchase Order :	CoC Number :
Office Address : Level 3, 25 Prowse Street, West Perth, WA 6005	Project Manager : Bianca Lockley	Project Number : 16.200	Quote ID : EP-100-16
	Email for results : bianca.lockley@westernenvironmental.com.au		Courier Consignment # :

Laboratory Address :
ALS Perth
10 Hod Way
Malaga WA 6090
Contact: Brandon Ovens

Email: Brandon.Ovens@alsglobal.com

Special Directions & Comments :
retain all samples for subsequent SPOCAS analysis

					Analytes											Container							
	#	Sample ID	Sample Date	Matrix	ASS Field TESTING	HOLD										ACM bag	250ml Green	Black MB plastic	100ml Red Plastic	100ml Purple Plastic	VIAL	Purple Amber (glass)	Glass Jar
10	61	BH05-2.25	8.6.17	SOIL	X																		
	62	BH05-2.50	8.6.17	SOIL	X																		
	63	BH05-2.75	8.6.17	SOIL	X																		
	64	BH05-3.00	8.6.17	SOIL	X																		
11	65	DUP1	8.6.17	SOIL	X																		
14	66	DUP2	8.6.17	SOIL	X																		
	67	DUP3	8.6.17	SOIL	X																		
	68	DUP4	8.6.17	SOIL	X																		
	69	BH04-0.00	8.6.17	SOIL	X																		
	70		8.6.17	SOIL	X																		
	71		8.6.17	SOIL	X																		
	72		8.6.17	SOIL	X																		
	73		8.6.17	SOIL	X																		
	74		8.6.17	SOIL	X																		
	75		8.6.17	SOIL	X																		

Relinquished By: ______________

Date & Time : ______________

Signature: ______________

Received By: ______________

Date & Time : ______________

Signature: ______________

Report Number : ______________

Turn around Time :
3 Days ▼

Comments :

Method Of Shipment :
☐ Courier
☐ Hand Delivered
☐ Postal

ALS Environmental

CERTIFICATE OF ABSALYSIS

Work Order	: **EP1706333**	Page	: 1 of 9
Client	: **WESTERN ENVIRONMENTAL P/L**	Laboratory	: Environmental Division Perth
Contact	: Bianca Lockley	Contact	: Brandon Ovens
Address	: Level 3, Prowse St West Perth	Address	: 10 Hod Way Malaga WA Australia 6090
Telephone	: 08 6162 8980	Telephone	: 08 9209 7655
Project	: Ex EP1706052 16.200	Date Samples Received	: 08-Jun-2017 16:30
Order number	: 16.200	Date Analysis Commenced	: 16-Jun-2017
C-O-C number	: ----	Issue Date	: 22-Jun-2017 16:16
Sampler	: ----		
Site	: ----		
Quote number	: EPBQ/100/16		
No. of samples received	: 17		
No. of samples analysed	: 17		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Daniel Fisher	Inorganics Analyst	Perth ASS, Malaga, WA
Daniel Fisher	Inorganics Analyst	Perth Inorganics, Malaga, WA
Jeremy Truong	Laboratory Manager	Perth Inorganics, Malaga, WA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG005T (Total Metals) : Poor matrix spike recovery for arsenic, selenium due to matrix interference. Confirmed by re-extraction and re-analysis.
- ASS: EA029 (SPOCAS): Retained Acidity not required because pH KCl greater than or equal to 4.5
- ASS: EA029 (SPOCAS): Excess ANC not required because pH OX less than 6.5.
- ASS: EA029 (SPOCAS): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime (CaCO3) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from kg/t dry weight to kg/m3 in-situ soil, multiply reported results x wet bulk density of soil in t/m3.

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**BH01-1.50**	**BH01-3.0**	**BH02-0.25**	**BH02-2.5**	**BH03-1.25**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1706333-001**	**EP1706333-002**	**EP1706333-003**	**EP1706333-004**	**EP1706333-005**
				Result	Result	Result	Result	Result
EA029-A: pH Measurements								
pH KCl (23A)	----	0.1	pH Unit	**6.4**	**5.4**	**5.5**	**6.4**	**9.1**
pH OX (23B)	----	0.1	pH Unit	**7.5**	**4.4**	**5.5**	**4.2**	**7.8**
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	**26**	**13**	<2	<2
Titratable Peroxide Acidity (23G)	----	2	mole H+ / t	<2	**132**	**2**	**34**	<2
Titratable Sulfidic Acidity (23H)	----	2	mole H+ / t	<2	**106**	<2	**34**	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.005	% pyrite S	<0.005	**0.041**	**0.020**	<0.005	<0.005
sulfidic - Titratable Peroxide Acidity (s-23G)	----	0.005	% pyrite S	<0.005	**0.211**	<0.005	**0.055**	<0.005
sulfidic - Titratable Sulfidic Acidity (s-23H)	----	0.005	% pyrite S	<0.005	**0.170**	<0.005	**0.055**	<0.005
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)	----	0.005	% S	<0.005	**0.039**	**0.005**	**0.016**	**0.056**
Peroxide Sulfur (23De)	----	0.005	% S	**0.023**	**0.096**	**0.011**	**0.114**	**0.051**
Peroxide Oxidisable Sulfur (23E)	----	0.005	% S	**0.023**	**0.057**	**0.006**	**0.098**	<0.005
acidity - Peroxide Oxidisable Sulfur (a-23E)	----	5	mole H+ / t	**14**	**36**	<5	**61**	<5
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)	----	0.005	% Ca	**0.104**	**0.147**	**0.055**	**0.020**	**0.206**
Peroxide Calcium (23Wh)	----	0.005	% Ca	**0.141**	**0.158**	**0.054**	**0.022**	**0.235**
Acid Reacted Calcium (23X)	----	0.005	% Ca	**0.037**	**0.011**	<0.005	<0.005	**0.029**
acidity - Acid Reacted Calcium (a-23X)	----	5	mole H+ / t	**18**	**5**	<5	<5	**14**
sulfidic - Acid Reacted Calcium (s-23X)	----	0.005	% S	**0.030**	**0.009**	<0.005	<0.005	**0.023**
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)	----	0.005	% Mg	<0.005	**0.058**	**0.072**	**0.028**	**0.047**
Peroxide Magnesium (23Tm)	----	0.005	% Mg	**0.005**	**0.060**	**0.070**	**0.028**	**0.063**
Acid Reacted Magnesium (23U)	----	0.005	% Mg	<0.005	<0.005	<0.005	<0.005	**0.016**
Acidity - Acid Reacted Magnesium (a-23U)	----	5	mole H+ / t	<5	<5	<5	<5	**13**
sulfidic - Acid Reacted Magnesium (s-23U)	----	0.005	% S	<0.005	<0.005	<0.005	<0.005	**0.021**
EA029-F: Excess Acid Neutralising Capacity								
Excess Acid Neutralising Capacity (23Q)	----	0.02	% CaCO3	**0.307**	----	----	----	**0.636**
acidity - Excess Acid Neutralising Capacity (a-23Q)	----	10	mole H+ / t	**61**	----	----	----	**127**
sulfidic - Excess Acid Neutralising Capacity (s-23Q)	----	0.02	% S	**0.098**	----	----	----	**0.204**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL)**

			Client sample ID	BH01-1.50	BH01-3.0	BH02-0.25	BH02-2.5	BH03-1.25
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	EP1706333-001	EP1706333-002	EP1706333-003	EP1706333-004	EP1706333-005
				Result	Result	Result	Result	Result
EA029-F: Excess Acid Neutralising Capacity - Continued								
EA029-H: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	**0.02**	**0.10**	**0.03**	**0.10**	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	**14**	**61**	**17**	**61**	<10
Liming Rate	----	1	kg CaCO3/t	**1**	**5**	**1**	**5**	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.02**	**0.10**	**0.03**	**0.10**	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**14**	**61**	**17**	**61**	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	**1**	**5**	**1**	**5**	<1

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**BH03-2.0**	**BH04-0.5**	**BH04-2.5**	**BH05-0.25**	**BH05-2.25**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1706333-006**	**EP1706333-007**	**EP1706333-008**	**EP1706333-009**	**EP1706333-010**
				Result	Result	Result	Result	Result
EA029-A: pH Measurements								
pH KCl (23A)	----	0.1	pH Unit	**6.0**	**7.0**	**6.0**	**5.9**	**5.7**
pH OX (23B)	----	0.1	pH Unit	**6.9**	**6.8**	**4.1**	**5.2**	**6.8**
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)	----	2	mole H+ / t	**4**	<2	**2**	**4**	**5**
Titratable Peroxide Acidity (23G)	----	2	mole H+ / t	<2	<2	**64**	<2	<2
Titratable Sulfidic Acidity (23H)	----	2	mole H+ / t	<2	<2	**61**	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.005	% pyrite S	**0.006**	<0.005	<0.005	**0.006**	**0.008**
sulfidic - Titratable Peroxide Acidity (s-23G)	----	0.005	% pyrite S	<0.005	<0.005	**0.102**	<0.005	<0.005
sulfidic - Titratable Sulfidic Acidity (s-23H)	----	0.005	% pyrite S	<0.005	<0.005	**0.098**	<0.005	<0.005
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)	----	0.005	% S	**0.007**	**0.014**	**0.019**	<0.005	**0.007**
Peroxide Sulfur (23De)	----	0.005	% S	**0.016**	**0.020**	**0.184**	**0.013**	**0.011**
Peroxide Oxidisable Sulfur (23E)	----	0.005	% S	**0.009**	**0.006**	**0.165**	**0.011**	<0.005
acidity - Peroxide Oxidisable Sulfur (a-23E)	----	5	mole H+ / t	**6**	<5	**103**	**7**	<5
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)	----	0.005	% Ca	**0.053**	**0.082**	**0.075**	**0.091**	**0.175**
Peroxide Calcium (23Wh)	----	0.005	% Ca	**0.055**	**0.092**	**0.077**	**0.095**	**0.180**
Acid Reacted Calcium (23X)	----	0.005	% Ca	<0.005	**0.010**	<0.005	<0.005	**0.005**
acidity - Acid Reacted Calcium (a-23X)	----	5	mole H+ / t	<5	<5	<5	<5	<5
sulfidic - Acid Reacted Calcium (s-23X)	----	0.005	% S	<0.005	**0.008**	<0.005	<0.005	<0.005
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)	----	0.005	% Mg	**0.077**	**0.071**	**0.052**	**0.013**	**0.151**
Peroxide Magnesium (23Tm)	----	0.005	% Mg	**0.076**	**0.082**	**0.056**	**0.013**	**0.157**
Acid Reacted Magnesium (23U)	----	0.005	% Mg	<0.005	**0.011**	<0.005	<0.005	**0.006**
Acidity - Acid Reacted Magnesium (a-23U)	----	5	mole H+ / t	<5	**9**	<5	<5	<5
sulfidic - Acid Reacted Magnesium (s-23U)	----	0.005	% S	<0.005	**0.014**	**0.005**	<0.005	**0.008**
EA029-F: Excess Acid Neutralising Capacity								
Excess Acid Neutralising Capacity (23Q)	----	0.02	% CaCO3	**0.116**	**0.294**	----	----	**0.103**
acidity - Excess Acid Neutralising Capacity (a-23Q)	----	10	mole H+ / t	**23**	**59**	----	----	**20**
sulfidic - Excess Acid Neutralising Capacity (s-23Q)	----	0.02	% S	**0.037**	**0.094**	----	----	**0.033**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			Client sample ID	**BH03-2.0**	**BH04-0.5**	**BH04-2.5**	**BH05-0.25**	**BH05-2.25**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706333-006**	**EP1706333-007**	**EP1706333-008**	**EP1706333-009**	**EP1706333-010**
				Result	Result	Result	Result	Result
EA029-F: Excess Acid Neutralising Capacity - Continued								
EA029-H: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	**0.02**	<0.02	**0.17**	**0.02**	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	**105**	**11**	<10
Liming Rate	----	1	kg CaCO3/t	**1**	<1	**8**	**1**	**1**
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.02**	<0.02	**0.17**	**0.02**	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	**105**	**11**	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	**1**	<1	**8**	**1**	**1**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**DUP1**	**BH01-3.0**	**BH02-1.5**	**DUP2**	**BH03-1.25**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1706333-011**	**EP1706333-012**	**EP1706333-013**	**EP1706333-014**	**EP1706333-015**
				Result	Result	Result	Result	Result
EA029-A: pH Measurements								
pH KCl (23A)	----	0.1	pH Unit	**6.5**	----	----	----	----
pH OX (23B)	----	0.1	pH Unit	**7.6**	----	----	----	----
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	----	----	----
Titratable Peroxide Acidity (23G)	----	2	mole H+ / t	<2	----	----	----	----
Titratable Sulfidic Acidity (23H)	----	2	mole H+ / t	<2	----	----	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.005	% pyrite S	<0.005	----	----	----	----
sulfidic - Titratable Peroxide Acidity (s-23G)	----	0.005	% pyrite S	<0.005	----	----	----	----
sulfidic - Titratable Sulfidic Acidity (s-23H)	----	0.005	% pyrite S	<0.005	----	----	----	----
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)	----	0.005	% S	**0.005**	----	----	----	----
Peroxide Sulfur (23De)	----	0.005	% S	**0.026**	----	----	----	----
Peroxide Oxidisable Sulfur (23E)	----	0.005	% S	**0.021**	----	----	----	----
acidity - Peroxide Oxidisable Sulfur (a-23E)	----	5	mole H+ / t	**13**	----	----	----	----
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)	----	0.005	% Ca	**0.128**	----	----	----	----
Peroxide Calcium (23Wh)	----	0.005	% Ca	**0.170**	----	----	----	----
Acid Reacted Calcium (23X)	----	0.005	% Ca	**0.042**	----	----	----	----
acidity - Acid Reacted Calcium (a-23X)	----	5	mole H+ / t	**21**	----	----	----	----
sulfidic - Acid Reacted Calcium (s-23X)	----	0.005	% S	**0.034**	----	----	----	----
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)	----	0.005	% Mg	**0.007**	----	----	----	----
Peroxide Magnesium (23Tm)	----	0.005	% Mg	**0.007**	----	----	----	----
Acid Reacted Magnesium (23U)	----	0.005	% Mg	<0.005	----	----	----	----
Acidity - Acid Reacted Magnesium (a-23U)	----	5	mole H+ / t	<5	----	----	----	----
sulfidic - Acid Reacted Magnesium (s-23U)	----	0.005	% S	<0.005	----	----	----	----
EA029-F: Excess Acid Neutralising Capacity								
Excess Acid Neutralising Capacity (23Q)	----	0.02	% CaCO3	**0.424**	----	----	----	----
acidity - Excess Acid Neutralising Capacity (a-23Q)	----	10	mole H+ / t	**85**	----	----	----	----
sulfidic - Excess Acid Neutralising Capacity (s-23Q)	----	0.02	% S	**0.136**	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

			Client sample ID	**DUP1**	**BH01-3.0**	**BH02-1.5**	**DUP2**	**BH03-1.25**
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00	08-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	**EP1706333-011**	**EP1706333-012**	**EP1706333-013**	**EP1706333-014**	**EP1706333-015**
				Result	Result	Result	Result	Result
EA029-F: Excess Acid Neutralising Capacity - Continued								
EA029-H: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	----	----	----	----
Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	----	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	<10	----	----	----	----
Liming Rate	----	1	kg CaCO3/t	<1	----	----	----	----
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.02**	----	----	----	----
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**13**	----	----	----	----
Liming Rate excluding ANC	----	1	kg CaCO3/t	**1**	----	----	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1	%	----	**21.2**	**19.3**	**15.5**	**14.7**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	**4640**	**6240**	**3420**	**4100**
Arsenic	7440-38-2	5	mg/kg	----	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	----	<1	<1	<1	**1**
Chromium	7440-47-3	2	mg/kg	----	**12**	**31**	**19**	**31**
Iron	7439-89-6	50	mg/kg	----	**13800**	**12300**	**9180**	**17500**
Lead	7439-92-1	5	mg/kg	----	**7**	**14**	**8**	**7**
Molybdenum	7439-98-7	2	mg/kg	----	**3**	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	----	<2	**11**	**5**	**7**
Selenium	7782-49-2	5	mg/kg	----	<5	<5	<5	<5
Zinc	7440-66-6	5	mg/kg	----	**37**	**9**	<5	**8**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	BH04-2.5	BH05-0.25	----	----	----
			Client sampling date / time	08-Jun-2017 00:00	08-Jun-2017 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EP1706333-016	EP1706333-017	--------	--------	--------
				Result	Result	----	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1	%	**17.9**	<1.0	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**2650**	**3170**	----	----	----
Arsenic	7440-38-2	5	mg/kg	<5	<5	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	----	----	----
Chromium	7440-47-3	2	mg/kg	**17**	**11**	----	----	----
Iron	7439-89-6	50	mg/kg	**6630**	**6550**	----	----	----
Lead	7439-92-1	5	mg/kg	**9**	**16**	----	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	----	----	----
Nickel	7440-02-0	2	mg/kg	**4**	<2	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	<5	----	----	----
Zinc	7440-66-6	5	mg/kg	**6**	**28**	----	----	----

APPENDIX D – Groundwater Quality Results

Appendix C, Table 1
Preliminary Acid Sulfate Soil Investigation
Groundwater Chemistry Results
Bindaring Wetland
July 2016

			Field Parameters							Lab Physical Parameters			Major Ions					Acidity & Alkalinity (as CaCO3)				Inorganics & Nutrients									Metals													
			DO (%S) (Field)	DO (mg/L) (Field) (Filtered)	Electrical conductivity (field)	pH (Field)	Redox (Field)	TDS (Field)	Temperature (Field)	Electrical conductivity (lab)	pH (Lab)	Total Dissolved Solids	Calcium	Magnesium	Potassium	Sodium	Chloride	Acidity (as CaCO3)	Alkalinity (total as CaCO3)	Alkalinity (Carbonate as CaCO3)	Bicarbonate Alkalinity as CaCO3	Nitrogen (Total)	Ammonia as N	Nitrate & Nitrite (as N)	Nitrate (as N)	Nitrogen (Organic)	Total Kjeldahl Nitrogen	Phosphate total (P)	Phosphorous filterable reactive (P)	Sulphate as S	Aluminium	Aluminium (Filtered)	Arsenic (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Iron	Iron (Filtered)	Lead (Filtered)	Manganese (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Selenium (Filtered)	Zinc (Filtered)
Units			%	mg/L	µS/cm	pH Units	mV	mg/L	°C	µS/cm	pH Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MG/L	mg/L	ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Laboratory Limit of Reporting (LOR)										1	0.1	10	0.5	0.5	0.5	0.5	1	10	20	10	20	0.2	0.01	0.05	0.02	200	0.2	0.05	0.05	5	0.05	0.05	0.001	0.0002	0.001	0.001	0.05	0.05	0.001	0.005	0.0001	0.001	0.001	0.001
WA ASS - DER 2014 Drinking water health																									50								0.01	0.002	0.05	2			0.01	0.5	0.001	0.02	0.01	
WA ASS - DER 2014 Fresh Waters - SW Aust. Wetlands						7-8.5					7-8.5											1.5	0.04									0.055	0.013	0.0002	0.001	0.0014	0.3		0.0034	1.9	0.00006	0.011	0.011	0.008
WA ASS - DER 2014 Short-term irrigation																460	700					125										20	2	0.05	1	5	10		5	10	0.002	2	0.05	5
WA DER 2015 ASS Criteria						<5					<5							40	<30													1												
Location	Date	Sample Code																																										
MB01	1/07/2016	M16-JI02035	33.1	3.07	1170	7.15	-23.2	1417	20	2300	7.8	1400	93	49	12	330	430	26	520	<10	520	0.4	<0.01	<0.05	0.02	400	0.4	0.07	<0.05	43	0.7	<0.05	0.003	<0.0002	<0.001	0.003	3.2	0.14	<0.001	0.034	<0.0001	0.001	<0.001	0.007
MB02	1/07/2016	M16-JI02034	18.1	1.59	9370	7.18	-71	6116.5	20.2	9300	7.6	5600	190	250	46	1400	2500	31	420	<10	420	1.3	0.22	0.38	0.37	700	0.9	<0.05	<0.05	290	0.91	<0.05	0.001	<0.0002	0.004	<0.001	5.7	3.4	<0.001	4.4	<0.0001	0.005	<0.001	0.005
MB03	1/07/2016	M16-JI02033	15.2	1.41	5500	4.84	120.5	3594.5	17.6	5600	3.6	3900	170	140	83	730	750	430	<20	<10	<20	0.8	0.11	<0.05	<0.02	700	0.8	0.12	<0.05	650	22	4.5	0.008	<0.0002	0.005	0.003	160	140	0.003	0.63	<0.0001	0.12	0.014	0.12
MB04	1/07/2016	M16-JI02032	14.7	1.35	5190	6.72	-87.9	3360.5	18.6	5000	7.4	2800	100	80	11	820	1000	60	630	<10	630	0.9	0.34	<0.05	<0.02	600	0.9	<0.05	<0.05	170	0.7	<0.05	<0.001	<0.0002	<0.001	<0.001	2.3	0.72	<0.001	0.073	<0.0001	0.001	<0.001	0.008
MB05	1/07/2016	M16-JI02031	4.2	0.37	3330	6.7	-0.8	2158	22.6	3300	7.2	1900	80	81	12	470	640	48	430	<10	430	8.3	0.2	7	7	1100	1.3	0.05	<0.05	87	3.8	<0.05	<0.001	<0.0002	<0.001	0.003	8.5	<0.05	<0.001	0.11	<0.0001	0.002	<0.001	0.008
Statistical Summary																																												
Number of Results			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Number of Detects			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	0	4	5	4	2	3	5	5	3	0	5	5	1	3	0	2	3	5	4	1	5	0	5	1	5
Minimum Concentration			4.2	0.37	1170	4.84	-87.9	1417	17.6	2300	3.6	1400	80	49	11	330	430	26	<20	<10	<20	0.4	<0.01	<0.05	<0.02	400	0.4	<0.05	<0.05	43	0.7	<0.05	<0.001	<0.0002	<0.001	<0.001	2.3	<0.05	<0.001	0.034	<0.0001	0.001	<0.001	0.005
Maximum Concentration			33.1	3.07	9370	7.18	120.5	6116.5	22.6	9300	7.8	5600	190	250	83	1400	2500	430	630	<10	630	8.3	0.34	7	7	1100	1.3	0.12	<0.05	650	22	4.5	0.008	<0.0002	0.005	0.003	160	140	0.003	4.4	<0.0001	0.12	0.014	0.12
Average Concentration			17	1.6	4912	6.5	-12	3329	20	5100	6.7	3120	127	120	33	750	1064	119	402	5	402	2.3	0.18	1.5	1.5	700	0.86	0.058	0.025	248	5.6	0.92	0.0026	0.0001	0.0021	0.002	36	29	0.001	1	0.00005	0.026	0.0032	0.03
Median Concentration			15.2	1.41	5190	6.72	-23.2	3360.5	20	5000	7.4	2800	100	81	12	730	750	48	430	5	430	0.9	0.2	0.025	0.02	700	0.9	0.05	0.025	170	0.91	0.025	0.001	0.0001	0.0005	0.003	5.7	0.72	0.0005	0.11	0.00005	0.002	0.0005	0.008
Standard Deviation			10	0.97	3033	0.97	82	1794	1.9	2692	1.8	1681	50	80	32	413	829	174	235	0	235	3.3	0.13	3.1	3.1	255	0.32	0.039	0	244	9.2	2	0.0032	0	0.0022	0.0014	69	62	0.0011	1.9	0	0.053	0.006	0.051
Number of Guideline Exceedances			0	0	0	3	0	0	0	0	1	0	0	0	0	4	3	3	1	0	0	1	4	0	0	0	0	0	0	0	0	1	0	0	2	3	5	0	0	2	5	1	1	3
Number of Guideline Exceedances(Detects Only)			0	0	0	3	0	0	0	0	1	0	0	0	0	4	3	3	1	0	0	1	4	0	0	0	0	0	0	0	0	1	0	0	2	3	5	0	0	2	0	1	1	3
Location	Date	SampleCode																																										
MB02	1/07/2016	M16-JI02034	18.1	1.59	9370	7.18	-71	6116.5	20.2	9300	7.6	5600	190	250	46	1400	2500	31	420	<10	420	1.3	0.22	0.38	0.37	700	0.9	<0.05	<0.05	290	0.91	<0.05	0.001	<0.0002	0.004	<0.001	5.7	3.4	<0.001	4.4	<0.0001	0.005	<0.001	0.005
QC01	1/07/2016	M16-JI02036	-	-	-	-	-	-	-	9400	7.8	5800	200	260	48	1400	2400	26	430	<10	430	1.3	0.31	0.38	0.37	600	0.9	<0.05	<0.05	290	0.83	<0.05	0.001	<0.0002	0.004	0.001	5.5	3.6	<0.001	4.6	<0.0001	0.005	<0.001	0.005
RPD			-	-	-	-	-	-	-	1%	3%	4%	5%	4%	4%	0%	4%	18%	2%	#	2%	0%	34%	0%	0%	15%	0%	#	#	0%	9%	#	0%	#	0%	#	4%	6%	#	4%	#	0%	#	0%

Definitions

LOR - Limits of Reporting
FWG - Freshwater Guidelines
STIWG - Short Term Irrigation Water Guideline
ASS - Acid Sulfate Soil
DW - Dewatering
ND - No Detect
"-" - denotes not analysed
"#" - denotes RPD cannot be calculated based on LOR Value

Relative Percentage Difference

*RPDs have only been considered where a concentration is greater than 1 times the EQL.

**High RPDs are in bold (Acceptable RPDs for each EQL multiplier range are:
50 (1-10 x EQL); 50 (10-30 x EQL); 50 (> 30 x EQL))

⬜	RPD < 50%
▨	RPD ≥ 50% and Result < 10 x EQL
🟨	RPD ≥ 50% and Result ≥ 10 x EQL

Notes

DER 2015 ASS Criteria

Dissolved Aluminimum value relates to water with a pH >6.50, no guideline is available for water pH<6.50.

DER 2014 Fresh Waters - SW Aust. Wetlands

Trigger values taken from *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000), and adopted by DER in Assessment and Management of Contaminated Sites (DER, 2014), and in the *National Environmental Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1)* (NEPM) (NEPC, 2013)

Arsenic (V) guideline value adopted for Arsenic (unspeciated)

Chromium (VI) guideline value adopted for Chromium (unspeciated)

Selenium value applies to a slightly–moderately disturbed system and a 95% level of protection (%species).

Nutrient values for South West Western Australian Wetland environments adopted from ANZECC/ARMACANZ 2000 Freshwater and Marine Guidelines, Table 3.3.6

DER 2014 Short-term irrigation

Chloride concentrations may cause foliar damage in non tolerant species.

APPENDIX E – Fauna Survey

Bindaring Park Bassendean -
Fauna Assessment

Wetland habitat within Bindaring Park study area (Rob Browne-Cooper)

Prepared for: Coterra Environment
Level 3, 25 Prowse Street,
WEST PERTH, WA 6005

Prepared by: Robert Browne-Cooper and Mike Bamford
M.J. & A.R. Bamford Consulting Ecologists
23 Plover Way
KINGSLEY WA 6026

6th April 2017

Summary

Bamford Consulting Ecologists was commissioned by Coterra Environment to conduct a Level 1 fauna assessment (desktop review and site inspection) of Bindaring Park in Bassendean (the study area). The fauna survey is required to provide information on the ecological values for the Town of Bassendean's Stage 2 Bindaring Wetland Concept Plan Development. This plan include developing design options (within wetland area) to enhance ecological values and habitat.

The purpose of this report is to provide information on the fauna values of the habitat, particularly for significant species, and an overview of the ecological function of the site within the local and regional context. This assessment focuses on vertebrate fauna associated with the wetland and surrounding parkland vegetation within the study area, with consideration for connectivity with the Swan River. An emphasis is placed on locally-occurring conservation significant species and their habitat. Relevant species include Carnaby's Black-Cockatoo, Forest Red-tailed Black-Cockatoo, and other local native species such as the Water Rat or Rakali.

The fauna investigations were based on a desktop assessment and a field survey conducted in February 2017. The desktop study identified 180 vertebrate fauna species as potentially occurring in the Bindaring Park study area (see Table 3 and Appendix 5): five fish, 6 frogs, 20 reptiles, 134 birds, 8 native and 7 introduced mammals. Note that this assemblage comes from databases and includes species that may occur occasionally on the site, but for which it is not important (such as birds that rarely fly overhead).

A total of 40 vertebrate species was recorded during the field survey. These were predominantly species of locally abundant birds that persist in urbanised settings and metropolitan wetland reserves
Key fauna values are:
Fauna assemblage. Depauperate and missing most of the most mammal fauna with the exception of small bat species and Rakali. Also low in richness of birds and reptiles.

Species of conservation significance. A large number of significant species may be present in the wider region, but for the majority of these there is little if any suitable habitat other than the wetland which may provide habitat for the Rakali. Significant species of note that are likely to occur on the site regularly include both the Forest Red-tailed and Carnaby's Black-Cockatoos, and Rakali. There is also a suite of birds recognised as declining in the Perth region and some of these were recorded as present.

Vegetation and Substrate Associations (VSAs). Four VSAs were identified. Most of the site contains open parkland (VSA 4) and remnant Flooded Gum trees (VSA 3). The lake and fringing vegetation (VSA 1) provides a small put important wetland habitat for urban wetland wildlife such as waterbirds, frogs and potentially the Rakali).

Patterns of biodiversity. Detailed patterns of biodiversity could not be examined, but it can be predicted that biodiversity will be concentrated in areas of even degraded native vegetation. The wetland, including the associated vegetation, are likely to be particularly important.

Key ecological processes. Main processes currently affecting the fauna assemblage in the survey area include habitat size and loss, connectivity and feral species (plants and animals), and local hydrology. Proximity and connectivity with the Swan River is important providing some degree of habitat linkage with this estuarine system. This linkage means the site is likely to have more species (especially birds) using the site regularly than might otherwise be the case, and it has a role in supporting biodiversity in nearby areas. Therefore connectivity with the River is an important local ecological process. Local hydrology may be important particularly if drainage causes short-term fluctuations in wetland water levels.

Recommendations relate to wetland and bushland management for fauna habitat value. These include:

- Further improve the quality and density of native vegetation cover, including the habitat linkage along the drainage line into the Swan River.
- Discourage the presence of feral species, particularly cats and foxes, by control measures and public awareness of responsible pet ownership. Some local government authorities have restrictions on cats near environmentally sensitive areas
- Maintain effective drainage though the lake and wetland habitat and into the Swan River; install signage into local residential streets and drains so that local residents are informed about the need to minimise domestic pollutants (herbicides, fertilisers, detergents, petroleum products) entering the wetland and River. If possible, monitor water level changes and determine if a natural cycle of seasonal rise and fall is taking place or can be established.
- Manage weeds long-term to replace weeds with native species, particularly wetland understorey and ground cover species such as sedge, native rushes and shrubs.
- Prevent the expansion of high risk species that are present such as Caster oil seedlings growing in the northeast corner of the study area.

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1 Introduction

1.1 Introduction

Bamford Consulting Ecologists was commissioned by Coterra Environment to conduct a Level 1 fauna assessment (desktop review and site inspection) of Bindaring Park in Bassendean (the study area). The fauna survey is required to provide information on the ecological values for the Town of Bassendean's Stage 2 Bindaring Wetland Concept Plan Development. This plan includes developing design options (within wetland area) to enhance ecological values and habitat.

The purpose of this report is to provide information on the fauna values of the habitat, particularly for significant species, and an overview of the ecological function of the site within the local and regional context.This assessment focuses on vertebrate fauna associated with the wetland and surrounding parkland vegetation within the study area, with consideration for connectivity with the Swan River. An emphasis is placed on locally-occurring conservation significant species and their habitat. Relevant species include Carnaby's Black-Cockatoo *Calyptorhynchus latirostris*, Forest Red-tailed Black-Cockatoo *Calyptorhynchus banksii naso*, and other local native species such as the Water Rat or Rakali *Hydromys chrysogaster*.

1.2 Description of Survey Area

The study area is located approximately 10 kilometres east-north-east of Perth CBD (see Figure 1) within the Town of Bassendean. The study area is within residential Bassendean and lies on an alluvial plain immediately north-west of the upper reaches of the Swan River. Drainage from the surrounding urban area flows into the lake within the study area and then feeds into the Swan River via a small creekline. This creekline meanders thought the study area and drains into the Swan River in an approximately south-west direction, although the creek was not flowing at the time of the site inspection. The site is approximately 580 metres in length and 430 metres in width. It consists of parkland, a wetland and the associated drainage creekline.

The lake within study area supports native wetland vegetation including flooded gums, paperbark, sheoak trees, and emergent reeds and sedges, as well as numerous exotic grasses and other weeds. The open parkland around the lake includes remnant flooded gums and patches of exotic eucalypt trees, and conifers.

The geography of the site is described as alluvial plain of the Pinjarra Plain with grey -brown clayey-loams. Sandy substrate within parkland areas may have been introduced for lawn growth. Being situated adjacent to the upper Swan River, the study area is subject to occasional flooding with a 20 year flood level of approximately 1.8 metres indicated.

Figure 1. Location of the Study Area

1.3 Regional Description

The Interim Biogeographic Regionalisation of Australia (IBRA) (Environment Australia, 2000) has identified 26 bioregions in Western Australia which are further divided into subregions. Bioregions are classified on the basis of climate, geology, landforms, vegetation and fauna (Thackway and Cresswell, 1995). IBRA Bioregions are affected by a range of different threatening processes and have varying levels of sensitivity to impact (EPA, 2004). The Survey Area lies in the Swan Coastal Plain Perth Subregion (DSEWPaC 2012) as shown in Figure 2.

The subregion is broadly characterised by 'low lying coastal plain covered with woodland dominated by Banksia or Tuart on sandy soils, *Casuarina obesa* on outwash plains, and paperbark in swampy areas. The subregion is composed of colluvial and aeolian sands, alluvial river flats, and coastal limestone' (Mitchell *et al.* 2002). The site is distinctive as it lies on the eastern edge of the sub-region (thus close to the Darling Escarpment) and the soils are those of an alluvial river flat.

The Swan Coastal Plain Perth Subregion is extensively developed. The site is a remnant area of swampy bushland with cleared portions having remnant Flooded Gum and exotic trees.

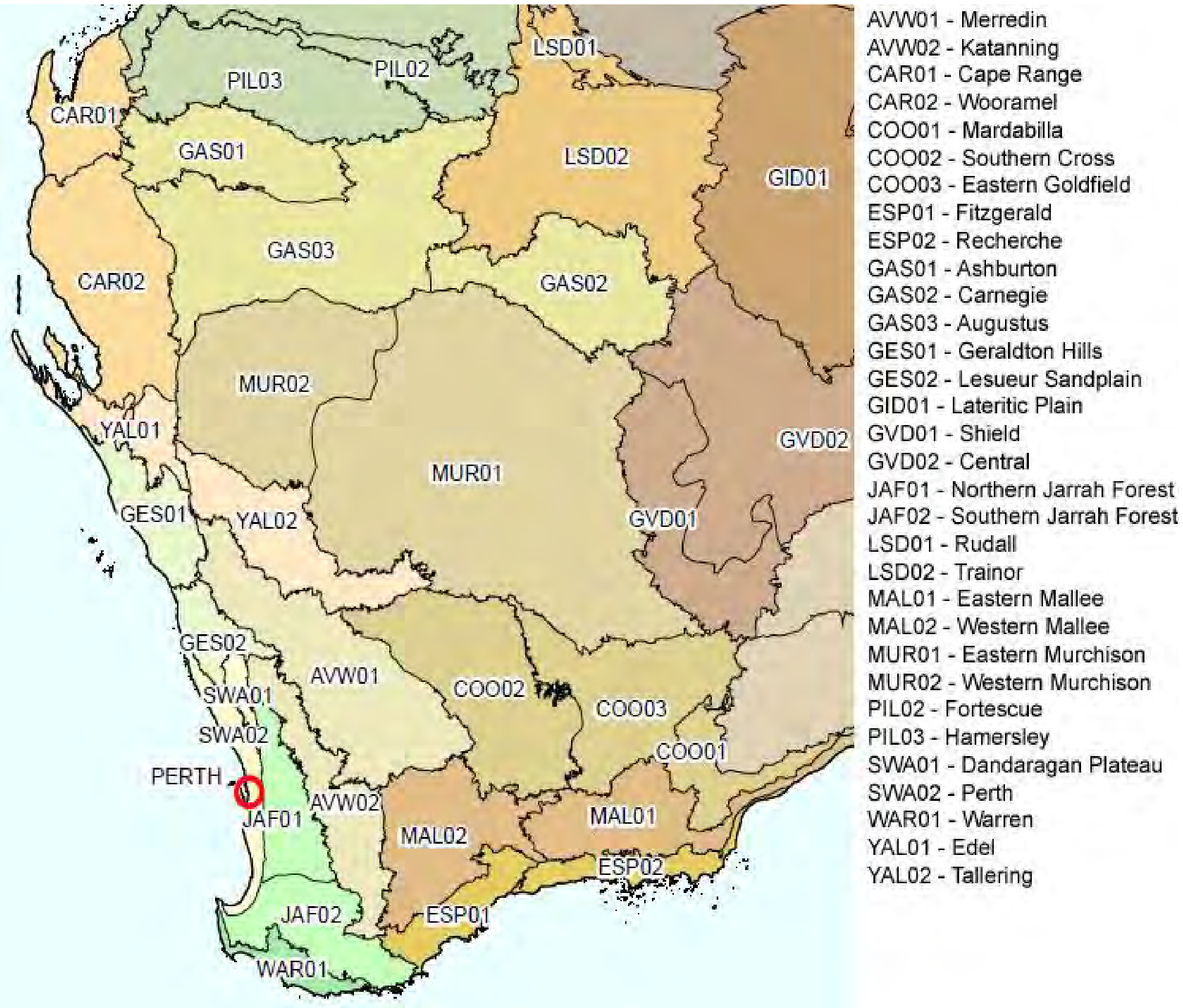

Figure 2. IBRA Subregions of Western Australia

Note that the study area lies in the SWA02 IBRA subregion.

2 Methods

2.1 Overview

The approach to fauna impact assessment was carried out with reference to guidelines and recommendations set out by the Western Australian Environmental Protection Authority (EPA) on fauna surveys and environmental protection, and Commonwealth biodiversity legislation (EPA 2002; EPA 2004). The EPA proposes two levels of investigation that differ in the approach to field investigations, Level 1 being a review of data and a site reconnaissance to place data into the perspective of the site, and Level 2 being a literature review and intensive field investigations (e.g. trapping and other intensive sampling). The level of assessment recommended by the EPA is determined by the size and location of the proposed disturbance, the sensitivity of the surrounding environment in which the disturbance is planned, and the availability of pre-existing data.

The following approach and methods is divided into three groupings that relate to the stages and the objectives of the fauna assessment:

- Desktop assessment. The purpose of the desktop review is to produce a species list that can be considered to represent the vertebrate fauna assemblage of the study area based on unpublished and published data using a precautionary approach.
- Field investigations. The purpose of the field investigations is to gather information on this assemblage: confirm the presence of as many species as possible (with an emphasis on species of conservation significance), place the list generated by the desktop review into the context of the environment of the study area, collect information on the distribution and abundance of this assemblage, and develop an understanding of the study area's ecological processes that maintain the fauna. Note that field investigations cannot confirm the presence of an entire assemblage, or confirm the absence of a species. This requires far more sampling over multiple years and seasons. For example, in an intensive trapping study, How and Dell (1990) recorded in any one year only about 70% of the vertebrate species found over three years. In a study spanning over two decades, Bamford (2010) has found that the vertebrate assemblage varies over time and space, meaning that even complete sampling at a set of sites only defines the assemblage of those sites at the time of sampling.

2.2 Desktop Assessment

2.2.1 Sources of information

Information on the fauna assemblage of the survey area was drawn from a wide range of sources. These included state and federal government databases and results of regional studies. Databases accessed were the DPaW NatureMap (incorporating the Western Australian Museum's FaunaBase and the DPaW Threatened and Priority Fauna Database), BirdLife Australia's Atlas Database (BA), the EPBC Protected Matters Search Tool and the BCE database (Table 1). Information from the above sources was supplemented with species expected in the area based on general patterns of distribution. Sources of information used for these general patterns were:

- Frogs: Tyler and Doughty (2009) and Anstis (2013);
- Reptiles: Storr *et al.* (1983, 1990, 1999, 2002); and Wilson and Swan (2013);
- Birds: Blakers *et al.* (1984); Johnstone and Storr (1998, 2004) and Barrett *et al.* (2003); and

- Mammals: Menkhorst & Knight (2004); Churchill (2008); and Van Dyck and Strahan (2008).

Table 1. Sources of information used for the desktop assessment.

Database	Type of records held on database	Area searched
NatureMap (DPaW 2017)	Records in the WAM and DPaW databases. Includes historical data and records on Threatened and Priority species in WA.	Point search: 115° 57' 30'' E by 31° 54' 40'' S plus 10 km buffer.Searched February 2017
BirdLife Australia Atlas Database (Birdlife Australia 2017)	Records of bird observations in Australia, 1998-2014.	Point search: 115° 57' 30'' E by 31° 54' 40'' S plus 10 km buffer.Searched February 2017
EPBC Protected Matters (DotE 2017)	Records on matters of national environmental significance protected under the EPBC Act.	Point search: 115° 57' 30'' E by 31° 54' 40'' S plus 10 km buffer.Searched February 2017
Atlas of Living Australia (ALA 2017)	Records in the ALA, and various State Government agency. Includes historical data and records on Threatened and Priority species in WA.	Point search: 115° 57' 30'' E by 31° 54' 40'' S plus 10 km buffer.Searched February 2017
Birdlife Australia Great Cocky Count roost data 2010 to 2014 (Unpublished data)	Black Cockatoo roost sites (confirmed, potential, and unconfirmed)	Roost site locations within Swan Shire.

2.2.2 *Previous Fauna Surveys*

The desktop assessment included a review of a fauna survey conducted by Basnett and Bamford (2014) in Bayswater approximately 2 km south-west of the study area. The report provides data on locally occurring terrestrial vertebrate assemblages recorded in a proximal site along the Swan River.

2.2.3 *Nomenclature and taxonomy*

As per the recommendations of EPA (2004), the nomenclature and taxonomic order presented in this report are based on the Western Australian Museum's (WAM) Checklist of the Fauna of Western Australia 2016. English names of species, where available, are used throughout the text; Latin species names are presented with corresponding English names in tables in the appendices.

2.2.4 Interpretation of species lists

Species lists generated from the review of sources of information are generous as they include records drawn from a large region and possibly from environments not represented in the survey area. A number of these species can be discounted based on the historical nature of some data for locally extinct species, highly urbanised surroundings, and small size of the study area. Therefore, some species that were returned by one or more of the data searches have been excluded because their ecology, current distribution or the environment within the survey area, meant that it was highly unlikely that these species would be present.

Even though the Swan River is not within the study area boundary, there is a hydrological link between the two via a creekline, and the close proximity means that a number of estuarine species are considered in this assessment due to their potential occurrence. Fauna species returned by the desktop review that are associated with the upper Swan River are considered to be potentially present in the study area whether or not they were recorded during field surveys, and whether or not the survey area is likely to be important for them. Species returned from databases but excluded from species lists as unlikely to occur are presented in Appendix 6.

Interpretation of species lists generated through the desktop review included assigning an expected status within the survey area to species of conservation significance. This is particularly important for birds that may naturally be migratory or nomadic, and for some mammals that can also be mobile or irruptive. The status categories used are:

- Resident: species with a population permanently present in the survey area;
- Regular migrant or visitor: species that occur within the survey area regularly in at least moderate numbers, such as part of annual cycle;
- Irregular Visitor: species that occur within the survey area irregularly such as nomadic and irruptive species. The length of time between visitations could be decades but when the species is present, it uses the survey area in at least moderate numbers and for some time;
- Vagrant: species that occur within the survey area unpredictably, in small numbers and/or for very brief periods. Therefore, the survey area is unlikely to be of importance for the species; and
- Locally extinct: species that has not been recently recorded in the local area and therefore is almost certainly no longer present in the survey area.

These status categories make it possible to distinguish between vagrant species, which may be recorded at any time but for which the site is not important in a conservation sense, and species which use the site in other ways but for which the site is important at least occasionally. This is particularly useful for birds that may naturally be migratory or nomadic, and for some mammals that can also be mobile or irruptive, and further recognises that even the most detailed field survey can fail to record species which will be present at times, or may have been previously confirmed as present. The status categories are assigned conservatively. For example, a lizard known from the general area is assumed to be a resident unless there is very good evidence that the site will not support it, and even then it may be classed as a vagrant rather than assumed to be absent if the site might support dispersing individuals.

2.3 Field Survey

2.3.1 Overview

The field survey included several components:

- identification of VSAs;
- targeted searching for conservation significant fauna, particularly Rakali, black-cockatoos species and Quenda;
- assessment of the site for black-cockatoo habitat values (foraging, breeding and roosting), and
- opportunistic fauna observations.

2.3.2 Dates and Personnel

The study area was visited on the 23rd of February 2017 by Mr Robert Browne-Cooper (B.Sc) who also prepared the fauna assessment report together with Dr Mike Bamford (B.Sc. Hons. Ph.D.).

2.3.3 Vegetation and Substrate Associations

Vegetation and Substrate Associations (VSAs) within the study area were assessed as part of the field investigations. All major or remnant VSAs were visited to develop an understanding of major fauna habitat types present, their extent and connectivity to assess the likelihood of conservation significant species being present.

2.3.4 Black-Cockatoos

Ecological values for Black-Cockatoos were assessed based on the definitions of breeding, foraging and roosting habitat as defined the EPBC Act referral guidelines for black cockatoos (DSEWPaC, 2012), with foraging and nesting values assessed using systems developed by Bamford Consulting (outlined below).

Foraging habitat assessment

Black-cockatoos, particularly Carnaby's Black-Cockatoo and the Forest Red-tailed Black-Cockatoo, forage widely in suitable vegetation in the Perth region and leave distinctive chew marks on dropped feeding material such as Marri and jarrah pods, banksia cones, as well as exotic food sources such as pine cones and cape lilac berries. Targeted searches were made for these signs below potential foraging habitat within the study area. The areas of remnant vegetation within the site were assessed for foraging value based on the method outlined in Appendix 7. Foraging habitat value was then mapped (Figure 4).

Breeding habitat assessment

The EPBC Act referral guidelines for black cockatoos (DSEWPaC, 2012) lists tree species known to be nesting habitat including Flooded Gum trees present within the study area. These trees were assessed for Black-Cockatoo breeding activity and potential tree suitability for nesting. For all trees with a trunk diameter (DBH) greater than 50 cm the following data was recorded:

- Tree species;
- GPS waypoint location;
- DBH;
- Tree status (alive or dead);
- presence of any competing species present (e.g. feral bees, corella)
- Tree class in terms of Black-Cockatoo nest potential (refer to Appendix 8).

Data on potential breeding trees is presented in Appendix 9 and locations shown in Figure 4.

Roosting habitat assessment

Vegetation was assessed for roosting habitat potential based on tree species present and canopy height, and on the occurrence of local confirmed or potential roosting sites (based upon records from the Great Cocky Count (Finn *et al.* 2014) which is a collation of roost data recorded frog 2010 to 2014.

2.3.5 Rakali

The Rakali or Water Rat *Hydromys chrysogaster* is a mammal of conservation significance that is expected to occur within the Bindaring Park study area. This species can be detected based on signs of activity within swampy areas. Targeted searches were carried out looking for feeding residue and foot prints in areas of suitable wetland habitat.

2.3.6 Quenda

The Quenda or Southern Brown Bandicoot *Isoodon obesulus* is a mammal of conservation significance that is known to persist in metropolitan bushland reserves. It leaves distinctive foraging excavations and also leaves distinctive tracks particularly in firm moist sandy substrates. Targeted searches for tracks and diggings were made.

2.3.7 Opportunistic observations

At all times, observations of fauna were noted when they contributed to the accumulation of information on the fauna of the site. These included such casual observations as birds or reptiles seen while walking through the study area. Other observations included introduced species (i.e. feral bees, foxes etc) and potential weeds that may be management considerations.

2.4 Survey Limitations

The EPA Guidance Statement 56 (EPA 2004) outlines a number of limitations that may arise during surveying. These survey limitations are discussed in the context of the BCE fauna survey at the survey area in Table 2.

Table 2. Survey limitations as outlined by EPA (2004).

EPA Limitation	BCE Comment
Level of survey.	Level 1 (desktop study with site assessment). Survey intensity was deemed adequate due to the small area, availability of previous data base records, and studies in the region.
Competency/experience of the consultant(s) carrying out the survey.	The authors have had extensive experience in conducting desktop reviews and have conducted multiple fauna surveys in the Perth Region with surveys focussed on relevant local considerations including wetland management, black cockatoos assessment, quenda and Rakali.

EPA Limitation	BCE Comment
Scope. (What faunal groups were sampled, and were some sampling methods not able to be employed because of constraints?)	The site investigation targeted descriptions of the environment and fauna values for the significant species potentially occurring of known to occur.
Proportion of fauna identified, recorded and/or collected.	Key significant species were identified and the desktop provided information on other species.
Sources of information e.g. previously available information (whether historic or recent) as distinct from new data.	Sources include a previous fauna surveys in the Bullsbrook area (Basnett and Bamford 2014) and databases (BA, DPaW, EPBC, BCE database).
The proportion of the task achieved and further work which might be needed.	This report provides fauna values for significant species.
Timing/weather/season/cycle.	There were no constraints from the weather and conditions allowed personnel to move around readily.
Disturbances (e.g. fire, flood, accidental human intervention etc.) that affected results of survey.	None.
Intensity. (In retrospect, was the intensity adequate?)	All major VSAs were visited and significant species habitat and traces were identified.
Completeness (e.g. was relevant area fully surveyed).	Site was fully surveyed.
Resources (e.g. degree of expertise available in animal identification to taxon level).	Field personnel have extensive experience with fauna detection and habitat assessment in the region.
Remoteness and/or access problems.	There were no remoteness/access problems encountered.
Availability of contextual (e.g. biogeographic) information on the region.	Extensive regional information was available and was consulted.

3 Results

3.1 Vegetation and Substrate Associations

Four Vegetation and Substrate Associations (VSAs) were identified across the study area. The location and extent of VSAs are shown in Figure 3, and Plates 1 to 4. The VSAs include:

- VSA1 - Wetland. This VSA includes the main lake, peripheral swampy areas, and the creek that feeds into the Swan River. Wetland vegetation includes the associated emergent and fringing vegetation of Melaleuca, Casuarina, occasional Flooded Gum, reeds, sedges, and exotic grasses such as Kykuyu and Couch, and other low weeds. This VSA includes some small areas of native vegetation plantings on the edge of the lake.
- VSA2 - Exotic tree plantings. Small patches or individual trees including pines, conifers, non-native eucalypt tree, cape lilac. Woodland lacking understorey and with ground layer of exotic grasses and other pasture weed on alluvial clay soil.
- VSA3 - Open Flooded Gum Parkland. Sparse Flooded Gum parkland areas over mown grass and low weeds on alluvial loam clay soil. Effectively an open woodland with no understorey over exotic grasses and other pasture weed on alluvial clay soil.
- VSA4 - Cleared open space. Areas of mown grasses and low weeds with little or no Flooded Gums present on clay loam and sandy areas.

Plate 1. VSA 1 – Wetland.

Plate 2. VSA 2 – Exotic tree plantings.

Plate 3. VSA 3 - Open Flooded Gum woodland.

Figure 3. Vegetation and Substrate Associations

3.2 Vertebrate Fauna

3.2.1 Overview of fauna assemblage

The desktop study identified 180 vertebrate fauna species as potentially occurring in the Bindaring Park study area (see Table 3 and Appendix 5): five fish, 6 frogs, 20 reptiles, 134 birds, 8 native and 7 introduced mammals. Fauna observed during the field visit are listed in Appendix 5, and an annotated list of fauna species recorded is included in Appendix 10. A total of 40 vertebrate species was recorded during the field survey. These were predominantly species of locally abundant birds that persist in urbanised settings and metropolitan wetland reserves.

No native fish species were recorded although four native species that can be expected seasonally are Western Minnow *Galaxia occidentalis*, and Swan River Goby *Pseudogobius olorum*. Introduced fish species recorded are detailed in the section below.

In addition to the two recorded frog species, several other common local species are likely to occur such as the Motorbike Frog and Ticking Frog. Other regionally occurring frog species are unlikely to occur due to the lack of suitable extensive wetland habitat, and changes to the natural flood cycles of urban wetlands caused by drainage alterations.

The paucity of low strata vegetation in the parkland and open space areas limits the reptile species assemblage expected to occur, although several reptiles known to persist in highly degraded environments were recorded such as the Snake-eyed (fence) Skink, Common Dwarf Skink and Two-toed Earless Skink. Another common local species associated with wetland habitat and likely to occur is the Western Three-lined Skink.

Of the 34 bird species recorded, many are common waterbirds that are expected to be residents or regular visitors to the wetland within Bindaring Park such as Yellow-billed Spoonbill, Australasian Grebe, Pink-eared Duck, White-faced Heron and Dusky Moorhen. Several woodland birds that persist in remnant local bushland were recorded including the Red-capped Parrot, Western Gerygone, Rufous Whistler, Striated Pardalote and Grey Fantail.

Native mammals potentially occurring include Common Brush-tail Possum, and several common local bats such as Gould's Wattled Bat. The Rakali (Water Rat) potentially inhabits or regularly visits the wetland environment (see section 3.2.2). No signs of Quenda were detected, and this species is unlikely to be present within the study area.

The vertebrate assemblage potentially includes 41 species of conservation significance (

Table **4**). For all significant species listed, comments are included regarding the expected type or frequency of occurrence. The desktop review also returned many species that do not occur in the site, such as locally extinct species and migratory shorebirds known to occur locally in tidal areas of the Swan-Canning River system. These are listed in Appendix 6.

The overall fauna assemblage reflects the impact of historical habitat loss and introduced species, as well as the level of resilience of a number of species that persist in urban and parkland settings locally and more widely across Swan Coastal subregion. Key features of the fauna assemblage expected in the survey area are:

- Uniqueness: The assemblage is likely to be typical of local remnant small wetlands and parklands along the Swan-Canning River system and in the eastern portion of the Swan Coastal Plain.

- Completeness: The assemblage of species from the study area has a paucity of native mammals, reptile and bird species. Some frogs may also be absent. Some smaller woodland bird species make use of the site based on species recorded during the field assessment. Waterbirds are well-represented due to presence of the wetland and proximity to Swan River. Many of the species from all fauna classes listed (fish, frogs, reptiles, birds and mammals) are associated with the lake and associated wetland vegetation or surrounding Flooded Gum trees.

