Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

Section 1 – Eligibility for Listing		
1. Name of the ecological community		
Stromatolite-like microbialite community of coastal freshwater lakes (Lake Richmond)		
2. Listing Category for which the ecological community is nominated		
	Current ranking under WA Minister ESA list in policy	EPBC Act (wholly or as a component)
Current listing category (Please check box)	☒ Critically endangered ☐ Endangered ☐ Vulnerable ☐ Priority 1-4 ☐ Data Deficient ☐ None – not listed	Name: Thrombolite (microbial) community of coastal freshwater lakes of the Swan Coastal Plain (Lake Richmond) ☐ Critically endangered ☒ Endangered ☐ Vulnerable ☐ None – not listed
	Recommended ranking under BC Act IUCN assessment	
Proposed listing category (Please check box)	☐ Collapsed ☒ CR: Critically endangered ☐ EN: Endangered ☐ VU: Vulnerable ☐ Priority 1-4	
Select one or more of the following criteria under which the community is to be nominated for BC Act listing. (Please check box). For further details on these criteria please refer to the Attachment to this form. The information you provide in Section 3 should support the criteria you select here.	☐ Criterion A – Reduction in geographic distribution ☒ Criterion B – Restricted geographic distribution ☐ Criterion C – Environmental degradation based on change in an abiotic variable ☐ Criterion D – Disruption of biotic processes or interactions based on change in a biotic variable ☐ Criterion E – Quantitative analysis that estimates the probability of ecosystem collapse	

Section 2 – Description, Condition, Threats & Recovery

Please answer all the questions, providing references where applicable. If no or insufficient information exists to answer a question, you must indicate this instead of leaving the question blank. The answers may be provided within this form or as attachments, ensuring that responses clearly indicate which question number they refer to.

Classification

3. What is the name of the ecological community?

Note any other names that have been used recently, including where different names apply within different jurisdictions. For example, is it known by separate names in different States or regions?

Stromatolite like microbialite community of coastal freshwater lakes (Lake Richmond) is listed under the EPBC Act (Endangered) under the name 'Thrombolite (microbial) community of coastal freshwater lakes of the Swan Coastal Plain (Lake Richmond)'. It is also commonly referred to as "Lake Richmond thrombolites".

4. What authorities/surveys/studies support or use the name?

The community was originally identified by Moore (1993). The community type has been recognised since the publication of the thesis and was endorsed as a critically endangered TEC by the WA Minister for Environment in 1995, but was ranked using ranking criteria developed in WA, that do not match those used for the IUCN RLE. The community was then listed as endangered under the name 'Thrombolite (microbial) community of coastal freshwater lakes of the Swan Coastal Plain (Lake Richmond)' under the EPBC Act in 2000, but has not been re-ranked using the new criteria recognised under that Act that also differ from the ranking criteria used for the IUCN RLE.

5. How does the nominated ecological community relate to other ecological communities that occur nearby or that may be similar to it?

Does it intergrade with any other ecological communities and, if so, what are they and how wide are the intergradation zones?
Describe how you might distinguish the ecological community in areas where there is overlap (also see Description section below).

Other microbial structures occur in Western Australia at Hamelin Pool, Shark Bay. Living microbialites in the south west of the State that are not as well-known also occur at Pink Lake (Esperance), Sea Cliffs (Augusta), Lake Clifton, Pamelup Pond - Lake Preston (Yalgorup); Government House Lake and other lakes on Rottnest Island; and Lake Thetis (Cervantes) (Moore 1993). Each of these constitutes a distinct and very significant community in terms of composition, history, structure, and morphology (Moore 1993).

The 'Sedgelands in Holocene dune swales' community borders the Lake Richmond thrombolite community. This community is currently ranked critically endangered in WA.

Description

6. List the main features that distinguish this ecological community from all other ecological communities.

Characteristic (or diagnostic) features can be biological (e.g. taxa or taxonomic groups of plants and animals characteristic to the community; a type of vegetation or other biotic structure), or associated non-biological landscape characteristics (e.g. soil type or substrate, habitat feature, hydrological feature). Please limit your answer to those features that are <u>specific</u> to the ecological community and can be used to distinguish it from other ecological communities.

The community occurs on a relict foredune plain on Holocene sands at Lake Richmond, Rockingham. It is a thrombolitic community comprising a distinctive complex assemblage of photosynthetic cyanobacteria and purple sulphur bacteria, eukaryotic microalgae and "true bacteria". The thrombolitic structures generally have an internal clotted structure and are formed through precipitation of calcium carbonate within the microenvironment of microbes as a result of photosynthetic and metabolic activity (Moore 1993).

7. Give a description of the biological components of the ecological community.

For instance, what species of plants and animals commonly occur in the community; what is the typical vegetation structure (if relevant).

The thrombolites of Lake Richmond is a reef of thrombolitic structures together with the microbial assemblage that creates the structures. The thrombolites are probably formed by precipitation of a particular form of calcium

carbonate, termed aragonite, within the microenvironment of the assemblage as a result of growth and metabolic activity (Moore 1993). They are formed by a distinctive complex assemblage of photosynthetic cyanobacteria and purple sulphur bacteria, eukaryotic microalgae and “true bacteria”. This assemblage of microbes forms the benthic microbial community (BMC). Cyanobacteria (‘blue-green algae‘) generally dominate microbial assemblages involved in the formation of thrombolites (Moore 1991). Dichothrix sp., a cyanobacterium was observed to be the dominant microbe at Lake Richmond and grows in fresh to brackish waters with low nutrient status ([redacted][1] personal observation circa 1993). Light and freshwater rich in carbonates are likely to be essential to the growth and survival of the thrombolites.   The rate of growth of the thrombolites at Lake Clifton was about 0.1mm per year, and the growth rate of the thrombolites in Lake Richmond is likely to be similarly low (Moore 1993; Moore and Burne 1994). Changes to physical parameters, such as an increase or decrease in salinity, may cause a shift in the microbes that dominate the thrombolites possibly replacing these with a different microbial community that may, or may not facilitate carbonate deposition and thrombolite formation.
8. Give a description of the associated non-biological landscape characteristics or components of the ecological community.   For instance, what is the typical landscape in which the community occurs? Note if it is associated with a particular soil type or substrate; what major climatic variables drive the distribution of the ecological community (e.g. rainfall). Note particular altitudes, latitudes or geographic coordinates
Lake Richmond is a relatively deep, perennial freshwater lake located about 1km south of Rockingham on the southern Swan Coastal Plain. The lake was isolated from the sea by beach ridges, when part of the marine portion of Cockburn Sound filled in during the last 4,000 years (Kenneally *et al*. 1987). The dunes around the lake were classified as part of the Quindalup Dune System by McArthur and Bettenay (1960). The coastal dune sequence and shallow marine sands that occur in the Lake Richmond area are described as relic foredune plain consisting of calcareous sands of aeolian origin (Gozzard 1983). The sands are “white, medium grained rounded quartz and shell debris, well sorted, of aeolian origin” (Gozzard 1983). The regional climate is Mediterranean, with hot, dry summers and cool, wet winters (Moore *et al*. 1984).   Lake Richmond is a throughflow lake receiving groundwater discharge from the Safety Bay Sand in a southerly arc spanning the lake from east to west. The lake leaks water to the north where it becomes part of the groundwater flow system that eventually discharges into Cockburn Sound. The lake also receives storm water runoff from drains. The lake is known to be 15m deep (Guerreiro *et al*. 2017) and its floor is covered with thick organic ooze, particularly in the southern area of the lake. The lake level varies little with season due to the drains that control inflow and outflow, however, the level falls sufficiently to expose the thrombolites at the end of summer (March - April) (English *et al*. 2003).
9. Provide information on the ecological processes by which the biological and non-biological components interact (where known).
The waters of the Lake Richmond contain low levels of dissolved calcium (approximately 0.5 parts per million (ppm)), which increase in winter and deplete in late summer when microbes involved in the construction of the thrombolites are most active (Passmore 1970). Calcium, carbonates, nitrogen and phosphorus in these waters are probably essential for growth of the microbialite structures.   Groundwater inflow into the lake occurs predominantly from southeast and east while seaward areas to the west and northwest constitutes the main outflow zones. During winter, however, the lake level tends to rise faster than the aquifer water levels due to stormwater inflow and the influx of groundwater is gradually reduced, becoming subordinate to runoff. Consequently, at the peak water levels the lake usually behaves as a groundwater recharge wetland, with surface water seeping into the aquifer in most directions, except to the southeast where the hydraulic gradient is essentially flat so little to no exchange occurs (Guerreiro *et al*. 2017). This differs from the historical surface water-groundwater interaction regime as described by Passmore (1970) from 1966 where the groundwater levels to the east, south and west of the lake were higher than the lake most of the time, indicating groundwater discharge into the lake. Groundwater levels to the north were lower except during the peak of

[1] previously PhD student, University of Western Australia.

winter, indicating discharge of aquifer water to the lake occurred most of the year, hence Lake Richmond was primarily a groundwater discharge wetland (Passmore 1970).

The salinity and pH of the lake (measured from 2013 to 2015) ranged from 0.55 to 0.7ppt and from 8.5 to 9.0, respectively, with higher values generally recorded during summer. Daily fluctuations in dissolved oxygen (DO), pH and redox potential are significant in the lake and tightly coupled, emphasizing the importance of biological processes on the lake water chemistry (Guerreiro *et al*. 2017). A saltwater interface occurs in the Rockingham Sand aquifer at a depth of about 65m beneath Lake Richmond. Upconing of this saline water may occur if prolonged high rates of groundwater abstraction are maintained in the area. During the drier months of the year, no water may discharge into the lake from drains.

