February 2020

CITY OF ROCKINGHAM

Lake Richmond Management Plan

city of Rockingham

where the coast comes to life

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Acknowledgment of **Traditional Owners**

The City of Rockingham respectfully acknowledges the traditional owners and custodians of the land on which Rockingham stands today, the Nyoongar people. The City pays its respects to their elders both past and present.

Nyoongar people successfully managed and nurtured the land and water for thousands of generations and an enduring spiritual and physical connection remains today. By showing respect for the land and water in the same way, the City can continue to work towards the sustainability of the environment for future generations.

The City of Rockingham is committed to working with the Nyoongar community on matters of land, water, culture, language and cultural heritage. The City's third Reconciliation Action Plan is in development and aims to build a community that demonstrates respect, builds positive relationships and creates opportunities for local Aboriginal and Torres Strait Islander people.

1.0

INTRODUCTION

1 Introduction

1.1 Background

The City of Rockingham is situated in the unique biogeographic region of south-western Australia, which is classed as one of the 35 global biodiversity hotspots (Mittermeier *et al.*, 2011). These hotspots are identified on the basis of containing large numbers of endemic species found nowhere else on Earth, whilst also being vulnerable to significant threats.

The City manages approximately 25 natural area reserves across 940 ha of diverse bushland, wetland and foreshore environments.

The Lake Richmond reserve ('the reserve') is 77.86 hectares in area and is one of the largest freshwater lakes on the Swan Coastal Plain occurring in close proximity to the ocean. The reserve is an important habitat for two nationally listed threatened ecological communities (TECs), including thrombolites and sedgelands, as well as numerous waterbirds and other fauna. Lake Richmond forms part of the Rockingham Lakes Regional Park (Figure 1), an important ecological linkage that connects a series of reserves and regionally significant bushland (Bush Forever) across the City's municipality.

The City's Community Plan Strategy: Natural Area Conservation (2017) identified the need for the previous Lake Richmond Management Plan (2008) to be reviewed, acknowledging the local and regional environmental significance of the reserve.

This Management Plan (the Plan) has been prepared for the Lake Richmond reserve (the reserve), informed by an assessment of vegetation, fauna and reserve infrastructure. The City also appointed microbialite expert, Dr Ryan Vogwill to undertake an assessment of the Lake Richmond thrombolites. Dr Vogwill's study included an assessment of current thrombolite health and activity, research into the optimal water conditions for microbialite growth and an assessment of thromobilite sensitivity to herbicides used in weed control. The findings of Dr Vogwill's assessment have been used to inform the robust Weed Management Strategy presented within this Management Plan.

This Plan has been prepared under the direction of Community Plan Strategy: Natural Area Conservation, guided by the City's overarching Strategic Community Plan 2019-2029.

Strategic Community Plan 2019-2029

Community Plan Strategy: Natural Area Conservation

Lake Richmond Management Plan

1.2 Vision

This plan addresses the following aspiration contained in the City's Strategic Community Plan 2019-2029:

Aspiration 3: Plan for Future Generations

Strategic Objective - Preservation and Management of bushland and coastal reserves.

Encourage the sustainable management and use of the City's bushland and coastal reserves.

1.3 Purpose

The purpose of this Management Plan is to provide key directions for the protection and enhancement of conservation and recreation values within the Lake Richmond reserve over next five years (2019-2024).

1.4 Objectives

This Plan is driven by the following overarching objectives:

- Protect and enhance conservation values through the removal of threatening processes.
- Encourage a range of sustainable recreational experiences through suitably located infrastructure and services.
- Ensure equity and safety for all reserve users.

1.5 Study Area

This Plan focuses on the Lake Richmond reserve as shown in Figure 2.

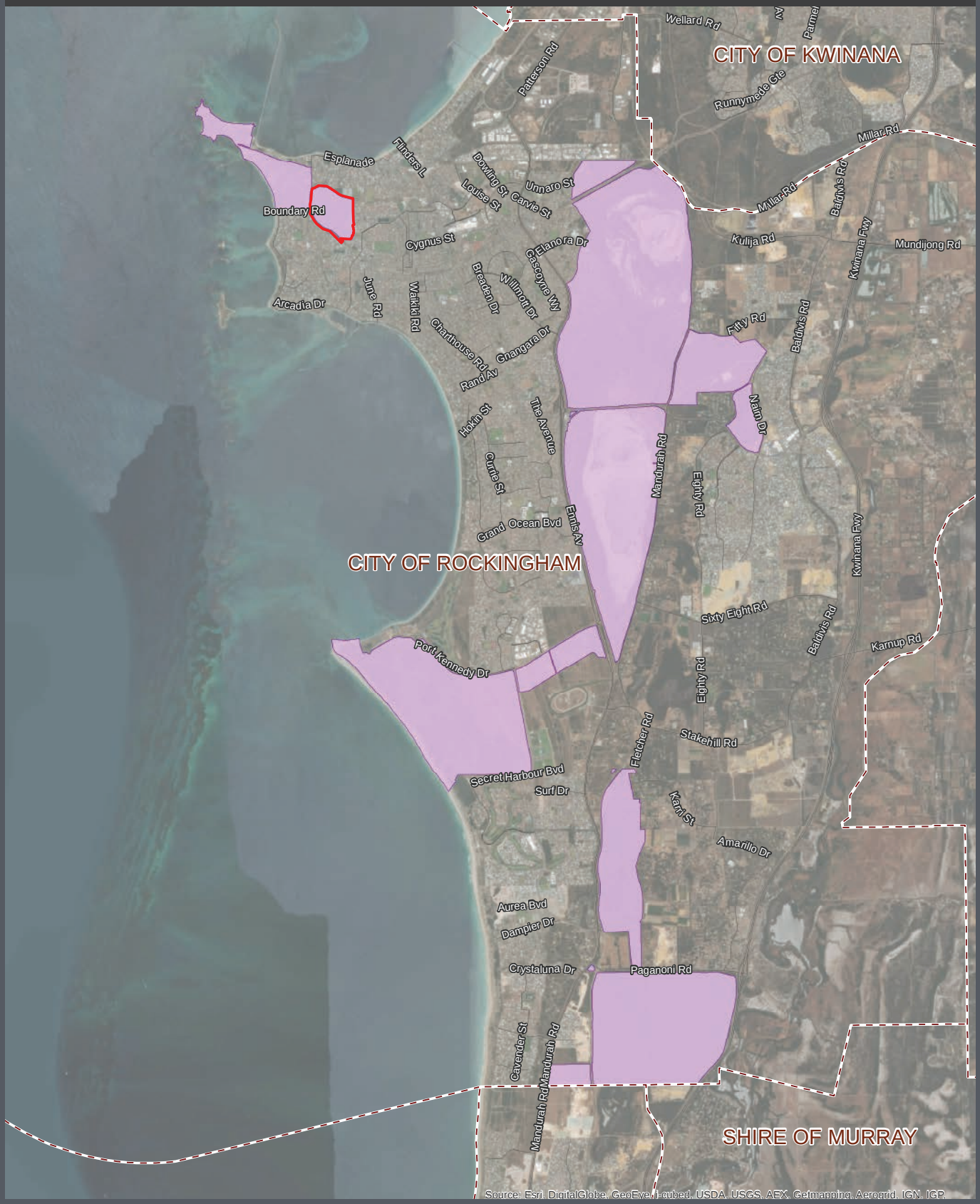
The Reserve is 77.86 hectares in area and is situated in the suburb of Rockingham less than 1 kilometre away from the Indian Ocean, to the north and West. The Reserve area comprises of the lake itself and the surrounding land. The lake is a marine relic which was once part of Cockburn Sound but the seaward advancement of the coastline forced it to be separated from the Sound around 4,000 years ago (Kenneally *et al.* 1997). The land surrounding the lake primarily consists of remnant native vegetation but also includes a turfed area to the north in the Water Corporation reserve, which is primarily used for passive recreation.

Tenure

Land tenure and vesting purposes are presented in Figure 3.

Lot 1530 on Plan 215849, within the reserve, also forms part of Water Corporation Reserve 42518. Water Corporation's long term objective is for a Sepia Depression Ocean Outlet Landline (SDOOL) to be constructed in this Reserve. The SDOOL will be constructed underground and will be fully contained, meaning that no sewerage will enter the Lake or the Reserve as it makes its way towards its terminus at the ocean outfall. It is anticipated that the existing infrastructure within Lot 1530 will eventually be removed to accommodate the SDOOL.

Figure 1 - Rockingham Lakes Regional Park - Lake Richmond boundary shown in red



N

0 0.5 1 1.5 2 2.5

Kilometres

Figure 2 - Study Area

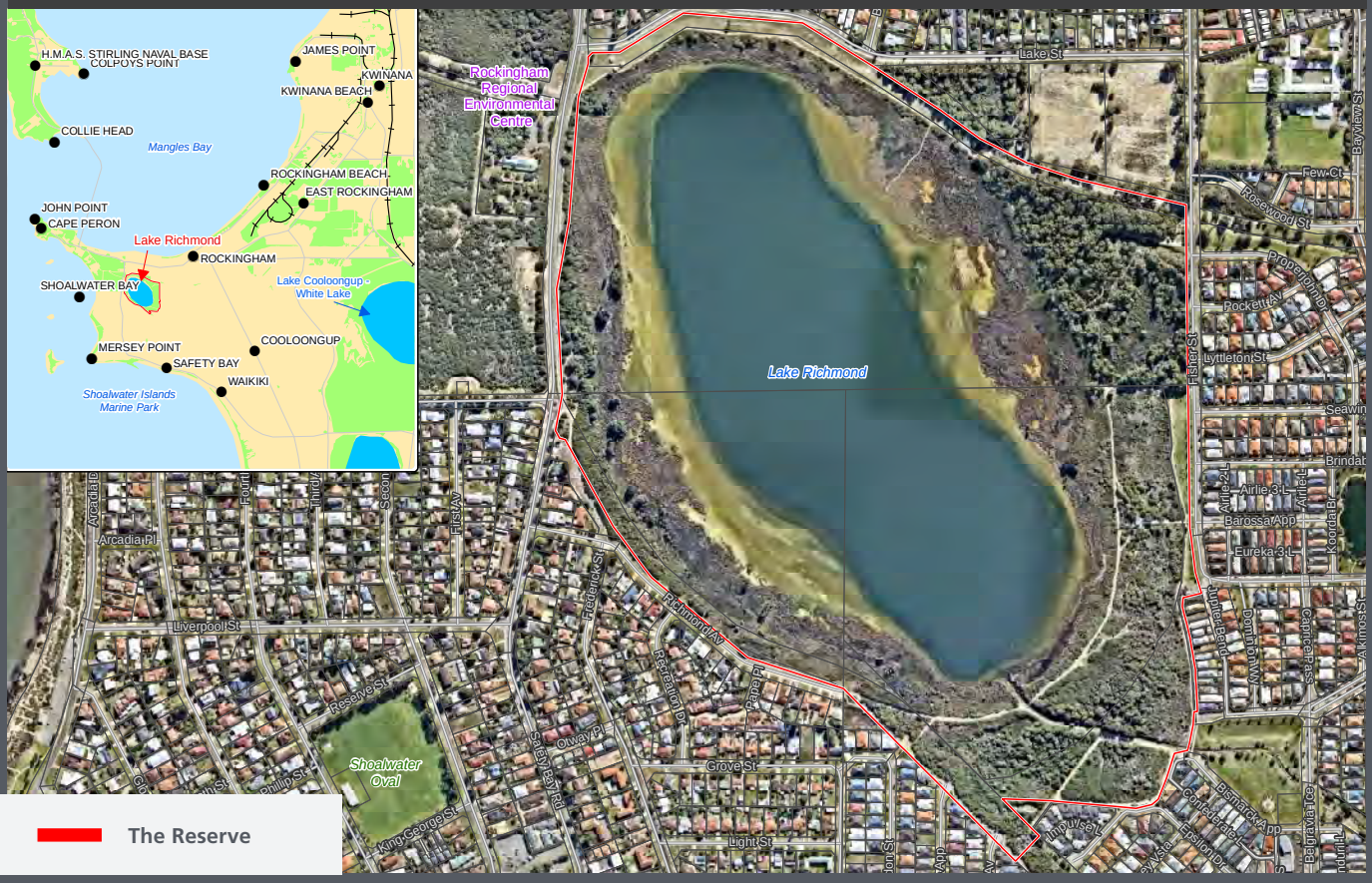


Figure 3 - Tenure

N

0 50 100 150 200 250

Metres

2.0

METHODS

2 Methods

2.1 Desktop Assessment

An assessment of publically available information and literature was undertaken by Strategen Environmental to inform the Environmental Assessment Report. In addition to this assessment, a review of scientific literature was undertaken by Dr Ryan Vogwill and Mike Whitehead to investigate the suitability of using herbicides to control weed species growing in close proximity to thrombolites.
The findings of both assessments are presented herein.

2.1.1 Database Searches

The following databases were reviewed as part of the desktop assessment for the Environmental Assessment Report:

1. Department of Biodiversity, Conservation and Attractions (DBCA) NatureMap database using a 10 km buffer of the survey area for vertebrate fauna and flora, and a 20 km buffer of the survey area for invertebrate fauna.
2. *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters Search Tool (PMST) using a 10 km buffer of the site; and
3. DBCA database of Threatened and Priority flora, fauna and ecological communities within the City's municipality.
4. Regional soil type mapping (Department of Primary Industries and Regional Development).
5. DBCA Geomorphic Wetlands Swan Coastal Plain dataset.
6. Regional vegetation mapping – (Heddle *et al.* 1980).
7. Biogeographic Region Dataset for Western Australia (Department of Energy and Environment).
8. Department of Planning, Lands and Heritage (DPLH) Online Aboriginal Heritage Enquiry System.
9. The Heritage Council's and the State Heritage Office's Inherit Database; and
10. The Western Australian Heritage Register.

2.1.2 Literature review – Thrombolite Assessment

2.1.2.1 Background

Thrombolite Community of Coastal Freshwater Lakes (Lake Richmond)

The 'Thrombolite Community of Coastal Freshwater Lakes (Lake Richmond)' is listed as endangered under the Commonwealth EPBC Act, and is ranked as critically endangered in WA. The TEC comprises a complex association of micro-organisms that aggregate in rock-like formations in the shallow waters of Lake Richmond (Department of Environment, Water, Environment, Heritage and the Arts 2008).

Microbialite communities of this nature were the dominant life forms on Earth in the period between 3,500 and 650 million years ago and were among the first creatures to produce oxygen. Today, thrombolites are found in just a few places around the world (Department of Biodiversity, Conservation and Attractions 2017).

At the surface, thrombolite communities are typically dominated by cyanobacteria ("blue-green algae") and other photosynthetic prokaryotes, like purple sulfur bacteria. Across the lake bed, the domal thrombolite structures are underlain by a widespread microbial pavement, which is known as the microbial mat.

Thrombolites are formed by a complex biochemical reaction between Extracellular Polymeric Substance (which is formed by lake bacteria), sulfide rich groundwater discharge and the carbonate stored with the mat. In order to form thrombolites, the mat must be exposed to prolonged sulfide rich groundwater flow. The sulfur will then react with the mat's carbonate and this reaction creates an upwelling of groundwater, which flows from beneath the surface into the lake water. When the upwelling comes into contact with Extracellular Polymeric Substance (EPS) in the lake water, carbonate is precipitated and it solidifies, forming the domal thrombolite structures "Whitehead and Vogwill 2014 – 2016 in prep". This formation process is very complex and relies on a very delicate balance of a number of factors, including lake bacterial health, water chemistry and seasonal hydrology. A slight disturbance to any of these factors has the potential to inhibit or prevent microbialite growth at Lake Richmond.

Lake Richmond thrombolites have a clotted internal structure (in contrast to stromatolites, which have a laminated internal structure) and unlike any other known occurrences of thrombolites, this ecological community appears to be adapted to fresh water.

Thrombolites are found on all sides of the lake and occupy an area that is up to 150m wide in some places, extending from the seasonally inundated near shore down to at least 6m water depth.

Figure 4 – Lake Richmond Thrombolites

Threatening Processes Affecting the Thrombolite Community

A primary concern is the invasive Saltwater Couch *(Paspalum vaginatum)* weed becoming interspersed with algae species around the periphery of the Lake and smothering the microbial mats and the thrombolites. There is concern that the application of non-selective herbicides, used to prevent the Couch from photosynthesising, could negatively impact on the assemblages of thrombolite formation.

A Literature Review was undertaken to consolidate and summarise the available scientific literature on the potential for impact to Lake Richmond's ecology from the use of herbicides currently being used by the City as part of standard practice. The key findings and recommendations proposed by the Literature review are outlined in the section below.

2.1.2.2 The Impact of Glyphosate and Fluazifop on Aquatic Microbial Communities

The Literature Review was conducted by hydrogeologist Dr Ryan Vogwill, and aquatic ecologist Mike Whitehead, in order to investigate the suitability of using the following chemicals to control weed species growing in proximity to the thrombolites:

TABLE 1 - Products used by the City in weed control.

Product	Active Constituent	Concentration in solution (g/L)	Form	Application Rate - when dissolved in water (mL/L)
Herbicide 1	Glyphosate	360	Isopropalymine Salt	15
Herbicide 2	FLUAZIFOP-P	128	Butyl ester	16
Surfactant	Vegetable based oils	851	Unknown	5
Red Marking Dye	Synthetic colouring agent	Unknown	Unknown	5

The Literature review is available upon request from the City. A summary of the key findings is provided below:

2.1.2.3 Summary of Glyphosate Impacts to Freshwater Aquatic Microbial Communities

1. The impact of glyphosate on freshwater microbial communities has not been studied in extensive detail, particularly not for the species present in Lake Richmond's microbial mats.
2. In the existing literature, impacts attributable to glyphosate did occur but these were predominantly minor and specific to a single species within a microbial assemblage.
3. A number of the studies deemed that surfactant mixed with glyphosate was more toxic than glyphosate applied on its own.
4. There was distinct variation in impacts based on the form that glyphosate was in, with commercial formulation of glyphosate as roundup being consistently ranked as having a greater impact than the free acid form of glyphosate. The order of impact, from greatest to smallest, was Roundup > isopropalymine salt > free acid. Noting that Roundup contains surfactant which could be the cause of the increased toxicity.
5. Some microbial species present actually increased in both activity and biomass following the application of glyphosate and there is evidence that some of these species can metabolise glyphosate. This may change the relative abundance of species or even the species composition in microbial mats which could influence microbial formation.
6. In natural environments microorganisms function as communities, and the metabolic abilities of individual species are often less important than the collective ability of the community. This is an important point in terms of microbial biomass and overall function of these communities in terms of carbon and nutrient cycles but is not relevant in the context of microbialite formation. In microbialite forming mats, there are key species present (e.g. archaea, sulfur oxidising bacteria and sulfur reducing bacteria) which are believed to drive structure formation *(Wong et al., 2017)*;
7. The effect of applying multiple herbicides simultaneously has not been well studied.
8. DNA (deoxyribonucleic acid) sequencing is the best available tool for identification of microbial species richness and abundance and also the impact of applying glyphosate.

2.1.2.4 Summary of Glyphosate Impacts to Soil Microbial Communities

Although studies on soil microbial communities are not directly relevant to Lake Richmond's microbial mats, the following findings of the Literature Review still bear relevance to this study:

1. Impacts to soil microbial communities from glyphosate are relatively minor in the available studies, with increased microbial activity and respiration often a potentially beneficial result of glyphosate application. These impacts appear typically less significant than for aquatic microbial communities. This could relate to the increased proportion of photosynthesising organisms in the aquatic mats.
2. Most studies are focused on short-term impacts, the fewer longer-term studies available show greater, but not critical, impact to soil microbial communities.
3. The impact of the simultaneous application of glyphosate and nitrogen based fertiliser to microbial species (specifically, ammonia oxidising bacteria and archaea) was found to be minor;
4. There are very few studies assessing the impact to archaea. No studies assessing archaea occurring in microbial mats were found.
5. The use of DNA is the most robust sampling and analysis technique for assessing impacts. Greater impacts are detected when these techniques are used, typically as changes in microbial community structure, as opposed to changes in microbial biomass.

2.1.2.5 Summary of Fluazifop-P Impacts

1. The Literature Review noted that there are considerably fewer studies on the effects of fluazifop-p on environmental systems, but those that do exist consistently identify it as having a significant negative impact.
2. There is also some evidence that the simultaneous application of Fluazifop-p and fertiliser can cause greater impacts than applying the products separately.
3. Studies where both glyphosate and fluazifop-p were assessed, indicated that fluazifop-p was the more toxic herbicide.
4. Unlike glyphosate, fluazifop-p's impacts to some South West Western Australian flora have been assessed, indicating a high risk of impact when seeds and seedlings are exposed to this chemical.

2.1.2.6 Summary of Surfactant and Red Marking Dye Impacts

1. No peer reviewed scientific papers were found that investigated the toxicity of vegetable oil based surfactants or red marking dye in environmental settings.
2. The Material Safety Data Sheet (MSDS) for the surfactant lists its ingredients as vegetable oil and polyethoxylated oil and states its 'Not classified as hazardous according to criteria of the National Occupational Health and Safety Commission' but also states 'do not contaminate any streams, lakes or ponds'.
3. The MSDS for the red marking dye states that it is 'not classified as hazardous according to ASCC criteria' and also states that no data is available on its ecotoxicology and that all components are readily biodegradable.

2.1.2.7 Literature Review Recommendations

The following recommendations made by the Literature Review identified the need for further assessment before using herbicides to control weeds growing around the periphery of Lake Richmond:

1. Dedicated testing for all proposed chemicals for application on the Lake Richmond microbial mats is required given the large knowledge gaps in the available literature and the species-specific nature of impacts investigated by existing studies. The effect of multiple simultaneous herbicide application is very poorly understood. A mat exposure experiment is proposed to identify how microbial mats react when exposed to the specified chemicals.
2. Molecular biology (i.e. DNA) is the best available tool we have for assessing impacts to microbial communities. It is recommended that changes to DNA are measured as part of the mat exposure experiment.
3. The impact potential of glyphosate is less than for fluazifop-p but both have impact potential, with the combined impact largely unknown. It may be that alternating between the two chemicals for any particular application period may help to minimise impact and reduce the potential for herbicide resistance to develop. This could be achieved by only using glyphosate during the first year and only using fluazifop-p in the following year.
4. There is evidence that the herbicide impact will vary depending on the timing (seasonality) of application. The species present and their relative abundance in the mats themselves will change distinctly during an annual cycle. Hence, it is recommended that the exposure experiment is conducted on the mats which will be present during the period of chemicals application (around June) but also during the most likely microbial forming period (autumn). Note that the presence of different species within the mats will be dependent on a year's rainfall and temperature. For example, the high magnitude out of season rainfall received in January 2018 delayed the peak microbialite formation period by keeping the water level elevated for a longer period of time. It is recommended that this out of season rainfall is accounted for in the mat sampling experiments.
5. The timing of herbicide application relative to rainfall events is important in the context of ecological impacts. It is recommended that application of any chemicals does not occur if any significant rainfall is possible for the next 10-14 days to minimise the transport of the chemicals and their breakdown products.
6. The surfactants have as high (if not higher) impact potential than the specific herbicide chemicals themselves, both to the microbial mats but also the wider ecosystem of Lake Richmond. Consequently, spraying without the use of any surfactants (or commercial formulations of the chemical which contain surfactants) is recommended.
7. The free acid form of glyphosate presents a reduced risk of impact in some of the studies identified. It is recommended that the City explores alternative glyphosate suppliers if glyphosate as an isopropalymine salt shows significant impacts under the exposure experiment.
8. Along with testing to the microbial mats themselves, it is recommended that the colour fastness of red marker dye on the microbial limestone is undertaken to ensure no unwanted aesthetic impact occurs. Many of the fossil thrombolites exist in areas where spraying will be required.
9. There are wide ranging estimates of the half-lives of glyphosate and the relevant break down products. They range from a number of days in soils to almost a year in flood waters. This suggests that application of these chemicals should be coupled with lake water monitoring for the chemicals and their associated break down products. This will enable assessment of the half-life of these chemicals in the Lake Richmond setting.
10. A number of the long-term glyphosate impact studies indicated that the effect on microbial communities was greater in the longer term. This suggest that if the City is proposing to use these chemicals repeatedly over many years, the short term experiments may not capture all of the impacts which could occur over time.

11. The combined impact of fertilisers and herbicides was shown in a study to cause greater impacts than the herbicides alone in soil bacteria. Bacteria are present in the microbial mats of Lake Richmond and this suggests that there should be separation between the timing of the herbicide and fertiliser application. Alternatively, the City could consider ceasing fertiliser use in the Reserve altogether. There is a complicating issue in that stormwater inflow is nutrient rich, with the nutrient assumed to be primarily fertiliser derived.
12. The City could explore the use of herbicide alternatives if the proposed chemicals are shown to be unacceptably dangerous.
13. *Nitella congesta* is the dominant submergent flora in the depression of the near shore littoral habitat and defines the habitat type where it occurs. It is crucial to the current diversity of both vertebrate and invertebrate taxa present and possibly the sediment chemistry which drives microbial formation. Weed control methods must take care to not impact this species.

Based on these recommendations, the City commissioned a comprehensive thrombolite mapping and DNA study in 2018 to enable the development of a robust Weed Management Strategy included as part of this Plan, with recommended actions based on scientific testing.

2.1.3 Assessment of likelihood of occurrence

In order to determine which conservation significant species have the potential to occur in the study area, the results of the database, literature searches and survey records were examined in the context of species known distributions and habitat preferences and whether suitable habitat was considered to be present on site. Species with habitat preferences that are not present within the study area were deemed unlikely to occur.

Of the TECs and priority ecological communities (PECs) recorded within the City's municipality, the likelihood of occurrence was determined for each community by comparing the known topography, hydrology, geology and flora species composition of each community to that present in the site.

2.2 Field Surveys

Extensive field surveys were undertaken as part of both the environmental and thrombolite assessments.

Environmental Assessment Report

The timing of the field surveys were selected to provide optimal conditions for the detection of flora and fauna species of conservation significance that may have been present in the Reserve. The field survey was conducted over two days (5 and 13 September 2017) by two experienced field botanists and two qualified zoologists from Strategen Environmental.

Thrombolite Assessment

The thrombolite mapping and lake water sampling was undertaken during the summer of 2017/2018 so that mapping could occur during the months where the lake water level was low. Low water levels provided the optimal time for mapping as it allowed for observations of the thrombolites that would be underwater during the wetter months.

2.2.1 Flora and Vegetation

A targeted and detailed flora and vegetation survey was undertaken in accordance with Environmental Protection Authority (EPA) Technical Guidance: *Flora and Vegetation Surveys for Environmental Impact Assessment (EPA, 2016).*

The following methodology was used to characterise the vegetation values and identify potential occurrences of TECs, PECs and conservation significant flora species:

- Analysing aerial photography of the Reserve to identify differences in vegetation structure and species composition.
- Traversing the Reserve on foot to identify and map changes in vegetation structure and type.
- Surveying 18 quadrats (measured at 10m x 10m).
- Additional opportunistic collecting was undertaken where previously unrecorded plants were observed.

The following was recorded from each survey location:

- Global Positioning System location.
- Topography.
- Soil type and colour.
- Outcropping rocks and their type.
- Percentage cover and average height of each vegetation stratum.
- Percentage cover and average height of major plant species present.

All plants collected during the field surveys were identified using appropriate reference material or through comparison with pressed specimens housed at the Western Australian Herbarium.

Areas suitable for revegetation were also recorded and mapped during the field survey.

2.2.1.1 Floristic Community Types

To identify the likely Floristic Community Types within the Reserve, analysis was undertaken to allow for comparisons between the field quadrats and the Floristic Community Types defined by Gibson *et al* (1994). The analysis was based on the presence or absence of key plant species being within the quadrats.

Figure 5 - Field Survey Locations

2.2.2 Weeds

Locations and numbers of Weeds of National Significance (WoNS) and Declared Pest plants were recorded where encountered, and the locations of larger-sized weeds of lower priority (i.e. large, woody species) were also recorded. Where weeds were widespread, these were identified and mapped by weed suites (weeds grouped by their growth form to allow for tailored control methods for each group).

2.2.3 Fauna

2.2.3.1 Level 1 Survey

A level 1 fauna survey was undertaken in accordance with the following EPA guidance documents:

1. *Technical Guidance – Sampling methods for terrestrial vertebrate fauna* (EPA 2016).
2. *Technical Guidance – Terrestrial Fauna Surveys* (EPA 2016).
3. *EPA Guidance Statement 56* (EPA 2004).

Fauna species and habitat data were collected from sample points that were considered to be representative of different fauna habitat types present. Specific habitat features were also used to determine the viability of the Reserve providing habitat for conservation significant fauna species.