- Richness: The assemblage is likely to vary annually and seasonally. The degraded condition of much of the survey area means some species may be absent or uncommon visitors. Overall, the site has low species richness compared with pre-disturbance levels, but is locally rich in species due to the extent or surrounding urbanisation.

Table 3. Composition of vertebrate fauna assemblage expected to occur in the study area.

Note: Values in parenthesis are numbers of introduced species included in the total. CS – Conservation Significance.

Taxon	Number of species expected	Significant fauna expected		
		CS1	CS2	CS3
Fish	5	0	0	0
Frogs	6	0	0	0
Reptiles	20	0	0	0
Birds	134 (34)	16	1	21
Native Mammals	8 (3)	0	2	1
Introduced Mammals	7	-	-	-
Total	**180 (37)**	**16**	**3**	**22**

Table 4. Conservation status of significant fauna expected to occur within the study area.

See Appendix 3 for descriptions of conservation significance levels. Species recorded are indicated and the predicted status of each species in the survey area is also given (as per Section 3.2.2). *Presence inferred from foraging residue (chewed seed pods).
EPBC Act listed species: V = Vulnerable, E = Endangered, C = Critically Endangered, M = Migratory.
WC Act listed species: S1 – S7 = Schedule 1 - 7, DEC Priority Species: P1 - P5 = Priority 1 - 5.

Species	Conservation Significance			Expected status in Study area
	CS1	CS2	CS3	
Blue-billed Duck *Oxyura australis*		P4		occasional visitor
Musk Duck Biziura lobata			X	regular visitor
Pink-eared Duck Malacorhynchus membranaceus			X	regular visitor. Recorded
Freckled Duck *Stictonetta naevosa*			X	Occasional visitor
White-necked Heron Ardea pacifica			X	occasional visitor
Eastern Great Egret *Ardea modesta*	M, S5			regular visitor
Cattle Egret *Ardea ibis*	M, S5			vagrant
Little Egret Egretta garzetta	M, S5			occasional visitor
Grey Plover *Pluvialis squatarola*	M, S5			vagrant
Common Sandpiper Acticus hypoleucos	M, S5			occasional visitor
Red-necked Stint Calidris ruficollis	M, S5			vagrant
Sharp-tailed Sandpiper Calidris acuminata	M, S5			vagrant
Curlew Sandpiper Calidris ferruginea	M, E, S5			vagrant
Common Greenshank Tringa nebularia	M, S5			occasional visitor
Caspian Tern Hydroprogne caspia	M, S5			occasional visitor
Common Bronzewing Phaps chalcoptera			X	occasional visitor
Fork-tailed Swift Apus pacificus	M, S5			migrant
Brown Goshawk Accipiter fasciatus			X	occasional visitor
Collared Sparrowhawk Accipiter cirrhocephalus			X	occasional visitor
White-bellied Sea-Eagle Haliaeetus leucogaster			X	occasional visitor
Little Eagle Hieraaetus morphnoides			X	occasional visitor
Peregrine Falcon Falco peregrinus	S7			occasional visitor
Carnaby's Black-Cockatoo Calyptorhynchus latirostris	E, S2			regular visitor. Recorded*
Baudin's Black-Cockatoo Calyptorhynchus baudinii	V, S2			occasional visitor
Forest Red-tailed Black-Cockatoo C. banksii naso	V, S3			regular visitor. Recorded
Rainbow Bee-eater Merops ornatus	S5			migrant. Recorded
Splendid Fairy-wren Malurus splendens			X	occasional visitor
White-winged Fairy-wren Malurus leucopterus			X	occasional visitor
White-browed Scrubwren Sericornis frontalis			X	occasional visitor
Weebill Smicrornis brevirostris			X	Resident. Recorded
Inland Thornbill Acanthiza apicalis			X	vagrant
Yellow-rumped Thornbill Acanthiza chrysorrhoa			X	occasional visitor
Western Wattlebird Anthochaera lunulata			X	occasional visitor
White-cheeked Honeyeater Phylidonyris nigra			X	occasional visitor
New Holland Honeyeater P. novaehollandiae			X	regular visitor. Recorded
Rufous Whistler Pachycephala rufiventris			X	regular visitor. Recorded
Varied Sittella Daphoenositta chrysoptera			X	vagrant
Black-faced Woodswallow Artamus cinereus			X	vagrant
Common Brush-tail Possum *Trichosurus vulpecula*			X	occasional visitor
Western False Pipistrelle *Falsistrellus mackenziei*		P4		occasional visitor
Rakali or Water Rat *Hydromys chrysogaster*		P4		occasional visitor

3.2.2 Species of conservation significance

Details on species of conservation significance returned from the database and expected (including those recorded) to occur in the survey area (even as vagrants) are presented in Table 4. This list includes 15 CS1 species, 3 CS2 species and 21 CS3 species. Note that species extinct within the region and that may have been present historically on the basis of broad patterns of distribution, and species highly unlikely to be present based on their biology, have not been included but are presented in Appendix 6.

The suite of significant species includes many that are expected to occur only as vagrants or occasional visitors (Table 4), and thus for which the study area is of low ecological importance. Other species and groups of species may utilise the study area more regularly and are discussed below.

Black-Cockatoos

Foraging signs of oth Forest Red-tailed and Carnaby's Cockatoos were found in the study area, and both species are likely to be regular visitors to the site as they are known to occur locally and regionally on the Perth Swan Coastal Plain and Darling Range. The site also contains potential nesting trees for Black-Cockatoos based on the definition within the EPBC Act referral guidelines (DSEWPaC 2012). Details about habitat values of the site for Black-Cockatoos are presented in Section 3.2.4.

Migratory Wetland Birds

This group includes three egret species, a plover, several sandpipers and one tern, although only the Eastern Great Egret is expected to be present regularly. The Bindaring Park wetland lacks extensive areas of shallow water or mud flats favoured by most of the sandpipers, while the Little and Cattle Egrets generally occur only occasionally and in small numbers around Perth.

Fork-tailed Swift

A summer migrant species that can occur aerially over a wide range of environments throughout much of coastal and inland Australia. This species does not breed in Australia, but may occur on an occasional basis on the Perth Swan Coastal bioregion. It exists largely independently of terrestrial ecosystems.

Peregrine Falcon

This species is known to occur over a wide range of environments throughout most of Australia. Preferred nesting locations include a range of highly elevated location with steep topography such as rocky hills, breakaways, cliffs and will also nest on high artificial structures. It will also nest in very large, horizontally-aligned tree hollows, with such a nest in Whiteman Park (M. Bamford pers. obs.). The Bindaring Park site could therefore provide a suitable nesting site within the mature eucalypt trees, and is at least likely to be within the foraging range of a pair of the species who would thus be regular visitors.

Rainbow Bee-eater

Until recently listed as migratory under the EPBC Act, and still listed as Shecule 5 (migratory) under the WA *Wildlife Conservation Act*, this species is a common summer migrant that breeds in the Perth area. The site represents foraging habitat, and the open clearings (VSA 4) are potential breeding habitat. This species is widespread and frequently uses areas cleared of native vegetation and other disturbed environments.

Conservation Significance level 3 birds

This suite of birds is considered to be of local conservation significance (CS3) because they have been identified in the Bush Forever Report (Dell and Banyard 2000) as declining in the Perth region and being reliant on native vegetation. For many of the species this conclusion has been reinforced by Davis *et al.* (2012). These are species reliant to varying degrees on large and interconnected areas of native vegetation within the urban landscape. They make up a large proportion of the significant birds that may use remnant vegetation within the Bindaring Park site. Three of these species (Weebill, New Holland Honey-eater, and Rufous Whistler) were observed in the survey area (

Table **4**). In addition, a pair of Pink-eared Ducks was observed within the open water of the lake (VSA 1), and the other four CS3 species were heard calling within the woodland habitat of the Bindaring Park (VSA 3).

Rakali

This species was not recorded during the field survey, but is likely to be a resident or frequent visitor to Bindaring Park due to close proximity to the Swan River, and the suitable dense wetland vegetation (VSA 1) which is mapped in Figure 4. Databases have recorded this species on the Swan River near the Garret Road Bridge (Bamford Consulting database). Bindaring Park was not included in the recent Rakali survey conducted by WWF and DPaW (Trocini *et al.* 2015), but that survey did confirm the presence of the species at multiple locations around Perth.

Western False Pipistrelle

May occur in nearby forest to east and individuals could occasionally fly along the Swan River. The site itself provides virtually no habitat for this species.

3.2.3 Introduced or feral species

The desktop study identified 16 introduced fauna species as potentially occurring in the Bindaring Park study area (Table 5). No evidence of the European Red Fox or Rabbit were observed within the site, however both species commonly occur in urban parkland and bushland areas. Domestic and feral cats are also highly likely to frequently hunt within Bindaring Park. Mosquito Fish *Gambusia holbrooki* were found to be abundant within the lake and other feral fish such as carp potentially occur. Feral bee hives were found to be occupying a number of tree hollows within the study area. The location and description of each is provided in Table 6.

Table 5. Introduced fauna species expected to occur in survey area

This list is based on desktop review and field investigation and includes species either recorded or expected to occur.

Common Name	Latin Name	Expected Status
FISH		
Goldfish	*Carassius auratus*	Resident
Carp	*Cyprinus carpio*	Possible resident, Ellen Brook
Mosquito Fish	*Gambusia holbrooki*	Resident (recorded)
BIRDS		
Eastern Long-billed Corella	*Cacatua tenuirostris*	Visitor
Rock Dove	*Columba livia*	Visitor
Laughing Kookaburra	*Dacelo novaeguineae*	Resident (recorded)
Spotted Turtle-Dove	*Streptopelia chinensis*	Resident
Laughing Turtle-Dove	*Streptopelia senegalensis*	Resident (recorded)
Rainbow Lorikeet	*Trichoglossus haematodus*	Regular visitor (recorded)
MAMMALS		

Common Name	Latin Name	Expected Status
Domestic Dog	*Canis lupus familiaris*	Resident (recorded)
Feral Cat	*Felis catus*	Resident (recorded)
House Mouse	*Mus musculus*	Resident
Rabbit	*Oryctolagus cuniculus*	Resident
Brown Rat	*Rattus norvegicus*	Resident
Black Rat	*Rattus rattus*	Resident (recorded)
European Red Fox	*Vulpes vulpes*	Resident

Table 6. Feral bee hive locations within the study area

Waypoint coordinates	**Description**
50 J 401488 6468765	feral bee hive in non-native Eucalyptus tree
50 J 401277 6469138	feral bee hive in Melaleuca tree hollow
50 J 401272 6469126	feral bee hive in Flooded Gum tree hollow
50 J 401624 6469005	feral bee hive in Flooded Gum tree hollow
50 J 401273 6469153	feral bee hive in Flooded Gum tree hollow

3.2.4 Black-Cockatoo habitat assessment

3.2.4.1 Black-Cockatoo foraging habitat

Each of the VSAs in the survey area was assessed and scored for black-cockatoo foraging value based on the abundance of forage species present. Foraging value was assigned to each VSA for any black-cockatoo species. The scoring system appears in Appendix 7 while Appendix 1 lists plant species used for foraging by black-cockatoos. Results are mapped on Figure 4.

The bulk of the site is of negligible or very low foraging value (score of 1). Low foraging value areas include non-native Eucalypt trees and Flooded Gum open parkland having low ranked foraging species present. Pine trees are mapped as low-to moderate foraging value (score of 3) based on the small area and low density of trees. Frequency with which black-cockatoos visit the site for foraging will depend on the success of flowering and pollination, and consequently seed production, and this will vary from year to year. Appendix 11 illustrates recently chewed Pine cones and Cape Lilac berries found in the study area, indicating visits by both Carnaby's and Forest Red-tailed Black-Cockatoos.

Both Forest Red-tailed and Carnaby's Black-Cockatoos are likely to be regular visitors to the site as both species are known to occur locally and regionally on the Perth Swan Coastal Plain and Darling Range. Throughout the Perth metropolitan area, very small patches know foraging tree species, and even individual trees, including non-native species, are important foraging resources for both these black-cockatoos.

3.2.4.2 Black-Cockatoo breeding habitat

Within Bindaring Park, 50 potential nesting trees were recorded during the field survey. These are all Flooded Gums as summarised in Table 7 and shown in Figure 4. Appendix 9 provides details including coordinates and a potential nesting value score for each tree. The potential nesting tree scoring system is outlined in Appendix 8. All of the listed trees are alive and have a DBH greater than 500 mm as per the Commonwealth guidelines (DSEWPaC 2012). The majority of these trees scored a 5 (no hollows but tree of a suitable size), but there were two Flooded Gums recorded with visible potential nest hollows of suitable size (score of 3). Breeding tree suitability not only depends on hollow characteristics, but also on quality and quantity of nearby foraging habitat available during breeding. In addition, tree species is an important consideration, i.e. Some tree species such as Wandoo and Marri are considered to be of primary or high breeding value (favoured tree species) for Carnaby's and Forest Red-tailed Black-Cockatoos respectively. Flooded Gums are considered as secondary breeding value for black-cockatoos.

Table 7. Summary of potential nesting trees recorded within Study Area.

nesting value score	Number of trees
3. Potential nest hollows of suitable size and inclination visible	2
4. Potential but marginally suitable (non-preferred) hollows visible	3
5. Tree of suitable size but no hollows visible or considered likely because of tree structure	45

3.2.4.3 Black-Cockatoo roosting habitat

Black-Cockatoos tend to have traditional roosting sites, often large trees close to water, and these have been documented in the Great Cocky Count (Finn *et al.* 2014). There are no known roost trees within Bindaring Park although this park does have the characteristics that make it a potential roost, such as tall trees and adjacent freshwater body. The nearest know roost site is in Guildford, approximately 1.5 kilometres north-east of Bundaring Park.

Figure 4. Black Cockatoo and Water Rat habitat values

This figure presents the wetland as Rakali foraging habitat, mature Flooded Gums as potential breeding trees for Black-Cockatoos, and scores vegetation within the study area as either low or low to moderate value foraging habitat.

3.3 Patterns of biodiversity

Investigating patterns of biodiversity can be complex and isoften beyond the scope even of level 2 investigations. However, the level of disturbance and the shape of the survey site are both significant factors in patterns of biodiversity. Within the project area, VSAs 1 and 3 may have higher biodiversity than other VSAs, but in such a fragmented landscape subject to extensive historical clearing they cannot be considered in isolation.

A large proportion of the study area consists of remnant Flooded Gums and predominantly exotic pasture grasses and other weeds. Fauna reliant upon undisturbed native vegetation and/or soil may be absent or uncommon. This would be especially be important for species dependent upon the understorey, such as small woodland birds (e.g. thornbills, fairy-wrens) and a range of reptile species.

The wetland habitat within the study area has a number of weed species present but remains intact in terms of native wetland vegetation structure, and has a degree of connectivity with wetland habitat to the adjacent north, and connectivity with the Swan River via the drainage channel. The fauna assemblage, particularly avian, is likely to be bolstered by the proximity to the Swan River. Davis *et al.* (2012) investigated bird assemblages in the Perth urban area in relation to the degree of habitat fragmentation, and noted the importance of large and interconnected reserves for avian biodiversity.

Although the fauna assemblage of the area is low in species richness due to factors such as size of remnant, isolation, habitat loss and degradation, and impacts of feral species, the site is locally rich because of the extent of surrounding urbanisation. It may even be rich for a small reserve because it encompasses a range of environments and because of the proximity of the river.

3.4 Ecological processes

The nature of the landscape and the fauna assemblage indicate some of the ecological processes that may be important for ecosystem function (see Appendix 4 for descriptions and other ecological processes). These include:

Local hydrology. The Wetland and associated habitat is dependent on seasonal drainage from surrounding urban areas. Runoff from these areas can potentially introduce nutrients and other pollutants, and overall water level cycles will influence the wetland vegetation community as well as species such as frogs and waterbirds. Intermittent runoff can result in short-term fluctuations in wetland water levels that disrupt the breeding cycles of some frogs and waterbirds.

Fire. Woodlands and wetlands of the Perth Swan Coastal bioregion are fire-adapted but the flora and fauna assemblages can be altered by too-frequent or too-infrequent fires; and even by fire exclusion. However Bindaring Park is likely to be managed to exclude fire due to the urban setting. In the natural bushland setting, fire season may be important in seed germination. Lack of fire could reduce recruitment of the remnant woodland vegetation and hence the biodiversity and resilience of the area.

Feral species and interactions with over-abundant native species. The fauna assemblage within remnant vegetation of the survey areas has been impacted by feral species (loss of a major component of the mammal fauna). Introduced rodents may cause further degradation to the native vegetation and, in combination with introduced predators (cats and foxes), reduce the capacity of the area to support native fauna diversity. Feral bees using tree hollows for hives will be displacing some fauna such as small hollow-roosting bat species, and hollow nesting birds.

Habitat degradation due to weed invasion. Weeds are prevalent within the study area and generally reduce natural habitat quality, although weeds can be an important component of the fauna habitat in disturbed or small fragmented areas where most of the original plant species and vegetation structure is missing. For example, VSA 1 has tall and moderately dense growth of kikuyu and other introduced grasses and other weeds, and potentially provides cover for small birds and reptiles in the absence of an understorey of native plants.

Connectivity and landscape permeability. There is a degree of connectivity of the wetland with the Swan River; this linkage has been highlighted in Figure 4 as an important connection with the Swan River for wildlife. Remaining areas of relatively isolated bushland and wetland areas have an increasingly important function as stepping stones for mobile species between the larger permanent conservation reserves and other remnants associated with the Swan River system.

3.5 Summary of Fauna Values

The desktop study identified 179 vertebrate fauna species as potentially occurring in the Bindaring Park study area including five fish, 6 frogs, 20 reptiles, 133 birds, 8 native and 7 introduced mammals. The vertebrate assemblage includes 37 species of conservation significance, with the most likely to frequently use the site being the Carnaby's Black-Cockatoo, Forest Red-tailed Black-Cockatoo and Water Rat (Rakali).

Fauna assemblage. Depauperate, and missing most medium-sized and small mammals, as well as many birds and reptiles.

Species of conservation significance. A large number of significant species may be present in the wider region, but for the majority of these there is little if any suitable habitat other than the wetland which may provide habitat for and Rakali. Significant species of note that are likely to occur on the site regularly include both the Forest Red-tailed and Carnaby's Black-Cockatoos, and Rakali. There is also a suite of birds recognised as declining in the Perth region and some of these were recorded as present.

Vegetation and Substrate Associations (VSAs). There are four VSAs identified. Most of the site contains open parkland clearing (VSA 4) and remnant Flooded Gum trees (VSA 3). The lake and fringing vegetation (VSA 1), provides a small put important wetland habitat for urban wetland wildlife such as waterbirds, frogs and potentially the Water Rat (Rakali).

Patterns of biodiversity. Detailed patterns of biodiversity could not be examined, but it can be predicted that biodiversity will be concentrated in areas of native vegetation even where this is degraded. The wetland, including the associated vegetation is likely to be particularly important.

Key ecological processes. Main processes currently affecting the fauna assemblage in the survey area include habitat size and loss, connectivity and feral species (plants and animals), and local hydrology. Proximity and connectivity with the Swan River is important providing some a degree of habitat linkage with this estuarine system. This linkage means the site is likely to have more species (especially birds) using the site regularly than might otherwise be the case, and it has a role in supporting biodiversity in nearby areas. Therefore connectivity with the River is an important local ecological process. Local hydrology may be adversely affecting the fauna assemblage if runoff is episodic and creates short-term fluctuations in wetland water levels.

4 Recommendations

Habitat fragmentation

- Further improve the quality, and density of native vegetation cover including the important habitat linkage along the drainage line into the Swan River.

Species interactions

- Discourage the presence of feral species, particularly cats and foxes, by control measures and public awareness of pet control.
- Encourage responsible pet ownership. Some local government authorities have restrictions on cats near environmentally sensitive areas.

Hydrological changes

- Maintain effective drainage though the lake and wetland habitat and into the Swan River.
- Install signage into local residential streets and drains so that local residents are informed about the need to minimise domestic pollutants (herbicides, fertilisers, detergents, petroleum products) entering the wetland and River.
- If possible, monitor water level changes and determine if a natural cycle of seasonal rise and fall is taking place or can be established.

Habitat degradation due to weed invasion

- Manage weeds long-term to replace weeds with native species, particularly wetland understorey and ground cover species such as sedge, native rushes and shrubs.
- Prevent the establishment of high risk species that are present such as Caster oil seedlings growing in the northeast corner of the study area.

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6 Appendices

Appendix 1. Black-cockatoos background information.

Species, ecology, habitat requirements and threats

The three south-western Western Australian taxa of black-cockatoo are listed in Table i. All species are listed under both the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999 and the Western Australian Wildlife Conservation Act 1950), as indicated in Table i. Two of these are likely to occur in the vicinity of the project area (Forest Red-tailed and Carnaby's Black-Cockatoo), with Baudin's Black-Cockatoo not expected (in the Perth area this species is generally restricted to the Darling Range and/or the very eastern edge of the Swan Coastal Plain).

Table i. Black-cockatoos likely to occur in the vicinity of the project area.
The status of each species under the Environment Protection and Biodiversity Conservation Act 1999 (EPBCA 1999) and the Western Australian Wildlife Conservation Act 1950 (WCA 1950) is shown.

Species		EPBCA 1999	WCA 1950
Calyptorhynchus banksii naso	Forest Red-tailed Black-Cockatoo	Vulnerable	Schedule 1 (Vulnerable)
Calyptorhynchus latirostris	Carnaby's Black-Cockatoo	Endangered	Schedule 1 (Endangered)
Calyptorhynchus baudinii	Baudin's Black-Cockatoo	Vulnerable	Schedule 1 (Endangered)

There is considerable published information on the ecology of, and threats to, these black-cockatoo species. Key references include:

- Action plans (Garnett et al. 2011);
- Recovery plans (Cale 2003; DEC 2007; DEC 2012);
- EPBC guidelines (DEWHA 2010);
- Commonwealth listing and conservation advice (DEWHA 2009a, b);
- The federal Department of Sustainability, Environment, Water, Population and Communities' (SEWPaC; formerly DEWHA) Species Profile and Threats (SPRAT) Database (DSEWPaC 2012a, b, c);
- Scientific literature (Davies 1966; Saunders 1974, 1979a, b, 1980; Saunders et al. 1982; Saunders 1986; Johnstone and Storr 1998; Higgins 1999; Johnstone and Kirkby 1999, 2008); and
- Major reports (Johnstone et al. 2011; Kabat et al. 2012).

Much of this information has been compiled by DSEWPaC (2012a, b, c, d). Summarising this work further, there are several salient points for assessing the potential value of the project area for black-cockatoos:

Key ecology

- All species are long-lived with low annual reproduction rates and cannot, therefore, rapidly increase their population size.
- Carnaby's and Baudin's Black-Cockatoos undergo regular, seasonal migration between breeding and non-breeding areas.

- Forest Red-tailed Black-Cockatoos are currently considered not to undergo regular migration. In recent years there appears to have been a distinct expansion of the range of this species on to the Swan Coastal Plain, including many suburbs within the Perth metropolitan area.
- In recent years there have been considerable shifts in the breeding ecology, distribution and movement patterns of Forest Red-tailed and Carnaby's Black-Cockatoos. These may be a response to habitat degradation/clearing and/or climatic factors.

Key habitat requirements

- All species are reliant on large tree-hollows in eucalypts, in which they breed. Each species has its own preference for nesting tree species and its own geographical breeding range (although these overlap between species). There is a solid understanding of these preferences (see Table ii for summary).
- All species primarily feed on plant seeds and flowers, but also consume wood-boring insect larvae when available. Each species has its own preference for food plant species (with considerable overlap). There is a solid understanding of these preferences (see Table ii for summary).

Key threats

- Key threatening processes include illegal shooting, habitat loss, habitat degradation, nest hollow shortage, competition for available nest hollows from other parrots and feral Honeybees (Apis mellifera), and illegal trade.

Nesting tree size and hollow dimensions

Black-cockatoos require tree hollows that have an entrance diameter of more than 100 mm (Whitford 2001). Internal dimensions may be more important than entrance diameter, although these are much more difficult to assess (Whitford 2001; Gibbons and Lindenmayer 2002; Whitford and Williams 2002). For Forest Red-tailed Black-Cockatoos, the minimum height of a nesting hollow was 4.4 m above the ground (Whitford 2001). The minimum diameter at breast height (DBH) of a nesting tree was 608 mm and the minimum age of an actual nesting tree was 214 years (Whitford 2002). In the study by Whitford and Williams (2002) the youngest tree to bear a hollow that was potentially suited to Forest Red-tailed Black-Cockatoos was 131 years (although this was not used). In general, hollows of sufficient size to support black-cockatoos do not form until trees at least 230 years old, and the majority of nests are found in 300-500 year old trees (Johnstone 2006). DSEWPaC (2010, 2011, 2012a, b, c, d) recommend that surveys for potential hollow-bearing trees should identify trees greater than 500 mm DBH (to include trees that are likely to become hollow-bearing in the next 50 years).

Table ii. Plants known to be used for foraging, roosting and nesting by black-cockatoos in south-western Western Australia. Data compiled from the literature (Davies 1966; Saunders 1974, 1979a, b, 1980; Saunders et al. 1982; Saunders 1986; Johnstone and Storr 1998; Higgins 1999; Johnstone and Kirkby 1999, 2008; Groom 2011; Johnstone et al. 2011; DSEWPaC 2012a, b; c, R. Johnstone pers. comm.).

FRTBC = Forest Red-tailed Black-Cockatoo, CBC = Carnaby's Black-Cockatoo, BBC = Baudin's Black-Cockatoo.

Plant status: blank = Western Australian native, AN = Australian native (but not naturally occurring in Western Australia), E = exotic (i.e. not native to Australia).

F = foraging, R = roosting, N or n = nesting (main and less commonly used species, respectively).

Plant species present within the study directly relevant to Black Cockatoos are highlighted.

Plant Species	Plant Status	FRTBC	CBC	BBC
Acacia baileyana (Cootamundra Wattle)	AN		F	
Acacia pentadenia (Karri Wattle)			F	
Acacia saligna (Orange Wattle)			F	
Agonis flexuosa (Peppermint Tree)			F	
Allocasuarina fraseriana (Sheoak)		F		F
Anigozanthos flavidus (Tall Kangaroo Paw)				F
Araucaria heterophylla (Norfolk Island Pine)	E		F	
Banksia ashbyi (Ashby's Banksia)			F	
Banksia attenuata (Slender Banksia)			F	
Banksia baxteri (Baxter's Banksia)			F	
Banksia carlinoides (Pink Dryandra)			F	
Banksia coccinea (Scarlet Banksia)			F	
Banksia dallanneyi (Couch Honeypot Dryandra)			F	
Banksia ericifolia (Heath-leaved Banksia)	AN		F	
Banksia fraseri (Dryandra)			F	
Banksia gardneri (Prostrate Banksia)			F	
Banksia grandis (Bull Banksia)			F	F
Banksia hookeriana (Hooker's Banksia)			F	
Banksia ilicifolia (Holly Banksia)			F	F
Banksia kippistiana (Dryandra)			F	
Banksia leptophylla			F	
Banksia lindleyana (Porcupine Banksia)				F
Banksia littoralis (Swamp Banksia)			F	F
Banksia menziesii (Firewood or Menzie's Banksia)			F	
Banksia mucronulata (Swordfish Dryandra)			F	
Banksia nivea (Honeypot Dryandra)			F	
Banksia nobilis (Golden Dryandra)			F	
Banksia praemorsa (Cut-leaf Banksia)			F	F
Banksia prionotes (Acorn Banksia)			F	

Plant Species	Plant Status	FRTBC	CBC	BBC
Banksia quercifolia (Oak-leaved Banksia)			F	F
Banksia sessilis (Parrot Bush)			F	F
Banksia speciosa (Showy Banksia)			F	
Banksia squarrosa (Pingle)			F	F
Banksia tricuspis (Lesueur Banskia or Pine Banksia)			F	
Banksia undata (Urchin or Cut-leaf Dryandra)			F	
Banksia verticillata (Granite Banksia)			F	
Brassica campestris (Canola, Rape)	E		F	
Callistemon spp.				F
Callistemon viminalis (Captain Cook Bottlebrush)	AN		F	
Callitris sp.			F	
Carya illnoinensis (Pecan)	E		F	F
Casuarina cunninghamiana (River Sheoak)	AN		F	
Citrullus lanatus (Pie or Afghan Melon)	E		F	
Corymbia calophylla (Marri)		F,N	F,n,R	F,n
Corymbia ficifolia (Red Flowering Gum)			F	
Corymbia haematoxylon (Mountain Marri)			F	
Corymbia maculata (Spotted Gum)			R	
Darwinia citriodora (Lemon-scented Darwinia)	AN		F	F
Diospryros sp. (Sweet Persimmon)	E		F	F
Eremophila glabra (Tarbush)			F	
Erodium aureum (Corkscrew Grass or Storksbill)	E		F	
Erodium botrys (Corkscrew Grass or Storksbill)	E		F	F
Eucalyptus caesia (Silver Princess)			F	
Eucalyptus camaldulensis (River Red Gum)	AN		R	
Eucalyptus citriodora (Lemon Scented Gum)	AN	F	F,R	F
Eucalyptus diversicolor (Karri)		n	n	N
Eucalyptus globulus (Tasmanian Blue Gum)	AN		R	
Eucalyptus gomphocephala (Tuart)		n	F,n,R	
Eucalyptus grandis (Flooded Gum, Rose Gum)	AN		R	
Eucalyptus longicornis (Red Morrell)			n	
Eucalyptus loxophleba (York Gum)			F,n	
Eucalyptus marginata (Jarrah)		F,N	F,n,R	F
Eucalyptus megacapa (Bullich)		n		n
Eucalyptus occidentalis (Swamp Yate)			n	
Eucalyptus patens (Blackbutt)		F	F,R	

Plant Species	Plant Status	FRTBC	CBC	BBC
Eucalyptus pleurocarpa (Tallerack)			F	
Eucalyptus preissiana (Bell-fruited Mallee)			F	
Eucalyptus robusta (Swamp Mahogany)			F,R	
Eucalyptus rudis (Flooded Gum)			n,R	
Eucalyptus salmonophloia (Salmon Gum)			F,N	
Eucalyptus salubris (Gimlet)			n	
Eucalyptus todtiana (Coastal Blackbutt or Prickley Bark)			F	
Eucalyptus wandoo (Wandoo)			F,N,R	F,n
Ficus sp. (Fig)			F	
Grevillea armigera (Prickly Toothbrushes)			F	
Grevillea bipinnatifida (Fuschia Grevillea)			F	
Grevillea hookeriana (Red Toothbrushes)			F	
Grevillea hookeriana subsp. apiciloba (Black Toothbrushes)			F	
Grevillea paniculata (Kerosene Bush)			F	
Grevillea paradoxa (Bottlebrush Grevillea)			F	
Grevillea petrophiloides (Pink Poker)			F	
Grevillea robusta (Silky Oak)			F	
Grevillea wilsonii (Native Fuchsia)				F
Hakea auriculata			F	
Hakea candolleana			F	
Hakea circumalata (Coastal Hakea)			F	
Hakea commutata			F	
Hakea conchifolia			F	
Hakea costata (Ribbed Hakea)			F	
Hakea cristata (Snail Hakea)			F	F
Hakea cucullata (Snail Hakea)			F	
Hakea cyclocarpa (Ramshorn)			F	
Hakea eneabba			F	
Hakea erinacea (Hedgehog Hakea)			F	F
Hakea falcata (Sickle Hakea)			F	
Hakea flabellifolia (Fan-leaved Hakea)			F	
Hakea gilbertii			F	
Hakea incrassata (Golfball or Marble Hakea)			F	
Hakea lasiantha (Woolly Flowered Hakea)			F	
Hakea lasianthoides			F	F

Plant Species	Plant Status	FRTBC	CBC	BBC
Hakea laurina (Pin-cushion hakea)			F	
Hakea lissocarpha (Honeybush)			F	F
Hakea marginata				F
Hakea megalosperma (Lesueur Hakea)			F	
Hakea multilineata (Grass Leaf Hakea)			F	
Hakea obliqua (Needles and Corks)			F	
Hakea oleifolia (Dungyn or Olive-leaved Hakea)			F	
Hakea pandanicarpa subsp. crassifolia (Thick-leaved Hakea)			F	
Hakea petiolaris (Sea Urchin Hakea)			F	
Hakea polyanthema			F	
Hakea preissii (Needle Tree)			F	
Hakea prostrata (Harsh Hakea)			F	F
Hakea psilorrhyncha			F	
Hakea ruscifolia (Candle Hakea)			F	F
Hakea scoparia (Kangaroo Bush)			F	
Hakea smilacifolia			F	
Hakea spathulata			F	
Hakea stenocarpa (Narrow-fruited Hakea)			F	F
Hakea sulcata (Furrowed Hakea)			F	
Hakea trifurcata (Two-leaved Hakea)			F	F
Hakea undulata (Wavy-leaved Hakea)			F	
Hakea varia (Variable-leaved Hakea)			F	F
Helianthus annuus (Sunflower)	E		F	
Hibiscus sp. (Hibiscus)	E		F	
Isopogon scabriusculus			F	
Jacaranda mimosifolia (Jacaranda)	E		F	F
Jacksonia furcellata (Grey Stinkwood)			F	
Kingia australis (Kingia)				F
Lambertia inermis (Chittick)			F	
Lambertia multiflora (Many-flowered Honeysuckle)			F	
Liquidamber styraciflua (Liquid Amber)	E		F	
Lupinus sp. (Lupin)	E		F	
Macadamia integrifolia (Macadamia)	E		F	F
Malus domestica (Apple)	E		F	F
Melaleuca leuropoma			F	

Plant Species	Plant Status	FRTBC	CBC	BBC
Melia azedarach (Cape Lilac or White Cedar)	E	F	F	
Mesomeleana sp.			F	
Persoonia longifolia (Snottygobble)		F		
Pinus canariensis (Canary Island Pine)	E		F	
Pinus caribea (Caribbean Pine)	E		F	
Pinus pinaster (Pinaster or Maritime Pine)	E		F,R	
Pinus radiata (Radiata Pine)	E		F,R	F
Protea 'Pink Ice'	E		F	
Protea repens	E		F	
Prunus amygdalus (Almond Tree)	E		F	
Pyrus communis (European Pear)	E			F
Quercus spp. (Oak spp.)	E			F
Raphanus raphanistrum (Wild Radish)	E		F	
Reedia spathacea				F
Tipuana tipu (Tipu or Rosewood Tree)	E		F	
Xanthorrhoea preissii (Grass Tree)			F	F

Appendix 2. Explanation of fauna values.

Fauna values are the features of a site and its fauna that contribute to biodiversity, and it is these values that are potentially at threat from a development proposal. Fauna values can be examined under the five headings outlined below. It must be stressed that these values are interdependent and should not be considered equal, but contribute to an understanding of the biodiversity of a site. Understanding fauna values provides opportunities to predict and therefore mitigate impacts.

Assemblage characteristics

Uniqueness. This refers to the combination of species present at a site. For example, a site may support an unusual assemblage that has elements from adjacent biogeographic zones, it may have species present or absent that might be otherwise expected, or it may have an assemblage that is typical of a very large region. For the purposes of impact assessment, an unusual assemblage has greater value for biodiversity than a typical assemblage.

Completeness. An assemblage may be complete (i.e. has all the species that would have been present at the time of European settlement), or it may have lost species due to a variety of factors. Note that a complete assemblage, such as on an island, may have fewer species than an incomplete assemblage (such as in a species-rich but degraded site on the mainland).

Richness. This is a measure of the number of species at a site. At a simple level, a species rich site is more valuable than a species poor site, but value is also determined, for example, by the sorts of species present.

Vegetation/substrate associations (VSAs)

VSAs combine broad vegetation types, the soils or other substrate with which they are associated, and the landform. In the context of fauna assessment, VSAs are the environments that provide habitats for fauna. The term habitat is widely used in this context, but by definition an animal's habitat is the environment that it utilises (Calver et al. 2009), not the environment as a whole. Habitat is a function of the animal and its ecology, rather than being a function of the environment. For example, a species may occur in eucalypt canopy or in leaf-litter on sand, and that habitat may be found in only one or in several VSAs. VSAs are not the same as vegetation types since these may not incorporate soil and landform, and recognise floristics to a degree that VSAs do not. Vegetation types may also not recognise minor but often significant (for fauna) structural differences in the environment. VSAs also do not necessarily correspond with soil types, but may reflect some of these elements.

Because VSAs provide the habitat for fauna, they are important in determining assemblage characteristics. For the purposes of impact assessment, VSAs can also provide a surrogate for detailed information on the fauna assemblage. For example, rare, relictual or restricted VSAs should automatically be considered a significant fauna value. Impacts may be significant if the VSA is rare, a large proportion of the VSA is affected and/or the VSA supports significant fauna. The disturbance of even small amounts of habitat in a localised area can have significant impacts to fauna if rare or unusual habitats are disturbed.

Patterns of biodiversity across the landscape

This fauna value relates to how the assemblage is organised across the landscape. Generally, the fauna assemblage is not distributed evenly across the landscape or even within one VSA. There may be zones of high biodiversity such as particular environments or ecotones (transitions between VSAs). There may also be zones of low biodiversity. Impacts may be significant if a wide range of species is affected even if most of those species are not significant per se.

Species of conservation significance

Species of conservation significance are of special importance in impact assessment. The conservation status of fauna species in Australia is assessed under Commonwealth and State Acts such as the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and the Western Australian Wildlife Conservation Act 1950 (Wildlife Conservation Act). In addition, the Western Australian Department of Environment and Conservation (DEC) recognises priority levels, while local populations of some species may be significant even if the species as a whole has no formal recognition. Therefore, three broad levels of conservation significance can be recognised and are used for the purposes of this report, and are outlined below. A full description of the conservation significance categories, schedules and priority levels mentioned below is provided in Appendix 3.

<u>Conservation Significance (CS) 1: Species listed under State or Commonwealth Acts.</u>

Species listed under the EPBC Act are assigned to categories recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994), or are listed as migratory. Migratory species are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA), the Republic of South Korea Australia Migratory Bird Agreement (ROKAMBA), and/or the Convention on the Conservation of Migratory Species of Wild Animals (CMS; also referred to as the Bonn Convention). The Wildlife Conservation Act uses a series of Schedules to classify status, but also recognizes the IUCN categories and ranks species within the Schedules using the categories of Mace and Stuart (1994).

<u>Conservation Significance (CS) 2: Species listed as Priority by the DEC but not listed under State or Commonwealth Acts.</u>

In Western Australia, the DEC has produced a supplementary list of Priority Fauna, being species that are not considered threatened under the Wildlife Conservation Act but for which the DEC feels there is cause for concern. Some Priority species are also assigned to the Conservation Dependent category of the IUCN.

<u>Conservation Significance (CS) 3: Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.</u>

This level of significance has no legislative or published recognition and is based on interpretation of distribution information, but is used here as it may have links to preserving biodiversity at the genetic level (EPA 2002). If a population is isolated but a subset of a widespread (common) species, then it may not be recognised as threatened, but may have unique genetic characteristics. Conservation significance is applied to allow for the preservation of genetic richness at a population level, and not just at a species level. Species on the edge of their range, or that are sensitive to impacts such as habitat fragmentation, may also be classed as CS3, as may colonies of waterbirds. The Western Australian Department of Environmental Protection, now DPaW, used this sort of interpretation to identify significant bird species in the Perth metropolitan area as part of the Perth Bushplan (DEP 2000).

Invertebrate species considered to be short range endemics (SREs) also fall within the CS3 category, as they have no legislative or published recognition and their significance is based on interpretation of distribution information. Harvey (2002) notes that the majority of species that have been classified as short-range endemics have common life history characteristics such as poor powers of dispersal or confinement to discontinuous habitats. Several groups, therefore, have particularly high instances of short-range endemic species: Gastropoda (snails and slugs), Oligochaeta (earthworms), Onychophora (velvet worms), Araneae (mygalomorph spiders), Pseudoscorpionida (pseudoscorpions), Schizomida (schizomids), Diplopoda (millipedes), Phreatoicidea (phreatoicidean crustaceans), and Decapoda (freshwater crayfish). The poor understanding of the taxonomy of many of the short-range endemic species hinders their conservation (Harvey 2002).

Introduced species

In addition to these conservation levels, species that have been introduced (INT) are indicated throughout the report. Introduced species may be important to the native fauna assemblage through effects by predation and/or competition.

Ecological processes upon which the fauna depend

These are the processes that affect and maintain fauna populations in an area and as such are very complex; for example, populations are maintained through the dynamic of mortality, survival and recruitment being more or less in balance, and these are affected by a myriad of factors. The dynamics of fauna populations in a project may be affected by processes such as fire regime, landscape patterns (such as fragmentation and/or linkage), the presence of feral species and hydrology. Impacts may be significant if processes are altered such that fauna populations are adversely affected, resulting in declines and even localised loss of species. Threatening processes as outlined below are effectively the ecological processes that can be altered to result in impacts upon fauna.

Appendix 3. Categories used in the assessment of conservation status.

IUCN categories (based on review by Mace and Stuart 1994) as used for theEnvironment Protection and Biodiversity Conservation Act 1999 and the Western Australian Wildlife Conservation Act 1950.

Extinct	Taxa not definitely located in the wild during the past 50 years.
Extinct in the Wild (Ex)	Taxa known to survive only in captivity.
Critically Endangered (CR)	Taxa facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (E)	Taxa facing a very high risk of extinction in the wild in the near future.
Vulnerable (V)	Taxa facing a high risk of extinction in the wild in the medium-term future.
Near Threatened	Taxa that risk becoming Vulnerable in the wild.
Conservation Dependent	Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened.
Data Deficient (Insufficiently Known)	Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.
Least Concern.	Taxa that are not Threatened.

Schedules used in the WA Wildlife Conservation Act 1950

Schedule 1 (S1)	Critically Endangered fauna.
Schedule 2 (S2)	Endangered fauna
Schedule 3 (S3)	Vulnerable Migratory species listed under international treaties.
Schedule 4 (S4)	Presumed extinct fauna
Schedule 5 (S5)	Migratory birds under international agreement
Schedule 6 (S6)	Conservation dependant fauna
Schedule 7 (S7)	Other specially protected fauna

WA Department of Environment and Conservation Priority species (species not listed under the Wildlife Conservation Act 1950, but for which there is some concern).

Priority 1 (P1)	Taxa with few, poorly known populations on threatened lands.
Priority 2 (P2)	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3 (P3)	Taxa with several, poorly known populations, some on conservation lands.
Priority 4. (P4)	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change.
Priority 5 (P5)	Taxa in need of monitoring. Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years (IUCN Conservation Dependent).

Appendix 4. Ecological and threatening processes identified under legislation and in the literature.

Ecological processes are processes that maintain ecosystems and biodiversity. They are important for the assessment of impacts of development proposals, because ecological processes make ecosystems sensitive to change. The issue of ecological processes, impacts and conservation of biodiversity has an extensive literature. Following are examples of the sorts of ecological processes that need to be considered.

Ecological processes relevant to the conservation of biodiversity in Australia(Soule et al. 2004):

- Critical species interactions (highly interactive species);
- Long distance biological movement;
- Disturbance at local and regional scales;
- Global climate change;
- Hydroecology;
- Coastal zone fluxes;
- Spatially-dependent evolutionary processes (range expansion and gene flow); and
- Geographic and temporal variation of plant productivity across Australia.

Threatening processes (EPBC Act)

Under the EPBC Act, a key threatening process is an ecological interaction that threatens or may threaten the survival, abundance or evolutionary development of a threatened species or ecological community. There are currently 20 key threatening processes listed by the federal Department of the Environment (DotE 2014b):

- Competition and land degradation by rabbits.
- Competition and land degradation by unmanaged goats.
- Dieback caused by the root-rot fungus (Phytophthora cinnamomi).
- Incidental catch (bycatch) of Sea Turtle during coastal otter-trawling operations within Australian waters north of 28 degrees South.
- Incidental catch (or bycatch) of seabirds during oceanic longline fishing operations.
- Infection of amphibians with chytrid fungus resulting in chytridiomycosis.
- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris.
- Invasion of northern Australia by Gamba Grass and other introduced grasses.
- Land clearance.
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants.
- Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (Anoplolepis gracilipes) on Christmas Island, Indian Ocean.
- Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases.
- Novel biota and their impact on biodiversity.
- Predation by European red fox.
- Predation by exotic rats on Australian offshore islands of less than 1000 km^2 (100,000 ha).
- Predation by feral cats.

- Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs.
- Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species.
- The biological effects, including lethal toxic ingestion, caused by Cane Toads (Bufo marinus).
- The reduction in the biodiversity of Australian native fauna and flora due to the red imported fire ant, Solenopsis invicta (fire ant).

General processes that threaten biodiversity across Australia (The National Land and Water Resources Audit):

- Vegetation clearing;
- Increasing fragmentation, loss of remnants and lack of recruitment;
- Firewood collection;
- Grazing pressure;
- Feral animals;
- Exotic weeds;
- Changed fire regimes;
- Pathogens;
- Changed hydrology—dryland salinity and salt water intrusion;
- Changed hydrology— such as altered flow regimes affecting riparian vegetation; and
- Pollution.

In addition to the above processes, DSEWPaC has produced Significant Impact Guidelines that provide criteria for the assessment of the significance of impacts. These criteria provide a framework for the assessment of significant impacts. The criteria are listed below.

- Will the proposed action lead to a long-term decrease in the size of a population?
- Will the proposed action reduce the area of occupancy of the species?
- Will the proposed action fragment an existing population?
- Will the proposed action adversely affect habitat critical to the survival of a species?
- Will the proposed action disrupt the breeding cycle of a population?
- Will the proposed action modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?
- Will the proposed action result in introducing invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat?
- Will the proposed action introduce disease that may cause the species to decline?
- Will the proposed action interfere with the recovery of the species?

Appendix 5. Vertebrate Fauna expected to occur in the Upper Swan site.

These lists are derived from the results of database and literature searches and from previous field surveys conducted in the local area. These are:

- Naturamap = Naturemap Database, searched February 2017;
- BA = Birdlife Australia's Birdata database, searched February 2017;
- EPBC = EPBC Protected Matters Search, searched February 2017;

Status codes:

- CS1, CS2, CS3 = (summary) levels of conservation significance. See Appendix 2 for full explanation.
- EPBC Act listings: E = Endangered, V = Vulnerable, M = Migratory (see Appendix 3).
- Wildlife Conservation Act listings: for all CS1 species S1 to 7 = Schedules 1 to 7 respectively, (see Appendix 3) with rankings shown in square parentheses: [e] = endangered, [v] = vulnerable.
- DEC Priority species: P1 to P5 = Priority 1 to 5 (see Appendix 3).
- LS= considered to be of local significance by Bamford Consulting Ecologists (Appendix 2).

Table 8. Species expected to occur in the survey area.