10. Does the ecological community show any consistent regional or other variation across its extent, such as characteristic differences in species composition or structure?

If so, please describe these.

No, this ecological community occurs at a single location.

11. Does the ecological community provide habitat for any listed threatened species and/or endemic species?

If so, please note the species and whether the species is listed on State and/or national lists and the nature of their dependence on the ecological community.

There are a number of bird species listed as migratory wading birds (listed as migratory in WA and under EPBC Act) and under the 1981 Agreement between the Government of Australia and the Government of Japan for Protection of Migratory Birds in Danger of Extinction and their Environment (Japan-Australia Migratory Bird Agreement (JAMBA)) that utilise the lake on a seasonal basis, for example, Greenshank (*Tringa nebularia*) and red-necked stints (*Calidris ruficollis*).

12. Identify major studies on the ecological community (authors, dates, title and publishing details where relevant).

Department of Environment and Conservation (2010) Rockingham Lakes Regional Park Management Plan 2010. Management Plan No. 67. Department of Environment and Conservation, Western Australia.

English, V., Blyth, J., Goodale, A., Goodale, B., Moore, L., Mitchell, D., Loughton, B., Tucker, J., Halse, S. and King, S. (2003) Thrombolite community of coastal freshwater lakes (Lake Richmond). Interim Recovery Plan 2003-2008. Department of Conservation and Land Management, Western Australia.

Goodale, B. (1996) Rockingham Conservation Reserves Management Plan. Lake Richmond Conservation Reserve, Karnup Nature Reserve, Baldivis Nature Reserve. Report for Rockingham City Council and Kwinana/Rockingham/ Mandurah Naturalists' Club (Inc).

Guerreiro, J.P., Vogwill, R. and Collins, L.B. (2017) Lake Richmond Microbialites. Summary Report to the Department of Biodiversity, Conservation and Attractions (DBCA). Curtin University of Technology.

Moore, L. (1991) Lake Clifton - An internationally significant wetland in need of management. Land and Water Research News. Issue No 8; 37-41.

Moore, L. (1993) The Modern Thrombolites of Lake Clifton South Western Australia. Unpublished PhD Thesis. University of Western Australia.

Vogwill, R. and Whitehead, M. (2018) Lake Richmond – Microbialites, Microbial Mat Mapping and Hydrology Report. Report prepared for the City of Rockingham.

Distribution

13. Describe the distribution across WA and nationally.

State the appropriate bioregions where the ecological community occurs. Attach or provide any maps showing its distribution with details of the source of the maps, or explain how they were created and the datasets used.

This ecological community occurs at a single location. Lake Richmond is located about 1km south of Rockingham on the southern Swan Coastal Plain. It is elliptical in shape, measuring approximately 1km by 0.6km (Appendix 1). The waterbody covers about 40ha, and the water in the lake is about 1m above sea level. The maximum water depth is known to be about 15m, with the level varying slightly with season.

The microbial structures at lake Richmond occur in a zone about 15m wide around much of the lake, occupying a total area of ~0.4km^2. The zone has lithified carbonate crust at the surface (Kenneally *et al*. 1987). The best developed thrombolites occur on the eastern side of the lake ([redacted][2], personal observation, from English *et al*. 2003).

14. What is the area of distribution of the ecological community?

For answers to parts a, b, c & d: please identify whether any values represent extent of occurrence or area of occupancy (as described in the Attachment); provide details of the source(s) for the estimates and explain how they were calculated and the datasets used.

14 a. What is the current known area (in ha)?

41ha

14 b. What is the pre-industrialisation extent or its former known extent (in ha)? An ecological community is considered to be naturally restricted if it has a pre-industrialisation area of occupancy that is less than 10 000 ha or a pre-industrialisation extent of occurrence that is less than 100 000 ha (refer to the Attachment A) 41 ha

Unknown, but thought to be relatively stable at significantly less than 10,000ha. Old stranded thrombolites (no longer living) have been identified immediately to the east of Lake Richmond in Lakes Cooloongup and Walyungup (DEC 2010).

14 c. What is the estimated percentage decline of the ecological community?

It is presumed that the Lake Clifton thrombolites occupy most of their former extent.

14 d. What data are there to indicate that future changes in distribution may occur?

Water quality data indicate significant ongoing decline since approximately 1968 (as shown in Guerreiro *et al*. 2017).

Lake water monitoring data showed a decline in lake level from 1975 to 2005 (DOW 2008) and change in seasonal fluctuation from 1945 to 2015 (Vogwill and Whitehead 2018 using DWER data).

Climate change trends from National Climate Change Adaptation Research Facility (NCCARF) website (accessed 2019) and Southern Metropolitan Regional Council (GHD 2009) indicate drying climate is likely to result in reduced groundwater inflows.

Patch size

15. What is the typical size (in ha) for a patch of the ecological community (if known)?

Explain how it was calculated and the datasets that are used. Relevant data includes the average patch size, the proportion of patches that are certain sizes, particularly proportions below 10 ha and below 100 ha, (but also below 1 ha and above 100 ha, for example). This could be presented as the range of patch sizes that comprise 90% of the occurrences.

There is only one location of this ecological community, and it covers 41 hectares.

16. Quantify, if possible, the smallest percentage or area required for a patch of the ecological community to be considered viable.

This refers to the minimum size of a remnant that can remain viable without active management. It may be determined through the requirements for dominant native species, level of species diversity, or the nature of invasive weeds.

There is only one location known, in a single waterbody/lake, therefore this question is not relevant.

Functionality

17. Is the present distribution of the ecological community severely fragmented?

If so, what are likely causes of fragmentation?
If fragmentation is a natural or positive characteristic of this ecological community, please explain this and state the reason.
Severely fragmented refers to the situation in which increased extinction risk to the ecological community results from most remnants being found in small and relatively isolated patches.

NA

18. Has there been a loss or decline of functionally important species?

[2] Volunteers, Rockingham Regional Environment Centre Naragebup

This refers to native species that are critically important in the processes that sustain or play a major role in the ecological community and whose removal has the potential to precipitate change in community structure or function sufficient to undermine the overall viability of the community.

Changes to physical parameters, such as an increase or decrease in salinity and nutrient concentrations, have likely caused a shift in the microbes that dominate the assemblage possibly replacing these with a different microbial community that may not facilitate carbonate deposition and thrombolite formation.

18 a. If yes, which species are affected?

The benthic microbial community dominated by the filamentous cyanobacteria ('blue-green algae') and diatoms.

18 b. How are the species functionally important and to what extent have they declined?

Photosynthetic and metabolic activity of the benthic microbial community facilitates carbonate deposition and thrombolite formation. The level of decline is not known and difficult to measure.

Reduction in community integrity

19. Please describe any processes that have resulted in a reduction in integrity and the consequences of these processes, e.g. loss of understorey in a woodland. Include any available information on the rate of these changes.

This recognises that an ecological community can be threatened with extinction through on-going modifications that do not necessarily lead to total destruction of all elements of the community. Changes in integrity can be measured by comparison with a benchmark state that reflects as closely as possible the natural condition of the community with respect to the composition and arrangement of its abiotic and biotic elements and the processes that sustain them. Please provide a description of the benchmark state where available. For further information please refer to the Guidelines.

The microbialite community of Lake Richmond has been subject to historical disturbance by alterations to the level of salinity, lake level and possibly other water quality parameters; physical crushing; and disturbance of the native vegetation buffer around the lake. The thrombolites are also likely to be subject to future threats, mainly from hydrological, chemical and physical changes (English *et al*. 2003).

Survey and Monitoring

20. Has the ecological community been reasonably well surveyed?

Provide an overview of surveys to date, including coverage of different land tenure, and the likelihood of the ecological community's current known distribution and/or patch size being a true reflection of its actual distribution (consider area of occupancy and area of extent, including any data on number and size of patches).

An extensive survey of the microbialite assemblages in many areas of south Western Australia was undertaken by Linda Moore for her PhD (Moore 1993).

21. Where possible, please indicate areas that haven't been surveyed but may add to the information required in determining the community's overall viability and quality.

Include commentary on issues to do with accessing different land tenures within the area of distribution, including private property, and the likelihood that these areas may include occurrences.

NA

22. Is there an ongoing monitoring program? If so, please describe the extent and length of the program.

Monitoring of salinity, pH and nutrient levels occurred in Lake Richmond from February 2013 to April 2015 (Guerreiro *et al*. 2017).

A monitoring program for the physical condition and microbial assemblage of the thrombolites occurred in 2013 to 2015; and then again in 2017 (Vogwill and Whitehead 2018).

Condition Classes and Thresholds

23. Do you think condition classes/thresholds apply to this ecological community? If not, give reasons.

The Committee recognises that ecological communities can exist in various condition states. In reaching its decision the Committee uses condition classes and/or thresholds to determine the patches that are included or excluded from the listed ecological community (see the Guidelines for details of the process of determining condition classes). Relevant here is recognition of different states following disturbance and the natural recovery of the occurrence towards a higher condition class.

While the thrombolite structures are persistent, it is not necessarily evident from visual cues to determine whether the structure-building communities are active, inactive, or deceased. This requires use of specialist techniques and knowledge to establish the status of the microbial community. Therefore, a condition class can be applied to the community as a whole based on:

- the presence/absence and species composition of the benthic microbial community and whether this will contribute to growth (accretion);
- hydrological changes within the lake;
- a visual survey of the physical condition of the thrombolite structures.