Fauna occupancy searches were undertaken in microhabits to determine the presence of different species within the Reserve. This involved looking through leaf litter, looking beneath overturned rocks, looking under decorticating bark and searching for scats, tracks, burrows and other evidence of animals throughout the Reserve.

Opportunistic sightings of fauna were also recorded as part of the field survey. These included visual sightings of active fauna as well as indirect signs of species presence such as burrows and scats of mammals and reptiles. Evidence of pest fauna species inhabiting the Reserve (i.e. bee hives and fox and rabbit warrens) were also recorded.

Species identified in the survey were recorded using appropriate taxonomy and nomenclature.

2.2.3.2 Black Cockatoo Habitat Assessment

The three species of Black Cockatoo endemic to the south-west of Western Australia; Carnaby's, Baudin's and Forest Red-Tailed Black Cockatoo; have been recorded or are likely to occur in the City. All three of these species are conservation significant and listed under the EPBC Act. The purpose of this assessment was to qualify and quantify foraging, roosting and potential breeding habitat for the Black Cockatoo species at Lake Richmond. The assessment was carried out in accordance with the *EPBC Act Referral guidelines for three threatened Black Cockatoo Species (SEWPaC 2012)*, and included:

1. An assessment of vegetation communities and their potential to provide foraging habitat.
2. An assessment of significant trees with the potential to provide roosting and/or breeding habitat.

Assessment of Black Cockatoo Foraging Habitat

Potential Black Cockatoo foraging habitat was assessed based on the presence of foraging species (i.e. Corymbia and Banksia sp.) and opportunistic Black Cockatoo sightings within the reserve. Searches for foraging evidence, such as chewed nuts and cones, were also used to assign a foraging value to each vegetation unit. Feeding residue presence provides an indication of the recent extent of usage of the reserve by Black Cockatoos, and can support assessment of foraging resources.

Assessment of Black Cockatoo Roosting and Breeding Habitat

The Reserve was searched for locally occurring breeding and roosting tree species, namely *Eucalyptus marginata* (Jarrah), *Corymbia calophylla* (Marri), *Eucalyptus gomphocephala* (Tuart), and *Eucalyptus grandis* (Flooded Gum) as outlined in the EPBC Act referral guidelines (SEWPaC, 2012). Where detected, the trees were assessed for trunk diameter at breast height (DBH). The Department of the Environment (DotE) considers that all habitat trees with a DBH greater than 500 mm have the potential to form hollows suitable for Black Cockatoo nesting (SEWPaC 2012). As such, trees with a DBH greater than 500mm were identi fied and the following data was recorded:

- GPS Location.
- Size category (500-1,000mm DBH; 1,000-2,000mm DBH; >2,000mm DBH).

According to the EPBC Act referral guidelines (SEWPaC, 2012), roosting sites are generally characterised by having tall Eucalytus or non-native canopy trees that are often higher than the surrounding vegetation, usually located adjacent to fresh water, and usually situated in proximity to feeding habitat. Areas of potential roosting habitat were recorded where present.

2.2.4 Infrastructure

During the field assessment, the location and condition of existing park infrastructure were documented to determine:

- The frequency of use for each asset.
- Whether each asset is performing its desired function.
- The suitability of the location of assets.
- The need for upgrades or replacements.
- The need for additional assets.

2.2.5 Thrombolite Sampling and Laboratory Analysis

2.2.5.1 Hydrological and Water Chemistry Assessment

Prior to the commencement of the chemical risk assessment, a one-off snapshot survey of invertebrate species in the lake was undertaken in November 2017. Habitat suitability for individual species was defined based on basic water and sediment chemistry. On top of this, electrical conductivity was measured and converted to total dissolved solids (TDS) using a conversion factor derived from laboratory analysis and evaporated samples. The pH was measured and the carbonate speciation was derived from laboratory analysis. This information was used to evaluate whether the appropriate hydrological and chemical conditions to support thrombolite growth are present.

2.2.5.2 Thrombolite Mapping and Microbial Activity Characterisation Assessment

Two full day field expeditions were undertaken by Dr Ryan Vogwill and aquatic ecologist, Mike Whitehead to map active and inactive microbialite structures as well as the microbial mats. The maps were drafted in the field using tablets with recent aerial photography. During the field surveys, measurements were taken to capture the Lake Richmond water level, relative groundwater level, water quality, water chemistry and electrical conductivity. Field observations were compared to the results of a previous PhD study (Guerreiro, in prep) ('the PhD Study') that mapped the extent of the Lake Richmond microbialites between 2013 and 2015.

Between the two full day expeditions, intermediate short trips were undertaken every month to visually assess any changes to the lake hydrology and thrombolite activity and to also map inundation period and water level extent relative to mat activity. The intermediate site visits were undertaken from November 2017 to June 2018.

2.2.5.3 Chemical Risk Assessment

Thrombolite samples were collected for the culturing and herbicide chemical risk assessment, as recommended by the Literature Review. The purpose of the Chemical Risk Assessment was to determine the suitability of applying herbicides to control invasive grasses growing in close proximity to the any microbialite formations. This was investigated by exposing thrombolite samples to herbicides in a laboratory and observing the impacts at a microscopic and at a DNA level. The methodology used for the Assessment is described below.

A Regulation 17 – License to take fauna for scientific purposes under the Wildlife Conservation Act 1950 was issued by the Department of Biodiversity, Conservation and Attractions prior to the collection of all microbial mat samples from the Lake. A copy of the License is contained within Appendix C of this Management Plan.

The samples were kept in sealed containers designed to prevent evaporation. These containers were transparent and exposed to natural sunlight to mimic the diurnal cycle. The containers were filled in thirds; one third microbial mat sample, one third lake water filtered to remove invertebrates and one third air.

The containers were unsealed for a few minutes each day to remove any build-up of microbial metabolic products such as hydrogen sulfide and to restore the natural carbon dioxide to oxygen ratio. Microbial colonies kept in this way have typically showed rapid and prolific growth due to the increased temperature experienced within the container coupled with the limited exposure to invertebrate grazing.

Collected and cultured samples were separated into two parallel experiments, one for DNA analysis and one for visual examination. All samples were divided into subsamples measured at 20mm^2 x the height of samples' depth profile. As the microbial colonies are arranged vertically, the sub-sampling included the entire depth profile to capture all microbial species present.

Each chemical under evaluation (Glyphosate, FLUAZIFOP-P, vegetable based oils and synthetic colouring agent) was added at the equivalent application dose to 100ml of filtered lake water and half (50ml) was removed and diluted at a one to one ratio four times to achieve 100%, 25%, 12.5% and 6.25% dilutions of the specified application rate. A microbial mat sample was added to each dilution and to filtered lake water as the control sample for each tested chemical. Small samples (1mm spheres) of each dilution for all combinations were taken every 48 hours to be examined and photographed under a microscope, the observations were then recorded and compared to the control sample. All changes in cell density and any visible cell defects were recorded. Wherever possible, cells were identified to the level of genus by visual characteristics. All further species identification was undertaken through the DNA analysis.

2.2.5.4 DNA Analysis

DNA (deoxyribonucleic acid) is the hereditary material in almost all organisms and is contained in almost every cell of any living organism. DNA analysis is an essential part of any ecological study seeking to analyse the effect of added chemicals over time. It allows characterisation of all members of a community – regardless of whether they are active or not. Laboratory analysis of mat samples DNA was undertaken to determine relative species abundance pre and post application of herbicides.

2.2.5.5 Weed Management Recommendations

The findings of the abovementioned thrombolite (microbial mat) studies were combined to provide a consolidated Weed Management Strategy for the grassy weeds growing around the periphery of the lake. The recommendations addressed the following:

- The suitability of each chemical for use in the reserve and the recommended application rates.
- The optimal long-term water level and water quality regime to maximise the health and condition of the microbialite community.
- The optimal timing of herbicide application.
- Non-chemical weed control methods.

These recommendations are discussed in the Results section of this Management Plan.

2 Methods (continued)

2.3 Methodology Limitations

The Level 1 fauna survey was not a comprehensive assessment of all of the fauna within the reserve and it is probable that not all fauna species have been recorded. However, the survey provides a good indication of the species likely to be present in the reserves based on the habitat types present and species identified opportunistically.

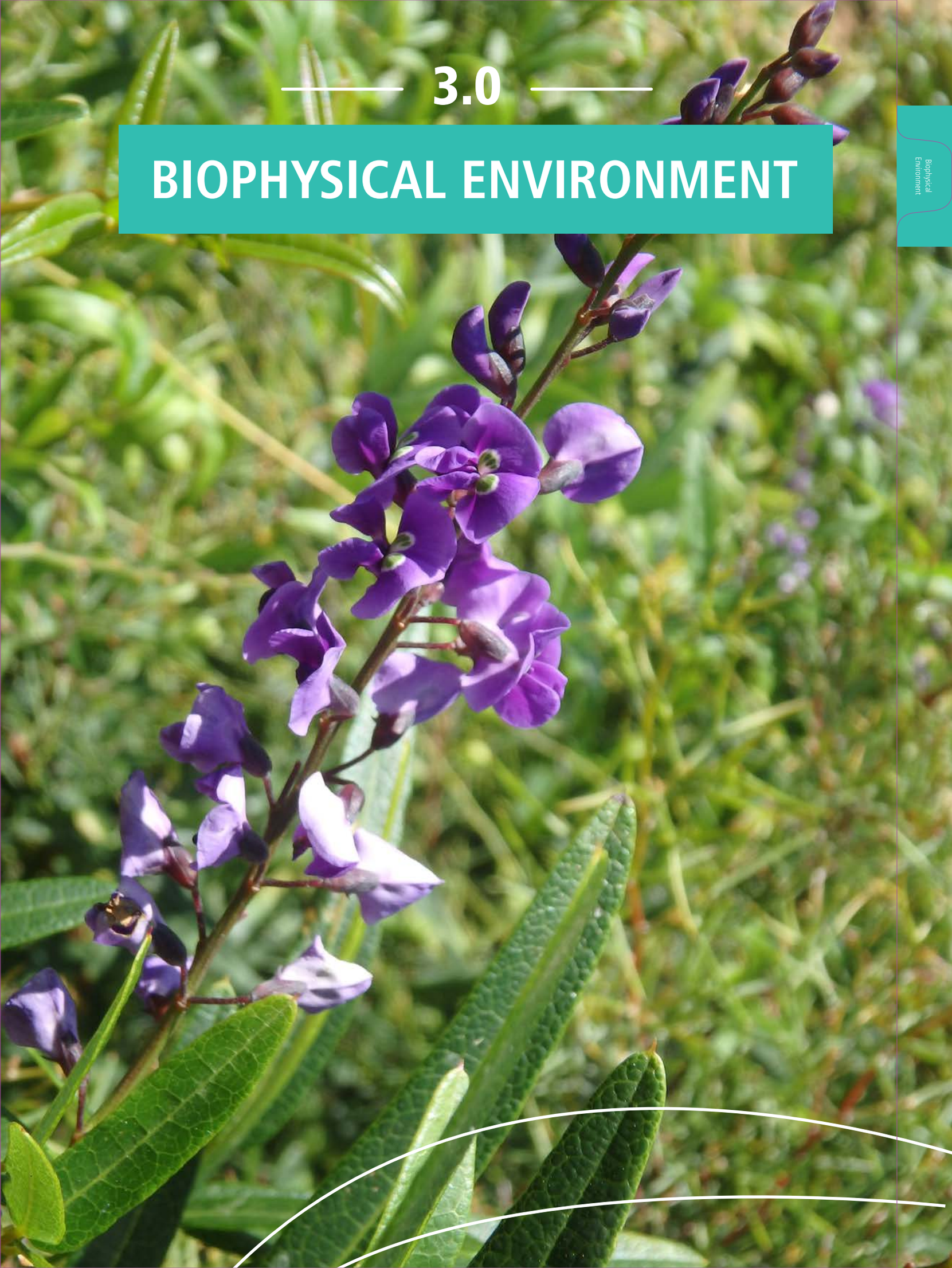
The WA Herbarium, in collaboration with the City's Parks Services, have identified the presence of an invasive plant species in the reserve that wasn't recorded by the field survey. The species identified is *Casuarina glauca*, a native of eastern Australia that has widely been planted in Western Australia and is now locally naturalised. It is very difficult to distinguish from its close relative, the WA native, *Casuarina obesa*, based on field surveys alone. There is a tendency for *Casuarina glauca* to have more strongly curved leaf teeth on younger specimens. A key identifying characteristic is that *Casuarina glauca* produces numerous suckers around the plant base, whereas suckers are usually absent in *Casuarina obesa*. As both species have been recorded from within the Lake Richmond reserve, an arborist will be engaged to survey the area of *Casuarina glauca*, so that control methods can be implemented to eradicate the invasive species from the reserve. This will likely include removal by an arborist in stages, with supplementary revegetation to infill areas where the species has been removed. This is detailed in the Implementation section of this Management Plan.

The majority of the data collected as part of Hydrological and Water Chemistry Assessment was the first time that any data of this kind has been collected from Lake Richmond. Unfortunately, the City is unable to make comparisons to historical data for many of the results obtained by this study. This means that the available data is insufficient to inform any lake water level or solute balance modelling with confidence. Hydrological and water chemistry data will continue to be collected to allow for a more comprehensive baseline dataset.

High water levels prevented access to some of the deeper thrombolites, meaning that all the samples collected were taken from the shallower formations. There is a possibility that the formation chemistry of the deep formations is different to the structures occurring around the lakes periphery.

3.0

BIOPHYSICAL ENVIRONMENT



3 Biophysical Environment

3.1 Land Use

With its significant environmental values, Lake Richmond has long been a popular place for walking and appreciating nature. A trail borders part of the lake, and leads to a boardwalk on the northern shore. The site is located adjacent to a small City managed reserve, being Lake Street Reserve to the northeast.

The immediate surrounding areas include the residential suburbs of Rockingham and Shoalwater as well as the Rockingham Lakes Regional Park, which extends westward from the Reserve. The two inlet drains and the outlet drains were installed by the Metropolitan Water Board in 1968 to reduce the water table and enable the development of the surrounding area (CALM 2003). These drains are now managed by Water Corporation.

A multi-storey residential building is proposed for the land that is bounded by Water Corporation Reserve 42518 to the south, Lake Street to the north, Fisher Street to the east and Lake Street Reserve to the west. The proposed apartment building will house members of the Australian Defence Force who are stationed at Garden Island.

The Naragebup Rockingham Regional Environment Centre (Naragebup) is located on Safety Bay Road, opposite Lake Richmond. Naregebup is a community run not-for-profit organisation that is actively involved in local conservation and environmental education initiatives.

3.2 Bioregion

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

The reserve lies within the Perth subregion of the Swan Coastal Plain bioregion, which is a low lying coastal plain mainly covered in woodlands (DEE 2017). The Perth subregion is dominated by Banksia and/or Tuart on sandy soils, *Casuarina obesa* on outwash plains, and paperbarks in swampy areas. In the east, the plain rises to duricrusted Mesozoic sediments dominated by Jarrah woodland. The outwash plains, once dominated by *Casuarina obesa*, *Corymbia calophylla* woodlands and *Melaleuca shrublands*, are only found extensively in the south (Mitchell & Williams 2002).

3.3 Climate

The study area has a warm Mediterranean climate, with hot, dry summers and cool, wet winters. Mean minimum and maximum temperatures range from 17.1°C to 31.6°C in February, the hottest month in summer; and 6.9°C to 18.0°C in July, the coolest month in winter (Bureau of Meteorology 2019). The nearest weather station at Garden Island recorded a mean annual rainfall of 601.4mm between 2002 and 2018.

3.4 Landform and soils

The landform can be described as low undulating relic foredune topography with variable thick sands overlying limestone at relatively shallow depths. The water table is high across the Reserve. This can be attributed to the fact that it contains a historically groundwater fed lake and numerous smaller wetlands.

The Reserve is located within the Quindalup Dune soil system which is a relatively recent landform comprising marine sands and Aeolian (windblown) soils. The Quindalup system is the youngest soil system on the Swan Coastal Plain, having formed the most recently. The Quindalup dunes are underlain by the Safety Bay Sand formation which comprises calcareous soils derived from Tamala limestone (Semeniuk 1990). A review of the soil type mapping (Department of Primary Industries and Regional Development) shows that the Reserve comprises of coastal sand dunes and calcarenite.

Based on regional mapping from the Department of Water and Environment Regulation, a high to moderate risk of acid sulfate soils (ASS) has been identified for the soils beneath the waterbody of Lake Richmond and the soils on the lakes periphery. ASS are naturally occurring, iron-sulphide rich soils that are formed under waterlogged conditions and are harmless when undisturbed. Oxidisation of the sulphide rich soils around the periphery of lakes has been found to be an important part of the hydraulic regime that support thrombolite growth (City of Rockingham 2018).

3.5 Hydrology

3.5.1 Wetlands

Lake Richmond is one of the largest freshwater lakes on the Swan Coastal Plain occurring in close proximity to the ocean. There are seven mapped Conservation Category Wetlands (CCWs) within the Reserve, these being Lake Richmond itself and the six associated basins. CCWs support a high level of ecological attributes and functions and is the State Government's highest classification for wetlands on the Swan Coastal Plain.

Figure 6 - Conservation Category Wetlands

3.5.2 Hydrology and Water Chemistry Assessment

As part of the Thrombolite Study, a Hydrology and Water Quality Assessment was undertaken to enable comparisons between the lake's historic and current water quality as well as hydrology.

3.5.2.1 Historic Hydrology

Prior to 1968, there were no surface water drains connected to the lake and the Lake Richmond basin was predominantly sustained by the inflow of groundwater and direct rainfall. The hydrology has since been significantly modified by the construction of the artificial drainage so that now drain inflow discharges are considered to be the main source of water to the lake (Guerreiro, in prep).

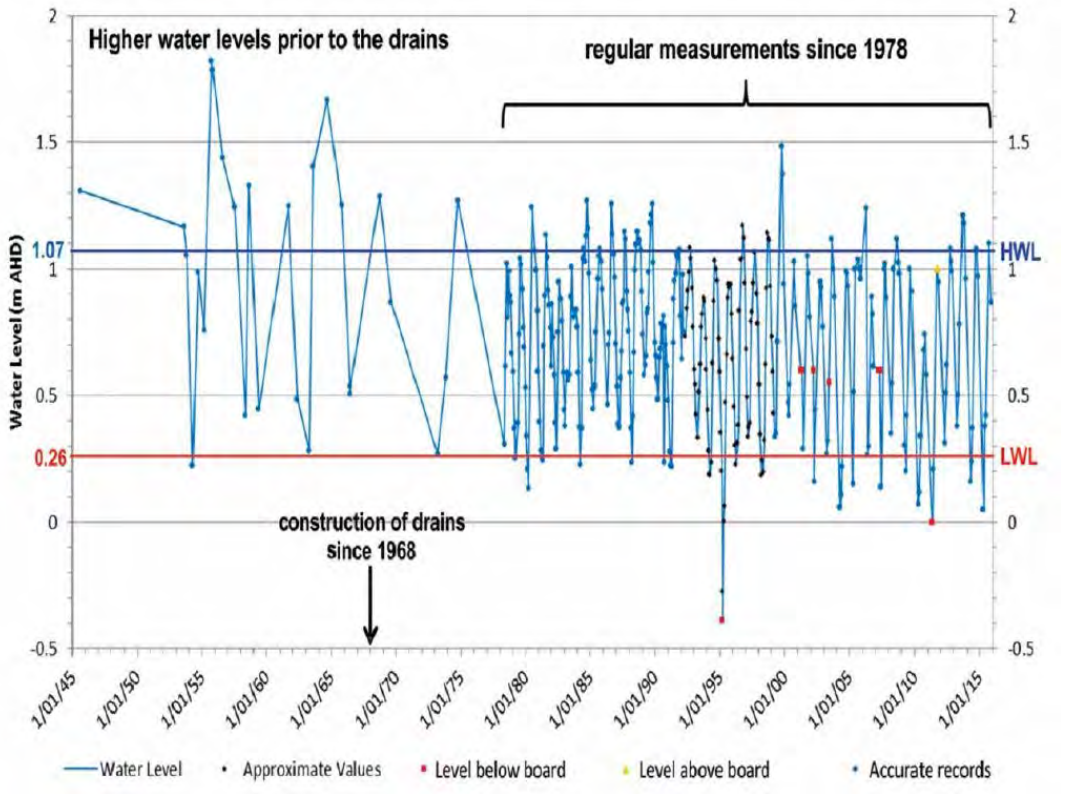
The available historical data shows how water level fluctuations have been altered since the installation of the drainage. In 1966, the groundwater levels immediately to the east, south and west of the lake were higher than the surface water level for most of the year, indicating that Lake Richmond was primarily fed by groundwater discharge. The use of the outlet board to control lake level has resulted in a reduction in mean water level as well as a decrease to the seasonal lake level fluctuations.

It is important to note that the infrequent collection of data prior to 1978 means that some of the older data may not be a completely accurate representation of the historical changes in water level.

The interaction between the lake and the adjoining groundwater aquifer was investigated further during the PhD study (2013-2015) (Guerreiro, in prep). It was established that, during summer, some groundwater inflow occurs from the southeast and east and outflow occurs towards the west and northwest. During the winter groundwater inflow is diminished as the lake level tends to rise faster than the surrounding aquifer due to the large volume of water entering the lake via the drains. As a consequence, this causes the lake to act as a groundwater recharge source, with lake water seeping into the aquifer in most directions, except to the southeast where the hydraulic gradient is virtually flat so little to no exchange occurs. This is distinctly different to the historical hydrological regime from 1966.

On average, Lake Richmond's water level fluctuated by 0.8m each year between 2013 and 2015. The average minimum level was 0.25m AHD and this measurement coincided with the end of summer. The average maximum, recorded at the end of winter, was approximately 1.05m AHD.

Figure 7 - Historical water level Figure



3.5.2.2 Current Hydrology

Between June 2016 and December 2017, lake water level varied between 1.1 and 0.62m AHD, maintaining a persistently higher water level and reduced seasonal fluctuation relative to previous years. A large out of season rainfall event (107.66mm on 16 January 2018) caused an approximate 0.3m rise in the water level due to the effect of direct rainfall on the lake and stormwater drainage inflow. This resulted in the lake level remaining approximately 0.4m higher than average throughout the summer microbial mat growth period. Throughout 2017 and 2018, the lake level was permanently above the set outlet drain level, indicating that lake water outflow was constantly occurring.

The Water Corporation drains have brought an influx of fresh water with high nutrient levels resulting in the proliferation of algae species to the detriment of the microbialites.

3.5.2.3 Historic Water Quality

The only available historical (pre 2000s) water quality data is in Passmore (1970) which states that, prior to the construction of the drains, total dissolved solids (TDS) used to fluctuate from 2000mg/L in winter to 3,500mg/L in summer. It should be noted that this study was conducted during a period of above average rainfall for the Perth region. Hence the lake would have likely been fresher than during the Holocene period when the microbialites first began to form.

By 2013, the PhD study identified that the nutrient levels in the lake water were consistently above the recommended concentrations as listed in the guidelines for freshwater ecosystems in Western Australia (Guerreiro, in prep). Due to their larger catchment area, the drains recorded the highest nutrient concentrations (4.2mg/L total nitrogen), with high concentrations also recorded in the areas of significant groundwater inflow (1.2mg/L total nitrogen).The nutrient concentrations increased during winter with the increases in runoff, and then fell during summer when the influx of drainage water was reduced and biota nutrient uptake was increased.

The phytoplankton and macrophyte productivity closely followed this trend and were visibly more abundant during winter when the availability of nutrients was higher.

The City also undertook biannual surface water monitoring (City of Rockingham 2015) at nine sampling points throughout the lake between 2012 and 2015 with a focus on measuring the following parameters:

- pH
- Electrical conductivity
- Total dissolved solid
- Sodium
- Calcium
- Magnesium
- Potassium
- Carbonate
- Bicarbonate
- Reactive phosphorus
- Ammonia
- Nitrate
- Total metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc)
- PAH
- TP
- Enterococci
- Escherichia coli.

The measurements of the above parameters were compared to the site trigger levels as defined by the Integrated Catchment Management Plan: Lake Richmond Rockingham (City of Rockingham 2012). Concentrations of nitrate, total nitrogen, total oxidised nitrogen, arsenic and zinc all exceeded the site trigger levels in the drains and in the lake. It is presumed that these high concentrations in the lake are attributable to surface water discharging from the inlet drains during the winter months. The monitoring results obtained over the course of the program do, however, indicate that nutrient levels were gradually decreasing over the monitoring period. Consistent with the findings of the Thrombolite Assessment, the lake water was identified to be slightly saline, slightly basic, net aerobic and net oxidising.

3.5.2.4 Current Water Quality

Water quality in 2017-18 was very similar to the 2013-2015 data with the overall chemical composition of the lake remaining relatively unchanged. Total Nitrogen varied from 0.8-1.7mg/L and total phosphorus was measured at 0.12mg/L. Carbonate speciation analysis by Vogwill and Whitehead identified that the lake water did not meet the conditions for carbonate precipitation, which is an important function for the growth of microbialites. The combined results of this study and the PhD study indicate that the lake water is likely to be net aggressive (i.e. predisposed for carbonate dissolution instead of precipitation), suggesting the current water conditions are potentially detrimental to microbialite health.

3.6 Vegetation

Regional vegetation has been mapped by Heddle *et al.* (1980) based on major geomorphic units on the Swan Coastal Plain. The mapping shows that the Lake Richmond Reserve occurs within the Quindalup Complex. This complex is well-represent both regionally and locally, with over 60% of its pre-European extent remaining.

The Quindalup complex is a coastal dune complex consisting of mainly two alliances – the strand and foredune alliance, and the mobile and stable dune alliance. Local variations include the low closed forest of *Melaleuca lanceolata – Callitris preisii* and the closed scrub of *Acacia rostellifera* (Heddle *et al.* 1980).

Vegetation type and extent has also been mapped at a regional scale by Beard (1990) who categorised vegetation into broad associations. Beard's mapping at a scale of 1:1,000,000 formed the basis of several regional mapping systems, including the biogeographic region dataset for Western Australia (Department of Energy and Environment). This dataset shows that the Reserve comprises Vegetation association 3048, described as 'Shrublands: scrub-heath on the Swan Coastal Plain'.

3.6.1 Desktop Review of TEC Mapping

A search of the DBCA database identified TECs within the Reserve:

1. Sedgelands in Holocene dune swales of the southern Swan Coastal Plain.
2. Thrombolite community of Coastal Freshwater Lakes (Lake Richmond).
3. Woodlands over sedgelands in Holocene dune swales of the southern Swan Coastal Plain

Sedgelands in Holocene dune swales of the southern Swan Coastal Plain

The 'Sedgelands in Holocene dune swales of the southern Swan Coastal Plain' TEC is listed as Endangered under the Commonwealth EPBC Act, and is recognised as Critically Endangered by the State WC Act. This TEC occurs primarily in Quindalup dunes in linear damplands and occasionally in sumplands in the swales between Holocene dunes. Typical dominant flora species include *Acacia rostellifera, Acacia saligna, Xanthorrhoea preisii*, the sedges *Baumea juncea, Ficinia nodosa, Lepidosperma gladiatum*, and the grass *Poa porphyroclados* (Department of Environment and Conservation 2011).

Though treated as one entity, two subtypes of this TEC are recognised (Government of Western Australia 2000, Department of Environment and Conservation 2011):

- SCP19a: 'Sedgelands in Holocene dune swales' – generally occurs in younger swales, and is the majority subcategory; and
- SCP19b: 'Woodlands over Sedgelands in Holocene dune swales' – tends to occur in older swales and has an overstorey of Woodland including *Eucalyptus gomphocephala, Melaleuca raphiophylla* and *Banksia littoralis*.

Thrombolite community of Coastal Freshwater Lakes (Lake Richmond).

See description of this TEC in section 2.1.2.1

Priority Ecological Communities

Priority Ecological Communities (PECs) are assemblages of flora and fauna communities that are recognised to be of significance, but do not meet the criteria of a TEC. There are five categories of PECs, none of which are currently protected by legislation (see Appendix A). The latest listing of PECs recognises 32 PECs in the Swan bioregion (Department of Biodiversity, Conservation and Attractions 2016). The desktop assessment determined that none of these PECs are mapped as occurring within the reserve.

Figure 8 - Desktop TEC Mapping

3.6.2 Vegetation Types

During the field assessment, six native Vegetation Types (VTs) were identified as occurring within the reserve (Figure 9 and Table 2).