Fish Species	Cons. Signif.	Database searches	BCE	Status in Study area
Gobionellinae (gobies)				
Swan River Goby *Pseudogobius olorum*		√		resident
Galaxiidae (minnows)				
Western Minnow *Galaxia occidentalis*		√		Occasional visitor
Poeciliidae (mosquito fish)				
Mosquito Fish *Gambusia holbrooki*	INT	√	√	resident
Cyprinidae (goldfish and carp)				
Goldfish *Carassius auratus*	INT	√		resident
Carp *Cyprinus carpio*	INT	√		resident
Total		5	1	

Frog Species	Cons. Signif.	Database searches	BCE	Status in Study area
Hylidae (tree-frogs)				
Slender Tree-Frog *Litoria adelaidensis*		√	√	resident
Motorbike Frog *Litoria moorei*		√		resident
Myobatrachidae (ground frogs)				
Clicking Frog *Crinia glauerti*		√		resident
Squelching Froglet *Crinia insignifera*		√		vagrant
Moaning Frog *Heleioporus eyrei*		√		resident
Banjo Frog *Limnodynastes dorsalis*		√	√	resident
Total	0	6	2	

Reptile Species	Cons. Signif	Database	BCE	Status in Study area
Cheluidae (side-necked tortoises)				
Long-necked Tortoise *Chelodina collei*		√		resident
Gekkonidae (geckoes)				
Marbled Gecko *Christinus marmoratus*		√		resident
Spiny-tailed Gecko *Strophurus spinigerus*		√		resident
Pygopodidae (legless lizards)				
Sandplain Worm Lizard *Aprasia repens*		√		vagrant
Agamidae (dragon lizards)				
Western Bearded Dragon *Pogona minor*		√		vagrant
Varanidae (monitors or goannas)				
Gould's Sand Goanna *Varanus gouldii*		√		vagrant
Scincidae (skinks)				
South-west Cool Skink *Acritoscincus trilineatum*		√		resident
Fence Skink *Cryptoblepharus buchananii*		√	√	resident
West Coast Ctenotus *Ctenotus fallens*		√		vagrant
King's Skink *Egernia kingii*		√		occasional visitor
Mourning Skink *Egernia luctuosa*		√		vagrant
Two-toed Skink *Hemiergis quadrilineata*		√	√	resident
Four-toed Lerista *Lerista elegans*		√		resident
Common Dwarf Skink *Menetia greyii*		√	√	resident
Spotted Morethia *Morethia lineoocellata*		√		vagrant
Shrubland Morethia *Morethia obscura*		√		vagrant
Bobtail *Tiliqua rugosa*		√		resident
Typhlopidae (blind snakes)				
Southern Blind Snake *Anilios australis*		√		occasional visitor
Elapidae (front-fanged snakes)				
Tiger Snake *Notechus scutatus*		√		occasional visitor
Dugite *Pseudonaja affinis*		√		regular visitor
Total	**0**	**20**	**3**	

Bird Species	Cons. Signif.	Database	BCE	Status in Study area
Phasianidae (quails)				
Brown Quail *Coturnix ypsilophora*		√		vagrant
Stubble Quail *Coturnix pectoralis*		√		vagrant
Anatidae (ducks, geese, teal)				
Black Swan *Cygnus atratus*		√		regular visitor
Chestnut Teal *Anas castanea*		√		occasional visitor

Bird Species	Cons. Signif.	Database	BCE	Status in Study area
Grey Teal *Anas gracilis*		√	√	resident
Domestic Waterfowl (domestic ducks and geese of several species)	INT	√		regular visitor
Australasian Shoveler *Anas rhynchotis*		√		occasional visitor
Pacific Black Duck *Anas superciliosa*		√	√	resident
Blue-billed Duck *Oxyura australis*	CS2, P4	√		occasional visitor
Hardhead (White-eyed Duck) *Aythya australis*		√		occasional visitor
Musk Duck *Biziura lobata*	CS3	√		regular visitor
Australian Wood Duck *Chenonetta jubata*		√	√	resident
Pink-eared Duck *Malacorhynchus membranaceus*	CS3	√	√	regular visitor
Freckled Duck *Stictonetta naevosa*	CS3	√		Occasional visitor
Australian Shelduck *Tadorna tadornoides*		√		regular visitor
Anhingidae (darters)				
Darter *Anhinga melanogaster*		√		occasional visitor
Phalacrocoracidae (cormorants)				
Great Cormorant *Phalacrocorax carbo*		√		occasional visitor
Pied Cormorant *Phalacrocorax varius*		√		occasional visitor
Little Black Cormorant *Phalacrocorax sulcirostris*		√		occasional visitor
Little Pied Cormorant *Phalacrocorax melanoleucos*		√		occasional visitor
Podicepididae (grebes)				
Great Crested Grebe *Podiceps cristatus*		√		occasional visitor
Hoary-headed Grebe *Poliocephalus poliocephalus*		√		occasional visitor
Australasian Grebe *Tachybaptus novaehollandiae*		√	√	resident
Pelecanoididae (pelicans)				
Australian Pelican *Pelecanus conspicillatus*		√		regular visitor
Ardeidae (herons and egrets)				
White-faced Heron *Egretta novaehollandiae*		√	√	regular visitor
White-necked Heron *Ardea pacifica*		√		Occasional vagrant
Eastern Great Egret *Ardea modesta*	CS1	√		regular visitor
Cattle Egret *Ardea ibis*	CS1	√		vagrant
Little Egret *Egretta garzetta*	CS1	√		vagrant
Nankeen Night Heron *Nycticorax caledonicus*		√		regular visitor
Threskionithidae (ibis and spoonbills)				
Australian White Ibis *Threskiornis molucca*		√	√	regular visitor
Glossy Ibis *Plegadis falcinellus*		√		vagrant
Straw-necked Ibis *Threskiornis spinicollis*		√		regular visitor
Yellow-billed Spoonbill *Platalea flavipes*		√	√	regular visitor
Rallidae (crakes and rails)				
Buff-banded Rail *Rallus philippensis*		√		occasional visitor
Baillon's Crake *Porzana pusilla*		√		occasional visitor
Australian Spotted Crake *Porzana fluminea*		√		occasional visitor

Bird Species	Cons. Signif.	Database	BCE	Status in Study area
Spotless Crake *Porzana tabuensis*		√		occasional visitor
Dusky Moorhen *Gallinula tenebrosa*		√	√	resident
Purple Swamphen *Porphyrio porphyrio*		√		resident
Eurasian Coot *Fulica atra*		√	√	resident
Recurvirostridae (stilts and avocets)				
Black-winged Stilt *Himantopus himantopus*		√		regular visitor
Banded Stilt *Cladorhynchus leucocephalus*		√		vagrant
Red-necked Avocet *Recurvirostra novaehollandiae*		√		vagrant
Charadriidae (lapwings and plovers)				
Grey Plover *Pluvialis squatarola*	CS1	√		vagrant
Red-capped Plover *Charadrius ruficapillus*		√		vagrant
Black-fronted Dotterel *Elseyornis melanops*		√		vagrant
Red-kneed Dotterel *Erythrogonys cinctus*		√		vagrant
Banded Lapwing *Vanellus tricolor*		√		vagrant
Scolopacidae (sandpipers and stints)				
Common Sandpiper *Acticus hypoleucos*	CS1	√		occasional visitor
Red-necked Stint *Calidris ruficollis*	CS1	√		vagrant
Sharp-tailed Sandpiper *Calidris acuminata*	CS1	√		vagrant
Curlew Sandpiper *Calidris ferruginea*	CS1	√		vagrant
Common Greenshank *Tringa nebularia*	CS1	√		occasional visitor
Laridae (gulls and terns)				
Whiskered Tern *Chilidonias hybrida*		√		occasional visitor
Crested Tern *Thalasseus bergii*		√		occasional visitor
Caspian Tern *Hydroprogne caspia*	CS1	√		occasional visitor
Silver Gull *Chroicocephalus novaehollandiae*		√		regular visitor
Columbidae (pigeons and doves)				
Rock Dove (Domestic Pigeon) *Columba livia*	INT	√		regular visitor
Laughing Dove *Streptopelia senegalensis*	INT	√		resident
Spotted Dove *Streptopelia chinensis*	INT	√	√	resident
Common Bronzewing *Phaps chalcoptera*	CS3	√		occasional visitor
Crested Pigeon *Ocyphaps lophotes*		√		occasional visitor
Podargidae (frogmouths)				
Tawny Frogmouth *Podargus strigoides*		√		occasional visitor
Apodidae (swifts)				
Fork-tailed Swift *Apus pacificus*	CS1	√		migrant
Pandionidae (ospreys)				
Eastern Osprey *Pandion cristatus*		√		occasional visitor
Accipitridae (kites, hawks and eagles)				
Black-shouldered Kite *Elanus axillaris*		√		occasional visitor
Square-tailed Kite *Lophoictinia isura*				occasional visitor
Whistling Kite *Haliastur sphenurus*		√		occasional visitor

Bird Species	Cons. Signif.	Database	BCE	Status in Study area
Swamp Harrier *Circus approximans*		√		occasional visitor
Brown Goshawk *Accipiter fasciatus*	CS3	√		occasional visitor
Collared Sparrowhawk *Accipiter cirrhocephalus*	CS3	√		resident
White-bellied Sea-Eagle *Haliaeetus leucogaster*	CS3	√		occasional visitor
Little Eagle *Hieraaetus morphnoides*	CS3	√		occasional visitor
Falconidae (falcons)				
Peregrine Falcon *Falco peregrinus*	CS1	√		occasional visitor
Australian Hobby *Falco longipennis*		√		occasional visitor
Brown Falcon *Falco berigora*				occasional visitor
Nankeen Kestrel *Falco cenchroides*		√		occasional visitor
Cacatuidae (cockatoos)				
Carnaby's Black-Cockatoo *Calyptorhynchus latirostris*	CS1	√	√	regular visitor
Baudin's Black-Cockatoo *Calyptorhynchus baudinii*	CS1	√		occasional visitor
Forest Red-tailed Black-Cockatoo *Calyptorhynchus banksii naso*	CS1	√	√	regular visitor
Sulphur-crested Cockatoo *Cacatua galerita*	INT	√		vagrant
Galah *Cacatua roseicapilla*		√	√	regular visitor
Eastern Long-billed Corella *Cacatua tenuirostris*	INT	√		regular visitor
Western Corella *Cacatua pastinator*		√		occasional visitor
Little Corella *Cacatua sanguinea*		√	√	regular visitor
Psittacidae (lorikeets and parrots)				
Rainbow Lorikeet *Trichoglossus haematodus*	INT	√	√	regular visitor
Australian Ringneck *Barnardius zonarius*		√	√	regular visitor
Red-capped Parrot *Purpureicephalus spurius*		√	√	regular visitor
Cuculidae (cuckoos)				
Fan-tailed Cuckoo *Cacomantis flabelliformis*		√		occasional visitor
Pallid Cuckoo *Cuculus pallidus*		√		occasional visitor
Horsfield's Bronze-Cuckoo *Chrysococcyx basalis*		√		occasional visitor
Shining Bronze-Cuckoo *Chrysococcyx lucidus*		√		occasional visitor
Strigidae (hawk-owls)				
Southern Boobook *Ninox novaeseelandiae*		√		resident
Tytonidae (barn owls)				
Barn Owl *Tyto alba*		√		occasional visitor
Halcyonidae (forest kingfishers)				
Sacred Kingfisher *Todiramphus sanctus*		√	√	regular visitor
Laughing Kookaburra *Dacelo novaeguineae*	INT	√	√	resident
Meropidae (bee-eaters)				
Rainbow Bee-eater *Merops ornatus*	CS3	√	√	migrant
Maluridae (fairy-wrens)				
Splendid Fairy-wren *Malurus splendens*	CS3	√		occasional visitor

Bird Species	Cons. Signif.	Database	BCE	Status in Study area
White-winged Fairy-wren *Malurus leucopterus*	CS3	√		occasional visitor
Pardalotidae (pardalotes)				
Striated Pardalote *Pardalotus striatus*		√	√	resident
Spotted Pardalote *Pardalotus punctatus*		√		Regular visitor
White-browed Scrubwren *Sericornis frontalis*	CS3	√		Occasional visitor
Weebill *Smicrornis brevirostris*	CS3	√	√	resident
Western Gerygone *Gerygone fusca*		√	√	regular visitor
Inland Thornbill *Acanthiza apicalis*	CS3	√		vagrant
Yellow-rumped Thornbill *Acanthiza chrysorrhoa*	CS3	√		vagrant
Meliphagidae (honeyeaters)				
Red Wattlebird *Anthochaera carunculata*		√	√	resident
Western Wattlebird *Anthochaera lunulata*	CS3	√		occasional visitor
Singing Honeyeater *Lichenostomus virescens*		√	√	resident
Brown Honeyeater *Lichmera indistincta*		√		resident
White-naped Honeyeater *Melithreptus chloropsis*		√		occasional visitor
White-cheeked Honeyeater *Phylidonyris nigra*	CS3	√		occasional visitor
New Holland Honeyeater *P. novaehollandiae*	CS3	√	√	regular visitor
White-fronted Chat *Epthianura albifrons*		√		vagrant
Acrocephalidae (reed-warblers)				
Australian Reed-Warbler *Acrocephalus australis*		√		occasional visitor
Megaluridae (grassbirds)				
Little Grassbird *Megalurus gramineus*		√		occasional visitor
Rufous Songlark *Cincloramphus mathewsi*		√		vagrant
Brown Songlark *Cincloramphus cruralis*		√		vagrant
Zosteropidae (white-eyes)				
Silvereye *Zosterops lateralis*		√	√	regular visitor
Pachycephalidae (whistlers)				
Rufous Whistler *Pachycephala rufiventris*	CS3	√	√	regular visitor
Dicruridae (flycatchers)				
Magpie-lark *Grallina cyanoleuca*		√	√	resident
Grey Fantail *Rhipidura fuliginosa*		√	√	resident
Willie Wagtail *Rhipidura leucophrys*		√	√	resident
Neosittidae (sittella)				
Varied Sittella *Daphoenositta chrysoptera*	CS3	√		vagrant
Campephagidae (cuckoo-shrikes)				
Black-faced Cuckoo-shrike *C. novaehollandiae*		√		resident
White-winged Triller *Lalage sueurii*		√		vagrant
Artamidae (woodswallows)				
Black-faced Woodswallow *Artamus cinereus*	CS3	√		occasional visitor
Dusky Woodswallow *Artamus cyanopterus*				occasional visitor
Grey Butcherbird *Cracticus torquatus*		√		

Bird Species	Cons. Signif.	Database	BCE	Status in Study area
Australian Magpie *Gymnorhina tibicen*		√	√	resident
Corvidae (ravens and crows)				
Australian Raven *Corvus coronoides*		√	√	resident
Motacillidae (pipits and true wagtails)				
Australian Pipit *Anthus novaeseelandiae*		√		regular visitor
Dicaeidae (flower-peckers)				
Mistletoebird *Dicaeum hirundinaceum*		√		regular visitor
Hirundinidae (swallows)				
White-backed Swallow *Cheramoeca leucosternus*				occasional visitor
Welcome Swallow *Hirundo neoxena*		√		regular visitor
Tree Martin *Petrochelidon nigricans*		√		regular visitor
Fairy Martin *Petrochelidon ariel*		√		occasional visitor
Total expected	**34**	**133**	**34**	

Mammal Species	Cons. Signif.	Database	BCE	Status in study area
Phalangeridae (brushtail possums)				
Brush-tailed Possum *Trichosurus vulpecula*	CS3	√		occasional visitor
Mollosidae (mastiff bats)				
White-striped Bat *Tadarida australis*		√		regular visitor
Vespertilionidae (vesper bats)				
Southern Forest Bat *Vespadelus regulus*		√		occasional visitor
Gould's Wattled Bat *Chalinolobus gouldii*		√		regular visitor
Chocolate Wattled Bat *Chalinolobus morio*		√		occasional visitor
Lesser Long-eared Bat *Nyctophilus geoffroyi*		√		occasional visitor
Western False Pipistrelle *Falsistrellus mackenziei*	CS2, P4			occasional visitor
Muridae (rats and mice)				
House Mouse *Mus musculus*	INT	√		resident
Water-rat or Rakali *Hydromys chrysogaster*	CS2, P4	√		regular visitor
Brown Rat *Rattus norvegicus*	INT	√		resident
Black Rat *Rattus rattus*	INT	√		resident
Leporidae (rabbits and hares)				
Rabbit *Oryctolagus cuniculus*	INT	√		occasional visitor
Canidae (foxes and dogs)				
European Red Fox *Vulpes vulpes*	INT	√		regular visitor
Dog *Canis lupus*	INT	√		regular visitor
Felidae (cats)				
Feral Cat *Felis catus*	INT	√		regular visitor

Appendix 6. Vertebrate species returned in database searches but unlikely to occur in survey area.

Database searches often return species that may have been recorded historically but are now extinct in a region. Databases can also include species found nearby but unlikely to be present in the study area due to lack of suitable habitat (e.g. aquatic species) or ecological barriers preventing them from reaching the area (e.g. island species). There are also some errors, out-of-date Latin names, zoo specimens and subtleties of distribution that are not recognised in databases. All of the species listed below are considered unlikely to be found in the survey area (some species could occur as very rare vagrants).

Table 9. Species returned in database searches which are unlikely to occur in the survey area.

Common name	Latin name	Native / Introduced
	FISH	
Western Minnow	*Galaxias occidentalis*	Native
Black-striped Minnow	*Galaxiella nigrostriata*	Native
	REPTILES	
Western Swamp Tortoise	*Pseudemydura umbrina*	Native
Odd-striped Skink	*Ctenotus impar*	Native
Bold Striped Sand Skink	*Lerista christinae*	Native
West Coast Worm Skink	*Lerista praepedita*	Native
Western Bluetongue Skink	*Tiliqua occipitalis*	Native
Stone Gecko	*Diplodactylus granariensis*	Native
Granite Worm Lizard	*Aprasia pulchella*	Native
Keeled Legless Lizard	*Pletholax gracilis*	Native
Southern Heath Dragon	*Ctenophorus adelaidensis*	Native
Shovel-nosed Snake	*Brachyurophis semifasciatus*	Native
Black-striped Snake	*Neelaps calonotos*	Native
	BIRDS	
Black-faced Cormorant	*Phalacrocorax fuscescens*	Native
Grey Wagtail	*Motacilla cinerea*	Native
Malleefowl	*Leipoa ocellata*	Native
Australian Painted-snipe	*Rostratula australis*	Native
Hooded Plover	*Charadrius rubricollis*	Native
Blue-breasted Fairy-wren	*Malurus pulcherrimus*	Native
Jacky Winter	*Micrieca fascinans*	Native
European Goldfinch	*Carduelis carduelis*	Introduced
House Sparrow	*Passer domesticus*	Introduced
Common Starling	*Sturnus vulgaris*	Introduced
Common Blackbird	*Turdus merula*	Introduced
	MAMMALS	
Chuditch	*Dasyurus geoffroii*	Native
Bilby, Dalgyte or Walpiri	*Macrotis lagotis*	Native
Honey Possum	*Tarsipes rostratus*	Native
Black-flanked Rock-Wallaby	*Petrogale lateralis lateralis*	Native
Brush Wallaby	*Macropus irma*	Native
Pig	*Sus scrofa*	Introduced

Appendix 7. Scoring system for the assessment of Black-Cockatoo foraging values.

Site score	Description of vegetation		
	Carnaby's Black-Cockatoo	Baudin's Black-Cockatoo	Forest Red-tailed Black-Cockatoo
0	No foraging value. No Proteaceae, eucalypts or other potential sources of food. Examples would be salt lakes and bare ground.	No foraging value. No eucalypts or other potential sources of food.	No foraging value. No eucalypts (i.e. Marri, Jarrah, Wandoo, Blackbutt or Karri) or other potential sources of food.
1	Negligible to low foraging value. Scattered specimens of known food plants but projected foliage cover of these <2%. Could include urban areas with scattered foraging trees. Blue Gum plantations are considered to have a score of 1 as foraging by Black-Cockatoos has been reported but appears to be unusual.	Negligible to low foraging value. Scattered specimens of known food plants (e.g. Marri and Jarrah) but projected foliage cover of these <1%. Could include urban areas with scattered foraging trees.	Negligible to low foraging value. Scattered specimens of known food plants but projected foliage cover of these <1%. Could include urban areas with scattered foraging trees.
2	Low foraging value. Examples: Shrubland in which species of foraging value, such as shrubby banksias, with <10% projected foliage cover. Open eucalypt woodland/mallee of small-fruited species. Paddocks with melons or other weeds (a short-term, seasonal food source).	Low foraging value. Example: Woodland or forest with scattered specimens of known food plants (e.g. Marri and Jarrah) but projected foliage cover of these 1-<5%. Could include urban areas with scattered foraging trees.	Low foraging value. Examples: Open eucalypt woodland (i.e. Marri, Jarrah, Wandoo, Blackbutt or Karri). Projected foliage cover of these 1-<5% Urban areas with scattered food plants such as Cape Lilac, Euc. caesia and E. erythrocorys.
3	Low to Moderate foraging value. Examples: Shrubland in which species of foraging value, such as shrubby banksias, with 10-20% projected foliage cover. Woodland with tree banksias 2-10% projected foliage cover. Eucalypt woodland/mallee of small-fruited species; Marri, if present, <10% project foliage cover.	Low to Moderate foraging value. Examples: Eucalypt woodland with known food plants (and in particular Marri) with a projected foliage cover of 5-<10%. Parkland-cleared eucalypt woodland with projected foliage cover of known food plants of 10-<20% can be considered low-to-moderate because of poor long-term viability without management.	Low to Moderate foraging value. Examples: Eucalypt woodland (i.e. Marri, Jarrah, Wandoo, and Blackbutt), if present, <10% project foliage cover.

Site score	Description of vegetation		
	Carnaby's Black-Cockatoo	Baudin's Black-Cockatoo	Forest Red-tailed Black-Cockatoo
4	Moderate foraging value. Examples: Woodland with tree banksias 20-40% projected foliage cover. Eucalypt woodland/forest with Marri 20-40% projected foliage cover.	Moderate foraging value. Examples: Eucalypt woodland with known food plants (and in particular Marri) with a projected foliage cover of 10-<20%. Parkland-cleared eucalypt woodland with projected foliage cover of known food plants of 20-<40% can be considered moderate because of poor long-term viability without management. Areas of orchards and especially those with apples can be considered of moderate value.	Moderate foraging value. Examples: Eucalypt woodland/forest (i.e. Marri, Jarrah, Wandoo, and Blackbutt) with 20-40% projected foliage cover.
5	Moderate to High foraging value. Examples: Banksia woodlands with tree banksias >40%. Vegetation condition moderate due to weed invasion and some tree deaths.	Moderate to High foraging value. Examples: Eucalypt woodland with known food plants (and in particular Marri) with a projected foliage cover of 20-<40%. Parkland-cleared eucalypt woodland with projected foliage cover of known food plants of >40% can be considered moderate because of poor long-term viability without management.	Moderate to High foraging value. Examples: Eucalypt woodland/forest (i.e. Marri, Jarrah, Wandoo, and Blackbutt) with >40% projected foliage cover. Vegetation condition moderate due to weed invasion and some tree deaths.
6	High foraging value. Example: Banksia woodlands of key species (e.g. B. attenuata, B. menziesii) with projected foliage cover >60%. Vegetation condition good with low weed invasion and low tree death to indicate it is robust and unlikely to decline in the medium term.	High foraging value. Example: Eucalypt woodland/forest with a high proportion of Marri (>40% projected foliage cover). Vegetation condition good with low weed invasion and low tree death to indicate it is robust and unlikely to decline in the medium term.	High foraging value. Example: Eucalypt woodland/forest (i.e. Marri, Jarrah, Wandoo, and Blackbutt) with >60% projected foliage cover. Vegetation condition good with low weed invasion and low tree death to indicate it is robust and unlikely to decline in the medium term.

Appendix 8. Grading system used to assess potential nest trees for Black-Cockatoos.

The following class descriptions relate to the tree class data presented in Appendix 9.

Class	Description of tree and hollows /activity
1	Active nest observed; adult (or immature) bird seen entering or emerging from hollow.
2	Hollow of suitable size and angle (i.e. near-vertical) visible with chew marks around entrance.
3	Potentially suitable hollow visible but no chew marks present; or potentially suitable hollow present (as suggested by structure of tree, such as large, vertical trunk broken off at a height of >10m).
4	Tree with large hollows or broken branches that might contain large hollows but hollows or potential hollows are not vertical or near-vertical; thus a tree with or likely to have hollows of sufficient size but not to have hollows of the angle preferred by Black-Cockatoos.
5	Tree lacking large hollows or broken branches that might have large hollows; a tree with more or less intact branches and a spreading crown.

Appendix 9. Black cockatoo potential nest tree data.

Coordinates	Tree species	DBH (cm)	Tree class	Tree status
50 J 401470 6468654	Flooded Gum (*Eucalyptus rudis*)	90	5	Alive
50 J 401457 6468680	Flooded Gum (*Eucalyptus rudis*)	51	5	Alive
50 J 401459 6468732	Flooded Gum (*Eucalyptus rudis*)	80	5	Alive
50 J 401447 6468735	Flooded Gum (*Eucalyptus rudis*)	75	5	Alive
50 J 401453 6468761	Flooded Gum (*Eucalyptus rudis*)	95	5	Alive
50 J 401449 6468774	Flooded Gum (*Eucalyptus rudis*)	150	5	Alive
50 J 401437 6468887	Flooded Gum (*Eucalyptus rudis*)	90	5	Alive
51 J 401430 6468890	Flooded Gum (*Eucalyptus rudis*)	80	5	Alive
52 J 401430 6468897	Flooded Gum (*Eucalyptus rudis*)	80	5	Alive
50 J 401602 6468905	Flooded Gum (*Eucalyptus rudis*)	120	3	Alive
50 J 401613 6468923	Flooded Gum (*Eucalyptus rudis*)	55	5	Alive
50 J 401637 6468972	Flooded Gum (*Eucalyptus rudis*)	60	5	Alive
50 J 401634 6468976	Flooded Gum (*Eucalyptus rudis*)	70	5	Alive
50 J 401643 6468982	Flooded Gum (*Eucalyptus rudis*)	85	5	Alive
50 J 401633 6468982	Flooded Gum (*Eucalyptus rudis*)	65	5	Alive
50 J 401624 6469005	Flooded Gum (*Eucalyptus rudis*)	100	3	Alive
50 J 401621 6469029	Flooded Gum (*Eucalyptus rudis*)	65	5	Alive
50 J 401633 6469044	Flooded Gum (*Eucalyptus rudis*)	120	5	Alive
50 J 401592 6469041	Flooded Gum (*Eucalyptus rudis*)	65	5	Alive
50 J 401570 6469028	Flooded Gum (*Eucalyptus rudis*)	70	5	Alive
50 J 401570 6469003	Flooded Gum (*Eucalyptus rudis*)	70	5	Alive
50 J 401559 6468979	Flooded Gum (*Eucalyptus rudis*)	70	5	Alive
50 J 401555 6469042	Flooded Gum (*Eucalyptus rudis*)	60	5	Alive
50 J 401551 6469042	Flooded Gum (*Eucalyptus rudis*)	100	4	Alive
50 J 401549 6469042	Flooded Gum (*Eucalyptus rudis*)	90	4	Alive
50 J 401517 6469042	Flooded Gum (*Eucalyptus rudis*)	180	5	Alive
50 J 401482 6469039	Flooded Gum (*Eucalyptus rudis*)	65	5	Alive
50 J 401470 6469035	Flooded Gum (*Eucalyptus rudis*)	55	5	Alive
50 J 401461 6469034	Flooded Gum (*Eucalyptus rudis*)	90	5	Alive
50 J 401437 6468985	Flooded Gum (*Eucalyptus rudis*)	95	5	Alive
50 J 401409 6468998	Flooded Gum (*Eucalyptus rudis*)	55	5	Alive
50 J 401415 6469041	Flooded Gum (*Eucalyptus rudis*)	60	5	Alive
50 J 401292 6469014	Flooded Gum (*Eucalyptus rudis*)	70	5	Alive
50 J 401318 6469058	Flooded Gum (*Eucalyptus rudis*)	80	4	Alive
50 J 401301 6469061	Flooded Gum (*Eucalyptus rudis*)	65	5	Alive
50 J 401246 6469086	Flooded Gum (*Eucalyptus rudis*)	51	5	Alive
50 J 401267 6469160	Flooded Gum (*Eucalyptus rudis*)	60	5	Alive
50 J 401284 6469162	Flooded Gum (*Eucalyptus rudis*)	70	5	Alive
50 J 401291 6469164	Flooded Gum (*Eucalyptus rudis*)	55	5	Alive
50 J 401297 6469165	Flooded Gum (*Eucalyptus rudis*)	70	5	Alive
50 J 401273 6469153	Flooded Gum (*Eucalyptus rudis*)	60	5	Alive
50 J 401271 6469151	Flooded Gum (*Eucalyptus rudis*)	51	5	Alive
50 J 401271 6469141	Flooded Gum (*Eucalyptus rudis*)	65	5	Alive
50 J 401274 6469133	Flooded Gum (*Eucalyptus rudis*)	70	5	Alive
50 J 401275 6469126	Flooded Gum (*Eucalyptus rudis*)	100	5	Alive

Coordinates	Tree species	DBH (cm)	Tree class	Tree status
50 J 401271 6469121	Flooded Gum (*Eucalyptus rudis*)	80	5	Alive
50 J 401278 6469101	Flooded Gum (*Eucalyptus rudis*)	90	5	Alive
50 J 401322 6469043	Flooded Gum (*Eucalyptus rudis*)	55	5	Alive
50 J 401509 6468989	Flooded Gum (*Eucalyptus rudis*)	65	5	Alive
50 J 401547 6468924	Flooded Gum (*Eucalyptus rudis*)	65	5	Alive

Appendix 10. Annotated list of fauna recorded during the field survey.

Note: non-native species are indicated by asterisk.

	Fish	Notes
1	Mosquito Fish *	Abundant in lake
	Frogs	
2	Banjo Frog	several calling in lake amongst emergent Melaleuca
3	Slender Tree Frog	several calling in lake amongst emergent Melaleuca
	Reptiles	
4	Snake-eyed Skink	active on flooded gum
5	Common Dwarf Skink	active in native garden bed
6	Two-toed Earless Skink	under leaf-litter near wetland
	Birds	
7	Red Wattlebird	several observed and heard calling
8	Magpie Lark	observed and heard calling
9	Grey Butcherbird	heard calling
10	Australian Magpie	several observed and heard calling
11	Striated Pardalote	heard calling
12	Australian Raven	observed and heard calling
13	Rainbow Bee-eater	one heard calling
14	Forest Red-tailed Black Cockatoo	several small groups flying over study area and foraging residue (chewed cape lilac)
15	Carnaby's Cockatoo	foraging residue (chewed pine cones)
16	Red-capped Parrot	two observed
17	Little Corella	heard calling
18	Galah	several in flooded gums
19	Australian Ringneck	several observed
20	Rainbow Lorikeet *	observed and heard calling
21	Willie Wagtail	heard calling
22	Weebill	several heard and two observed
23	Grey Fantail	several heard and observed
24	Silvereye	several heard and observed
25	Singing Honeyeater	two heard calling
26	Western Gerygone	one heard
27	Rufous Whistler	one female observed
28	Grey Teal	on open water
29	Pink-eared Duck	a pair on open water
30	Wood Duck	several on open water
31	Pacific Black Duck	on open water
32	Eurasian Coot	several on open water
33	Australasian Grebe	on open water
34	White-faced Heron	observed in wetland shallows
35	Australian White Ibis	several perched in paperbarks
36	Yellow-billed Spoonbill	within wetland shallows
37	Spotted Dove *	observed and heard calling
38	Dusky Moorhen	heard calling within wetland
40	Laughing Kookaburra *	heard calling within study area

Appendix 11. Additional photographs taken within the study area.

	
Foraging residue of Forest Red-tailed Black Cockatoo (chewed cape lilac berries)	Foraging residue of Carnaby's Black-Cockatoo (chewed pine cones)
	
Pink-eared Ducks using wetland habitat	White-faced Herron using wetland habitat
	
Red Wattlebird using woodland habitat	Feral bees swarm in Flooded Gum tree hollow

APPENDIX F – HYDRAULIC MODELLING

Overview

Hydraulic modelling has been undertaken to provide a greater understanding of the hydraulic function of Bindaring Wetland and its potential for inundation. The modelling results have been used to inform the development of the wetland concept design options. The model builds upon the previous hydraulic study which examined the northern portion of the wetland (GHD, 2016a).

The modelling has been undertaken using XPSWMM (2017.1.1) software and has been set up as a fully dynamic 1D/2D hydraulic model. The model results are used to assess the existing overland flow paths, extents, depths and velocities.

XPSWMM (2017.1.1) was selected due to its compatibility with the previous hydrological study which also used XPSWMM (Cardno, 2016), and the previous hydraulic study which used TUFLOW (GHD, 2016a).

Model Extent

The model extends from the base of the northern wetland zone at the footbridge on Anstey Road/Lovelock Place to the outlet of the southern wetland zone on the Swan River.

The northern wetland boundary coincides with the downstream boundary of the GHD (2016) model.

Design Storm Events

The model has been run for following design storm events:

- ‘Frequent event’ – approximately equivalent to half of the 5 year 18 hour duration ARI event.
- 5 year ARI 18 hour duration event.
- 10 year ARI 18 hour duration event.
- 100 year ARI 18 hour duration event.

These events have been selected for consistency with the GHD (2016) model in the northern wetland zone. The 18 hour duration event was identified as the critical duration event of the upstream stormwater network during modelling of the Town of Bassendean stormwater network undertaken by Cardno in 2016.

The ‘frequent’ event was based on halving the inflows for the 5 year ARI event. This methodology was used to maintain consistency with the GHD (2016) study.

Key Model Inputs and Assumptions

Topography

The topography within the model was represented using survey data captured by Links Surveying in February 2017. The survey data is provided in Appendix A.

A fine scale Digital Elevation Model (DEM) was created from the survey data to define the existing overland flow paths. The DEM defines the topography of the catchment and has been used in the two dimensional (2D) model topography and to report hydraulic model results.

A 3 x 3 m grid cell size has been adopted. This was considered an appropriate resolution for the site. Some manual adjustments have been made to the data to improve the resolution of some channels and features such as the weir in the lower portion of the southern wetland.

Structure Details

Details of the location, size and materials of structures were sourced from the site feature survey (Links Surveying, 2017) and site visits undertaken by Coterra Environment in February and March 2017.

There are five inflow structures located within the middle and southern zones of the wetland. These structures typically comprise of circular or rectangular concrete culverts discharging from the Town of Bassendean stormwater network to the wetland.

Four of the five inflow structures were included in the model. The inflow located on the north western corner of the middle portion of the wetland was not included as this inflow was captured in the previous (GHD, 2016a) modelling. Inflow structures were represented using 2D flow boundaries.

Causeway

A built up driveway (known as ‘the causeway’) separates a portion of the wetland south of Hyland Street from the remainder of the southern portion of the wetland. A culvert at the base of the causeway allows stormwater discharged to the west of the causeway to flow into the remainder of the wetland. The culvert is currently partially blocked with only a small capacity remaining.

The culvert has been included in the model in its current state (partially blocked).

Weir

A limestone block weir is located at the downstream extent of the southern zone of the wetland. The weir is thought to influence wetland hydrology by restricting discharge from the wetland to the Swan River when the river level is low, and by restricting inflows from the Swan River to the wetland when the river level is high.

The weir has been represented in the model through modification of the DEM to the surveyed weir elevations.

Outlet channel to Swan River

The wetland is connected to the Swan River via an open channel. The channel is culverted under Bassendean Parade and a small footbridge. The channel and culverts have been represented in the model using a 1D network. Structure details are based on survey.

Roughness

The hydraulic model includes spatially varied roughness related to different land use types within the study area. Land use types were derived from aerial photography purchased from Landgate. Roughness values were obtained from standard engineering text. Table 1 provides a summary of the values used in the study.

Table 1 Model Roughness Values

Land Use	Manning's 'n' value
Open water	0.02
Thick vegetation	0.05
Sparse vegetation	0.035
Grass	0.03
Hardstand	0.02

Hydrological Inflows

Urban Runoff

A drainage assessment has previously been undertaken for the whole Town of Bassendean local government area by Cardno in 2016. The drainage network was established through liaison with the Town, previous studies, aerial photography and a site visit.

Cardno used a 1D/2D hydraulic model (XPSWMM) to assess the existing drainage infrastructure. Hydrological inputs were derived using a rain-on-grid method. 2, 5, 10 and 100 year ARI events were simulated.

The drainage system discharges to the Bindaring Wetland in five locations in the middle and southern portions of the wetland. Inflow hydrographs were provided at these inflow locations by Cardno for the critical duration (18 hour) event in the 5, 10 and 100 year events.

Northern Wetland Zone

As outlined in Section 3.1 above, hydraulic modelling of the northern portion of the wetland was undertaken by GHD in 2016. The downstream boundary of this model was at the footbridge on Anstey Road/Lovelock Place.

The discharge at the downstream boundary of GHD's model was used as an input to the model to simulate discharge from the northern wetland zone to the middle zone.

Direct Rainfall

Design rainfall hydrographs were included in the model to account for direct rainfall over the wetland during the design storm events.

Design rainfall data was obtained from the Bureau of Meteorology's IFD database (BoM, 2017). The 1987 version of the IFD curves and temporal patterns (zone 8) were selected for consistency with the rainfall data used in the previous hydrological study (Cardno, 2016).

The frequency and duration was selected to match the same critical storm events run in the Cardno and GHD studies.

Downstream Boundary

As outlined in Section 3.2.2.3 the wetland discharges to the Swan River via a partially culverted drain. The downstream boundary elevation at this location was determined based on gauge data from the Swan River at Meadow Street Bridge station located approximately 3.5 km upstream of the site.

Average daily maximum water levels at the Swan River at Meadow Street bridge station were analysed for the last 6 years of record (2011-2016). The highest average daily maximum water level over this period was 0.46 mAHD in 2011. This level was adjusted for the bed level elevation change between the Meadow Street Bridge and the site (0.3 m). As such a downstream boundary of 0.16 mAHD was applied.

It was assumed that the Swan River was not in flood during the simulation. As the critical duration of the Bassendean stormwater network was estimated by Cardno (2016) to be approximately 18 hours and the critical duration of the Swan River is likely to be in order of 3 – 5 days this is considered to be an appropriate assumption.

Model Results

As outlined above, inundation within Bindaring Park has been simulated during the 'frequent', 5, 10 and 100 year ARI events. The area and depth of inundations within the park are shown in figures F1 to F4 and are summarised in Tables 2 and 3 below.

Table 2 Summary of Model Results

Storm event (ARI)	Reference point 1 (middle wetland)			Reference point 2 (southern wetland)		
	Ground elevation (mAHD)	Max water level (mAHD)	Max depth (m)	Ground elevation (mAHD)	Max water level (mAHD)	Max depth (m)
Frequent	0.05	0.818	0.768	-0.11	0.818	0.928
5		0.915	0.865		0.913	1.023
10		0.953	0.903		0.949	1.059
100		1.168	1.118		1.158	1.268

Table 3 Results at Outfall (Swan River)

Storm event (ARI)	Max flow (m^3/s)	Max water depth (m)	Max velocity (m/s)	Total volume (m^3)
Frequent	0.399	0.240	0.560	12,010
5	0.760	0.259	0.770	30,779
10	0.827	0.271	0.790	40,611
100	1.288	0.344	0.890	63,182

The results of the modelling indicate that flooding in the middle wetland zone is generally confined to the main channel 'Bindaring Creek' during frequent events, but inundates a wider area during large (>10 year ARI events).

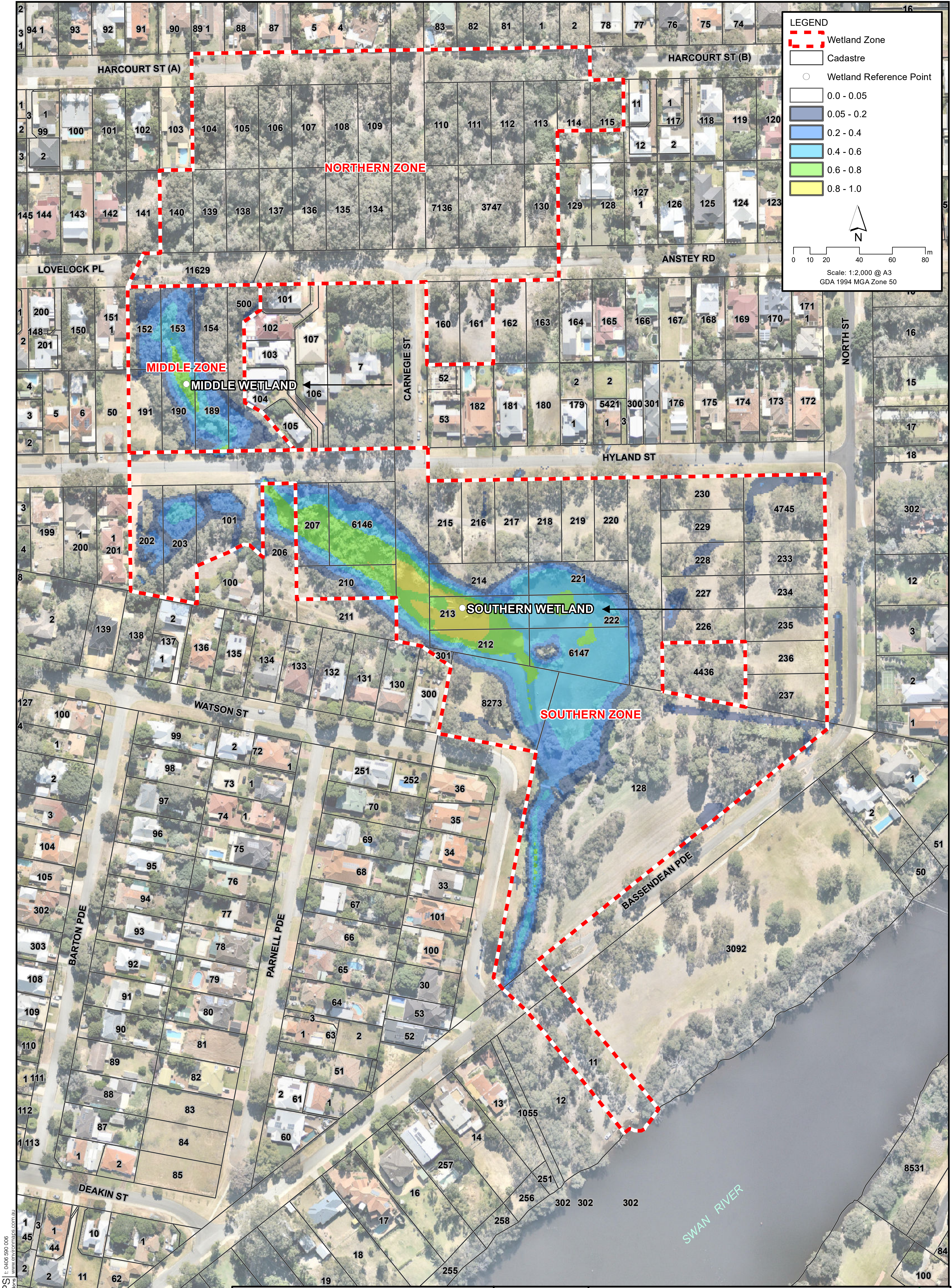
Flow is discharged from the middle to southern zone through culverts under Hyland Street. Flow through these culverts is unrestricted in 'frequent' events, and provides some restriction in the 5, 10 and 100 year ARI events although the capacity is not exceeded (overtopping).

Significant inundation occurs within the southern wetland zone to the west of the causeway as a result of a relatively large inflow from the local stormwater network and restricted outflow under the causeway via the partially blocked culvert. Water levels in the centre of this area range from 40 – 60 cm during frequent events and exceed 1.2 m during the 100 year ARI event.

Within the remainder of the southern zone, inundation is largely contained within the main body of the wetland during minor events, although some shallow ponding occurs in low points throughout the park. This ponding is predominately contained within the minor drainage channels that traverse the park and trapped low points.

In larger events flooding extends over the wetland bank on all sides with the largest area of flooding occurring in the south east in proximity to the weir. The footpath adjacent to the wetland floods in this area in all the storm events simulated.

The results also indicate that the weir is overtopped during ‘frequent’ and large ARI events. Water is discharged from the wetland via an outlet culvert under Bassendean Parade and an open channel that stretches from Bassendean Parade to the Swan River. The discharge was found to be contained within the culvert and outflow channel during all events, with the exception of some overflow of the culverts under the footbridge adjacent to the boat ramp during the 100 year ARI event.



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COTERRA ENVIRONMENT

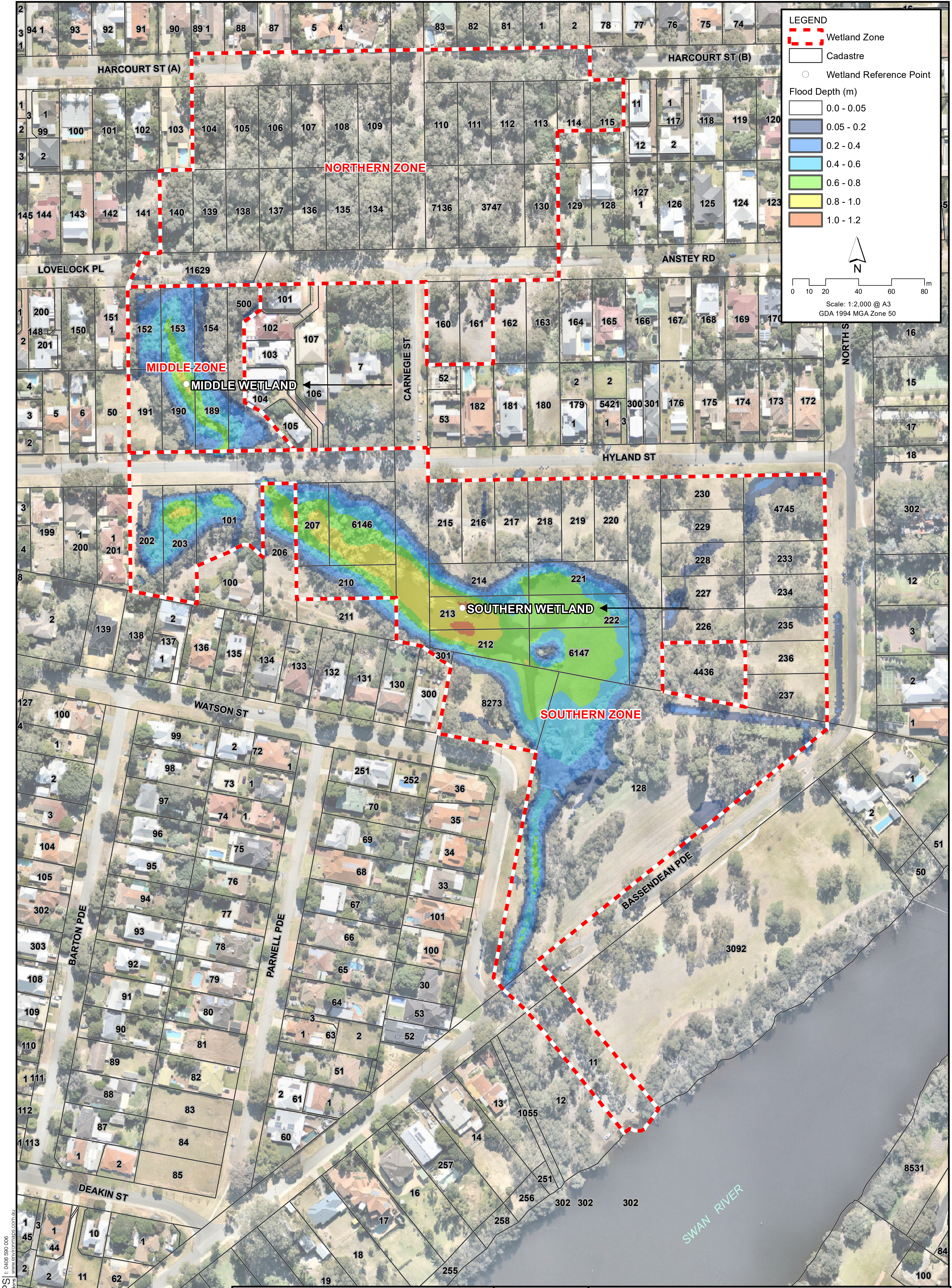
Job: TOBBWC01
Doc: APPF F01
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

Town of Bassendean
BINDARING WETLAND CONCEPT PLAN
BINDARING WETLAND, BASSENDEAN

FREQUENT EVENT FLOOD MAP

Figure 1

C:\GIS\Jobs\CoTerra\TOBBWC01 - Bindaring Wetland, Bindaring Wetland Concept Plan\Figures\TOBBWC01_AppF F01 Frequent Event Flood Map_170720.mxd



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COTERRA
ENVIRONMENT

Job: TOBBWC01
Doc: APPF F02
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

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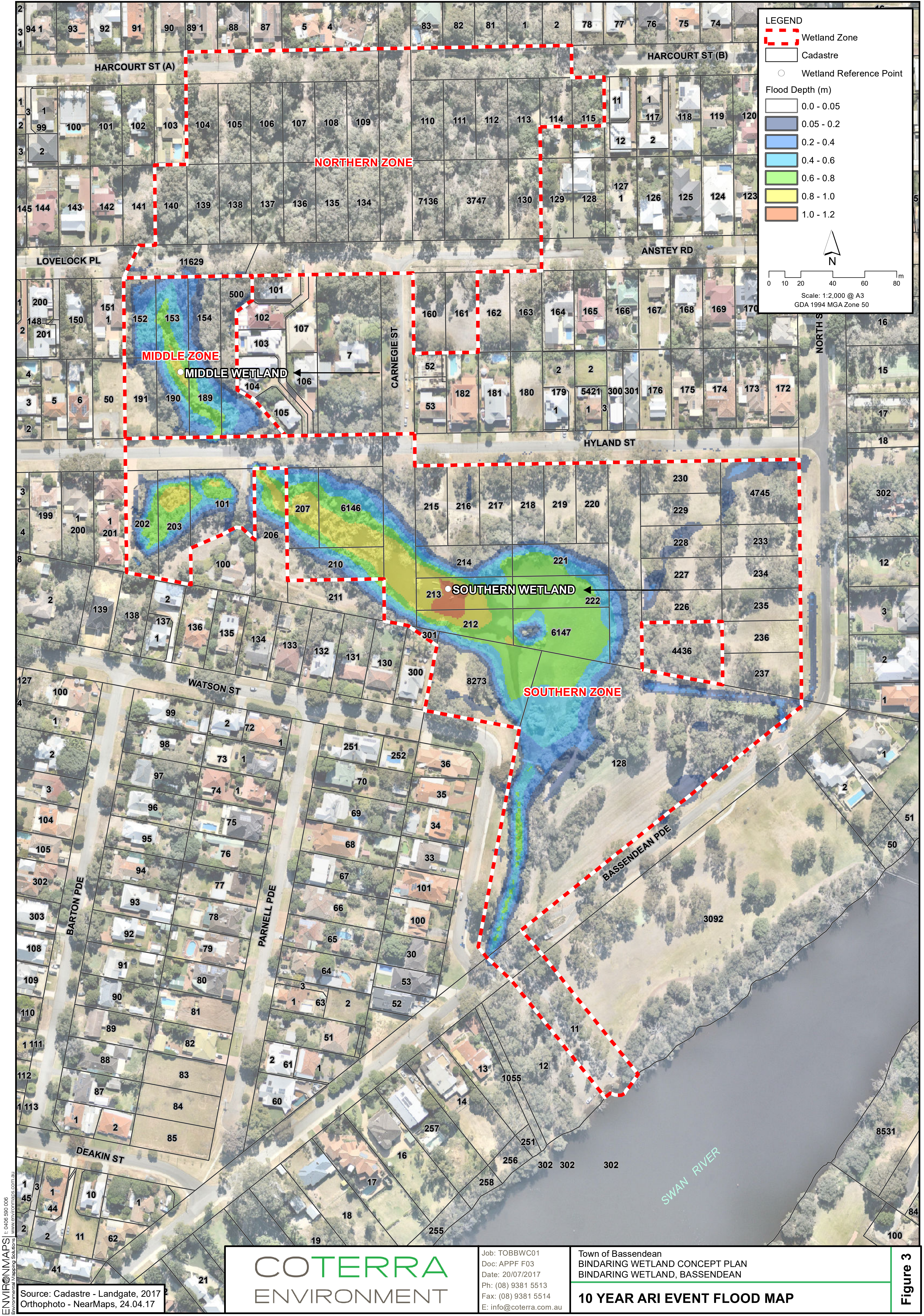
5 YEAR ARI EVENT FLOOD MAP

Figure 2



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COTERRA ENVIRONMENT

Job: TOBBWC01
Doc: APPF F03
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

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BINDARING WETLAND CONCEPT PLAN
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10 YEAR ARI EVENT FLOOD MAP

Figure 3

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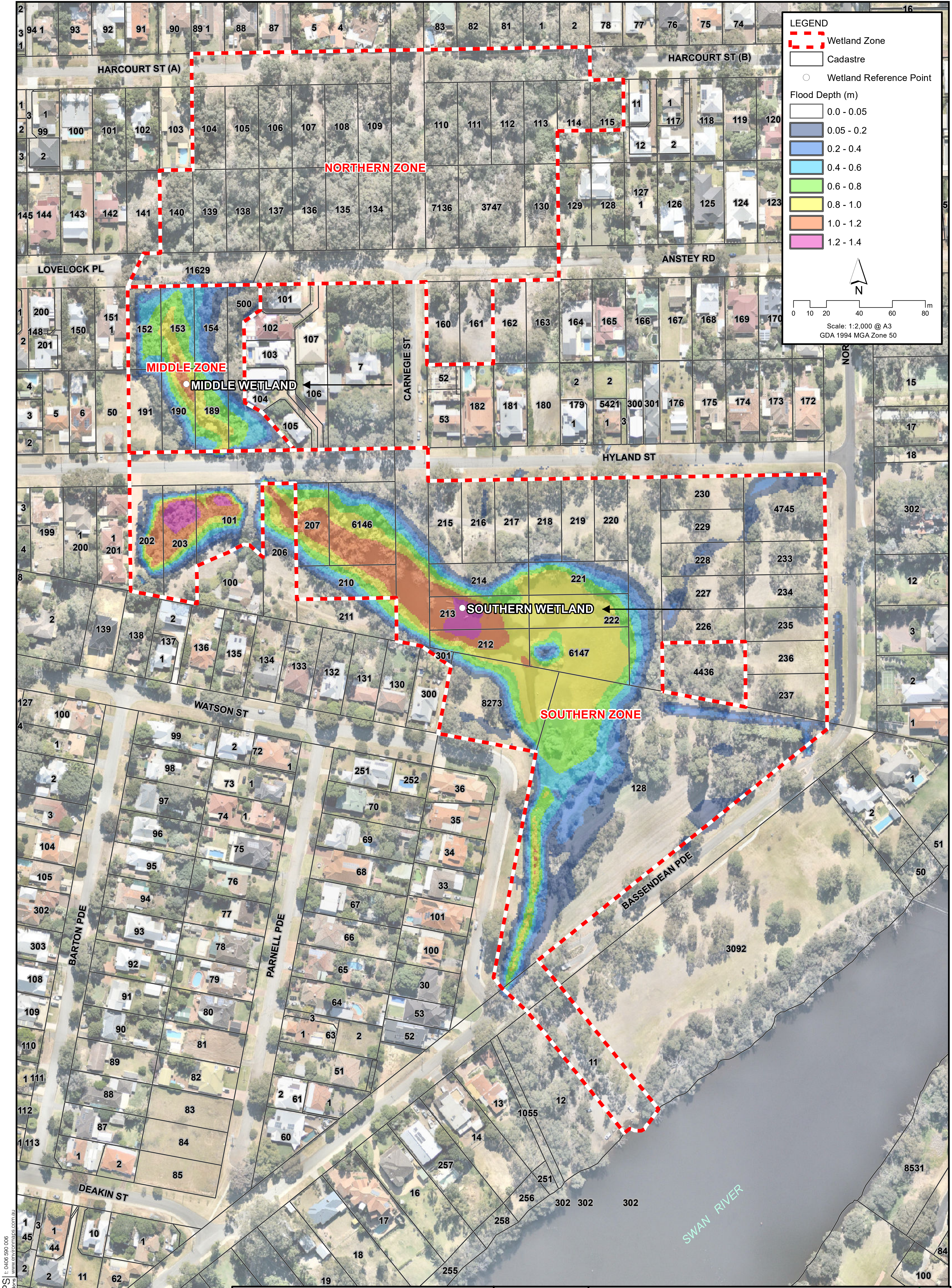

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t: 0406 590 006
www.environmaps.com.au

COTERRA
ENVIRONMENT

Job: TOBBWC01
Doc: APPF F04
Date: 20/07/2017
Ph: (08) 9381 5513
Fax: (08) 9381 5514
E: info@coterra.com.au

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BINDARING WETLAND CONCEPT PLAN
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100 YEAR ARI EVENT FLOOD MAP

Figure 4

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APPENDIX G – Weed Management Plan

ecoscape

Bushland Weed Management Plan

For Town of Bassendean

Document Status

Rev. No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
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2	MM	MM				

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Direct all inquiries to:

Ecoscape (Australia) Pty Ltd
9 Stirling Highway • PO Box 50 North Fremantle WA 6159
Ph: (08) 9430 8955 Fax: (08) 9430 8977

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Bushland Weed Management Plan

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Steve McCabe, Environmental Officer/ Planning, Town of Bassendean

Peter Randolf, Senior Heritage Officer, Department of Indigenous Affairs

Summary

Bushland Weed Management Plan

Ecoscape conducted a weed assessment of five reserves vested in the town of Bassendean. Items examined included:

- bushland condition
- weed species inventories
- distribution of weed species
- priority of weed species
- weed types
- control options
- constraints that may affect weed control activities.

Broadway and Success Hill were all assessed as in Degraded bushland condition while the remnant vegetation in Jubilee Reserve and Pickering Park were assessed as Good or better bushland condition. A total of 80 weed species were recorded across the five reserves. Of these, 24 species were considered to be of high priority for control. A total of 25 weed maps were produced to indicate the distribution of the majority of these weed species.

Aboriginal heritage sites were recorded within or in the near vicinity of each reserve. The importance of preserving and enhancing these heritage sites meant obtaining consent from the Minister for Indigenous Affairs before any weed control activities may take place. Such consent would require strict procedures and controls to be in place.

Dieback was identified as another constraint for weed control activities in Success Hill. Any work would require stringent hygiene procedures to prevent further spread of this disease.

Recommendations for the town of Bassendean to undertake weed control activities in their reserves are summarised in **Table 1** on the following page.

Table 1: Summary of weed control recommendations for Bassendean reserves

No.	RECOMMENDATIONS
1	Target weed species in each reserve: • in order of priority • during optimal times of the year • using recommended methods: o according to their morphology and nature of infestation o in a manner that will not have an impact on the environment or heritage values of the reserve.
2	Monitor changes to weed populations.
3	Continue to map populations of high priority weed species.
4	Appropriate herbicides are to be selected for use near wetlands, waterways or springs in Bindaring Park, Broadway, Pickering Park and Success Hill. The Town is to refer to MSDS and the DOW (2000) *Statewide Policy 2: Pesticides in Public Drinking Water Sources Areas* when choosing appropriate herbicide treatments.
5	Follow the conditions and requests made by the Minister for Indigenous Affairs.
6	Ensure hygiene practices are in place for any weed control activities in Success Hill to prevent further spread of dieback infection.
7	Restrict access to and revegetate informal paths in Broadway, Jubilee B and Success Hill.
8	Develop formal paths using appropriate materials in Bindaring North and Success Hill to prevent further bushland degradation.

1.0 Introduction

Bushland Weed Management Plan

There has been an increasing awareness of the need to conserve and manage the town of Bassendean's bushland area. Such management should aim to enhance the visual, functional, landscape, heritage and environmental qualities of each natural area. A critical component of this work is to develop a bushland weed management plan to remove or reduce the presence of weed species that are degrading these qualities.

The following Bushland Weed Management Plan was prepared by Ecoscape for five reserves vested in the Town of Bassendean:

- Bindaring Park (10.3 ha)
- Broadway Arboretum in Nyibra Swamp (2.97 ha)
- Jubilee Reserve (13.8 ha)
- Pickering Park (3.32 ha)
- Success Hill (3.51 ha).

The locations of these reserves within the Town are presented in **Figure 1**.

The objectives of the Bushland Weed Management Plan are to:

1. map bushland condition and the location of weed species within each reserve
2. identify weed species that are of high priority to control
3. provide strategies for controlling all identified weed species
4. enhance the cultural heritage within each reserve
5. identify constraints to weed control activities
6. identify management priorities
7. provide an opinion of probable cost for controlling weed species in each reserve
8. identify possible funding sources to finance the recommended works.

