

THROMBOLITE COMMUNITY OF COASTAL FRESHWATER LAKES (LAKE RICHMOND), INTERIM RECOVERY PLAN

**(Coastal freshwater lakes thrombolitic
aragonite community formed by biologically
influenced precipitation of a mineral phase)**

2003-2008

by

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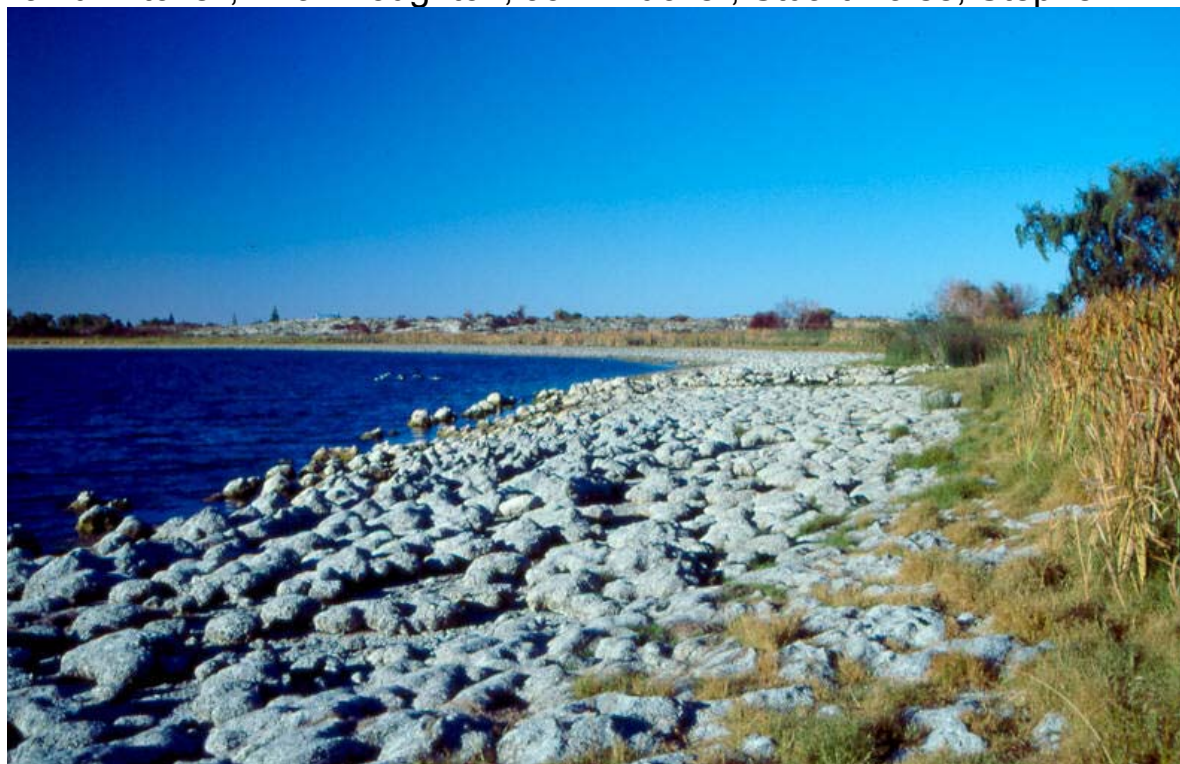


Photo: Val English

2003

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FOREWORD

Interim Recovery Plans (IRPs) are developed within the framework laid down in Department of Conservation and Land Management (the Department) Policy Statements Nos. 44 and 50.

IRPs outline the recovery actions that are required to urgently address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities, and begin the recovery process.

The Department is committed to ensuring that Critically Endangered taxa and communities are conserved through the preparation and implementation of Recovery Plans or Interim Recovery Plans and by ensuring that conservation action commences as soon as possible and always within one year of endorsement of that rank by the Minister.

This Interim Recovery Plan will operate from July 2003 to June 2008 but will remain in force until withdrawn or replaced. It is intended that, if the community is still ranked Critically Endangered, this IRP will be replaced by a full Recovery Plan after five years.

This IRP was approved by the Director of Nature Conservation on 11 July 2003. The provision of funds identified in this Interim Recovery Plan is dependent on budgetary and other constraints affecting the Department, as well as the need to address other priorities.