- **Vegetation Type 1** – Low woodland of *Melaleuca rhaphiophylla* over tall shrubland of *Acacia rostellifera* and *Spyridium globulosum* over closed sedgeland of *Gahnia trifida* and *Ficinia nodosa* to closed grassland of *Poaceae* sp.
- **Vegetation Type 2** – Tall shrubland of *Acacia rostellifera* over very open shrubland of *Olearia axilaris*, *Acacia saligna* and *Spyridium globulosum* over open to closed herbland of **Oxalis pes-caprae* and *Poaceae* sp.
- **Vegetation Type 3** – Tall woodland of *Eucalyptus gomphocephala* and *Callitris preissii* over open shrubland of *Spyridium globulosum*, *Diplolaena dampieri* and *Acacia cochlearis*, over herbland of **Stenotaphrum secundatum*, *Rhagodia baccata* and *Acanthocarpus preissi*.
- **Vegetation Type 4** – Closed sedgeland of *Juncus kraussii* and *Ficinia nodosa* with occasional *Rhagodia baccata*, *Acanthocarpus preissii* and **Stenotaphrum secondatum*.
- **Vegetation Type 5** – Closed tall shrubland of *Xanthorrhoea preissis*, *Hakea varia* and *Acacia saligna* over occasional *Conostylis candicans*, *Leucopogon parviflorus* and *Lepidosperma pubisquameum*.
- **Vegetation Type 6** – Open shrubland of *Acacia saligna*, *Acacia rostellifera* and *Xanthorrhoea preissii* over *Ficinia nodosa* and mixed introduced species.

In addition to the six Vegetation Types, an area designated as 'Parkland' was identified within the reserve. The parkland is located at the northern boundary of the reserve and comprises the grassed area within the Water Corporation SDOOL reservation. There is another small area of parkland on the eastern boundary of the Reserve, adjacent to Fisher Street.

Excluding the Lake Richmond waterbody, the dominant VT within the Reserve was VT4. Table 2 and Figure 9 below shows the area covered by each VT within the Reserve.

TABLE 2: Extent of VT coverage.

Vegetation Type	Area (ha)	Percentage of total Reserve (excluding waterbody)
VT1	2.7	6.7%
VT2	7.9	19.5%
VT3	5.02	12.4%
VT4	17.3	42.7%
VT5	1.71	4.2%
VT6	4.77	2.7%
Parkland	4.77	11.8%
Total	40.5	100%

3.6.3 Floristic Community Type Similarity Analysis

Indicative Floristic Community Types (FCTs) were assigned to the vegetation types recorded in the reserve. Note that a FCT was unable to be determined for VT6 due to the high level of disturbance from fire and weed invasion. Analysis indicated that VT3, VT4 and VT5 were representative of TECs.

The surveys identified that the on-ground extent of the 'Sedgelands in Holocene Dune Swales' TEC differed slightly to the formal boundaries shown by the DBCA TEC mapping. In addition, prior to this survey, the '*Callitris preissii* (or *Melaleuca lanceolata*) forests and woodlands, Swan Coastal Plain' TEC had never previously been recorded at Lake Richmond. The presence and true extent of the TECs will be determined through further detailed vegetation surveys and subsequent liaison with DBCA, this is detailed in the 'Implementation' section of the Report.

The mapped extent of the TECs identified during the field survey are displayed in Figure 10.

TABLE 3: Indicative FCTs recorded within the reserve.

Vegetation Type	Indicative FCT	FCT Name	WA Conservation Status	Commonwealth Conservation Status
1	17	*Melaleuca rhaphiophylla – Gahnia trifida* seasonal wetlands	Not listed	Not listed
2	29b	*Acacia* shrublands on taller dunes, southern Swan Coastal Plain	Priority 3	Not listed
3	30a	*Callitris preisii* (or *Melaleuca lanceolata*) forests and woodlands, Swan Coastal Plain	Vulnerable	Not listed
4	19a	Sedgelands in Holocene dune swales	Critically Endangered	Endangered
5	19b	Woodlands over sedgelands in Holocene dune swales	Critically Endangered	Endangered

Figure 9 - Vegetation Type

Figure 10 - Field assessment TEC mapping

3.6.4 Vegetation Condition

Vegetation condition within the reserve ranged from completely Degraded to Excellent, as defined by the Keighery Condition Scale (1994) (Table 4). The majority of the reserve comprised vegetation in Good to Very Good condition (28.65 ha) with approximately 3.95 ha representing habitat in Degraded condition. A total of 11.8 ha was classified as Completely Degraded and comprised of the recreational areas and the areas for car and pedestrian access.

TABLE 4: Vegetation Condition within the reserve (excludes waterbody).

Vegetation Condition	Area (ha)	Percentage of the Reserve (%)
Completely Degraded	4.77	11.8
Degraded	3.95	9.8
Good – Very Good	28.65	70.7
Very Good – Excellent	3.13	7.7
Total	**40.5**	**100**

3.7 Flora

3.7.1 Flora Diversity

A total of 53 native vascular plant species (71%) and 22 introduced weed species (29%) were recorded across the reserve. The species identified within the reserve represented 27 families with the Myrtaceae (12 taxa) and Cyperaceae (7 taxa) families having the most representation. The comprehensive list of plants recorded during the field surveys are presented in Appendix B.

3.7.2 Conservation Significant Flora

The desktop and literature searches identified 20 flora species of conservation significance known to occur within the City. Of these, based on broad habitat requirements, two threatened and 12 priority flora species were considered to have the potential to occur within the Reserve (Table 5). However, none of these flora species have been previously been recorded in or near the Reserve.

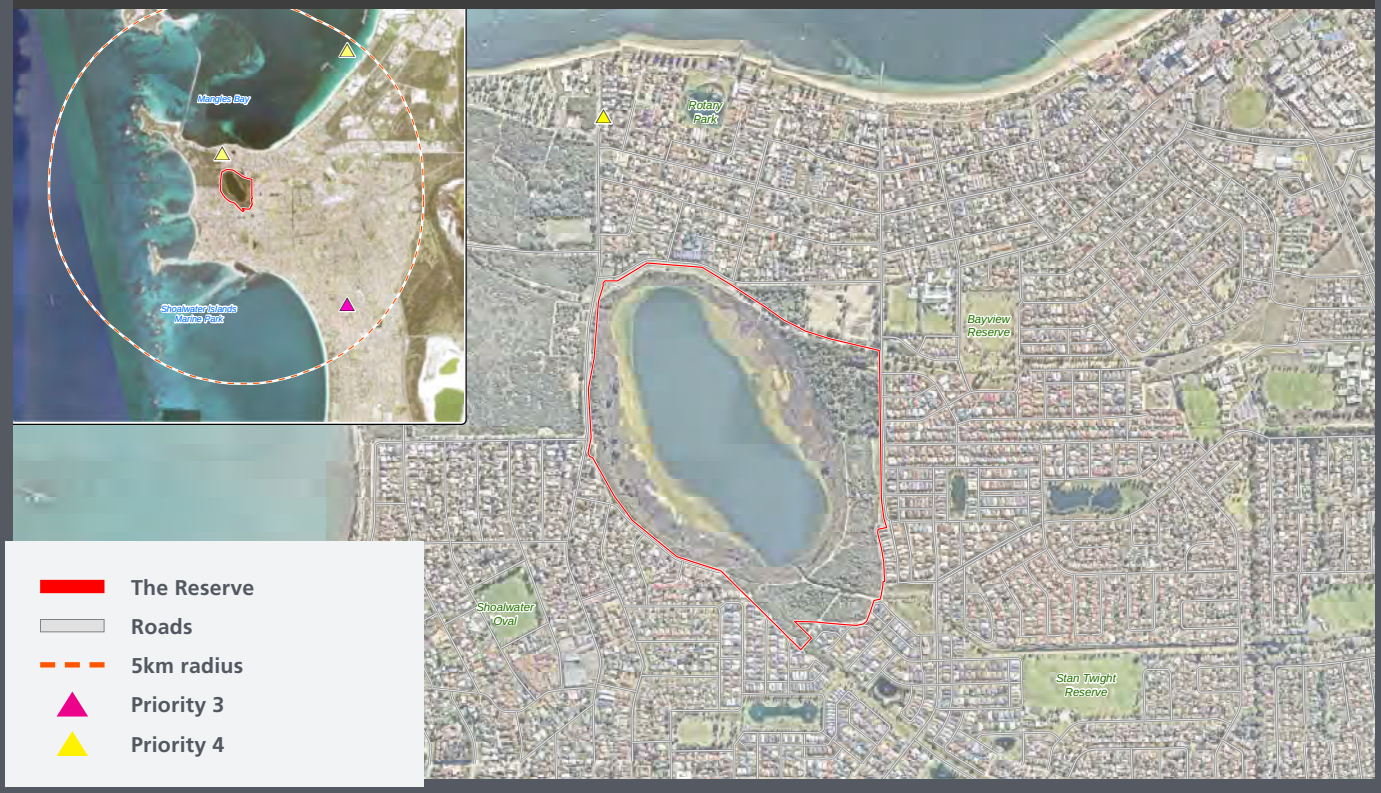
TABLE 5: Conservation significant flora potentially occurring in the Reserve.

Conservation Rating	Species	Habitat
Threatened under the WC Act and EPBC Act	*Diuris drummondii* (Tall Donkey Orchid)	Low-lying depressions in peaty and sandy clay swamps. Plants are frequently observed standing in several centimetres of water even during the summer flowering period.
	Synaphea sp. Serpentine (G.R Brand 103) (Serpentine Synaphea)	Occurs on heavy soils on the eastern side of the Swan Coastal Plain, so very unlikely to occur.
Priority 1	*Lachnagrostis nesomytica* subsp. paralia	Calcareous sands, coastal dunes and swales.
Priority 2	*Cardamine paucijuga*	Moist to dry substrates.
Priority 3	*Beyeria cinerea* subsp. cinerea	Grey/white or red sand. Coastal limestone and dunes.
	Calandrinia oraria	As no habitat description is available for this species, it should be considered to potentially occur within the Reserve.
	Dillwynia dillwynioides	Sandy soils in winter wet depressions.
	Lasiopetalum membranaceum	Sandy substrate over limestone.
	Sphaerolobium calcicola	White-grey-brown sand over limestone or sandy clay substrate over black-peaty-sandy-clay. This species has been found to occur on tall dunes, and in low-lying areas including interdunal swamps and winter-wet flats.
Priority 4	*Conostylis pauciflora subsp. pauciflora*	Grey sand over limestone on hillslopes and consolidated dunes.
	Dodonaea hackettiana (Hackett's Hopbush)	Sand and outcropping limestone.
	Jacksonia sericea (Waldjumi)	Calcareous and sandy soils.
	Lepidium puberulum	Sandy soils.
	Myosotis australis (Austral Forget-me-not)	Grey sand over limestone.

During the field assessment, none of the above conservation significant flora species were recorded in the Reserve despite the entire area being thoroughly surveyed.

Figure 11 - Vegetation Condition

Figure 12 - Regional Conservation Significant Flora



3.7.3 Weeds

Weeds were common and widespread across the Reserve. The location and distribution of all weeds are shown in Figures 15 and 16. A weed species list summarising presence at the Reserve is presented in Appendix C. The weed species have been sorted by weed suites, which groups the weeds based on their growth form to allow for control methods being tailored to treat each individual suite. The two weed suites identified at the Reserve were 'grassy weeds' and herbaceous weeds'.

The following species which were not identified to occur in the Reserve at the time of the 2008 survey, were found to be present in 2017:

- *Bromus diandrus* (Great Brome)
- *Planted Agonis flexuosa* (Peppermint)
- *Dimorphotheca ecklonis* (Cape Marguerite)
- Planted *Eucalyptus platypus* (Moort)
- *Galium murale* (Small Goosegrass)
- *Hypochaeris glabra* (Smooth Cats-ear)
- *Lysimachia arvensis* (Pimpernel)
- *Ursinia anthemoides* (Ursinia).

Significant Weeds

Bridal Creeper (*Asparagus asparagoides*) was found in two locations within the reserve. This weed has been assessed as a Weed of National Significance (WoNS) by the Australian Department of the Environment and Energy and is also a declared pest under the *Biosecurity and Agriculture Management Act 2007* (Department of Primary Industries and Regional Development 2018).

Bridal Creeper is regarded as one of the worst weeds in Australia because of its invasiveness, potential for spread and its associated economic and environmental impacts. Bridal Creepers' climbing stems and foliage smother native plants, restricting photosynthesis. It also forms a thick mat of underground tubers that impeded the root growth of other plants and often prevents seedling establishment. The flowers are white, with flowering recorded between August and September producing more than 1,000 berries per square metre. The seeds are effectively distributed after being consumed by the birds, rabbits and foxes that eat the berries. Bridal Creeper is known to grow across a number of soil types including sandy, loam, clay and granite soils. The specimens present at Lake Richmond are growing in the deep Quindalup Sands that are usually associated with foredune environments.

The control category for Bridal Creeper is C3 management (Department of Primary industries and Regional Development 2018) which includes requirements such as:

- Prohibiting the introduction and/or supply of this pest into an area
- Infestations must be managed
- Persons undertaking work in an infested area must be aware of control measures.

Three larger and more prominent weeds were found within the reserve, these include:

- *Foeniculum vulgare* (Fennel)
- *Gazania linearis* (Treasure Flower)
- *Schinus terebinthifolius* (Brazilian Pepper).

Figure 13 - Distribution of Grass Weeds

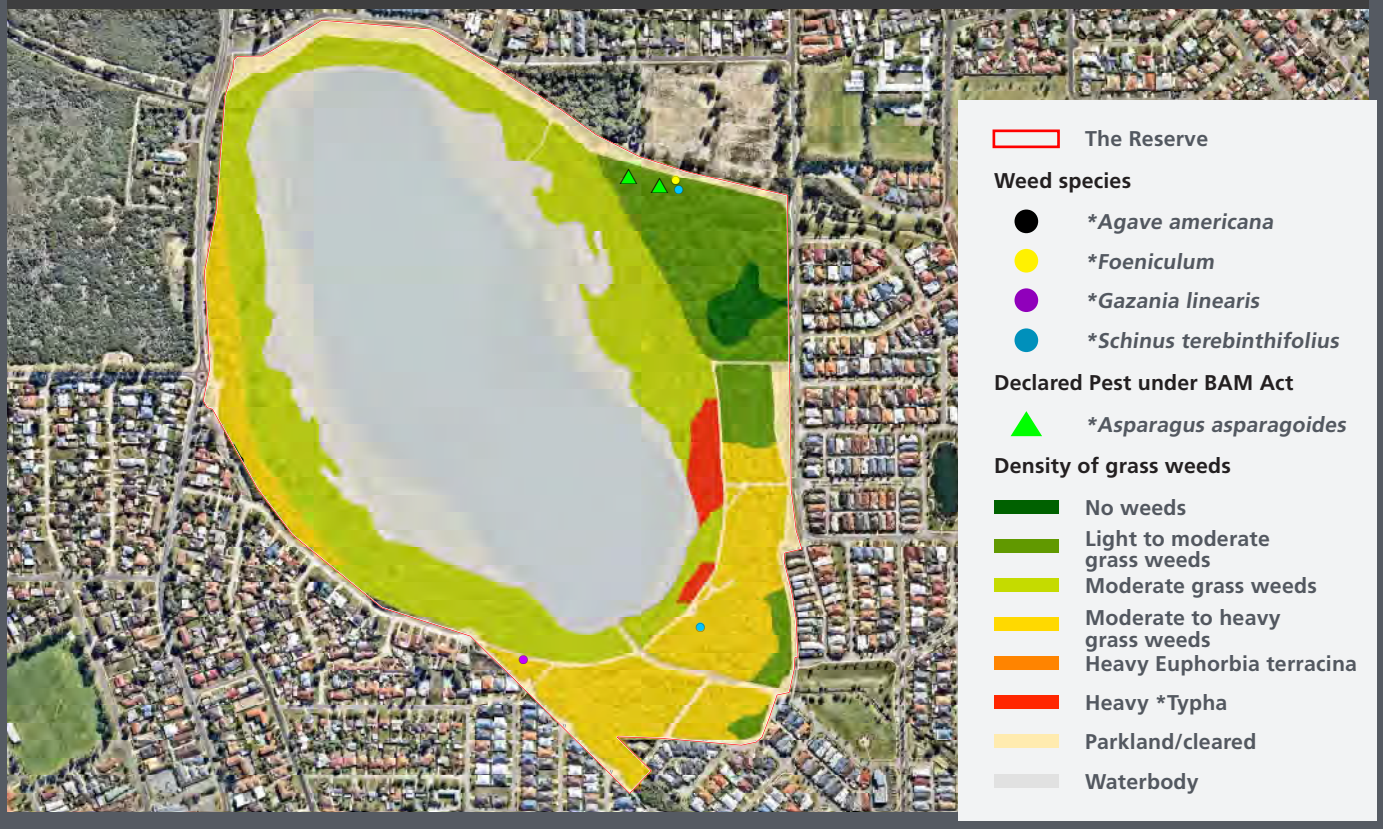


Figure 14 - Distribution of Herbaceous Weeds

N

0 50 100 150 200 250

Metres

3.8 Fauna

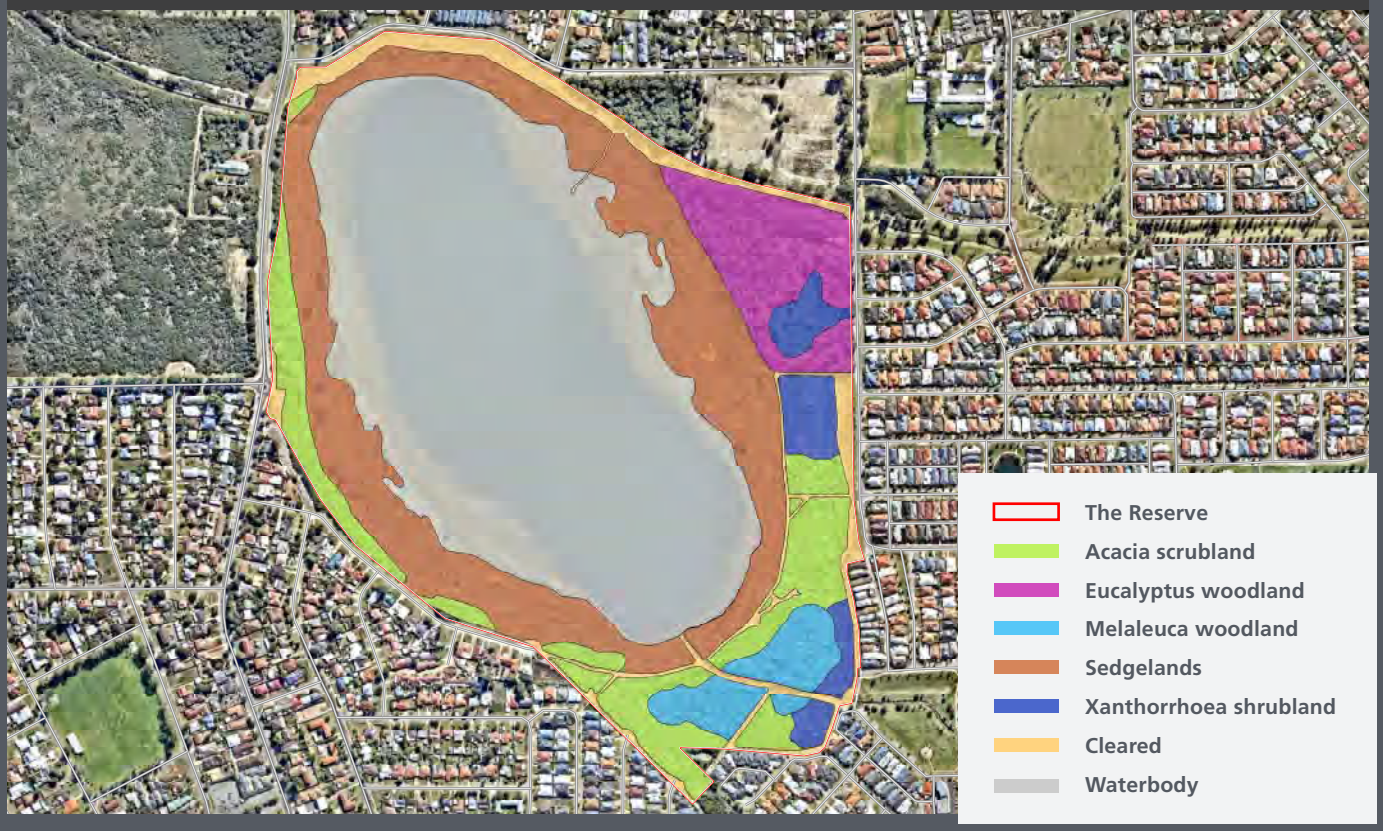
3.8.1 Fauna Habitats

A total of six broad habitat types were recorded in the field survey in addition to the cleared parkland areas (4.8ha). The description of these habitat types are shown in Table 6 and their representation across the reserve is displayed in Figure 15.

TABLE 6: Fauna habitat types throughout the reserve

Fauna Habitat Type	Description	Area (ha) within Reserve	Area (%) of Reserve	Habitat Suitability for Fauna Species
Acacia Shrubland	This habitat consists of *Acacia rostellifera*, with no overstorey and very limited understorey.	8.13	10.1	This habitat lacks woody debris and leaf litter and therefore provides limited habitat for small reptiles, birds and mammal species.
Eucalyptus Woodland	This habitat has an overstorey that consists of large Tuart trees, over a middle-storey that comprises species including *Callitris preissii* and *Melaleuca lanceolata*, over an understorey of *Xanthorrhoea preiisii* and mixed weeds.	5.02	6.3	This habitat has vegetation in multiple strata as well as woody debris and leaf litter, which provides habitat for small reptile, bird and mammal species. However, as this patch is isolated from areas of similar habitat, fauna movement is limited, particularly for smaller reptiles and mammals. This woodland provides potential breeding and foraging habitat for Black Cockatoos.
Melaleuca Woodland	This habitat consists of *Melaleuca* trees over a ground storey of weedy grass species.	2.7	3.4	There is a low diversity of microhabitats within this woodland.
Sedgelands	This habitat consists of reeds and sedges. *Juncus krausii* and *Ficinia nodosa* are common.	17.3	21.5	The sedgelands provide shelter and foraging habitat for birds and amphibians.
Xanthorrhoea shrubland	This habitat consists of *Xanthorrhoea preissii* with no overstorey and very limited understorey.	2.81	3.5	This habitat lacks woody debris and leaf litter and therefore offers limited habitat for small reptile, bird and mammal species. This habitat does however offer viable foraging habitat for Black Cockatoos.
Waterbody	The Lake Richmond waterbody.	39.8	49.6	Habitat for waterbird species such as the Crested Tern, as well as amphibian species such as the Squelching Froglet.

Figure 15 - Habitat Types



3.8.2 Fauna Assemblage

A total of 47 species from 26 families were recorded during the Level 1 Fauna Assessment undertaken in September 2017. This consisted of five amphibian species, 40 bird species and two mammal species.

A full list of the taxonomic groups is available from Appendix D.

3.8.3 Conservation Significant Fauna

Fauna records compiled from the database and literature searches identified that a total of eight reptile species, 78 bird species and 25 mammal species have the potential to occur within the Reserve. It is important to note the limitations of the DBCA database search as it included fauna species that have:

- Specific habitat requirements that are not present within Lake Richmond
- Limited or patchy distribution
- Become locally extinct
- Been erroneously identified in previous surveys.

Following the exclusion of fauna species that met the above criteria, a total of 23 conservation significant species were identified as potentially occurring within 5km of the Reserve. These 23 species comprise two reptiles, 18 bird and three mammal species.

TABLE 7: Conservation significant fauna potentially occurring in the Reserve.

Likelihood of occurrence	Number of species	Species
Likely to occur	18	Silver Gull, Caspian Tern, Perth Slider, Carnaby's Black Cockatoo, Forest Red-tailed Black Cockatoo, 11 species of waterbirds and waders, Rainbow Bee-eater and Southern Brown Bandicoot
Possibly occurring	3	Black-striped Snake, Peregrine Falcon and Baudin's Black Cockatoo
Unlikely to occur	2	Western Quoll and Southern Brush-tailed Phascogale

N

0 50 100 150 200 250

Metres

During the field survey, only two of the 23 potentially occurring conservation listed species were recorded. The two species observed were:

- Silver Gull (*Chroicocephalus novaehollandiae*) - Marine; and
- Caspian Tern (*Hydroprogne caspia*) – Migratory/Marine.

The Silver Gull is a web-footed seabird that occurs in flocks, mostly along the coast, on islands or at sea. It is a very common gull with a white head and no dark markings. The species is very common on the Australian coastal mainland, as well as along inland waterways, typically increasing in numbers near colonies of nesting waterbirds.

Silver Gull

Photo source: John Peter, BirdLife Australia

The Caspian Tern is Australia's largest tern and is distinguished by its large red bill and black facial markings. It is a long-winged and short-legged waterbird that inhabits both saltwater and freshwater environments. This tern hunts by plunging headlong after fish or by using its beak to scoop up smaller prey swimming just beneath the surface. The Caspian Tern is also known to occasionally feed on insects such as grasshoppers and dragonflies

Caspian Tern

Photo source: Glenn Ehmke, BirdLife Australia

The likelihood of occurrence for the remaining conservation significant species identified during the desktop assessment were confirmed by the habitat assessment. As a result, the following species were determined as likely to occur based on the habitat present within the reserve:

- Perth Slider (*Lerista lineata*)
- Carnaby's Black Cockatoo (*Calyptorhynchus latirostris*)
- Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*)
- Blue-billed Duck (*Oxyura australis*)
- Great Egret (*Ardea modesta*)
- Sharp-tailed Sandpiper (*Calidris acuminate*)
- Curlew Sandpiper (*Calidris ferruginea*)
- Red-necked Stint (*Calidris ruficollis*)
- Common Greenshank (*Tringa nebularia*)
- Ruddy Turnstone (*Arenaria interpres*)
- Sanderling (*Calidris alba*)
- Peregrine Falcon (*Falco peregrinus*)
- Bridled Tern (*Onychoprion fuscata*)
- Roseate Tern (*Sterna dougallii*)
- Australian Fairy Tern (*Sternula nereis nereis*)
- Rainbow Bee-eater (*Merops ornatus*)
- Southern Brown Bandicoot (*Isodon obesulus fusciventer*).

Based on the habitat available, the following species were assessed as having the potential to occur within the reserve:

- Black-striped snake (*Neelaps calonotos*)
- Baudin's Black Cockatoo (*Calyptorhynchus baudinii*).

An absence of suitable habitat meant that the following species are unlikely to be present within the reserve:

- Western Quoll (*Dasyurus geoffroi*)
- Southern Brush-tailed Phascogale (*Phascogale tapoatafa*).

Descriptions and habitat requirements of all species of conservation significance are provided in Appendix E.

3.8.4 Other Fauna

There are numerous other fauna species occurring in the reserve that are not classified as conservation significant and therefore not detected in the database searches. One species of local significance is the Southwestern snake-necked turtle (*Chelodina colliei*), the turtle has been identified to occur within the reserve by a Fish Survey in 2004 (Rose *et al.*) and an Aquatic Fauna Survey commissioned by the City (City of Rockingham 2014).

A survey specifically targeting the Southwestern snake-necked turtle was commissioned by the City in 2020. The results of the survey identified that Lake Richmond provides habitat to a healthy population of these turtles, with over 60 individuals recorded. The City will continue to monitor populations of this species across other wetlands in the City and take appropriate conservation actions, where required.

The Southwestern snake-necked turtle can be found between Hill River, 170km north of Perth, and Fitzgerald River National Park, east of Albany. It is locally significant as it is the only native freshwater turtle to occur in wetlands on the Swan Coastal Plain (Bartholomaeus 2015). A number of recent studies have identified a decline in southwestern snake-necked turtle populations across wetlands in proximity to developed areas (Santoro 2017; Bartholomaeus 2015; Giles 2008; Tysoe 2005; Dawson 2014; Dawson 2016; Bencini

Figure 16 - Southwestern snake-necked turtle

2016). Nesting turtles are known to venture away from their usual wetland habitat to find suitable habitat to lay eggs. In developed areas, this has resulted in turtles having to cross roads to find a suitable nesting site, exposing them to the risk of getting struck by a vehicle. Predation of eggs and hatchlings by feral animals such as foxes and cats has also been identified to be a major problem.

The implementation section of this Management Plan identifies surveying for *Chelodina colliei* as a matter of high priority. This survey will confirm the presence of the species within the Reserve, and additional management actions will be identified once the size and extent of the population has been established.

3.8.5 Black Cockatoo Habitat Assessment

The three species of Black Cockatoo endemic to the south-west; Carnaby's, Baudin's and Forest Red-tailed Black Cockatoo, are listed as likely or possibly occurring in the study. This indicates they utilise the habitat available for activities such as breeding, foraging and roosting.

Foraging Habitat

The field surveys identified 5.08 ha of good quality foraging habitat for Black Cockatoos within the reserve. The identified foraging habitat consisted primarily of Tuart trees (*Eucalyptus gomphocephala*) and grass trees (*Xanthorrhoea preisii*), both trees are known dietary items for all three Black Cockatoos (Johnstone and Kirkby 2011). Despite the high quality habitat values, no chewed nuts or cones were found to provide evidence of Black Cockatoo foraging.