24. If so, how much of the community would you describe as in relatively good condition, i.e. likely to persist into the long-term with minimal management?

In 2017 to 2018, there was no apparent calcification of the microbial mats as the lake's physical and chemical conditions were not suitable for structure accretion (Vogwill and Whitehead 2018). If using the presence of the specific benthic microbial community and hydrological conditions as a baseline for 'good condition', then it can be inferred that very little of the community is in 'good condition'.

25. What features or variables do you consider to be most valuable for identifying a patch of the ecological community in relatively good condition?

Variables for establishing the highest condition class may include: patch size; connectivity; native plant species composition; diversity and cover (for example in overstorey; mid-shrub and/or understorey layers); recognised faunal values; and cover of weeds or other invasive species.

As per criteria in question 24, a 'good' condition class can be described as presence of specific benthic microbial community which contributes to accretion, specific hydrological conditions within the lake that promote accretion and intact condition of thrombolite structures.

26. How much of the community would you describe as in relatively medium condition, i.e. likely to persist into the long-term future with management?

Likely none (see above).

27. Please describe how you would identify areas in medium condition using one or a combination of indicators such as species diversity, structure, remnant size, cover of weeds or other invasive species, etc.

A 'medium' condition class can be described as some presence of specific benthic microbial community which contributes to accretion, minimal changes to the hydrological conditions within the lake that promote accretion, and mostly intact condition of dome-like structures.

28. How much of the community would you describe as in relatively poor condition, i.e. unlikely to be recoverable with active management?

It is inferred that 100% of the community is in poor to medium condition. In 2017 to 2018, there was no apparent calcification of the microbial mats as the lake's physical and chemical conditions were not suitable for structure accretion and water chemistry favourable for accretion was not recorded anywhere in the lake. The prospects for ongoing formation of structures were better in 2013-14-15 but not ideal and only minor carbonate formation is believed to have occurred. In 2013-2015 during the main microbialite formation period (late summer) water chemistry that promotes dissolution of structures was only recorded near the main drain inflow at the southern end of the lake (Vogwill and Whitehead 2018). Sampling in 2012 revealed microbialites were active at the eastern and northern ends of the lake, compared to the south end where they had not been active for some time. Dome structures are still present in the lake however, and microbial assemblages that are capable of accreting in appropriate conditions are likely to be present in the lake.

29. Please describe how you would identify areas in poor condition using one or a combination of indicators such as species diversity, structure, remnant size, cover of weeds or other invasive species, etc.

A 'poor' condition class can be described as the complete absence of specific benthic microbial community which contributes to accretion; and permanent detrimental changes to hydrological conditions within the lake so that accretion is no longer possible.

Threats

Note: If you plan to identify climate change as a threat to the ecological community, please refer to the IUCN Red List of Ecosystem Guidelines for information on how this should be addressed.

30. Identify PAST threats to the ecological community indicating whether they are *actual* or *potential*.

The microbialite community of Lake Richmond has been subject to historical disturbance by alteration to the level of salinity, lake level and possibly other water quality parameters; physical crushing; and disturbance of the native vegetation buffer around the lake.

31. Identify CURRENT threats to the ecological community indicating whether they are *actual* or *potential*.

The microbialite community of Lake Richmond is subject to recent and ongoing disturbance by alterations to the level of salinity, nutrients, deposition of sediment, other water quality parameters, lake level; physical crushing; drying climate, and disturbance of the native vegetation buffer around the lake.

32. Identify FUTURE threats to the ecological community indicating whether they are *actual* or *potential*.

It is predicted that in the future the microbialite community of Lake Richmond will continue to be threatened by alterations to the levels of nutrients, lake level and other water quality parameters; physical crushing; disturbance of the native vegetation buffer around the lake.

For each threat describe:

32 a. How the threat has impacted on this ecological community in the past.

Physical crushing

The thrombolites have been subject to physical crushing underfoot by visitors to Lake Richmond in recent decades. Visitors are likely to be unaware of the significance of the thrombolites unless they have noted the interpretive information that occurs at the site. In the 1970s and 1980s water skiing on the lake was allowed and the remains of a ski jump still exist on the western edge (Goodale 1996). Active recreation such as skiing would have significant impact on the thrombolites through crushing. As the population of the area increases, the impact of crushing is likely to increase unless actions are taken to ameliorate visitor impacts.

Nutrient enrichment and increases in other pollutants

Increasing nutrient levels may result in growth of the green alga Cladophora which decreases light penetration and reduces or prevents photosynthesis of the thrombolite forming benthic microbial community, thereby preventing thrombolite formation. The three inlet drains direct nutrients from an area of urban catchment into the lake and result in increased nutrient levels. Nutrient concentrations appear to rise during winter, when runoff discharges increase, and fall during summer, when the influx of drainage water is lower, and biota consume the nutrients. Nutrient (phosphorus and nitrogen) levels in the lake water normally remain well above the guidelines for freshwater ecosystems in Western Australia (ANZEEC 2000). Sampling in 2012 revealed microbialites were active at the eastern and northern ends of the lake, possibly due to the influx of fresh groundwater, compared to the south end where they had not been active for some time. This inactivity at the southern end of the lake is possibly related to water chemistry including the influx of nutrients as indicated by the presence of macro-algae on the structures near the drain that is favouring organisms that graze on microbialites and others that compete with them. Guerreiro *et al*. (2017) reported total nitrogen levels during the 2013 to 2015 monitoring period as between 0.62 to 1.202mg/L, well above the 0.35mg/L standard recommended in ANZEEC (2000). High nutrient levels observed in the lake are triggering the proliferation of algae which in some areas form a dense meadow, completely obscuring the microbialites and preventing the development of microbial mats. Guerreiro *et al*. (2017) reported Charophytes being particularly abundant in the deeper portions, forming a dense cover at the lake bottom, and completely obscuring the microbialite substrate. Groundwater outflow also contributes to through flow of Lake Richmond (Passmore 1970). Contamination of local groundwater with nutrients or other pollutants is increasingly likely with urbanisation of the catchment to the east of the lake (English *et al*. 2003).

Hydrological changes

The level of the lake is likely to be crucial for maintaining the thrombolites, as they rely on sufficient water to cover the growing surface of the structures while still having adequate levels of light and raw materials such as calcium and carbonate ions for their growth. The hydrology of the lake was significantly modified by the construction of an artificial outlet and three inlets on the eastern, southern and western margins in 1968. Historical lake level data shows the reduction in lake level and seasonal fluctuation after the drains were installed (figure 1) (Vogwill and Whitehead 2018). These drains were built to dispose of surface water from the developed catchment, however the increase in volume served to dilute ions, trace elements and other contained substances such as calcium, carbonate and bicarbonate that provide the raw materials such as carbonates and calcium in sufficient concentrations to support thrombolite growth. Prior to 1968, Passmore (1970) noted the total dissolved solids (TDS) concentration of the lake was from 2,000 to 3,500mg/L, with chloride typically the dominant anion. In sampling from 2013 to 2015, and 2017 to 2018, Vogwill and Whitehead (2018) found the dominant anion was bicarbonate, suggesting that the net dissolution of the structures and the carbonate generally in the lake were most likely occurring.