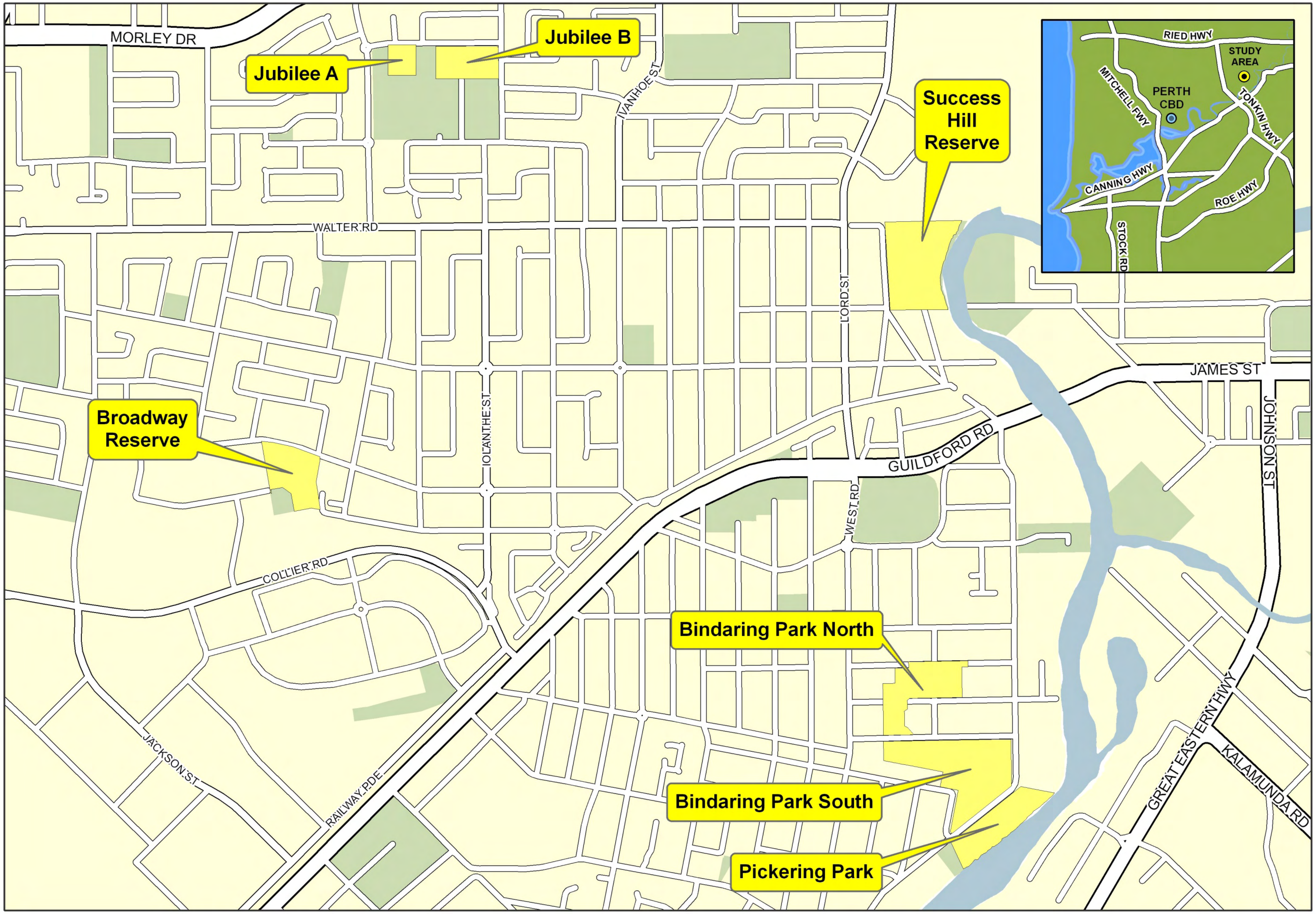

Figure 1: Selected reserves in Town of Bassendean

2.0 Methodology

Fieldwork for all five reserves occurred between the 20th and 27th October 2009.

2.1 Bushland Condition and Land Function

Bushland condition and distribution were determined using the Keighery (1994) condition scale. Areas within the sites that were not bushland were also assessed and mapped according to their current land function using categories adopted from the City of Cockburn (2008) *Biodiversity Assessment templates*. The condition and land function categories are described in **Table 2** below.

Table 2: Bushland Condition and Land Function categories

CATEGORY	DESCRIPTION
Bushland Condition (Keighery 1994)	
Pristine	No obvious signs of disturbance.
Excellent	Vegetation structure intact, disturbance only affecting individual species and weeds are non-aggressive species.
Very Good	Vegetation structure altered, obvious signs of disturbance (eg repeated fires, aggressive weeds, dieback, logging and grazing).
Good	Vegetation structure altered, obvious signs of disturbance. Retains basic vegetation structure or ability to regenerate it. The presence of very aggressive weeds at high density, partial clearing, dieback, logging and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Requires intensive management. The presence of very aggressive weeds at high density, partial clearing, dieback, logging and grazing.
Completely Degraded	Vegetation structure is no longer intact and the area is completely or almost completely without native flora.
Land Function (City of Cockburn 2008)	
Revegetation	Clear signs of planting works in progress (eg tubestock) using local native species to restore area.
Parkland	Clear signs of planting works in progress (eg tubestock) using non-local native species for soft landscapes.
Open Water	Permanent water body.
Other	Other land use to those described above.

2.2 Weeds

2.2.1 Weed Inventory

Weed inventories were collated and distributions of all observed weed species were mapped for each site. A total of 80 weed species were observed across all sites (**Appendix One**). However, it must be noted that this list is not exhaustive and additional weed species may be present at different times of the year.

2.2.2 Weed Mapping

The distribution of the majority of the weed species in each reserve were mapped where practical.

Jubilee Reserve consists of predominantly parkland, the two small areas of remnant vegetation were mapped separately and renamed:

- Jubilee Reserve (A) – remnant bushland at central northern edge of the reserve
- Jubilee Reserve (B) – fenced bushland in the north-east corner of reserve.

The size of Bindaring Park (10 ha) made it impractical to effectively illustrate weed populations on a single A3 page. The reserve was therefore separated into two sections, using Hyland Street as the dividing border. The two sections were named according to whether they were north or south of Hyland Street:

- Bindaring Park (North)
- Bindaring Park (South).

Weed species were subdivided into four broad groups based upon their morphology and similar control methods. Maps were then prepared for each reserve or section, indicating locations of weed species according to the group type. This approach allowed for the locations and distributions of 65 weed species across seven reserves/sections to be illustrated across 25 maps.

Locations of individual plants were recorded using a GPS hand held unit. Distributions of populations were recorded by either using a GPS handheld unit to trace the perimeter of each population or by marking boundaries on printed aerial photographs of the reserve.

Densities of each weed population were classed by the following percentage weed covers:

- *Trace* - <1% cover
- *Low* - 1-10% cover
- *Moderate* - 11-50% cover
- *High* - >50% cover.

2.2.3 Priority Weed Species

Each weed species was assigned a priority rating according to their deemed threat level to each particular reserve:

- *High Priority* - need to have immediate targeted strategies developed and implemented
- *Moderate Priority* - should be targeted to enhance the site condition if there are any resources available after controlling the high priority weed species
- *Low Priority* - should be controlled as part of non-target or site-focused maintenance weed strategies if there are any resources available after controlling the high and moderate priority weed species.

The priority ratings of each weed species were determined after examining:

- the ratings under the *Environmental Weed Strategy of Western Australia* (EWSWA) by the Department of Conservation and Land Management (CALM 1999)
- the ratings under the *Environmental Weed Census and Prioritisation* (EWCP) by the Swan Natural Resource Management (Swan NRM 2008)
- the ratings under Dixon and Keighery (1995) *Recommended methods to control specific weed species*
- whether it was listed under the DAFWA (1976) *Agricultural and Related Resources Protection Act* (ARRPA)
- whether it was listed as a *Weed of National Significance* (WONS) (Weed Australia 2008)
- its local significance to the natural areas.

It should be noted that a weed species may differ in its priority status between reserves as a result of its local significance. For example, a weed species may be more invasive and dominant in a wetland community than in a sandy upland community. Therefore this species should be regarded as a higher priority to control in reserves containing wetlands than in reserves containing only upland vegetation.

The full methodology for determining the priority of each weed species, and associated calculations for each reserve, is presented in **Appendix Two.**

2.2.4 Weed Types

Weed species were separated into four groups:

- grass, sedge and rush weeds
- geophyte weeds (ie those that propagate from bulbs, corms and tubers)
- broad leaf herb weeds
- tree, shrub and climber weeds.

Separation was chiefly based according to their biology and similarities in methods of control. The grouping was to aid in understanding what types of weeds were dominating each reserve and what main control actions would be needed to reduce their diversity and presence.

2.3 Constraints

2.3.1 Aboriginal Heritage

The presence of aboriginal heritage sites and dieback in the reserves was identified to determine whether they could be potentially impacted by weed control methodologies. Weed control activities will need to be permitted by the Minister for Indigenous Affairs for any identified sites before any works may commence. Activities must be designed towards enhancing the cultural significance of the sites, not purely for ecological purposes. The nature of the heritage sites may also impose additional constraints on weed control activities. Permission may be granted through either Section 18 or Regulation 10 of the Government of Western Australia (1972) *Aboriginal Heritage Act*.

Ecoscape consulted the Department of Indigenous Affairs (DIA 2009) *Aboriginal Heritage Enquiry System - Sites and Surveys* dataset to determine if any registered indigenous heritage sites occur within any of the five reserves and whether any additional constraints were present. All identified heritage sites are tabulated in **Appendix Three**.

2.3.2 Dieback

The dieback status of each reserve was determined by consulting relevant Town of Bassendean documents. The constraints of this disease in conducting weed control were then discussed.

2.4 Access

The location and distribution of current footpaths and "goat tracks" in each reserve were mapped. The access tracks were then assessed to determine whether any of them should be closed or formalised in order to improve bushland condition and to prevent further spread of weeds.

3.0 Status of Reserves

Bushland condition and weed maps for all five reserves are presented in **Appendix Four**.

3.1 Bindaring Park

3.1.1 Bushland Condition and Land Function

Half of Bindaring Park is made up remnant vegetation, with the remaining half being parkland or open water. All of the vegetation in Bindaring was assessed as either *Degraded* or *Completely Degraded* condition. The northern section was in poorer condition than the southern section. The degraded condition was attributed to clearing and weed dominance. Weeds were predominantly located in or near the waterways of the southern section, while they were scattered throughout the northern section. Little to no native understorey remained. No restoration work was observed in this reserve (**Maps 1a and 1b**).

3.1.2 Weed Species

A total of 57 weed species were recorded in Bindaring Park. Of these:

- 16 species were High Priority
- 21 species were Moderate Priority
- 20 species were Low Priority.

The southern section had a greater diversity of weed species (51) than the northern section (37).

The High Priority weed species in this reserve were:

- Arum Lily (*Zantedeschia aethiopica*)
- Barley Grass (*Hordeum leporinum*)
- Bridal Creeper (*Asparagus asparagoides*)
- Brome grass (*Bromus diandrus*)
- Buffalo Grass (*Stenotaphrum secundatum*)
- Couch (*Cynodon dactylon*)
- Edible Fig (*Ficus carica*)
- Hares Tail Grass (*Lagurus ovatus*)
- Japanese Pepper (*Schinus terebinthifolia*)
- Kikuyu (*Pennisetum clandestinum*)
- Mile-a-Minute (*Ipomoea cairica*)
- Paspalum (*Paspalum dilatatum*)
- Perennial Veldt Grass (*Ehrharta calycina*)

- Soursob (*Oxalis pes-caprae*)
- Watsonia (*Watsonia meriana*)
- Wild Oat (*Avena barbata*)
- Watsonia (*Watsonia meriana*).

Most of the high priority weed species in Bindaring Park were grasses and geophytes that dominated the understorey adjacent to the waterway. Overall, there was a large diversity of all four weed types present in this reserve (**Maps 1c to 1j**).

3.1.3 Constraints

Heritage

The DIA database search indicated that there were two Aboriginal Heritage sites recorded in or in the immediate vicinity of Bindaring Park:

- Swan River (Site number S02548)
- Helena River (Site number S02148).

Swan River is recognised has mythological significance. This site has open access and a known location. No additional constraints were identified.

Helena River also has mythological significance. It is a ceremonial site with a repository. Additional constraints that must be completed before any weed control activities may commence include obtaining:

- the exact location of the site
- consent from the Minister for Indigenous Affairs to access the closed site.

Dieback

No dieback infestations are currently known in this reserve.

3.1.4 Access

Bindaring North has three formal access paths. One is a footpath which provides a link between Lovelock Place and Anstey Road. Another footpath starts in the north east corner, extending westwards from Paul Place. Near the eastern perimeter, a vehicle access track provides a link between Anstey Road and the northern footpath. An informal track was observed linking Harcourt Street in the north-west corner to Anstey Road (**Map 1k**).

Bindaring South has only one formal access – a pathway aligned immediately to the east of the waterway. At the northern end, a new formal path section has been created to shorten the pathway. No informal paths or goat tracks were observed (**Map 1l**).

3.2 Broadway Arboretum in Nyibra Swamp

3.2.1 Bushland Condition and Land Function

The vegetation in Broadway reserve was assessed in *Degraded* or *Completely Degraded* condition. Weeds dominated the understorey. Very few native understorey plants were observed (**Map 2a**).

Only a small section of the reserve was assessed as *Parkland*. Formal paths existed throughout the reserve, however several informal tracks were also observed. Some minor revegetation work has been carried out in the eastern section where tree seedlings have been planted.

3.2.2 Weed Species

A total of 37 weed species were recorded in Broadway Reserve. Of these:

- 9 species were High Priority
- 18 species were Moderate Priority
- 10 species were Low Priority.

The High Priority weed species identified in this reserve were:

- Brome Grass (*Bromus diandrus*)
- Couch (*Cynodon dactylon*)
- Geraldton Carnation Weed (*Euphorbia terracina*)
- Japanese Pepper (*Schinus terebinthifolia*)
- Summer Scented Wattle (*Acacia rostellifera*)
- Tamarisk (*Tamarix aphylla*)
- Tobacco Tree (*Nicotiana glauca*)
- Wild Oat (*Avena barbata*)
- Wild Radish (*Raphanus raphanistrum*).

Most of the high priority weed species were grasses and trees. Over half of the identified weed species were broad leaf herbs. No geophyte weed species were recorded. The locations and distributions of weed species in this reserve are presented in **Maps 2b to 2d**.

3.2.3 Constraints

Heritage

The DIA database search revealed three aboriginal heritage sites within or immediately adjacent to the Broadway reserve:

- Snake Swamp (Site number S00712)
- Bennet Brook (Site number S01997)
- Nyimbra Swamp (Site number S02198).

Snake Swamp is recorded as being an artefacts/scatter site, with open access and identified locations. Bennet Brook is registered as a ceremonial, mythological and historical site that is recorded as containing skeletal material/ burials sites, man-made structures, fish traps and scattered artefacts. The locations of both sites are known to be outside the reserve. As weed activities will not impact on the adjacent areas, no additional constraints were identified to protect these sites.

Nyibra Swamp was recently determined by the Aboriginal Cultural Material Committee as not being a site that was defined under section 5 of the *Aboriginal Heritage Act 1972* (Randolph pers comm.). As such this site is not protected under this Act.

Dieback

No dieback infestations are currently known in this reserve.

3.2.4 Access

The site is divided by a series of formal paths. One path has a bridge which crosses the far eastern end of the swamp, however it is currently in need of repair and has been fenced off. This restriction has resulted in pedestrians using an access track around the eastern side of the swamp. There are also vehicle access tracks along the eastern boundary of the study area. An informal track was observed traversing from the playground, along the northern side of the swamp to a path along the western boundary (**Map 2e**).

3.3 Jubilee Reserve

3.3.1 Bushland Condition and Land Function

The majority of Jubilee reserve was assessed as *Parkland*, with just over 10% being remnant vegetation. Jubilee (A) was assessed as *Very Good* bushland condition, with only some signs of disturbance and reduced understory species. (**Map 3a**). Most of the vegetation in Jubilee (B) was *Good* to *Excellent*, however areas adjacent to the pathways and along most of the fencing were *Degraded* from site disturbance and weed invasion (**Map 3b**).

3.3.2 Weed Species

A total of 20 weed species were recorded in Jubilee Reserve. Of these:

- 5 species were High Priority
- 13 species were Moderate Priority
- 2 species were Low Priority.

The High Priority weed species identified in this reserve were:

- Couch (*Cynodon dactylon*)
- Guildford Grass (*Romulea rosea*)
- Perennial Veldt Grass (*Ehrharta calycina*)
- Soursob (*Oxalis pes-caprae*)
- Wild Gladiolus (*Gladiolus caryophyllaceus*).

Half of the High Priority weed species were grasses while the other half were geophytes. Overall, most of the weed species in Jubilee were broad leaf herbs.

The locations and distributions of weed species in this reserve are presented in **Map 3c to 3i**.

3.3.3 Constraints

Heritage

A total of five Aboriginal Heritage sites were recorded in the immediate vicinity of Jubilee Reserve:

- Bennet Brook: Rosher Park (Site number S0662)
- Bennet Brook: Lord Street 1 (Site number S02663)
- Bennet Brook: Lord Street 2(Site number S02664)
- Bennet Brook: Camp Area (Site number S01997)
- Walkington Way (Site number S00717).

All five sites are closed to public access. All of the Bennet Brook sites do not have their exact locations given while Walkington Way's location is noted to be unreliable. The Bennet Brook Lord Street and Camp Area sites are also identified as having skeletal remains or burial sites. As such, additional constraints for this reserve are listed below:

- Obtain consent from the Minister for Indigenous Affairs to:
    - access all of the closed sites.
    - to conduct weed control, including possible digging.
- Ensure procedures are in place if skeletal material is revealed from any digging activities.

Dieback

No dieback infestations are currently known in this reserve.

3.3.4 Access

Jubilee (A) had a single formal path along its eastern boundary. No informal tracks were observed (**Map 3j**).

Jubilee (B) has a pathway connecting May Road to the western boundary. This path divides in the centre which connects to the car park located to the south of the bushland area. Two informal tracks were observed in this area, both starting from the entrance at the western end. One track traverses north-east into the bushland. The other acts as a shortcut to the southern car park (**Map 3k**).

3.4 Pickering Park

3.4.1 Bushland Condition and Land Function

Most of Pickering Park is designated as *Parkland*. Some revegetation work was observed adjacent to the entrance road to the parking area and within the bushland area along the waterway. Most of the vegetation was assessed as *Very Good* bushland condition, except where there was disturbance or weed invasion (**Map 4**).

3.4.2 Weed Species

A total of 18 weed species were recorded in Pickering Park. Of these:

- 2 species were High Priority
- 11 species were Moderate Priority
- 5 species were Low Priority.

The High Priority weed species identified in this reserve were:

- Couch (*Cynodon dactylon*)
- Kikuyu (*Pennisetum clandestinum*).

All three high weed species are lawn grasses. Almost all of the weed species in Pickering Park were broad leaf herbs and grasses, barring one shrub species – Black Nightshade (*Solanum nigrum*). No geophyte weed species were recorded.

The locations and distributions of weed species in this reserve are presented in **Map 4b**.

3.4.3 Constraints

Heritage

As Pickering Park is adjacent to Bindaring Park, the same heritage sites were identified within or in vicinity of this reserve. The Minister for Indigenous Affairs (Roberts 2007) has already given consent for improvement activities to occur in Pickering Park, on subject on set conditions. The only condition relevant to weed control activities is:

> "If any skeletal remains are found, they are to be reported to the Western Australian Police and the Registrar of Aboriginal Sites ("the Registrar"). Where it is determined that the remains are Aboriginal in original and not a police matter, they must remain in situ and undisturbed until the Registrar makes a decision about how to proceed in respect of the Remains. The Landowner must at its expense manage the Remains in accordance with the Registrar's decision and report the whereabouts of the remains to the DIA and Anthropology Department of the Western Australian Museum."

In addition, Roberts (2007) referred to the Aboriginal Cultural Management Committee having two requests relevant to weed control activities:

> "The Landowner give due consideration to requests made by the Aboriginal people consulted about the Purpose [including weed control activities], regarding the protection of Aboriginal heritage and the recognition of Aboriginal culture and history."
>
> "The Landowner ensure that all persons employed or engaged in respect of the Purpose [including weed control activities] be made aware of their obligations under the AHA"

Dieback

No dieback infestations are currently known in this reserve.

3.4.4 Access

A single formal access path occurs along the northern side of the bushland at Pickering Park. The path begins from the car park in the south-west corner and extends to the length of the open parkland area. No informal tracks were observed (**Map 4c**).

3.5 Success Hill

3.5.1 Bushland Condition and Land Function

Vegetation covered just over half of the reserve. Bushland condition varied from *Degraded* to *Completely Degraded* as a result of severe site disturbance and weed invasion. The remaining area consisted of *Parkland* and a car park (**Map 5a**).

The site experienced a fire on December 31st 2009, after the site assessment. As a result, there was extensive damage to the northern half of the bushland vegetation along the foreshore (Town of Bassendean 2010). This damage is likely to have lowered some of the site's bushland condition from Degraded to Completely Degraded.

3.5.2 Weed Species

A total of 30 weed species were recorded in Success Hill. Of these:

- 8 species were High Priority
- 19 species were Moderate Priority
- 53 species were Low Priority.

The High Priority weed species identified in this reserve were:

- Arum Lily (*Zantedeschia aethiopica*)
- Bridal Creeper (*Asparagus asparagoides*)
- Kikuyu (*Pennisetum clandestinum*)
- Lantana (*Lantana camara*)
- Perennial Veldt Grass (*Ehrharta calycina*)
- Wild Gladiolus (*Gladiolus caryophyllaceus*)
- Wild Oat (*Avena barbata*)
- Watsonia (*Watsonia meriana*).

Kikuyu (*Pennisetum clandestinum*), Perennial Veldt Grass (*Ehrharta calycina*) and Watsonia (*Watsonia meriana*) are of particularly high importance to control as they are all known to rapidly invade and dominate sites after a bushfire.

The high priority weed species were a composition of all four weed types. This was also reflected in the total species inventory for this reserve.

The locations and distributions of weed species in this reserve are presented in **Maps 5a to 5e.**

3.5.3 Constraints

Heritage

The DIA database indicated nine recorded heritage site within or in the immediate vicinity of Success Hill:

- Bennet Brook: Eden Hill R. (S02661)
- Bennet Brook: Lord St. 1 (S02663)
- Bennet Brook: Lord St. 2 (S02664)
- Swan River (S02548)
- Bennet Brook: In Toto (S02254)
- Success Hill (S02147)
- Helena River (S02148)
- Bennet Brook: Camp Area (S01997)
- Pyrton A5 (no site number given).

Helena River, Success Hill and all of the Bennet Brook sites are closed sites and do not have their exact locations provided in the database search. Bennet Brooks: Lord 1 and 2 and Camp Area, Success Hill are identified as containing skeletal remains or burials sites.

The Minister for Indigenous Affairs (Roberts 2008) has already given consent for improvement activities to occur in Success Hill, subject to set conditions. The two conditions relevant to weed control activities are:

> "If any skeletal remains are found, they are to be reported to the Western Australian Police and the Registrar of Aboriginal Sites ("the Registrar"). Where it is determined that the remains are Aboriginal in original and not a police matter, they must remain in situ and undisturbed until the Registrar makes a decision about how to proceed in respect of the Remains. The Landowner must at its expense manage the Remains in accordance with the Registrar's decision and report the whereabouts of the remains to the DIA and Anthropology Department of the Western Australian Museum."
>
> "Provide to the Registrar annual, or at the completion of the Purpose…. a written report advising the Registrar whether and what extent the Purpose has impacted on all or any Sites or objects within the meaning of section 6 of the AHA ("Objects") that may be located on the Land and to assist the AMC to reassess the status of the Sites"

In addition, Roberts (2008) referred to the Aboriginal Cultural Management Committee having two requests relevant to weed control activities:

> "The Landowner give due consideration to requests made by the Aboriginal people consulted about the Purpose [including weed control activities], regarding the protection of Aboriginal heritage and the recognition of Aboriginal culture and history."
>
> "The Landowner ensure that all persons employed or engaged in respect of the Purpose [including weed control activities] be made aware of their obligations under the AHA"

Dieback

The entire reserve is reported to be infected with dieback (Dieback Treatment Services 2008). Weed control activities will be constrained to limit any further spread of the disease in of out of the reserve.

3.5.4 Access

Success Hill only has one formal path. This path extends eastwards from the car park to the foreshore vegetation and then southwards to River Street. A vehicle access track starts from the parkland and extends in a north-east direction, adjacent to the foreshore vegetation. (**Map 5f**).

The reserve has experienced a high level of foot traffic. The grassland in the northern portion is criss-crossed with intersecting tracks. Another track extends from the formal footpath to the foreshore edge.

3.6 Status of Reserves Summary

The bushland condition status of each reserve is summarised in **Table 3** below:

Table 3: Areas of Bushland Condition and land function of Bassendean reserves

CATEGORY	RESERVE					TOTAL AREA	
	Bindaring	Broadway	Jubilee	Pickering	Success Hill	ha	%
Condition							
Pristine	0	0	0	0	0	0	0
Excellent	0	0	0.60	0	0	0.60	4.5
Very Good	0	0	0.46	0.56	0	1.02	7.7
Good	0	0.15	0.20	0.07	0	0.42	3.2
Degraded	3.94	1.38	0.34	0.04	3.12	8.82	66.5
Completely Degraded	0.88	1.13	0	0	0.39	2.40	18.1
Total Vegetation	**4.82**	**2.66**	**1.60**	**0.67**	**3.51**	**13.26**	**100**
Land Function							
Revegetation	0	0	0	0.01	0	0.01	0.04
Parkland	3.42	0.12	11.26	2.24	2.02	19.06	83.2
Open water	1.17	0	0	0	0	1.17	5.1
Other	0.92	0.19	0.94	0.40	0.22	2.67	11.6
Total Land Function	**5.51**	**0.31**	**12.20**	**2.65**	**2.24**	**22.91**	**100**
TOTAL	**10.33**	**2.97**	**13.80**	**3.32**	**5.75**	**36.17**	

The numbers of different priority weed species and groups for each reserve is summarised in **Table 4** below:

Table 4: Priority ratings and weed groups of weeds identified in Bassendean reserves

CATEGORY	RESERVE				
	Bindaring	Broadway	Jubilee	Pickering	Success Hill
Priority Rating					
High	11	9	4	2	8
Moderate	21	15	11	10	19
Low	25	13	5	6	3
Weed Type					
Grass, Sedge and Rush	20	7	3	7	11
Geophyte	4	0	3	0	6
Broad Leaf Herb	21	21	12	11	10
Tree, Shrub and Climber	12	9	2	0	3
TOTAL	**57**	**36**	**20**	**19**	**30**

The determined high priority weeds species for each reserve is listed in **Table 5** below:

Table 5: High Priority Weed Species identified in Bassendean Reserves

WEED SPECIES		RESERVE					
Scientific Name	**Common Name**	**Bindaring Park**	**Broadway**	**Jubilee**	**Pickering Park**	**Hill Success**	**TOTAL**
Grass, Sedge and Rush							
Avena barbata	Wild Oat	*	*			*	**3**
Bromus diandrus	Brome Grass	*	*				**2**
Cynodon dactylon	Couch	*	*	*	*		**4**
Ehrharta calycina	Perennial Veldt Grass	*		*		*	**3**
Hordeum leporinum	Barley Grass	*					**1**
Lagurus ovatus	Hares Tail Grass	*					**1**
Paspalum dilatatum	Paspalum	*					**1**
Pennisetum clandestinum	Kikuyu	*			*	*	**3**
Stenotaphrum secundatum	Buffalo Grass	*					**1**
Geophyte							
Asparagus asparagoides	Bridal Creeper	*				*	**2**
Gladiolus caryophyllaceus	Wild Gladiolus			*			**1**
Oxalis pes-caprae	Soursob	*		*			**2**
Romulea rosea	Guildford Grass			*			**1**
Watsonia meriana	Watsonia	*				*	**2**
Zantedeschia aethiopica	Arum Lily	*				*	**2**
Broad Leaf Herb							
Euphorbia terracina	Geraldton Carnation Weed		*				**1**
Raphanus raphanistrum	Wild Radish		*				**1**
Tree, Shrub and Climber							
*Acacia rostellifera**	Summer Scented Wattle*		*				**1**
Ficus carica	Edible Fig	*					**1**
Lantana camara	Lantana					*	**1**
Ipomoea cairica	Mile-a-Minute	*					**1**
Nicotiana glauca	Tobacco Tree		*				**1**
Schinus terebinthifolia	Japanese Pepper	*	*				**1**
Tamarix aphylla	Tamarisk		*				**1**
TOTAL		**16**	**9**	**5**	**2**	**7**	**24**

A summary of identified constraints for weed control activities is presented in **Table 6:**

Table 6: Identified constraints on weed control activities for Bassendean reserves

CONSTRAINT	RESERVE
Permission required from Minister of Indigenous Affairs before any weed control activities may commence in recorded Aboriginal heritage sites	Bindaring Jubilee
Permission from Minister of Indigenous Affairs required to access closed Aboriginal heritage sites	Jubilee
Locations of certain aboriginal heritage need to be established before weed control activities may commence.	All reserves
Procedures must be in place for managing exposure of any skeletal remains	Broadway Jubilee Pickering Park Success Hill
Weed control activities must be carried out in manner that does not spread dieback within or out of reserve.	Success Hill

4.0 Weed Control Strategy

Bushland Weed Management Plan

4.1 Objectives

The objectives of the Weed Control Strategy are to:

- identify the weed species with the highest priority for control
- prevent introduction of additional weed species
- prevent further encroachment of weeds into bushland areas
- integrate the weed control programme with heritage enhancement programs
- set performance targets aimed at demonstrating the effectiveness of control strategies, reductions in weed populations and improvement in bush condition.

4.2 Background

Weeds are plants that establish themselves in native plant communities. Impacts caused by weeds include:

- resource competition, as weeds often out-compete native species
- prevention of seedling recruitment of native species
- alteration to geomorphological processes, such as increased erosion
- changes to soil nutrient status
- alteration of fire regime, usually through increased fire frequency
- reduction in the abundance of indigenous fauna due to less diverse habitat
- loss of native species diversity
- changes to the structure of vegetation communities, often by the removal of the shrub layer or native ground covers.

The following Weed Control Strategy is aimed at prioritising and controlling weed species within five reserves by the Town of Bassendean. It is important that the weed control measures aimed at reducing the extent of weeds are coupled with improving the condition of the bushland condition and overall amenity of the area. This can be achieved through the preparation of specific weed control programmes.

4.3 Weed Strategy

4.3.1 Priority

The priority status of individual weed species should be used as a basis for their control. In general:

- High Priority weed species should be targeted first
- Moderate Priority weed species should be controlled opportunistically, if resources allow after targeted control of High Priority Weeds
- Low Priority weed species should be controlled opportunistically, if resources allow after control of Moderate and High Priority Weeds.

4.3.2 Control Timing

Control timing is crucial in effectively managing weeds. Generally, weed populations should be targeted when actively growing (ie usually in winter or spring) to allow maximum uptake of herbicides, but before flowering to prevent seed spread. In certain cases, this time window can sometimes be reduced to target weed species without harming native species (eg many annual grass weed species flower before native grasses) (Hussey & Wallace 2003).

The optimal times of the year to control all the observed weed species in each reserve are presented in **Table 7** below. The methodology for selecting the best optimal times are illustrated in **Tables A2.2** to **A2.6** in **Appendix Two**.

Table 7: Optimal control times for targeting priority weed species in Bassendean reserves

RESERVE	OPTIMAL CONTROL TIME											
	J	F	M	A	M	J	J	A	S	O	N	D
Bindaring Park			🟥					🟥			🟥	
Broadway			🟥					🟥		🟥		
Jubilee			🟥					🟥		🟥		
Pickering Park			🟥					🟨			🟥	
Success Hill			🟥					🟥		🟥		

🟥 Optimal times to target High Priority Weed species

🟨 Additional times to target additional Moderate and Low Priority Weed species

For all reserves except Pickering Park will require a minimum of having three rounds of weed control activities a year to target all High Priority weed species: May, August and October/ November. Pickering Park will require a minimum of two rounds of weed control activities to target all of its High Priority weed species: May and November.

These months are also ideal in targeting all of the Moderate and Low Priority weed species for all of the reserves except for Pickering Park. If resources allow, opportunistic control of the non-high priority weeds should also occur while personnel are on site.

If the Town chooses to target non-high priority weed species in Pickering Park, an additional site visit in August will be required to effectively target several non-priority species that are most vulnerable in this month.

The optimal control times for several Moderate and Low Priority weed species lie just outside the indicated months (eg Curled Dock's optimal control time is June to July). However, given their close proximity to the proposed control times, these species should still be reasonably controlled in the recommended control times.

It should be noted that the timing for the targeting of specific weeds presented in this report is an estimate only, and can vary depending on local weather conditions (eg a hot dry spring may cause weeds to seed earlier). Reserves should be monitored before these target months each year to detect the most effective time to conduct weed control.

It should also be noted that as weed control of priority species progresses, other weed species which previously may not have been rated as high, may spread and become greater threats. It is important to keep weed control programmes flexible and updated according to monitoring data to ensure that as soft landscape condition changes and weed species dominance changes, the control activities are adjusted accordingly.

4.4 Control Methods for Weeds

4.4.1 Approach

When controlling weeds, the process should follow the Bradley (1971) *Bush Regeneration* method. The aim of the Bradley Method is the systematic removal of weeds to allow native plants to re-establish themselves when and where they choose. This method does not involve replanting – simply the gradual removal of weeds so that no large openings are made. This makes the Bradley method ideal for many situations, such as where native plants are able to colonise the site by seeds or vegetative means, areas sensitive to erosion and areas likely to be over-used. The process of the Bradley method is detailed in **Appendix Five.**

A variety of control methods for each weed species has been provided in **Appendix Six**. Details of the different options which are suitable are described on the following pages. Weed management recommendations are based on information from:

- Brown and Brooks (2002) *Bushland Weeds*
- Dixon and Keighery (1995) *Recommended methods to control specific weed species*
- Moore and Wheeler (2008) *Southern Weeds and their control.*

4.4.2 Manual Removal

Methods

Removing weeds by hand is the most common method recommended for dealing with individual plants or small populations. Care must be taken to extract the main roots; as if left in the soil they may resprout. Any weed material should be disposed of appropriately away from the site. It should be noted that this method is difficult for weed species that produce tubers or corms underground. In such cases, the soil surrounding each individual plant will need to also be removed and disposed.

4.4.3 Herbicides

Methods

Five methods of applying herbicides are recommended:

- wicker wiping
- cut stump
- stem injection
- spot spraying
- basal bark spraying.

Herbaceous weed species may be treated with herbicide by wicker wiping. This involves sponge or rope soaked in a concentrated herbicide solution which is wiped against the leaves of the plant (Dixon & Keighery 1995). Wiping is often more effective in targeting weed plants and not harming adjacent native plants, however this process may be more labour intensive. Weeds most ideal for this treatment are small populations of small shrubs and broadleaf herbs.

Some species may be controlled by cutting down to ground level and treating the stump with straight herbicide. Typical species suitable for cut stump treatment are trees, shrubs and vines (Dixon & Keighery 1995).

An easy method to kill large trees and shrubs is with stem injection. To do this, a hole into the trunk at a 45 degree angle and to immediately fill the hole with herbicide. The hole must be deep enough to penetrate the sapwood to ensure the herbicide is absorbed and circulated within the plant. If the plant has multiple stems, then all stems will need to be treated (Dixon & Keighery 1995).

Spot spraying involves fine spraying a weak solution of herbicide over the foliage of the weeds. Surfactants and wetting agents are often included to increase the amount of herbicide absorbed by the plants. Care must be taken to avoid accidental spraying of adjacent native plants.

Basal bark spraying is an alternative method for controlling trees. Similar to spot spraying, the base of the trunks with particular herbicides diluted in diesel.

Chemicals

Where possible, a variety of herbicides were recommended for controlling each weed species. Selective herbicides that target the weed species yet have minimal harm to adjacent native plants are preferred over broad spectrum herbicides (Dixon & Keighery 1995). It is up to the Town to decide which herbicide is the most appropriate to use, depending on costs and availability of the herbicides.

As Bindaring Park, Broadway, Pickering Park and Success Hill are near wetlands and waterways, particular care should be exercised when selecting herbicide treatments in these areas. Many common herbicides such as Roundup® contain NPE surfactants which are known to affect the development of amphibian species such as frogs, which can lead to a decline or even loss of such fauna species (Mann 2000). Alternative formulations of herbicides not containing NPE surfactants, such as Roundup Biactive®, are strongly recommended. Other herbicides that are known to have low toxicities to aquatic animals are Ally®, Brushoff® and Fusilade® (Water and Rivers Commission 2001). Information relating to the mobility of herbicides in soil, average half life in soil and water, and bioaccumulation can be found within the herbicide's Materials Safety Data Sheet (MSDS). The herbicide's label should also contain a section outlining appropriate measures for the "Protection of Wildlife, Fish, Crustaceans and Environment".

The application of herbicides must also be in accordance with water catchment restrictions. Chemical based weed control strategies in particular must recognise potential adverse impacts on water resources such as lakes, wetlands, streams, rivers and dams. Clearly, significant control measures must be implemented in Public Drinking Water Sources Areas for the water we consume. The Department of Water's (DOW 2000) *Statewide Policy No.2 Pesticides in Public Drinking Water Sources Areas* will provide further advice on this matter.

It should also be noted that the strength of herbicide treatments are a suggestion only and many were adapted from large scale agriculture rates. The types and rates of herbicides should be verified by a qualified weed scientist before any such methods are used near any water source.

It is necessary that the application of herbicides be in accordance to labelling requirements or the manufacturers MSDS and must be undertaken by personnel trained in the use of herbicide chemicals. The application of any herbicide for purposes not specified on the labelling requires an Off-Label Permit from the National Registration Authority in Canberra.

Details of the herbicides recommended for controlling weeds in the Bassendean reserves are provided in **Appendix Six.**

4.5 Weed Types

It is important to understand the biology of each identified weed species in order to determine the best way to control them. Knowledge should focus on how the plant grows and propagates in order to both remove the existing plants and to prevent future generations. As such, the identified weed species were separated into four types, according to their biology and the type of control methods.

The following section describes the biology of each of the four weed types and notes which of the above control method are the most effective to control that type. It also lists which High Priority weed species belonged to that weed type and in which reserves such species occur. It should be reminded that the high priority weed species listed here may not be high priority for all of the reserve they were recorded in.

4.5.1 Grasses, Sedges and Rushes

Grass, sedge and rush species are all monocots. As such, they have similar physiology which makes them susceptible to certain herbicides that may not be as harmful to broad leaf plants. Using grass selective herbicides such as Fusilade® may assist in controlling monocot weeds while having minimal impact to adjacent broad leaf native plants. Herbicides may be applied through wicker wiping or spot spraying.

Many of these species are highly competitive with native plants and can dominate the understorey. Most monocot weeds, particularly annuals, produce high numbers of seeds to ensure seedling recruitment in the following year. It is therefore vital to control infestations before they set seed to prevent further spread of these populations.

Some of these species, in particular lawn grasses, can also spread by rhizomes and stolons. If the grasses cover the ground, effectively forming a lawn, they may in some circumstances be controlled by either smothering them in black plastic in summer. If the grasses are invading into bushland areas, they may be controlled by manually gathering the spreading rhizomes/ stolons and removing them off the site.

All five reserves contained High Priority grass species. Three species are escaped lawn grasses:

- Buffalo Grass (*Stenotaphrum secundatum*)
- Couch (*Cynodon dactylon*)
- Kikuyu (*Pennisetum clandestinum*)

The remaining grass species are common weeds in the Perth region:

- Barley Grass (*Hordeum leporinum*)
- Brome Grass (*Bromus diandrus*)

- Hares Tail Grass (*Lagurus ovatus*)
- Paspalum (*Paspalum dilatatum*)
- Perennial Veldt Grass (*Ehrharta calycina*)
- Wild Oat (*Avena barbata*).

4.5.2 Geophytes

Many geophyte weeds are 'garden escapes'; originally planted in people's gardens for aesthetics where seeds have entered adjacent bushland. Most of these species are Irises (family Iridaceae) from the cape region of South Africa. The similar climate and soil types made the Perth metropolitan region and south west highly suitable for these species to proliferate and become major environmental weeds.

Geophyte weeds are plants capable or reproducing though underground propagules such as bulbs, corms and tubers. Normal weed control practices are inefficient, as the parent plant may be killed, but the plants may return from sprouting underground propagules. Weed control therefore requires targeting the propagules as well as the parent plant.

If the populations are small, it may be practical to manually remove the plants. Care must be taken to dig around each plant and ensure that all of the underground propagules are also removed, otherwise new plants will appear in the following year. Caution must also be taken if digging in aboriginal heritage sites, as this method risks exposing burial remains.

Certain herbicides such as chlorsulfuron, metsulfuron and 2, 2 DPA are often used to control geophytes, as they can poison both the parent plant and the underground propagules. Such herbicides are best applied when the plants are flowering to maximise the absorption into the propagules. Application can be carried out by either wicker wiping or spot spraying, depending on the species (eg wicker wiping is ineffective on Guildford Grass but is highly effective on Watsonia). Special care must be taken to ensure that adjacent native plants are not exposed to these harmful chemicals.

High Priority geophyte weed species were identified in Bindaring Park, Jubilee and Success Hill. Such weed species to be targeted in these reserves are:

- Arum Lily (*Zantedeschia aethiopica*)
- Bridal Creeper (*Asparagus asparagoides*)
- Guildford Grass (*Romulea rosea*)
- Soursob (*Oxalis pes-caprae*)
- Watsonia (*Watsonia meriana*)
- Wild Gladiolus (*Gladiolus caryophyllaceus*).

4.5.3 Broad Leaf Herbs

Along with grasses, broad leaf herbs are usually the most common type of weed species in a bushland. Most species do not invade good condition bushland, rather they are opportunists that enter when a site is disturbed. Broad leaf herbs are generally easier to control than geophytes, as they only spread by seed and do not have underground propagules. Such weeds should therefore be controlled before they can set seed, as this is their only method of reproduction.

Broad leaf herbs are can be controlled though most general methods. Small populations should be manually removed before they set seed. Care must be taken to remove the crown and taproot, otherwise plants may resprout.

Most species are susceptible to glyphosate when activity growing, although other herbicides may be required on some glyphosate tolerant species. Herbicide application may be though either wicker wiping or spot spraying, depending on the size and nature of the infestation in each reserve.

High Priority broad leaf weed species require to be targeted in Bindaring Park. Two High Priority broad leaf herb species identified in this reserve were:

- Geraldton Carnation Weed (*Euphorbia terracina*)
- Wild Radish (*Raphanus raphanistrum*).

4.5.4 Trees, Shrubs and Climbers

Many tree, shrub and climber weeds are ‘garden escapes’ which have invaded adjacent bushlands. Other species, such as the Summer Scented Wattle, are local native species which can be aggressive and dominate in disturbed environments. Most species of this type are generally easy to control. Timing should focus on when they are actively growing and before they set seed.

Mature plants of trees, shrubs and perennial climbers may be cut to ground level and the stump treated with straight glyphosate to prevent the roots from resprouting. Trees and shrubs with prominent stumps may be treated with stem injection or basal bark spraying.

Seedlings and annual climbers should be eliminated before they can mature. If numbers are small, it is best to manually remove them. If numbers are high, spot spraying would be more practical.

Reserves identified as having High Priority tree, shrub and climber species were:

- Bindaring Park
- Broadway Reserve
- Success Hill.

High Priority tree, shrub and climber species identified were:

- Edible Fig (*Ficus carica*)
- Japanese Pepper (*Schinus terebinthifolia*)
- Lantana (*Lantana camara*)
- Mile-a-Minute (*Ipomoea cairica*)
- Summer Scented Wattle (*Acacia rostellifera*)
- Tamarisk (*Tamarix aphylla*)
- Tobacco tree (*Nicotiana glauca*).

No climber species were rated as a high priority to control.

4.6 Managing Constraints

4.6.1 Aboriginal Heritage

Recorded aboriginal heritage sites were identified within or in the vicinity of all five reserves. Any proposed works in these sites must first be approved by the Minister for Indigenous Affairs, either under Section 18 or Regulation 10 of the Government of Western Australia's *Aboriginal Heritage Act 1972*. Works must also have the approval of the local aboriginal people.

Many of the sites are closed sites and their exact location not given. The Town will need to contact the Department of Indigenous Affairs (DIA) to request the locations of these sites before any works can commence. It is also possible that the exact location is not known. In this case, the Town will need to commission a study of the area to identify heritage values and location of the site.

Any proposed restoration works within heritage sites cannot be for ecological reasons alone. Instead, works must aspire towards enhancing the heritage value of the sites. It is under this objective that suitable weed management works may be developed.

Several of the sites are registered as containing skeletal remains or being burial sites. Procedures must be developed and enforced for handling any situations when remains are exposed. Works must immediately cease and the exposure reported to DIA. Only when the DIA is satisfied that the remains have been correctly deal with, can weed management works resume.

4.6.2 Dieback

Description

Dieback infestation was identified throughout Success Hill.

There are 15 *Phytophthora* species known to exist in Western Australia. These are soil-borne water moulds that kill a wide selection of plant species within the south west of Western Australia. As *Phytophthora* is a parasite, it requires a living host on which to feed and extracts nutrients and water through a mass of thread-like mycelium, which forms the body of the organism. *Phytophthora* kills its host by girdling the base of the stem, destroying the roots and depriving the plant access to nutrients and water. *Phytophthora cinnamomi* is the most significant species and its life cycle requires moist, non-alkaline conditions that favour survival, sporulation and dispersal (Murray 1997).

Many native plant species are known to be vulnerable to dieback, particularly those of the family Proteaceae (eg Banksias, Grevilleas, Hakeas, Isopogons, Petrophiles, Woolybushes), and also in several other families: Dilleniaceae (eg Hibbertias), Papilionaceae (eg Daviesias, Jacksonias), Epacridaceae (eg Leucopogons) and Xanthorrhoeaceae (Grasstrees) (Groves, Hardy & McComb 2007). It is thought that up to 41% of the 6000 species in South West Botanical province are susceptible to this disease (Dunstan et al. 2008).

Control

Human activity is the biggest factor contributing to the spread of this disease. Infected soil can be moved around the reserve by vehicles, footwear, animal movements, road construction and earth moving equipment.

As dieback cannot be cured, the best control is to prevent further spread of infection. Hygiene measures should be practiced in any weed control activity to prevent the transfer of any infected soil or water into dieback free sites. Such activities include:

- only working in dry conditions
- ensuring all machinery, vehicles, equipment and footwear entering or leaving Success Hill is free of soil and mud
- minimising movement of vehicles, machinery, equipment and footwear between disease free and disease infected sites
- not removing any road making materials (eg gravel) from infected sites
- working in mini catchments and not moving material from one catchment to another (Hussey & Wallace 2003).

4.7 Access

Several of the reserves were observed to have informal tracks. Such tracks need to be either formalised or blocked to prevent further degradation of bushland condition and invasion of weeds. Access to the other informal tracks should be restricted with temporary fencing and planted with appropriate local plants to restore the bushland condition. Educational signs could inform the public of the importance of them to remain on the formal paths, thus reducing further trampling of the vegetation.

Several formal paths have been recommended for Bindaring (North) and Success Hill (**Maps 1k and 5F**). These paths should act to direct pedestrians to their destination without needing to trample more vegetation.

Pathways should not be left as bare sand as this may encourage weeds to establish. Instead they should be covered with path materials to prevent weed seed germinating on the paths. Several path materials are presented below, which should be considered for each site:

- bitumen
- concrete
- crushed limestone stabilised with concrete
- gravel stabilised with concrete
- shredded mulch.

The Town should decide which path material is most appropriate to be used in both sites according to the reserve’s social and environmental values.

Weeds may still appear along the sides of the path. As such the paths will need to be routinely inspected as part of monitoring efforts and any weeds observed to be removed.

Path width should be ideally wide enough to act as a vehicle access track. This will allow maintenance and emergency vehicle (eg fire fighting trucks) to effectively traverse the reserves without needing to damage vegetation. It may also serve as a form of fire break, and reduce the spread of any fire outbreak. It is recommended that the paths be at least 3 m in width.

4.8 Monitoring

4.8.1 Monitoring Criteria

When monitoring the site, the following strategies should be adopted:

- Establish monitoring quadrats in the area subject to weed control programs to record the effectiveness of control methods.
- Monitor any change in distribution of the species identified in **Table 4.**
- Monitor for establishment of new weed species.

4.8.2 Performance Criteria

In order to determine the effectiveness of any weed control programme, there needs to be a method of determining success and ongoing progress. The following performance criteria could be used for each reserve, based on the monitoring data collected:

- Control/ eradicate at least three priority weed species over the next five years.
- Reduction in the area of priority weed infestations by 20% over 5 years.
- Reduction in the total number of weed species by 20% over 5 years.

Although not appropriate as performance criteria, other information can be recorded to assist in an overall view of the effectiveness of weed control activities within the site:

- The number of new weed species recorded – it is expected that, initially, new weed species may be recorded as they may not have been identifiable at the time of the field survey. Over time, it is anticipated that the total number of weed species recorded should plateau, and then decrease.
- Any new infestations of High Priority species – this information can be used to determine areas of new infestations, and allow an analysis for the control of these new infestations.

4.8.3 Frequency of Monitoring

Monitoring of bushland condition is recommended to be undertaken every 1-2 years. This is based on the time it takes to undertake initial weed control and then follow-up weed control to remove plants missed. Monitoring bushland condition within the site over a shorter time frame is unlikely to show dramatic changes and could be a waste of resources.

Monitoring of weed quadrats should occur annually, and updating of records should occur as often is as practicable. The bushland condition could be remapped after the performance targets have been met (ie after five years).

Weeds to be mapped annually

Highly invasive weeds with the potential to expand rapidly are high priorities for control and should be mapped each year. These include:

- Bridal Creeper (*Asparagus asparagoides*)
- Geraldton Carnation Weed (*Euphorbia terracina*)
- Kikuyu (*Pennisetum clandestinum*)
- Perennial Veldt Grass (*Ehrharta calycina*)
- Watsonia (*Watsonia meriana*).

Weeds to be mapped every 2 years

High Priority weeds that are not rapid invaders should be mapped every two years. These include:

- Arum Lily (*Zantedeschia aethiopica*)
- Barely Grass (*Hordeum leporinum*)
- Brome Grass (*Bromus diandrus*)
- Buffalo Grass (*Stenotaphrum secundatum*)
- Couch (*Cynodon dactylon*)
- Edible Fig (*Ficus carica*)
- Guildford Grass (*Romulea rosea*)
- Hares Tail Grass (*Lagurus ovatus*)
- Japanese Pepper (*Schinus terebinthifolia*)
- Lantana (*Lantana camara*)
- Mile-a-Minute (*Ipomoea cairica*)
- Paspalum (*Paspalum dilatatum*)
- Soursob (*Oxalis pes-caprae*)
- Summer Scented Wattle (*Acacia rostellifera*)
- Tamarisk (*Tamarix aphylla*)
- Tobacco Tree (*Nicotiana glauca*)
- Wild Oat (*Avena barbata*)
- Wild Radish (*Raphanus raphanistrum*)
- Wild Gladiolus (*Gladiolus caryophyllaceus*).

5.0 Costs and Funding

Bushland Weed Management Plan

5.1 Indicative Costs

Significant funding is required for reducing and eliminating weed species in the Bassendean reserves. An Opinion of Probable Cost (OPC) for improving weed control for each reserve is provided in **Tables 8 to 12** and a summary of all reserve costs are presented in **Table 13**. The OPC calculations were derived using a variety of assumptions. The indicative costs are projected over a 5 year period to improve the overall bushland condition of the reserves. This OPC is intended as a guide only as costs can vary considerably depending on various factors such as whether work is undertaken by staff or volunteers rather than weed contractors.

It should be noted that figures for Success Hill may be underestimated, as the site was subject to a fire after it had been assessed. It is likely that the weeds may invade and dominate the burnt areas, leading to an increase of cost and resources.

5.1.1 Calculated Cost

Calculations were based on bushland condition area figures:

- *Degraded* and *Completely Degraded* areas contained more weed cover, therefore would be more expensive to control than *Good* areas in terms of man hours and resources.
- *Very Good* and *Excellent* areas contained less weeds, however would require more highly skilled workers to locate and remove them without disturbing the site, and therefore would be more expensive to control than *Good* areas.

The unit costs of various weed control and monitoring methods were estimated from examining previous works provided by several weed control contractors and followed the below listed assumptions:

- Weed control is always conducted at optimal times using recommended methods.
- A decline of 20% weed cover subsequently occurs each year as a result of the previous weed control activities.
- Unit area weed costs increase if site characteristics make weed control more difficult (eg dieback hygiene practices, care in not disturbing heritage sites).

5.1.2 Floor Cost

It was realised that as weed presence declined over the years, the costs of actual weed control work may be lower than the estimated costs for conducting monitoring, maintenance and mapping each reserve each year (eg mobilisation, staff hours involved). As such, a “floor cost” was estimated for conducting the minimal required work for each reserve. If the calculated cost was lower than the floor cost, the floor cost figure was used instead. The final chosen figure per year (either calculated or floor cost) for each reserve are in bold font in **Tables 8 to 12**.

5.1.3 Extra Costs

Additional funding was allowed for each reserve for each year to account for the following factors:

- A contingency of 5% was included each year to fund any additional work required to control any new threats or site disturbances (eg introduction of new weed species, fire).
- It is anticipated that the costs of labour and herbicides will increase by 3% per year over the five year period.

5.1.4 Days Labour

The rate to conduct weed control at a site (hours/hectare) corresponded to:

- the difficulty in traversing that site (eg Bindaring Park would take longer to traverse per hectare than Pickering Park)
- the difficulty in conducting weed control (eg controlling some species require more time and effort than other species)

The number of days of weed control labour in each reserve was estimated by:

- summing the total areas for each weed treatment (ha)
- dividing by the rate to conduct weed control (hours)
- dividing by the number of hours in a working day.