Information in this IRP was accurate at July 2003.

SUMMARY

Name: Thrombolite community of coastal freshwater lakes (Lake Richmond)

Description: Microbial thrombolite community that occurs in a coastal freshwater lake. Community occurs on relic foredune plain on Holocene sands at Lake Richmond, Rockingham and is a complex association of photosynthetic cyanobacteria and purple sulphur bacteria, eukaryotic microalgae and 'true bacteria'. Thrombolitic structures (those that have an internal clotted structure as opposed to those that have a laminated organisation which are stromatolitic) are formed through precipitation of calcium carbonate within the microenvironment of microbes as a result of photosynthetic and metabolic activity.

Departmental Region: Swan

Departmental District: Swan Coastal

Local Government Authority: City of Rockingham

Recovery Team: Representatives from the Department's Swan Region (including Swan Coastal District), WA Threatened Species and Communities Unit (WATSCU) and Science Division, the Rockingham Regional Environment Centre, the City of Rockingham, Water Corporation and a private consultant, and by invitation representatives from Bowman Bishaw Gorham, Curtin University, Department of Environmental Protection and other expertise as required.

Technical Advisory Group (TAG): Representatives from the Department, Water and Rivers, Water Corporation and a private consultant.

Current status: Assessed 21 November 1995 as Critically Endangered in Western Australia, and was also listed as Endangered in July 2000 under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Habitat requirements: The growth of the community is probably dependent upon continuing supply of fresh water rich in calcium, bicarbonate and carbonate. Calcium carbonate is precipitated out by the biological activity of the microbes. These microbes are likely to include cyanobacteria dominated by *Dichothis* sp., and other photosynthetic bacteria that depend on light for growth and survival (L. Moore, pers. comm.). The source of the calcium in the waters of Lake Richmond is probably groundwater that has passed through sand dunes that surround the lake. The catchment for this groundwater is not known. The waters of Lake Richmond vary from 0.04 to 0.14% (0.4 to 1.4 parts per thousand (ppt)) salt and have a pH between 8.3 and 9.3, which is significantly alkaline (Moore 1993).

The community is located upon relic foredune plain on Holocene sands (Gozzard 1983). These sands are calcareous, and composed of quartz sands and shell debris of aeolian origin (Gozzard 1983).

Critical habitat: The critical habitat for the thrombolite community of coastal freshwater lakes is the water and substrate of Lake Richmond itself, and the catchments for the surface waters, streams and drains and the groundwater that contributes to the lake waters.

Habitat critical to the survival of the species, and important populations: Given that this community is listed as Critically Endangered, all known habitat for the only known occurrence is considered critical habitat.

Benefits to other species/ecological communities: The 'sedgeland in Holocene dune swales' community is listed as Endangered under the Commonwealth EPBC Act. The sedgeland surround much of the lake's perimeter. Recovery actions, such as weed control, implemented to improve the security of the thrombolites are likely to improve the quality of the habitat of the sedgeland community. In addition, the

peregrine falcon (*Falco peregrinus*) occurs in the immediate vicinity of the lake. This species is listed as specially protected fauna under the WA Wildlife Protection Act 1950.

International Obligations: This plan is fully consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993, and will assist in implementing Australia's responsibilities under that Convention. There are also a number of species listed 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, common green shanks (*Tringa nebularia*) and red necked stints (*Calidris ruficollis*)

Role of indigenous people and their knowledge: Aboriginal beliefs relate to Lake Richmond. 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. Structures that resemble fish traps and may have been constructed by indigenous people have been identified in the lake, however, actions recommended in this plan will not impact on these.

Social and economic impact: There are a number of development plans that have the potential to impact upon the lake and thrombolites. For example, the Garden Island Freeway is planned to cut through the lake, and would impact upon the hydrology and the thrombolites. Urban development planned for the east side of the lake has the potential to impact lake hydrology. Buffer areas have been negotiated that should help to prevent the hydrological impacts of urban development. The implementation of this recovery plan therefore has the potential to have some limited social and economic impact, where development proposals have potential to impact the lake. Recovery actions refer to continued liaison between stakeholders with regard to these proposals.