Breeding and Roosting Habitat

Nine Tuart trees (*Eucalyptus gomphocephala*) were identified as potential breeding trees (trees with a DBH greater than 500mm). None of these potential breeding trees had visible hollows considered potentially suitable for Black Cockatoo nesting; however many vertical or trunk hollows are not visible from the ground. All of the potential breeding trees are located in the north-eastern portion of the reserve, adjacent to Fisher Street (Figure 18). A review of historical aerial imagery shows that the tuarts did not colonise the reserve until after the two inlet drains were constructed in 1968 (see Figure 17 for a comparison between the 1965 aerial and another photo of the same location taken in August 2018). It is assumed that the additional water brought by the drains helped to establish conditions favourable for Tuart growth.

Figure 17 - 1965 aerial and 2018 aerial

Tuart trees are considered to be a secondary or non-preferred breeding tree species based on recorded usage of tuart compare to the primary breeding trees, Wandoo and Salmon Gum, however, there are several records of Carnaby's Black Cockatoo breeding within the Tuart trees on the Swan Coastal Plain (Johnstone and Kirby 2011).

The Tuart trees recorded within the reserve also provide suitable roosting habitat for Black Cockatoos. Black Cockatoos roost in tall Eucalypts, usually close to an important water source or within a quality foraging area (SEWPaC 2012). Black Cockatoos usually forage within 6km of a night roost when not breeding (SEWPaC 2012).

3.8.6 Introduced Fauna

Domestic cats, domestic dogs and the Rock Dove were observed during the field surveys. The European Rabbit was previously recorded at the Reserve, but it was not recorded during the 2017 field survey. Despite not being recorded during the surveys, it is quite likely that house mice and foxes are present in the reserve.

Figure 18 - Black Cockatoo Habitat

3.9 Conservation areas

3.9.1 Regional Parks

DBCA manages multiple regional parks across WA, which comprise of land reserved for parks and recreation in the metropolitan area. The reserve forms part of the Rockingham Lakes Regional Park (RLRP). The RLRP is managed by DBCA in collaboration with the City.

Although it forms part of the RLRP, the Lake Richmond Reserve is managed by the City and the adjacent, Cape Peron Reserve, also part of the RLRP, is managed by DBCA.

3.9.2 Bush Forever

The Government of Western Australia's *Bush Forever* (2000) policy is a strategic plan for conserving regionally significant bushland within the Swan Coastal Plain portion of the Perth Metropolitan Region. The objective of Bush Forever is to protect comprehensive representations of all original ecological communities by targeting a minimum of 10% of each vegetation complex for protection (Government of WA 2000). Bush Forever sites are representative of regional ecosystems and habitat and have a key role in the conservation of Perth's biodiversity. The Reserve forms Bush Forever Site no. 358.

3.9.3 Environmentally Sensitive Areas

Environmentally sensitive areas (ESAs) are prescribed under the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004* and have been identified to protect native vegetation values of areas surrounding significant, threatened or scheduled flora, vegetation communities or ecosystems. An ESA covers the entire study area. This ESA is very large and extends away from the Reserve for two kilometers in all directions.

3.9.4 Ecological linkages

Ecological linkages play an important role in maintaining the diversity and vigour of ecological systems. They also enable native fauna to move through the landscape by providing continuous or near-continuous habitat. Linkages may occur as continuous stretches of habitat, or as a close network of reserves and remnant vegetation separated by short distances. Where the distance between habitats is great, the ability of flora and fauna to disperse is limited.

Many natural areas in the Perth metropolitan region, particularly on the Swan Coastal Plain, are small and fragmented due to increasing pressures from urbanisation and industrial development. Natural areas that connect or are adjacent to regionally significant areas provide valuable linkages that help to reduce the effects of threats on ecological systems (WALGA 2017). This increases the long-term viability of both regionally and locally significant natural areas.

Ecological linkages across the City's municipality were defined as part of a Natural Areas Technical Assessment undertaken by Eco Logical Australia in 2017. Ecological linkages were initially constructed as linear pathways joining reserves and larger patches of remnant vegetation. Paths were then expanded into 500m wide corridors. Corridors this wide were considered suitable given size of the City.

The Natural Areas Technical Assessment identified one ecological linkage running through majority of the study area which extends to the north of the study area through Tamworth Hill. Any natural areas within or contiguous with these defined ecological linkages were defined as 'linking vegetation'. The study area was also identified as supporting 'linking vegetation' that is greater than 4 ha in size.

The Natural Areas Technical Assessment identified that the reserve forms part of an important ecological linkage that connects areas of conservation value. This major green corridor runs from the coast at Cape Peron via Lake Richmond through to Lake Cooloongup.

3.10 Heritage

Aboriginal heritage

The City of Rockingham is situated within Nyoongar Country, an area that holds special significance to its traditional owners with many sacred sites occurring within the region (City of Rockingham 2015).

In Western Australia, the *Aboriginal Heritage Act 1972* protects places and objects customarily used by, or traditional to, the original inhabitants of Australia. A register of such places and objects is maintained under the Act, however, all sites are protected under the Act whether they have been entered on the register or not.

In Western Australia, the Aboriginal Affairs branch of the Department of Planning, Lands and Heritage manages the online Aboriginal Heritage Enquiry System, which identifies any registered Nyoongar heritage sites within the vicinity of the search area. A search of this database confirmed Lake Richmond as a registered site, for its historical significance as a ceremonial, spiritual and camp site.

A summary of Indigenous heritage sites within and surrounding the reserve is presented in Table 8 below.

TABLE 8: Local Indigenous heritage sites.

Site ID	Name	Type	Location
15974	Lake Richmond	Ceremonial, Camp & Spiritual Significance	Lake Richmond waterbody
22888	Mooribirdup Ceremonial Grounds	Ceremonial, Camp, Named Place & Plant Resource	530m northwest of Lake Richmond waterbody
31265	Sister Kate's Children's Home (Summer Camp)	Historical Camp, Mission, Water Source	1.3km northwest of Lake Richmond waterbody
3471	Rotary Park, Rockingham	Mythological	476m north of Lake Richmond waterbody

Lake Richmond is also included on the state register of Other Heritage Places (site 352) for having "Fish Traps - Man-made structure".

European Heritage

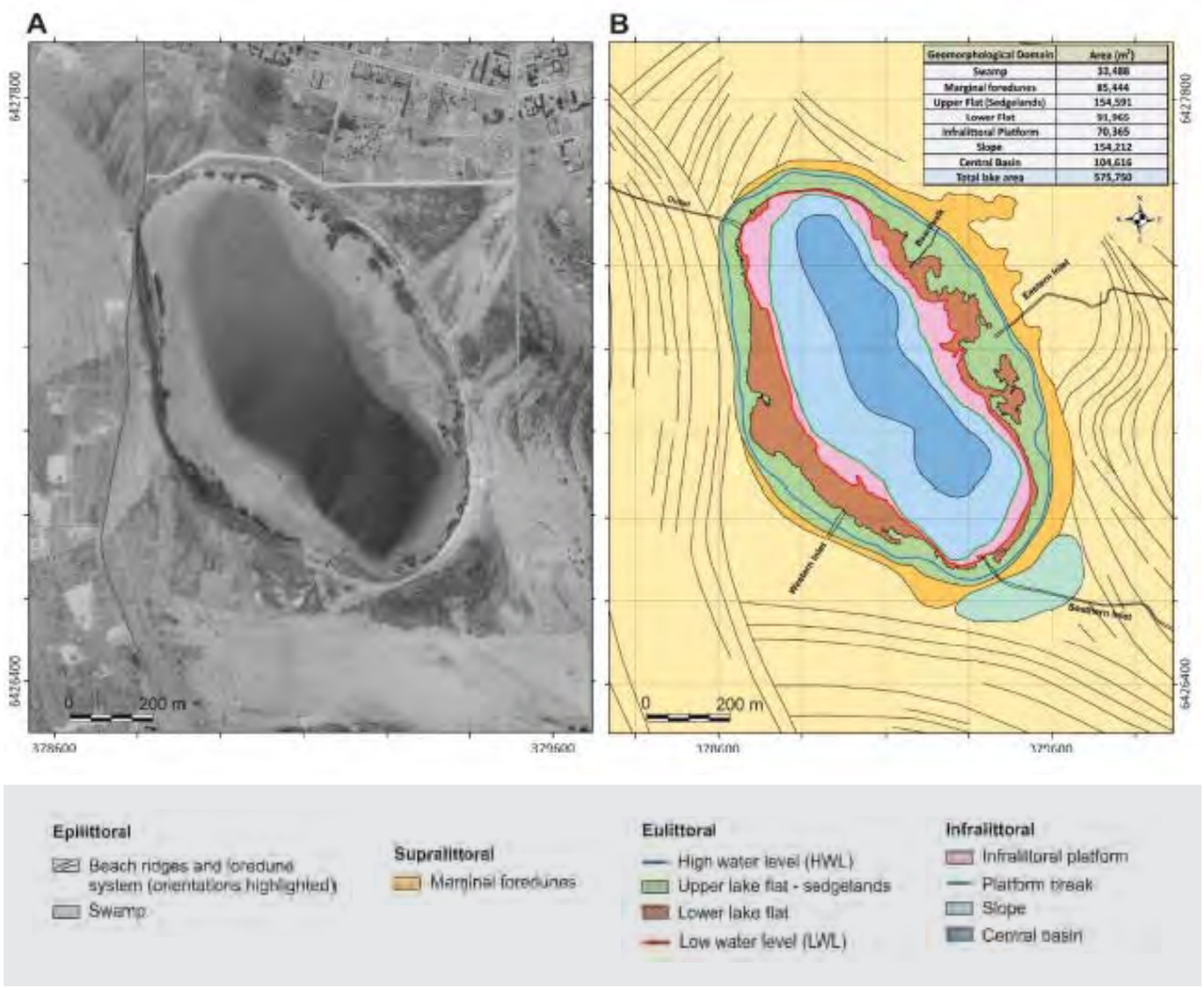
The Heritage Council and the State Heritage Office manage an online database called Inherit. Inherit contains comprehensive information about cultural heritage places listed in heritage inventories at all tiers of Government as well as non-government lists and surveys. The Western Australian Heritage Register recognises the cultural and environmental value that Lake Richmond has to the State, and gives statutory protection for its conservation into the future.

Figure 19 - Registered Indigenous Heritage Sites

3.11 Thrombolites Distribution and Health

Figure 20 shows the mapped geomorphological domains at Lake Richmond. These domains are referred to frequently and describe the distribution of the microbialites across the lake.

Figure 20: Geomorphic Domains



(A) November 1953 aerial photography (source: Landgate) showing Lake Richmond area, surrounding beach-ridges and dunes prior to urbanisation. Note the wide lake flat and infralittoral platform along the east and west margins of the lake, in contrast to the narrow littoral on the north and south. (B) Map illustrating the geomorphic domains identified in the area and described in the text (Guerreiro, in prep).

3.11.1 Historical Microbialite Distribution

Unfortunately no reliable data on the historical distribution of the microbialites exists prior to the PhD study that was undertaken in 2013.

Between 2013 and 2015, there was visible microbialite growth in the lower portions of the lake flat and in the infralittoral platform (Guerreiro, in prep).

Field observations identified that water availability is critical to the persistence of the microbial mats, this can be through immersion in lake water or in areas where wet conditions are maintained by groundwater discharge.

Radiocarbon dating was undertaken on the microbialites on the south eastern margin of the lake and it was determined that the historical growth rate of the structures ranged from 0 to 1.2mm a year. Unfortunately, carbon dating can no longer be used to ascertain if accretion is occurring, due to the oversaturation of carbon introduced into the atmosphere by nuclear testing in the 20th century.

The study determined that it is unlikely that all of the observed morphologies of microbialites at Lake Richmond were formed by the microbial mats currently in the lake. It is likely that many morphologies were formed during the Holocene when water and solute balances were considerably different to what they are today. It appears that recent activity is greatly reduced in spatial extent and intensity as compared to earlier in the Holocene era.

3.11.2 Current Microbialite Distribution

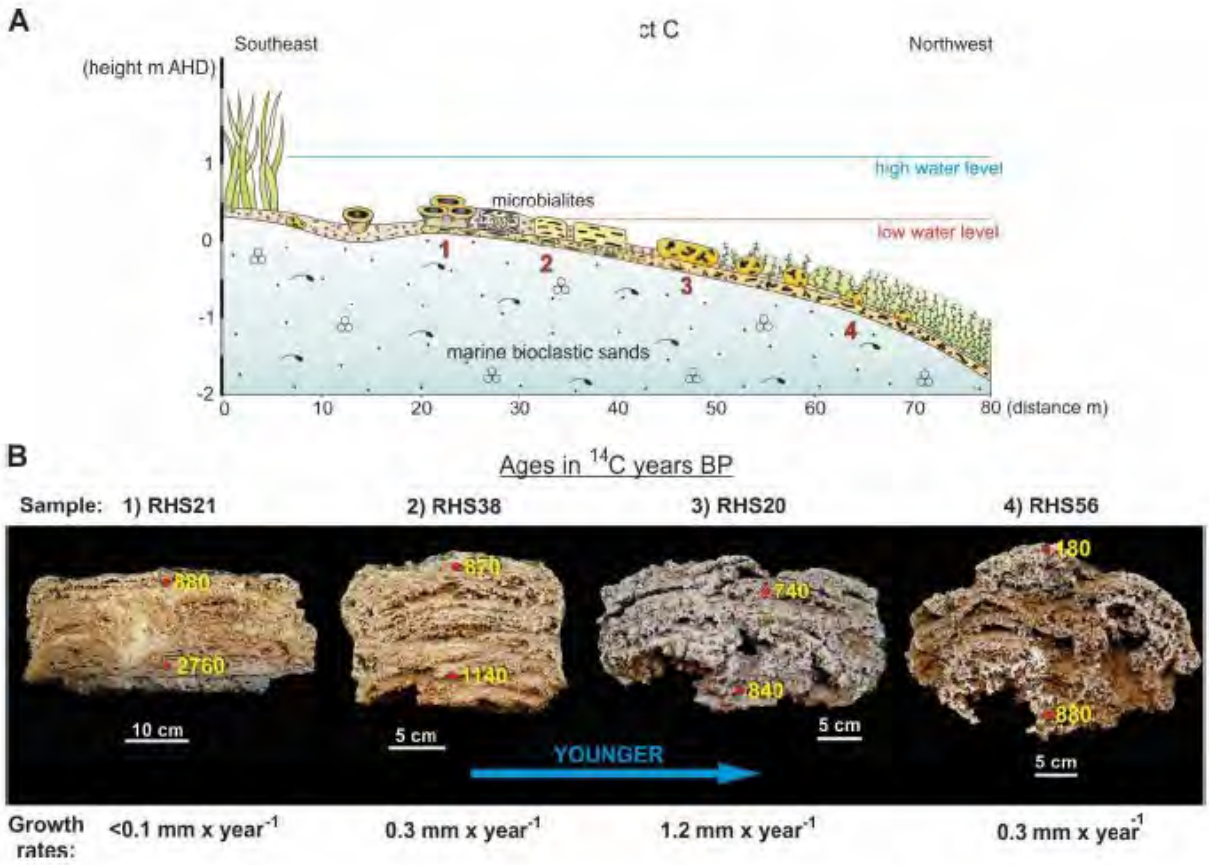
This 2017/18 thrombolite mapping study recorded various forms of mirobialites on all sides of the lake. The microbialites occupy an area extending from the seasonally inundated near shore environment to at least 6m water depth. This area of occupancy is approximately 150m in width and is covered by a microbialite pavement, from which domal thrombolites are able to grow.

The north and south ends of the lake demonstrate the highest density of microbialite structures, while the east side contains lower bioherms (mounds). The bioherms are currently inactive but appear to be the most recently active formations. The west side of the lake is dominated by coarse carbonate rubble which is likely to have formerly been part of historical microbial structures.

During the field study, only the green, smooth microbial mats were seen across the littoral zone with differentiated growth patterns caused by air because the lake water level never receded sufficiently for exposure to occur.

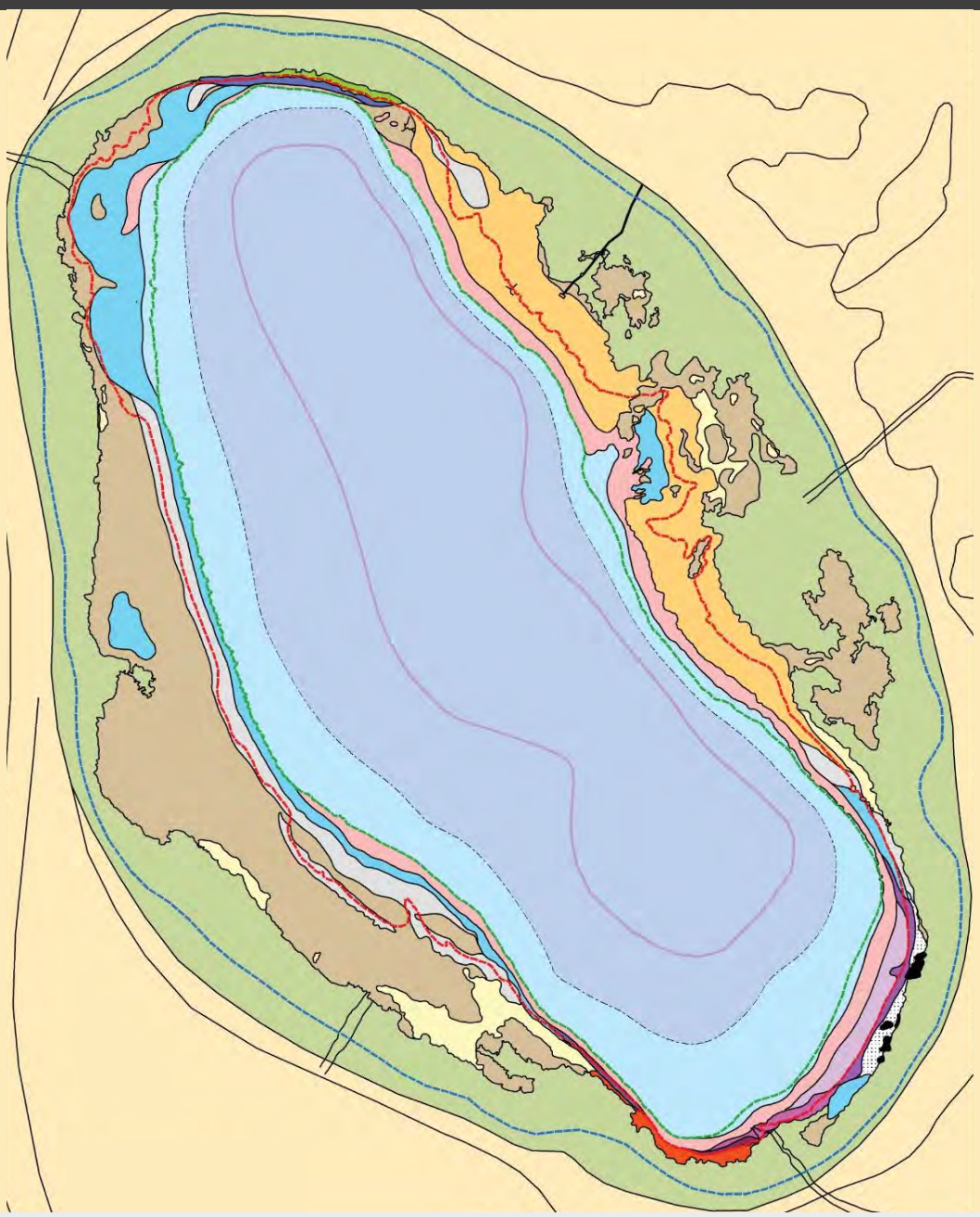
The distribution and morphology of the microbialites were found to be determined by a series of environmental controls relating to the hydrologic, topographic, geochemical and biological conditions of the lake. For example, the height of the microbialite is directly influenced by the water level, with taller structures found in the deeper parts of the lake.

Figure 21: Lake Transect



(A) Transect at the southeastern margin of Lake Richmond; red numbers indicate the location of bioherms shown in (B). (B) Microbialite bioherms and respective radiocarbon ages in 14C years BP shown as yellow numbers. Calculated growth rates assume a linear growth rate between 14C dates which is likely a simplification (Guerreiro, in prep).

Figure 22 - Microbialite Distribution



Aeolian

- Mixed skeletal and quartz sands
- Average high water level (1.07m AHD)

Lacustrine:

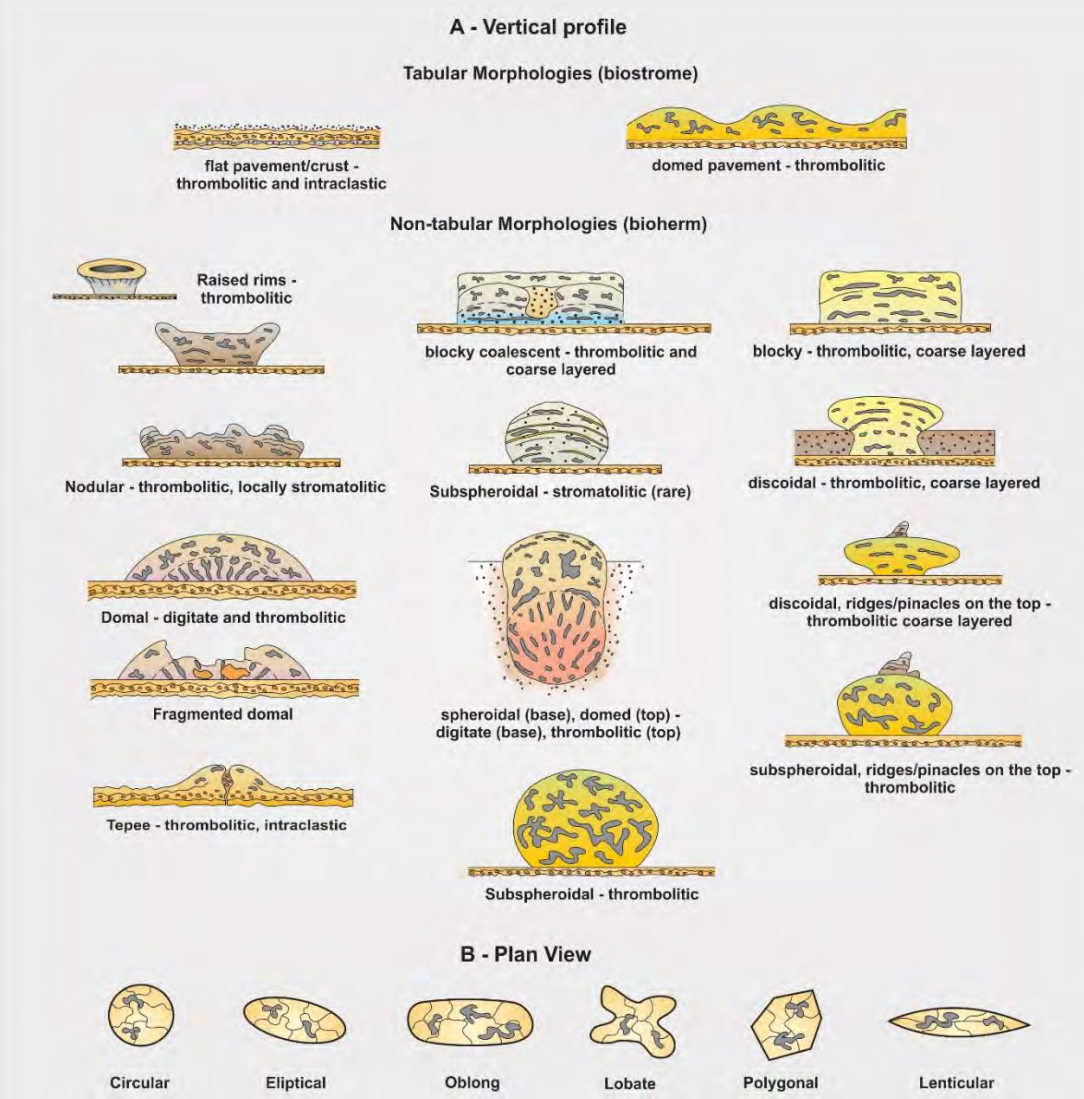
- Intraclastic organic-rich sand (peat) - Sedgelands
- Intraclastic sands
- Poorly preserved bioherms
- Coalescing subspheroidal and flat-top terraces
- Fragmented domal bioherms
- Bioherms with raised rims
- Buried bioherms
- Blocky bioherms (polygonal shape)
- Nodular bioherms
- Average low water level (0.26m AHD)
- Flat pavement
- Domal bioherms
- Domed pavement
- Discoidal bioherms
- Composite bioherms (subspheroidal or discoidal with nodules, ridges or pinacles on the top)
- Blocky bioherms (elongated, perpendicular to the littoral)
- Subspheroidal bioherms
- Slope break
- Brown, organic-rich sandy-mud and dense macrophyte cover - microbialites possibly present underneath
- Central basin
- Brown, organic-rich mud and floculent microbial mat

N

0 50 100 150 200 250

Metres

Figure 23 - Types of Microbialites



3.11.3 Microbialite Health

A number of important hydrological processes which have been identified to be critical to forming microbialites were absent at Lake Richmond. The perpetually high lake level is inhibiting groundwater discharge as groundwater and lake water level were recorded as being at similar heights for the duration of 2018. When compared to some of the other microbialite forming sites in Western Australia (ie. Lake Preston and Lake Clifton), the absence of significant dune systems adjacent to the shoreline reduces the available hydraulic gradient to drive groundwater discharge into the lake. This means that the Lake Richmond system is significantly more susceptible to disruption if minor changes occur to the remaining components of microbialite formation.

None of the mats or structures were identified to have any active sulfur bacteria present. In addition, no calcification of Extracellular Polymeric Substance was observed. The absence of both of these processes strongly indicates that the required formation chemistry has not been occurring for some time. A laboratory test was undertaken to measure microbialite carbonate deposition and the results indicated the microbialites are currently inactive and not precipitating carbon.

The presence of sulfur bacteria in the basal lamina of microbial mats is typically used a measure of microbialite health (City of Rockingham 2018). No sulfur reducing bacteria activity was observed throughout the Thrombolite Assessment, with only loose granular carbonate deposition seen upon examination of the microbial mats.

Additionally, it appears that recent emergent vegetative growth has allowed for increased sediment accumulation around the periphery of the lake. This has reduced the area occupied by near shore pools where bacterial sulfur cycling enriches groundwater that is discharged through the microbial mats, meaning that the microbialites have less exposure to the required formation chemistry.

It appears that in its current condition, Lake Richmond has a very limited ability to form microbial carbonate in anything other than a very small capacity.

Despite these findings, it should be noted that the possibility of the continued formation of the Lake Richmond microbialites should not be excluded. Other studies (Whitehead and Vogwill) have identified that carbonate deposition only occurs under a specific set of climatic conditions. For example, the Lake Preston microbialites are most active in years when the El Niño weather cycle is present and at the onset of the rains in autumn. It should also be noted that the significant January rainfall event prevented the microbial mat from completing a normal seasonal growth cycle.

The Hydrology and Water Chemistry Assessment determined that the lake water is currently dissolving carbonate due to the current mild acidity (rainfall is mildly acidic) of water discharging from the drain. Ideally, water discharging to the lake would be dominated by groundwater rich bicarbonate through exposure to limestone to promote carbonate precipitation. Carbonate precipitation is a critical process for microbialite growth, the current water chemistry is likely to be having a detrimental effect on the existing structures.

3.12 Impact of Herbicides on Lake Richmond Microbial Mats

3.12.1 Microbialite Health

Fusillade

Of the tested herbicides, Fusillade was shown to be the most toxic to bacteria and other species within the microbial community. As an oil-based product, Fusillade forms an emulsion when mixed with lake water. As such, the risk of floating herbicide droplets impacting non-target species is high when applying fusillade in wet areas. Fusillade is not considered suitable for controlling invasive grasses at Lake Richmond.

Combination Application of Glyphosate, Surfactant and Red Marking Dye

This combination was the most toxic application to higher taxa over the 14 day trial. The dye stained carbonate grains and stained the EPS within the microbial mat profile, the staining had not diminished by the 60 day endpoint of the study. The use of dye may adversely impact the visual amenity of the lake and will not be used. The use of a surfactant was found to cause high mortality rates in the taxa above the bacterial level.

Glyphosate

Glyphosate alone showed the least impact overall to the species composition and resulted in the lowest mortality rates. Species within the mat repopulated the mat through their egg and cyst stages after glyphosate application, this did not occur when fusillade was applied. These life stages also survived the period of microbial mat desiccation that occurs during summer to repopulate the lake in the following season.