Table 8: OPC for weed control in Bindaring Park over five years

Task	Figure	Unit	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Weed Control								
Degraded	39,400	sq m	$23,640	$18,912	$15,130	$12,104	$9,683	$79,468
Completely Degraded	8,800	sq m	$6,600	$5,280	$4,224	$3,379	$2,703	$22,187
Calculated Cost			**$30,240**	**$24,192**	**$19,354**	**$15,483**	**$12,386**	$101,655
Floor Cost	$2,000	$/ha	$9,640	$9,640	$9,640	$9,640	$9,640	$48,200
Contingency	5	%	$1,512	$1,210	$968	$774	$619	$5,083
Inflation	3	%	$0	$726	$1,179	$1,435	$1,554	$4,894
Total	**4.82**	**ha**	**$31,752**	**$26,127**	**$21,500**	**$17,692**	**$14,560**	**$111,632**
No. days labour		days	20.2	16.1	12.9	10.3	8.3	**67.8**

Table 9: OPC for weed control in Broadway over five years

Task	Figure	Unit	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Weed Control								
Good	1,500	sq m	$450	$360	$288	$230	$184	$1,513
Degraded	13,800	sq m	$6,624	$5,299	$4,239	$3,391	$2,713	$22,267
Completely Degraded	11,300	sq m	$6,780	$5,424	$4,339	$3,471	$2,777	$22,792
Calculated Cost			**$13,854**	**$11,083**	**$8,867**	**$7,093**	**$5,675**	$46,572
Floor Cost	$2,000	$/ha	$5,320	$5,320	$5,320	$5,320	$5,320	$26,600
Contingency	5	%	$693	$554	$443	$355	$284	$2,329
Inflation	3	%	$0	$332	$540	$658	$712	$2,242
Total	**2.66**	**ha**	**$14,547**	**$11,970**	**$9,850**	**$8,105**	**$6,670**	**$51,142**
No. days labour		days	11.5	9.2	7.4	5.9	4.7	**38.8**

Table 10: OPC for weed control in Jubilee Reserve over five years

Task	Figure	Unit	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Weed Control								
Excellent	6,000	sq m	$2,940	$2,352	$1,882	$1,505	$1,204	$9,883
Very Good	4,600	sq m	$1,932	$1,546	$1,236	$989	$791	$6,495
Good	2,000	sq m	$700	$560	$448	$358	$287	$2,353
Degraded	3,400	sq m	$1,904	$1,523	$1,219	$975	$780	$6,400
Calculated Cost			**$7,476**	**$5,981**	**$4,785**	**$3,828**	$3,062	$25,131
Floor Cost	$2,000	$/ha	$3,200	$3,200	$3,200	$3,200	**$3,200**	$16,000
Contingency	5	%	$374	$299	$239	$191	$160	$1,263
Inflation	3	%	$0	$464	$792	$1,024	$1,190	$3,470
Total	**1.6**	**ha**	**$7,850**	**$6,744**	**$5,816**	**$5,043**	**$4,550**	**$30,003**
No. days labour		days	5.3	4.3	3.4	2.7	2.2	**18.0**

Table 11: OPC for weed control in Pickering Park over five years

Task	Figure	Unit	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Weed Control								
Very Good	5,600	sq m	$2,016	$1,613	$1,290	$1,032	$826	$6,777
Good	700	sq m	$210	$168	$134	$108	$86	$706
Degraded	400	sq m	$192	$154	$123	$98	$79	$645
Calculated Cost			**$2,418**	**$1,934**	**$1,548**	$1,238	$990	$8,128
Floor Cost	2,000	ha	$1,340	$1,340	$1,340	**$1,340**	**$1,340**	$6,700
Contingency	5	%	$121	$97	$77	$67	$67	$429
Inflation	3	%	$0	$58	$94	$124	$168	$445
Total	**0.67**	**ha**	**$2,539**	**$2,089**	**$1,719**	**$1,531**	**$1,575**	**$9,454**
No. days labour		days	1.3	1.1	0.9	0.7	0.6	**4.5**

Table 12: OPC for weed control in Success Hill over five years

Task	Figure	Unit	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Weed Control								
Degraded	31,200	sq m	$44,928	$35,942	$28,754	$23,003	$18,403	$151,030
Completely Degraded	3,900	sq m	$7,020	$5,616	$4,493	$3,594	$2,875	$23,598
Calculated Cost			**$51,948**	**$41,558**	**$33,247**	**$26,597**	**$21,278**	$174,628
Floor Cost	$2,000	ha	$7,020	$7,020	$7,020	$7,020	$7,020	$35,100
Contingency	5	%	$2,597	$2,078	$1,662	$1,330	$1,064	$8,731
Inflation	3	%	$0	$1,247	$997	$798	$638	$3,680
Total	**3.51**	**ha**	**$54,545**	**$44,883**	**$35,906**	**$28,725**	**$22,980**	**$187,040**
No. days labour		days	14.4	11.5	9.2	7.4	5.9	**48.5**

Table 13: OPC for total costs for weed control in Bassendean reserves over five years

Reserve	Area	Unit	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Bindaring Park	4.82	ha	$31,752	$26,127	$21,500	$17,692	$14,560	$111,632
Broadway	2.66	ha	$14,547	$11,970	$9,850	$8,105	$6,670	$51,142
Jubilee	1.6	ha	$7,850	$6,744	$5,816	$5,043	$4,550	$30,003
Pickering Park	0.67	ha	$2,539	$2,089	$1,719	$1,531	$1,575	$9,454
Success Hill	3.51	ha	$54,545	$44,883	$35,906	$28,725	$22,980	$187,040
Total	**13.26**	**ha**	**$111.233**	**$91,813**	**$71,791**	**$61,096**	**$50,335**	**$389,271**

5.2 Funding Opportunities

A variety of other funding sources are available which may be approached to further finance the work scheme. Many of these sources cannot be directly approached by local governments, however local community groups may apply for and manage the funds for a particular project. Also, some of these sources may require the Town to contribute part of the funds.

National funding bodies include:

- Australia Post Landcare Community Development
- Australian Bird Environment Foundation (ABEF)
- Australian Tourism Development Program
- Caring for our Country (DEWHA)
- Envirofund
- Mazda Foundation
- Myer Foundation
- National Landcare Program
- Norman Wettenhall Foundation
- Threatened Species network Community Grant (WWF)
- Westpac: Operation Backyard.

Possible state sources include:

- Alcoa Foundation
- Bushland Benefits (DEC)
- Community Conservation Grants (DEC)
- Conservation Volunteers Australia
- Environmental Eduction Grants Program (Environment Australia)
- Gordon Reid Conservation of Natural Heritage Grants
- Grants to Voluntary Environment and Heritage Organisitons (DEH)
- Ian Potter Foundation
- Lotterywest grants
- Regional NRM catchment councils
- SGIO Community Help Grant Program
- Swan Alcoa Landcare grants
- Western Australian Regional Initiatives Scheme (WARIS).

Funding may also be possibly obtained from state and Commonwealth heritage programs to enhance the heritage values of the aboriginal sites in the reserves. Suitable sources include:

- Heritage Grants Program
- Indigenous Heritage Program
- Indigenous Protected Areas Program
- Indigenous Start Up and Incentive Land Care Grants.

Volunteer groups may also be approached for on ground works and training opportunities, which may reduce the costs of works. Possible groups include:

- Green Corps
- Green Skills
- local Friends groups.

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Appendix One: Weed Inventory

Bushland Weed Management Plan

Table A1.1: Weed inventory of Bassendean reserves

WEED SPECIES		RESERVES							
Scientific Name	**Common Name**	**Bindaring Park (North)**	**Bindaring Park (South)**	**Broadway**	**Jubilee (A)**	**Jubilee (B)**	**Pickering Park**	**Success Hill**	**TOTAL**
Grass, Sedge and Rush Weeds									
Arundo donax	Giant Reed	*	*					*	**3**
Avena barbata	Wild Oat	*	*	*				*	**4**
*Bolboschoenus caldwellii**	Marsh Club-rush*		*						**1**
Briza maxima	Blowfly Grass	*	*		*	*	*	*	**6**
Briza minor	Shiver Grass	*	*					*	**3**
Bromus diandrus	Brome Grass		*	*				*	**3**
Cynodon dactylon	Couch		*	*	*		*		**4**
Cyperus involucratus	Cyperus	*							**1**
Digitaria sanguinalis	Crab Grass	*	*	*			*		**4**
Ehrharta calycina	Perennial Veldt Grass		*		*	*		*	**4**
Ehrharta longifolia	Annual Veldt Grass			*			*		**2**
Hordeum leporinum	Barley Grass	*	*				*		**3**
Lagurus ovatus	Hares Tail Grass		*					*	**2**
Lolium rigidum	Ryegrass	*	*	*				*	**4**
Paspalum dilatatum	Paspalum	*	*						**2**
Pennisetum clandestinum	Kikuyu	*	*				*	*	**4**
Phyllostachys sp.	Bamboo	*	*						**2**
Polypogon monspeliensis	Annual Barbgrass	*	*				*	*	**4**
Setaria palmifolia	Pigeon Grass	*							**1**
Stenotaphrum secundatum	Buffalo Grass		*						**1**
*Typha domingensis**	Bullrush*	*	*	*				*	**4**
Geophyte Weeds									
Asparagus asparagoides	Bridal Creeper	*	*					*	**3**
Freesia sp.	Freesia							*	**1**
Gladiolus caryophyllaceus	Wild Gladiolus					*		*	**2**
Oxalis pes-caprae	Soursob	*	*		*			*	**4**
Romulea rosea	Guildford Grass				*	*			**2**
Watsonia meriana	Watsonia	*	*					*	**3**
Zantedeschia aethiopica	Arum Lily	*	*					*	**3**
Broad Leaf Herb Weeds									
Anagallis arvensis	Pimpernel	*	*	*					**3**
Arctotheca calendula	Capeweed		*			*	*		**3**
Citrullus lanatus	Wild Melon			*					**1**
Conyza bonariensis	Fleabane	*	*	*	*		*	*	**6**
Euphorbia terracina	Geraldton Carnation Weed			*					**1**
Fumaria capreolata	Whiteflower Fumitory	*	*	*				*	**4**
Galium sp.	Bedstraw		*	*					**2**
Geranium molle	Dove-foot Cranebill			*					**1**
Hypochaeris sp.	Flatweed	*	*	*	*	*	*	*	**7**

WEED SPECIES		**RESERVES**							
Scientific Name	**Common Name**	**Bindaring Park (North)**	**Bindaring Park (South)**	**Broadway**	**Jubilee (A)**	**Jubilee (B)**	**Pickering Park**	**Success Hill**	**TOTAL**
Lactuca serriola	Prickly Lettuce	*	*	*	*	*	*	*	**7**
Lotus angustissimus	Birdsfoot	*	*	*		*			**4**
Lupinus angustifolius	Narrow leaf Lupin			*		*		*	**3**
Lupinus cosentinii	Western Blue Lupin							*	**1**
Malva parviflora	Small Flowered Mallow		*	*					**2**
Medicago polymorpha	Burr Medic		*	*			*		**3**
Melilotus indicus	Common Meliot			*		*	*	*	**4**
Oenothera drummondii	Beach Evening Primrose			*					**1**
Ornithopus compressus	Yellow Seradella				*	*	*		**3**
Plantago lanceolata	Ribwort Plantain	*	*				*		**3**
Raphanus raphanistrum	Wild Radish	*	*	*					**3**
Rorippa nasturtium-aquaticum	Watercress	*							**1**
Rumex crispus	Curled Dock	*	*						**2**
Solidago canadensis	Goldenrod	*							**1**
Solanum nigrum	Black Nightshade	*	*	*			*		**4**
Sonchus asper	Prickly Sowthistle	*	*	*	*	*	*	*	**7**
Sonchus oleraceus	Sowthistle		*	*	*	*		*	**5**
Stachys arvensis	Stagger Weed						*		**1**
Tribulus terrestris	Caltrop			*					**1**
Trifolium angustifolium	Narrowleaf Clover	*	*		*	*			**4**
Trifolium arvense	Hares Tail Clover					*		*	**2**
Tropaeolum majus	Nasturtium	*							**1**
Unknown sp.			*						**1**
Wahlenbergia capensis	Cape Bluebell			*					**1**
Trees, Shrubs and Climber Weeds									
*Acacia rostellifera**	Summer Scented Wattle*			*					**1**
Campsis radicans	Trumpet Vine	*							**1**
Chamaecytisus palmensis	Tagasaste			*					**1**
Chamelaucium uncinatum	Geraldton Wax			*					**1**
Ficus carica	Edible Fig		*						**1**
Hibiscus sp.	Hibiscus		*						**1**
Ipomoea cairica	Mile-a-Minute		*						**1**
Ipomoea indica	Morning Glory	*	*					*	**3**
*Kennedia nigricans**	Black Kennedia		*						**1**
Lantana camara	Lantana							*	**1**
Lathyrus tingitanus	Tangier Pea							*	**1**
Melia azedarach	Cape Lilac Tree		*	*					**2**
Nicotiana glauca	Tobacco Tree			*					**1**
Ricinus communis	Castor Oil		*	*				*	**3**
Schinus terebinthifolia	Japanese Pepper	*	*	*		*			**4**
Tamarix aphylla	Tamarix			*					**1**
Vicia sativa	Vetch	*	*	*		*			**4**
Vitis vinifera	Grapevine		*						**1**
Washingtonia filifera	Cotton Palm		*						**1**
TOTAL		37	51	36	12	17	19	32	**80**

* native species

Methodology of Prioritising Weeds

Rating Systems

The priority ratings of each weed species were determined after examining:

- the ratings under the *Environmental Weed Strategy of Western Australia* (EWSWA) by the Department of Conservation and Land Management (CALM 1999)
- the ratings under the *Environmental Weed Census and Prioritisation* (EWCP) by the Swan Natural Resource Management (Swan NRM 2008)
- the ratings under Dixon and Keighery (1995) *Recommended methods to control specific weed species*
- whether it was listed under the DAFWA (1976) *Agricultural and Related Resources Protection Act* (ARRPA)
- whether it was listed as a *Weed of National Significance* (WONS) (Weed Australia 2008)
- its local significance to the natural areas.

The role of EWSWA is to highlight which weed species pose significant environmental risk in Western Australia. The EWSWA rating provides a basis for determining which weeds are most critical to control. The three characteristics used for determining the EWSWA rating are:

- *invasiveness* – ability to invade bushland in good to excellent condition
- *distribution* – wide current or potential distribution including consideration of known history of wide distribution elsewhere in the world
- *environment impacts* – ability to change the structure, composition and function of ecosystems, in particular to form a monoculture in a vegetation community.

EWSWA weed species were rated accordingly:

- *High* – have all three of the characteristics
- *Moderate* – have two of the characteristics
- *Mild* – have one of the characteristics
- *Low* – not deemed to have any of the characteristics.

However, EWSWA is a general guide for prioritising weeds across the State. The Swan Natural Resource Management (2008) *Environmental Weed Census and Prioritisation* (EWCP) rates weeds species as a threat in Perth bushland conditions. A total of eight ratings are used, according to the risk each species poses to environmental assets in the region, based on invasiveness, ecological impact, current and potential distribution, and thus priority for management. In order of descending, priority, they are:

- Very High
- High
- Further Assessment Required (FAR)/ High
- Moderate/ High
- Moderate
- Low/ Moderate
- Low
- Further Assessment required (FAR)

Dixon and Keighery (1995) developed a rating system for 145 weed species. The rating system classified each species according to the threat they pose to bushland in the Perth Metropolitan region. The three classifications used were:

- *Priority 1* – major weeds, which are the most serious weeds within their ecosystem, often affecting many reserves or habitats in ways likely to permanently degrade them -
- *Priority 2* – nuisance weeds, which are generally found only in a few locations or ecosystems, usually in disturbed areas
- *Priority 3* – minor weeds, which have little known effect and occur in smaller numbers or are less competitive than *Priority 2* weeds.

The type of control for ARRPA declared weed species are listed below:

- *P1* – Prohibits movement of plants or their seeds within the State. This prohibits the movement of contaminated machinery and produce including livestock and feed.
- *P2* – Eradicate infestation to destroy and prevent propagation each year until no plants remain. The infested area must be managed in such a way that prevents the spread of seed or plant parts on or in livestock, fodder, grain, vehicles and/or machinery.
- *P3* – Control infestation in such a way that prevents the spread of seed or plant parts within and form the property on or in livestock, fodder, grain, vehicles and/or machinery. Treat to destroy and prevent seed set all plants.
- *P4* – Prevent the spread of infestation from the property on or in livestock, fodder, grain, vehicles and/or machinery. Treat to destroy and prevent seed set on all plants.

WONS was jointly declared by the Minister for Forestry and Conservation, the Minister for Agriculture, Fisheries and Forestry and the Minister for The Environment in 1999 as part of the *National Weeds Strategy*. The four characteristics used for determining where the species was of national significance were:

- invasiveness
- impacts
- potential for spread
- socioeconomic and environmental values.

Ranking Priority Weeds

The above sources were used to rank the recorded weed species in order of priority for control. Both the EWCP (Swan Natural Resource Management 2008) and EWSWA (CALM 1999) ratings were used because it allowed most weeds identified in the study area to be assigned a rating and thereby ranked. If only one source had been used, some of the weed species would have not been assigned a rating score.

The use of two rating systems does result in some conflict when assigning a ranking for a weed species. To overcome this issue, a matrix scoring system was developed to enable the ranking of the weed species. The matrix scoring system is summarised in **Table A2.1.** For the purposes of this study, the system gave a slight bias to the EWCP system, as this system was more relevant for the study area.

In addition, as weed species listed under either ARRPA or WONS are required by legislation to be controlled, any of these listed weed species recorded were automatically given a rating of 6.

Table A2.1: Matrix scoring system for rating weed priority

RATING SYSTEM		EWSWA				
		Unrated	Low	Mild	Moderate	High
Perth NRM	Unrated	1	1	3	4	5
	FAR	1	1	3	4	5
	Low	2	2	3	4	5
	L/M	2	3	4	4	5
	M	3	4	4	4	5
	M/H	4	4	4	5	6
	FAR/H	5	5	5	5	6
	H	5	5	5	6	6
	VH	6	6	6	6	6

If any weed species not assigned a rating by these any of the previous sources, the Dixon and Keighery (1995) rating system would then be used:

- Priority 1 = Rating 6
- Priority 2 = Rating 4
- Priority 3 = Rating 2

If any weed species were not given a rating be any of the previous systems, they would receive a default rating of 1.

The calculated ratings were then adjusted according to whether the species were more or less of a threat or dominant in the local native areas. Species with low ratings that were posing a greater threat or were already highly dominant had the rating raised. In contrast, species with high ratings but were not considered to be a local threat had their rating lowered accordingly.

The priority of each weed species was then classified by the final rating:

- Species given a rating of 5 or 6 were *High Priority Weeds*.
- Species with a final rating of 3 or 4 were *Moderate Priority Weeds*.
- Species with a rating of 1 or 2 were *Low Priority Weeds.*

Results

State and National Significance

The following weed species were given priority scores of 6 (High Priority) as they were listed by WONS and/or ARRPA:

- Arum Lily (*Zantedeschia aethiopica*) ARRPA
- Bridal Creeper (*Asparagus asparagoides*) - WONS and ARRPA
- Lantana (*Lantana camara*) WONS and ARRPA
- Tamarix (*Tamarix aphylla*) – ARRPA.

Local Significance

Several mature trees of Japanese Pepper (*Schinus terebinthifolia*) were observed throughout Bindaring Park. Another specimen was recorded resprouting form a root in Jubilee Reserve (B). A sapling was also observed in Broadway. Mature Japanese Peppers are known to dominate and outcompete overstorey species in wetlands and waterways of the Perth metropolitan region. Physical removal of mature trees is also a costly and laborious exercise. As such the species score was upgraded from 1 (Low Priority) to 4, as it is considered to be a Moderate Priority to control in both reserves.

The native species Summer Scented Wattle (*Acacia rostellifera*) was originally planted in Broadway reserve as part of the Arboretum. This species is not local to the Bassendean area. Instead, it naturally occurs in coastal areas, where is an aggressive coloniser of beach sand dunes. This aggressive character has resulted in the many seedlings sprouting across the reserve. The priority score for Summer Scented Wattle was therefore increased from 1 (Low Priority) to 5 (High Priority) for Broadway, as immediate action is required to control the seedlings before the reserve is further degraded.

Large infestations of Brome Grass (*Bromus diandrus*) and Wild Radish (*Raphanus raphanistrum*) were observed dominating much the understorey of Broadway. The species initially scored 4 (Moderate priority) and 2 (Low Priority), respectively. However, the urgency to reduce the cover of these species to restore the native understorey warrants their priority scores to be raised to 5 (High Priority) for this reserve.

Similarly, a large population of Tobacco Tree (*Nicotiana glauca*) was observed in the southwest section of Broadway. The priority score was accordingly raised from 2 (Low Priority) to 5 (High Priority), as this species needs to be immediately controlled before it spreads further.

Numerous populations of Birdsfoot (*Lotus angustissimus*) were recorded bordering the Nyibra Swamp in Broadway. The priority score of this species was raised from 2 (Low Priority) to 4 (Moderate Priority) to reflect the need to reduce the cover of this weed species.

A single plant of Geraldton Wax (*Chamelaucium uncinatum*) was recorded on the southern edge of Nyibra Swamp in the Broadway reserve. This species not known to be an invader of bushland. As this species is not considered to be a threat to the site, its priority score was reduced from 4 (Moderate Priority) to 2 (Low Priority).

The lawn grass Kikuyu (*Pennisetum clandestinum*) was observed along the shoreline in Success Hill. Several parts of the shoreline were covered in Kikuyu, resembling a lawn. The weed species was also observed spreading into the understorey near the shoreline. Similarly, large populations of Watsonia (*Watsonia meriana*) were recorded on and near the slope area of Success Hill. Both species are well known to dominate and smother the understorey of wetlands and waterways in the Perth metropolitan area. They are especially invasive and dominant after a fire, which this site experienced on December 31st 2009. The extreme threats of these species to this reserve resulted in their priority scores to be raised from 5 to 6 (High Priority) to stress their importance to be controlled.

Small infestations of Couch (*Cynodon dactylon*), Freesia (*Freesia* sp.), Hares Tail Grass (*Lagurus ovatus*) and Western Blue Lupin (*Lupinus cosentinii*) were recorded in Success Hill.

The calculated scores for this species are 5, 6, 5 and 6 respectively, indicating that they are all High Priorities. However, as this reserve already has many high priority weed species that needs extensive resources to control (ie Perennial Veldt Grass, Lantana, Arum Lily and Watsonia), the threat of these species to the bushland was relevantly less important. Their scores in Success Hill were therefore reduced to 4 (Moderate Priority).

Table A2.2: Prioritisation and optimal control times of weeds observed at Bindaring Park

WEED SPECIES		**SECTION**		**PRIORITISATION**									**OPTIMAL CONTROL TIME**											
Scientific Name	**Common Name**	**Bindaring North**	**Bindaring South**	**EWSWA**	**Swan NRM**	**WONS**	**ARRPA**	**Dixon & Keighery**	**Calculated Rating**	**Locally significant**	**Final Rating**	**PRIORITY**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Asparagus asparagoides	Bridal Creeper	*	*	High	Very High	*	P1	1	6		**6**	**High**							🟥	▨	🟥			
Avena barbata	Wild Oat	*	*	Moderate	Very High			1	6		**6**							🟥	🟥	▨				
Bromus diandrus	Brome Grass		*	High	Very High			3	6		**6**										🟥	🟥	▨	
Cynodon dactylon	Couch		*	Moderate	Very High			1	6		**6**					🟥	▨					🟥	▨	
Ehrharta calycina	Perennial Veldt Grass		*	High	Very High			1	6		**6**					🟥	▨			▨	🟥			
Ficus carica	Edible Fig		*	Moderate	High			1	6		**6**									▨	🟥	🟥	▨	🟥
Hordeum leporinum	Barley Grass	*	*	Moderate	High			3	6		**6**								🟥	▨	🟥			
Lagurus ovatus	Hares Tail Grass		*	High	High			2	6		**6**							🟥	🟥	▨	🟥			
Paspalum dilatatum	Paspalum	*	*	Moderate	High			2	6		**6**									▨	🟥	🟥	▨	
Pennisetum clandestinum	Kikuyu	*	*	Moderate	High			1	6		**6**		🟥	🟥	🟥	🟥	▨	🟥	🟥	▨	🟥	🟥	▨	🟥
Schinus terebinthifolia	Japanese Pepper	*	*	Unrated	Very High				6		**6**										🟥	🟥	▨	🟥
Stenotaphrum secundatum	Buffalo Grass		*	Moderate	High			1	6		**6**		🟥	🟥									▨	🟥
Watsonia meriana	Watsonia	*	*	High	Very High			1	6		**6**										🟥	🟥	▨	
Zantedeschia aethiopica	Arum Lily	*	*	High	Very High		P1, P4	1	6		**6**							🟥	🟥	▨	🟥	🟥	▨	
Ipomoea cairica	Mile-a-Minute		*	Mild	High			3	5		**5**		🟥	🟥	🟥	🟥	▨	🟥	🟥	▨	🟥	🟥	▨	🟥
Oxalis pes-caprae	Soursob	*	*	Mild	High			2	5		**5**								🟥	▨	🟥			
Arctotheca calendula	Capeweed		*	Moderate	High			3	6	No	**4**	**Moderate**						🟨	🟨	▨	🟨			
Briza maxima	Blowfly Grass	*	*	Moderate	FAR			2	4		**4**							🟨	🟨	▨	🟨			
Briza minor	Shiver Grass	*	*	Moderate	FAR			2	4		**4**							🟨	🟨	▨	🟨			
Cyperus involucratus	Cyperus	*		Low	Moderate				4		**4**		🟨								🟨	🟨	▨	🟨
Fumaria capreolata	Whiteflower Fumitory	*		Mild	Moderate/ High			2	4		**4**										🟨	🟨	▨	
Galium sp.	Bedstraw		*	Moderate	Unrated			3	4		**4**							🟨	🟨	▨	🟨			
Hypochaeris sp.	Flatweed	*	*	Moderate	High			3	6	No	**4**									▨	🟨	🟨	▨	
Ipomoea indica	Morning Glory	*	*	Mild	Moderate/ High			3	4		**4**		🟨	🟨	🟨	🟨	▨	🟨	🟨	▨	🟨	🟨	▨	🟨
Lactuca serriola	Prickly Lettuce	*	*	Moderate	High			3	6	No	**4**											🟨	▨	🟨
Lolium rigidum	Ryegrass	*	*	Moderate	Unrated			3	4		**4**							🟨	🟨	▨				
Lotus angustissimus	Birdsfoot	*	*	Low	High			3	5	No	**4**								🟨	▨	🟨	🟨	▨	🟨
Polypogon monspeliensis	Annual Barbgrass	*	*	Moderate	Unrated			3	4		**4**							🟨	🟨	▨	🟨			
Rorippa nasturtium-aquaticum	Watercress	*		Moderate	Unrated				4		**4**										🟨	🟨	▨	
Solanum nigrum	Black Nightshade	*	*	Moderate	Moderate			2	4		**4**										🟨	🟨	▨	🟨
Sonchus asper	Prickly Sowthistle	*	*	Moderate	FAR				4		**4**						▨	🟨	🟨	▨				
Sonchus oleraceus	Sowthistle	*	*	Moderate	FAR			3	4		**4**						▨	🟨	🟨	▨				
Vicia sativa	Vetch	*	*	Moderate	FAR			3	4		**4**							🟨	🟨	▨	🟨	🟨		
Arundo donax	Giant Reed	*	*	Unrated	Unrated			2	3		**3**									▨	🟨	🟨	▨	🟨
Medicago polymorpha	Burr Medic		*	Mild	FAR			3	3		**3**									▨	🟨	🟨	▨	🟨
Raphanus raphanistrum	Wild Radish	*	*	Mild	FAR			3	3		**3**							🟨	🟨	▨	🟨			
Rumex crispus	Curled Dock	*	*	Mild	FAR			3	3		**3**							🟨	🟨	▨				

WEED SPECIES		SECTION		PRIORITISATION									OPTIMAL CONTROL TIME											
Scientific Name	**Common Name**	**Bindaring North**	**Bindaring South**	**EWSWA**	**Swan NRM**	**WONS**	**ARRPA**	**Dixon & Keighery**	**Calculated Rating**	**Locally significant**	**Final Rating**	**PRIORITY**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Anagallis arvensis	Pimpernel	*	*	Moderate	FAR			3	4	No	**2**	**Low**							🟩	▨	🟩	🟩		
Conyza bonariensis	Fleabane	*	*	Low	Low			3	2		**2**											🟩	▨	🟩
Digitaria sanguinalis	Crab Grass	*	*	Low	Low				2		**2**									▨	🟩	🟩	▨	🟩
Malva parviflora	Small Flowered Mallow		*	Low	Low			3	2		**2**									▨	🟩	🟩	▨	🟩
Melia azedarach	Cape Lilac		*	Low	Low				2		**2**		🟩	🟩	🟩	🟩	▨	🟩	🟩	▨	🟩	🟩	▨	🟩
Plantago lanceolata	Ribwort Plantain	*	*	Low	FAR			3	2		**2**											🟩	▨	🟩
Setaria palmifolia	Pigeon Grass	*		Low	Low				2		**2**								🟩	▨	🟩	🟩		
Solidago canadensis	Goldenrod	*		Low	Low				2		**2**								🟩	▨	🟩	🟩	▨	
Trifolium angustifolium	Narrowleaf Clover	*	*	Unrated	FAR			3	2		**2**										🟩	🟩	▨	
Tropaeolum majus	Nasturtium	*		Low	Low			3	2		**2**									▨	🟩	🟩	▨	🟩
Washingtonia filifera	Cotton Palm		*	Mild	FAR			3	3	No	**2**							🟩	🟩	▨	🟩			
*Bolboschoenus caldwellii**	Marsh Club-rush*		*						1		**1**										🟩	🟩	▨	
Campsis radicans	Trumpet Vine	*							1		**1**									▨	🟩	🟩	▨	🟩
Hibiscus sp.			*	Low					1		**1**							🟩	🟩	▨	🟩	🟩		
Kennedia nigricans			*	Unrated	FAR				1		**1**		🟩	🟩	🟩	🟩	▨	🟩	🟩	▨	🟩	🟩	▨	🟩
Phyllostachys sp.	Bamboo	*	*						1		**1**		🟩	🟩	🟩	🟩	▨							🟩
Ricinus communis	Castor Oil		*	Low	Unrated			3	1		**1**						▨	🟩	🟩					
*Typha domingensis**	Bullrush*	*	*	Low	Unrated				1		**1**											🟩	▨	🟩
Unknown Sp. 2			*						1		**1**										🟩	🟩	▨	🟩
Vitis vinifera	Grapevine		*	Unrated	Unrated				1		**1**		🟩									🟩	▨	🟩

▨ Optimal control times for targeting weed species

Table A2.3: Prioritisation and optimal control times of weeds observed at Broadway

WEED SPECIES		**PRIORITISATION**									**OPTIMAL CONTROL TIME**											
Scientific Name	**Common Name**	**EWSWA**	**Swan NRM**	**WONS**	**ARRPA**	**Dixon & Keighery**	**Calculated Rating**	**Locally significant**	**Final Rating**	**PRIORITY**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Avena barbata	Wild Oat	Moderate	Very High			1	6		**6**	**High**						🟥	🟥	▨				
Bromus diandrus	Brome Grass	High	Very High			3	6		**6**										🟥	▨	🟥	
Cynodon dactylon	Couch	Moderate	Very High			1	6		**6**					🟥	▨					▨	🟥	
Euphorbia terracina	Geraldton Carnation Weed	High	Very High			1	6		**6**						▨	🟥						
Schinus terebinthifolia	Japanese Pepper	Unrated	Very High				6		**6**										🟥	▨	🟥	🟥
Tamarix aphylla	Tamarisk	Moderate	High		P1		6		**6**										🟥	▨	🟥	
*Acacia rostellifera**	Summer Scented Wattle*						1	Yes	**5**										🟥	▨	🟥	🟥
Nicotiana glauca	Tobacco Tree	Mild	Moderate			3	4	yes	**5**										🟥	▨	🟥	
Raphanus raphanistrum	Wild Radish	Mild	FAR			3	3	Yes	**5**							🟥	🟥	▨	🟥			
Chamelaucium uncinatum	Geraldton Wax	Moderate	Moderate			2	4		**4**	**Moderate**									🟨	▨	🟨	
Ehrharta longifolia	Annual Veldt Grass	Moderate	FAR			3	4		**4**							🟨	🟨	▨	🟨	▨		
Fumaria capreolata	Whiteflower Fumitory	Mild	Moderate/ High			2	4		**4**										🟨	▨	🟨	
Galium sp.	Bedstraw	Moderate	Unrated			3	4		**4**							🟨	🟨	▨	🟨			
Hypochaeris sp.	Flatweed	Moderate	High			3	6	No	**4**									▨	🟨	▨	🟨	
Lactuca serriola	Prickly Lettuce	Moderate	High			3	6	No	**4**											▨	🟨	🟨
Lolium rigidum	Ryegrass	Moderate	Unrated			3	4		**4**							🟨	🟨	▨				
Lotus angustissimus	Birdsfoot	Low	High			3	5	No	**4**								🟨	▨	🟨	▨	🟨	🟨
Melilotus indicus	Common Meliot	Moderate	Unrated			3	4		**4**									▨	🟨	▨	🟨	🟨
Oenothera drummondii	Beach Evening Primrose	Moderate	Unrated			3	4		**4**									▨	🟨	▨	🟨	🟨
Solanum nigrum	Black Nightshade	Moderate	Moderate			2	4		**4**										🟨	▨	🟨	🟨
Sonchus asper	Prickly Sowthistle	Moderate	FAR				4		**4**						▨	🟨	🟨	▨				
Sonchus oleraceus	Sowthistle	Moderate	FAR			3	4		**4**						▨	🟨	🟨	▨				
Tribulus terrestris	Caltrop	Low	Moderate/ High				4		**4**									▨	🟨	▨	🟨	🟨
Vicia sativa	Vetch	Moderate	FAR			3	4		**4**							🟨	🟨	▨	🟨	▨		
Chamaecytisus palmensis	Tagasaste	Mild	FAR			2	3		**3**				🟨	🟨	▨				🟨	▨	🟨	
Lupinus angustifolius	Narrow leaf Lupin	Mild	Unrated			3	3		**3**							🟨	🟨	▨				
Medicago polymorpha	Burr Medic	Mild	FAR			3	3		**3**									▨	🟨	▨	🟨	🟨
Anagallis arvensis	Pimpernel	Moderate	FAR			3	4	No	**2**	**Low**							🟩	▨	🟩	▨		
Conyza bonariensis	Fleabane	Low	Low			3	2		**2**											▨	🟩	🟩
Digitaria sanguinalis	Crab Grass	Low	Low				2		**2**		🟩								🟩	▨	🟩	🟩
Geranium molle	Dove-foot Cranebill	Low	Moderate			3	4	No	**2**									▨	🟩	▨	🟩	🟩
Malva parviflora	Small Flowered Mallow	Low	Low			3	2		**2**									▨	🟩	▨	🟩	🟩
Melia azedarach	Cape Lilac Tree	Low	Low				2		**2**		🟩	🟩	🟩	🟩	▨	🟩	🟩	▨	🟩	▨	🟩	🟩
Wahlenbergia capensis	Cape Bluebell	Moderate	FAR			3	4	No	**2**									▨	🟩	▨	🟩	🟩
Citrullus lanatus	Wild Melon	Low	Unrated			3	1		**1**										🟩	▨	🟩	
Ricinus communis	Castor Oil	Low	Unrated			3	1		**1**										🟩	▨	🟩	
*Typha domingensis**	Bullrush*	Low	Unrated				1		**1**										🟩	▨	🟩	🟩

▨ Optimal control times for targeting weed species

Table A2.4: Prioritisation and optimal control times of weeds of weeds observed at Jubilee

WEED SPECIES		SECTION		PRIORITISATION									OPTIMAL CONTROL TIME											
Scientific Name	**Common Name**	**Jubilee A**	**Jubilee B**	**EWSWA**	**Swan NRM**	**WONS**	**ARRPA**	**Dixon & Keighery**	**Calculated Rating**	**Locally significant**	**Final Rating**	**PRIORITY**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cynodon dactylon	Couch	*		Moderate	Very High			1	6		**6**	**High**				🟥	▨					▨	🟥	
Ehrharta calycina	Perennial Veldt Grass	*	*	High	Very High			1	6		**6**					🟥	▨			▨	🟥			
Gladiolus caryophyllaceus	Wild Gladiolus		*	Moderate	FAR/ High			1	5		**5**									▨	🟥	▨	🟥	
Oxalis pes-caprae	Soursob	*		Mild	High			2	5		**5**								🟥	▨	🟥			
Romulea rosea	Guildford Grass	*	*	High	FAR			1	5		**5**									▨	🟥			
Arctotheca calendula	Capeweed		*	Moderate	High			3	6	No	**4**	**Moderate**						🟨	🟨	▨	🟨			
Briza maxima	Blowfly Grass	*	*	Moderate	FAR			2	4		**4**							🟨	🟨	▨	🟨			
Hypochaeris sp.	Flatweed	*	*	Moderate	High			3	6	No	**4**									▨	🟨	▨	🟨	
Lactuca serriola	Prickly Lettuce	*	*	Moderate	High			3	6	No	**4**											▨	🟨	🟨
Lotus angustissimus	Birdsfoot		*	Low	High			3	5	No	**4**							🟨	🟨	▨	🟨	▨	🟨	🟨
Melilotus indicus	Common Meliot		*	Moderate	Unrated			3	4		**4**									▨	🟨	▨	🟨	🟨
Schinus terebinthifolia	Japanese Pepper		*	Unrated	Very High				6	No	**4**									▨	🟨	▨	🟨	🟨
Sonchus asper	Prickly Sowthistle	*	*	Moderate	FAR				4		**4**						▨	🟨	🟨	▨				
Sonchus oleraceus	Sowthistle	*	*	Moderate	FAR			3	4		**4**						▨	🟨	🟨	▨				
Trifolium angustifolium	Narrowleaf Clover	*	*	Unrated	FAR			3	2	yes	**4**							🟨	🟨	▨				
Trifolium arvense	Hares Tail Clover		*	Moderate	FAR			3	4		**4**							🟨	🟨	▨				
Vicia sativa	Vetch		*	Moderate	FAR			3	4		**4**								🟨	▨	🟨	▨		
Lupinus angustifolius	Narrow leaf Lupin		*	Mild	Unrated			3	3		**3**							🟨	🟨	▨	🟨			
Conyza bonariensis	Fleabane	*		Low	Low			3	2		**2**	**Low**										▨	🟩	🟩
Ornithopus compressus	Yellow Seradella	*	*	Mild	Moderate			3	4	No	**2**							🟩	🟩	▨				

▨ Optimal control times for targeting weed species

Table A2.5: Prioritisation and optimal control times of weeds observed at Pickering Park

WEED SPECIES		PRIORITISATION									OPTIMAL CONTROL TIME											
Scientific Name	**Common Name**	**EWSWA**	**Swan NRM**	**WONS**	**ARRPA**	**Dixon & Keighery**	**Calculated Rating**	**Locally significant**	**Final Rating**	**PRIORITY**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cynodon dactylon	Couch	Moderate	Very High			1	6		**6**	**High**				🟥	▨							
Pennisetum clandestinum	Kikuyu	Moderate	High			1	6		**6**		🟥	🟥	🟥	🟥	▨	🟥	🟥	🟥	🟥	🟥	▨	🟥
Arctotheca calendula	Capeweed	Moderate	High			3	6	No	**4**	**Moderate**						🟨	🟨	▦	🟨			
Briza maxima	Blowfly Grass	Moderate	FAR			2	4		**4**							🟨	🟨	▦	🟨			
Ehrharta longifolia	Annual Veldt Grass	Moderate	FAR			3	4		**4**							🟨	🟨	▦	🟨	🟨		
Hordeum leporinum	Barley Grass	Moderate	High			3	6	No	**4**								🟨	▦	🟨			
Hypochaeris sp.	Flatweed	Moderate	High			3	6	No	**4**									▦	🟨	🟨		
Lactuca serriola	Prickly Lettuce	Moderate	High			3	6	No	**4**									▦	🟨	🟨		
Melilotus indicus	Common Meliot	Moderate	Unrated			3	4		**4**									▦	🟨	🟨	▨	🟨
Polypogon monspeliensis	Annual Barbgrass	Moderate	Unrated			3	4		**4**							🟨	🟨	▦	🟨			
Solanum nigrum	Black Nightshade	Moderate	Moderate			2	4		**4**						▨	🟨	🟨	▦				
Sonchus asper	Prickly Sowthistle	Moderate	FAR				4		**4**						🟨	🟨	🟨	▦				
Medicago polymorpha	Burr Medic	Mild	FAR			3	3		**3**									▦	🟨	🟨	▨	🟨
Conyza bonariensis	Fleabane	Low	Low			3	2		**2**	**Low**										🟩	▨	🟩
Digitaria sanguinalis	Crab Grass	Low	Low				2		**2**		🟩								🟩	🟩	▨	🟩
Ornithopus compressus	Yellow Seradella	Mild	Moderate			3	4	No	**2**							🟩	🟩	▦				
Plantago lanceolata	Ribwort Plantain	Low	FAR			3	2		**2**											🟩	▨	🟩
Stachys arvensis	Stagger Weed	Low	Unrated			3	1		**1**								🟩	▦	🟩	🟩		

▨ Optimal control times for targeting high priority weed species

▦ Additional time for targeting Mod and low priority weed species

Table A2.6: Prioritisation and optimal control times of weeds observed at Success Hill

WEED SPECIES		PRIORITISATION									OPTIMAL CONTROL TIME											
Scientific Name	**Common Name**	**EWSWA**	**Swan NRM**	**WONS**	**ARRPA**	**Dixon & Keighery**	**Calculated Rating**	**Locally significant**	**Final Rating**	**PRIORITY**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Asparagus asparagoides	Bridal Creeper	High	Very High	*	P1	1	6		**6**	**High**						🟥	🟥	▨	🟥			
Avena barbata	Wild Oat	Moderate	Very High			1	6		**6**							🟥	🟥	▨				
Ehrharta calycina	Perennial Veldt Grass	High	Very High			1	6		**6**					🟥	▨			▨	🟥			
Lantana camara	Lantana	Moderate	Moderate	*	P1	3	6		**6**										🟥	▨	🟥	
Pennisetum clandestinum	Kikuyu	Moderate	High			1	6		**6**		🟥	🟥	🟥	🟥	▨	🟥	🟥	▨	🟥	▨	🟥	🟥
Watsonia meriana	Watsonia	High	Very High			1	6		**6**										🟥	▨	🟥	
Zantedeschia aethiopica	Arum Lily	High	Very High		P1, P4	1	6		**6**							🟥	🟥	▨	🟥	▨	🟥	
Gladiolus caryophyllaceus	Wild Gladiolus	Moderate	FAR/ High			1	5		**5**									▨	🟥	▨	🟥	
Briza maxima	Blowfly Grass	Moderate	FAR			2	4		**4**	**Moderate**						🟨	🟨	▨	🟨			
Briza minor	Shiver Grass	Moderate	FAR			2	4		**4**							🟨	🟨	▨	🟨			
Bromus diandrus	Brome Grass	High	Very High			3	6	No	**4**										🟨	▨	🟨	
Cynodon dactylon	Couch	Moderate	Very High			1	6	No	**4**					🟨	▨					▨	🟨	
Freesia sp.	Freesia	Unrated	High			1	5	No	**4**									▨	🟨			
Fumaria capreolata	Whiteflower Fumitory	Mild	Moderate/ High			2	4		**4**										🟨	▨	🟨	
Hypochaeris sp.	Flatweed	Moderate	High			3	6	No	**4**									▨	🟨	▨	🟨	
Ipomoea indica	Morning Glory	Mild	Moderate/ High			3	4		**4**		🟨	🟨	🟨	🟨	▨	🟨	🟨	▨	🟨	▨	🟨	🟨
Lactuca serriola	Prickly Lettuce	Moderate	High			3	6	No	**4**											▨	🟨	🟨
Lagurus ovatus	Hares Tail Grass	High	High			2	6	No	**4**							🟨	🟨	▨				
Lolium rigidum	Ryegrass	Moderate	Unrated			3	4		**4**							🟨	🟨	▨				
Lupinus cosentinii	Western Blue Lupin	High	Unrated			1	5	No	**4**								🟨	▨	🟨			
Melilotus indicus	Common Meliot	Moderate	Unrated			3	4		**4**									▨	🟨	▨	🟨	🟨
Oxalis pes-caprae	Soursob	Mild	High			2	5	No	**4**								🟨	▨	🟨			
Polypogon monspeliensis	Annual Barbgrass	Moderate	Unrated			3	4		**4**								🟨	▨	🟨			
Sonchus asper	Prickly Sowthistle	Moderate	FAR				4		**4**						▨	🟨	🟨	▨				
Sonchus oleraceus	Sowthistle	Moderate	FAR			3	4		**4**						▨	🟨	🟨	▨				
Trifolium arvense	Hares Tail Clover	Moderate	FAR			3	4		**4**							🟨	🟨	▨				
Arundo donax	Giant Reed	Unrated	Unrated			2	3		**3**									▨	🟨	▨	🟨	🟨
Lupinus angustifolius	Narrow leaf Lupin	Mild	Unrated			3	3		**3**								🟨	▨	🟨			
Conyza bonariensis	Fleabane	Low	Low			3	2		**2**	**Low**										▨	🟩	🟩
Lathyrus tingitanus	Tangier Pea	Low	Low			3	2		**2**									▨	🟩	▨		
*Typha domingensis**	Bullrush*	Low					1		**1**											▨	🟩	🟩

▨ Optimal control times for targeting high priority weed species

Table A3.1: Registered Aboriginal sites listed in or adjacent to Bassendean reserves

Site id	Status	Access	Restriction	Site Name	Site type	Grid Ref. (MGA94 Zone 50)	Site No.
Bindaring Park and Pickering Park							
3536	Permanent	Open	None	Swan River	Mythological	443400mE 6461957mN	S02548
3758	Permanent	Closed	None	Helena River	Ceremonial, Mythological, Repository/ cache	Not available	S02148
Broadway							
3134	Insufficient information	Open	None	Snake Swamp	Artefacts/ Scatter	399378mE 6469734mN	S00712
3748	Stored data	Open	None	Nyibra Swamp	Hunting Place	399013mE 6469737mN	S02198
3840	Permanent	Closed	None	Bennet Brook	Ceremonial, Mythological, Skeletal material/ Burial, Man-made structures, Fish Trap, Artefacts/ Scatter, Historical	Not available	S01997
Jubilee Reserve							
3488	Permanent	Closed	None	Bennet Brook: Rosher Park	Meeting Place/ Camp	Not available	S02662
3489	Permanent	Closed	None	Bennet Brook: Lord Street 1	Ceremonial, Skeletal material/ Burial	Not available	S02663
3490	Insufficient information	Closed	None	Bennet Brook: Lord Street 2	Ceremonial, Skeletal material/ Burial	Not available	S02664
3840	Permanent	Closed	None	Bennet Brook: Camp Area	Ceremonial, Mythological, Skeletal material/ Burial, Man-made structure, First Trap, Artefacts/ Scatter, Historical	Not available	S01997
4369	Stored data	Closed	None	Walkington Way	Artefacts/ Scatter	400014mE 64713914mN (unreliable)	S00717
Success Hill							
3487	Permanent	Closed	None	Bennet Brook: Eden Hill	Meeting Place, Camp, Water Source	Not available	S02661
3489	Permanent	Closed	None	Bennet Brook: Lord Street 1	Ceremonial, Skeletal material/ Burial	Not available	S02663
3490	Insufficient information	Closed	None	Bennet Brook: Lord Street 2	Ceremonial, Skeletal material/ Burial	Not available	S02664
3536	Permanent	Open	None	Swan River	Mythological	443400mE 6461957mN	S02548
3692	Permanent	Closed	None	Bennet Brook: In Toto	Mythological	Not available	S02254
3757	Permanent	Closed	None	Success Hill	Ceremonial, Mythological, Repository/ cache, Man-Made Structure, Fish Trap, Quarry, Artefacts/ Scatter	Not available	S02147
3758	Permanent	Closed	None	Helena River	Ceremonial, Mythological, Repository/ cache	Not available	S02148
3840	Permanent	Closed	None	Bennet Brook	Ceremonial, Mythological, Skeletal material/ Burial, Man-made structures, Fish Trap, Artefacts/ Scatter, Historical	Not available	S01997
17041	Stored data	Open	None	Pyrton A5	Artefacts/ Scatter	401268mE 6470775mN	

Appendix Four: Maps

Bushland Weed Management Plan

The section contains bush condition, weed and walk trail maps in the following order:

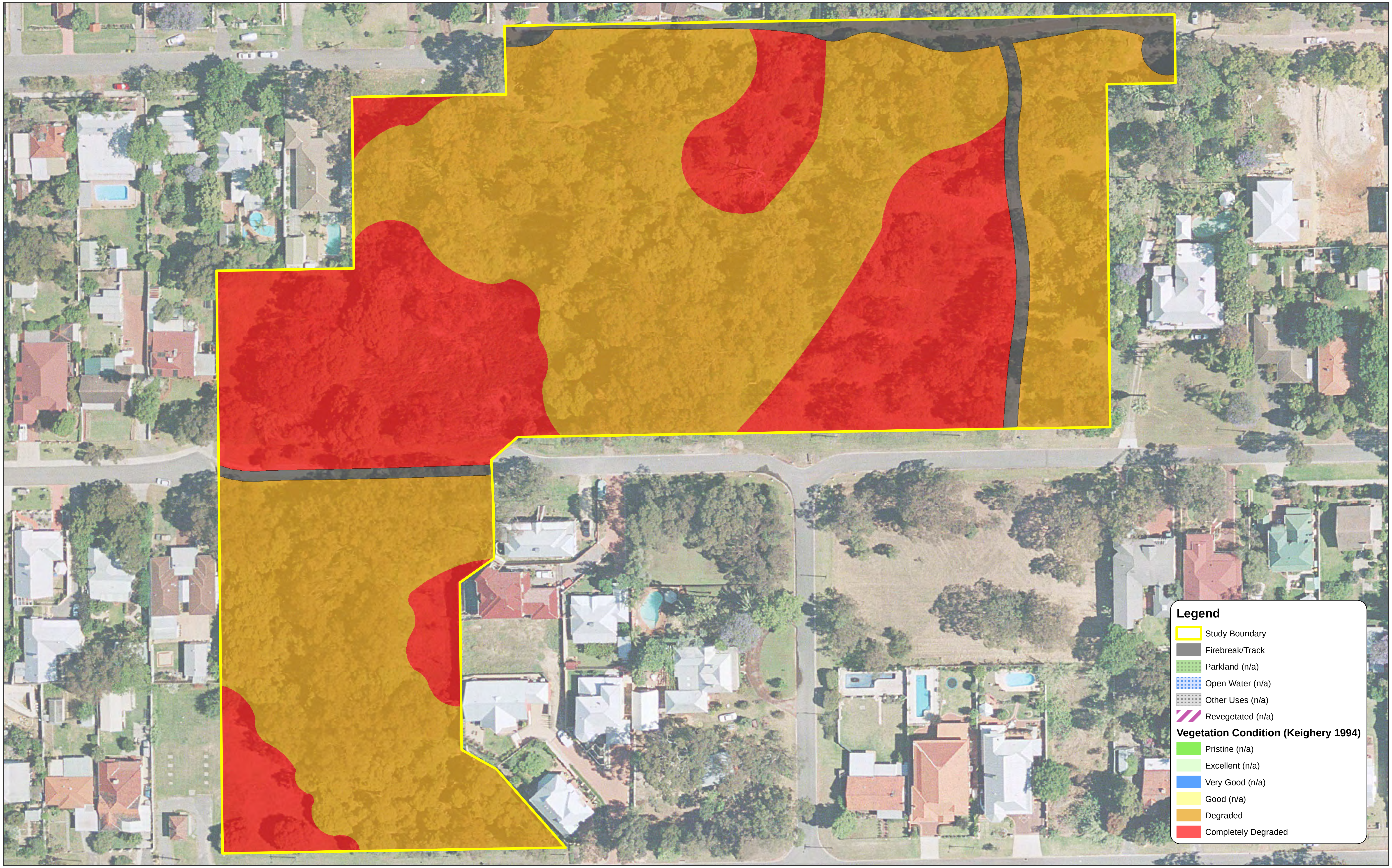
1. **Bindaring Park (North and South)**
    a. Bindaring Park (North) Bush Condition
    b. Bindaring Park (South) Bush Condition
    c. Bindaring Park (North) Monocot Weeds
    d. Bindaring Park (South) Monocot Weeds
    e. Bindaring Park (North) Geophyte Weeds
    f. Bindaring Park (South) Geophyte Weeds
    g. Bindaring Park (North) Broad Leaf Herb Weeds
    h. Bindaring Park (South) Broad Leaf Herb Weeds
    i. Bindaring Park (North) Tree, Shrub and Climber Weeds
    j. Bindaring Park (South) Tree, Shrub and Climber Weeds
    k. Bindaring Park (North) Walk Trails
    l. Bindaring Park (South) Walk Trails

2. **Broadway**
    a. Broadway Bush Condition
    b. Broadway Monocot Weeds
    c. Broadway Broad Leaf Herb Weeds
    d. Broadway Tree, Shrub and Climber Weeds
    e. Broadway Walk Trails

3. **Jubilee Reserve (A and B)**
    a. Jubilee Reserve (A) Bush Condition
    b. Jubilee Reserve (A) Monocot Weeds
    c. Jubilee Reserve (A) Geophyte Weeds
    d. Jubilee Reserve (A) Broad Leaf Herb Weeds
    e. Jubilee Reserve (B) Bush Condition
    f. Jubilee Reserve (B) Monocot Weeds
    g. Jubilee Reserve (B) Geophyte Weeds
    h. Jubilee Reserve (B) Broad Leaf Herb Weeds
    i. Jubilee Reserve (B) Tree, Shrub and Climber Weeds
    j. Jubilee Reserve (A) Walk Trails
    k. Jubilee Reserve (B) Walk Trails

4. **Pickering Park**
    a. Pickering Park Bush Condition
    b. Pickering Park Monocot Weeds
    c. Pickering Park Walk Trails

5. **Success Hill**
    a. Success Hill Bush Condition
    b. Success Hill Monocot Weeds
    c. Success Hill Geophyte Weeds
    d. Success Hill Broad Leaf Herb Weeds
    e. Success Hill Tree, Shrub and Climber Weeds
    f. Success Hill Walk Trails