Evaluation of the Plan's Performance: The Department of Conservation and Land Management, in conjunction with the Recovery Team will evaluate the performance of this IRP. In addition to annual reporting on progress with listed actions and comparison against the criteria for success and failure, the plan is to be reviewed within five years of its implementation.

Habitat requirements: The thrombolites are only found in Lake Richmond. They are dependent on maintenance of water levels and quality within limits that are currently unidentified. This plan describes recommendations for research that will help determine these parameters.

Guide to decision makers: Section 1 provides details of current and possible future threats. Any on-ground works (clearing, drainage works, roadworks etc) in the immediate vicinity of the thrombolites of Lake Richmond will require assessment. On-ground works should not be approved unless the proponents can demonstrate that they will not have an impact on the community or on its potential habitat, or on the local surface or groundwater catchments such that hydrology of the wetland habitat would be altered.

IRP Objective(s): To maintain or improve the overall condition of the microbial community in the only known location.

Criteria for success:

- Maintenance of water quality and levels in Lake Richmond
- Maintenance of the vigour and extent of the microbial community including maintenance of the composition of the microbial species
- An increase in the area of this community or its catchment area under conservation management

Criteria for failure:

- Significant and sustained detrimental changes to water quality or levels in Lake Richmond
- Significant decline in area as measured by physical damage or loss of thrombolite structures
- Decline in health as measured by a major shift in composition of the microbial community

Recovery Actions:

Establish a Recovery Team	Conduct baseline water quality studies
Establish a Technical Advisory Group	Monitor water quality and hydrology
Clarify the extent and condition of the	Ensure hydrological regimes are not altered

community	outside of the range of normal fluctuations
Map Critical Habitat	Manage water quality
Agree on a suitable native vegetation buffer area	Provide information to surrounding landholders to ensure actions on their lands do not impact the thrombolites
Seek to ensure the proposed 'Garden Island Highway' does not impact the thrombolites	Collect baseline information and ongoing monitoring data for buffer vegetation
Conduct biological research	Rehabilitate adjacent plant communities
Manage access to site	Liaise with adjacent developer and City of Rockingham to develop and implement an approved fire management strategy
Ensure drainage from adjacent lands does not impact the thrombolites	Liaise with adjacent landholders and Fire and Emergency Services Authority to ensure fire suppression doesn't impact community
Ensure areas containing the microbial community are protected from physical damage	Report on success of management strategies for the thrombolite community
Manage physical impacts to thrombolites through education	Write full Recovery Plan, if required
Undertake ongoing monitoring of physical condition of thrombolites	

1. BACKGROUND

1.1 History, defining characteristics of ecological community, and conservation significance

There are three basic types of microbial structures ('microbialites') formed in benthic areas: stromatolites, thrombolites, and structures that have a less tangible internal framework. Stromatolites have a laminated internal structure, thrombolites have a clotted internal appearance and others such as algal mats and tufa have an ill-defined structure. Microbialites can occur in marine, fresh or hypersaline waters, from sub-tropical to cool temperate environments (Moore 1993).

Fossilised stromatolites are the earliest record of life on earth. They dominated the Pre-Cambrian period - between 3.5 billion and 600 million years before present. This life form declined, probably due to the evolution of grazing and burrowing animals which disturbed the structures, around 570 million years ago (early in the Phanerozoic era). The thrombolites then became more dominant as they were probably more resistant to grazing and burrowing animals. Around 395 million years ago, faster-growing marine organisms such as corals and macroalgae then led to the decline of the thrombolites as a result of competition for space (Moore 1991).

Microbialites are therefore interesting as they are the oldest evidence of life on Earth and provide evidence of historical environments through information encrypted within their structure. Worldwide, these structures are restricted to a few areas of limited extent including the Bahamas, Bermuda and Western Australia (Moore *et al.* 1984).

Western Australia contains the oldest microbialite fossils, at 3.5 billion years (Moore 1993). The State also contains the greatest number and most varied occurrences of living microbialites in the world (Moore 1993). Perhaps the best known microbialites in Western Australia occur 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 (Rottnest Island); Lake Thetis (Cervantes) and at Lake Richmond in Rockingham (Moore 1993). Each of these constitutes a distinct and very significant community in terms of history, structure, and morphology (Moore 1993).