However, glyphosate application triggered prolific productivity in some heterotrophic bacteria and Lyngbya, a toxic undesirable cyanobacterium that otherwise occurs in very low population densities in the habitat.

The visual evaluation suggests that glyphosate is the herbicide of choice, but its application would be subject to strict seasonal timeframes to minimise the risk of causing a Lyngbya bloom or harm non target species.

3.12.2 Results of DNA Sequencing and Analysis

Observations Prior to the Application of Herbicides

DNA analysis identified 243 bacterial families in the microbial mat systems prior to the application of herbicides.

Fusillade

Fusillade application was found to have the greatest effect on abundance of specific species. Species in the Oscillatoriales order, which includes Lyngbya, and the Chroococcales order, were found to increase in abundance after a high dose of fusillade was applied. Fusillade application was seen to increase the abundance of functions which are likely to have negative impacts on the health of mat communities. Such functions include the production of chlorophyll degradation and the metabolism of sugar-phosphate stress regulation. These processes can limit photosynthesis in the mat system and put the microbialites under environmental stress.

The effect on microbial functions was seen to increase with increases to the concentration of applied fusillade.

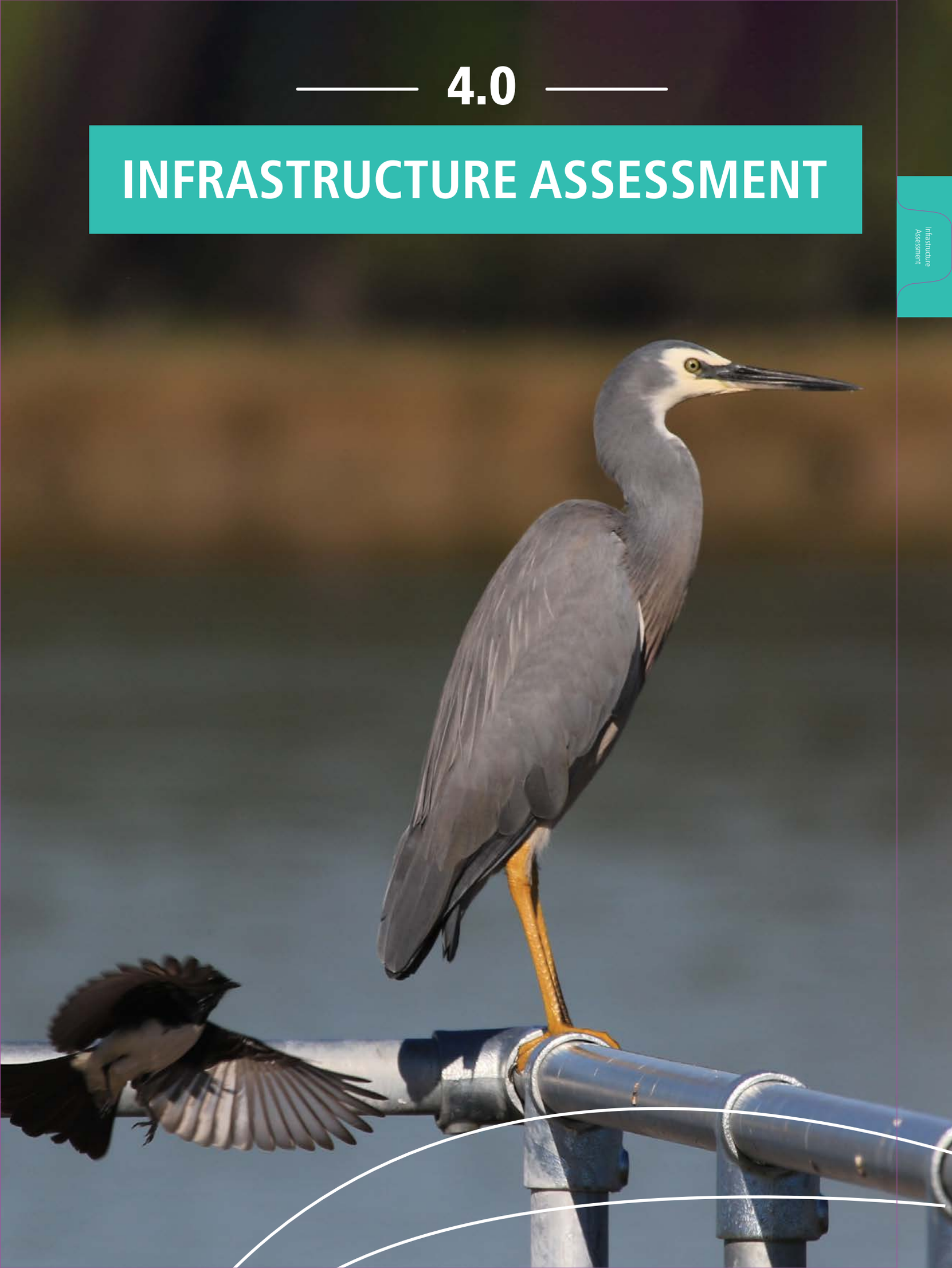
Glyphosate

The taxa that were identified to proliferate after the application of fusillade, were found to be unaffected by the addition of glyphosate (with or without the combination of dye and surfactant).

Glyphosate also had a lesser effect on the functioning of the mat communities, when compared to fusillade. Overall, the negative effects caused by applying glyphosate were less pronounced than the negative effects caused by applying fusillade. This is supported by the observations made during the visual assessment.

4.0

INFRASTRUCTURE ASSESSMENT



4 Infrastructure Assessment

Well maintained and appropriately located infrastructure plays an important role in ensuring recreational uses do not adversely impact upon conservation values. The existing site infrastructure provides visitors with a picnic area, bushwalking trails, a boardwalk over the lake and two observation decks. Existing infrastructure is shown on Figure 27 and all the locations for recommended repairs and replacements to existing infrastructure are shown on Figure 29.

4.1 Fencing

Fencing of sensitive areas is important to prevent undesirable impacts from uncontrolled access, such as trampling of vegetation and the potential spreading of weeds. Fencing is installed around the majority of the reserve and is predominantly in good condition. Despite this, a total of 284m of post and wire fencing has been identified for repair as it is in poor condition and does not provide adequate restrictions to unauthorised access to conservation areas (Figure 29). Examples of the types of fencing used at the reserve are displayed in Table 9, below.

TABLE 9: Reserve fencing

Type of fencing	Image
Green plastic chain link fence with wooden posts	
Black plastic chain link fence with black metal posts	
Metal post and wire fence	
Wooden post and wire fence	
Wooden post and wire fence with wooden top rail	

4 Infrastructure Assessment (continued)

4.2 Access

There are 15 gates providing pedestrian and vehicular access to the reserve. All gateways are in good condition, with little to no damage apparent. Five gates in the reserve have been designed to prevent cars from gaining access to the areas of vegetation (see Figure 24 below). Whilst these gates are effective in preventing access to cars, they do not prevent access to motorbikes. As motorbikes can potentially endanger park users and impact upon wildlife, upgrades to these gates will seek to inhibit their unauthorised access.

Figure 24: Gate restricting reserve access to cars

4.3 Paths and Tracks

Pathways and tracks are well connected within the Reserve, providing a circuit around the lake and good access to the existing facilities. There are a range of formalised path types in the reserve, including; well-maintained concrete surfaces, limestone walking tracks and compacted soil access tracks (Figure 28). None of the formalised pathways are in need of being upgraded as they are all in good condition.

Approximately 1.112km of informal tracks are located in the northeast of the reserve (Figure 25). These tracks are facilitating unstructured recreation activities for off-road bikers and include ramps and jumps. These tracks need to be managed to ensure that uncontrolled access does not lead to further degradation of the reserve. The tracks will be revegetated and fenced off immediately to prevent continued unauthorised use.

The creation of unauthorised tracks can lead to weed invasion, erosion and degradation of the surrounding areas. Creation of more tracks should be discouraged and community awareness programs should include information on the potential impacts of unauthorised tracks.

Figure 25: Dirt bike track

4.4 Signage

The condition of all signs within the reserve is outlined in Appendix I and the locations of these signs is displayed on Figure 28. Most of the Reserve is well signed, with the signs in good condition.

There is opportunity for additional signage to help further discourage unauthorised access into the reserve. Any new signs will be designed to align with the Rockingham Lakes Regional Park Sign System.

Figure 26a: Good Condition Signage

Figure 26b: Poor Condition Signage

4.5 Other Park Infrastructure and Facilities

The remaining park furniture comprises of:

- Park shelters
- Rubbish bins
- Seats and benches
- Picnic tables
- A barbeque
- Observations decks.

The majority of the remaining park furniture was found to be in good condition and appropriately located away from the areas of conservation value. There is an opportunity to install exercise facilities in the cleared area to the north of the reserve to enhance the recreation value of Lake Richmond.

The type and condition of all park furniture is presented in Appendix I and their locations shown on Figure 27. Management recommendations are provided in the Implementation section of this report.

Figure 27 - Existing Infrastructure

Legend

- Main attraction areas
- The Reserve
- Transperth transport service

General infrastructure features

- Bin
- Fire hydrant
- Observation deck
- Parking
- Pedestrian walkway/bridge
- Sheltered tables and BBQ facility
- Seat
- Access locations

Fence description

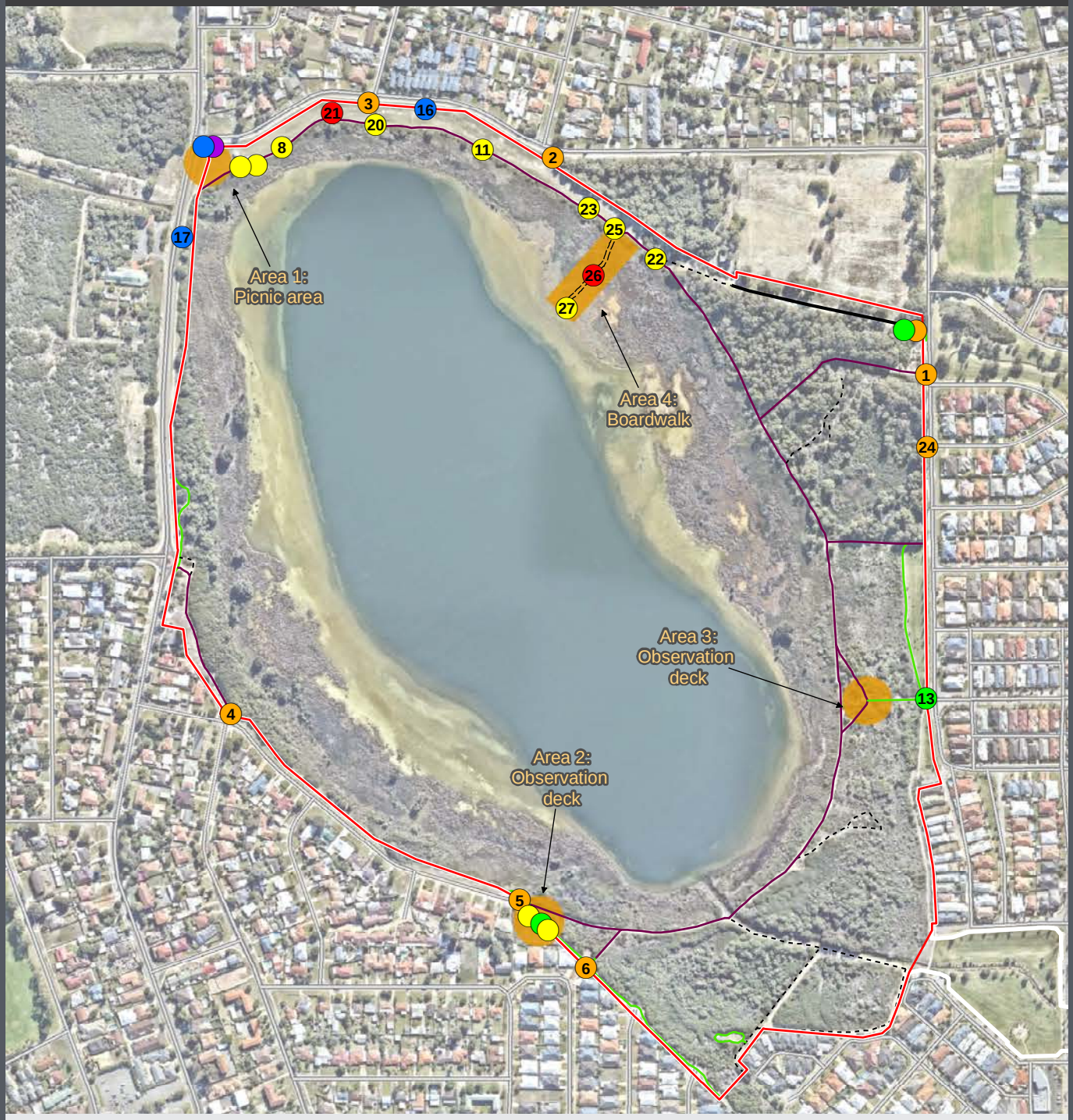
- Post and wire fencing
- Black plastic netting with metal black structure
- Green plastic netting with wooden pillar structure
- Wire fencing with wooden piller structure
- Wooden structure fence

N

0 50 100 150 200 250

Metres

Figure 28 - Existing Signage and Pathways



Legend

- Main attraction areas
- The Reserve

Pathway type

- Bitumen Road
- Boardwalk
- Compact sand path
- Concrete path
- Soil tracks

Existing signage

- Directional
- Educational
- Hazard
- Interpretative
- Regulatory
- Reserve Name

N

0 50 100 150 200 250

Metres

Figure 29 - Infrastructure Repairs and Upgrades

5.0

THREATENING PROCESSES

5 Threatening Processes

A key objective of this Plan is to identify management actions aimed at removing, or limiting the effects of, threatening processes. The processes that threaten biodiversity conservation can vary according to the unique biophysical characteristics of the region. As such, the actions identified in this section of the Management Plan will be specifically targeted to the Lake Richmond environment and will be implemented by the Parks Services Team to address the following threatening processes:

- **Weed invasion**
- **Water quality impacts**
- **Feral animals**
- **Inappropriate access**
- **Vandalism and rubbish dumping**
- **Climate change**
- **Fire**
- **Diseases and pathogens.**

5.1 Weed Invasion

Invasive species, such as weeds, present the biggest threat to biodiversity after direct habitat loss (DotE 2014).

Weeds may impact on the biodiversity values within the reserve by:

- Outcompeting native species for nutrients water, space and sunlight
- Restricting the growth of native plants and thrombolites by smothering them and restricting photosynthesis
- Roots penetrating the thrombolites and facilitating their breakdown;
- Reducing habitat for native animals
- Altering fire regimes.

The major vectors for the introduction and spread of weeds in the reserve includes:

- Edge effects from roads and cleared areas
- Dumping of rubbish
- Escape of garden plants and grasses
- Human and animal transport (particularly through unauthorised tracks)
- Asexual reproduction following mechanical slashing
- Dispersal through waterways, including the lake water body and the drains
- Transport by wind.

Management Actions

Management actions will seek to remove/reduce existing weed infestations, minimise the spread of weeds and limit the introduction of new weeds as much as practicable. Particular focus will be given to removing all occurrences of Saltwater Couch (*Paspalum vaginatum*) from the near-shore environment and eradicating Bridal Creeper (*Asparagus asparagoides*) from the reserve.

5.2 Water Quality Impacts

The results of the Microbialite Mapping and Hydrology Report determined that the Lake Richmond microbialites are not currently accreting due to the unfavourable water conditions and hydrology. It was identified that a number of factors needed to be changed to improve the potential for the microbialites to continue to grow, whilst still maintaining a healthy ecosystem. These factors are heavily influenced by the quality of the water entering the lake via the drains. The Implementation section of this Management Plan details how the following parameters will be managed to ensure impacts to aquatic life that are caused by poor water quality, are minimised.

1. Availability of sulfide
2. Concentration of Total Dissolved Solids (TDS)
3. Lake level
4. Groundwater level
5. Nutrient and pollutant concentrations.

5.3 Feral Animals

Potential Impact

Feral animals can detrimentally impact upon the reserve by:

- Predation on native fauna
- Competing for food and shelter
- Habitat destruction
- Introducing and spreading diseases.

Management Objectives and Actions

Management objectives include reducing the occurrence and spread of feral animals as well as enhancing the habitat value for native species. This will be achieved through the implementation of the management actions listed in the Implementation Table in Section 7.

5 Threatening Processes (continued)

5.4 Inappropriate Access

Potential Impact

Inappropriate access can result in habitat degradation or loss through trampling of native vegetation. Trampling of vegetation can also lead to changes in flora composition through introduction of non-native species and vegetation cover. Trampling impacts can also lead to soil erosion which can affect wetland health.

Management Objectives and Actions

The objective is to provide safe, convenient and structured access within the reserve. Management actions will seek to restrict unauthorised access to conservation areas and rehabilitate informal tracks. Actions are listed in the Implementation Table in Section 7.

5.5 Vandalism and Rubbish Dumping

Potential Impacts

Vandalism and dumping of rubbish can reduce the visual amenity of the reserve and the overall recreational value to the community. It can also facilitate the spread of weeds throughout the reserve.

Management Objectives and Actions

The management objective is to enhance the recreational and amenity value of the reserve by providing an adequate number of rubbish bins and restricting unauthorised activity within the reserve.

5.6 Climate Change

Potential Impact

There is consensus amongst climate scientists that increasing levels of greenhouse gases produced by human activities are likely to be contributing to global warming. Changes observed over the 20th century include increases in global average air and ocean temperature, widespread melting of snow and ice and rising global sea levels. The extra heat in the climate system also has other impacts such as affecting atmospheric and ocean circulation, which influences rainfall and wind patterns (Department of the Environment and Energy 2015).

Records show that the decade of 2001-2010 was the world's warmest decade and in Australia, each decade has been warmer than the last since the 1950s (DoTEE 2015). Scientists predict that as the unique biodiversity in south-western Australia are particularly sensitive to changes in temperature and rainfall, the capacity of these natural systems to adapt to climate change is limited.

Management Objectives and Actions

The City's management approach acknowledges the consensus that healthy ecosystems are likely to be more resilient in the face of climate change (DoTEE 2017). The actions outlined in this Management Plan will seek to provide species and communities with an opportunity to adapt to changing climatic conditions by:

- Managing threatening processes
- Promoting species diversity through revegetation
- Continuing to monitor the Lake Richmond ecosystem in order to detect changes and take informed action as required.

5.7 Fire

Potential Impact

The vegetation surrounding Lake Richmond contains a large amount of fuel for bushfires which creates a fire prone environment and as such, there is a long history of fires occurring within the Reserve. The FireWatch database lists a total of 34 fires taking place between 2000 and 2007. The Department of Fire and Emergency Services records also show that a further 18 fires occurred within the Reserve between 2007 and 2017.

Fire impacts on native vegetation in a variety of ways, depending on the scale of the fire and the vegetation. The impacts of fire on vegetation can be very complex with both positive and negative effects. Clearing of vegetation for bushfire risk mitigation purposes can have a detrimental impact on natural systems by reducing the areas of available habitat, reducing shelter for native fauna species and increasing weed invasion. Potential negative impacts of fires in the Lake Richmond reserve include:

- Loss of human life
- Damage to native vegetation and fauna habitats
- Destruction or damage to infrastructure and nearby homes and buildings
- Air pollution.

Management Objectives and Actions

To achieve an appropriate balance between bushfire risk management measures, biodiversity conservation, environmental protection and landscape amenity values , in accordance with the City's Bushfire Risk Management Plan.

6.0

LANDSCAPE CONCEPTS

6 Landscape Concepts

With consideration for the recommended management actions in this plan, a landscape concept has been developed to highlight a number of potential upgrades which would improve the visual amenity and recreational capacity of the Lake Richmond reserve. The recreational sector, in the northwest of the reserve, has the potential to become a focal point for community recreation that will help meet the overarching objective to 'encourage a range of sustainable recreational experiences through suitably located infrastructure and services.'

LEGEND

Existing Water Corporation Reserve. Any proposed works within the easement must be approved by the Authority.

Proposed revegetation areas, refer to the Management Plan for details regarding plant species and densities.

Investigate opportunities to revegetate existing stormwater drains and create living streams to improve water quality, wildlife habitat and install interpretation signage.

New Street Trees (*Agonis flexuosa)* Weeping Peppermints on Lake Street

Upgrade existing pathway from the picnic node to the boardwalk with limestone coloured concrete or similar hardstand, located to avoid seasonal inundation and accommodate universal access. Second priority is to provide access to Fisher Street and the future public open space adjacent the development site. Location and design of footpath (is to be separate to the asphalt access driveway) to be confirmed by Water Corporation.

Existing tracks to be upgraded with bitumen stabilised limestone, with priority given to completeing the 'main loop' lake track and as funding allows.

Possible new seating opportunity to take advantage of the topography and views across the lake.

Existing seats to be removed/relocated due to overgrown viewpoints

Existing vehicle Access gate / pedestrian access-way (to prevent unauthorized motorbikes etc into the reserve)

1 **Strategic planting [within Water Corporation Reserve]**
Shade trees installed to improve usability of grass areas for picnics and recreation.

2 **Stormwater Management and Potential Bio-filtration Planted Areas**
Investigate existing stormwater recieved from adjoining streets (catchments, sizes, volumes) with the view of amalgamating the stormwater outlets to discharge into localised bio-filtration planted areas and/or redirect flows outside of the Lake Richmond catchment in consultation with Water Corporation.

3 **Improve footpath link to Naragebup**
Improve pedestrian footpath link to Naragebup - Rockingham Regional Environment Centre, including footpath to a center median pedestrian refuge

4 **Potential On-Street Carparking**
Investigate potential for on-street carparks along Fisher and Lake Streets, to support increase visitor use of the reserve. This will require realignment of the existing footpath.

5 **Unirrigated Turf and Trees to 'low threat' standard**
Unirrigated turf with specimen shade trees planted minimum 10 metre centres along pathway, treatment to be confirmed by bushfire risk consultants.

6 **Safety Bay Road - Street trees**
Install new street trees (*Eucalyptus gomphocephala* - Tuarts) along Safety Bay Road. Investigate removing areas of grass and replace with revegetation planting where appropriate.

7 **Existing Water Corporation Compound**
Existing Water Corporation compound accessed from Fisher Street via an existing asphalt driveway.

8 **Relocated New Picnic Node**
Relocate existing picnic node out of the existing Water Corporation Reserve and replace with new infrastructure - see detailed concept drawing.

9 **Possible Secondary Seating Node**
Possible additional seating node with picnic table and seating to provide views north over the Lake. Investigate possible shelter at this location in the long term. Consideration must be given to the visual impact a shelter would have from other view points along the lake loop track.

SIGNAGE STRATEGY
Lake Richmond is part of the *'Rockingham Lakes Regional Parks'* and as such the Regional Parks Signage Manual sets out requirements for signage in the Reserve. The following identifies possible new sign locations within the Reserve.

New Regional Parks Primary Entry sign

New Regional Parks - Secondary Entry Sign

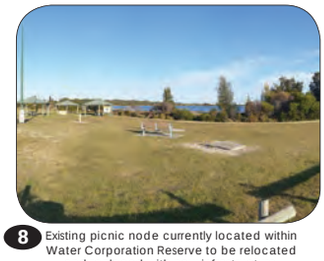
New Regional Parks - Boundary sign

New Regional Parks - Trail head sign for interpretation

Existing Regional Parks - Interpretation sign

2 Existing stormwater outflow from Lake Street into grass area to be enhanced into a bio-filtration planted area with nutrient stripping plants to slow and treat stormwater.

6 New Street Trees (*Eucalyptus gomphocephala*) Tuarts on Safety Bay Road enhancing the pedestrian experience and creating shade.

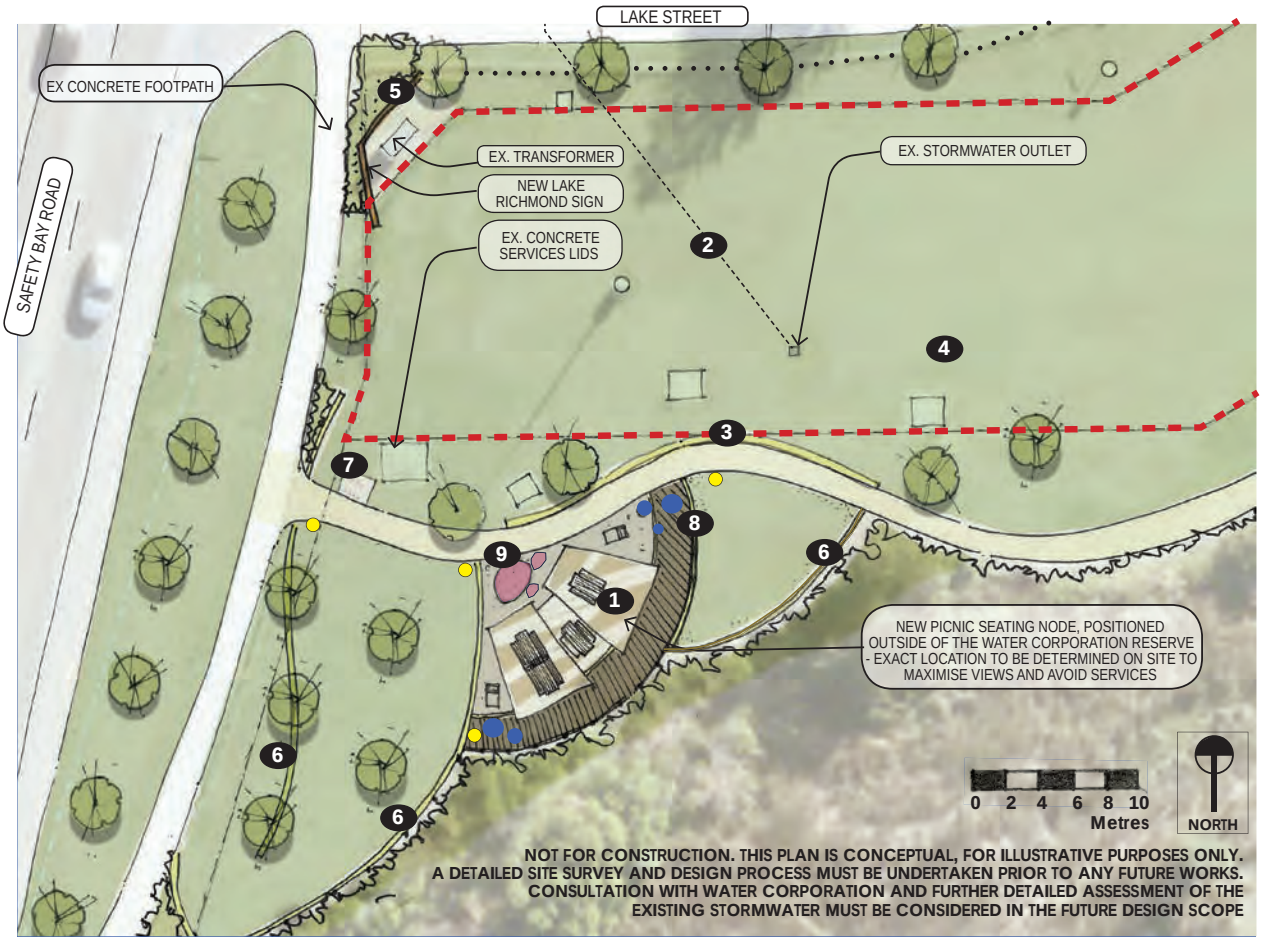


8 Existing picnic node currently located within Water Corporation Reserve to be relocated and replaced with new infrastructure. Final location to be determined on site. See Detailed Concept Plan.

9 Possible secondary new seating node located to take advantage of the north facing views over the lake.

6 Landscape Concepts (continued)

6 Landscape Concepts (continued)



LAKE RICHMOND - PICNIC NODE

LEGEND

Water Corporation Reserve
All major infrastructure to be located outside the reserve, unless otherwise agreed upon by all parties.

Existing Grass Area

New bollards
New timber bollards to Lake Street boundary. Bollards to be removed from Safety Bay Road interface and replaced with street trees.

New footpath link to Existing Boardwalk
New limestone coloured concrete footpath or similar (2 metres wide). Realign path where necessary to avoid seasonal inundation.

New composite decking platform
Decking area with leaning rail to provide views to the Lake and vegetation, while protecting the Lake's edge.

New specimen trees
Mix of *(Eucalyptus gomphocephala)* Tuart and (*Agonis flexuosa)* Weeping Peppermint trees.

New low groundcover planting
To reflect the Lake Richmond '*sedgeland in holoscene dune swales in Southern Swan coastal plain*'.

Potential lighting to Picnic node
Investigate potential pole top lighting to picnic node only to improve surveillance and security.

Exposed aggregate paving
Picnic node to have feature exposed aggregate paving.