Map 1a

Bushland Weed Management Plan

Bindaring Park (North) Bush Condition

Feb 2010

prepared for CITY OF BASSENDEAN

1:1,000 @ A3
Project No. 2366-09

ecoscape

Map 1b

Bushland Weed Management Plan

Bindaring Park (South) Bush Condition

Feb 2010

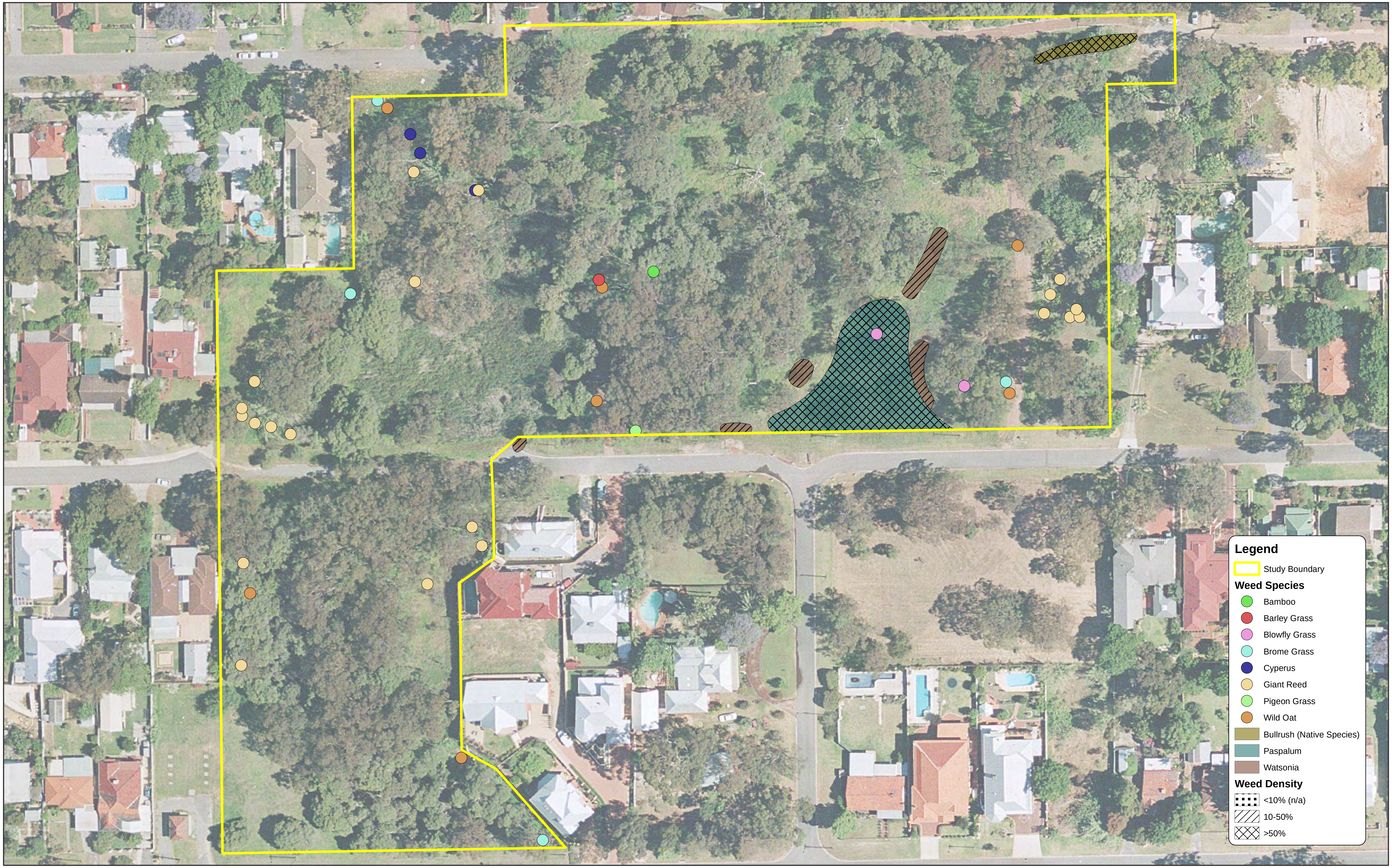
prepared for CITY OF BASSENDEAN

0 10 20 30 40 50
Metres

1:1,300 @ A3

Project No. 2366-09

ecoscape



Map 1c

Bushland Weed Management Plan

Bindaring Park (North) Grass, Sedge and Rush Weeds

Feb 2010

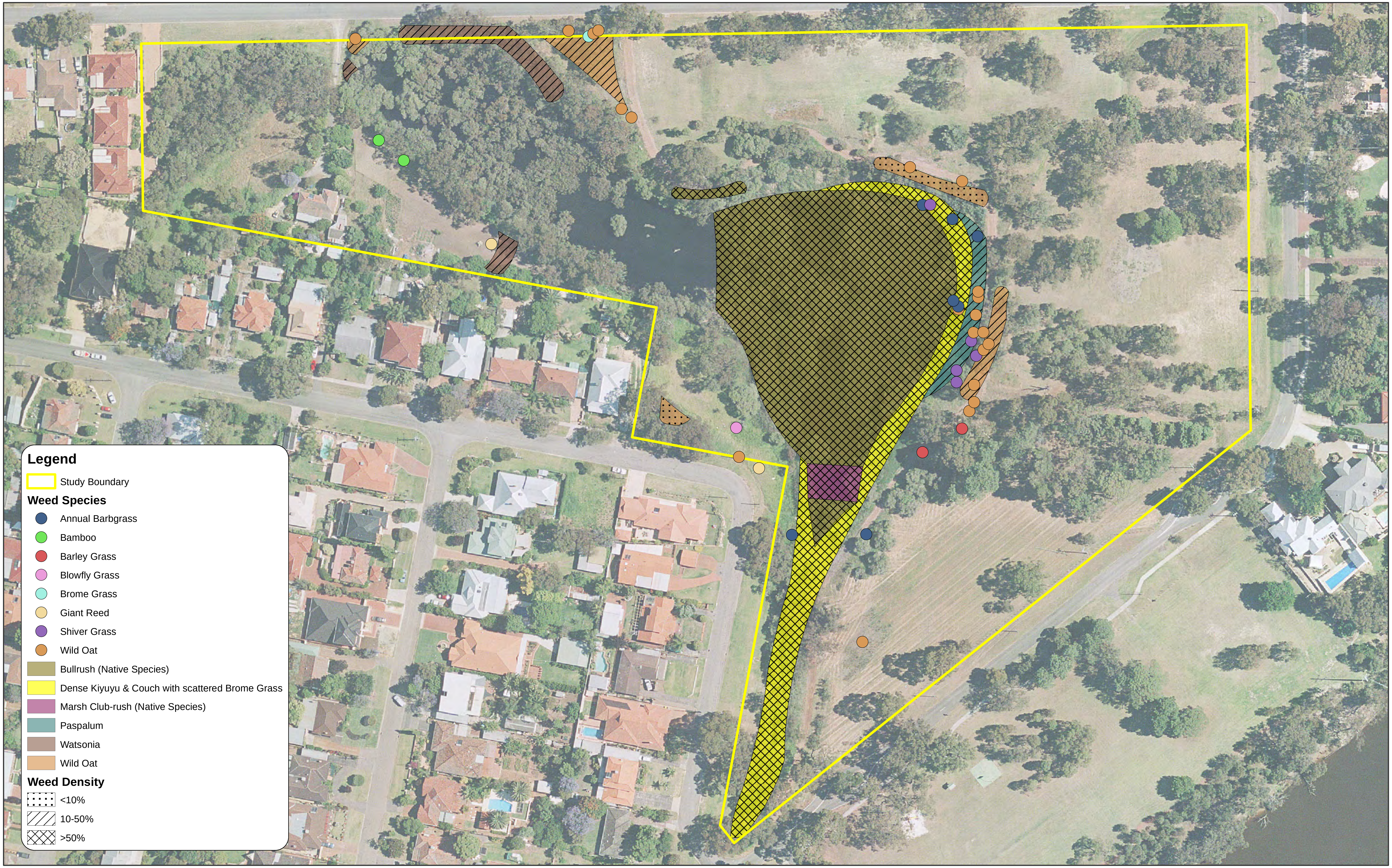
prepared for CITY OF BASSENDEAN

0 10 20 30 40 50
Metres

1:1,000 @ A3

Project No. 2366-09

ecoscape



Map 1d

Feb 2010

Bushland Weed Management Plan

Bindaring Park (South) Grass, Sedge & Rush Weeds

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,300 @ A3

Project No. 2366-09

ecoscape

Map 1e

Bushland Weed Management Plan

Bindaring Park (North) Geophyte Weeds

Feb 2010

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,000 @ A3

Project No. 2366-09

ecoscape

Map 1f

Bushland Weed Management Plan

Bindaring Park (South) Geophyte Weeds

Feb 2010

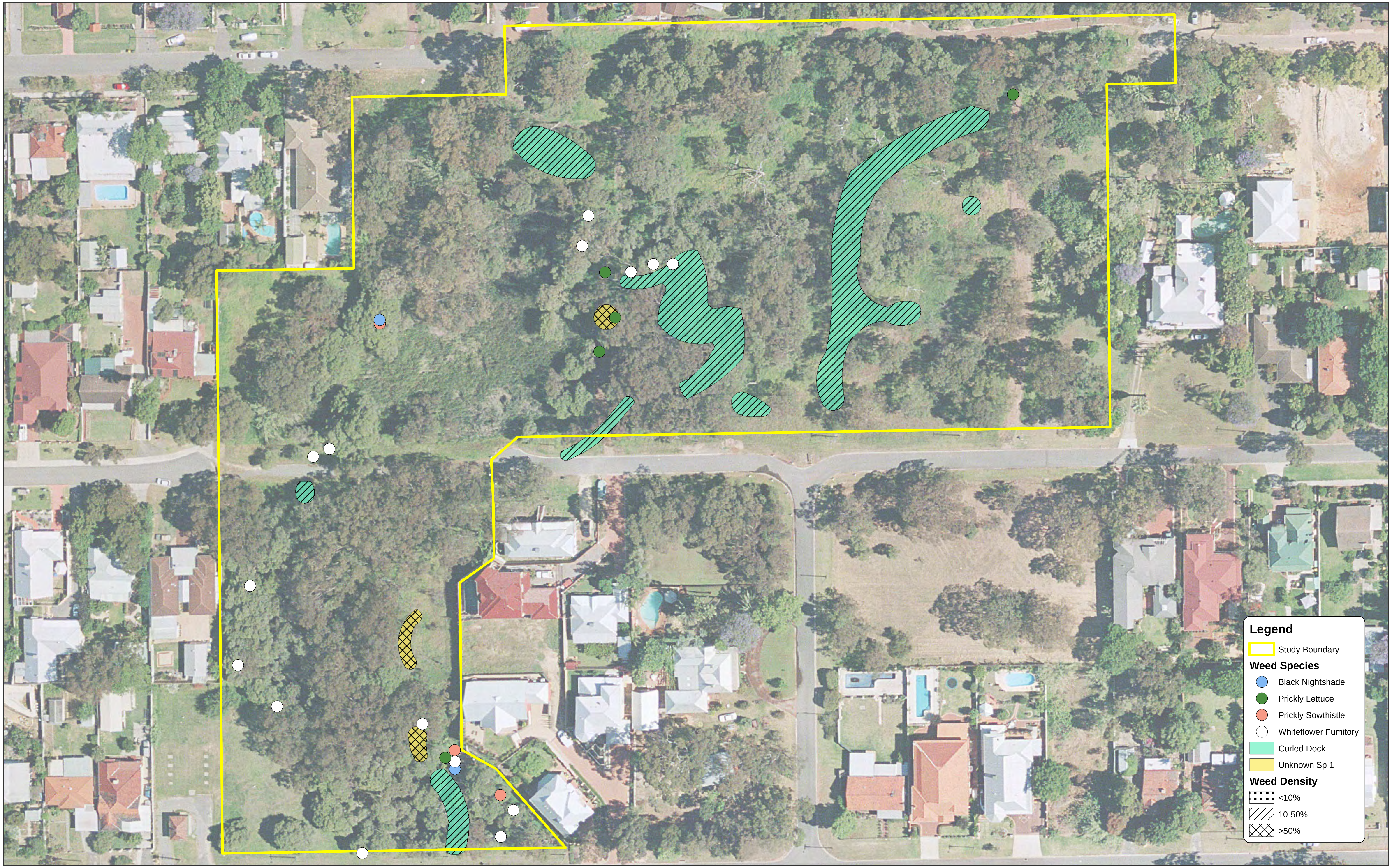
prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,300 @ A3

Project No. 2366-09

ecoscape



Map 1g

Bushland Weed Management Plan

Bindaring Park (North) Broad Leaf Herb Weeds

Feb 2010

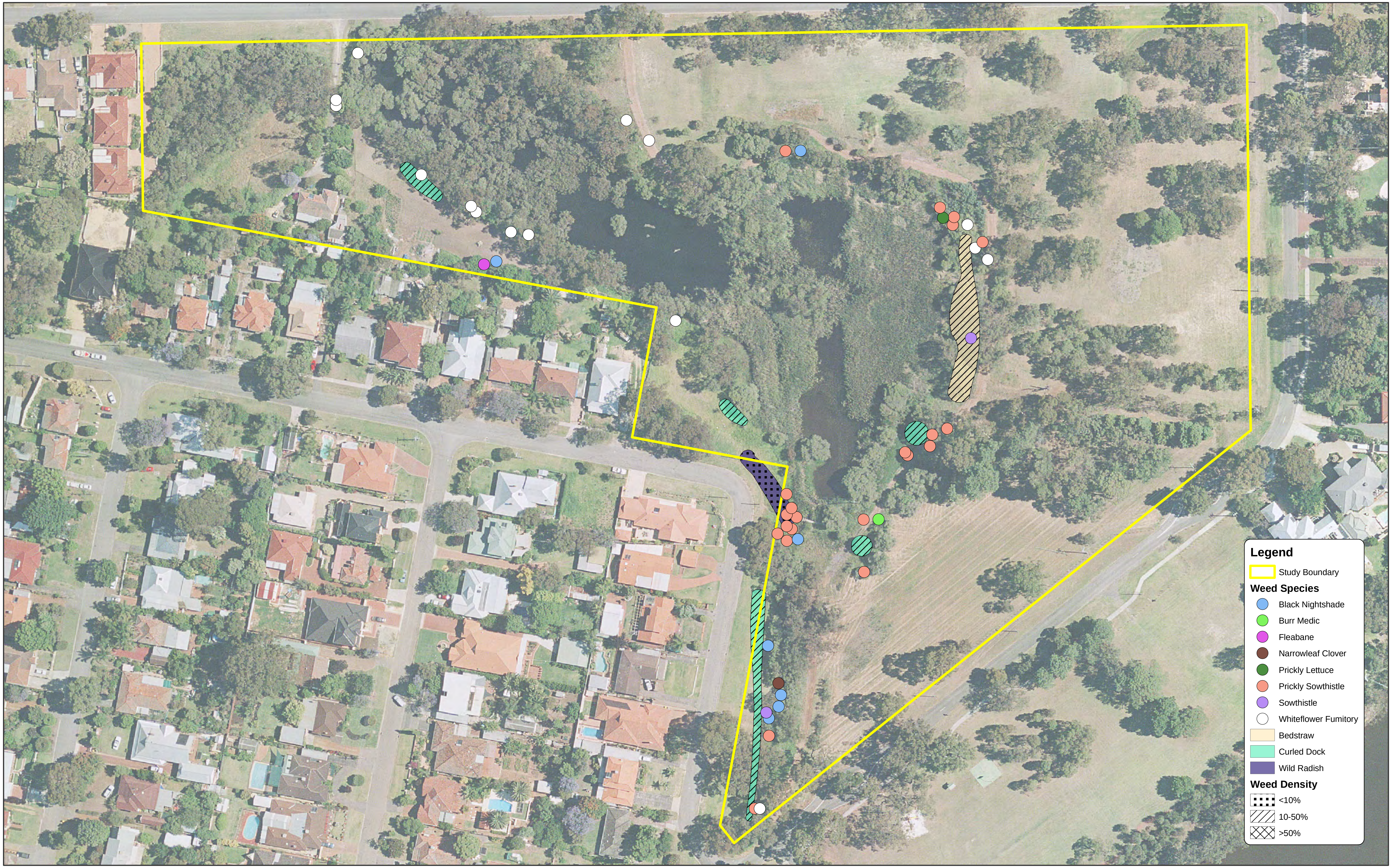
prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,000 @ A3

Project No. 2366-09

ecoscape



Map 1h

Bushland Weed Management Plan

Bindaring Park (South) Broad Leaf Herb Weeds

Feb 2010

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,300 @ A3

Project No. 2366-09

Map 1i

Bushland Weed Management Plan

Bindaring Park (North) Tree, Shrub and Climber Weeds

Feb 2010

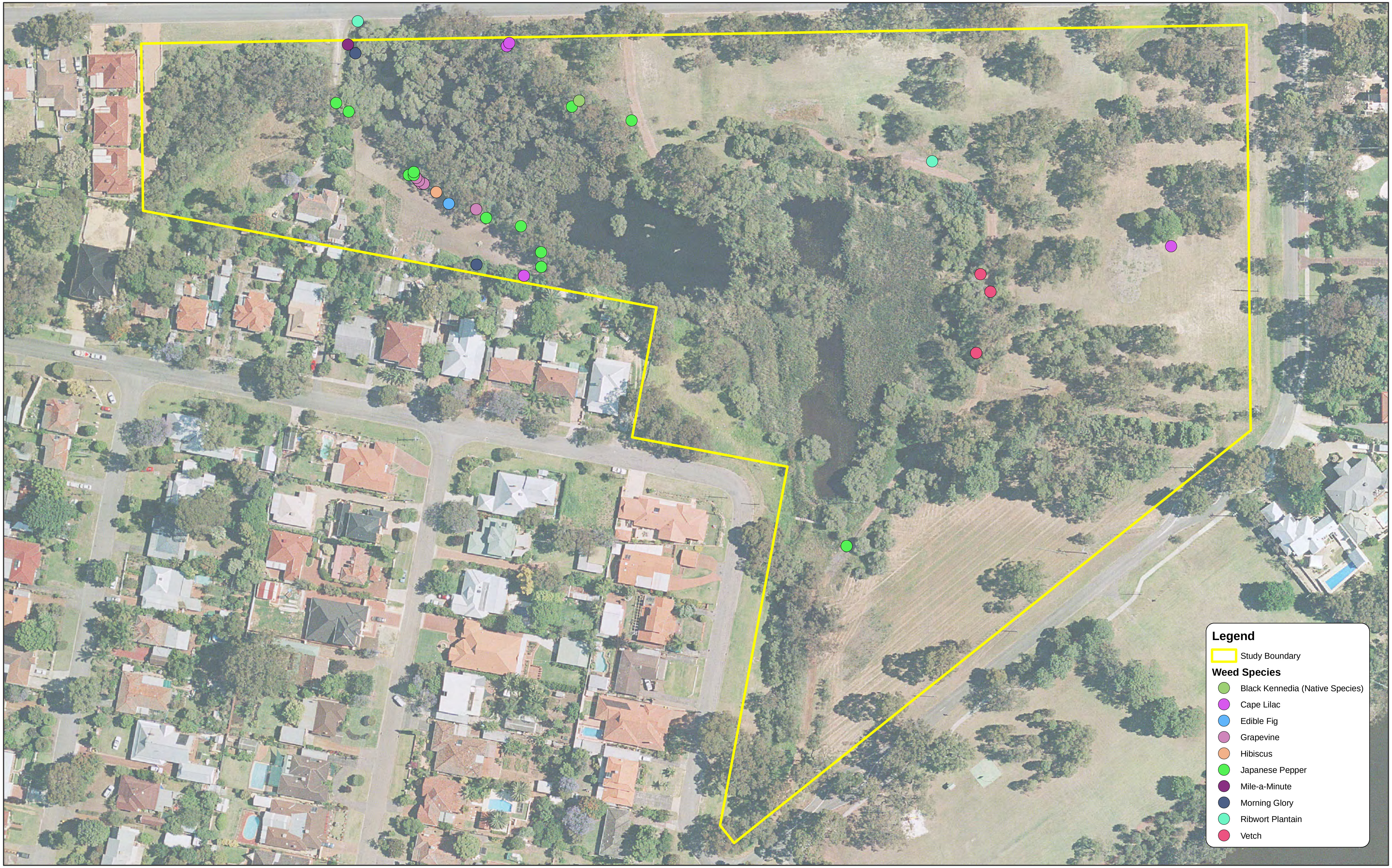
prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,000 @ A3

Project No. 2366-09

ecoscape



Map 1j

Feb 2010

Bushland Weed Management Plan

Bindaring Park (South) Tree, Shrub and Climber Weeds

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50
Metres

1:1,300 @ A3

Project No. 2366-09

ecoscape

Map 1k

Bushland Weed Management Plan

Bindaring Park (North) Access

May 2010

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,000 @ A3

Project No. 2366-09

ecoscape

Map 1l

Bushland Weed Management Plan

Bindaring Park (South) Access

May 2010

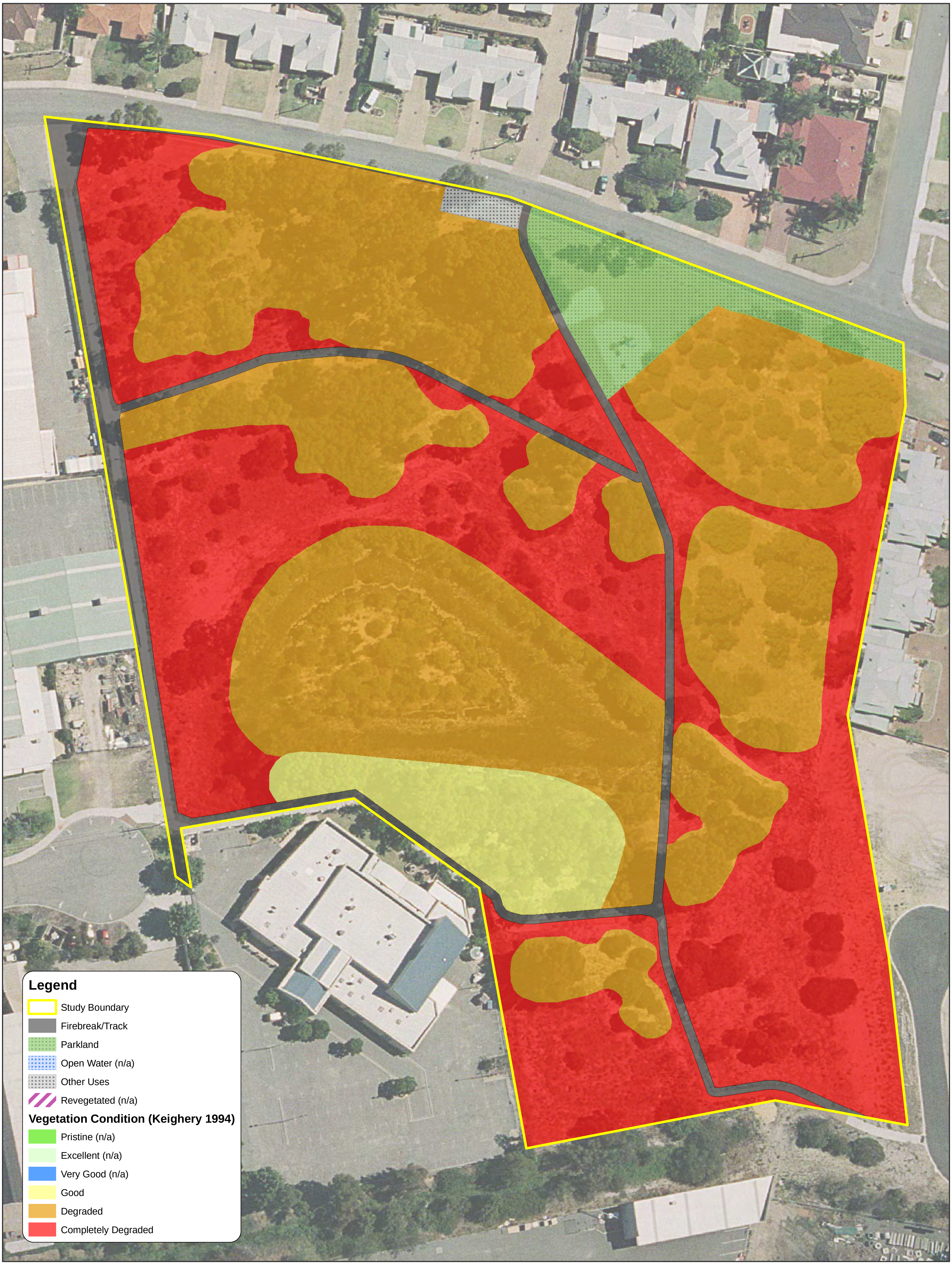
prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,300 @ A3

Project No. 2366-09

ecoscape



Map 2a

Feb 2010

Bushland Weed Management Plan

Broadway Reserve Bush Condition

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Meters

1:750 @ A3

Project No. 2366-09

ecoscape

Map 2b(i)

Bushland Weed Management Plan

Broadway Reserve Grass, Sedge and Rush Weeds

Feb 2010

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Meters

1:750 @ A3

Project No. 2366-09

Map 2b(ii)

Feb 2010

Bushland Weed Management Plan

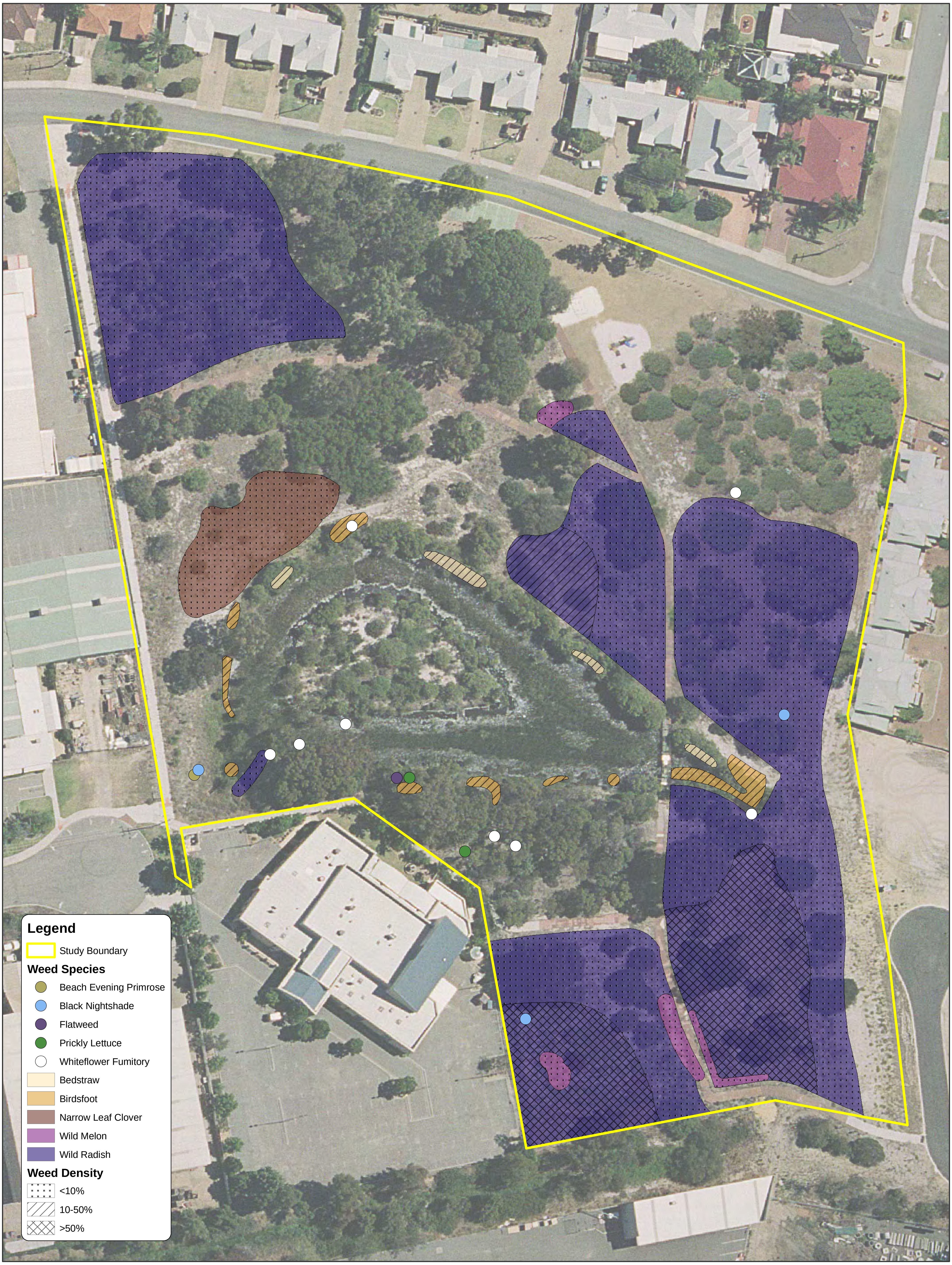
Broadway Reserve Grass, Sedge and Rush Weeds

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25
Meters

1:750 @ A3

Project No. 2366-09



Map 2c

Feb 2010

Bushland Weed Management Plan

Broadway Reserve Broad Leaf Herb Weeds

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Meters

1:750 @ A3

Project No. 2366-09

ecoscape

Map 2d

Feb 2010

Bushland Weed Management Plan

Broadway Reserve Trees, Shrub and Climber Weeds

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Meters

1:750 @ A3

Project No. 2366-09

ecoscape

Map 2e

May 2010

Bushland Weed Management Plan

Broadway Reserve Access

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Meters

1:750 @ A3

Project No. 2366-09

ecoscape

Map 3a

Bushland Weed Management Plan

Jubilee Reserve (A) Bush Condition

Feb 2010

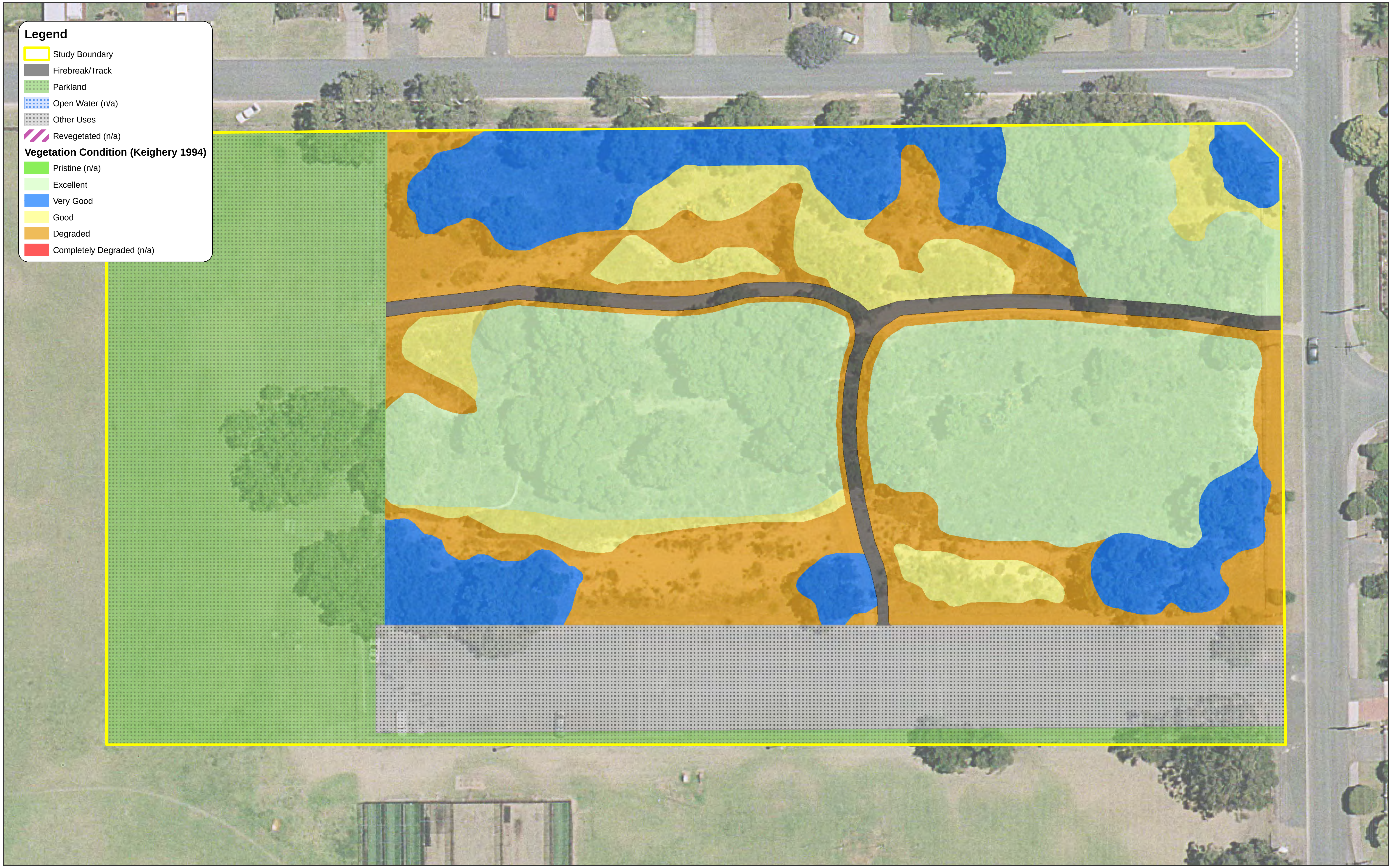
prepared for CITY OF BASSENDEAN

0 5 10 15 Metres

1:350 @ A3

Project No. 2366-09

ecoscape



3b

Feb 2010

Bushland Weed Management Plan

Jubilee Reserve (B) Bush Condition

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Metres

1:600 @ A3

Project No. 2366-09

ecoscape

Map 3c

Bushland Weed Management Plan

Jubilee Reserve (A) Grass, Sedge & Rush Weeds

Feb 2010

prepared for CITY OF BASSENDEAN

0 5 10 15
Metres

1:350 @ A3

Project No. 2366-09

ecoscape

3d

Feb 2010

Bushland Weed Management Plan

Jubilee Reserve (B) Grass, Sedge and Rush Weeds

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Metres

1:600 @ A3

Project No. 2366-09

ecoscape

Map 3e

Feb 2010

Bushland Weed Management Plan

Jubilee Reserve (A) Geophyte Weeds

prepared for CITY OF BASSENDEAN

1:350 @ A3

Project No. 2366-09

ecoscape

3f

Feb 2010

Bushland Weed Management Plan

Jubilee Reserve (B) Geophyte Weeds

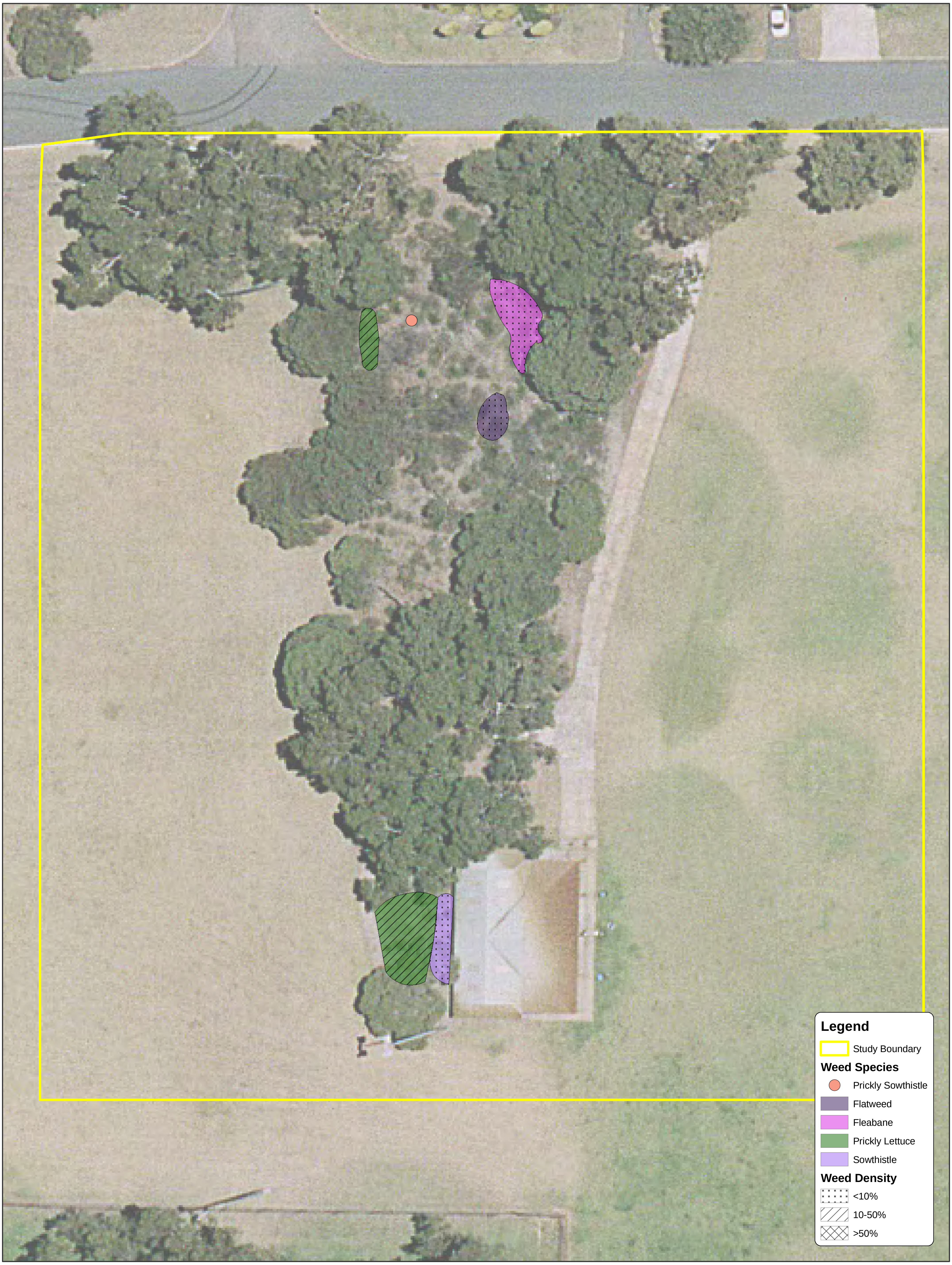
prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Metres

1:600 @ A3

Project No. 2366-09

ecoscape



Map 3g

Feb 2010

Bushland Weed Management Plan

Jubilee Reserve (A) Broad Leaf Herb Weeds

prepared for CITY OF BASSENDEAN

1:350 @ A3

Project No. 2366-09

ecoscape

3h(i)

Bushland Weed Management Plan

Jubilee Reserve (B) Broad Leaf Herb Weeds

Feb 2010

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Metres

1:600 @ A3

Project No. 2366-09

ecoscape

3h(ii)

Bushland Weed Management Plan

Jubilee Reserve (B) Broad Leaf Herb Weeds

Feb 2010

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25
Metres

1:600 @ A3

Project No. 2366-09

ecoscape

3i

Bushland Weed Management Plan

Jubilee Reserve (B) Tree, Shrub & Climber Weeds

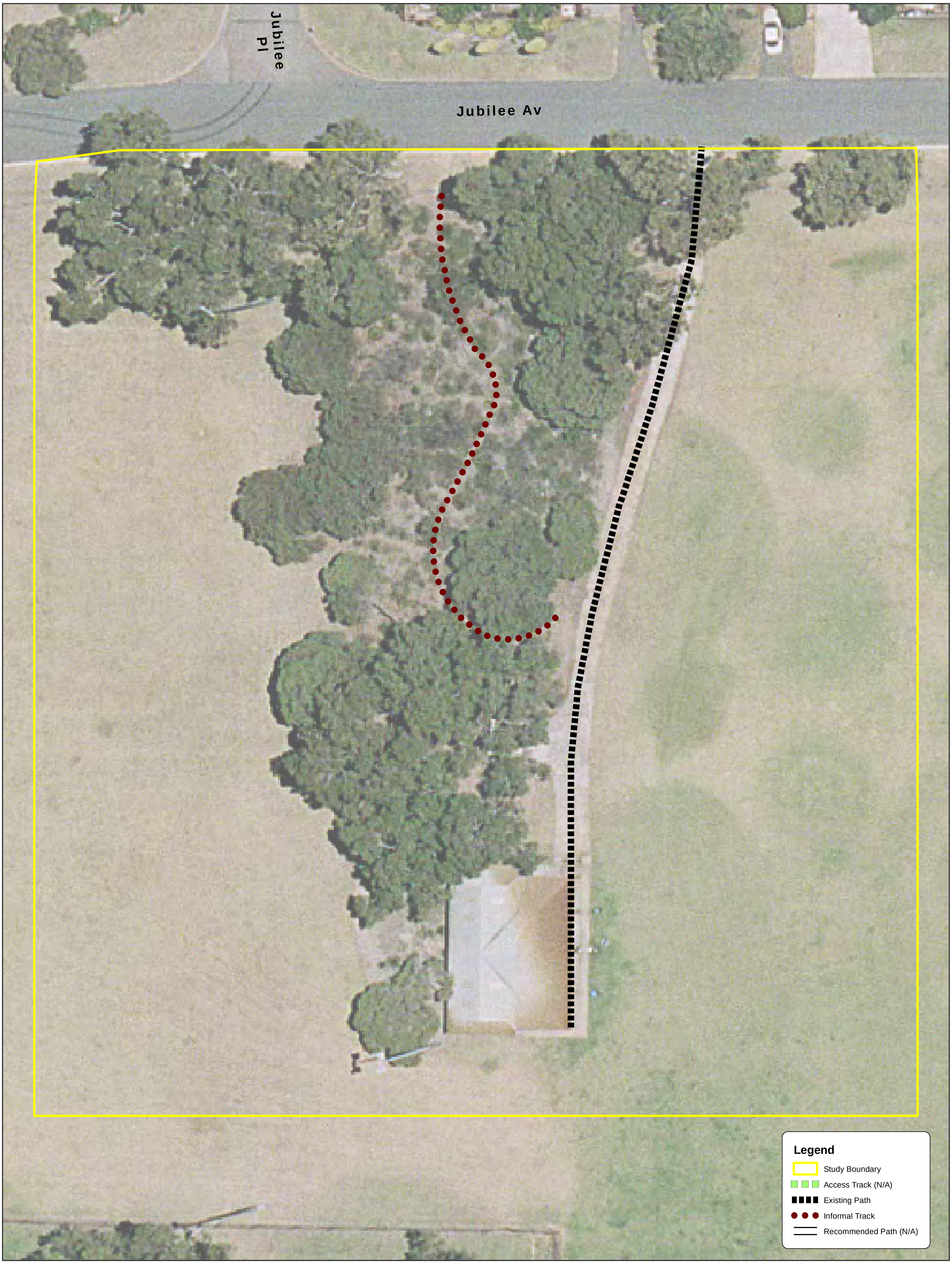
Feb 2010

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Metres

1:600 @ A3

Project No. 2366-09



Map 3j

Bushland Weed Management Plan

Jubilee Reserve (A) Access

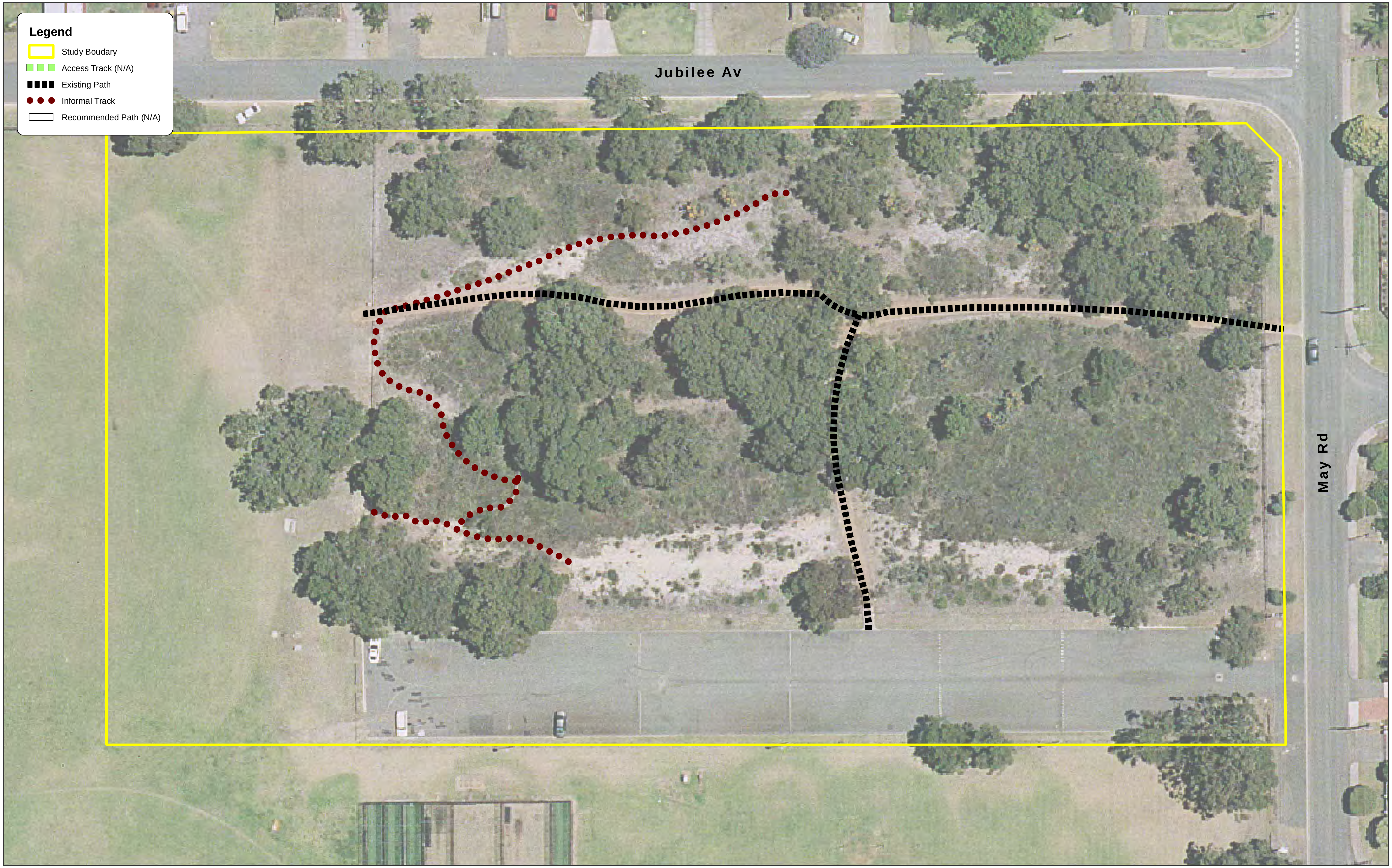
May 2010

prepared for CITY OF BASSENDEAN

0 5 10 15 Metres

1:350 @ A3

Project No. 2366-09



3k

May 2010

Bushland Weed Management Plan

Jubilee Reserve (B) Access

prepared for CITY OF BASSENDEAN

0 5 10 15 20 25 Metres

1:600 @ A3

Project No. 2366-09

ecoscape

4a

Bushland Weed Management Plan

Pickering Park Bush Condition

Feb 2010

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,250 @ A3

Project No. 2366-09

ecoscape

4b

Feb 2010

Bushland Weed Management Plan

Pickering Park Grass, Sedge and Rush Weeds

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50
Metres

1:1,250 @ A3

Project No. 2366-09

ecoscape

4c

Bushland Weed Management Plan

Pickering Park Access

May 2010

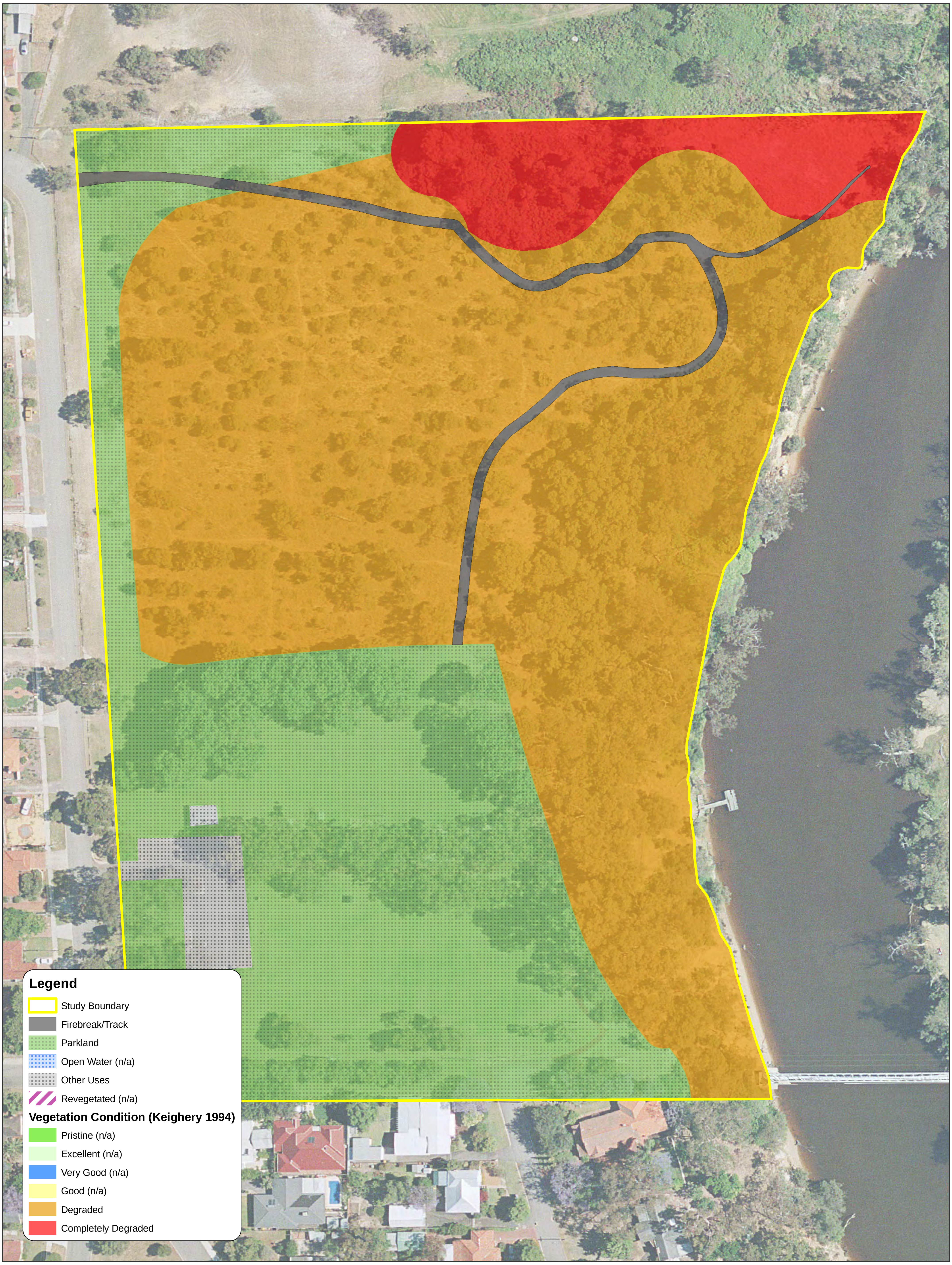
prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,250 @ A3

Project No. 2366-09

ecoscape



Map 5a

Bushland Weed Management Plan

Success Hill Bush Condition

Feb 2010

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,000@ A3

Project No. 2366-09

ecoscape

Map 5b

Bushland Weed Management Plan

Success Hill Grass, Sedge & Rush Weeds

Feb 2010

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,000@ A3

Project No. 2366-09

ecoscape

Map 5c

Bushland Weed Management Plan

Success Hill Geophyte Weeds

Feb 2010

prepared for CITY OF BASSENDEAN

0 10 20 30 40 50 Metres

1:1,000@ A3

Project No. 2366-09

ecoscape

Map 5d

Bushland Weed Management Plan

Success Hill Broad Leaf Herb Weeds

Feb 2010

prepared for CITY OF BASSENDEAN

1:1,000@ A3

Project No. 2366-09

ecoscape

Map 5e

Feb 2010

Bushland Weed Management Plan

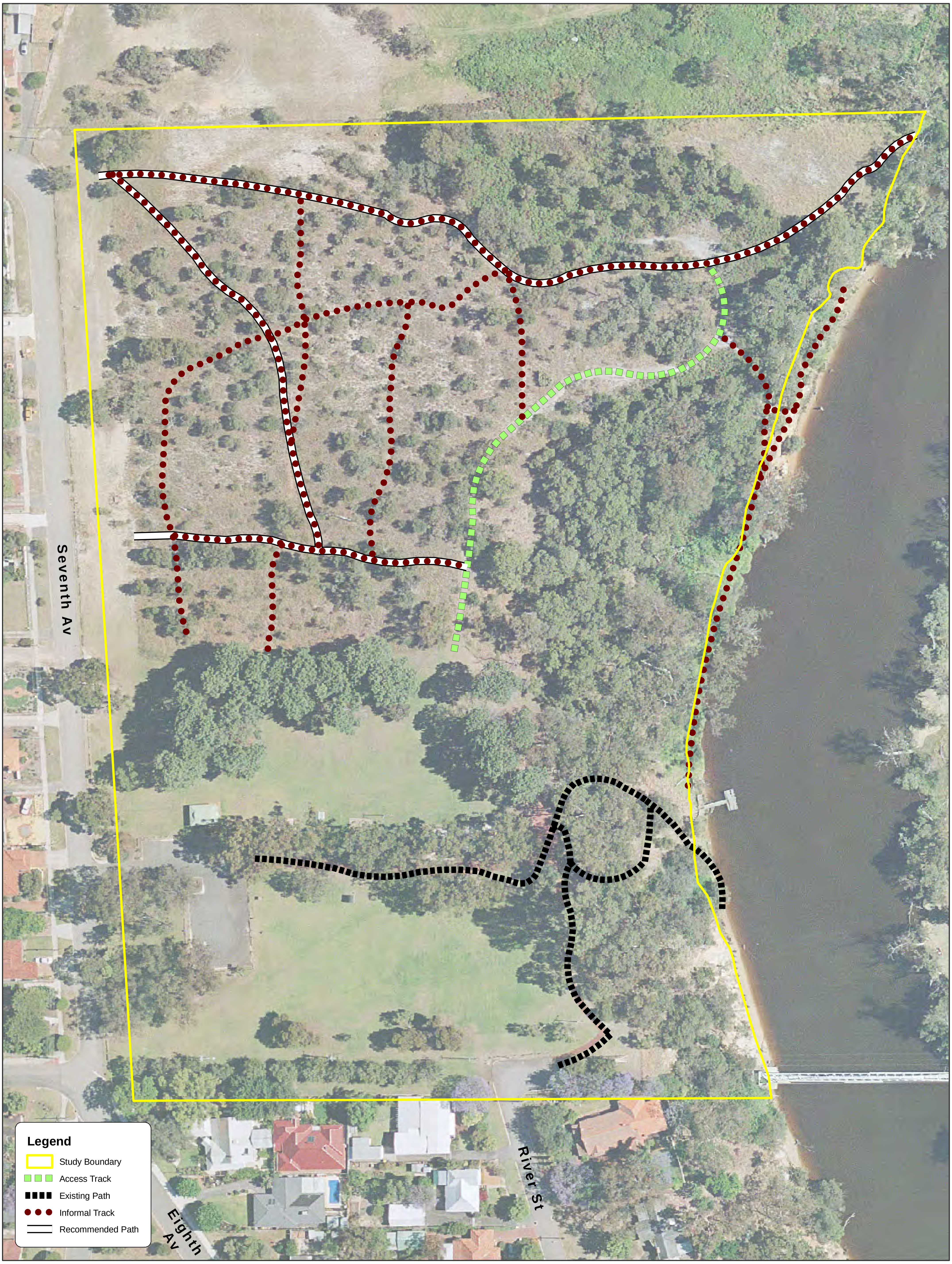
Success Hill Trees, Shrub and Climber Weeds

prepared for CITY OF BASSENDEAN

1:1,000@ A3

Project No. 2366-09

ecoscape



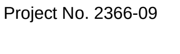
Map 5f

Bushland Weed Management Plan

Success Hill Access

May 2010

prepared for CITY OF BASSENDEAN



1:1,000 @ A3

Project No. 2366-09

Bradley Method

(Developed from Bradley 1971, Bradley 1988 and Buchanan 1989)

Underlying Principles

1. Always work from areas with native plants towards weed-infested areas.

This makes good ecological sense. If you are relying on natural regeneration then choose areas that will contain the maximum number of existing native plants and native plant seeds, and minimal weed seeds and vegetative reproductive organs of weeds.