Lake Richmond is a relatively deep, perennial freshwater lake located about 1 km south of Rockingham on the southern Swan Coastal Plain. The lake was isolated from the sea when part of the marine portion of Cockburn Sound filled in during the last 4,000 years (Kenneally *et al.* 1987). This separated the lake from the sea by beach ridges. Lakes Walyungup and Cooloongup further inland were isolated earlier than Lake Richmond and are shallow and saline (Kenneally *et al.* 1987).

Lake Richmond is elliptical, measuring approximately 1 km by 0.6 km. The waterbody covers about 40 ha, and the water in the lake is about 1 m above sea level. The maximum water depth is known to be about 10 m, with the level varying slightly with season.

A sedgeland community only known from Holocene dune swales occurs around the lake edge (Department of Environmental Protection 1997). An Interim Recovery Plan has been prepared for this plant community (English *et al.* 2002) that has also been assessed as critically endangered and is most extensive at Becher Point. Lake Richmond is also important habitat for both migratory and local bird life (Goodale 1996).

The microbial structures occur in a zone about 15 m wide around much of the lake. The zone has lithified carbonate crust at the surface (Kenneally *et al.* 1987). The structures have recently been sectioned and the internal structure indicates that the microbialites are thrombolitic in formation (L. Moore, personal observation). The best developed thrombolites occur on the eastern side of the lake (A. and B. Goodale, personal observation).

The rate of growth of the stromatolites at Hamelin Pool is about 0.5 mm per year, and the growth rate of the thrombolites in Lake Richmond is likely to be similarly low. 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 which occurred between 2,900 and 4,800 years ago (Woods and Searle 1983).

Old stranded thrombolites (no longer living) have recently been identified immediately to the east of Lake Richmond (A. and B. Goodale, personal observation) in an area that is included in the proposed Rockingham Lakes Regional Park as Public Open Space. Scientific studies of this area may provide important information about the history of the Lake Richmond thrombolites.

The dunes around the lake were classified as part of the Quindalup Dune System by McArthur and Bettenay (1960). Only 14 percent of Quindalup vegetation occurs in reserves (State of Western Australia 1998). 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 waters of the lake contained approximately 0.5 parts per million (ppm) calcium which is a low level for lake waters (Passmore 1970). Passmore also noted that there is an increase in dissolved calcium in winter, and a depletion in late summer when microbes involved in construction of the thrombolites would be most active. Calcium, carbonates, nitrogen and phosphorus in these waters are probably essential for growth of the microbialite structures. However, an excess of nitrogen and phosphorus may cause macroalgal and planktonic blooms of other algae that may smother the thrombolites.

Urbanisation has resulted in clearing around Lake Richmond, with a subsequent rise in runoff. Inlet and outlet drains were built at Lake Richmond by the Metropolitan Water Board in 1968 to allow for a reduction in the water table which was essential for further building to occur in the area. These drains are now managed by the Water Corporation. Water levels in the lake now vary little with season (Kenneally *et al.* 1987). Two sets of reflux gates prevent sea water entering through the outlet drain. Salinity, nitrogen levels, bacterial contamination and other physical characteristics were monitored twice per year by the former Metropolitan Water Board between 1968 and 1977 in the lake and connecting drains to detect pollution from septic systems or detergents. Data from 1973 to 1977 indicated that the lake was still relatively unpolluted (Kenneally *et al.* 1987). Safety Bay Senior High School now monitor water quality in the lake as part of the "Ribbons of Blue"

project. Studies by Passmore (1970) indicate the composition of lake water in the mid-1960s was similar to the groundwater, with the exception that lake waters had a lower calcium content.

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 at least 10 m deep (possibly 15 m - Kenneally 1987) and its floor is covered with thick organic ooze, particularly in the southern area of the lake.

Vegetation limits the amount of recharge to the aquifer through interception of rainfall and evapotranspiration. Urban development generally increases groundwater recharge through a decline in the amount of rainfall intercepted and increased channelling of storm water from roof and road catchments into the ground. This results in a slight rise in watertable level necessitating drainage in many areas. Under these conditions water levels can be expected to rise in Lake Richmond as nearby areas become increasingly urbanised.

Deep sewerage is planned for the development to the east of Lake Richmond. Nearby areas already developed that are currently on septic systems will also link to deep sewerage within five years. This infill sewerage is expected to reduce the potential for nutrient pollution entering Lake Richmond from this source. Excessive irrigation and fertiliser application in the catchment, for example of sports grounds, golf courses, private lawns and market gardens, also has the potential to result in pollution of the lake due to leaching of contaminants to groundwater or through surface runoff.