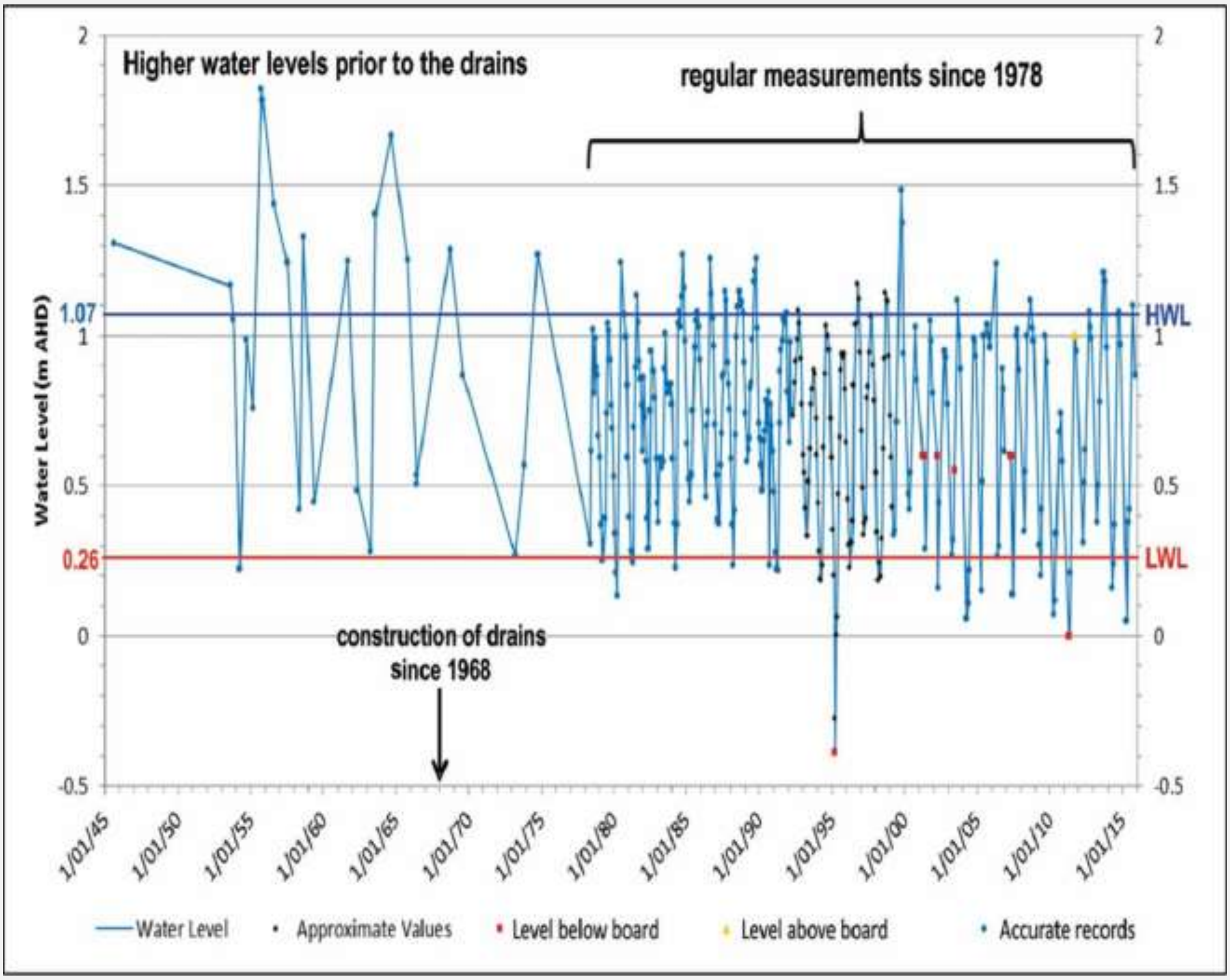


Figure 1. Historical water level fluctuations in Lake Richmond from DWER data (as shown in Vogwill and Whitehead 2018).

Furthermore, groundwater abstraction for urban or other purposes in the groundwater catchment of Lake Richmond has resulted in further lowering of the water level in the lake, this may expose the thrombolites and the BMC preventing growth of the structures in favour of microbialite erosion. Groundwater monitoring in the Warnbro Subarea on the Rockingham Sand Aquifer (T281) by DOW (2008) has seen a decline in the seasonal variation in water levels of around 0.5m from 1975 to 2005 due to a decline in winter levels (Figure 2) (DOW 2008). In addition, water level monitoring by Vogwill and Whitehead (2018) from 2013 to 2015 also reported a 57% reduction in the flooded area by the end of summer, resulting in the exposure of the microbial communities along the lake flat for a considerable part of the year.

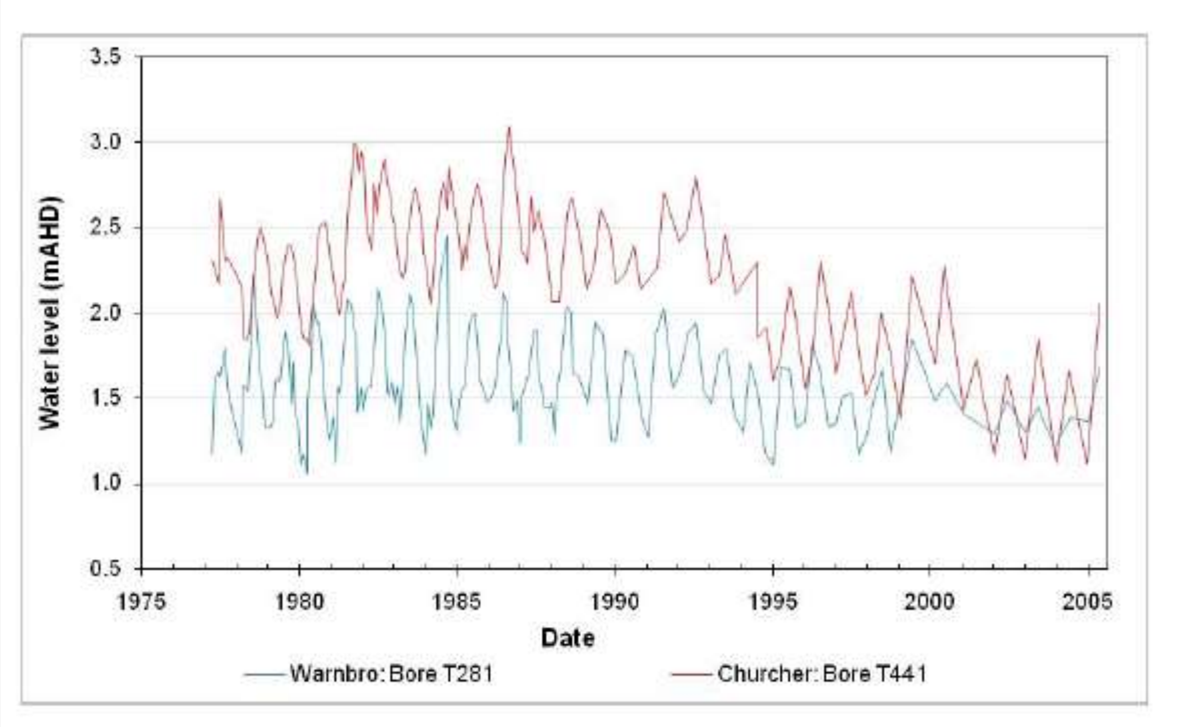


Figure 2. Rockingham sand aquifer groundwater levels from T281 1975 to 2005 (graph from DOW 2008).

The salinity of the lake water changed leading to a change in the dominant microbes which may not support microbial accretion. Prior to the construction of the drains, salinity levels of 2 to 3.5ppt were recorded by Passmore (1970) between 1965 and 1966. Following the installation of the drains, salinity levels in the lake declined to between 0.4 and 1.4 ppt (Kenneally *et al*. 1987). In 2013 to 2015, Vogwill and Whitehead (2018) recorded salinity of the lake which ranged from 0.55 to 0.7ppt, depending on the seasonal variation in rainfall.

Land development (potential)

An inland marina and hotel (Mangles Bay Marina) was also proposed for the northwest of the lake and had the potential to alter hydrological gradients and result in incursion of saltwater to Lake Richmond. The proposal was withdrawn in 2018.

Construction of the proposed Garden Island Highway has the potential to involve direct burial or removal of thrombolites in part of the lake. If constructed as originally planned the highway would result in destruction of approximately 0.3 ha of thrombolites (about 16% of the current area of the community).

A housing development was proposed for the eastern side of the lake by [redacted]. This included subdividing the land into residential lots, group dwellings and lots for associated commercial uses. A Consultative Environmental Review was developed (Bowman Bishaw Gorham 1997). Under Ministerial Conditions imposed (Environmental Protection Authority (EPA) 1998), the lakebed which was at the time owned by the company, was ceded to the Crown. In addition, the Public Open Space boundary adjacent to the lake was set to ensure a minimum buffer zone of about 100m to a maximum of about 200m, between the lake and the development.

Degradation of vegetative buffer

The vegetation buffer has been impacted historically by grazing, horticulture and dairy farms, and more recently by visitors. Vegetation near the lake shore can be important in areas of surface and groundwater intrusion as a buffer can significantly reduce the level of nutrients entering the lake from surface flow. Drains into the lake reduce the effectiveness of a buffer (Davies and Lane 1996). The invasion of weeds into the vegetated buffer area around the lake has the potential to impact the thrombolites. Between 1953 and 2017 much more littoral zone has been exposed and this is closely related to weed encroachment. Weeds such as couch grass have been observed growing in between the thrombolites and causing the build-up of sediment, which can lead to smothering of the thrombolites. Chemicals used for weed control in the drain and immediately adjacent to the thrombolites may also impact the structures through impacting on the photosynthetic capability of the microbial assemblages and favouring specific parts of the assemblage not involved in accretion. The level of weeds in the remnant vegetation adjacent to the lake is therefore significant in the management of the thrombolitic structures. All disturbance in such remnants results in increasing weed invasion, particularly where remnants are small. Therefore, fire frequency and other disturbances such as trampling should be minimised. In addition, the risk of fire is increased by the presence of grassy weeds in the understorey, as they are likely to be more inflammable than original native species in the herb layer. Fire in the vegetation buffer would also result in a short-term flush of nutrients being washed into the lake, both because of the removal of the retentive physical barrier, and due to release of nutrients from the burnt vegetation. Fires as a consequence of arson are common in the vegetation around the lake.

Studies by Vogwill and Whitehead (2018) indicated that the effects of herbicides on sulphur cycling organisms was the most significant issue. In addition, they noted the following issues regarding the use of herbicides near the lake:

- Fluazifop and surfactant turn milky in water, strongly inhibiting photosynthesis from a light penetration perspective. Fluazifop strongly impacts the mats even at low application rates.
- Microbial mats were badly impacted at 100% application rate of glyphosate. At 50% rate of application, damage was minimal, and assemblages recovered quickly.
- Glyphosate without surfactant or dye is recommended and avoiding direct spraying on wet areas or mats.

Smothering by sediment

Removal of vegetation that surrounds the lake by clearing, grazing or fire may result in erosion of the underlying soils by wind and water. This is likely to lead to increased sediment flowing into the lake. Sediment also enters the lake through drains. Such sediment has the potential to smother the thrombolites, preventing their growth and ultimately causing their death. Sediment may also provide an additional source of nutrients in the lake. As noted above, weeds such as couch grass that are invading in between the thrombolites also increase the accumulation of sediment that may smother the thrombolites.

Rubbish dumping

Chemical drums, plastics, fridges, tyres and other rubbish may enter the lake through the direct disposal in the lake area. If not removed quickly some types of litter could smother the thrombolites. Contaminated containers can also introduce pollutants such as oil and other toxic chemicals into the lake, which could impact the photosynthetic capacity of the structures and possibly cause their death. Vigilance in cleaning up litter and preventing vehicle access to undeveloped portions of the catchment would help ameliorate impacts of litter.