1. New custom designed shelter with laser cut out details of thromoblites and the lake, fixed to the roof. The space to accomodate several different sized picnic tables (for larger groups) and two BBQS.
2. Investigate existing stormwater outlet within the grass area near the picnic node and determine if possible to relocate the outlet downstream from Lake Richmond.
3. New limestone block wall, 450mm high that functions as a bench seat for larger gatherings and school groups.
4. Remove existing infrastructure (3 shelters and picnic settings and bbq). Relocate existing memorial seat. Salvage materials where possible. Retain bush poles (from shelters) for reuse within the reserve as possible art pieces, which could form a community art project.
5. New Lake Richmond sign and entrance planting to screen existing western power transformer. Sign to be in accordance with the Regional Parks Signage Manual.
6. New flush limestone block edging, finished level with surroundings.
7. New bicycle racks at entrance of picnic node.
8. New composite bench circular seating, with bright colours and signage elements telling the Lake Richmond thrombolites story.
9. Rubber softfall mound replicating the form of the Lake Richmond thrombolites, creating an element of surprise and interest.

6 Landscape Concepts (continued)

LAKE RICHMOND LANDSCAPE CHARACTER

- In order to enhance Lake Richmond's character, it is important to maintain consistency of all infrastructure and ensure that any upgrades are designed and considered as part of the Management Plan.


Park furniture corten steel with composite timber battens


Opportunity for high bench type seating to provide views over the Lake


Custom designed shelter to accommodate a range of picnic table sized settings and includes unique design cues from Lake Richmond


Perforated steel elements inspired by Lake Richmond flora and fauna, inset into the shelters roof


Low limestone wall for seating


Composite timber platform provides interface to the Lake edge and connection to vegetation


Composite circular seating benches provide colour and potential for activities marked into the benches


Example of a new Lake Richmond Park Entrance Signage, in accordance with the Rockingham Lakes Regional Parks Signage Manual. A corten steel vertical element screens the Western Power Transformer and is enhanced with low growing planting

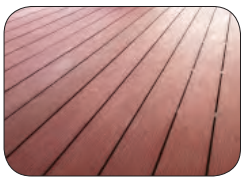

Agonis flexuosa - Weeping Peppermint


Eucalyptus gomphocephala - Tuart

MATERIALITY


Corten Steel


Limestone coloured concrete


Composite Timber


Exposed Aggregate Concrete Boral 'Southern Cross'


Rockingham Lakes Regional Park Colour Palette

PLANTING


Calothamnus quadrifidus


Xanthorrhoea - Grass Trees


Ficinia nodosa


Acanthocarpus preissii


Juncus kraussii

7.0

RECOMMENDATIONS AND IMPLEMENTATION

7 Recommendations and Implementation

7.1 Weed Control

The ultimate objective for rehabilitating areas of degraded vegetation is to remove any invasive weeds prior to revegetating the site with appropriate native species.

A weed control program for preparing a site for revegetation has been prepared by the Department of Water and Environment Regulation. Key recommendations are as follows:

- Ideally one or two years before planting or seeding, a broad spectrum herbicide should be applied to the revegetation area
- A follow-up application in autumn is also required
- A third spray can be applied 10 weeks after the second spray to control opportunistic weeds
- A final spray is required just before planting.

TABLE 10 - Weed control methods

Species	Common name	Priority	Location and site notes	Weed suite	Recommended control method at Lake Richmond
Asparagus asparagoides	Bridal Creeper	High	Plants shown on Figures 15 and 16	Geo-phyte	Spot spray localised infestations when flowering with 0.2g metsulfuron methyl + Pulse ® in 15L water
Paspalum vaginatum	Saltwater Couch	High	The nearshore environment surrounding the lake water body	Grass	Management actions for Saltwater Couch growing in close proximity to the thrombolites is provided in Section 7.1.1, below.
Bromus diandrus	Great Brome	High	Light to moderate infestations throughout the Reserve	Grass	Hand pull plants amongst native vegetation. In degraded areas use 1% glyphosate on seedlings and young or flowering plants
Cynodon dactylon	Couch	High	Light to moderate infestations throughout the Reserve	Grass	Spray Fusilade ® Forte at 13 ml/L + wetting agent In sensitive areas (e.g. in areas of inundated native vegetation) paint runners and crowns with 50% glyphosate Follow-up usually required
Euphorbia terracina	Geraldton Carnation Weed	High	Light to heavy infestations throughout the Reserve	Herb	Manual removal for individual plants Logran ® at 12.5 g/100L + Pulse ® for larger infestations
Lagurus ovatus	Hare's Tail Grass	High	Light to heavy infestations throughout the Reserve	Grass	Manual removal for individual plants and small isolated infestations Spray with 13 ml/10 L Fusilade® Forte in winter at the 2-8 leaf stage before stem elongation
Pelargonium capitatum	Rose Pelargonium	High	Light to heavy infestations throughout the Reserve	Herb	Manual removal for individual plants and small isolated infestations. Entire stem must be removed to avoid reshooting Hand pull isolated plants taking care to remove the entire stem as it can reshoot from below ground level. Spot spray metsulfuron methyl 5 g/ha + Pulse®
Poaceae sp.	Grass (unidentified in field)	High	Light to heavy infestations throughout the Reserve	Grass	Manual removal for individual plants and small isolated infestations Spray with grass selective herbicide such as Fusilade® Forte in winter 4-6 weeks after opening rains
Schinus terebinthifolius	Japanese Pepper	High	Individual seedlings shown on Figures 15 and 16	Shrub	Manual removal for seedlings ensuring removal of all root material Stem inject older plants using 50% glyphosate or basal bark with 250 ml Access® in 15 L of diesel to bottom 50 cm of trunk during summer NB. Only seedlings were observed during survey
*Typha orientalis**	Bulrush / Typha	High	Light to heavy infestations within and adjacent to VT4	Grass	Apply Roundup Biactive® (360 g/L) at 13 ml/L when actively growing through backpack/handheld spray or high volume spray, complete coverage of foliage is necessary. Avoid producing drift. Plants with one third of the stem below water may not absorb enough herbicide to be killed by spraying - either wait till water levels are lower or plants have matured. Cutting shoots 15 cm below the water surface two to three times in a season when actively growing, but before seeds are formed, greatly reduces stands. Repeat treatment annually to ensure against reinfestation. To avoid loss of water quality by anaerobic decomposition of dead plant material in water, consider physical removal of dead biomass or burning 6weeks after spraying

7 Recommendations and Implementation (continued)

Weed control methods and timing for targeted weed species and other aggressive/invasive weeds are provided in Table 10 below. Where timing of manual and chemical controls differ, shaded months indicate optimal timing for chemical control, 'M' indicates additional months for manual control and 'C' indicates additional months for chemical control. Weeds species should be targeted according to the Weed Suite Mapping presented in Section 3.6.2.

Monitoring will consist of annual walk-overs to review the success of the program.

Complete eradication will present an extreme challenge and may not be achievable due to the number of recruitment opportunities presented by the historic modifications to the habitat and the surrounding urban environment which provides a constant source for reinfestation.

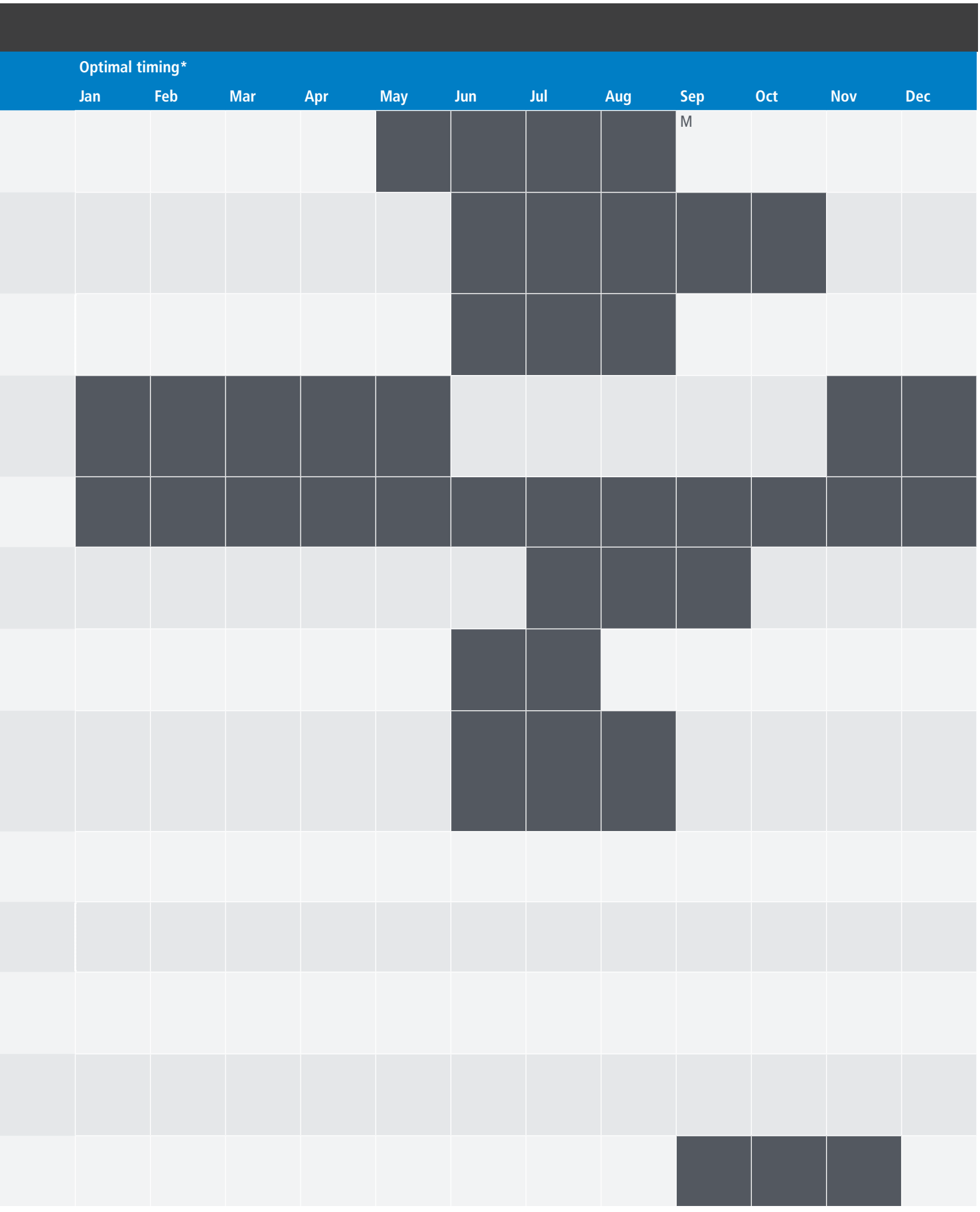
**Typha orientalis* is not a weed, however, given its invasive nature and tendency to dominate other native species, the aim for management will be to monitor and maintain the current extent of *Typha* at Lake Richmond.

Optimal timing*											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
								M	M	M	
								M	M	M	M
										M	
										M	

TABLE 10 - Weed control methods (continued)

Species	Common name	Priority	Location and site notes	Weed suite	Recommended control method at Lake Richmond
Hypochaeris glabra	Dandelion, Smooth Catsear	Medium	Light to moderate infestations throughout the Reserve	Herb	Manual removal for individual plants For small infestations, wipe rosettes with glyphosate at 30% For dense infestations, apply Lontrel® 10 ml /10 L + wetting agent
Lolium sp.	Ryegrass	Medium	Light to heavy infestations throughout the Reserve	Grass	Manual removal for individual plants and small isolated infestations Spray with grass selective herbicide such as Fusilade® Forte in winter 4-6 weeks after opening rains Increase rates of grass selective herbicide 3– 4 fold for larger plants up to flowering stage
Sonchus sp.	Sowthistle	Medium	Light to moderate infestations throughout the Reserve	Herb	Manual removal for individual plants and small isolated infestations Spot spray Lontrel® 10 ml/10 L + wetting agent preferably at the rosette stage
Stenotaphrum secundatum	Buffalo Grass	Medium	Light to heavy infestations throughout the Reserve, largely within VT4	Grass	Consider undertaking annual controlled burns in alternating quadrats. After the burning, any new sprouts should be spot sprayed with Fusillade at 13mL/L
Agave americana	Century Plant	Medium	Single plant/s at Figure	Herb	Manual removal for small infestations
Fumaria capreolata	Whiteflower Fumitory	Medium	Light to moderate infestations throughout the Reserve	Herb	Spray metsulfuron methyl at 0.1 g/15 L (2.5 g/ha) + wetting agent or glyphosate 0.5%
Oxalis pes-caprae	Soursob	Medium	Light to heavy infestations throughout the Reserve	Herb	Spot spray metsulfuron methyl 0.2 g/15 L + Pulse®, or 1% glyphosate at bulb exhaustion, generally just on flowering
Trachyandra divaricata	Onion Weed	Medium	Light infestations throughout the Reserve	Herb	Manual removal for individual plants and small isolated infestations prior to flowering For small infestations, wipe with 50% glyphosate solution before flowering For dense infestations in degraded areas spot spray 0.4 g chlorosulfuron plus 25 ml wetting agent in 10 L of water when plants actively growing
Galium murale		Low	Light infestations in VT5	Herb	Specific information not available for this taxon
Gazania linearis	Gazania	Low	Single plant/s at the Reserve	Herb	Manual removal for individual plants ensuring rhizome is removed
Lysimachia arvensis	Pimpernel	Low	Light to moderate infestations throughout the Reserve	Herb	Specific information not available for this taxon
Ursinia anthemoides	Ursinia	Low	Light to moderate infestations throughout the Reserve	Herb	Specific information not available for this taxon
Foeniculum vulgare	Fennel	Not rated	Localised infestation at Figures 15 and 16	Herb	Manual removal for individual plants or smaller localised infestations Spot spray with 1.5% glyphosate or metsulfuron methyl 0.7 g/10 L (20 g/ha) + Pulse®

7 Recommendations and Implementation (continued



*where timing of manual and chemical control differs, shaded months indicate optimal timing for chemical control, 'M' indicates additional months for manual control.

7.1.1 Management of Saltwater Couch in Proximity to the Thrombolites

The saltwater couch occurs as a dominant species over fairly large areas in the near-shore environment and there are a number of native sedges intermingled within the established infestations. In some instances, these sedges will need to be sacrificed in order to achieve effective control as hand picking around the sedges is not a feasible approach due to the extensive nature of the couch infestation surrounding the thrombolites.

The Weed Management Study determined that Glyphosate was the most appropriate herbicide for managing weeds in proximity to the thrombolites. Criteria and management actions for selecting the right time to apply the chemical is presented in Table 11 below. Glyphosate should only ever be applied when the following 10 conditions are met.

TABLE 11 - Glyphosate application conditions

	Application Conditions	Rationale
1	Glyphosate should only be applied to the Saltwater Couch grass during dry weather conditions and in areas where the sediments are dry to minimise any impact the application may have on the ecology of the habitat. A separation of four meters should be maintained up from the lake water's edge to avoid contamination of the lake water from over spray.	The Weed Management Strategy has shown that direct exposure to Glyphosate at the recommended application concentration for the purpose is unacceptably toxic to some aquatic vertebrate species, macro invertebrates and cyanobacteria. Conversely it may also result in prolific reproduction in undesirable species such as the cyanobacteria Lyngbya and some heterotrophic bacteria species. In dry areas the cyanobacteria will be mostly inactive and in a cyst stage which our tests have shown to be mostly resilient to Glyphosate and capable of repopulating the habitat once resubmerged in the following season. Applying Glyphosate to dry sediments restricts the movement of the chemical into the soil and lake minimising the chance of impact on microbial mats, macro invertebrates and vertebrate fauna.
2	Apply Glyphosate during a dry period where there has been no rainfall for four days before application and no rainfall is forecast to fall for seven days after application.	Glyphosate or its decay products may be washed into the lake habitat by rainfall which could impact cyanobacteria or non target vegetation along the water's edge.
3	Do not apply Glyphosate to wet areas of runoff water where drainage from isolated inshore pools occurs.	Spray application to wet areas may result in Glyphosate or its decay products being transported in runoff water to the lake water.
4	Do not apply Glyphosate to any inshore pool areas which have not dried out.	This may result in killing non target flora species and may impact any fauna present in the pools.
5	The effectiveness of Glyphosate will be reduced if more than one quarter of the plant height is submerged in water.	As per the product instruction booklet.
6	Operators should take care to avoid spraying areas where the macroscopic plant, *Nitella congesta*, is present. The presence of the plant can be identified in the field by visual examination. The Implementation Table has identified that City staff will be inducted on how to identify the plant in an onsite meeting scheduled for the summer of 2019-2020.	*Nitella congesta* is the dominant flora species in the depression of the near shore littoral zone and is critical to the habitat type where it occurs. It has also been observed to restrict the shoreward movement of the Saltwater Couch. Its presence is therefore crucial to the current diversity of both vertebrate and invertebrate taxa present under the current water quality conditions of the lake habitat and it should not be sprayed with glyphosate under any circumstances.
7	Glyphosate will have the greatest impact on the Saltwater Couch if applied when the plant is at a vulnerable stage of the growth cycle.	Saltwater Couch flowers in January which coincides with the seasonal dry period when the application conditions with regard to rainfall and lake water level can be met.
8	Glyphosate should be applied in December, provided that the lake level has dropped sufficiently to meet the application criteria in relation to dry exposed sediments.	Treatment will still be effective at this time and is preferred to application later in the season when seeds have formed as seeds may still be viable and have the potential to repopulate the area.
9	If the lake water levels does not recede sufficiently to meet the application conditions described above the City has the option of lowering the lake level via the discharge drain.	This option will allow continuity of Glyphosate application from year to year preventing reestablishment of the Saltwater Couch grass if treatment is missed for a year.
10	Under no circumstances should Glyphosate be applied if all application conditions are not met. Weed management should not take place in years where the lake water level does not recede sufficiently during summer	To reduce the impact on non-target aquatic species.

Application of Glyphosate Procedure

1. Sites are to be assessed against the above 'Application Conditions'. If the conditions are favourable, proceed to step 2.
2. The Glyphosate is to be mixed in water at the recommended concentration for controlling saltwater couch (15mg/L).
3. As red marking dye can leave stain-marks on the microbialites, areas to be treated should be defined by pegging and taping quadrats, starting from the treatment area nearest to the lake waterline (Note: Dye is only not recommended in proximity to Thrombolites. It can still be used in other areas of the reserve).
4. The next treatment area is then defined by leaving the landward pegs in place and repositioning the lakeside pegs. This will result in the application areas gradually moving away from the waterbody.

7.2 Revegetation

7.2.1 Identification of Revegetation Areas

Four revegetation areas were noted by the field survey and the City's internal assessment (Figure 30). These revegetation areas were identified based on their potential to enhance local conservation values by:

1. Improving the overall condition and environmental function of the revegetation site.
2. Improving fauna habitat within revegetation areas by increasing the diversity of flora species.

The recommended planting mixes were selected so that the revegetation would match the surrounding vegetation types, as recorded during the field survey.

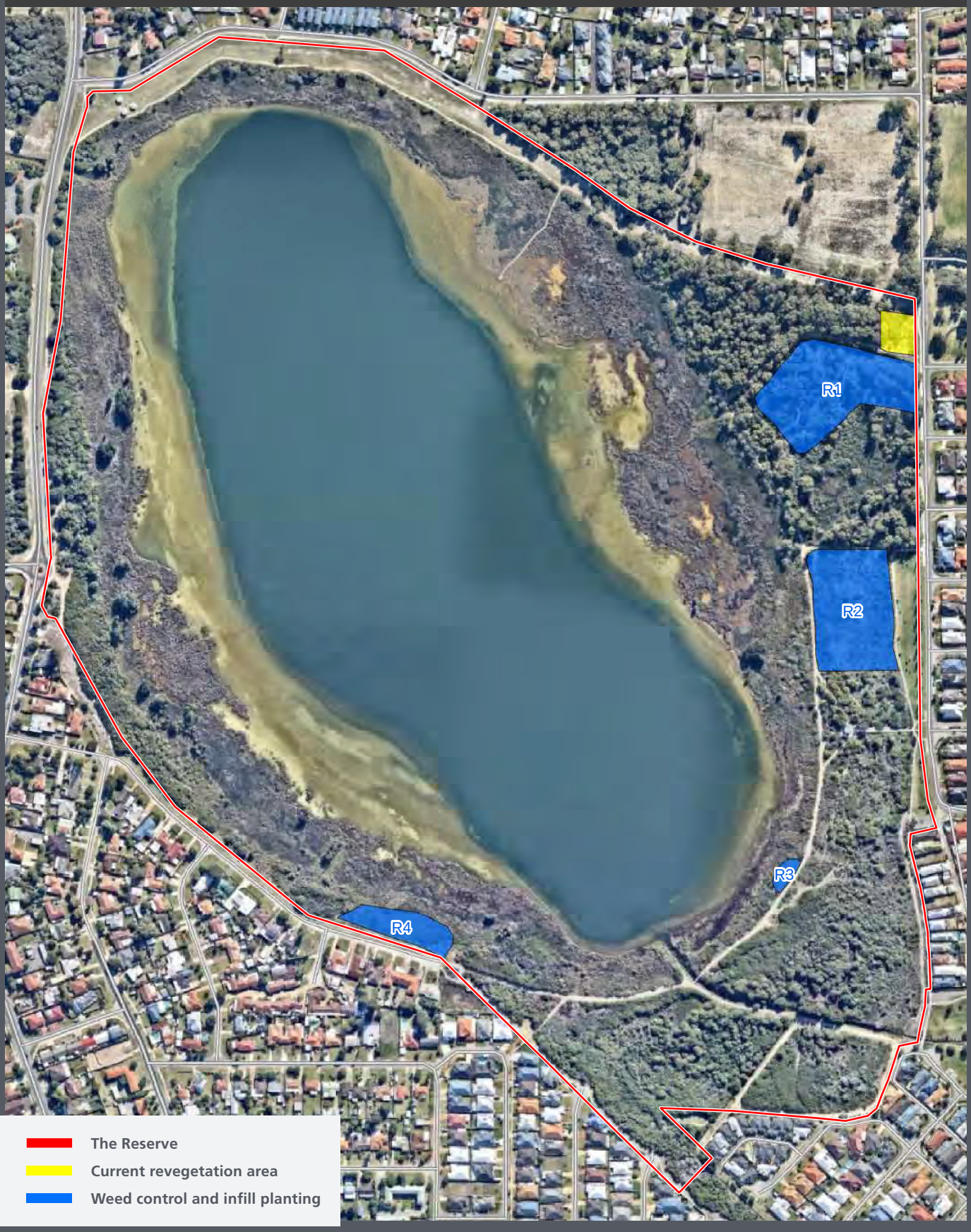
Descriptions of each revegetation area is provided in Table 12, below.

TABLE 12 - Revegetation areas

Area	Description
Revegetation Area 1 (~0.5 ha)	This area is adjacent to the potential occurrence of the '*Callitris preisii* (or *Melaleuca lanceolata*) forests and woodlands' TEC. Revegetation Area 1 appears to have been subject to a recent fire and has been recolonised with native middle-storey trees and shrubs, along with a number of weeds. It is quite likely that this area was also representative of the TEC prior to the burning and associated degradation. Revegetation of this area will help to limit weed encroachment and further degradation of the possible TEC located immediately adjacent to Revegetation Area 1.
Revegetation Area 2 (~1.2 ha)	This area is heavily infested with weeds and is currently allowing a number of weed species to encroach further into the reserve. Revegetating this area would create a buffer of native vegetation to separate the wetland flora from the parkland grasses adjacent to Fisher Street. It is likely that Revegetation Area 2 was formerly representative of VT2 prior to it becoming degraded.
Revegetation Area 3 (~0.1 ha)	This area is located in the south-east of the Reserve, adjacent to the main footpath that circulates the Lake. Revegetation Area 3 has been historically cleared of native vegetation and recolonised with mixed introduced species. It is likely that this area was representative of VT4 prior to the native vegetation being cleared.
Revegetation Area 4 (~0.4 ha)	This area is located adjacent to the main footpath towards the southern extent of the reserve. Similar to Revegetation Area 3, this area appears to have been historically cleared of native vegetation and subsequently recolonised by weeds. Restoration of Revegetation Area 4 will help return the vegetation to its natural state and will also provide a native vegetation buffer to the fringing wetland vegetation. It is likely that Revegetation Area 4 was formerly representative of VT4.

A detailed revegetation strategy for each revegetation area is provided in the Implementation Section of this Management Plan.

Figure 30 - Revegetation Areas



7.2.2 Revegetation Management

The revegetation of the four sites displayed above will seek to:

- Maintain and enhance local vegetation quality.
- Create fauna habitat by providing a diverse mix of species.
- Use species that will survive with minimal ongoing maintenance.
- Use species that were recorded during the 2017 field survey.
- Enhance the amenity of the reserve.
- Minimise the introduction and spread of weeds.
- Restrict unauthorised access and the associated effects (trampling, littering etc.).
- Minimise soil erosion.

Proposed planting mixes and recommended planting density are shown in Table 13 below. It is recommended that tubestock and seeds be sourced from local provenance seed (a seed containing a local genetic variation) wherever possible, hardened off and in good condition prior to planting. Propagation of plants from provenance seed improves the potential for success, as the plants are suited to the site conditions. Prior to seedling planting, site preparation activities are required to be undertaken, to ensure successful revegetation.

Tree guards can prevent animals such as rabbits grazing on the tubestock, however, if tree guards are not removed they can become litter resulting in negative impacts to the lake. If tree guards are used for revegetation it is recommended they be made from compostable material and removed in the first winter following planting if the plants are well established. Alternative measures to minimise animal grazing should be considered such as using temporary fencing around revegetation areas to prevent access.

Table 13 below summarises revegetation works to be undertaken in the reserve, sites are to be revegetated in order of priority.

TABLE 13 - Revegetation treatments (continued)

Location	Description	Suggested treatment	Proposed planting mix	Recommended planting density
R1 Priority Rank 1	Vegetation appears to have been burnt in recent years and has been recolonised largely with *Callitris preissii*, *Spyridium globulosum* and *Acacia* spp. Some tall overstorey species remain including Eucalypts. It is likely that this site was formerly VT3.	Proposed revegetation treatment for this site includes: • at least one round of spot weed control prior to planting. • ensure that any potential occurrences of the Pink Fairy Orchid (*Caladenia latifolia*) are avoided during weed control. • ongoing weed control thereafter as revegetation is establishing. • seed collection from other areas of VT3 within the Reserve and / or procurement of seedlings from local nurseries. • ensure seedlings (in the form of Tubestock) are suitably mature, between six to 12 months and not root bound to enable optimal establishment and growth.	• *Eucalyptus gomphocephala* • *Callitris preissii* • *Spyridium globulosum* • Diplolaena dampieri • Rhagodia baccata • Acanthocarpus preissi.	1 plant/m^2 1/10m^2 or 1/20m^2 for trees, depending on existing canopy cover
R2 Priority Rank 2	Vegetation appears to have been burnt in recent years and has been recolonised largely with *Acacia saligna*, *Jacksonia furcellata*, *Acacia rostellifera* and mixed introduced species. It is likely that this site was formerly VT2.	Proposed revegetation treatment for this site includes: • at least one round of spot weed control prior to planting. • ensure that any potential occurrences of the Pink Fairy Orchid (*Caladenia latifolia*) are avoided during weed control. • ongoing weed control thereafter as revegetation is establishing. • seed collection from other areas of VT2 within the Reserve and / or procurement of seedlings from local nurseries. • ensure seedlings (in the form of Tubestock) are suitably mature, between six to 12 months and not root bound to enable optimal establishment and growth.	• *Acanthocarpus preissii* • *Agonis flexuosa* • *Conostylis candicans* • *Hardenbergia comptoniana* • *Jacksonia furcellata* • *Melaleuca systena* • *Olearia axillaris.*	1 plant/m^2 1/10m^2 or 1/20m^2 for trees, depending on existing canopy cover
R3 Priority Rank 4	Vegetation has been cleared or disturbed and has recolonised largely with mixed introduced species (mainly *Euphorbia terracina*). It is likely that this site was formerly VT4.	Proposed revegetation treatment for this site includes: • at least one round of blanket weed control prior to planting. • ensure that any potential occurrences of the Pink Fairy Orchid (*Caladenia latifolia*) are avoided during weed control. • ongoing weed control thereafter as revegetation is establishing. • seed collection from other areas of VT4 within the Reserve and / or procurement of seedlings from local nurseries. • ensure seedlings (in the form of Tubestock) are suitably mature, between six to 12 months and not root bound to enable optimal establishment and growth.	• *Juncus kraussii* • *Ficinia nodosa* • *Rhagodia baccata* (occasional) • *Acacia saligna* (occasional).	1 plant/m^2
R4 Priority Rank 3	Vegetation has been cleared or disturbed and has recolonised largely with mixed introduced species. It is likely that this site was formerly VT4.	Proposed revegetation treatment for this site includes: • at least one round of blanket weed control prior to planting. • ensure that any potential occurrences of the Pink Fairy Orchid (*Caladenia latifolia*) are avoided during weed control. • ongoing weed control thereafter as revegetation is establishing • ensure seedlings (in the form of Tubestock) are suitably mature, between six to 12 months and not root bound to enable optimal establishment and growth.	• *Juncus kraussii* • *Ficinia nodosa* • *Rhagodia baccata* (occasional) • *Acacia saligna* (occasional).	1 plant/m^2

Revegetation works are to continue post initial planting to ensure revegetation efforts improve vegetation condition within the revegetation site. Ongoing management activities will include revegetation monitoring, and follow up weed control and infill planting if identified as necessary by the monitoring.