A Caravan Park occurs to the north east of the lake and houses occur immediately north and south west of the lake. An additional housing development is planned adjacent to the lake, to the east. A Consultative Environmental Review has been developed for the proposed development on the land to the east of Lake Richmond (Bowman Bishaw Gorham 1997). The landholders, Australand Holdings Pty Ltd, propose to subdivide the land into 1035 residential lots, 86 group dwellings, and into lots for associated commercial uses. Under Ministerial Conditions imposed as a provision of the Australand Holdings development (Environmental Protection Authority (EPA) 1998), the lake bed currently owned by the company has been ceded to the Crown. In addition, the Public Open Space boundary adjacent to the lake has been set to ensure a minimum buffer zone of about 100 metres to a maximum of about 200 metres, between the lake and the development. Landcorp is also proposing a development on public land to the north east of the lake.

An inland marina and hotel have been proposed on the promontory to the north west of the lake, approximately 1.5 km from the lake. This is discussed further in Section 1.5 – threatening processes.

Safety Bay Road lies just west of the lake. Uncleared dunes that will be included in the new Rockingham Lakes Regional Park occur between Shoalwater Bay, further west again, and Safety Bay Road. The alignment of the road reserve for the proposed Garden Island Highway cuts through the south west corner of the lake.

Until recently, the lake and immediate surrounds consisted of two separate reserves—numbers 9458 and 33659—and private land— (part lot 402 of Cockburn Sound Location 16). In June 1995, reserve 33659 was amalgamated into reserve 9458. The reserve is vested in the City of Rockingham for the purpose of “Conservation and Public Recreation”. The area of reserve 9458 is now 48.12 hectares. The privately owned land that has just come under the care, control and management of the Western Australian Planning Commission (WAPC) covers approximately a quarter of the lake bed and also includes the foreshore and immediate surrounds to the east of the lake (Lot 8001, 23.1 hectares).

The recently declared Rockingham Lakes Regional Park includes Lake Richmond. The Management Plan to be developed for the Regional Park will include general management specifications for Lake Richmond.

A Management Plan has been drafted for Lake Richmond and two other reserves in the area (Goodale, 1996). Two of the specific management objectives in the Plan for Lake Richmond relate directly to preservation of the thrombolites, namely;

- To maintain and rehabilitate Lake Richmond as an example of a coastal wetland.
- To protect and conserve the special feature of Lake Richmond landscape: the thrombolitic structures.

The Management Plan provided information about funding for maintenance of the reserve and indicated where the funding would be used. Commitments to the following are of particular note in terms of conservation of the thrombolites;

- monitoring of the general condition of the reserve
- monitoring of water quality and weeds
- provision of educational and general tourism information
- provision of board walks to enable non destructive access to the thrombolites and other areas
- seeking of funds for conservation projects on the reserve
- upgrading of facilities while maintaining conservation values
- rehabilitation of foreshore vegetation - including weed control and rubbish removal from the foreshore
- fire prevention
- fencing of sensitive areas to allow only appropriate access

The Management Plan also noted the importance of achieving public ownership of the portion of the lake and foreshore that was in private ownership.

1.2 Extent and location of occurrences

Occurrence Number	Location	Estimated area
Occurrence 1	Lake Richmond, Rockingham	Approximately 3 ha of thrombolites

The total lake area is about 50 hectares, with an approximately 15 m wide strip of thrombolites covering most of the perimeter. The total extent of the thrombolites is approximately 3 ha, of which around 0.75 ha was on private land.

Additional occurrences are considered extremely unlikely to occur.

1.3 Biological and ecological characteristics

Thrombolites are formed by complex associations of photosynthetic prokaryotes (ie, cyanobacteria and purple sulphur bacteria), eukaryotic microalgae (eg, diatoms), and both chemoautotrophic and chemoheterotrophic microbes (ie, true bacteria) (Moore 1991). This assemblage of microbes forms the Benthic Microbial Community (BMC). Cyanobacteria ('blue-green algae') generally dominate microbial communities involved in the formation of thrombolites (Moore 1991). *Dichothis* sp., a cyanobacterium is the dominant microbe at Lake Richmond and grows in fresh to brackish waters with low nutrient status (L. Moore personal observation). The thrombolites of Lake Richmond are probably formed by precipitation of a particular form of calcium carbonate, termed aragonite, within the microenvironment of the community as a result of growth and metabolic activity (Moore 1993). Light and fresh water rich in carbonates are likely to be essential to the growth and survival of the thrombolites.