Influx of rubbish through drains

Some rubbish also enters the lake through drains from locally dumped rubbish. Trash racks across the drains would help ameliorate impacts of litter.

32 b. What its expected effects are in the future. Include or reference supporting research or information.

Increasing nutrients

Nutrient levels have increased in Lake Richmond. In 2017, Vogwill and Whitehead (2018) reported high total nitrogen (up to 1.2mg/L) and phosphorus (0.12mg/L) levels of in lake waters, and higher in the drains (total nitrogen up to 4.2mg/L), well above that reported by Guerreiro *et al*. (2017) from 2013 to 2015, and above the 0.35mg/L trigger value recommended for total nitrogen levels and 0.01mg/L total phosphorus, for freshwater ecosystems in Western Australia (ANZEEC 2000). High nutrient levels observed in the lake are triggering the proliferation of algae which in some areas form a dense meadow, completely obscuring the microbialites and preventing the development of microbial mats. Vogwill and Whitehead (2018) noted that the elevated nutrients are causing a proliferation of algae and aquatic vegetation and forming a dense cover, particularly in the deeper portions of the infralittoral platform and upper slope. In many areas the substrate has been completely obscured and devoid of microbial mats on microbialites. Active growth of the thrombolites in the southern end of the lake where the major drain is located has not been observed since at least the mid-1990s (pers comm. [redacted][3]).

[3] Principal Ecologist, DBCA

Hydrological changes

Groundwater allocation limits for future public water supply from the Warnbro superficial- Rockingham sand aquifer, in the area of Lake Richmond have been set by DOW (2008) at 7,800,000kL/year. Allocation limits may require revision if a drying trend continues.

A drying climate is likely to result in declining rainfall in the south west of the state (from NCCARF website accessed 08 March 2019); https://www.nccarf.edu.au/sites/default/files/attached_files_publications/PDF%20Report%20Card%20Low%20Res.pdf). This will likely result in declining groundwater levels, influx of fresh groundwater, and subsequent change in water quality as follows:

- Reduction in rainfall by 2030 by 2-14% (median 8%). Southwest to predicted to experience some of the largest reductions in rainfall in all of Australia;
- Reduction in runoff by 10-42% (median 25%) by 2030;
- Decline in groundwater levels by 2030 (extractive yields may decrease by a third to a half in some areas).

It is inferred that future changes to the hydrology of the lake from groundwater abstraction for agricultural, urban or other purposes, as well as from a drying climate, will result in a change in lake levels and seasonal variation, higher water temperatures, and changes in salinity levels, thereby affecting the BMC and potentially the accretion (growth) of the structures. The drains into and out of the lake will, however, continue to have a marked effect on the water quality in the lake, and may override the consequences of drying climate in terms of their substantial influence on water quality and levels.

Physical crushing

The Rockingham Regional Environment Centre located adjacent to Lake Richmond provides visitors with educational and scientific information to ensure that recreational use does not adversely impact on the thrombolites. The boardwalk has also served to decrease the impact of physical crushing by visitors to the lake (personal observations [redacted]). Despite this, physical crushing of thrombolites is likely to continue, and with no apparent ongoing accretion of the structures, will likely result in ongoing decline of the structures over time

Land development

The land tenure changes necessary for the proposed inland marina and hotel (Mangles Bay Marina) were not supported and the proposal was withdrawn. It is uncertain if development of the Garden Island Highway will be progressed, however any proposal will need to consider the environmental implications on Lake Richmond. Further potential impacts may occur if land use planning decisions support subdivision and development of the adjacent buffer area.

Alterations to surrounding vegetation

Chemicals used for weed control may impact on the thrombolites if used immediately adjacent to the structures as they are photosynthetic. A three-year investigation on the chemical risk and weed management at Lake Richmond was initiated in 2017 (Vogwill *et al*. 2017). The study aims to provide informed weed management options that achieve the lowest levels of negative impact to the microbial assemblages.

32c. Identify whether the threat only affects certain portions or occurrences. Give Details.

The threats listed above have and are likely to continue to impact on the lake, the thrombolites and their microbial assemblage, as well as the surrounding vegetation buffer.

33. Identify any natural catastrophic event/s

Explain its likely impact and indicate the likelihood of it occurring (e.g. a drought/fire in the area every 100 years). Catastrophic events are those with a low predictability that are likely to severely affect the ecological community.

Drought may reduce lake water levels and groundwater inflows, and result in other impacts on water quality that may affect the microbial community and hence thrombolite growth/accretion. Unless management of drains is altered, however, the inlet and outlet drains are likely to continue to have very high level impacts on water quality.

Major fires can occur any time and have potential for major impacts to the vegetation buffer, and increased nutrients and sediment in the lake.

34. Additional biological characteristics

Identify and explain any additional biological characteristics particular to the community or species within it that are threatening to its survival (e.g. low genetic diversity). Identify and explain any models addressing survival or particular features.

34 a. How does it respond to disturbance?

Physical disturbance, such as by walkers, can damage the thrombolites through crushing.

Fire in the vegetated buffer increases weed levels and produces a short-term flush of nutrients into the lake, both because of the removal of the retentive vegetation barrier, and due to nutrients and sediment from the burnt vegetation. Thrombolites are likely to be impacted by the release of nutrients into the lake, the loss of the dense sedges as a physical barrier to walkers trampling on the structures, and by the release of sediment immediately following fire in the remnant buffer near the lake. Chemicals used for weed control can impact on the thrombolites if used immediately adjacent to the structures as they are photosynthetic.

34 b. How long does it take to regenerate and/or recover?

Vogwill and Whitehead (2018) note that radiocarbon (C_{14}) dating of microbialites at the south eastern margin of the lake indicates a historical annual growth rate range of 0 - 1.2 mm. Radiocarbon dating cannot ascertain if modern accretion is occurring due to releases from nuclear testing after 1950. Based on this low growth rate, recovery of microbialites following physical damage would take many years.

The surrounding vegetation buffer will recover from occasional fire, but too frequent fire could potentially result in loss of fire-sensitive species.

There is no information available to indicate how quickly the microbial assemblage might recovery if the salinity, nutrient and other hydrological factors improve.

Threat Abatement and Recovery

35. **Identify key management documentation available for the ecological community,** e.g. recovery plans, biodiversity management programmes, or site specific management plans (e.g. for a reserve).

English, V., Blyth, J., Goodale, A., Goodale, B., Moore, L., Mitchell, D., Loughton, B., Tucker, J., Halse, S. and King, S. (2003) Thrombolite community of coastal freshwater lakes (Lake Richmond). Interim Recovery Plan 2003-2008. Department of Conservation and Land Management, Western Australia.

Department of Environment and Conservation (2010) Rockingham Lakes Regional Park Management Plan 2010. Management Plan No. 67. Department of Environment and Conservation, Western Australia.

36. **Give an overview of how threats are being/potentially abated and other recovery actions underway and/or proposed.** Identify who is undertaking these activities and how successful the activities have been to date.

Application of environmental impact assessment processes that control development, including the WA *Environmental Protection Act 1986* and planning legislation, have placed limits on clearing in the surrounding vegetation.

Other key measures required to mitigate risks to the ecological community include application of principles for improving the management of the lake identified through scientific studies, ensuring adjacent landowners are aware of the significance of the thrombolite community, the construction of a boardwalk on the edge of the lake to allow visitors to view the thrombolites without crushing them, the development of a visitor education centre to inform the public about the importance of the thrombolites, and control of weeds in the rehabilitation areas on the lake edge.

37. **What portion of the current extent of the ecological community is protected in a reserve set aside for conservation purposes, and what proportions are private land, or other tenure?** Give details including the name of the reserves, and the extent the ecological community is protected within these reserves.

Lake Richmond thrombolite community occurs within several crown reserves (C Class) for the purpose of conservation and public recreation that are vested with and managed by the City of Rockingham.

378 a. Which of the reserves are actively managed?

Note which, if any, reserves have management plans and if they are being implemented.

Lake Richmond occurs within lands managed by the City of Rockingham. The area has a management plan that is being implemented (Rockingham Lakes Regional Park Management Plan No 67, 2010).

378 b. Give details of any other forms of protection, such as conservation covenants, and whether the protection mechanisms are permanent.

Tenure: C Class Crown reserves 9458, 47145 and 47553.

378 c. Indigenous interests

Is the nominated ecological community or parts thereof known to occur on any culturally significant sites? If so comment on any issues with respect to aboriginal interests, in particular with regard to management of the ecological community.

The Rockingham area has significance to both Aboriginal and non-Aboriginal people. Traditionally, Aboriginal family groups travelled this area throughout the seasons. Lake Richmond was an important area for gathering food and camping (DEC 2010). A member of the local Naramya Aboriginal Corporation is consulted about management planning for the lake and also provides information about Aboriginal culture for lake visitors. The Rockingham Lakes Regional Park Management Plan recommends a number of actions related to the protection and conservation of the park's Aboriginal cultural values (DEC 2010).

378 d. Native Title

Do Native Title or Indigenous Protected Areas apply to any parts of the community? If so comment on any issues with respect to exclusive possession and rights to plants and animals, in particular with regard to management of the ecological community.

NA

39. Give details of recovery actions that are or could be carried out at the local and regional level, e.g. develop and implement management plan for the control of specific weed species (regional), undertake weeding of known sites (local).