2. Make minimal disturbance.

Application of this principal depends on the native species to regenerate. Many plant communities (both weeds and native) need disturbed and sunlit soil for successful regeneration. However, by following the 1st principle above, any weed regeneration should be minimised. Any soil that is disturbed should be returned in its original layers, thus ensuring that any native seed stored in the soil will still be on top. This principle also applies to the application of natural plant mulch in the work area – where a gap is left as a result of weeding, it is recommended that mulch from surrounding areas be added to the gap. This helps to minimise weed regeneration.

3. Let native plant regeneration dictate the rate of weed removal.

The ability to follow this principle may depend on the amount of time and money committed to a particular project. If few weeds and many native plants regenerate, or if the ground remains weed free, little time will need to be spent re-weeding a site, allowing time to be spent on other sites. If masses of weeds regenerate then a lot of time will be required re-weeding so that regenerating native plants can flourish.

DEVELOPING WORK PLANS

1. Prevent deterioration of good areas.

Start by removing weeds scattered through otherwise clean bush. Practically no follow up work will be needed, but it should be checked once or twice a year.

2. Improve the next best area.

Once you are confident you have prevented deterioration of better condition bush, you can start work on thicker patches of weed. Choose a place you can visit easily and often, where thick native growth is pushing up against weeds, preferably no worse than one weed species to every two native plant species. Start with a strip approximately 12 feet wide and no longer than can be managed with monthly weeding days. If the area to be cleared of weeds runs up a slope which may erode, clear a number of smaller patches instead.

3. Hold the advantage gained.

Resist the temptation to push deeper into the weeds before regenerating natives have stabilised each cleared area. The natives do not need to be very tall, but they usually need to form an almost complete ground cover. Weeds will always nearly keep germinating until this is achieved. These newly regenerated areas are most vulnerable to weed reinvasion and so must be re-weeded as required. If weeding occurs adjacent to the regenerating area prior to sufficient new cover light from adjacent cleared patches can affect the regeneration of natives.

4. Cautiously move into the really bad areas.

When new growth coming up consists almost entirely of native plants with only a few weeds among them, it is safe to move deeper into the weeds. Keep working along the regeneration boundary, making new clearings smaller as the weeds get more dense.

WEEDING TECHNIQUES

1. Disturb the soil as little as possible.

All tools used for weeding programmes should be small, such as a broad boning knife, trowels, secateurs, pliers (for pulling roots), loppers, hatchet and small saws. This recommendation is based on the belief that using small tools will cause minimum soil disturbance and minimal damage to the roots and shoots of nearby native plants.

2. Sweep back the mulch surface.

Any weeding will disturb the ground litter and soil will be exposed. Repair the damage as you go, by pushing back as much mulch as possible. It is often helpful to sweep aside mulch prior to removing large plants, so that it can easily be redistributed when you have finished removing the plant.

3. Mulch with the weeds themselves.

Weeds removed can be used to add to existing mulch. In dry areas leaving the weed with its roots exposed will be sufficient to kill it. In moist areas, hanging the weeds on nearby native vegetation will allow them to dry out and die. Some items are unsuitable for mulch, and these are removed from the site. Such items include bulbs and tubers, plants that root at every node and free-seeders with ripe seed.

4. Watch where you put your feet.

Be careful how you move through the bush. A small weeding party moving through thick bush single file can open up a track. Efforts should be made to not walk on the same paths all the time, and to watch where you walk to ensure you are not trampling native vegetation.

Appendix Six: Weed Management Guide

The following pages provide descriptions and a variety of control methods the weed and aggressive native species recorded in the town of Bassendean.

Weed management recommendations are based on information from:

1. Brown and Brooks (2002) *Bushland Weeds*
2. Dixon and Keighery (1995) *Recommended methods to control specific weed species*
3. Moore and Moore (2008) *Herbiguide.*

Herbicide recommendations have superscripted numbers assigned to them to indicate which of these sources above provided the information on herbicide type and dosage.

The quantities of herbicides suggested for spot spraying rate have been calculated for a 10L backpack with 25mL of wetting agent. It should be noted that surfactants should not be used near and wetlands or waterways. It is recommended that selective herbicides be implemented where practical to limit their impact on adjacent native plants.

Information on each of the recommended herbicide brands are summarised on **Table A6.1** on the following page.

It should be noted that manual control should always be considered first before using herbicides.

Table A6.1: Summary of Herbicide information

Product	H. Group	Active ingredient/s	Concentration	Other ingredients	Poison Schedule	Supplier/Manufacturer	Specific targeted weeds
Access ®	I	2,4-D amine	500g/L	10-20% Diethylene glycol monoethyl ether w/w, 30 - 50%, Aromatic hydrocarbon solvent w/w	S5	Dow AgroSciences	woody and noxious weeds
Achieve ®	A	tralkoxydim	400g/kg	10-30% Talc w/w	S5	Cropcare	Annual grasses (predominantly annual ryegrass and wild oats)
Brodal®	F	diflufenican	500g/L	5% propane-1,2-diol w/w	unscheduled	Bayer	weeds in clover-based pasture, field peas, lentils, lupins and oilseed poppy
Eclipse®	B	metosulam	714g/kg		S6	Bayer	Cereals and Lupins
Fusilade®	A	fluazifop	212g/L		S6	Syngenta	grasses
Garlon 600	I	triclopyr	600g/L			Dow AgroSciences	woody weeds and melons
Logran®	B	triasulfuron	750g/kg		exempt	Syngenta	annual ryegrass, Paradoxa grass and certain broadleaf weeds in wheat; and for post-emergent control of Wild Radish in wheat, oats and barley
Lontrel®	I	clopyralid	300g/L		S5	Dow AgroSciences	broadleaf
Propon®	A	2,2,-D	850g/kg		S2, S13	Agricrop	Couch, kikuyu, annual and perennial grasses, cumbungi and phragmites
Roundup Bioactive®	M	glyphosate	360g/L		S5	Nufarm	annual weeds, perennial weeds ,woody weeds and problem trees
Starane®		Fluroxypyr methylheptyl etster	303g/L			Dow AgroSciences	White clover, docks, large flowered mallow and creeping mallow
Sertin®	A	sethoxydim	186g/L		S5	Bayer	grasses
Starane 200®	I	fluroxypyr	200g/L	59% Aromatic hydrocarbon solvent w/w	S5	Dow AgroSciences	wide range of broadleaf Weeds
Targa®	A	quizalofop	99.5g/L		S6	Sipcam	annual and perennial grasses in alfalfa, onion, carrot, garlic, Swiss chard, spinach, radishh, Chinese cabbage and red beets
Tordon® 75D	I	2,4-D / picloram	300g/L , 75g/L		S5	Dow AgroSciences	broadleaf
Verdict® 520	A	haloxyfop	520g/L		S6	Dow AgroSciences	annual and perennial grass weeds in grain, legume and oilseed crops, lucerne, medic, clover pasture and seed crops, forestry, bananas, citrus, grapes, pineapples, pome fruit, stone fruit, pyrethrum, tropical fruit

Appendix Six: Weed Management Guide

The following pages provide descriptions and a variety of control methods the weed and aggressive native species recorded in the town of Bassendean.

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Achieve ®	A	tralkoxydim	400g/kg	10-30% Talc w/w	S5	Cropcare	Annual grasses (predominantly annual ryegrass and wild oats)
Brodal®	F	diflufenican	500g/L	5% propane-1,2-diol w/w	unscheduled	Bayer	weeds in clover-based pasture, field peas, lentils, lupins and oilseed poppy
Eclipse®	B	metosulam	714g/kg		S6	Bayer	Cereals and Lupins
Fusilade®	A	fluazifop	212g/L		S6	Syngenta	grasses
Garlon 600	I	triclopyr	600g/L			Dow AgroSciences	woody weeds and melons
Logran®	B	triasulfuron	750g/kg		exempt	Syngenta	annual ryegrass, Paradoxa grass and certain broadleaf weeds in wheat; and for post-emergent control of Wild Radish in wheat, oats and barley
Lontrel®	I	clopyralid	300g/L		S5	Dow AgroSciences	broadleaf
Propon®	A	2,2,-D	850g/kg		S2, S13	Agricrop	Couch, kikuyu, annual and perennial grasses, cumbungi and phragmites
Roundup Bioactive®	M	glyphosate	360g/L		S5	Nufarm	annual weeds, perennial weeds ,woody weeds and problem trees
Starane®		Fluroxypyr methylheptyl etster	303g/L			Dow AgroSciences	White clover, docks, large flowered mallow and creeping mallow
Sertin®	A	sethoxydim	186g/L		S5	Bayer	grasses
Starane 200®	I	fluroxypyr	200g/L	59% Aromatic hydrocarbon solvent w/w	S5	Dow AgroSciences	wide range of broadleaf Weeds
Targa®	A	quizalofop	99.5g/L		S6	Sipcam	annual and perennial grasses in alfalfa, onion, carrot, garlic, Swiss chard, spinach, radishh, Chinese cabbage and red beets
Tordon® 75D	I	2,4-D / picloram	300g/L , 75g/L		S5	Dow AgroSciences	broadleaf
Verdict® 520	A	haloxyfop	520g/L		S6	Dow AgroSciences	annual and perennial grass weeds in grain, legume and oilseed crops, lucerne, medic, clover pasture and seed crops, forestry, bananas, citrus, grapes, pineapples, pome fruit, stone fruit, pyrethrum, tropical fruit

Annual Barbgrass (*Polypogon monspeliensis*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Pickering Park • Success Hill
Appearance	Tufted annual to 40cm tall. The flower is dense, narrowly-ovate to oblong and up to 15cm long. The awns give it a soft, feathery appearance.
Habitat	Common weed of disturbed wetlands, both fresh and brackish.
Comments	Flowers in spring and summer. Can sometimes be confused with the native species, *P. tenellus*. Native to Europe, North Africa and Asia.
CONTROL	
Priority	**Moderate**
Timing	Jun - Sep
Manual Control	Manually remove small plants before seeding.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	• 100 mL glyphosate (1)

Annual Veldt Grass (*Ehrharta longiflora*)

DESCRIPTION	
Location	- Broadway - Pickering Park
Appearance	Tufted annual to 30cm tall. The greenish-purple inflorescence is a narrow panicle, to 15cm long, flowering in spring.
Habitat	It is a widespread weed of offshore islands, coastal dunes and sandy soils, from Shark Bay to Eucla and inland along disturbed creeklines and grazed woodlands in the western Wheatbelt.
Comments	Smothers small plants and competes with natives. A serious fire hazard.
CONTROL	
Priority	Moderate
Timing	Jun - Oct
Manual Control	Remove small populations by hand.
Wipe/ Cut Stump	No specific information.
Spot Spray	- 20 mL Fusilade® + wetting agent before flowering stem emerges provides good control with little damage to broad-leaf species (1 & 2) - 10 mL Fusilade® at 3 – 5 leaf stage (2) - In non-selective situations 40 mL glyphosate applied up to flowering provides good control (2)

Arum Lily (*Zantedeschia aethiopica*)

DESCRIPTION	
Locations	- Bindaring Park North and South - Success Hill
Appearance	Arum Lily has a tuft of dark green, shiny, somewhat succulent leaves arising from tuberous roots. The leaf blades are heart-shaped to arrow-shaped and usually about 25 cm long on a stalk almost as long. Easily recognised by its conspicuous large white funnel-like "flower" about 10 cm across, which has a central pencil-like column of minute male and female flowers. In fruit the tiny female flowers at the base of this column are replaced by orange-yellow berries. Perennial.
Habitat	Arum Lily is a common and widespread serious weed of pasture and bushland, particularly of damp areas but also invading drier sites.
Comments	Replaces native species mainly in highly disturbed sites. Now being found in much drier areas. The berries are spread by birds. Arum Lily may be toxic to stock. Flowers mostly late winter and spring. Native to South Africa.
CONTROL	
Priority	High
Timing	June - Nov
Manual Control	Mechanical removal is only effective if all the root fragments are removed.
Wipe/ Cut Stump	Not recommended.
Spot Spray	- Spot spray metsulfuron or chlorsulfuron 0.4 g/15 L of water plus Pulse®, higher concentrations in a one litre hand held sprayer applying a single squirt to leaves avoids off target damage (1) - 1 g chlorsulfuron plus 10 mL 2,4-D amine (500g/L) plus 25 mL Pulse® (2) - 1g metsulfuron + 25 mL Pulse ® (2) - glyphosate is relatively ineffective (2).

Bamboo (*Phyllostachys sp.*)

DESCRIPTION	
Locations	- Bindaring Park North and South
Appearance	Tall, woody, grass-like, perennial that sends out tough horizontal runners that rapidly send out vertical shoots and begin to clump. Once established the stems and runners occupy the total surface area of the ground. Produces thick leaf mulch that allows nothing else to grow and often hides the runners spreading out just under the surface of the ground.
Habitat	An Asian ornamental species which has escaped from gardens. Typically colonises along the edges of lakes.
Comments	Suspect specimens in Bindaring South were planted by neighbouring resident.
CONTROL	
Priority	Low
Timing	All year round
Manual Control	Cut shoots down low and then use a crowbar or mattock to dig out or lever up roots and rhizomes.
Wipe/ Cut Stump	Cut shoots down low and paint new shoots when they are about 1 m high with neat glyphosate.
Spot Spray	No specific information.

Barley Grass (*Hordeum leporinum*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Pickering Park
Appearance	Annual grass up 60 - 100 cm tall. Flowers in spring with an unbranched bristly head of prominently long-awned spikelets 3-10 cm long.
Habitat	Mainly disturbed areas. It also occurs as a weed anywhere seed is spilt on road and rail verges, but does not persist.
Comments	Escaped agricultural species. Native to Europe
CONTROL	
Priority	**Moderate**
Timing	July-Sep
Manual Control	Manually remove individuals before seeding.
Wipe/ Cut Stump	Not recommended.
Spot Spray	• 5 mL Fusilade®212 + 100 mL spray oil in winter when the grass has 2 – 8 leaves. This treatment is very selective and does not damage broad-leaved native plants (2) • Alternatively, spot spray with 10 mL glyphosate in spring when the seed heads are just emerging. Most natives will tolerate this treatment but higher rates will cause damage (2) • In sensitive areas, 10 – 20 mL Fusilade®212 + 100 mL spray oil applied any time before flowering will provide reasonable control of seed set (1 & 2)

Beach Evening Primrose (*Oenothera drummondii*)

DESCRIPTION	
Location	• Broadway Arboretum in Nyibra Swamp
Appearance	Erect herbs with a basal rosette of large leaves and a tall leafy spike of flowers. The flowers are yellow, opening in the evening, becoming tinged with red and withering the following day. The flowers are up to 10 cm across with a slender tube, 4 large spreading petals and 8 stamens. The fruit is long and slender. Perennial
Habitat	Occurs mainly in highly disturbed areas, especially in coastal dune sands.
Comments	Large populations may only be able to controlled in sheltered areas where erosion from wind is unlikely. Native to North America.
CONTROL	
Priority	**Moderate**
Timing	Aug-Dec
Manual Control	It is difficult to remove by hand because it tends to break off and regrow from the rootstock. If removing manually, use a weed fork and ensure that all the fleshy rootstock is collected and burnt or buried more than 1 m deep.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	• Control in seedling stage, older plants relatively tolerant of herbicide (1 & 2) • 0.4g chlorsulfuron plus 100 mL spray oil (1) • 1 g Logran® plus 100 mL spray oil (2)

Bedstraw (*Galium* sp.)

DESCRIPTION	
Locations	- Bindaring Park South - Broadway Arboretum in Nyibra Swamp
Appearance	Galium are spring flowering herbs, with slender branches, leaves in ring-like arrangements, and terminal branched greenish-white flowers.
Habitat	Widespread on wasteland, swamps, granite rocks and woodlands.
Comments	
CONTROL	
Priority	Moderate
Timing	Jun - Sep
Manual Control	Hand pull small infestations.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	No specific information on herbicide control. Suggest 100mL glyphosate when actively growing before seed set (3).

Birdsfoot (*Lotus angustissimus*)

DESCRIPTION	
Locations	- Bindaring Park North and South - Broadway Arboretum in Nyibra Swamp - Jubilee Reserve B
Appearance	Sprawling herbs with their leaves divided into 5, often hairy, leaflets. Three of the leaflets are towards the tip of the leaf and the remaining two at the base and often somewhat clasping the stem. There are small stalked clusters of flowers produced in spring and summer. The flowers are yellow to orange and 4-7 mm long. The seed pods are narrow and cylindric 2-3 cm long.
Habitat	Birdsfoot has become a weed along roadsides, in winter-wet areas, and particularly along creek lines.
Comments	Native to Europe
CONTROL	
Priority	Low
Timing	Jul-Dec
Manual Control	Mowing to 5 cm every 3 weeks provides reasonable control. Do not burn infested areas. Improve drainage to reduce water logging during winter.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water
Spot Spray	- Use 100 mL Tordon® 75-D plus 25 mL wetting agent in grass dominant situations or on small infestations (2) - 10 mL Lontrel + 25 mL wetting agent provides reasonable selective control in native vegetation (2) - 1 g Logran + 25 mL wetting agent (2) - 0.1 g metsulfuron + wetting agent also provides good control but may damage young native species at these rates (1 & 2) - Glyphosate generally provides little control (2)

Black Kennedia (*Kennedia nigricans*)*

DESCRIPTION	
Location	- Bindaring Park South
Appearance	Robust trailing or twining shrub or climber to 4 m high, with leaves divided in three large leaflets and clusters of black and yellow flowers, produced between July and November.
Habitat	Native to the south-coast between Albany and Esperance, widely cultivated and now naturalised within coastal and swampy sites around Perth.
Comments	
CONTROL	
Priority	**Low**
Timing	Jul - Oct
Manual Control	Hand pull isolated individuals.
Wipe/ Cut Stump	No specific information. Suggest wiping with 1:2 glyphosate to water.
Spot Spray	No specific information on herbicide control.

Black Nightshade (*Solanum nigrum*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Broadway Arboretum in Nyibra Swamp • Pickering Park
Appearance	Herb or small short-lived shrub to 1 m high. The leaves are 2-7.5 cm long, entire or very shallowly lobed. Flowers for much of the year, flowers are white, in short-stalked clusters, each flower about 1 cm across with 5 spreading petals. The succulent, globular berries are at first green but becoming black at maturity.
Habitat	Common weed of horticulture, gardens, pasture and waste land it is readily spread by birds into bushland.
Comments	Probably native to Europe.
CONTROL	
Priority	**Moderate**
Timing	Sep-Dec
Manual Control	Hand-weed small infestations. Shade reduces seed production.
Wipe/ Cut Stump	No specific information. Suggest wiping with 1:2 glyphosate to water.
Spot Spray	• On large infestations, 20 mL Starane®, applied when the weed is actively growing in summer will provide reasonable selective control (2) • 20 mL 2,4-D amine (500g/L) can also be used for the control of young plants in early summer and at these rates cause little damage to most established native species (2)

Blowfly Grass (*Briza maxima*) and Shiver Grass (*Briza minor*)

DESCRIPTION		
Locations	Blowfly Grass • Bindaring Park North and South • Jubilee Reserve A and B • Pickering Park • Success Hill	Shiver Grass • Bindaring Park North and South • Success Hill
Appearance	Slender tufted annual grasses to 60cm tall. Flowering spikes, produced in spring, consist of a loose compound arrangement of nodding green spikelets. Spikelets of *Briza minor* are much smaller and more numerous the *B. maxima*.	
Habitat	Widespread and common weeds of wasteland, granite rocks, wetlands and woodlands throughout South-western Australia.	
Comments	Easy to control.	
CONTROL		
Priority	Moderate	
Timing	Jun-Sep	
Manual Control	Manually remove individuals before seeding.	
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.	
Spot Spray	• 10 mL Fusilade®212 + wetting agent at 3 – 5 leaf stage (1) • 10 mL glyphosate in late winter to early spring before flowering (2) • 200 g Propon® + 25 mL wetting agent applied as above will provide some residual action (2) • 4 g Achieve® plus 10 mL Supercharge® oil will provide highly selective control and is applied between the 2 leaf and tillering stage of the grass in winter (2)	

Bridal Creeper (*Asparagus asparagoides*)

DESCRIPTION	
Locations	- Bindaring Park North and South - Success Hill
Appearance	Perennial herb and climber, growing to between 1 to 5m high. Flowers in spring, produces red fleshy berries to about 1 cm in diameter before dying back in summer. Re-shoots rapidly to climb and sprawl over other vegetation, eventually smothering it.
Habitat	Extremely invasive, spreading rapidly down roadsides, creeklines and even into undisturbed bushland.
Comments	One of the State's most urgent environmental weed problems, especially in coastal dune ecosystems. It is extremely invasive, spreading rapidly over other vegetation, eventually smothering it. Flowers in spring, dies back over summer and then shoots away in autumn. Native to southern Africa.
CONTROL	
Priority	High
Timing	Jul-Sep
Manual Control	As plants are usually under trees and shrubs they are difficult to dig out. However, young plants are easily removed by hand. Mats of bridal creeper can be rolled up and destroyed.
Wipe/ Cut Stump	Apply 1:2 glyphosate to water to leaves and stems with a sponge glove or brush taking care to avoid other species.
Spot Spray	- 0.04g metsulfuron + 25 mL Pulse® (1 & 2) provides good suppression and may be applied with a mister or hand spray in winter with little damage to the bush (1&2) - 100 mL glyphosate + 25 mL Pulse® (1)

Brome Grass (*Bromus diandrus*)

DESCRIPTION	
Locations	• Bindaring Park South • Broadway Arboretum in Nyibra Swamp • Success Hill
Appearance	Tufted annual grass to 90cm with softly hairy, flat or loosely folded leaves. Flowering spikes are either erect or drooping, to 15 – 25 cm long, and consist of a compound arrangement of oblong spikelets with very prominent, rough awns to 60 mm long.
Habitat	Widespread and serious weed of offshore islands, wetlands, road verges, granite rocks, pastures and crops throughout the south-west of WA.
Comments	Competes with natives. Fire hazard.
CONTROL	
Priority	Bindaring and Success Hill – **Moderate** Broadway – **High**
Timing	Sep-Nov
Manual Control	Manually remove individuals.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	• 10 mL Fusilade®212 plus 100 mL spray oil (1,2 & 3) • 2 mL Verdict®520 plus 100 mL spray oil (2) • 5 mL glyphosate (2)

Buffalo Grass (*Stenotaphrum secundatum*)

DESCRIPTION	
Locations	• Bindaring Park South • Pickering Park
Appearance	Prostrate perennial grass forming dense colonies. Green - purple flowering heads are produced in summer and consist of a flat central stem with imbedded spikelets.
Habitat	Planted as a lawn grass, it is a weed of riverine edges, swamps and road verges.
Comments	Because of its dense growth habit, it can smother herbaceous species. Native to North and South America and Africa.
CONTROL	
Priority	High
Timing	Nov - Feb
Manual Control	Rake the grass out of the rushes and roll back out of the rushes with a small amount of digging. Remove as much of the buffalo grass thatch as possible. Cover the remaining buffalo grass in June/July with black plastic held down with rocks.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water
Spot Spray	• 100 mL glyphosate + 25 mL Pulse applied when the grass is actively growing is the most effective control (1 & 2) • 8 mL Fusilade®212 + wetting agent (1) • 10 mL Verdict®520 + 100 mL of spray oil (2)

Bullrush (*Typha* sp.)*

DESCRIPTION	
Locations	• Bindaring Park North and South • Broadway Arboretum in Nyibra Swamp • Success Hill
Appearance	Tall rigid reed to 4.5 m high with flat strap-like leaves to 2 m long and a thick cylindrical stem. The flowering stem is tipped by a cylindrical, brown, velvety brush of densely packed tiny flowers. Flowers in spring and summer. Perennial.
Habitat	Wetlands and waterways.
Comments	*Typha orientalis* is native to eastern Australia while native Typha (*T. domingensis*) is native to Western Australia. Both species are aggressive colonisers of disturbed wetlands and compete with other native plants. The species can be difficult to correctly identify, especially as it is known to hybridise. Fire hazard.
CONTROL	
Priority	Low
Timing	Oct - Dec
Manual Control	Difficult to dig out even small populations and reinfestation can be rapid. Ensure all the rhizomatous root is removed. Remove flowers, seed source. Cut stems below water level in summer or just prior to recharge of wetland, plants then rot. Repeated cuttings in growing season (summer) will kill plants. Remove cut material.
Wipe/ Cut Stump	Hard to get at to wipe, but try wiping with a high rate of Roundup Biactive® (eg 1 to 10 water). Slash plants first and wipe new growth when leaves approximately 1m high(3).
Spot Spray	100mL Roundup Biactive® after the male flowers have opened and before the female flowers have expanded. Better results when not stood in water, wait if possible for water level to recede.

Burr Medic (*Medicago polymorpha*)

DESCRIPTION	
Locations	• Bindaring Park South • Broadway Arboretum in Nyibra Swamp • Pickering Park
Appearance	Low-growing sprawling herb with stems up to 60 cm long and leaves divided into 3 heart-shaped leaflets each 4-25 mm long. Flowers in winter and spring producing small clusters of yellow pea flowers. The fruit is a small, tightly coiled burr, often spiny.
Habitat	Burr Medic is a common weed of gardens, pastures and roadsides.
Comments	So common it may not be practical to control it.
CONTROL	
Priority	Low
Timing	Aug - Dec
Manual Control	Manually remove individuals from site and destroy.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	• For small infestations and grass dominant areas an annual application of 10 mL Tordon®75-D in early winter gives excellent control of existing plants and has residual activity to control later seedlings (2) • In bushland, 10 mL Lontrel® + 25 mL wetting agent **or** 1 g Logran® + 25 mL wetting agent applied in early winter provides reasonably selective control (2) • 0.1 g metsulfuron + wetting agent (1&2)

Caltrop (*Tribulus terrestris*)

DESCRIPTION	
Locations	- Broadway Arboretum in Nyibra Swamp
Appearance	Caltrop, also known as puncture vine or cats head, is a low spreading annual with pinnate leaves, yellow flowers less than 1cm across and very spiny fruits. The upper surface of leaves is dark green, while the lower surface is covered in hairs, giving it a silvery appearance.
Habitat	It is widespread in the Kimberley and arid zone, and is spreading along roadsides in the south-west.
Comments	This herb plant is a cosmopolitan weed, and forms of it may be native to Western Australia or introduced prior to European settlement. There are several rather similar native caltrops which generally have larger flowers and less spiny fruits.
CONTROL	
Priority	Low
Timing	Dec - Jan
Manual Control	Handpulling is effective if the infested area is no too large. Make sure to remove the tap root by pulling from the root crown (where the weed spreads from).
Wipe/ Cut Stump	No specific information. Suggest wiping with 1:2 glyphosate to water.
Spot Spray	- 100 mL glyphosate effective on seedlings (1)

Cape Bluebell (*Wahlenbergia capensis*)

DESCRIPTION	
Location	• Broadway Arboretum in Nyibra Swamp
Appearance	Slender, erect annual up to 50cm tall. The stems and leaves are shortly-hairy and the leaves have wavy, toothed edges. Each flowering stem is terminated by a single cup-shaped flower up to 2cm across, bluish-green with a dark blue centre, appearing in spring.
Habitat	Widespread on roadsides, in woodlands and heaths on sandy soils and occasionally in gardens, from Geraldton to Ravensthorpe.
Comments	Native to the Cape Province, South Africa.
CONTROL	
Priority	Moderate
Timing	Aug - Dec
Manual Control	Manually remove small populations before seeding.
Wipe/ Cut Stump	No specific information. Suggest wiping with 1:2 glyphosate to water.
Spot Spray	• No specific information for herbicide control. Suggest 75-100 mL glyphosate, when actively growing (3)

Cape Lilac (*Melia azedarach*)

DESCRIPTION	
Locations	• Bindaring Park South • Broadway Arboretum in Nyibra Swamp
Appearance	Deciduous tree to 15m tall, with leaves up to 75 cm long, composed of many leaflets each 2-5cm long. It produces loose sprays of fragrant lilac flowers in spring, then many hard yellow berries, 1-2cm long.
Habitat	Native to the Kimberley, but in the south of the State it is naturalised and is spreading in wasteland around Perth and other settlements.
Comments	Widely grown as an ornamental tree. Native from Iran to northern Australia.
CONTROL	
Priority	Low
Timing	All year round
Manual Control	Hand pull seedlings.
Wipe/ Cut Stump	• Inject 100% glyphosate • Basal bark – 10 % triclopyr (summer)
Spot Spray	No specific information, suggest spraying regrowth with 100 mL glyphosate.

Capeweed (*Arctotheca calendula*)

DESCRIPTION	
Locations	• Bindaring Park South • Jubilee Reserve B • Pickering Park
Appearance	An annual daisy with a flat basal rosette of deeply lobed leaves. The leaves are 3 to 25 cm long, green on the upper surface but the lower surface white-hairy. Flowers in late winter and spring producing daisy flower heads, up to 6 cm in diameter held on individual stalks, with the radiating yellow petals and tiny central black florets.
Habitat	A common weed of pastures, crops and roadsides, but also quite common in disturbed bushland.
Comments	Native of South Africa.
CONTROL	
Priority	**Moderate**
Timing	Jun - Sep
Manual Control	Manually remove small populations before flowering.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	• 5 mL Lontrel® + 25 mL wetting agent applied in early growth stages will provide good control and is safe on many native species (1 & 2) • 10 mL glyphosate is also fairly selective in bushland and roadside situations if applied when young or at the budding stage (2)

Castor Oil (*Ricinus communis*)

DESCRIPTION	
Locations	• Bindaring Park South • Broadway Arboretum in Nyibra Swamp • Success Hill
Appearance	Soft-wooded spreading shrub to 4m tall. The leaves are held on stalks 20-60cm long, are palm-like with seven to nine lobes each 10-40cm long. The flowers are large, the male flowers yellow, the female flowers red. The seeds are very poisonous.
Habitat	Common in disturbed sites, it is scattered on road and rail verges, wasteland, rubbish tips, rivers, creeks and wetlands from Port Hedland to the Fraser Range.
Comments	Native to tropical Africa and Asia, it has been successfully controlled in Walunga National Park by slashing before flowering.
CONTROL	
Priority	**Low**
Timing	Dec - May
Manual Control	Manually remove seedlings.
Wipe/ Cut Stump	• Cut plant to ground and treat stump with straight glyphosate • Basal bark – triclopyr or Garlon® (spring-summer)
Spot Spray	• 125 mL glyphosate for large populations of seedlings (3)

Common Meliot (*Melilotus indica*)

DESCRIPTION	
Locations	- Broadway Arboretum in Nyibra Swamp - Jubilee Reserve B - Pickering Park - Success Hill
Appearance	Erect annual or short-lived perennial to 50cm with leaves divided into three toothed leaflets. It has small (2-3mm) yellow flowers produced in spring and summer, held on stalks between 2-10cm long originating from at the base of the leaflets.
Habitat	Occasional weed of pasture paddocks and a widespread weed of islands, coastal dunes, wasteland, creeks, granite rocks and coastal woodlands from Shark Bay to Esperance.
Comments	Native to the Mediterranean, it is an aromatic contaminant in hay and meat products.
CONTROL	
Priority	**Moderate**
Timing	Aug - Dec
Manual Control	Manually remove small plants. If slashing cut below lowest branch axil to prevent re-sprouting.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	- No specific information for herbicide control, suggest 50-75 mL glyphosate when actively growing (3)

Cotton Palm (*Washingtonia filifera*)

DESCRIPTION	
Location	- Bindaring Park South
Appearance	Palm growing to 12–25 m high with a dense crown of fan-shaped, palmate leaves.
Habitat	Garden escape spreading at Kununurra, Millstream, and in the Perth area.
Comments	Native to south-western USA and Mexico.
CONTROL	
Priority	Low
Timing	Aug - Dec
Manual Control	Hand pull seedlings, crop off at base when not in fruit.
Wipe/ Cut Stump	Cut stump and paint with neat glyphosate.
Spot Spray	No specific information on herbicide control.

Couch (*Cynodon dactylon*)

DESCRIPTION	
Locations	• Bindaring Park South • Broadway Arboretum in Nyibra Swamp • Jubilee Reserve A • Pickering Park • Success Hill
Appearance	Prostrate perennial grass, spreading both above and below ground to several metres across, rooting at the nodes, and bluish-green leaves. Flowers in late spring and summer, producing windmill-like (digitate) inflorescences comprising two to seven purplish spikes.
Habitat	Mainly in highly disturbed areas. It is widely planted as a lawn grass and it invades wetlands and river edges in southern Western Australia.
Comments	Competes with native species. It is native to the Kimberley and the tropics worldwide.
CONTROL	
Priority	High
Timing	Oct – Nov, Apr - May
Manual Control	Shade out with black plastic during spring and autumn.
Wipe/ Cut Stump	No specific information.
Spot Spray	• 50 mL Fusilade®212 + wetting agent in late spring/summer and then in autumn (1) • 100 mL glyphosate (1)

Crab Grass (*Digitaria sanguinalis*)

DESCRIPTION	
Locations	- Bindaring Park North and South - Broadway Arboretum in Nyibra Swamp - Pickering Park
Appearance	Annual grass with creeping stems, 2-15cm tall. Flowers in summer, producing erect inflorescences comprised of 3 to 10 purple racemes arranged in a windmill (digitate) arrangement.
Habitat	A very common garden weed in southern Western Australia.
Comments	Native to the Mediterranean.
CONTROL	
Priority	Low
Timing	Sep - Jan
Manual Control	Manually remove individuals.
Wipe/ Cut Stump	No specific information.
Spot Spray	- 100 mL glyphosate in spring (1)

Curled Dock (*Rumex crispus*)

DESCRIPTION	
Locations	- Bindaring Park North and South
Appearance	Erect herbs up to 1.5 m with pointed oval leaves 4-24 cm long. The leafless flower spike has densely clustered flowers in ring-like arrangements, greenish in colour but turning reddish, and swollen in the centre when in fruit. Flowers in winter, spring and early summer.
Habitat	A weed of creeklines, pasture and disturbed woodland.
Comments	Native to Europe and south-west Asia.
CONTROL	
Priority	Low
Timing	May - Jul
Manual Control	Remove individual plants by cutting their roots at least 20 cm below ground level.
Wipe/ Cut Stump	Can be wiped with a mixture of 1 L glyphosate in 2 L of water.
Spot Spray	- On small infestations 0.5 g chlorsulfuron plus 100 mL Tordon®75-D in winter will control existing plants and seedlings for about a year (2) - 100 mL glyphosate in early bud stage (1)

Cyperus (*Cyperus involucratus*)

DESCRIPTION	
Location	• Bindaring Park North
Appearance	Robust, tufted perennial, to 1.2–1.8 m high, producing brown - green flowers from December through to February. Similar growth habit to the other *Cyperus* species, except that it is tall, leafier, and the stems are cylindrical.
Habitat	Garden ornamental found in some wetlands around Perth.
Comments	
CONTROL	
Priority	Low
Timing	Aug - Dec
Manual Control	Manually remove isolated individuals, ensuring all tubers and rhizomes are removed.
Wipe/ Cut Stump	No specific information, suggest to wipe leaves with 1: 2 glyphosate to water.
Spot Spray	No specific information, though other *Cyperus* species are known to be controlled by 100 mL glyphosate + Pulse® (1 & 3)

Dove-foot Cranebill (*Geranium molle*)

DESCRIPTION	
Location	- Broadway Arboretum in Nyibra Swamp
Appearance	Spreading or ascending, softly-hairy, short-lived annual or perennial herb. Leaves are palm-like, with pink flowers and a hairless fruit.
Habitat	Found on wasteland, roadsides and occasionally on pastures between Perth and Albany.
Comments	
CONTROL	
Priority	Low
Timing	Aug - Dec
Manual Control	Manually remove individuals before seeding.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	No specific information, suggest glyphosate when actively growing. Metsulfuron at 5g/ha will control some plants from the Geraniaceae family (3).

Edible Fig (*Ficus carica*)

DESCRIPTION	
Location	• Bindaring Park South
Appearance	Small tree, 1–10 m high. Easily recognised by its large, lobed, hand-shaped leaves and fleshy green or purple pear-shaped fruits that appear in early summer.
Habitat	Usually in disturbed areas, has spread to river banks and creek lines around Perth and also persists at old settlement sites throughout the south-west. Replaces native Melaleuca species.
Comments	Believed to be native to the Mediterranean and the Middle East. Familiar as a cultivated fruit tree. Suspect specimen was planted by neighbouring resident.
CONTROL	
Priority	High
Timing	Aug – Dec
Manual Control	Remove seedlings and small populations.
Wipe/ Cut Stump	• Wicker wipe seedlings with 1: 2 glyphosate to water. • Cut trees to ground level and treat stumps with straight glyphosate • Inject with 50 to 100% glyphosate (summer)
Spot Spray	• Spray regrowth with 100 mL glyphosate (1)

Flatweeds (*Hypochaeris glabra* and *H. radicata*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Broadway Arboretum in Nyibra Swamp • Jubilee Reserve A and B • Pickering Park • Success Hill
Appearance	*Hypochaeris* has two species in WA, *H. glabra* (smooth catsear) and *H. radicata* (flatweed). They are difficult to tell apart but it is probably not necessary to distinguish them for most practical purposes. They are annuals or short-lived perennials, with a basal rosette of leaves and yellow, dandelion-like flower heads at the top of slender, leafless stalks. *H. glabra* is usually annual, with smooth leaves and heads up to 1.5cm across, *H. radicata* is usually perennial, with rough, bristly leaves and heads up to 3cm across; however, intergrades of all features exist.
Habitat	Common weeds of lawns, horticultural areas, roadsides and bushland throughout the south-west.
Comments	Native to Europe, competes with native herbs especially in richer soils and disturbed areas.
CONTROL	
Priority	Moderate
Timing	Aug - Nov
Manual Control	Use a weed fork to extract the taproot if hand pulling before seeding.
Wipe/ Cut Stump	Wipe rosettes with 1: 2 glyphosate to water.
Spot Spray	• 10 mL Lontrel® + 25 mL wetting agent (1) • For small infestations 50 mL Tordon®75-D will control growing plants and leave a soil residual to control seedlings for 12 months (2) • 100 mL glyphosate (3)

Flax Fleabane (*Conyza bonariensis*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Broadway Arboretum in Nyibra Swamp • Jubilee Reserve A • Pickering Park • Success Hill
Appearance	Annual herbs usually to 1 m high, with a basal rosette of entire or toothed leaves and an erect, often greyish, leafy flowering stem. The small flower heads are cream to white and do not have the radiating petal-like florets seen in many daisies. Flowers in summer and autumn.
Habitat	Common weed of roadsides and disturbed bushland in Perth.
Comments	Produces large numbers of seed therefore difficult to control. In poor seasons can flower when only a few cm high. Native to South America.
CONTROL	
Priority	Low
Timing	Oct - Dec
Manual Control	Hand pulling after stem elongation is effective on loose soils, but on heavier soils a weed fork is required to prevent the plant breaking and regrowing from the base. Manually remove small populations before they spread.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	• 5 mL Lontrel® plus 25 mL wetting agent can be used for fairly selective control in bushland (2) • Isolated patches can be sprayed with 50 mL Tordon®75-D for control of plants and residual control of seedlings (2)

Freesia (*Freesia* sp.)

DESCRIPTION	
Locations	- Success Hill
Appearance	Tufted plant with soft light green basal leaves arising from a corm. The erect flowering stem is bent to one side just below the lowest flower. Flowers are cream to yellow, or white which often have yellow to orange markings with an attractive scent. Flowers in spring.
Habitat	This popular garden flower has become a serious weed of urban bushland, coastal heath, woodland, and granite rocks from Gingin to Israelite Bay.
Comments	A hybrid of two South African species.
CONTROL	
Priority	**Moderate**
Timing	Aug – Sep
Manual Control	Very difficult to control by hand weeding because they produce seed, corms and cormels. Loosen the soil before removal to prevent the corm breaking off.
Wipe/ Cut Stump	Painting leaves or wiping with a sponge glove dipped in a mixture of 1 part glyphosate in 2 parts water can be used in selective areas.
Spot Spray	0.1 g metsulfuron + 25 mL Pulse® (1 & 2) provides reasonable control with much less damage to native species 50 mL glyphosate plus 25 mL Pulse applied in winter or spring before the end of flowering provides good control of ewxristing plants but there is often a subsequent germination.

Geraldton Carnation Weed (*Euphorbia terracina*)

DESCRIPTION	
Location	• Broadway Arboretum in Nyibra Swamp
Appearance	Erect perennial to 80cm tall, much branched from the base. The leaves are 1-4cm long, linear to lanceolata, minutely toothed and without stalks. Highly modified yellow-green flowers are located at the end of branches.
Habitat	Common and serious weed of grazing land, road verges, coastal heath and Tuart woodlands from Geraldton to Esperance. Common in Tuart woodland and coastal limestone.
Comments	Produces a very toxic and irritating milky sap when cut. Native to the Mediterranean.
CONTROL	
Priority	High
Timing	May - Jun
Manual Control	Manually remove individuals and small populations before seeding.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	Large infestations spray with: • 0.1 g metsulfuron in 15 L of water • 0.1 g metsulfuron + 150 mL glyphosate in 15 L of water before flowering (1)

Geraldton Wax (*Chamelaucium uncinatum*)

DESCRIPTION	
Location	• Broadway Arboretum in Nyibra Swamp
Appearance	Erect sparse shrub, 0.5–4 m high with white to pink flowers. Perennial.
Habitat	White, grey or yellow sand, over limestone, laterite. Coastal areas, edges of swamps, hillsides, plains.
Comments	Very popular garden species. Should not be confused with the local Wembley Wax that occurs around Bold Park, which is the same species but of different provenance.
CONTROL	
Priority	Low
Timing	Sep - Nov
Manual Control	Manually remove seedlings.
Wipe/ Cut Stump	Cut trees to ground level and treat stumps with straight glyphosate.
Spot Spray	Not recommended

Giant Reed (*Arundo donax*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Adjacent to Broadway Arboretum in Nyibra Swamp • Success Hill
Appearance	Similar appearance to Bamboo, only branches are much thicker. Both sub-species (variegated and non-variegated) occur in the study areas. Perennial.
Habitat	Mainly disturbed areas.
Comments	Difficult to control. Serious weed.
CONTROL	
Priority	Moderate
Timing	Aug - Dec
Manual Control	Manually remove juvenile individuals.
Wipe/ Cut Stump	Cut down close to ground and paint with neat glyphosate.
Spot Spray	Carefully spot spray regrowth with • 100 mL glyphosate before 60 cm high • 10 mL Verdict®120 + wetting agent • 10mL Fusilade®212 + wetting agent (1)

Grapevine (*Vitis vinifera*)

DESCRIPTION	
Location	- Bindaring Park South
Appearance	Woody climber
Habitat	Creek and river banks, lake margins
Comments	Suspect the specimens were planted by a neighbouring resident.
CONTROL	
Priority	Low
Timing	Oct - Jan
Manual Control	Remove small seedlings.
Wipe/ Cut Stump	Cut to ground level and paint stump with 50 – 100% glyphosate.
Spot Spray	No specific information available relating to herbicide control, suggest spot spraying regrowth with 100 mL glyphosate.

Guildford Grass (*Romulea rosea*)

DESCRIPTION	
Locations	• Jubilee Reserve A and B
Appearance	Small herb with long and slender, but very tough, cylindrical basal leaves which are produced annually from a small corm: The flowers are formed at the base of the plant on stalks which gradually elongate upwards during flowering and then recurve in fruit. The star-like flowers have a short broad yellowish tube and 6 pink to purple pointed petal lobes 8-15 mm long.
Habitat	A weed of roadsides, garden and pasture, also commonly occurring in bushland.
Comments	Native to South Africa.
CONTROL	
Priority	🟥 High
Timing	Aug - Oct
Manual Control	Manual control is often difficult because corms tend to break off unless soil is very loose. Very regular and close mowing with a rotary mower and cultivation in summer or early autumn to expose corms so they dry out and die provides some control but also may spread the infestation.
Wipe/ Cut Stump	Blanket wiper treatments using 1-2 L/ha of glyphosate in combination with 10-20 g/ha of chlorsulfuron or metsulfuron have worked well.
Spot Spray	• 0.5 g chlorsulfuron + 25 mL Pulse in winter before flowering (2) • 0.2 g metsulfuron + 37.5 mL Pulse in 15 L of water (1)

Hares Tail Clover (*Trifolium arvense*)

DESCRIPTION	
Locations	- Jubilee Reserve B - Success Hill
Appearance	Erect or sprawling herb with leaves divided into 3 narrow leaflets approx. 5-20 mm long and ovoid to shortly cylindrical heads of white or pink flowers. Flowers late winter, spring and summer.
Habitat	Common weed of roadsides, gardens and waste places, sometimes invading bushland.
Comments	Native to Europe, Asia and northern Africa.
CONTROL	
Priority	Moderate
Timing	Jun-Jul
Manual Control	Hand pull scattered individuals, pulling from the root crown, before flowering.
Wipe/ Cut Stump	Wipe with 1:2 glyphosate to water.
Spot Spray	- 10 mL Lontrel® + 25 mL wetting agent in early winter before flowering (1 & 2) - 1g Logran (2) + 25 mL wetting agent - 0.1 g metsulfuron (2) + 25 mL wetting agent - 0.1 g chlorsulfuron (2) + 25 mL wetting agent - In grass dominant areas, 10 mL Tordon®75-D in early winter gives excellent control of existing plants and has residual activity to control seedlings.

Hares Tail Grass (*Lagurus ovatus*)

DESCRIPTION	
Locations	- Bindaring Park South - Success Hill
Appearance	Hairy annual grass, to 30cm tall. Flowering heads are dense, ovoid, pale green and head at the top of slender stalks, ageing straw-coloured, with long hairs. Flowers during spring and summer.
Habitat	A common weed of sandy soils, especially near the coast.
Comments	Competes with native plants. Native to the Mediterranean.
CONTROL	
Priority	Bindaring Park – **High** Success Hill - **Moderate**
Timing	Jun - Aug
Manual Control	Manually remove individuals. Prevent seed set for 2-3 years by mowing, grazing or cultivation.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	- 10 to 20 mL Fusilade®212 + 100 mL spray oil applied before flowering will provide reasonable control in sensitive areas where there are seedling native or broadleaved plants (1 & 2) - Alternatively, 5 mL glyphosate plus 25 mL wetting agent applied in winter when the grass is in the vegetative stage will provide reasonably selective control in bushland (2) - Use higher rates for higher levels of control in non-selective situations (2)

Hibiscus (*Hibiscus* sp.)

DESCRIPTION	
Location	- Bindaring Park South
Appearance	Small trees or shrubs up to about 4m high. Perennial. Flowers usually solitary.
Habitat	-
Comments	Suspect specimen was planted by neighbouring resident.
CONTROL	
Priority	Low
Timing	Aug - Dec
Manual Control	Remove small seedlings by hand.
Wipe/ Cut Stump	No specific information, suggest cutting to near ground level and painting stump with straight glyphosate.
Spot Spray	No specific information, suggest 100 – 150 mL glyphosate sprayed on the foliage of seedlings till run-off.

Japanese Pepper (*Schinus terebinthifolia*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Jubilee Reserve B
Appearance	A tree or shrub with several trunks, 3-6 m tall. The pinnate leaves and leaflets have a red to yellow midrib and smell like turpentine when crushed. Female plants produce clusters of small, bright red berries at ends of branches during winter. Male trees have many small cream flowers in late summer.
Habitat	Common in older suburbs as a street tree and garden specimen. It has escaped from cultivation and forms thickets on disturbed land. Found in damp sites near Geraldton, and on river banks and swampy sites around Perth.
Comments	Smothers native plants. Has the potential to become more widespread. Seed spread by birds. Roots can resprout. Very difficult to control. Can cause health problems in some people.
CONTROL	
Priority	**Moderate**
Timing	Sep - Dec
Manual Control	Remove small seedlings by hand.
Wipe/ Cut Stump	• Inject trunk with 50% glyphosate • Cut to near ground level and treat stump with straight glyphosate within 30 seconds of cutting • Basal bark – triclopyr/picloram (summer)
Spot Spray	Not recommended.

Kikuyu (*Pennisetum clandestinum*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Pickering Park • Success Hill
Appearance	Spreading perennial grass that can form large colonies up to 2m tall. The inflorescences are hidden amongst the leaves, though, when in flower, kikuyu lawns may seem covered in spider threads of protruding filaments. Flowers in summer and apparently does not set seed in Australia.
Habitat	Occurs mainly in highly disturbed areas. Naturalised in swamps and wetlands in the wetter south-west from Dandaragan to Albany.
Comments	Readily escapes from parklands into bushlands. Smothers native plants. Native to East Africa.
CONTROL	
Priority	High
Timing	All year round
Manual Control	Rake and remove as much of the kikuyu thatch as possible. Cover the remaining kikuyu in June/July with black plastic held down with rocks or pegs. In summer remove the black plastic, control any live kikuyu runners and seed or plant with native species.
Wipe/ Cut Stump	Not recommended.
Spot Spray	• 100 mL glyphosate + 25 mL Pulse when the grass is actively growing provides the best control. Repeat every 8 weeks or when regrowth reaches about 5 cm tall (1 & 2). • 10 mL Fusilade® + wetting agent (1) • 10 mL Verdict + 100 mL spray oil (2)

Lantana (*Lantana camara*)

DESCRIPTION	
Location	- Success Hill
Appearance	Evergreen shrub with arching, spreading branches that can form a dense tangled mass over 3m high and wide. The ovate, serrate leaves are rough to the touch. The flowers are arranged in flat heads, pale cream, aging to cerise, and produced in spring and summer. The black berries are edible and are spread by birds.
Habitat	Naturalised in wetter wasteland areas around Perth.
Comments	Native of South America. Several other lantanas are planted in gardens, and may have the potential to become naturalised. Prolific seeder. Releases chemicals in soil that inhibit germination of native seeds. A serious bushland weed in eastern Australia.
CONTROL	
Priority	High
Timing	Sep to Nov
Manual Control	Manually remove seedlings.
Wipe/ Cut Stump	Cut stump or basal bark – triclopyr/picloram (summer – autumn).
Spot Spray	- Foliar spray regrowth and small plants under 2 m tall with 150 mL glyphosate when actively growing(1)

Marsh Club-rush (*Bolboschoenus caldwellii*)*

DESCRIPTION	
Location	- Bindaring Park South
Appearance	Perennial sedge 0.3 to 1.2 m high. Flowers yellow, brown, produced between August and March.
Habitat	White or grey sand, mud, saline silt, sandy clay. Swamps, drains, brackish river edges, salt marshes.
Comments	Local native species that can be aggressive and overtake waterways and block water flow. Population requires monitoring and possible thinning.
CONTROL	
Priority	**Low**
Timing	Jun-Sep
Manual Control	Dig out small infestations ensuring all tubers and rhizomes are removed.
Wipe/ Cut Stump	No specific information.
Spot Spray	No specific information.

Mile-a-Minute (*Ipomoea cairica*) and Morning Glory (*I. indica*)

DESCRIPTION		
Locations	Mile-a-Minute • Bindaring Park South	Morning Glory • Bindaring Park North and South • Success Hill
Appearance	*Ipomoea cairica* is a hair-less perennial vine with tuberous roots. The young stems are red and the leaves ovate in outline but with five to seven finger-like lobes. Flowers are funnel-shaped, mauve-pink. *I. indica* is similar to the above, but is a softly hairy vine with tri-lobed leaves and bright blue flowers.	
Habitat	Both species and occur as garden escapes on wasteland from Geraldton to Albany, flowering in spring and summer. They are common along rivers and creeks in the Perth area, where they smother fringing trees and shrubs.	
Comments		
CONTROL		
Priority	Low	
Timing	All year round	
Manual Control	Hand pull seedlings.	
Wipe/ Cut Stump	Scrape and paint stem with 20% to 100% glyphosate.	
Spot Spray	No specific information. Suggest high rates of glyphosate (ie 200 mL) plus 25 mL Pulse. Cut down large plants and spray regrowth, two or more applications are likely to be required (3).	

Narrow Leaf Lupin (*Lupinus angustifolius*)

DESCRIPTION	
Locations	• Broadway Arboretum in Nyibra Swamp • Jubilee Reserve B • Success Hill
Appearance	Naturalised in Western Australia, often on roadsides or sandy bushland adjoining paddocks. Has blue flowers in spring and have leaves divided into a number of finger-like leaflets, each up to 6mm wide. Annual.
Habitat	It is a weed of road verges and woodlands from Geraldton to Albany.
Comments	Competes with natives.
CONTROL	
Priority	Low
Timing	Jul-Oct
Manual Control	Manually remove scattered individuals.
Wipe/ Cut Stump	Not recommended.
Spot Spray	• Small areas can be treated with 20 mL Tordon®75-D in early winter leaving a soil residual which will control lupin and other broadleaf seedlings for about a year (2). • In bushland, 10 mL Lontrel® or 1g Logran® are relatively selective (1 & 2). • 0.1 g metsulfuron can also be used but is less selective (1 & 2). • glyphosate is relatively ineffective (2)

Narrowleaf Clover (*Trifolium angustifolium*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Jubilee Reserve A and B
Appearance	Erect annual up to 60cm tall, with relatively few, straight, unbranched stems. The large leaves have long, narrow leaflets. The stems are topped by long cylindrical heads of small pink flowers, in spring and early summer.
Habitat	A weed in a wide variety of situations, common along roadsides and tracks in less fertile sites, not common in grazed pastures, throughout the south-west between Perth and Albany.
Comments	No agricultural value. Native to the Mediterranean.
CONTROL	
Priority	Low
Timing	Jun - Jul
Manual Control	Remove scattered individuals, pulling from the root crown, before flowering.
Wipe/ Cut Stump	Wipe with 1:2 glyphosate to water.
Spot Spray	• 10 mL Lontrel® + 25 mL wetting agent in early winter before flowering (1 & 2) • 1g Logran® (2) + 25 mL wetting agent • 0.1 g metsulfuron (2) + 25 mL wetting agent • 0.1 g chlorsulfuron (2) + 25 mL wetting agent • In grass dominant areas, 10 mL Tordon®75-D in early winter gives excellent control of existing plants and has residual activity to control seedlings (2).