The biology and ecology of the thrombolites of Lake Richmond are not well studied. Living thrombolites were recognised at Lake Richmond in a recent survey by Dr Linda Moore and the organisms that formed the thrombolites continue to live and grow at the site (L. Moore, personal

observation). It is possible that alterations to physical parameters, such as a decline in salinity, may cause a shift in the microbes that dominate the thrombolites possibly replacing these with a different BMC that does not facilitate carbonate deposition and thrombolite formation (L. Moore, personal observation).

The salinity of the lake fell to approximate the level of the water running into it when the outlet drain was built. Passmore (1970), whose work was done in 1965 and 1966 prior to the drains being constructed in the lake, recorded salinity levels of 2 to 3.5 ppt. Later work (Kenneally *et al.* 1987) notes salinity levels in the lake between 0.4 and 1.4 ppt.

1.4 Hydrology and Water Quality

Groundwater up hydraulic gradient from Lake Richmond and in the superficial formations is less than 1000 mg/L TDS (milligrams per litre Total Dissolve Solids). The groundwater down gradient from the lake may be marginally more brackish due to evaporation of water from the lake concentrating the salts. The salinity of lake water ranges between 400 mg/L and 1,400 mg/L depending on seasonal variations in rainfall. The lake water is slightly alkaline having a pH range of 8.3 to 9.3.

A saltwater interface occurs in the Rockingham Sand aquifer at a depth of about 65 m 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. The lake and drains were sampled twice per year and assayed for principle ions, trace elements including heavy metals, dissolved gases and bacteriological purity between 1968 and 1977 (Kenneally *et al.* 1987). Only data between 1973 and 1977 were quoted in the Kenneally paper, and it is possible that significant changes have occurred since then.

Total nitrogen in Lake Richmond fluctuates seasonally, but remained relatively low between 1973 and 1977 (Kenneally *et al.* 1987). At that time, there were no indications of significant nutrient enrichment.

Data for 1973 to 1977 indicate high counts of *Escherichia coli* and other bacteria on the edges of the lake but not in the centre (Kenneally *et al.* 1987). This probably indicates that contamination is due to birds (Kenneally *et al.* 1987).

Both phosphate and heavy metal levels were low between 1973 and 1978 (Kenneally *et al.* 1987), indicating little contamination from fertilisers, detergents or general industrial pollution respectively.

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).

1.5 Critical Habitat

Critical habitat is habitat identified as being critical to the survival of a listed threatened species or listed threatened ecological community. Habitat is defined as the biophysical medium or media (a) occupied (continuously, periodically or occasionally) by an organism or group of organisms; or (b) once occupied (continuously, periodically or occasionally) by an organism, or group of organisms, and into which organisms of that kind have the potential to be reintroduced (sections 207A and 528 of Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)).

The critical habitat for the thrombolite community of coastal freshwater lakes community is Lake Richmond itself and the catchment for the surface waters, streams and drains, and the groundwater that contributes to the lake waters.

Habitat critical to the survival of the species, and important populations

Given that this community is listed as Critically Endangered, all known habitat for the only known occurrence is considered critical habitat.

Benefits to other species/ecological communities

The 'sedgeland in Holocene dune swales' community is listed as Endangered under the Commonwealth EPBC Act. The sedgelands surround much of the lake's perimeter. Recovery actions, such as weed control, implemented to improve the security of the thrombolites are likely to improve the quality of the habitat of the sedgeland community. In addition, the peregrine falcon (*Falco peregrinus*) occurs in the immediate vicinity of the lake. This species is listed as specially protected fauna under the WA Wildlife Protection Act 1950.

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1.6 Historical and Current Threatening Processes

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 as follows (in approximate order of level of threat posed);

- **Physical crushing**

The thrombolites have been subject to some 15 years of physical crushing underfoot by visitors to Lake Richmond. 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 addition, two applications were made to the Shire in the 1970s and 1980s to allow water skiing on the lake, 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 with the use of boardwalks, for example.