The recovery plan (English *et al*. 2003) refers to biological research to better understand the community's management requirements, access control, utilising planning mechanisms to minimise impacts to the community, education, monitoring, managing water quality, rehabilitation of adjacent vegetation and managing fire. Most of the recommended actions have been implemented to some degree. Many actions are ongoing, including monitoring, research, weed control and fire management.

40. Is there an existing support network for the ecological community that facilitates recovery? e.g. an active Landcare group, Conservation Management Network.

There is a recovery team that covers the Lake Richmond thrombolites and the Sedgelands in Holocene dune swales community. The Recovery Team is largely responsible for initiating and guiding actions and securing funds. The team consists of representatives from DBCA, the City of Rockingham, and community representatives. The Recovery Team will continue to coordinate recovery actions for the Lake Richmond thrombolite community. Reports are prepared by the department annually and include review of progress of the recovery plan, implementation of recovery actions and results of analysis of monitoring within an adaptive management framework.

Naragebup, the Rockingham Regional Lakes Environmental Centre is located directly adjacent to Lake Richmond and serves as an education and resource facility for the community to facilitate a greater understanding of environmental issues, including those that affect Lake Richmond.

41. Describe methods for identifying the ecological community including when to conduct surveys.

For example, season, time of day, weather conditions; length, intensity and pattern of search effort; and limitations and expert acceptance; recommended methods; survey-effort guide. Include references.

The thrombolite community was originally described by Moore (1993). Thrombolitic structures can be identified by their internal clotted structure as opposed to those that have a laminated organisation which are stromatolitic. They are formed through precipitation of calcium carbonate within the microenvironment of microbes, a complex

association of photosynthetic cyanobacteria and purple sulphur bacteria, eukaryotic microalgae and what are known as 'true bacteria', as a result of photosynthetic and metabolic activity. Vogwill and Whitehead's (2018) studies of the community at Lake Richmond included macroscopic studies of microbialite morphology, microscopic studies of the microbial biota, and calcification studies. Other methods for identifying microbialites include DNA and RNA studies of the microbial biota that form the structures. At Lake Richmond microbial mats occupied by phototrophic cyanobacteria occur on the shoreline in 50mm to 700mm of water (Vogwill and Whitehead 2018). Vogwill and Whitehead (2018) note that microbialite formation requires the transfer of sulphur compounds to microbial mats by groundwater or surface water. Sulphur chemotrophs in the mats then form carbonate during sulphur cycling processes. The combination of specific conditions to support microbialite formations is found in very few lakes. The specific combination of hydrological and biological components creates the specific conditions that promote the precipitation of carbonates and elemental sulphur within the Extracellular polymeric substances (EPS) matrix of the microbial mats, causing the formation and growth of microbialite structures. Vogwill and Whitehead (2018) noted that appropriate water chemistry and water levels is required to support transport of the appropriate chemistry in pore water flows to the site of microbialite formation in relation to lake water level. Microbialite formation is favoured in warmer temperatures in sunny conditions, and when the local hydrological processes (including water level) are most favourable for the delivery of the chemicals that are required to build microbialites. Survey and identification of the microbialite assemblage should occur when likelihood of detection is maximised. A specific method for monitoring of the health of the microbial community is described in Regan (2009) for Lake Clifton but which is likely applicable for Lake Richmond. Samples of both the thrombolites and microbial mats were taken sporadically, a metre apart, in October. The samples under the microscope were examined to identify some of the different microorganisms identified in the thrombolites and microbial mat microbial assemblages. Both light and fluorescence microscopy were used to examine the thrombolite and microbial mat samples (Regan 2009).
42. Are there other any aspects relating to the survival of this ecological community that you would like to address?
No

Section 3 - Justification for this nomination

In order for the nomination to be considered further, one or preferably more of the following criteria need to be fulfilled and substantiated. A clear case for why the ecological community is eligible for listing under the criteria is required, including evidence as to how it meets the requirements for listing under a particular listing category, e.g. 'David *et al*. (1999) finding of 95% decline in geographic distribution suggests it should be listed as critically endangered'. The type of data available will determine which criteria will be used to justify the application of a listing category.
At least one criterion must trigger the thresholds of a listing category as indicated in the Attachment. Criteria may be of different levels of listing category e.g. Criterion 1 = CR and Criterion 3 = VU.

43. Provide data that demonstrates why the ecological community meets at least one of the following criteria for the nominated listing category.

Please use data provided in previous sections to demonstrate how it specifically meets at least one of the following criteria. Advice on how to interpret the listing criteria is in Attachment A. Provide a response for every sub-criterion.

Criterion A: Reduction in geographic distribution.

Criterion A ☐ CR ☐ EN ☐ VU ☒ not eligible	☐ **A1** ☐ **A2a** ☐ **A2b** ☐ **A3**

Justification for assessment under Criterion A:
For criteria A and B, the ecosystem was assumed to collapse when the mapped distribution declines to zero. The Lake Richmond thrombolite community has not incurred the threshold 30% reduction in geographic distribution over any 50-year period, or a 50% reduction since 1750 to meet the category VU under criterion A.

Criterion B: Restricted geographic distribution.

Criterion B ☒ CR ☐ EN ☐ VU ☐ not eligible	☒ **B1** (specify at least one of the following) ☐**a)(i)** ☒**a)(ii)** ☒**a)(iii)** ☒**b)** ☒**c);** ☒ **B2** (specify at least one of the following) ☐**a)(i)** ☒**a)(ii)** ☒**a)(iii)** ☒**b)** ☒**c);** ☐ **B3** (only for Vulnerable Listing)

Justification for assessment under Criterion B:

B1: The extent of a minimum convex polygon enclosing the Lake Richmond thrombolites community is 0.41km^2 (<2,000km^2, which is significantly less than the threshold for CR).

B2: The Lake Richmond thrombolites community is estimated to occupy one 10 × 10km square grid cell (threshold for EN is 20 and for CR is two grid cells). As for criterion B1, there is evidence of continuing decline in the microbial community inferred from changes to the hydrological regime, and decline in biological processes associated with microbialite formation, therefore the status under criterion B2 is Critically Endangered.

a): Data are available to measure decline in environmental quality (ii) or disruption to biotic interactions (iii). The Lake Richmond thrombolite community is dependent on a specific hydrologic regime including fresh calcium-rich groundwater for survival of the micro-organisms and the growth of the thrombolites. In 2017 to 2018, there was no apparent calcification of the microbial mats as the lake's physical and chemical conditions were not suitable for structure accretion (Vogwill and Whitehead 2018).

b): Decline observed from the impacts of recreational activities; and changes to the hydrologic regime.

c): Ecosystem exists at one threat-defined location (threshold for CR is one and for EN is five threat-defined locations (ie. from IUCN RLE Guidelines V1.1 '*a geographically or ecologically distinct area in which a single threatening event can rapidly affect all occurrences of an ecosystem type*').

Ecosystem meets CR

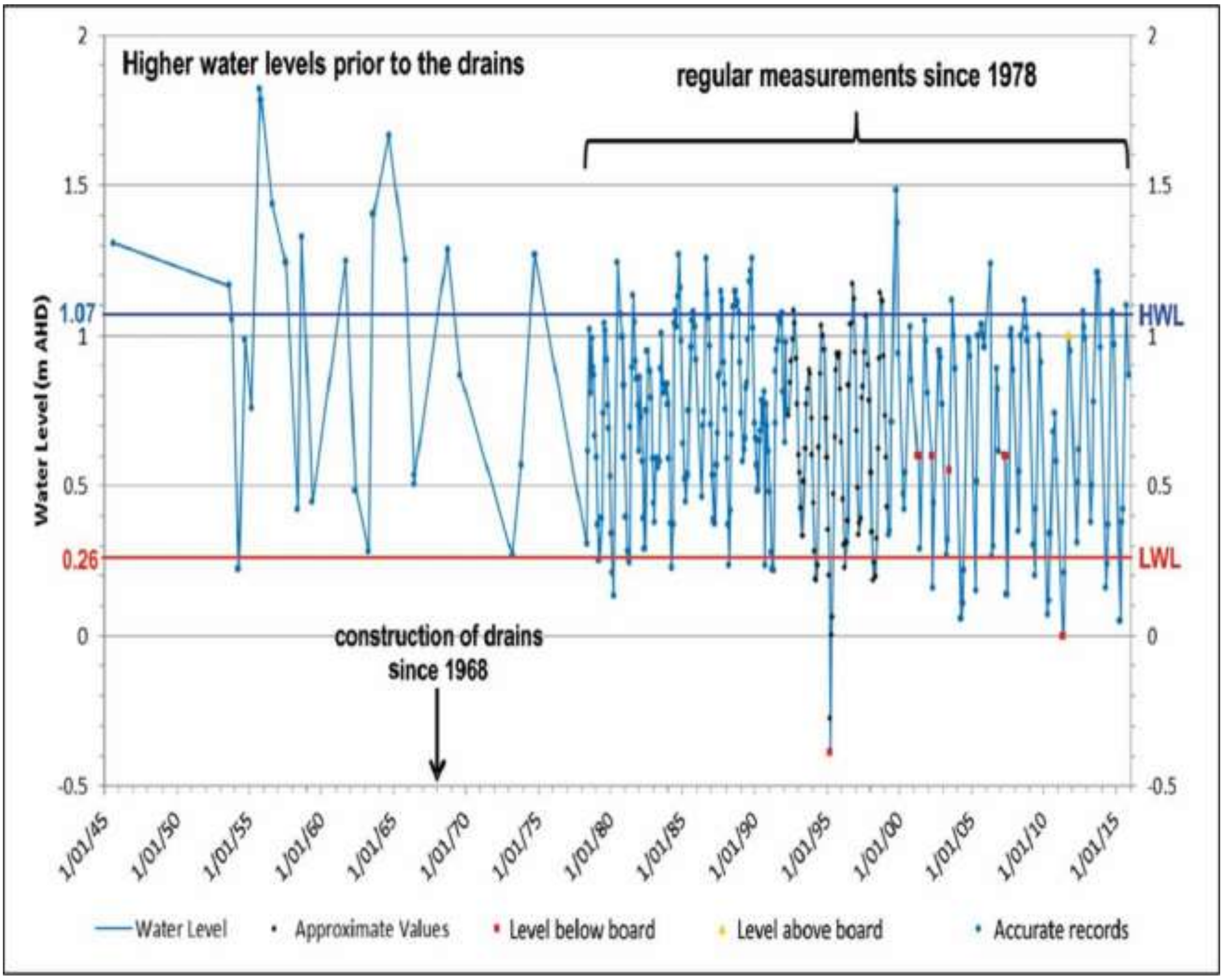
B3: The Lake Richmond thrombolite community is dependent on a specific hydrologic regime including fresh calcium-rich groundwater for survival of the micro-organisms and the growth of the thrombolites. The effects of human activities or stochastic events may cause the ecosystem to collapse within a very short period of time, given its highly restricted distribution, and ongoing threats posed by hydrological changes. The ecosystem therefore meets Vulnerable status under criterion B3.