Nasturtium (*Tropaeolum majus*)

DESCRIPTION	
Location	- Bindaring Park North
Appearance	Annual, or sometimes a short-lived perennial, with sprawling fleshy stems and circular leaves held aloft on long stalks like parasols. The striking, spurred, trumpet-shaped flowers are all shades of red, orange and yellow, produced in spring.
Habitat	A garden escape, it occurs on wasteland and along creeklines from Perth to Albany.
Comments	*Tropaeolum majus* is a hybrid between *T. ferreyrae* and *T. minor*, both native to Ecuador and Peru, and is not known from the wild.
CONTROL	
Priority	Low
Timing	Sep – Nov
Manual Control	Manually remove, ensuring the larger roots are also collected and burn. There is typically a large germination of seedlings following the removal of parent plant. These can be controlled by light cultivation or herbicides.
Wipe/ Cut Stump	Not recommended.
Spot Spray	- 80 mL 2,4-DB plus 25 mL wetting agent will provide reasonably selective control in bushland situation (2) - Where hormone herbicides can't be used (ie close to gardens, vineyards and orchids), apply 20 mL glyphosate plus 25 mL wetting agent (2)

Paspalum (*Paspalum dilatatum*)

DESCRIPTION	
Location	• Bindaring Park North and South
Appearance	Tufted rhizomatous perennial to 1m tall. The inflorescence consists of 2 to 10 pendulous, slender and spreading branches each with 2 rows of small spikelets, produced in spring and summer.
Habitat	A fodder grass, it is found in disturbed claypans (and in natural ones, where it is a serious weed), swamps, lawns, verges and pastures from Kalbarri to Albany and also at the Ord River.
Comments	Native to South America.
CONTROL	
Priority	Moderate
Timing	Aug - Nov
Manual Control	Cut out small populations – ensure rhizome removal.
Wipe/ Cut Stump	Cut near ground level and wide with 10% glyphosate (100 mL / 1 L of water).
Spot Spray	• Spray adult plants with 100 mL Fusilade® + wetting agent. Rate can be reduced to 10 mL when spraying seedlings (1) • 100 mL glyphosate + 25 mL wetting agent (2 & 3)

Perennial Veldt Grass (*Ehrharta calycina*)

DESCRIPTION	
Locations	• Bindaring Park South • Jubilee Reserve A and B • Success Hill
Appearance	Tufted perennial grass to 80cm tall. The inflorescence is a drooping erect panicle of reddish-purple flowers, 7-22cm long. Flowers in spring.
Habitat	Widespread weed of roadsides and bushland on sandy soils, from Geraldton to Esperance and is especially common on the Swan Coastal Plain.
Comments	Serious environmental weed.
CONTROL	
Priority	High
Timing	Aug - Sep
Manual Control	Manual remove small populations before seeding, ensuring crown removal. Do not slash.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	• 80 mL Fusilade®212 + wetting agent, followup in subsequent years; utilise unplanned fires and spray regrowth and seedlings with 4 – 6 weeks (1).

Pigeon Grass (*Setaria palmifolia*)

DESCRIPTION	
Location	- Bindaring Park North
Appearance	Robust, tufted perennial, to 1.5m tall with palm-like leaves to 1m long. The inflorescence is an erect or nodding, loose panicle, with long zig-zagging to straight branches. Flowers in summer.
Habitat	A garden plant, now scattered in disturbed swamps and creeks from Perth to Busselton.
Comments	Minor weed species
CONTROL	
Priority	Low
Timing	Jun - Oct
Manual Control	Manual remove small populations before seeding, ensuring crown removal.
Wipe/ Cut Stump	No specific information, suggest wicker wipe with 1:2 glyphosate to water.
Spot Spray	No specific information, suggest 100 mL glyphosate + 25 mL wetting agent applied prior to flowering.

Pimpernel (*Anagallis arvensis*)

DESCRIPTION	
Locations	- Bindaring Park North and South - Broadway Arboretum in Nyibra Swamp
Appearance	Hairless, spreading annual, with more or less square stems, and opposite, ovate, stalkless leaves. The flowers are produced in spring and are about 1cm across, held on stalks above the leaves.
Habitat	Occurs within disturbed sites throughout the south-west, including coastal dunes and limestone.
Comments	Competes with small herbs. Mainly a problem in moist badly disturbed areas when the plants become more vigorous. Therefore only worth controlling in these areas.
CONTROL	
Priority	Moderate
Timing	Jul - Oct
Manual Control	Manually remove individuals.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	No specific information relating to herbicide control, suggest: - 50-100 mL glyphosate + 25 mL wetting agent - 0.5 g chlorsulfuron or metsulfuron (3)

Prickly Lettuce (*Lactuca serriola*)

DESCRIPTION	
Locations	- Bindaring Park North and South - Broadway Arboretum in Nyibra Swamp - Jubilee Reserve A and B - Pickering Park - Success Hill
Appearance	Summer-growing annual with a short-lived basal rosette of leaves and an erect leafy stem, 1-2m tall, repeatedly branching at the top to form an open pyramid of small yellow flower heads. Stems are prickly, as are the deeply lobed leaves. The leaves tend to be held vertically, orientated north/south or east/west.
Habitat	Found in crops, pastures, along roadsides and on wasteland and in disturbed bushland throughout the south-west especially along bush tracks.
Comments	Occasionally misidentified as skeleton weed. Native to Europe.
CONTROL	
Priority	Moderate
Timing	Oct - Dec
Manual Control	Manually remove individuals before flowering.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	- 50-75 mL glyphosate + 25 mL wetting agent (3)

Ribwort Plantain (*Plantago lanceolata*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Pickering Park
Appearance	Slightly hairy annual or short-lived perennial with ribbed stems to 1m high in favourable locations, but often shorter. The leaves are lance shaped, much longer than wide, and usually held erect. The inflorescence is a brown cylinder, up to 7cm long.
Habitat	Common on disturbed areas such as sports ovals and roadsides from Perth to Albany.
Comments	Native to Europe and Asia.
CONTROL	
Priority	Low
Timing	Oct - Dec
Manual Control	Manually remove individuals before flowering. Ensure tap root is removed.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	• Spray in early growth stages with 100 mL glyphosate + 25 mL wetting agent (1)

Ryegrass (*Lolium rigidum*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Broadway Arboretum in Nyibra Swamp • Success Hill
Appearance	Annual grass to 1 m tall. The inflorescence is a slender, flat, two-ranked spike, cream to yellowish green in colour, up to 30 cm long. Flowers in spring and summer.
Habitat	An important weed of crops and a widespread weed of islands, coastal sands, disturbed sites and road verges from Shark Bay to Busselton.
Comments	Some of the selective grass herbicides are far better than others in controlling this species. Native to the Mediterranean.
CONTROL	
Priority	**Moderate**
Timing	Jun - Aug
Manual Control	Manually remove small populations. Cut at or slightly below ground level, rarely regrows. Remove any seed heads.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	• Spray with 5 mL of Select® (or other grass-selective herbicides ie Fusilade®212, Sertin®, Targa® etc) plus 100 mL spray oil in winter when grass has 2 – 8 leaves. For larger plants, up to flowering, increase rate to 20mL (1 & 2). • Where populations are resistant to grass selective herbicides, use 10 mL of glyphosate when the ryegrass is still vegetative to the time the seed heads are emerging. Most natives will tolerate this treatment (2)

Small Flowered Mallow (*Malva parviflora*)

DESCRIPTION	
Locations	• Bindaring Park South • Broadway Arboretum in Nyibra Swamp
Appearance	Erect or decumbent annual or perennial, herb 0.05 to 1.2 m high. Very small mauve, pink or white flowers are produced between March/July and November.
Habitat	Occurs mainly in highly disturbed sites.
Comments	Competes with herbs and small shrubs.
CONTROL	
Priority	Low
Timing	Aug - Dec
Manual Control	Manually remove small populations before seeding.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	No specific information, suggest high rates of glyphosate (ie 100-150 mL) in early growth stages and when actively growing (3).

Soursob (*Oxalis pes-caprae*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Jubilee Reserve A • Success Hill
Appearance	Perennial herb consisting of stalked leaves made up of three heart-shaped leaflets, and many-flowered inflorescences on cylindrical stalks that grow from deeply placed tubers and bulbs. Leaflets often spotted or marked. The bright yellow flowers appear in late autumn and winter.
Habitat	A major weed of crops, pastures, orchards, gardens, roadsides, wasteland and disturbed native vegetation throughout the south-west.
Comments	Competes with and smothers native plants forming large colonies. Toxic. Physical removal can result in spread of bulbils. Native to South Africa.
CONTROL	
Priority	Moderate
Timing	July - Sep
Manual Control	Mowing and grazing are generally ineffective. Manual removal very difficult as it requires all the soil surrounding the roots to also be removed to prevent spread of bulbils.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate.
Spot Spray	• 0.1 g metsulfuron (2) • 0.2 g chlorsulfuron (2) • 100 mL glyphosate (1 & 2)

Sowthistle (*Sonchus oleraceus*) and Prickly Sowthistle (*S. asper*)

<table>
<tr><th colspan="3">DESCRIPTION</th></tr>
<tr><td>Locations</td><td>Sowthistle
• Bindaring Park South
• Broadway Arboretum in Nyibra Swamp
• Jubilee Reserve A and B
• Success Hill</td><td>Prickly Sowthistle
• Bindaring Park North and South
• Pickering Park
• Broadway Arboretum in Nyibra Swamp
• Jubilee Reserve A and B
• Success Hill</td></tr>
<tr><td>Appearance</td><td colspan="2">Sowthistles are annual or short-lived perennials with erect, sparsely branched hollow stems producing latex when cut. The flower heads are composed of yellow ray florets, opening in the morning, closing in the afternoon. <i>Sonchus asper</i> (prickly sowthistle) is a stout upright annual to 1.5m, with large, leathery leaves with very prickly margins. <i>Sonchus oleraceus</i> (sowthistle) is less robust and the leaves are generally flaccid and are weakly prickly or have no prickles at all.</td></tr>
<tr><td>Habitat</td><td colspan="2">A common weed of pasture and waste land, but also invades bushland particularly in damp areas.</td></tr>
<tr><td>Comments</td><td colspan="2">Sow thistles flower much of the year but mainly in spring and early summer. Native to Europe, Asia and northern Africa.</td></tr>
<tr><th colspan="3">CONTROL</th></tr>
<tr><td>Priority</td><td colspan="2">Moderate</td></tr>
<tr><td>Timing</td><td colspan="2">May - Aug</td></tr>
<tr><td>Manual Control</td><td colspan="2">Manually remove isolated plants.</td></tr>
<tr><td>Wipe/ Cut Stump</td><td colspan="2">Wicker wipe with 1: 2 glyphosate to water prior to budding.</td></tr>
<tr><td>Spot Spray</td><td colspan="2">• 10 mL Lontrel + 25 mL wetting agent applied at rosette stage (1)
• 50-75 mL glyphosate (2 & 3)</td></tr>
</table>

Stagger Weed (*Stachys arvensis*)

DESCRIPTION	
Location	- Pickering Park
Appearance	Weak, hairy annual, with upright stems that bear small, broad leaves with rounded teeth on the leaf margin. The small flowers are pink to purple in small clusters amongst the upper leaves. Flowering in winter and early spring.
Habitat	Widespread in cultivated agricultural and disturbed land, granite outcrops and urban woodlands throughout the south-west.
Comments	Toxic to livestock, causing 'staggers'.
CONTROL	
Priority	Low
Timing	Jul - Oct
Manual Control	Manually remove small infestations prior to flowering.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate.
Spot Spray	No specific information, suggest glyphosate 50 – 75 mL when actively growing (3)

Summer Scented Wattle (*Acacia rostellifera*)*

DESCRIPTION	
Location	• Broadway Arboretum in Nyibra Swamp
Appearance	Dense shrub or tree to 6 m high. Bark is dark grey and fissured on main trunks. Deep yellow spherical flower-heads are produced between July and December and occur in groups of two to seven arranged either side of a central axis.
Habitat	Mainly on consolidated sand dunes.
Comments	Aggressive native coloniser, especially of disturbed or degraded areas.
CONTROL	
Priority	High
Timing	Sep - Dec
Manual Control	Manually remove seedlings before seed set, ensuring as much root material is removed as possible. Hand pulled juveniles that have broken off often re-shoot.
Wipe/ Cut Stump	• Cut mature trees to ground level and paint stump with one part glyphosate to two parts water. Monitor for re-spouting (suckering) and for new seedlings. • Basal bark - A mixture of 1 L of Access® in 60L of diesel applied to the lower 50 cm of trucks can be used to individual trees.
Spot Spray	• No specific information, suggest spraying seedlings and juvenile trees with 100 mL glyphosate + 25 mL Pulse until foliage is just wet [(3)].

Tagasaste (*Chamaecytisus palmensis*)

DESCRIPTION	
Location	- Broadway Arboretum in Nyibra Swamp
Appearance	Large shrub or small tree up to 5 m high with weeping branches and greyish green, softly hairy foliage. The leaves are divided into 3 oval leaflets each 10-45 mm long. The scented, white to cream pea flowers are each 12-17 mm long and occur in small showy clusters. The seed pod is flat, 40-50 mm long and 8-12 mm wide. Flowers in winter and early spring.
Habitat	Grown as a fodder plant, it has since become weedy along roadsides, sometimes invading bushland. It is common between Albany and Esperance.
Comments	Seed may remain in the soil for more than 10 years but seedlings rarely establish in dense shade. Native to the Canary Islands.
CONTROL	
Priority	**Low**
Timing	Mar- May, Sep - Nov
Manual Control	Chain and bulldoze trees, burn, than manually remove seedlings.
Wipe/ Cut Stump	Basal bark - A mixture of 1 L of Access® in 60L of diesel applied to the lower 50 cm of trucks can be used to individual trees.
Spot Spray	- Seedlings can be sprayed with 0.5 g metsulfuron + 25 mL Pulse® in spring or autumn (1 & 2)

Tamarix (*Tamarix aphylla*)

DESCRIPTION	
Location	- Broadway Arboretum in Nyibra Swamp
Appearance	Dense, spreading evergreen tree to 10m, often creating dense thickets by suckering. It has a stout trunk, fine, greyish-green linear leaves and spikes of tiny pink flowers in summer.
Habitat	Tamarix is a potentially serious weed of arid zone watercourses, causing alteration of flow and salinisation of the water and seedlings are currently being removed from the Gascoyne River mouth at Carnarvon. It has also recently been noted to be reproducing from seed in the south-west agricultural area.
Comments	A native of North Arica, it is commonly planted as a shade tree in arid areas, and requires a good supply of water. It can spread from the plantings when broken branches take root and if the trees are fertile, masses of seedlings are also produced
CONTROL	
Priority	High
Timing	Sep - Nov
Manual Control	Hand pull seedlings. If removing established trees using loaders, tractors, excavators etc, ensure the entire crown and tap root to at least 1m is removed
Wipe/ Cut Stump	- Inject into root crown – neat glyphosate - Cut and paint – 30% triclopyr (ie Garlon®) or Access® 17 mL/L in diesel
Spot Spray	- Basal bark - Access 17 mL/L in diesel applied to the lower 30 cm of trucks can be used to individual trees - Spray regrowth and seedlings once 1 m tall with 100 mL Garlon®

Tangier Pea (*Lathyrus tingitanus*)

DESCRIPTION	
Location	- Success Hill
Appearance	Twining annual herb or climber, up to 3 m high, 2 m in diameter. The leaves have two leaflets and tendrils. Spikes of pink or bright cerise sweet-pea like flowers, 3cm in size.
Habitat	It is a garden escape found between Perth and Albany, and is increasing rapidly on roadsides and other disturbed ground in the Darling Range near Perth, creating a fire hazard when it dies back in summer.
Comments	Native to the western Mediterranean and the Azores.
CONTROL	
Priority	Low
Timing	Sep - Nov
Manual Control	Manually remove individuals before flowering.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	No specific information, suggest high rates of glyphosate + 25 mL wetting agent when actively growing(3)

Tobacco Tree (*Nicotiana glauca*)

DESCRIPTION	
Location	- Broadway Arboretum in Nyibra Swamp
Appearance	Erect, often spindly, tree-like shrub to 6 m high; the smallest branches often drooping. Branches and leaves hair-less, new growth and inflorescences sparsely hairy. Leaves are bluish-grey, ovate or elliptic, mostly to 13 cm long and to 5 cm wide. Sprays of nodding, tubular yellow flowers held on slender stalks are produced in spring and summer.
Habitat	Usually highly disturbed areas, also a common weed on old building sites.
Comments	Seed appear to remain viable for a considerable length of time.
CONTROL	
Priority	High
Timing	Sep - Nov
Manual Control	Remove small plants by hand.
Wipe/ Cut Stump	Cut stump and wipe with 50 – 100% glyphosate.
Spot Spray	- Spray seedlings and juveniles with 100 – 150 mL glyphosate plus wetting agent to runoff (3)

Trumpet Vine (*Campsis radicans*)

DESCRIPTION	
Location	- Bindaring Park North
Appearance	Spreading, scrambling or shrubby climber up to 3 m high and 5 to 8 m across. Grows from rhizomes and has orange-red flowers in summer.
Habitat	A garden escape found from Muchea to Bunbury.
Comments	Native to eastern North America.
CONTROL	
Priority	Low
Timing	Sep - Nov
Manual Control	Hand pull seedlings.
Wipe/ Cut Stump	Scrape and paint stem with 20% to 100% glyphosate.
Spot Spray	No specific information. Suggest high rates of glyphosate (ie 100 - 200 mL).

Vetch (*Vicia sativa*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Broadway Arboretum in Nyibra Swamp • Jubilee Reserve B
Appearance	Scrambling herb climbing by means of branched tendrils. The leaves are divided like a feather into 3-10 pairs of small narrow leaflets, each 8-30 mm long. There are pink to purple pea flowers, each 1-2 cm long and either single or in few-flowered clusters. The seed pod is narrow, slightly flattened and 3-5 cm long. Flowers in spring.
Habitat	Weed of roadsides, waste land, sometimes invading bushland.
Comments	Native to western Asia, so common may not be practical to control in most instances.
CONTROL	
Priority	**Moderate**
Timing	Jun - Oct
Manual Control	Manually remove small plants in winter prior to flowering.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	• In bushland, 10 mL Lontrel® or 1 g Logran® plus 25 mL wetting agent applied in early winter provides reasonable selective control (1 & 2). • 0.1 g metsulfuron + 25 mL wetting agent, though is less selective than the above (1 & 2) • 50 – 75 mL glyphosate, though relatively tolerant (2 & 3)

Watercress (*Rorippa nasturtium-aquaticum*)

DESCRIPTION	
Location	- Bindaring Park North
Appearance	Perennial aquatic plant, rooting at the nodes of the hollow, angular, hair-less stems. The leaves are mostly to 10 cm long and comprised of 1 to 5 pairs of lobes. White flowers are produced in spring and early summer. The fruits are up to 2cm long, slightly curved; with seeds in two rows on each side of the septum.
Habitat	Found in disturbed wetlands, drains, seepages and creeks from Geraldton to Albany.
Comments	Introduced from Europe, probably for its astringent leaves which used in salads.
CONTROL	
Priority	**Moderate**
Timing	Sep - Nov
Manual Control	Hand pull isolated plants and small infestations.
Wipe/ Cut Stump	No specific information, suggest wicker wipe with 1:2 Roundup® to water.
Spot Spray	No specific information, suggest high rates of glyphosate (ie 100-150 mL) in early growth stages and when actively growing.

Watsonia (*Watsonia meriana*)

DESCRIPTION	
Locations	- Bindaring Park North and South - Success Hill
Appearance	Southern Africa has about 70 species of Watsonia, and so far six, all garden escapes, have been recorded as naturalised in Western Australia. All arise from corms, and form clumps of stiff, sword-shaped, upright leaves. Most spread by seeds and corms. Since they are of garden origin, it is often difficult to place them into exact species. *Watsonia meriana* typically has dull orange flowers, but it may also be white, pink, or purplish red.
Habitat	Tends to grow in sites where the soil dries out in summer, for example, around granite rocks, and in wandoo woodlands. A serious environmental weed, it is found between Perth and Albany.
Comments	
CONTROL	
Priority	High
Timing	Sep - Nov
Manual Control	Dig up isolated plants and burn the corms and bulbils. Thick infestations are difficult to control manually.
Wipe/ Cut Stump	Wipe individual leaves with sponge glove with 1 L of glyphosate plus 2 L of water.
Spot Spray	- 100 g 2,2-DPA + 25 mL wetting agent $^{(1 \& 2)}$ - In degraded areas use 100 mL glyphosate + 25 mL wetting agent $^{(1 \& 2)}$.

Western Blue Lupin (*Lupinus cosentinii*)

DESCRIPTION	
Location	• Success Hill
Appearance	Annual herb, flowers in spring and have leaves divided into a number of finger-like leaflets. Has blue flowers in ring-like arrangements around long main stalks, and 7 to 13 leaflets, up to 1.5cm wide.
Habitat	Mainly in highly disturbed areas. A widespread and serious weed of roadsides, woodlands and heath from Carnarvon to Esperance.
Comments	Competes with native plants. Nitrogen fixing legume.
CONTROL	
Priority	**Moderate**
Timing	Aug - Nov
Manual Control	Manually remove small populations before seeding.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	• Small areas can be treated with 20 mL Tordon®75-D in early winter leaving a soil residual which will control lupin and other broadleaf seedlings for about a year (2). • In bushland, 10 mL Lontrel® **or** 1g Logran® are relatively selective (1 & 2). • 0.1 g metsulfuron can also be used but is less selective (1 & 2). • glyphosate is relatively ineffective (2)

Whiteflower Fumitory (*Fumaria capreolata*)

DESCRIPTION	
Locations	Bindaring Park North and South Broadway Arboretum in Nyibra Swamp Success Hill
Appearance	*Fumaria capreolata* is the only fumitory in the State with creamy white flowers. The tips of the petals are a dark, blackish red and its leaves are bright green. As the fruits ripen, their stalks turn downwards - a character that also distinguishes this species from the pink-flowered species. It sprawls and climbs, its stems sometimes reaching 1m in length. Flowers mainly in winter and spring.
Habitat	Occurs mainly in highly disturbed areas. It is commonly associated with settlements from Mullewa to Albany and east to Lake Grace. On the Swan Coastal Plain it is common on wasteland, road verges and shrublands, and on granite rocks in the Darling Range.
Comments	Large colonies suppress native flora.
CONTROL	
Priority	Moderate
Timing	Sep - Nov
Manual Control	Small populations can be pulled by hand, best when the plants are large but before seeding.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	0.1 g metsulfuron + wetting agent (1) 50 - 75 mL glyphosate + wetting agent (1 & 3)

Wild Gladiolus (*Gladiolus caryophyllaceus*)

DESCRIPTION	
Locations	- Jubilee Reserve B - Success Hill
Appearance	There are about 200 species of Gladiolus in Africa and the Mediterranean and eight species, all originally introduced as garden plants, have been recorded as naturalised in Western Australia. They all die back each summer to an underground corm. *Gladiolus caryophyllaceus* is spring-flowering, and flowers have an unpleasant smell. Leaves have a distinctive red margin and, in young plants, are twisted spirally in an anti-clockwise direction.
Habitat	Common in urban bushland and Banksia woodlands on the Swan Coastal Plain, extending eastwards to Lake Grace.
Comments	Dies back each summer to an underground corm. Highly invasive although does not appear to displace native plants
CONTROL	
Priority	High
Timing	Aug - Nov
Manual Control	Manually remove flower heads of individuals to prevent seeding.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water just on flowering when corm is exhausted.
Spot Spray	- 100 mL glyphosate (1)

Wild Melon (*Citrullus lanatus*)

DESCRIPTION	
Location	- Broadway Arboretum in Nyibra Swamp
Appearance	Summer growing annual with long, leafy, trailing stems. The prostrate, bristly stems radiate from a fleshy tap root and bear large, deeply lobed leaves up to 20cm long as well as branched tendrils. The separate male and female flowers, produced in summer and autumn are bright yellow and 3-4cm across. The mature spherical fruit is up to 15cm across, hairy, with mottled green stripes at first, but becoming yellow and hairless with age.
Habitat	Paddocks in agricultural regions, along roadsides and disturbed water courses.
Comments	Native to tropical and southern Africa, wild relative of the water melon.
CONTROL	
Priority	Low
Timing	Sep - Nov
Manual Control	Hand pull small infestations and isolated plants. Remove melons from site and destroy.
Wipe/ Cut Stump	No specific information.
Spot Spray	- 120 – 160 mL/ha Garlon®600

Wild Oat (*Avena barbata*)

DESCRIPTION	
Locations	• Bindaring Park North and South • Broadway Arboretum in Nyibra Swamp • Success Hill
Appearance	Tufted annual grass to 1.5m tall. The loosely branched, usually one-sided inflorescence has large drooping, spikelets. The mature seeds are usually straw-coloured. Flowers in spring.
Habitat	Common species in uncropped situations, including roadsides, wasteland and disturbed bushland, occasionally extending into crop margins.
Comments	Easy to control. Native of the Mediterranean.
CONTROL	
Priority	High
Timing	Jun - Aug
Manual Control	Manually remove individuals before seeding.
Wipe/ Cut Stump	Wicker wipe with 1:2 glyphosate to water.
Spot Spray	• 5 mL – 10 mL Fusilade®212 or Targa® (or 2 mL Verdict®) plus 100 mL spray oil applied in winter before flowering will provide control with little effect on broad-leaved species (1 & 2) • 100 mL of glyphosate in non-selective situations (2).

Wild Radish (*Raphanus raphanistrum* sp.)

DESCRIPTION	
Locations	- Bindaring Park North and South - Broadway Arboretum in Nyibra Swamp
Appearance	Annual herb, up to 1m tall characterised by a basal rosette of stalked leaves which are lobed or toothed. The leaves and stem usually bear bristly hairs and the petals are pale yellow, white or occasionally purple to lilac, 15-20mm long, often with dark veins. Flowers throughout the year but mainly in spring. On ripening, the fruit breaks into single-seeded sections.
Habitat	Scattered around settlement sites from Exmouth to Geraldton and a very common agricultural, horticultural and roadside weed from Geraldton southwards.
Comments	Native to Europe, economically one of the most important weeds of cropping in Western Australia. Typically does not usually invade bushland.
CONTROL	
Priority	Bindaring Park – **Low** Broadway – **High**
Timing	Jun - Sep
Manual Control	Manually remove small populations before seeding.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	- In bushland situations, fairly selective control can be achieved with 0.1 g Eclipse® or 0.5 g Logan® plus 100 mL of spray oil. 10 mL Brodal® is often added to this mix to provide short term residual control of seedlings (2). - 100 mL glyphosate prior to flowering (1 & 2)

Yellow Serradella (*Ornithopus compressus*)

DESCRIPTION	
Locations	- Jubilee Reserve A and B - Pickering Park
Appearance	Sprawling grey-hairy annual herb with leaves divided into 7 to 18 pairs of narrow leaflets. Yellow Serradella has stalked headlike clusters of yellow pea flowers and narrow, but compressed, seed pods.
Habitat	Have become weeds along roadsides, particularly in wetlands.
Comments	
CONTROL	
Priority	Low
Timing	Jun - Jul
Manual Control	Hand pull scattered infestations before flowering.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	- In bushland, 10 mL Lontrel® or 1 g Logran® plus 25 mL wetting agent applied in early winter provides reasonable selective control (2). - In grass dominant areas, 10 mL Tordon®75-D in early winter gives excellent control of existing plants and has residual activity to control seedlings (2).

Unknown Species 1

DESCRIPTION	
Location	- Bindaring Park North
Appearance	2m tall broad leaf herb. Flower type unknown.
Habitat	Moist shaded understorey, near waterways.
Comments	Aggressive spread of plants suggest this species to be a high priority to control.
CONTROL	
Priority	High
Timing	Jul - Nov
Manual Control	Manual remove small populations before seeding.
Wipe/ Cut Stump	Wicker wipe with 1: 2 glyphosate to water.
Spot Spray	No specific information, suggest 100mL glyphosate

Unknown Species 2

No picture available

DESCRIPTION	
Location	- Bindaring Park South
Appearance	Prostrate creeper, dark green stems, leaves usually less than 2cm in length. Inconspicuous flowers.
Habitat	-
Comments	Garden escape plant, commonly used in hanging baskets. Hardy. Broken part of plant may resprout.
CONTROL	
Priority	Low
Timing	Aug - Dec
Manual Control	Remove entire plant from site and destroy.
Wipe/ Cut Stump	Not recommended.
Spot Spray	Not recommended.

APPENDIX H – WATER QUALITY MODELLING

Overview

Department of Water has recently released the Urban Nutrient Decision Outcomes (UNDO) tool, a conceptual decision support tool developed to assess the effectiveness of treatment train options for urban developments. The tool is specific to developments located on the Swan Coastal Plain.

The UNDO tool is suitable for proposed urban developments, or retrofitting of treatment infrastructure in existing urban developments. The tool calculates:

- Total nitrogen and phosphorous input from the development area based on land use.
- Pre-treatment nutrient export based on soil and fill characteristics, groundwater separations and effluent disposal mechanisms.
- Post-treatment nutrient export based on the proposed water quality treatment train. The tool models specific treatment methods only, including constructed wetlands, floating treatment wetlands, biofilters, detention/infiltration basins, swales, living streams, and spiral wrapped filter media.

The tool is currently available for use to determine the relative effectiveness of different treatment options. DoW has advised that targets for maximum nutrient export concentrations will be released in the future however targets are not currently available.

In this study, the UNDO tool has been applied to compare water quality treatment effectiveness of three water quality concept designs for Bindaring Park. The three options are outlined in Table 1 below.

Table 1 Water Quality Concept Design Options

	Water quality treatment	Other design considerations
Option 1	Biofilters at all major inflows. Swales at minor inflows. Floating wetland within open water of Bindaring Wetland.	▪ Extensive weed control – some exotic species that have habitat value to be retained. ▪ Rehabilitation planting proposed. ▪ Additional paths and boardwalks proposed. ▪ Picnic areas, seating and

		playspace proposed.
Option 2	Biofilter at largest catchment inflow (catchment A). Swales at all other inflows.	▪ Extensive weed control – some exotic species that have habitat value to be retained. ▪ Rehabilitation planting proposed. ▪ Additional paths and boardwalks proposed. ▪ Picnic areas, seating and playspace proposed.
Option 3	Swales at all inflows.	▪ Extensive weed control – some exotic species that have habitat value to be retained. ▪ Rehabilitation planting proposed. ▪ Additional paths and boardwalks proposed. ▪ Picnic areas, seating and playspace proposed. ▪ Removal of Hyland Street and the causeway.

Model Inputs and Assumptions

The UNDO tool was used to compare water quality treatment effectiveness of direct stormwater discharges to Bindaring Wetland for each of the three concept design options. The UNDO model only considers runoff from the ‘first flush’ rainfall event, typically the first 15 mm of rainfall.

Consistent with the assumptions of the Town of Bassendean stormwater drainage network modelling undertaken by Cardno (2016), all lots were assumed to infiltrate the first 15 mm of rainfall within their property boundaries, and as such were not included in the model. Stormwater runoff from roads and road reserve only were assumed to discharge to Bindaring Wetland, and were included in the modelling.

It was assumed that there is no subsoil drainage discharging to the wetland.

Sub-regions

Model sub-regions were delineated on the basis of catchments provided by Cardno. The catchments were drawn based on Town of Bassendean GIS data files and analysis undertaken as part of the Cardno (2016) stormwater network modelling. It is noted that the catchments are indicative only, as the GIS information provided to Cardno is considered to be incomplete and/or incorrect in some areas.

The largest sub-region, sub-region A was divided into two separate sub-regions (sub-regions A1 and A2) on the basis of differing soil types. Sub-region areas were calculated using GIS. The UNDO sub-regions and the location of each stormwater inflow to the wetland (labelled A1-G) are shown in Figure H1.

Land Use Distribution and Configuration

As outlined above, the UNDO tool was set up to address water quality of stormwater discharges to Bindaring Wetland only. As such, only areas that drain to the wetland (roads and road reserves) are included in the model. Areas assumed to infiltrate to groundwater during small events (lots and POS) were excluded.

Road areas were calculated by digitising aerial photography in GIS. Road areas were divided into area of sealed road, impervious verge (e.g. footpaths), fertilised/irrigated verge, and non-fertilised/irrigated verge. It was assumed that 50% of the verges are irrigated/fertilised. This is considered to be a conservative estimate.

Soil type

Soil type was selected from the UNDO soil map viewer which indicated that the catchment was comprised of sands from the Pinjarra and Bassendean systems.

It was assumed that lots are constructed on in-situ soils and fill has not been used. Some uncontrolled fill is known to have been used within and around Lot 27 Hyland Street. This fill was estimated to have been deposited within an area of approximately 5,000 – 6,000 m^2 (Gamec, 2013). As this area is small compared to the total catchment it is not considered likely to have a significant impact on the results.

Groundwater

Groundwater depth and slope were estimated based on regional groundwater contours provided in the Perth Groundwater Map (Department of Water, 2017).

Treatment

Water quality treatment is provided for each stormwater inflow location to Bindaring Park except inflow E (see figure H1). Inflow E was found to have no/very minor inflow during the hydraulic modelling (described in Appendix D). As such, water quality treatment is not considered to be required.

All water quality treatment areas were sized at approximately 2% of the sub-region road reserve area, excluding sub-region A where the total treatment size was limited to 500 m^2 to manage cost and space constraints.

The treatment type and sizing for each option is listed in Table 2 below.

Table 1 Treatments applied – concept options 1 to 3.

	Option 1		Option 2		Option 3	
Inflow	BMP	Treatment area (m^2)	BMP	Treatment area (m^2)	BMP	Treatment area (m^2)
A1	Biofilter	421	Biofilter	421	Swale	421
A2	Biofilter	24	Biofilter	24	Swale	24
A3	Biofilter	55	Biofilter	55	Swale	55
B	Biofilter	483*	Swale	483*	Swale	483*
C	Biofilter	122	Swale	122	Swale	122
D	Swale	60	Swale	60	Swale	60
E	–	–	–	–	–	–
F	Biofilter	113	Swale	113	Swale	113
G	Swale	25	Swale	25	Swale	25
H	Swale	56	Swale	56	Swale	56
All	Floating wetland	200	–	–	–	–

*An existing swale (460 m^2) is installed upstream in the catchment. As such only an additional 23 m^2 of treatment is required in this catchment.

BMPs Proposed

Biofilter

Biofilters are vegetated infiltration areas designed to reduce nutrient export from stormwater. Biofilters typically comprise of the following profile:

- Vegetation: at least 50% of the plants to be effective at nutrient removal (Monash University, 2014). Remainder to be local, native, ephemeral plants. Plant density 6 per m^2.

- Protective surface layer: 100-150 mm deep overlying the biofilter media consisting of a coarser particle size than the media. Stone mulch not to be used due to recent findings by Monash University that heat retained in stone mulch layers affects plant survival. Plants to be planted at a density of 6 per m^2 to reduce likelihood of erosion and soil evaporation.
- Filter: 300 mm amended soil layer. PRI > 10. Saturated K 100-300 mm/hr.
- Transition and Drainage: >300 mm of sand. Subsoil drainage to discharge treated runoff may be used in some biofiltration areas, where required (i.e. where underlying soils are too shallow or impermeable for infiltration).
- Where possible, this will equate to a depth of 650 mm of biofiltration layers beneath the base of the biofilters.

A typical biofilter vertical profile is shown in Plate 1 below.

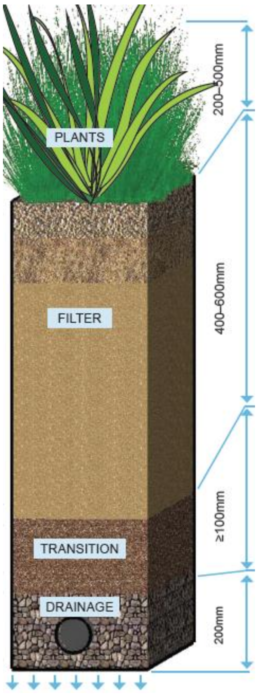


Plate 1 Typical Biofilter Vertical Profile (DoW, 2011).

Swale

Swales are broad shallow channels with an infiltration and/or conveyance function. Swales are usually vegetated, but may be grassed to assist with integration with landscape design and provision of uninterrupted active open space.

Swales provide treatment of stormwater through plant uptake and P sorption to high PRI soils. Swales should be underlain with amended soils to increase soil PRI where the in-situ PRI is low (i.e. <10).

Swales typically have shallow (1:4 -1:8) side slopes to protect public safety and assist with maintenance. A maximum depth of 0.5 m is generally suitable for conveyance swales such as those proposed in Bindaring Park.

Floating Wetland

Floating wetlands are a commercial product which use floating recycled media to provide a fertile base for nutrient stripping vegetation to grow within a water body. An example of in-situ floating wetlands is provided in Plate 2 below.

Plate 2 Floating Wetlands source: SPEL Environmental.

Floating wetlands are typically more effective at nutrient removal than fringe planting as the plant roots extend into the water column, significantly increasing the surface area available for nutrient uptake. Floating wetlands may also assist with improvement of other water quality parameters including total suspended solids and heavy metals.

Floating wetlands are anchored or tethered in place, and can operate in fluctuating water levels, however long periods of dry conditions may affect plant survival.

Results

Pre-treatment export

The results of the UNDO modelling indicate that pre-treatment nutrient export from stormwater discharges to Bindaring wetland equate to approximately 1.70 kg/ha/yr of nitrogen and 0.19 kg/ha/yr of phosphorous.

It is noted that these values represent the nutrients discharged from the urban stormwater network to Bindaring Park and do not include the export of nutrients from the existing urban development to groundwater via infiltration on lots (e.g. soakwells). As such, the total nutrient export from the developed area to the environment is likely to exceed the values presented above.

Department of Water have not released guidance on appropriate levels of nutrient export from urban development to date. As such, the results have been compared to levels derived from the ANZECC (2000) guidelines for reference. These values suggest that an export of 1 – 2 kg/ha/yr of nitrogen and 0.2 –0.3 kg/ha/yr of phosphorous may be appropriate.

Post-treatment export

Post-treatment nutrient export was assessed for the three concept design options summarised in Tables 1 and 2. The results of this analysis are provided in Table 3 below.

Post-treatment nutrient concentrations range from 0.84 – 1.43 kg/ha/yr of nitrogen and 0.11– 0.18 kg/ha/yr of phosphorous across the three concept options. All options fall within the reference criteria of 1 – 2 kg/ha/yr of nitrogen and 0.2 – 0.3 kg/ha/yr of phosphorous.

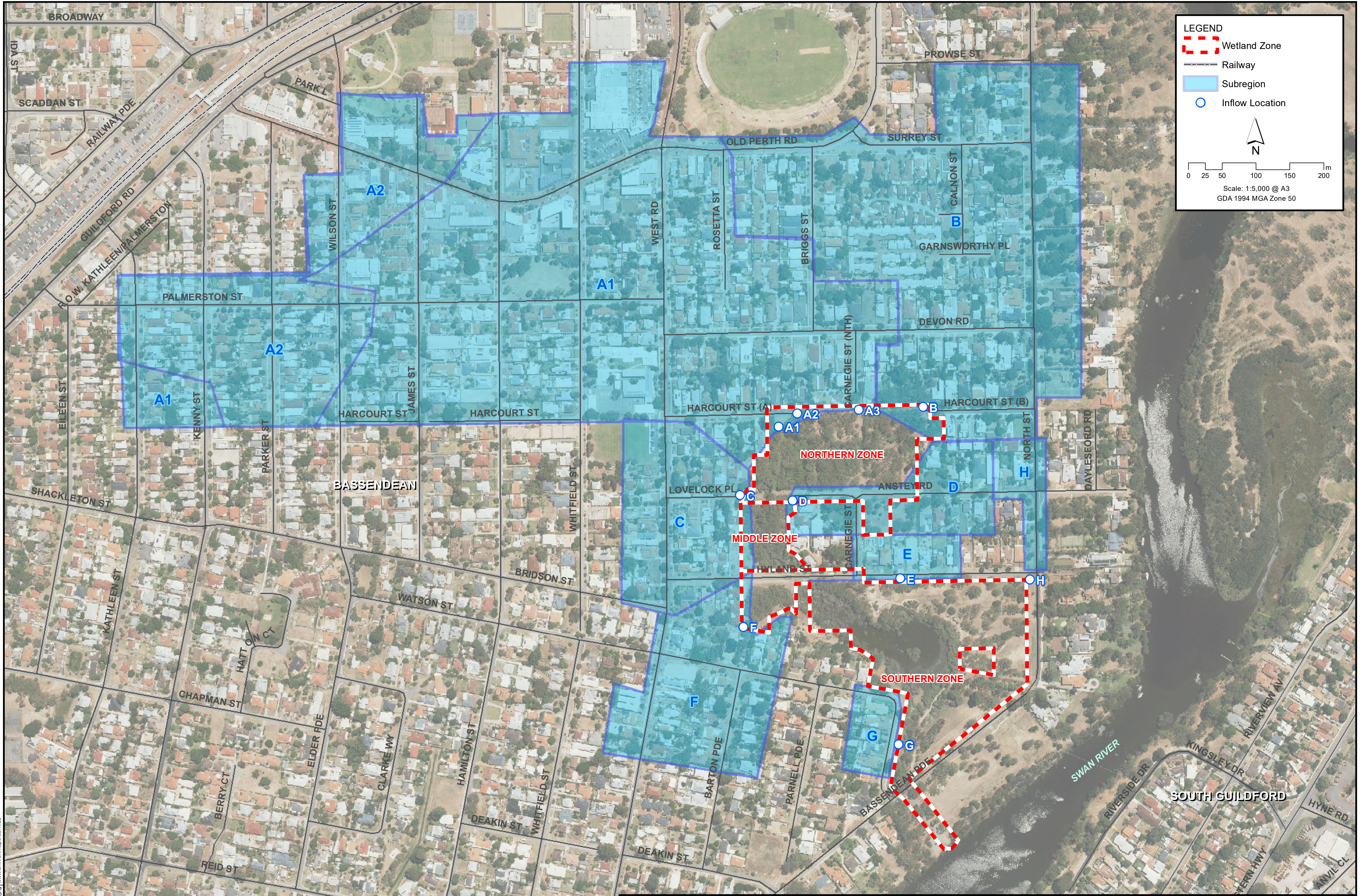
Nutrient removal was highest in concept option 1 which included biofilters all at major inflow points and swales at minor inflow points. A floating wetland installed within the open water of Bindaring Wetland also contributed to the high level of nutrient removal.

Nutrient removal was significantly decreased in concept options 2 and 3 where biofilters were replaced with swales to varying degrees and the floating wetland was excluded.

Table 2 Water Quality Treatment Effectiveness

		Total treatment areas (m^2)				Pre-treatment export (kg/ha/yr)		Total nutrient removed (kg/ha/yr)		Post-treatment export (kg/ha/yr)		Rank*
Concept	Treatment method	Biofilter	Swale	Floating wetland	Total	N	P	N	P	N	P	
Indicative maximum export criteria										1-2	0.2-0.3	
Option 1	Biofilter at major inflows. Swale at minor inflows. Floating Wetland.	785	141	200	1126	1.70	0.19	0.86	0.08	0.84	0.11	1
Option 2	Biofilter at inflow A. Swales at all other inflows.	500	426	0	926	1.70	0.19	0.56	0.05	1.13	0.14	2
Option 3	Swales at all inflows.	0	926	0	926	1.70	0.19	0.27	0.01	1.43	0.18	3

*Where a rank of 1 represents the greatest improvement in water quality.



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Source: Cadastre - Landgate, 2017
Orthophoto - NearMaps, 24.04.17

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Fax: (08) 9381 5514
E: info@coterra.com.au

Town of Bassendean
BINDARING WETLAND CONCEPT PLAN
BINDARING WETLAND, BASSENDEAN

UNDO SUBREGIONS AND INFLOWS

Figure H1

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APPENDIX I – Indicative Cost Estimates

Project: Bindaring Wetland
Landscape and Rehabilitation Works

Preliminary Opinion of Probable Cost - OPTION 1 REV C
Date: 27th July 2017

	ITEM	QTY	UNIT	RATE ($)	TOTAL ($)
1.0	**PRELIMINARIES**				
1.1	Site Establishment and Preliminaries	1	item	15,000.00	15,000.00
2.0	**SITE PREPARATION**				
2.1	Bulk Earthworks	1,000	m3	15.00	15,000.00
2.2	Fine Grading	3,500	m2	0.75	2,625.00
2.3	Weed Removal and Disposal (one-off operation)	1	sum	10,000.00	10,000.00
3.0	**HARDSCAPE WORKS**				
3.1	Supply and Install Stabilised limestone paths and surfacing	2,350	m2	45.00	105,750.00
3.2	Supply and Install Stabilised limestone Vehicle Access Tracks	400	m2	45.00	18,000.00
3.3	Supply and Install Concrete footpaths	2,400	m2	42.00	100,800.00
3.4	Supply and install Asphalt Cycleway	800	lm	75.00	60,000.00
3.5	Supply and install Extruded Concrete Edging	50	lm	32.00	1,600.00
3.6	Limestone Boulders and Rock Pitching Around Drainage Outfalls	200	m2	150.00	30,000.00
4.0	**BUILT ELEMENTS AND FURNITURE**				
4.1	Timber Boardwalk	585	m2	800.00	468,000.00
4.2	Balustrade to boardwalks (where necessary)	320	lm	400.00	128,000.00
4.3	Viewing Deck	130	m2	800.00	104,000.00
4.4	Bird Hide	1	each	40,000.00	40,000.00
4.5	Conservation Fencing	400	lm	40.00	16,000.00
4.6	Wayfinding Signage	18	each	1,500.00	27,000.00
4.7	Interpretive Signage	4	each	3,000.00	12,000.00
4.8	Bin and enclosure	1	each	2,600.00	2,600.00
4.9	Picnic Table Setting	2	each	5,000.00	10,000.00
4.10	Bench Seats	8	each	1,800.00	14,400.00
5.0	**SOFTWORKS**				
5.1	Supply and Install 100L trees	30	each	280.00	8,400.00
5.2	Supply and Install Shrub Planting (at 800mm Centres)	300	m2	10.00	3,000.00
5.3	Supply & Install Tubestock and Littoral Planting (at 600mm Centres)	6,500	m2	7.00	45,500.00
5.4	Imported Mulch to Shrubs and Tubestock 75mm depth	3,000	m2	4.00	12,000.00
5.5	Jute Matting for Slope Stabilisation	600	m2	10.00	6,000.00
6.0	**DRAINAGE INFLOW LANDSCAPE TREATMENTS**				
6.1	Biofilter Basin Amended Soils	758	m2	35.00	26,530.00
6.2	Gravel mulch to Swales and Biofilter Basins	900	m2	10.00	9,000.00
6.3	Floating Wetlands	200	m2	600.00	120,000.00
7.0	**PROVISIONAL SUMS**				
7.1	Arborist Works	1	sum	60,000.00	60,000.00
8.0	**CONTINGENCY**				
		1	item	20,000.00	20,000.00

9.0	**Total Landscape Works**				1,491,205.00
10.0	***GST***	*10*	*%*	*10*	*149,120.50*
11.0	**TOTAL inc GST**				1,640,325.50

EXCLUSIONS

1 Hyland Street causeway and existing dwelling demolition or modifications
2 Hyland Street road and traffic modifications
3 General road and carpark works
4 Civil services and drainage infrastructure
5 Dewatering or subsurface drainage
6 Pickering Park improvements
7 Maintenance, ongoing weeding and replacement planting
8 Lighting and electrical
9 Tree survey and assessment
10 Bore and irrigation works
11 Upgrades to private property boundary walls or fencing
12 Pest Control
13 Design and Consultancy Fees
14 Multiple site mobilisations (assumes all works completed as one contract)

Project: Bindaring Wetland
Landscape and Rehabilitation Works

Preliminary Opinion of Probable Cost - OPTION 2 REV C
Date: 27th July 2017

	ITEM	QTY	UNIT	RATE ($)	TOTAL ($)
1.0	**PRELIMINARIES**				
1.1	Site Establishment and Preliminaries	1	item	15,000.00	15,000.00
2.0	**SITE PREPARATION**				
2.1	Bulk Earthworks	1,000	m3	15.00	15,000.00
2.2	Fine Grading	3,500	m2	0.75	2,625.00
2.3	Weed Removal and Disposal (one-off operation)	1	sum	10,000.00	10,000.00
3.0	**HARDSCAPE WORKS**				
3.1	Supply and Install Stabilised limestone paths and surfacing	2,350	m2	45.00	105,750.00
3.2	Supply and Install Stabilised limestone Vehicle Access Tracks	400	m2	45.00	18,000.00
3.3	Supply and Install Concrete footpaths	2,400	m2	42.00	100,800.00
3.4	Supply and install Asphalt Cycleway	800	lm	75.00	60,000.00
3.5	Supply and install Extruded Concrete Edging	50	lm	32.00	1,600.00
3.6	Limestone Boulders and Rock Pitching Around Drainage Outfalls	200	m2	150.00	30,000.00
4.0	**BUILT ELEMENTS AND FURNITURE**				
4.1	Timber Boardwalk	585	m2	800.00	468,000.00
4.2	Balustrade to boardwalks (where necessary)	320	lm	400.00	128,000.00
4.3	Viewing Deck	70	m2	800.00	56,000.00
4.4	Conservation Fencing	400	lm	40.00	16,000.00
4.5	Wayfinding Signage	18	each	1,500.00	27,000.00
4.6	Interpretive Signage	4	each	3,000.00	12,000.00
4.7	Bin and enclosure	1	each	2,600.00	2,600.00
4.8	Picnic Table Setting	2	each	5,000.00	10,000.00
4.9	Bench Seats	8	each	1,800.00	14,400.00
5.0	**SOFTWORKS**				
5.1	Supply and Install 100L trees	30	each	280.00	8,400.00
5.2	Supply and Install Shrub Planting (at 800mm Centres)	300	m2	10.00	3,000.00
5.3	Supply & Install Tubestock and Littoral Planting (at 600mm Centres)	6,500	m2	7.00	45,500.00
5.4	Imported Mulch to Shrubs and Tubestock 75mm depth	3,000	m2	4.00	12,000.00
5.5	Jute Matting for Slope Stabilisation	600	m2	10.00	6,000.00
6.0	**DRAINAGE INFLOW LANDSCAPE TREATMENTS**				
6.1	Biofilter Basin Amended Soils	500	m2	35.00	17,500.00
6.2	Gravel mulch to Swales and Biofilter Basins	900	m2	10.00	9,000.00
7.0	**PROVISIONAL SUMS**				
7.1	Arborist Works	1	sum	60,000.00	60,000.00
8.0	**CONTINGENCY**				
		1	item	20,000.00	20,000.00
9.0	**Total Landscape Works**				1,274,175.00

10.0	***GST***	*10*	*%*	*10*	*127,417.50*
11.0	**TOTAL inc GST**				1,401,592.50

EXCLUSIONS

1 Hyland Street causeway and existing dwelling demolition or modifications
2 Hyland Street road and traffic modifications
3 General road and carpark works
4 Civil services and drainage infrastructure
5 Dewatering or subsurface drainage
6 Pickering Park improvements
7 Maintenance, ongoing weeding and replacement planting
8 Lighting and electrical
9 Tree survey and assessment
10 Bore and irrigation works
11 Upgrades to private property boundary walls or fencing
12 Pest Control
13 Design and Consultancy Fees
14 Multiple site mobilisations (assumes all works completed as one contract)
15 Refinements to flood modelling in relation to Hyland Street Causeway modifications
16 Environmental assessments and approvals relating to the alterations around the Conservation Category Wetland

Project: Bindaring Wetland
Landscape and Rehabilitation Works

Preliminary Opinion of Probable Cost - OPTION 3 REV C
Date: 27th July 2017

	ITEM	QTY	UNIT	RATE ($)	TOTAL ($)
1.0	**PRELIMINARIES**				
1.1	Site Establishment and Preliminaries	1	item	15,000.00	15,000.00
2.0	**SITE PREPARATION**				
2.1	Bulk Earthworks	1,000	m3	15.00	15,000.00
2.2	Fine Grading	3,500	m2	0.75	2,625.00
2.3	Weed Removal and Disposal (one-off operation)	1	sum	10,000.00	10,000.00
3.0	**HARDSCAPE WORKS**				
3.1	Supply and Install Stabilised limestone paths and surfacing	2,350	m2	45.00	105,750.00
3.2	Supply and Install Stabilised limestone Vehicle Access Tracks	400	m2	45.00	18,000.00
3.3	Supply and Install Concrete footpaths	2,400	m2	42.00	100,800.00
3.4	Supply and install Asphalt Cycleway	800	lm	75.00	60,000.00
3.5	Supply and install Extruded Concrete Edging	50	lm	32.00	1,600.00
3.6	Limestone Boulders and Rock Pitching Around Drainage Outfalls	200	m2	150.00	30,000.00
4.0	**BUILT ELEMENTS AND FURNITURE**				
4.1	Timber Boardwalk	550	m2	800.00	440,000.00
4.2	Balustrade to boardwalks (where necessary)	320	lm	400.00	128,000.00
4.3	Viewing Deck	130	m2	800.00	104,000.00
4.4	Bird Hide	1	each	40,000.00	40,000.00
4.5	Conservation Fencing	400	lm	40.00	16,000.00
4.6	Wayfinding Signage	18	each	1,500.00	27,000.00
4.7	Interpretive Signage	5	each	3,000.00	15,000.00
4.8	Bin and enclosure	1	each	2,600.00	2,600.00
4.9	Picnic Table Setting	2	each	5,000.00	10,000.00
4.10	Bench Seats	8	each	1,800.00	14,400.00
5.0	**SOFTWORKS**				
5.1	Supply and Install 100L trees	40	each	280.00	11,200.00
5.2	Supply and Install Shrub Planting (at 800mm Centres)	300	m2	10.00	3,000.00
5.3	Supply & Install Tubestock and Littoral Planting (at 600mm Centres)	6,500	m2	7.00	45,500.00
5.4	Imported Mulch to Shrubs and Tubestock 75mm depth	3,000	m2	4.00	12,000.00
5.5	Jute Matting for Slope Stabilisation	600	m2	10.00	6,000.00
6.0	**DRAINAGE INFLOW LANDSCAPE TREATMENTS**				
6.1	Gravel mulch to Swales	900	m2	10.00	9,000.00
7.0	**PROVISIONAL SUMS**				
7.1	Arborist Works	1	sum	60,000.00	60,000.00
8.0	**CONTINGENCY**				
		1	item	20,000.00	20,000.00
9.0	**Total Landscape Works**				1,322,475.00

10.0	***GST***	*10*	*%*	*10*	*132,247.50*
11.0	**TOTAL inc GST**				1,454,722.50

EXCLUSIONS

1 Hyland Street causeway and existing dwelling demolition or modifications
2 Hyland Street road and traffic modifications
3 General road and carpark works
4 Civil services and drainage infrastructure
5 Dewatering or subsurface drainage
6 Pickering Park improvements
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14 Multiple site mobilisations (assumes all works completed as one contract)
15 Refinements to flood modelling in relation to Hyland Street Causeway modifications
16 Environmental assessments and approvals relating to the alterations around the Conservation Category Wetland

COTERRA
ENVIRONMENT

Level 3, 25 Prowse Street
West Perth WA 6005

T (08) 9381 5513

www.coterra.com.au
info@coterra.com.au