Signs indicating that walking on thrombolites causes damage have been erected around the lake edge.

- **Nutrient enrichment and increases in other pollutants**

Competition can occur between thrombolitic benthic microbial communities (BMC) and macroalgae and/or planktonic cyanobacteria as a result of increased nutrient levels. A threat has recently emerged to the thrombolites of Lake Clifton, approximately 50 km south of Lake Richmond. There, blooms of the green alga *Cladophora* have been noted as a result of nutrient enrichment of waters entering the lake (Moore 1991). This alga effectively competes for light with the microbes forming the thrombolites. It can lead to decreased light penetration that reduces or prevents photosynthesis of the thrombolite forming benthic microbial community, and can prevent thrombolite formation. The source of the additional nutrients entering the waters of Lake Clifton is runoff from increasing areas of land utilised for farming and pastoral uses, and from nutrient contamination of groundwater (Moore 1991).

It is not known if algal blooms have occurred in Lake Richmond; however, with increasing urbanisation, the concomitant rise in runoff of nutrients and other pollutants from adjacent properties may emerge as a major threat to the growth and survival of the thrombolites. It is also possible that increased flushing from drains into and out of the lake may help prevent nutrient build up. It is most likely that these drains direct nutrients from an area of urban catchment into the lake and result in increased nutrient levels. The first heavy rains in winter are known to flush large amounts of nutrient from urban areas into wetlands (Cullen *et al.* 1978). 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.

- **Groundwater drawdown / saltwater intrusion / altered groundwater flowthrough**

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. Therefore, if groundwater abstraction for urban or other purposes in the groundwater catchment of Lake Richmond results in lowering of the water level in the lake, this may expose the thrombolites and the BMC preventing growth of the structures.

The inland marina and hotel that has been proposed for the promontory to the northwest of the lake has the potential to alter hydrological gradients and cause incursion of salt water to Lake Richmond.

A decline in the lake volume would also increase the salinity and concentrate all other constituents of the lake water. As mentioned, an increase in salinity may lead to a change in the dominant microbes. A salinity increase is likely to have more significant impacts to the function of the thrombolites than would a decrease.

The impact of changes in salinity levels and other water quality parameters on the thrombolites may be dependent on the level of stratification and mixing that occurs in the lake. The thrombolites may occur in an area where there is an upwelling of groundwater and be relatively unaffected by alterations to the water quality of the lake. However, if mixing within the lake is substantial, then hydrological changes may impact the thrombolites.

- **Increased runoff**

Clearing and urbanisation on the Swan Coastal Plain has typically resulted in increased runoff as less rainfall is intercepted by vegetation, and less groundwater is transpired by vegetation (Allen 1981). A rise in groundwater is probably the most likely outcome of urbanisation of the catchment of Lake Richmond, with the opposing forces of increased runoff and increasing abstraction in the area (A. Davidson¹ personal communication).

Drainage into Lake Richmond has increased as a result of construction of drains into the lake. These drains were built to dispose of surface water from the developed catchment, and to lower the water table to allow for urban development (Kenneally *et al.* 1987). Increased volume dilutes ions, trace elements and other contained substances such as calcium, carbonate and bicarbonate. The thrombolites rely on lake waters to provide the raw materials such as carbonates and calcium in sufficient concentrations to support their growth.

The inlet and outlet drains currently control the lake level. Lake levels required to sustain the growth and survival of the thrombolites need to be determined in the future through monitoring.

- **Alterations to surrounding vegetation**

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. A 200 m vegetated buffer from the high water mark would be considered a minimum in sandy soils for an effective buffer area to prevent nutrient enrichment in wetlands (Davies and Lane 1996). Drains into the lake would reduce the effectiveness of this buffer, however (Davies and Lane 1996).

The invasion of weeds into the vegetated buffer area around the lake has the potential to impact the thrombolites. Weeds such as couch grass are actually growing in between the thrombolites and causing the build up of sediment. Such sediment can smother the structures, and is discussed further in this section. Chemicals used for weed control in the drain and if used immediately adjacent to the thrombolites may also impact the structures.

¹ Dr Angus Davidson; previously hydrologist, Water and Rivers Commission

The level of weeds in the remnant vegetation adjacent 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. 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.