Criterion C: Environmental degradation based on change in an abiotic variable.	
Criterion C ☐ CR ☐ EN ☐ VU ☐ not eligible	☐ **C1** ☐ **C2** ☐ **C3**

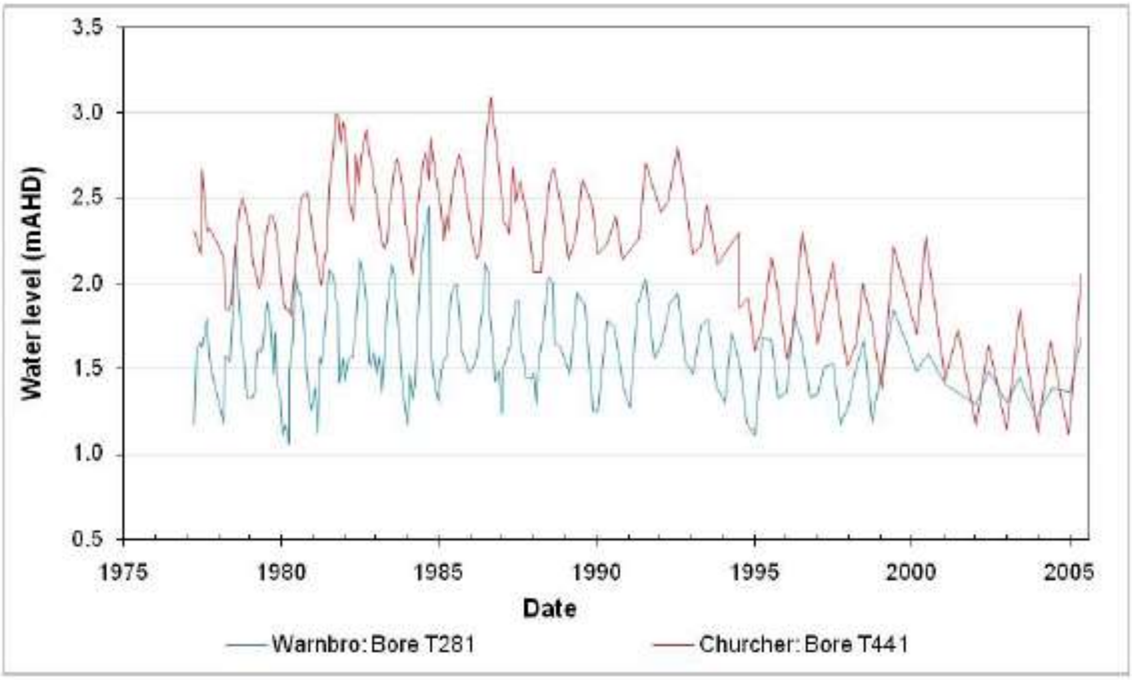
Justification for assessment under Criterion C:

The most significant abiotic variable affecting the community is hydrological change. 100% of the extent community is considered in medium to poor condition due to changes in lake hydrology and water chemistry that have occurred mainly since 1968 and water quality is considered to be indicative of the level of degradation of the community. Collapse of the community is defined under criterion C as an increase in lake water level and decline in salinity and total alkalinity (total concentration of bases and total dissolved solids) in the lake such that net carbonate accretion of the microbialites is no longer supported and is unlikely to be supported in future. The levels that would result in collapse are not known however. Vogwill and Whitehead (2018) found the dominant anion was bicarbonate, suggesting that the net dissolution of the structures and the carbonate generally in the lake were most likely occurring. The proportion of the total extent of the community in which accretion was occurring is not known, however. Due to lack of the required data it is not possible to determine the proportional extent of decline or the relative severity of decline in relation to the specified collapse state. It is not known if the threshold for proportion of the extent (≥30%) of the community or relative severity of degradation (≥30%) over the past 50 years, or any 50-year period, has been met, to meet Vulnerable (VU) under criteria C1 and C2.

C1: Historical data shows changes in the lake level, with a reduction in lake level and seasonal fluctuations since 1945 (graph below from Vogwill and Whitehead 2018). This change was noticeable from 1968 onwards when an artificial outlet and three inlets on the eastern, southern and western margins were constructed. The level of the lake is likely to be crucial for maintaining the thrombolites, as they rely on sufficient water to cover the growing surface of the structures coincident with adequate levels of light and raw materials such as calcium and carbonate ions for their growth. Prior to 1968, Passmore (1970) noted the total dissolved solids (TDS) concentration of the lake was from 2,000 to 3,500mg/L, with chloride typically the dominant anion. More recent sampling from 2013 to 2015, and from 2017 to 2018, Vogwill and Whitehead (2018) found the dominant anion was bicarbonate, suggesting that net dissolution of the structures and the carbonate generally in the lake were most likely occurring.



Furthermore, groundwater abstraction for urban or other purposes in the groundwater catchment of Lake Richmond has resulted in reduced groundwater inflow. Groundwater monitoring in the Warnbro Subarea on the Rockingham Sand Aquifer (T281) by DOW (2008) has seen a decline in the seasonal variation in groundwater levels of around 0.5m from 1975 to 2005 due to a decline in winter levels (graph below from DOW 2008).



Lake salinity has also declined, leading to a change in the dominant microbes. Prior to 1968, salinity levels of 2 to 3.5 parts per thousand (ppt) were recorded by Passmore (1970). Later work (Kenneally *et al*. 1987) notes salinity levels in the lake between 0.4 and 1.4 ppt. In 2013 to 2015, Vogwill and Whitehead (2018) recorded a substantial decline in the salinity of the lake which ranged from 0.55 to 0.7ppt, which is still much lower than pre-1968 levels. Higher salinity assists the microbialites by excluding organisms that graze on them and others that compete with them.

Vogwill and Whitehead (2018) note the following: "*Between December 2017 and June 2016 lake water level varied between 1.1 and 0.62mAHD (Figure 16) maintaining a persistently higher water level and reduced fluctuation relative to previous years. The presence of a large out of season rainfall event (107.6mm on the 16th of January) caused a nearly 0.3m increase in lake water level due to the effect of incident rainfall and stormwater inflow. This resulted in a lake level which stayed consistently high throughout the summer microbial mat growth period, approximately 0.4m higher than usual. The lake level was permanently above the outlet drain level in 2017-18, indicating that lake surface water outflow was constantly occurring. This had a pronounced effect on the microbial mat community. Lake level never receded to the point where mats could be exposed to substantial groundwater discharge from the near shore sulfidic stores, a precursor to microbialite formation in some of our other sites (Lake Clifton, Lake Preston and Rottnest Island salt lakes in particular).*"

The drains clearly have a significant impact on the composition of the lake waters, away from that favourable to microbialite growth.

C2: Drying climate predictions for the South Metropolitan Regional Council region show that the total yearly rainfall will decline by 5 to 10% by 2030; 10 to 20% by 2050 and up to 20 to 40% by 2070 (GHD 2009).
It is expected that future changes to the hydrology of the lake from groundwater abstraction for agricultural, urban or other purposes, as well as from a drying climate, will result in a change in lake levels and seasonal variation, higher water temperatures, and an increase in nutrients, thereby likely resulting in further changes to the BMC. The inlet and outlet drains are, however, likely to have a greater influence on the composition of lake waters than declining rainfall, as the drains likely act as a substantial source of fresh water contaminated with high levels of nutrients, but not as a source of water of the ionic composition to best support microbialite accretion.

Groundwater allocation limits for future public water supply from the Warnbro superficial- Rockingham sand aquifer, in the area of Lake Richmond have been set by DOW (2008) at 7,800,000kL/year. Groundwater extraction impacts on groundwater into the lake, likely decreasing the availability of water of the appropriate composition to best support microbialite accretion.

C3: The local geology indicates that age of the thrombolites in Lake Clifton is likely to be approximately 3,000-6,000 years (Moore 1991) and that the thrombolites in Lake Richmond are likely to have been formed at a similar or later time as a consequence of the timing of the isolation of the lake from the sea (English *et al*. 2003). It is inferred that the majority of changes in hydrological conditions in Lake Richmond since 1750 are similar to those recorded since 1968. Prior to 1968 hydrological conditions were more appropriate for growth to occur. It is not possible however, to determine the relative severity of decline in relation to the specified collapse state as a collapse state has not been determined. Therefore the status of the community in regard to thresholds for proportion of the extent (50%) or proportional severity of disruption of abiotic processes (50%) since 1750 in relation to the criteria for CR under C3 also cannot be determined.