Further revegetation management actions are outlined in the Implementation Table.

7.3 Creating a Hydrological Regime that Favours Microbialite Growth

As discussed in Section 5, a number of hydrologic factors need to change in order to improve the potential for microbialite growth continuing into the future. These factors are:

1. Availability of sulfide
2. Concentration of Total Dissolved Solids (TDS)
3. Lake level
4. Groundwater level
5. Nutrient concentrations.

Availability of Sulfide

Issue:

Inflow of sulfide compounds to the lake littoral zone is known to be an important part of the hydraulic regime that supports microbialite formation. This process has, however, been absent at Lake Richmond for at least eight years, since the commencement of the PhD study. For sulfur inflow to occur, a sulfur source is needed in the surrounding soils. A suitable hydraulic gradient is then needed to bring the sulfide into the lake via groundwater discharge. As part of the Thrombolite Mapping Report, a preliminary assessment of potential sulfide sources above the shoreline was undertaken. The study determined that there is a high likelihood that there are still some sources adjacent to the lake.

Management Response:

The first step would be to confirm the presence of sulfur sources around the lake through detailed onsite sampling and analysis. This would include testing for pyrite and gypsum deposits in the near-shore environment. The presence of these deposits will determine whether Lake Richmond is able to produce microbialites. As such, their presence needs to be confirmed prior to any further research being undertaken.

It should also be noted that both pyrite and gypsum are finite sulfur resources and there is a possibility that the ongoing groundwater discharge into the lake over the past six-million years may have depleted these sulfur deposits. Therefore, if the field sampling does not identify any sulfur sources, it means that Lake Richmond no longer has the ability to form microbialites. If this is the case, the primary management objective would be to preserve the existing microbial structures as a reminder of the lake's historical significance.

If deposits of sulfur minerals are found to be present around the lake, they will need to be oxidised through prolonged drying in order to produce sulfide. This isn't occurring at the moment due to the elevated summer lake levels keeping the near-shore environment wet and limiting oxidation. For these deposits to dry out during the summer, the lake would need to be restored to its pre-modification condition where the surface water level was significantly reduced to allow for the primary inflow to the lake being from groundwater discharge. In order to do this, the City will need to undertake a detailed feasibility study to investigate the viability of restoring the lake to its pre-1968 hydrological regime. The details of the proposed feasibility study are provided below.

Feasibility Study – Recreating the Natural Lake Richmond Water Level by Reducing Stormwater Inflow

This would involve the seasonal diversion of significant amounts of stormwater around Lake Richmond and the outlet level being controlled to restore the historic seasonal lake level variation (of approximately 1.5-2m). Each year, the outlet weir board would need to be lowered to achieve the desired reduction in lake level and mimic the timing and magnitude of historical fluctuations. Historically, the reductions in water level would have occurred as a result of evaporation and exchange to groundwater.

It should also be noted that should any increases in lake level be required by this study, the level of the water in the drains and in the surrounding groundwater aquifers will also rise. The study will need to address the impacts that this may have on the lake and on the surrounding area by undertaking detailed flood modelling.

Concentration of Total Dissolved Solids

Issue:

The only pre-modification lake TDS data suggested the concentration once fluctuated between 2,000-3,500mg/L. This is considerably higher than the concertation today which is consistently below 1,000mg/L. Restoration of the lake's TDS to these historic levels would support microbialite formation as it would exclude a number of freshwater species which are currently competing with the microbial mats and/or consuming the mats as they form. Increasing the salinity will also encourage the productivity of cyanobacteria species that promote microbialite formation. An increase in TDS concentration would have a second benefit of helping to control invasive weeds, such as saltwater couch, which cannot tolerate brackish water.

Management Response:

It is unclear if microbialites were forming in 1968, prior to the construction of the drains, but the Lake Richmond Hydrology Report determined that it was significantly more likely that they were forming during this time.

Prior to commencing any projects aimed at restoring the lakes hydrology by altering the inflows, outflows and overall solute balance, the City will determine how the microbial mats respond to lake water samples with increased TDS concentration. If current mat samples are able to form microbialites when exposed to artificially modified lake water that replicates the 1968 formation chemistry, then the City can commence a feasibility study aimed at investigating re-engineering the Lake Richmond hydrological catchment to return the lake to its pre-1968 regime.

Lake Level

Issue:

The current lake level regime has become heavily modified due to the influx of stormwater. Prior to the construction of the stormwater drains, the lake had a higher average water level and a greater degree of seasonal variation. Historically, the lake was maintained at a higher level for a longer period of time due to the absence of a surface water outflow drain, this allowed for increased evapo-concentration of Total Dissolved Solids to occur. Thus, creating a more brackish environment which benefited microbial formation.

Management Response:

Ideally the lake would be restored to the pre-modification hydraulic regime, where the lake level used to fluctuate between 1 and 2mAHD. However, it is unclear whether this is feasible given the constraints imposed by the use of the lake for stormwater disposal.

In order to fully recreate the lake level conditions that were historically in place at Lake Richmond, the feasibility study would need to be undertaken by the City.

Using the outlet control, establishing a regime with an annual lake level low of 0mAHD would still have a number of benefits, including; facilitating sulfur-rich groundwater discharge into the lake and increasing the concentration of TDS. The lake level will be reduced to 0m AHD at the end of every summer until such a time that the feasibility study has been completed.

Groundwater Level

Issue:

Prior to modification, the lake level was typically lower than the surrounding groundwater levels, aside from a small area on the northern side. During this time, groundwater discharge carried in high concentrations of TDS creating a more brackish environment than we see today.

Following the artificial modification of the lake system, the surrounding groundwater levels have receded significantly, causing the hydraulic gradient to reverse with lake water now discharging into the aquifer. It is preferable that the groundwater level be higher than the lake level for the majority of the year to create a hydraulic gradient towards the lake, and to increase TDS concentrations.

Management Response:

The abovementioned Feasibility Study will investigate the viability of restoring the historical interaction between Lake Richmond and the surrounding groundwater aquifer.

Nutrient Concentrations

Issue:

The Lake Richmond nutrient concentrations measured during the PhD study and during the Lake Richmond Hydrology Report exceeded the recommended maximum concentrations identified by the guidelines for freshwater ecosystems in Western Australia (ANZECC & ARMCANZ 2000). This is detrimentally impacting upon the ability to form microbial mats. The elevated nutrients are causing a proliferation of algae and aquatic vegetation, which is forming a dense cover around the periphery of the lake. In some of these areas, the lake bed has been completely blocked from receiving any sunlight and is completely devoid of microbial mats as a result.

Management Response:

If the feasibility study determines that the lake TDS can be elevated as recommended above, the high nutrient levels would pose a greatly reduced threat as many of the problem organisms would be excluded by the brackish water quality. Diverting stormwater away from Lake Richmond would also reduce nutrient concentrations over the longer term as the size of the fertiliser runoff catchment would be reduced.

Future Recommended Research Actions

The Thrombolite Study has identified that the artificial recharge and discharge introduced by the stormwater drainage system has significantly modified the hydrological regime and water chemistry of Lake Richmond. The balance of hydrological and chemical processes that contribute to the microbialite formation process has been negatively impacted by these modifications and the ability of the system to form microbialites has been compromised. Modification of the drainage system to restore these processes may be possible but will be a very expensive undertaking. Before committing to such an investment, the City will undertake the following studies in the below order to determine what level of benefit can be achieved (Table 14). The initial studies are relatively inexpensive compared to the investment in remodelling the drainage system and will identify in advance whether this investment could result in no positive gain, Additionally, they will inform the targets that need to be achieved in relation to lake level fluctuations and water chemistry requirements.

TABLE 14 - Future research actions to be undertaken (in order)

Item	Study Required	Outcomes and Benefits
1.	**Post glyphosate application impact assessment** This will assess changes to macro-invertebrate population by conducting a Spring survey in the year following glyphosate application. The results of this survey will then be compared to the results of the 2018 baseline survey. It will also involve a microscopic assessment of microbial mat communities in November of the year following glyphosate application. The results of this assessment will also be compared to the baseline data from 2018.	This study will identify if glyphosate application has negatively impacted the ecology of the habitat. Undesirable effects include a reduction in species diversity or abundance. The outcome of this study will inform whether the glyphosate application program should be modified or halted in the future.
2.	**Water level and quality monitoring** There is a limited availability of historical data pertaining to water level and water chemistry balance. The dataset must be expanded so that lake water level and solute balance modelling can be undertaken with confidence.	A comprehensive baseline dataset will increase the accuracy of any future modelling of the seasonal lake level and water chemistry requirements needed to restore the historical conditions that promoted microbialite formation. It will also assess whether target values are achievable in advance of any commitment to future investment.
3.	**Sulfur sources and cycling** This will determine if there is sufficient sulfur sources to allow for microbialite formation still existing around the lake.	If the sulfur sources have become depleted there is no chance that the microbialite formation process can be restored by re-engineering the Lake Richmond catchment. This study is essential for determining whether the desired outcomes of future studies can be achieved.
4.	**Microbialite formation capability** This investigation will determine if the current species composition within the microbial mats are capable of forming microbialites. It would also determine the extent of change to the solute balance required to support a change to a species composition that would support microbialite formation.	This study will inform future investment into modification of the seasonal lake levels and water chemistry. It will determine the level of modification that is necessary to achieve restoration of the historic microbialite formation process. It will also identify how changes to water chemistry will impact the current biology of the habitat.
5.	**Modification of lake water and solute balances** The final study to model how re-engineering the drainage system will achieve restoration of seasonal lake water level fluctuations and solute balances.	Re-engineer the drainage system to restore historic function to the microbialite process.
6.	**Monitor Microbialite Health and Growth.** To be undertaken following the completion of the above research projects.	This will determine the success of the abovementioned projects and identify if any further modifications are required to be made.

7 Recommendations and Implementation (continued)

7.4 Implementation Table

TABLE 15 - Implementation Table

Objective	Recommendation Number	Management Action	Potential Cost	Team Plan	Team	Indicative Timing	Priority
	Protection of Native Vegetation						
To ensure conservation values within Lake Richmond are protected	1.	Install two new vehicle restriction signs and remove GHD survey sign in the areas identified in Figure 29	$1,000	O	PS	2019/2020	Low
	2.	Further surveys to determine the occurrence of SP30a TEC and liaison DBCA	$20,000	C	SPE	2020/2021	Medium
	3.	Install two new 'Dogs must be kept on a leash' signs	$1,000	C	PS	2020/2021	Medium
	Weed Control						
To minimise the spread, and prevent the introduction of new weeds within the Reserve	4.	Implement Weed Control in accordance with the methodology presented in Section 7.1 of this Management Plan.	$30,800	O	PS	2019/2020	High
	5.	Field induction for staff and contractors identifying *Nitella congesta*	$500	C	SPE	2019/2020	High
	6.	Arrange a briefing session for senior City staff and contractors on the findings of the Weed Management Strategy with respect to preserving the Thrombolites	$500	C	SPE	2019/2020	High
	7.	Undertake weed control for Bridal Creeper (*Asparagus asparagoides*) as defined in Figures 15 and 16	Officer Time	O	PS	2019/2020	High
	8.	Ensure vehicles, machinery, equipment and footwear are free of mud and soil when entering the Reserve	Officer Time	O	PS	Ongoing	High
	9.	Collect dislodged floating mats of saltwater couch from the lake shoreline in winter to prevent recolonization in new areas	Officer Time	O	PS	As required during winter or after significant storms	High
	10.	Survey for *Casuarina glauca* and undertake control if required. This action could potentially be undertaken in conjunction with Action no. 3	$5,000	O	PS	Between June 2020 and November 2020	High
	11.	Investigate feasibility of undertaking annual controlled burns in alternating quadrats for patches of Buffalo grass in consultation with DBCA and DFES, as per Table 10	Officer Time	O	PS	2020/2021	Low
	12.	Undertake ongoing liaison with adjacent land management authorities to ensure a holistic approach to regional weed management.	Officer Time	O	PS	Ongoing	High
	Revegetation						
To improve the 'Degraded' condition of native vegetation within the Reserve through revegetation.	13.	Revegetation of Area 1 (~0.5ha) using a minimum plant density of 1 plant/m2, ensuring weed spraying is undertaken prior to tubestock planting	$20,000	O	PS	2022/2023	High
	14.	Revegetation of Area 2 (~1.2ha) using a minimum plant density of 1 plant/m2, ensuring weed spraying is undertaken prior to tubestock planting	$48,000	O	PS	2021/2022	High

TABLE 15 - Implementation Table (continued)

Objective	Recommendation Number	Management Action	Potential Cost	Team Plan	Team	Indicative Timing	Priority
	Revegetation						
	15.	Revegetation of Area 3 (~0.1ha) using a minimum plant density of 1 plant/m2, ensuring weed spraying is undertaken prior to tubestock planting	$4,000	O	PS	2020/2021	High
	16.	Revegetation of Area 4 (~0.4ha) using a minimum plant density of 1 plant/m2, ensuring weed spraying is undertaken prior to tubestock planting	$16,000	O	PS	2023/2024	High
	Fauna						
To protect native fauna values within the Reserve	17.	Retain hollow logs and other vegetative debris in revegetation areas defined in Figure 28 to supplement habitats at the Reserve	Officer Time	O	PS	Ongoing	Medium
	18.	Continue fox, cat and rabbit population control and commence control of feral fish and feral yabbies	$1,500	O	PS	Annual	Medium
	19.	Undertake ongoing community education on the impacts of dumping unwanted feral fish and aquatic plants into the lake or the drains.	$500	O	SPE	Annual	Medium
	20.	Undertake a 'Responsible Pet Ownership' letter drops to residents living in proximity to the reserve. The letter will encourage the following: - Pet cats to remain indoors at night - Cats to be fitted with collars with bells - Keep dogs on leads at all times.	$500	O	CELT	Annual	Medium
	21.	Investigate suitable locations within the *Eucalyptus* woodland for artificial black cockatoo nesting boxes and install up to two nesting boxes.	$2,400	O	PS	2020/2021	Low
	22.	Investigate suitable locations for installation of bat boxes with interpretive signage to educate reserve users about bats.	$5,000	O	PS	2020/2021	Low
	23.	Investigate opportunities for construction of fauna underpasses beneath Safety Bay road to allow species to move between the Reserve and Bush Forever Site 355.	Officer Time	O	SPE	2022/2023	Medium
	24.	Undertake a survey for the Western Snake-Necked Turtle (*Chelodina colliei*) to determine the health of the population within the lake	$5,000	C	SPE	2019/2020	High
	25.	Liaise with the Water Corporation with regard to minimising the number of feral fish entering the reserve via the drains.	Officer time	O	SPE	2020/2021	Medium
	Drainage litter						
Minimise litter entering the Lake	26.	Undertake ongoing litter removal from the Water Corporation drains	Officer time	O	PS	Twice per year (minimum)	High
	27.	Engage a consultant to investigate feasibility of a range of best practice litter management options for the drains entering the lake, including liaison with Water Corp	$15,000	C	PS	2020/2021	Medium
	28.	Engage a contractor to install recommended litter management system, as determined through Consultant's report and in discussion with Water Corp	TBD	C	PS/ES	2021/2022	Low

TABLE 15 - Implementation Table (continued)

Objective	Recommendation Number	Management Action	Potential Cost	Team Plan	Team	Indicative Timing	Priority
	Access						
To restrict access to conservation areas	29.	Install 284m of 3 strand rural style fencing and install 5 pedestrian gates as outlined in Figure 29 to minimise unstructured recreation impacting native vegetation.	$7,600	C	PS	2020/2021	High
	30.	Replace concrete footings at the three gate access ways shown on Figure 29, to avoid further damage to gate way.	$280	C	PS	2019/2020	Low
	Park Furniture						
To enhance the recreation value within the Reserve	31.	Ongoing regular cleaning of seating on the boardwalk	Officer Time	O	PS	Ongoing	High
	32.	Install a new bin at the Picnic Seating Node, as shown in the Landscape Concepts	$3,000	C	PS	Following upgrade of the recreation area	Low
	33.	Mechanically clean paved areas as necessary to maintain the highest standards of presentation.	Officer Time	O	PS	Ongoing	Low
	34.	Maintain paving free from weeds and grasses by hand weeding or by application of approved herbicide.	Officer Time	O	PS	Ongoing	Low
	Landscape Concepts						
To provide a sustainable recreational experience which is compatible with the surrounding environment	35.	Undertake street tree planting around the Reserve, as identified by the Landscape Concepts	TBD (Greening Plan Budget)	C	PS	2019/2020	Medium
	36.	Initiate detailed design for the Picnic Seating Node infrastructure renewal	TBD	C	PS	2020/2021	Low
	Supporting Microbialite Growth						
To improve the potential for microbialites to continue to grow at Lake Richmond	37.	Post glyphosate application impact assessment as described in Table 14	TBD	C		2019/2020	High
	38.	Undertake annual water level and water quality monitoring in accordance with Table. Particular focus will be given to measuring the following parameters: - Concentration of TDS; - Concentration of nutrients; and - Concentration of sulfide compounds	TBD	O	PS (with input from SPE)	Ongoing	High
	39.	Undertake detailed onsite sampling and analysis to confirm the presence of sulfur sources around the lake. This would include testing for pyrite and gypsum deposits in the near-shore environment.	TBD	C	SPE	2019/2020	High
	40.	Expose mat samples to artificially modified lake water that replicates the 1968 formation chemistry in order to determine the ability of the current system to form microbialites	TBD	C		2020/2021	High
	41.	Subject to precursor assessment and studies as recommended, engage with the Water Corp to investigate altering drainage system to assist in restoring historic mircobialite processes.	TBD	C	SPE	2024/2025 if deemed to be feasible	Medium

TABLE 15 - Implementation Table (continued)

Objective	Recommendation Number	Management Action	Potential Cost	Team Plan	Team	Indicative Timing	Priority
	Bushfire Mitigation						
To implement measures to reduce the risk of uncontrolled bushfires within Lake Richmond	41.	Ongoing monitoring of Thrombolite health as part of future management plan reviews	TBD	C	SPE	Ongoing	High
	42.	Engage a consultant to undertake a bushfire risk assessment and recommend actions to reduce the risk rating held by adjacent properties. Recommended actions must not detrimentally impact upon the biodiversity conservation or landscape amenity values of the reserve.	$12,000	O	PS	Ongoing	High
	43.	Maintain existing firebreaks	Officer time	O	PS	Ongoing	High

7.5 Measuring Success

Over the next five years, the City will continue to work towards the performance objectives and actions identified in this Management Plan.

The Strategic Planning and Environment Team will liaise with the City's Parks Services team at the start of each calendar year to discuss and review:

- The completion of management actions identified for the financial year
- Management actions scheduled to take place during the remainder of the financial year
- Management actions scheduled to occur in the upcoming financial year
- Progression of the landscape concepts
- Success from management actions implemented
- Lessons learnt and potential improvements.

Implementation progress will be reported annually in the Sustainability Snapshot Report.

8.0

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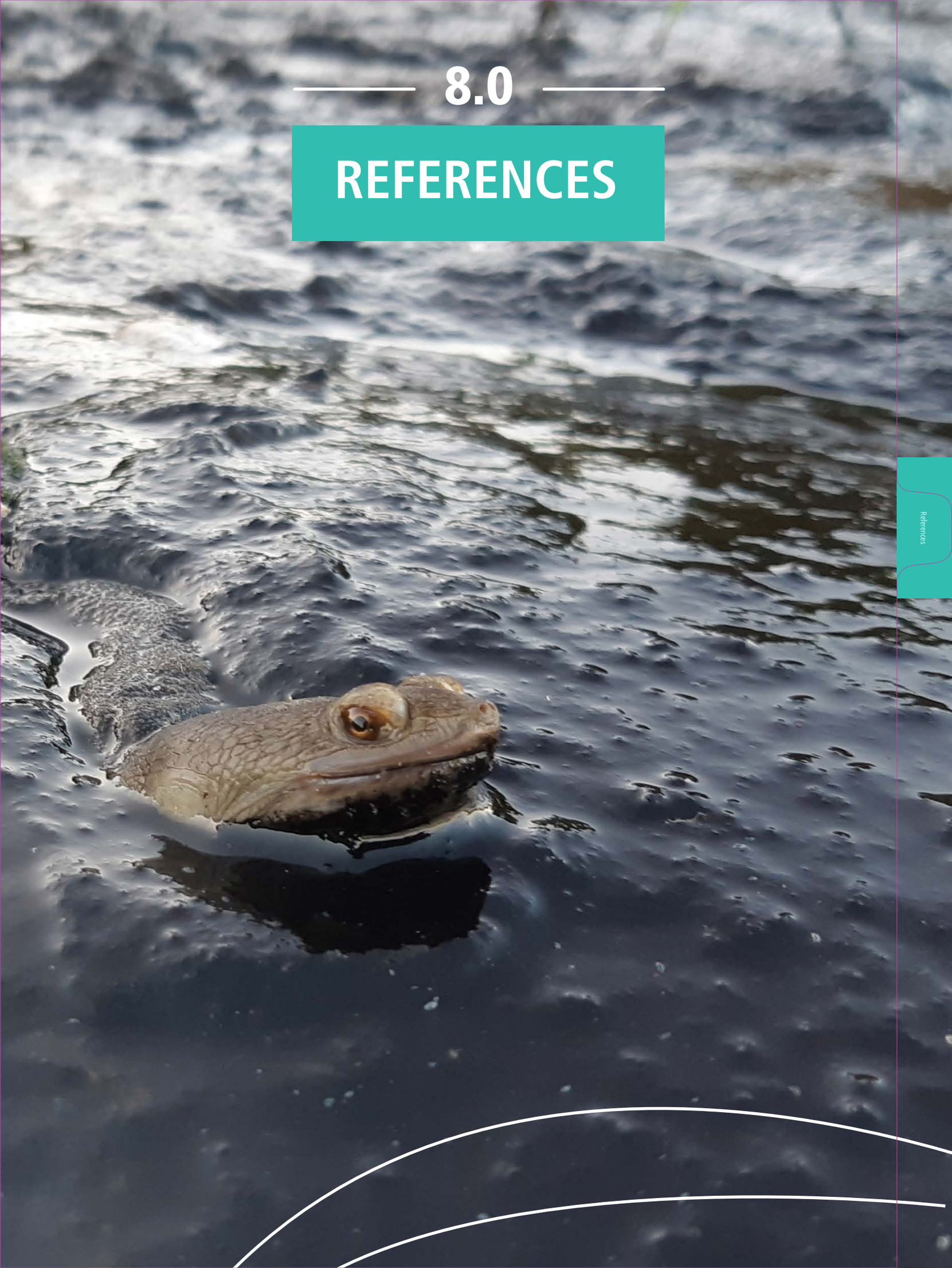

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APPENDICES

9 Appendix A Legislation, Background Information and Conservation Codes

Federal *Environment Protection and Biodiversity Conservation Act 1999*

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places, which are defined in the EPBC Act as matters of national environmental significance (MNES).

There are currently nine MNES protected under the EPBC Act, these include:

- world heritage properties
- national heritage places
- wetlands of international importance (listed under the Ramsar Convention)
- listed threatened species and ecological communities
- migratory species
- Commonwealth marine areas
- the Great Barrier Reef Marine Park
- nuclear actions (including uranium mines)
- a water resource, in relation to coal seam gas development and large coal mining development.

The Federal conservation level of flora and fauna species and their significance status is assessed under the EPBC Act. The significance levels for fauna used in the EPBC Act are those recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN).

The EPBC Act is administered by the Federal Department of the Environment and Energy (DotEE).

State *Biodiversity Conservation Act 2016*

The *Biodiversity Conservation Act 2016* (BC Act) recently replaced the outdated *Wildlife Conservation Act 1950*. The objects of the BC Act are:

- to conserve and protect biodiversity and biodiversity components in the State; and
- to promote ecologically sustainable use of biodiversity components in the State.

The BC Act's associated *Biodiversity Conservation Regulations 2018* are administered by the DBCA and provide the licensing arrangements for activities involving the State's fauna and flora.

Under the BC Act the Minster for the Environment can list a native species or ecological community as "Threatened" if a species are considered to be at risk of extinction or a community is at risk of becoming eligible for being a collapsed ecological community. The BC Act provides protection for threatened species, including conservation of their habitats and measures to conserve threatened ecological communities and critical habitats.

The State conservation level of flora and fauna species are listed on the Wildlife Conservation (Rare Flora) Notice 2018 and Wildlife Conservation (Specially Protected Fauna) Notice 2018.

State *Biosecurity and Agriculture Management Act 2007*

The *Biosecurity and Agriculture Management Act 2007* (BAM Act) provides for the declaration of Declared Pests by the Department of Primary Industries and Regional Development (DPIRD) which are prohibited organisms or organisms for which a declaration under Section 22(2) is in force. The main purposes of the BAM Act and its regulations are to:

- prevent new animal and plant pests and diseases from entering Western Australia
- manage the impact and spread of those pests already present in the state
- safely manage the use of agricultural and veterinary chemicals
- increased control over the sale of agricultural products that contain violative chemical residues.

Introduced plants (weeds)

Declared Pests

The DPIRD maintains a list of Declared Pests for Western Australia that have been declared under the BAM Act. If a Pest is declared for the whole of the State or for particular Local Government Areas, all landholders are obliged to comply with the specific category of control. Declared Pests are gazetted under categories, which define the action required. The category may apply to the whole of the State, districts, individual properties or even paddocks. Among the factors considered in categorising Declared Pests as Category C1 to C3 (with C3 being the most severe pests):

- the impact of the plant on individuals, agricultural production and the community in general
- whether it is already established in the area
- the feasibility and cost of possible control measures.

Weeds of National Significance

To help focus national efforts to address weed problems in Australia, a list of Weeds of National Significance (WoNS) was compiled. The assessment of WoNS is based on four major criteria:

- invasiveness
- impacts
- potential for spread
- environmental, social and economic impacts.

Australian state and territory governments have identified thirty two WoNS; a list of 20 WoNS was endorsed in 1999 and a further 12 were added in 2012.

Conservation Codes for Western Australian Flora and Fauna (DBCA 2019)

Threatened, Extinct and Specially Protected fauna or flora are species which have been adequately searched for and are deemed to be, in the wild, threatened, extinct or in need of special protection, and have been gazetted as such.

Categories of Threatened, Extinct and Specially Protected fauna and flora are:

T **Threatened species**

Listed by order of the Minister as Threatened in the category of critically endangered, endangered or vulnerable under section 19(1), or is a rediscovered species to be regarded as threatened species under section 26(2) of the BC Act.

Threatened fauna is that subset of 'Specially Protected Fauna' listed under schedules 1 to 3 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018* for Threatened Fauna.

Threatened flora is that subset of 'Rare Flora' listed under schedules 1 to 3 of the Wildlife Conservation (Rare Flora) Notice 2018 for Threatened Flora.

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

CR **Critically endangered species**

Threatened species considered to be "facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with criteria set out in the ministerial guidelines".

Listed as critically endangered under section 19(1)(a) of the BC Act in accordance with the criteria set out in section 20 and the ministerial guidelines. Published under schedule 1 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018 for critically endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for critically endangered flora.*

EN **Endangered species**

Threatened species considered to be "facing a very high risk of extinction in the wild in the near future, as determined in accordance with criteria set out in the ministerial guidelines".

Listed as endangered under section 19(1)(b) of the BC Act in accordance with the criteria set out in section 21 and the ministerial guidelines. Published under schedule 2 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018* for endangered fauna or the *Wildlife Conservation (Rare Flora) Notice 2018* for endangered flora.

VU **Vulnerable species**

Threatened species considered to be "facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with criteria set out in the ministerial guidelines".

Listed as vulnerable under section 19(1)(c) of the BC Act in accordance with the criteria set out in section 22 and the ministerial guidelines. Published under schedule 3 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018* for vulnerable fauna or the *Wildlife Conservation (Rare Flora) Notice 2018* for vulnerable flora.

Extinct species

EX **Extinct species**

Species where "there is no reasonable doubt that the last member of the species has died", and listing is otherwise in accordance with the ministerial guidelines (section 24 of the BC Act).

Published as presumed extinct under schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for extinct fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for extinct flora.