Criterion D: Disruption of biotic processes or interactions based on change in a biotic variable.

Criterion D	
☒ CR ☐ EN ☐ VU ☐ not eligible	☒ **D1** ☒ **D2** ☒ **D3**

Justification for assessment under Criterion D:

The most significant biotic variable affecting the community is competition with macrophytes. The high nutrient levels and fresh water quality currently occurring in the lake provide an ideal environment for the proliferation of macrophytes, to the detriment of the microbialites. An increase in nutrients entering the lake since 1968 has resulted in an increase in macrophyte growth that form a dense cover and 'smother' the thrombolites, preventing growth. The level of nutrients is considered to be indicative of the level of biotic degradation of the community, however the current available evidence does not link nutrient levels and severity of impacts to the accretion of thrombolites. The collapse state is considered to be the extent and coverage of macrophytes that completely inhibits biotic processes in the microbialite assemblage that support carbonate accretion.

D1, D2: The introduction of the drains in 1968 led to an increase in nutrient levels in Lake Richmond. In 2017, Vogwill and Whitehead (2018) reported high total nitrogen (up to 1.2mg/L) and phosphorus (0.12mg/L) levels of in lake waters, and higher in the drains (total nitrogen up to 4.2mg/L), well above that reported by Guerreiro *et al*. (2017) from 2013 to 2015, and above the 0.35mg/L trigger value recommended for total nitrogen levels and 0.01mg/L total phosphorus, for freshwater ecosystems in Western Australia (ANZEEC 2000). High nutrient levels observed in the lake are triggering the proliferation of macroalgae that in some areas form a dense meadow, completely obscuring the microbialites and preventing the development of microbial mats. Vogwill and Whitehead (2018) noted that the elevated nutrients are causing a proliferation of algae and aquatic vegetation and forming a dense cover, particularly in the deeper portions of the infralittoral platform and upper slope. In many areas the substrate has been completely obscured and is devoid of microbial mats on microbialites. Active growth of the thrombolites in the southern end of the lake where the major drain is located has not been observed since at least the mid-1990s (pers comm. [redacted]). Due to lack of the required data it is not possible to determine the relative severity of decline in relation to the specified collapse state. It is not known if the community meets the threshold for proportion of the extent (≥30%) of the community or relative severity of degradation (≥30%) over the past 50 years, or any 50-year period, to meet vulnerable (VU) under criteria D1 and D2.

D3: Radiometric dating indicates of the age of the lake as 2590 $_{14}$C years before present (Guerreiro *et al* 2017). Microbialites are older in the lake flat and younger towards deeper areas in the infralittoral platform. It is inferred that the changes to nutrient status of Lake Richmond since 1750 are similar to those recorded since 1968, and prior to 1968 conditions were apparently more suitable for growth to occur. It is not possible however, to determine the relative severity of decline in relation to the specified collapse state as a collapse state has not been determined. Therefore the status of the community in regard to thresholds for proportion of the extent (50%) or proportional severity of disruption of abiotic processes (50%) since 1750 in relation to the criteria for CR under D3 also cannot be determined.

Criterion E: Quantitative analysis that estimates the probability of ecosystem collapse.

<u>Criterion E</u> ☐ CR ☐ EN ☐ VU ☒ not eligible	
Justification for assessment under Criterion E: The ecosystem could not be assessed under Criterion E as there were no quantitative estimates of the risk of ecosystem collapse.	

Summary assessment against IUCN RLE Criteria

Criterion	Rank indicated	Overall conclusion
A1	-	• Available data do not indicate community meets criterion
A2a	-	• Available data do not indicate community meets criterion
A2b	-	• Available data do not indicate community meets criterion
A3	-	• Available data do not indicate community meets criterion
B1a	CR	• EOO is <2,000km^2 • An observed decline in environmental quality (ii) and biotic interactions (iii) has occurred due to the change in the specific hydrologic regime that supports the process of accretion in the microbial assemblage. • Meets criterion for CR
B1b	CR	• EOO is <2,000km^2 • Observed and inferred continuing decline in the microbial assemblage inferred from changes to the hydrological regime. • Meets criterion for CR
B1c	CR	• EOO is <2,000km^2 • Ecosystem exists at 1 threat-defined location • Meets criterion for CR
B2a	CR	• AOO is one grid cell • An observed decline in environmental quality (ii) and biotic interactions (iii) has occurred due to the change in the specific hydrologic regime that supports the process of accretion in the microbial assemblage. • Meets criterion for CR
B2b	CR	• AOO is one grid cell • Observed and inferred continuing decline in the microbial assemblage inferred from changes to the hydrologic regime. • Meets criterion for CR
B2c	CR	• AOO is one grid cell • Ecosystem exists at one threat-defined location • Meets criterion for CR
B3	VU	• Known from one threat-defined location • Prone to the effects of hydrological change, recreational activities • Meets criterion for VU
C1	-	• Insufficient evidence to indicate the community meets the minimum thresholds for proportion of the extent (80%) or proportional severity of degradation (80%) over past 50 years to meet CR.
C2	-	• Insufficient evidence to indicate the community meets the minimum thresholds for proportion of the extent (80%) or proportional severity of degradation (80%) over any 50-year period to meet CR.
C3	-	• Insufficient evidence to indicate community meets the minimum thresholds for proportion of the extent (90%) or proportional severity of disruption of abiotic processes (90%) since 1750 to meet CR.
D1	-	• Insufficient evidence to indicate the community meets the minimum thresholds for proportion of the extent (80%) or proportional severity of disruption of biotic processes (80%) over past 50 years to meet CR.
D2	-	• Insufficient evidence to indicate the community meets the minimum thresholds for proportion of the extent (80%) or proportional severity of disruption of biotic processes (80%) over any 50-year period to meet CR.
D3	-	• Insufficient evidence available to indicate community meets the minimum thresholds for proportion of the extent (90%) or proportional severity of disruption of biotic processes (90%) since 1750 to meet CR.
E	NA	• No quantitative estimates of the risk of ecosystem collapse.

		Meets CR under B1a(ii,iii),b,c; B2a(ii,iii),b,c

Section 4 – References/Standard of Scientific Evidence/Critical habitat

Note: The opinion of appropriate scientific experts may be cited (with their approval) in support of a nomination. If this is done the names of the experts, their qualifications and full contact details must also be provided in the reference list below. Harvard style of referencing is preferred.

44. Please provide copies of key documentation/references used in the nomination.

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45. Statement on the Standard of Scientific Evidence

Published data on the Lake Richmond thrombolite community was sufficient to apply the Red List of Ecosystem criteria. There are likely to be inaccuracies in various aspects of the assessment, particularly with distinguishing historical decline estimations. However, the outcomes of the assessment are robust.

46. Has this document been reviewed and/or have relevant experts been consulted?
If so, indicate by whom and provide their contact details.

DBCA Regional Leader Nature Conservation, Swan Region;

Principal Ecologist, DBCA Species and Communities Program

47. Do you wish to propose any areas of habitat for consideration as Critical Habitat for the nominated community?
If so, refer to Ministerial Guideline No 5 and attached a separate nomination proposal addressing the matters required under that guideline. Indicate location/s including a map, and attached shapefiles.

No, the lake and immediate surrounds are already in a reserve that is regional park.

Section 5 - Nominator Details & Declaration	
48. Contact Details Note: Nominator details are subject to the provision of the *Privacy Act 1988*	
Title/Full Name	Robyn Luu
Organisation or Company name	Department of Biodiversity, Conservation and Attractions
Postal address	17 Dick Perry Avenue, Kensington Post: Locked Bag 104, Bentley Delivery Centre, WA 6983.
Email	robyn.luu@dbca.wa.gov.au
Phone	9219 9356
Fax	
49. Declaration	
Signature (Or insert electronic signature)	***I declare that the information in this nomination form and any attachments is true and correct to the best of my knowledge.***
Date signed	

Section 6 – Completed nomination form checklist

Please check all items on this list have been completed or are included with your nomination.

- ☐ I have read and applied the further information and guidelines for completing this nomination form in Attachment A
- ☐ Nominator details including name, address contact phone number included
- ☐ Name of the EC
- ☐ Any other names it is known by
- ☐ Map included or attached
- ☐ References cited
- ☐ If questions are left unanswered, a statement indicating that insufficient information is available

A description of:

- ☐ Biological components of the ecological community
- ☐ Non biological components of the ecological community
- ☐ Key interactions and functional processes
- ☐ Characters distinguishing it from other ecological communities
- ☐ Key species (dominant, characteristic or diagnostic, threatened etc)
- ☐ Known or estimated current extent of the ecological community
- ☐ Past/current/future threats including actual/potential, how/ where, how being/how could be abated
- ☐ Which listing category/categories it should be listed under and why

How to lodge your nomination

Completed nominations may be lodged either:

1. by email to: **communities.data@dbca.wa.gov.au**

If submitting by email, please also mail hard copies of attachments that cannot be emailed.

OR

2. by mail to: Species and Communities Branch
Department of Biodiversity, Conservation and Attractions, WA Government
Locked Bag 104, BENTLEY DELIVERY CENTRE WA 6983

If submitting by mail, please include an electronic copy on memory stick or CD.

Appendix 1. Lake Richmond Thrombolites community (in red)