Specially protected species

MI **Migratory species**

Fauna that periodically or occasionally visit Australia or an external Territory or the exclusive economic zone; or the species is subject of an international agreement that relates to the protection of migratory species and that binds the Commonwealth; and listing is otherwise in accordance with the ministerial guidelines (section 15 of the BC Act).

Includes birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and fauna subject to the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), an environmental treaty under the United Nations Environment Program. Migratory species listed under the BC Act are a subset of the migratory animals that are known to visit Western Australia, protected under the international agreements or treaties, excluding species that are listed as Threatened species.

Published as migratory birds protected under an international agreement under schedule 5 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018.*

9 Appendix A Legislation, Background Information and Conservation Codes

CD **Species of special conservation interest (conservation dependent fauna)**

Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as threatened, and listing is otherwise in accordance with the ministerial guidelines (section 14 of the BC Act).

Published as conservation dependent fauna under schedule 6 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018*.

OS **Other specially protected fauna**

Fauna otherwise in need of special protection to ensure their conservation, and listing is otherwise in accordance with the ministerial guidelines (section 18 of the BC Act).

Published as other specially protected fauna under schedule 7 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2018*.

P **Priority species**

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

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

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

1 **Priority 1: Poorly-known species**

Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.

2 **Priority 2: Poorly-known species**

Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.

3 **Priority 3: Poorly-known species**

Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.

4 **Priority 4: Rare, Near Threatened and other species in need of monitoring**

(a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands.

(b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for vulnerable but are not listed as Conservation Dependent.

(c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

Ecological Communities

Federal legislation

Under the EPBC Act, a person must not undertake an action that has or will have a significant impact on a listed TEC without approval from the Australian Government Minister for the Environment, unless those actions are not prohibited under the EPBC Act. A description of each of these categories of TECs is presented in Appendix 2. The current EPBC Act list of TECs can be located on the DEE (2017d) website.

State legislation

A TEC is defined under the EP Act as an ecological community listed, designated or declared under a written law or a law of the Australian Government as Threatened, Endangered or Vulnerable. There are four State categories of TECs (DEC 2010b)

- presumed totally destroyed (PD)
- critically endangered (CR)
- endangered (EN)
- vulnerable (VU).

A description of each of these TEC categories is presented in Appendix 2. TECs are gazetted as such (DBCA 2017d) and some Western Australian TECs listed by DBCA (2016) are also listed as Threatened under the EPBC Act.

Ecological communities identified as Threatened, but not listed as TECs, are classified as Priority Ecological Communities (PECs). These communities are under threat, but there is insufficient information available concerning their distribution to make a proper evaluation of their conservation status. DBCA categorises PECs according to their conservation priority, using five categories, P1 (highest conservation significance) to P5 (lowest conservation significance), to denote the conservation priority status of such ecological communities.

Note: * denotes introduced weed species, DP= Declared pest under BAM Act, WoNS=Weed of National Significance

9 Appendix B Native Flora Species List

Native Flora Species List			
Family	**Species**	**Family**	**Species**
Apiaceae	*Centella asiatica*	Phyllanthaceae	*Phyllanthus calycinus*
Asparagaceae	*Acanthocarpus preissii* *Lomandra maritima*	Poaceae	*Austrostipa flavescens* *Neurachne alopecuroidea*
Asteraceae	*Olearia axillaris* *Senecio condylus*	Polygonaceae	*Muehlenbeckia adpressa*
Chenopodiaceae	*Rhagodia baccata*	Proteaceae	*Hakea prostrata* *Hakea varia*
Crassulaceae	*Crassula colorata*	Ranunculaceae	*Clematis linearifolia*
Cupressaceae	*Callitris preissii*	Restionaceae	*Desmocladus flexuosus*
Cyperaceae	*Ficinia nodosa* *Gahnia trifida* *Lepidosperma calcicola* *Lepidosperma gladiatum* *Lepidosperma leptostachyum* *Lepidosperma pubisquameum* *Lepidosperma sp.*	Rhamnaceae	*Spyridium globulosum*
Ericaceae	*Leucopogon parviflorus*	Rutaceae	*Diplolaena dampieri*
Euphorbiaceae	*Adriana quadripartita*	Scrophulariaceae	*Eremophila glabra*
Fabaceae	*Acacia cochlearis* *Acacia rostellifera* *Acacia saligna* *Hardenbergia comptoniana* *Jacksonia furcellata* *Kennedia prostrata*	Urticaceae	*Parietaria debilis*
Haemodoraceae	*Conostylis candicans*	Xanthorrhoeaceae	*Xanthorrhoea preissii*
Hemerocallidaceae	*Dianella revoluta*		
Juncaceae	*Juncus kraussii*		
Malvaceae	*Thomasia cognata*		
Montiaceae	*Calandrinia liniflora*		
Myrtaceae	*^Eucalyptus platypus* *Agonis flexuosa* *Calothamnus quadrifidus* *Calothamnus sp.* *Eucalyptus gomphocephala* *Melaleuca huegelii* *Melaleuca lanceolata* *Melaleuca preissiana* *Melaleuca rhaphiophylla* *Melaleuca sp.* *Melaleuca systena* *Myrtaceae sp.*		

9 Appendix C Introduced Flora Species List

Introduced Flora Species List
Exotic plant species list
**Agave americana*
**Asparagus asparagoides*
**Bromus diandrus*
**Cynodon dactylon*
**Euphorbia terracina*
**Foeniculum vulgare*
**Fumaria capreolata*
**Galium murale*
**Gazania linearis*
**Hypochaeris glabra*
**Lagurus ovatus*
**Lolium sp.*
**Lysimachia arvensis*
**Oxalis pes-caprae*
**Pelargonium capitatum*
**Poaceae sp.*
**Schinus terebinthifolius*
**Sonchus sp.*
**Stenotaphrum secundatum*
**Trachyandra divaricata*
**Typha ?orientalis*
**Ursinia anthemoides.*

9 Appendix D Taxonomic Groups

Fauna Assemblage	
Taxonomic group	**Anticipated species numbers**
Frogs	Five amphibian species have been previously recorded from the following three families in the surrounding area: Limnodynastidae, Myobatrachidae and Hylidae. During the field assessment, five amphibian species were recorded from the above three families. The above amphibian species are likely to be locally common, regionally widespread and can be expected to breed in seasonal wetlands in the region.
Reptiles	A total of 39 reptile species have been previously recorded from the following 10 families in the surrounding area; Cheloniidae, Cheluidae, Dermochelyidae, Diplodactylidae, Pygopodidae, Gekkonidae, Scincidae, Agamidae, Varanidae and Elapidae. No reptile species were recorded during the field assessment. A number of the above reptile species are likely to be locally common and regionally widespread.
Birds	A total of 202 bird species from 52 families have been previously recorded in the surrounding area. During the field assessment 40 bird species were recorded from the following 21 families: Anatidae, Podicipedidae, Anhingidae, Phalacrocoracidae, Pelecanidae, Columbidae, Accipitridae, Rallidae, Laridae, Psittacidae, Cuculidae, Halcyonidae, Maluridae, Acanthizidae, Meliphagidae, Dicruridae, Cracticidae, Corvidae, Megaluridae, Timaliidae and Hirundinidae. These families may include bird species that occasionally utilise Lake Richmond and are therefore not entirely dependent on the Reserve.
Mammals	A total of 25 mammal species from 12 families have been previously recorded in the surrounding area. A total of 19 of these species were marine species from seven families. During the field assessment two introduced mammal species were recorded; the domestic dog and domestic cat. Mammal species potentially occurring in the Reserve are known to occur in the region.

9 Appendix E Conservation Significant Fauna Potentially Occurring in the Reserve

Fauna Assemblage				
Taxa	**EPBC Act conservation status**	**WC Act conservation status**	**Fauna assessment**	**Likelihood and results**
Reptiles				
Perth Slider (*Lerista lineata*)	Not ranked	P3	The Perth Slider is listed as P3 under the DBCA Priority List (Appendix 2). This species is restricted to a 90 km sandy coastal strip near Perth from Mandurah to Lancelin. It occurs in dunes and sand-plains with heaths as well as Eucalypt-Banksia Woodland (Cogger 2014). It is one of 71 reptile species occurring in the Perth region, which, make this area as diverse as any similar sized coastal region in Australia (How & Dell 1994). The Perth Slider is a burrowing species which is usually found in loose soil or sand beneath stones, logs, termite mounds etc, where they feed on ants, termites and other small insects. There were 27 records of the Perth Slider in the DBCA threatened fauna database within 5 km of the Reserve (Appendix 9), 14 of which were recorded from 2001. The Reserve contains deep sandy soils considered suitable for the Perth Slider and; therefore, is expected likely to occur.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Black-striped Snake (*Neelaps calonotos*)	Not ranked	P3	The Black-striped Snake is listed as P3 under the DBCA Priority List (Appendix 2). It is restricted to a narrow coastal and near-coastal strip of south-western WA, from about Lancelin to Rockingham and inland for about 90 km. It is a burrowing snake found in coastal heaths and low shrubland, where it feeds on lizards mostly of the burrowing skink genus Lerista. Four historic records of the Black-striped Snake were identified within 5 km of Reserve (Appendix 9). However, Reserve lacks heath habitat, but contains areas of Tuart and Acacia rostellifera and mix grasses with deep sandy soils, which provide suitable habitat for the Black Striped Snake. In addition to this, the Black Striped Snake preferred prey item, Lerista, was also returned from database searches. As such the Black-striped Snake expected to possibly occur within the Reserve.	**Possible.** Limited or no suitable habitat is present in Reserve, but is located nearby. The species has good dispersal abilities and is known from the general area.
Birds				
Blue-billed Duck (*Oxyura australis*)	Not ranked	P4	Waterbirds and wading birds all inhabit waterbodies including shores, estuaries, lakes, ponds and coastal lagoons. This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Great Egret (*Ardea modesta*)	MiMa	S5	The Eastern Great Egret has been reported in a wide range of wetland habitats (for example inland and coastal, freshwater and saline, permanent and ephemeral, open and vegetated, large and small, natural and artificial). The species usually frequents shallow waters. This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Sharp-tailed Sandpiper (*Calidris acuminate*)	MiMa	S5	Waterbirds and wading birds all inhabit waterbodies including shores, estuaries, lakes, ponds and coastal lagoons. This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.

9 Appendix E Conservation Significant Fauna Potentially Occurring in the Reserve

Fauna Assemblage				
Taxa	**EPBC Act conservation status**	**WC Act conservation status**	**Fauna assessment**	**Likelihood and results**
Birds				
Curlew Sandpiper (*Calidris ferruginea*)	CE; MiMa	S3	Mainly occurs on intertidal mudflats in sheltered coastal areas, non-tidal swamps and man-made water bodies. This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Red-necked Stint (*Calidris ruficollis*)	MiMa	S5	Waterbirds and wading birds all inhabit waterbodies including shores, estuaries, lakes, ponds and coastal lagoons. This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Common Greenshank (*Tringa nebularia*)	MiMa	S5	The Common Greenshank is found in a wide variety of inland wetlands and sheltered coastal habitats of varying salinity. It occurs in sheltered coastal habitats, typically with large mudflats and saltmarsh, mangroves or seagrass. Habitats include embayments, harbours, river estuaries, deltas and lagoons and are recorded less often in round tidal pools, rock-flats and rock platforms. The species uses both permanent and ephemeral terrestrial wetlands, including swamps, lakes, dams, rivers, creeks, billabongs, waterholes and inundated floodplains, claypans and saltflats (DEE 2017c). This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Ruddy Turnstone (*Arenaria interpres*)	MiMa	S5	Waterbirds and wading birds all inhabit waterbodies including shores, estuaries, lakes, ponds and coastal lagoons. This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Sanderling (*Calidris alba*)	MiMa	S5	Waterbirds and wading birds all inhabit waterbodies including shores, estuaries, lakes, ponds and coastal lagoons. This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Peregrine Falcon (*Falco peregrinus*)	Not ranked	S7	The Peregrine Falcon is listed as S7 under the WC Act (Appendix 2) and is an uncommon but a wide-ranging bird across Australia. It occurs mainly along rivers and ranges as well as wooded watercourses and lakes and nests primarily on cliffs, granite outcrops and quarries. The diet of the Peregrine Falcon has been well studied and includes primarily flocking species such as European Starlings (Olsen et.al. 2008). Eight records of the Peregrine Falcon were identified within 5 km of the Reserve (Appendix 9). The Reserve lacks cliffs for nesting, however it does contain some wooded areas near the lake, which provides limited, but suitable habitat. As such the Peregrine Falcon is expected to possibly occur within Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.

Fauna Assemblage				
Taxa	**EPBC Act conservation status**	**WC Act conservation status**	**Fauna assessment**	**Likelihood and results**
Birds				
Silver Gull (*Chroicocephalus novaehollandiae*)	Ma	Not ranked.	The Silver Gull is listed as Marine under the EPBC Act and S5 under the WC Act (Appendix 2). Gulls are gregarious web-footed seabirds mostly occurring on coasts, islands and at sea, usually not far from shore. The Silver Gull is a very common gull with a whitehead and lacking any dark markings. It is very common on coastal mainland, as well as on inland waterways, increasing in numbers for example near colonies of nesting waterbirds. No records of the Silver Gull were identified within 5 km of the Reserve, however suitable habitat is present and the species was recorded flying low over Lake Richmond on a number of occasions.	**Recorded.** Recorded during the 2017 field assessment.
Caspian Tern (*Hydroprogne caspia*)	MiMa	S5	The Caspian Tern is listed as Migratory Marine under the EPBC Act and S5 under the WC Act (Appendix 2). Terns ae long-winged short-legged waterbirds which feed in salt or fresh water, either by plunging headlong after fist or by scooping up small prey items swimming just under the surface. The Caspian Tern also feeds on insects, particularly grasshoppers and dragonflies. The Caspian Tern is the largest of the terns, distinguished by its large red bill and black cap. A total of records of the Caspian Tern was identified within 5 km of Lake Richmond (Appendix 9) suitable habitat is present and the species was recorded flying low over and landing on Lake Richmond on a number of occasions.	**Recorded.** Recorded during the 2017 field assessment.
Bridled Tern (*Onychoprion fuscata*)	MiMa	S5	Waterbirds and wading birds all inhabit waterbodies including shores, estuaries, lakes, ponds and coastal lagoons. This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Roseate Tern (*Sterna dougallii*)	MiMa	S5	Waterbirds and wading birds all inhabit waterbodies including shores, estuaries, lakes, ponds and coastal lagoons. This wetland habitat is present in the Reserve and will provide foraging and breeding habitat for this species. As a result, this species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Australian Fairy Tern (*Sternula nereis nereis*)	Vu	S3	This species nests on sandy beaches, spits and banks above the high tide line and below vegetation and roosts on beach at night. It is also found in embayments of a variety of habitats including offshore, estuarine or lacustrine (lake) islands, wetlands and mainland coastline. (DEE 2017c). The Reserve contains some suitable habitat for the species and; therefore, species is likely to occur within the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.

9 Appendix E Conservation Significant Fauna Potentially Occurring in the Reserve

Fauna Assemblage				
Taxa	**EPBC Act conservation status**	**WC Act conservation status**	**Fauna assessment**	**Likelihood and results**
Birds				
Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*)	Vu	Vu	Forest Red-tailed Black-Cockatoos, listed as Vulnerable under the EPBC Act (Appendix 2), depend primarily on Marri and Jarrah trees for both foraging and nesting. The seeds of both eucalypts are the favoured food source of the birds and hollows within live or dead individual trees are utilised for nesting purposes (Johnstone & Kirkby 1999). Breeding varies between years and occurs at times of Jarrah and Marri fruiting. These black cockatoos breed in woodland, forest or artificial nest boxes, but may also breed in former woodland or forest that has been reduced to isolated trees (DEE 2017c). The Reserve is located within the known distribution of this species and the vegetation contains species, such as Tuart which provide suitable foraging and breeding habitat. A total of 20 records of FRTBC was identified within 5 km of the Reserve (Appendix 9) and; therefore, is likely to occur in this area.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Baudin's Black Cockatoo (*Calyptorhynchus baudinii*)	Vu	En	Baudin's Black-Cockatoos primarily occur in Eucalypt forests and forage at all strata levels within the forests with a tendency to favour areas containing Marri (Johnstone and Kirkby 2008, DEE 2017c). Breeding generally occurs in the Jarrah, Marri and Karri forests of the southwest of Western Australia in areas averaging more than 750 mm of rainfall annually (DEE 2017c). The Reserve is on the extremity of Baudin's Black Cockatoo distribution and the no records of Baudin's Black Cockatoo in from within 5 km of Reserve (Appendix 9). However, the Reserve does contain species, including Tuart which provide suitable foraging and breeding habitat. Given that these species are all highly mobile and the DEE distribution maps are indicative Baudin's Black Cockatoo is expected to possibly occur in the Reserve.	**Possible.** Limited or no suitable habitat is present in the Reserve, but is located nearby. The species has good dispersal abilities and is known from the general area.
Carnaby's Black Cockatoo (*Calyptorhynchus latirostris*)	En	En	Carnaby's Black-Cockatoos, listed as Endangered under the EPBC Act (Appendix 2), feed on the seeds, nuts and flowers, of a variety of native and introduced plant species and insect larvae (DEE 2017c). Food plants generally occur within proteaceous genera such as Banksia, Dryandra, Hakea and Grevillea, though are known to forage on eucalypt species in woodland areas. Carnaby's black cockatoos have also adapted to feeding on exotic species such as pines and cape lilac and weeds such as wild radish and wild geranium (DEE 2017c). Carnaby's black cockatoos usually breed between July and December in the hollows of live or dead eucalypts; primarily in Salmon Gum and Wandoo, but also within Jarrah, Marri and other eucalypt species (Johnstone 2010a). Hollows are usually at least 2 m above ground, sometimes over 10 m and the depth of the hollow varies from 0.25 m to 6 m (DEE 2017c). The DBCA renewed the Carnaby's Cockatoo Recovery Plan in 2013, clearly mapping the distribution of likely breeding and non- breeding areas in southwest WA for CBC (Parks and Wildlife 2013). Based on this map, the Reserve is located within the known distribution of this species and the vegetation contains species, such as Tuart which provide suitable foraging and breeding habitat. A total of 201 records of the Carnaby's Black Cockatoo was also identified within 5 km of the Reserve (Appendix 9) and therefore is likely to occur within Lake Richmond.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.

Fauna Assemblage				
Taxa	**EPBC Act conservation status**	**WC Act conservation status**	**Fauna assessment**	**Likelihood and results**
Birds				
Rainbow Bee-eater (*Merops ornatus*)	MaMi	S5	The Rainbow Bee-eater is listed as Marine under the EPBC Act and S5 under the WC Act (Appendix 2). This species is one of the most common and widespread birds in Australia with a distribution that covers the majority of Australia (Barrett *et al.* 2003). It occurs in lightly wooded, often sandy country, preferring areas near water. It feeds on airborne insects, and nests throughout its range in WA in burrows excavated in sandy ground or banks, often at the margins of roads and tracks. In WA this species can occur as a 'resident, breeding visitor, postnuptial nomad, passage migrant and winter visitor' (Johnstone & Storr 1998). The Richmond Reserve contains potential foraging habitat for this species. A total of 13 records of the Rainbow Bee-eater was recorded within 5 km of the Reserve, and suitable habitat is present. As a result, the Rainbow Bee-eater is likely to occur in the Reserve.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.
Mammals				
Western Quoll (*Dasyurus geoffroii*)	Vu	S1	The Western Quoll is listed as Vulnerable under the EPBC Act and S1 under the WC Act (Appendix 2). The Western Quoll was formerly distributed over nearly 70% of the continent, occurring in every mainland State and Territory. The Western Quoll is now restricted to the south- west of WA, particularly in the jarrah forest and nearby areas, however small, isolated subpopulations persist in the Avon wheatbelt, eastern Goldfields woodlands and mallee and in the Fitzgerald River National Park and Ravensthorpe Ranges. There have been recent records on the Swan Coastal Plain near Baldivis and Yalgorup National Park (Woinarski *et al.* 2014. Western Quoll diet includes mammals, birds, reptiles, invertebrates, plants and rubbish, which is consistent with it being a generalist predator. This species is highly mobile, and appears able to utilise bush remnants and corridors and requires hollow logs or earth burrows in which to den (Van Dyck & Strahan 2008). During this assessment, very few large hollow logs or earth burrow were recorded. In addition to a lack of denning habitat, five records of the Western Quoll were identified within 5 km of the Reserve (Appendix 9), however they are all from the Paganoni Swamp Reserve, Karnup, which is approximately 18 km to the south of the Reserve. As such the Western Quoll is unlikely to occur in the Reserve.	**Unlikely.** No suitable habitat is present in the Reserve but is nearby, the species has poor dispersal abilities, but is known from the general area; or suitable habitat is present, however the Reserve is outside of the species' known distribution.
South-western Brush- tailed Phascogale (*Phascogale tapoatafa*)	Not ranked.	S6	The Southern Brush-tailed Phascogale is listed S6 under the WC Act (Appendix 2). It is restricted to the extreme southwest, and its characteristic low population densities make it vulnerable to localised extinction (Van Dyck & Strahan 2008). This subspecies has been observed in dry sclerophyll forests and open woodlands containing hollow-bearing trees with a sparse ground cover. A total of 21 records of the Southern Brush-tailed Phascogale was identified within 5 km of Reserve (Appendix 9). These records were all from the Paganoni Swamp Reserve, the majority of which were from survey undertaken from 2010 to 2013. Some sections of the Reserve do have potential foraging habitat for this species, however, there were very few hollows observed in which the species could den. As such the Southern Brush-tailed Phascogale is unlikely to occur at Lake Richmond.	**Unlikely.** No suitable habitat is present in the Reserve but is nearby, the species has poor dispersal abilities, but is known from the general area; or suitable habitat is present, however the Reserve is outside of the species' known distribution.

9 Appendix E Conservation Significant Fauna Potentially Occurring in the Reserve

Fauna Assemblage				
Taxa	**EPBC Act conservation status**	**WC Act conservation status**	**Fauna assessment**	**Likelihood and results**
Mammals				
Southern Brown Bandicoot (*Isoodon obesulus fusciventer*)	Not ranked.	P5	The Southern Brown Bandicoot is listed as P5 under the DBCA Priority List (Appendix 2). It once occurred throughout southwest WA; it now occurs from Guilderton southwards on the SCP, including the Perth Metropolitan area, in Jarrah and Karri (Eucalyptus diversicolor) forests and adjacent coastal vegetation complexes. The species inhabits scrubby, often swampy, vegetation with dense cover up to about 1m high. It feeds in adjacent forest and woodland that is burnt on a regular basis and in areas of pasture and cropland lying close to dense cover. The Southern Brown Bandicoot is patchily distributed in suitable habitat, with populations inhabiting Jarrah and Wandoo forests usually associated with watercourses. On the Swan Coastal Plain it is often associated with wetlands with dense vegetation where they feed on fruit, seeds, insects and fungi (Woinarski *et al.* 2012). More than 400 records were identified for this species within a 5 km radial search from Reserve. The Reserve contains soft sands and vegetation cover providing habitat for the Southern Brown Bandicoot. As such the species is considered likely to occur at Lake Richmond.	**Likely.** Suitable habitat is present in the Reserve and the Reserve is in the species' known distribution.

En = Listed as Endangered under the EPBC Act, Vu = Listed as Vulnerable under the EPBC Act, Mi = Listed as Migratory under the EPBC Act, Ma = Listed as Marine under the EPBC Act, S = Scheduled under the WC Act, and P = Listed as Priority by the DBCA.

9 Appendix F Summary of Infrastructure Assets within the Reserve

Summary of Infrastructure Assets within the Reserve			
Type	**Map reference**	**Current condition**	**Repair/upgrades and recommendations**
Signage			
Directional	Item 14 on Figure 28	Good	None required
	Item 16 on Figure 28	Good	None required
	Item 17 on Figure 28	Good	None required
Educational	Item 8 on Figure 28	Good	None required
	Item 9 on Figure 28	Good	None required
	Item 10 on Figure 28	Good	None required
	Item 11 on Figure 28	Good	None required
		Poor	Structure damaged – requires replacement. Refer to Item 22 on Figure 29
	Item 12 on Figure 28	Good	None required
	Item 15 on Figure 28	Good	None required
	Item 20 on Figure 28	Good	None required
	Item 22 on Figure 28	Good	None required
	Item 23 on Figure 28	Good	None required
	Item 25 on Figure 28	Good	None required
		Good	None required
	Item 27 on Figure 28	Good	None required
Hazard	Item 21 on Figure 28	Good	None required
	Item 26 on Figure 28	Poor	Sign faded; requires replacement. Refer to Item 23 on Figure 29
Interpretative	Item 13 on Figure 28	Good	None required
	Item 18 on Figure 28	Good	None required
	Item 19 on Figure 28	Good	None required
Regulatory	Item 1 on Figure 28	Good	None required
	Item 2 on Figure 28	Good	None required
	Item 3 on Figure 28	Good	None required
	Item 4 on Figure 28	Good	None required
	Item 5 on Figure 29	Good	None required
	Item 6 on Figure 29	Good	None required
	Item 7 on Figure 29	Good	None required
	Item 24 on Figure 29	Good	None required
Reserve Name	Item 28 on Figure 29	Good	None required
Fencing			
Post and wire fence with metal stakes (284 m)	Item 12 on Figure 28	Poor	Damaged – requires 284 m of fencing to be replaced. Refer to Item 12 on Figure 29
Wooden structure fence, no netting (651 m)	Figure 28	Good	None required, structure integrity remains intact
Green plastic chain mesh with wooden pillar structure (287 m)	Figure 28	Good	None required, structure integrity remains intact
Wire fencing with wooden pillar structure (624 m)	Figure 28	Good	None required, structure integrity remains intact

9 Appendix F Summary of Infrastructure Assets within the Reserve

Summary of Infrastructure Assets within the Reserve			
Type	**Map reference**	**Current condition**	**Repair/upgrades and recommendations**
Fencing			
Black plastic chain mesh fencing metal black structure (55 m)	Figure 28	Good	None required, structure integrity remains intact
Access			
Gates	Item 1 on Figure 27	Good	Install pedestrian gate to prevent motorbike access. Refer to Item 2 on Figure 29
	Item 2 on Figure 27	Good	None required
	Item 3 on Figure 27	Good	Upgrade white rusted gate to improve amenity value. Refer to Item 4 on Figure 29
	Item 5 on Figure 27	Good	Replace footings for pedestrian gate. Refer to Item 5 on Figure 29
	Item 6 on Figure 27	Good	Replace footings for pedestrian gate. Refer to Item 6 on Figure 29
	Item 7 on Figure 27	Good	Replace chained access with formal gate to prevent damage. Refer to Item 7 on Figure 29
	Item 8 on Figure 27	Good	None required; however, vegetation obstruction prevents pedestrian and vehicle access.
	Item 9 on Figure 27	Good	None required
	Item 10 on Figure 27	Good	Replace footings. Refer to Item 8 on Figure 29
	Item 11 on Figure 27	Good	None
	Item 12 on Figure 27	Good	Insert pedestrian gate to prevent motorbike access. Refer to Item 9 on Figure 29
	Item 13 on Figure 27	Good	None required
	Item 15 on Figure 27	Good	None required
External access	Item 4 on Figure 27	Not applicable	Insert vehicle and pedestrian gate to prevent unauthorised access into the Reserve. Refer to Item 2 on Figure 29.
	Item 14 on Figure 27	Good	None required; restricts vehicles through presence of bollards
Pathways/tracks			
Bitumen road (242 m)	Figure 28	Good	None required
Compact sand (2532 m)	Figure 28	Good	None required
Concrete (1017 m)	Figure 28	Good	None required
Informal tracks (1122 m)	Item 1 on Figure 28	Poor	Install fencing to minimise creation of additional informal tracks. Refer to item 1 on Figure 29.
Park furniture			
Park shelters	Picnic area on Figure 28	Good	None required
Rubbish bins	Bin locations on Figure 27	Good	None required, all existing bins are serviceable. Potential for additional bins at all access locations within the Reserve. Indicative locations for additional bins are outlined in Items 13–16 on Figure 28
Memorial seats	Picnic area on Figure 28	Good	None required
Seating	Seating on Figure 27	Poor–Good	Replace seating or improve cleaning frequency at two bench locations identified as Item 13 on Figure 29
Barbeques	Picnic area on Figure 28	Good	None required
Buildings	Observation sites on Figure 27	Good	None required
Pedestrian walkways	Pedestrian walkways on Figure 28	Good	None required
Parking facilities	Parking located on Figure 27	Good	No repair or upgrades required.

9 Appendix G Signage Types

Directional

Educational

Interpretative

Regulatory

Reserve Name

CITY OF ROCKINGHAM

Lake Richmond
Management Plan

city of Rockingham

where the coast comes to life