- **Smothering by weed infestations or 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.

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 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 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.

- **Road construction**

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 destroy about 0.3 ha of thrombolites (about 16% of the current area of the community).

1.7 Guide For Decision-Makers

Section 1.6 above provides details of current and possible future threats. Proposed developments in the region of Lake Richmond require assessment. No developments should be approved unless the proponent can demonstrate that they will have no significant impact on the lake, its hydrology or the thrombolites. Impacts on the surface or groundwaters, leading to either changes in water quality or levels in the lake, would be expected to have a significant impact on the threatened ecological community.

1.8 Conservation status

The thrombolite community of coastal freshwater lakes meets the following criteria for Critically Endangered (CR) ecological communities:

- i) current distribution is limited and currently subject to known threatening processes which are likely to result in total destruction in the immediate future (within approximately 10 years) if trends continue.
- ii) current distribution is limited and there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes.

1.9 Strategy for recovery

To influence the management of Lake Richmond, and to identify and influence the management of its catchment area, so maintaining natural biological and non-biological attributes of the site and the current area covered by the community.

To conduct appropriate research into the ecology of the community to develop further understanding about the management actions required to maintain or improve the condition of the community.

2. RECOVERY OBJECTIVE AND CRITERIA

Objective: To maintain or improve the overall condition of the microbial community in the only known location.

Criteria for success:

- Maintenance of water quality and levels in Lake Richmond
- Maintenance of the vigour and extent of the microbial community including maintenance of the composition of the microbial species.
- An increase in the area of this community under conservation management.

Criteria for failure:

- Significant and sustained detrimental changes to water quality or levels in Lake Richmond
- Significant decline in area as measured by physical damage or loss of thrombolite structures.
- Decline in health as measured by a major shift in composition of the microbial community

3. RECOVERY ACTIONS

3.1 Establish a Recovery Team

Responsibility: the Department (WATSCU)
 Cost: \$2000 pa to run team
 Completion date: Completed

3.2 Establish a Technical Advisory Group

The Recovery Team requires an expert group to provide advice on specific issues.

Responsibility: Recovery Team; the Department (Swan Coastal District, WATSCU)
 Cost: \$1000 pa
 Completion date: Completed

3.3 Clarify the extent and condition of the community

Funds will be sought to develop and implement a strategy to determine, through detailed survey, the extent (including number of individual structures if possible), size and condition of the thrombolite structures at Lake Richmond, to provide baseline data for future comparison. The best preserved areas will also be determined.

Divers will undertake initial sub-surface monitoring and mapping of the thrombolites in the lake.

Visual inspection of the structures for the presence of filamentous algae (macroalgae indicative of algal blooms) will be done on a bi-annual basis.

The Rockingham Regional Environment Centre undertook the survey in 1997/98 with funds from the World Wide Fund for Nature, and with advice from Dr Linda Moore.

Responsibility: Recovery Team; the Department (Swan Coastal District); City of Rockingham
Cost: \$5,000 in Year 1; then \$1,000 in Year 3 and 5
Completion date: Initial studies completed, monitoring ongoing

3.4 Map Critical Habitat

It is a requirement of the EPBC Act that spatial data relating to critical habitat be determined. Although critical habitat is described in Section 1, the areas as described have not yet been mapped and that will be done under this action. If any additional areas are located, then critical habitat will also be determined and mapped for these locations.

Action: Map critical habitat
Responsibility: The Department (Swan Coastal District, WATSCU) through Recovery Team
Cost: \$2000 in Year 2
Completion date: End of Year 2

3.5 Agree on a suitable native vegetation buffer area between the development to the south east of the lake and the lake

A 200 m wide vegetated buffer measured from the high water mark would be considered the minimum for an effective buffer area (Davies and Lane 1996) to help provide effective protection for the thrombolite community. General disturbance should be minimised within this zone and the area should not be utilised for other purposes such as retention basins or filtering lakes.

The old stranded thrombolites to the west of the lake are included in the Parks and Recreation zoning.

Responsibility: Recovery Team; DEP, Department of Planning and Infrastructure (DPI), City of Rockingham, the Department (Swan Coastal District); adjacent developers in response to Ministerial Conditions
Cost: Costs of all liaison \$5,000 p.a.
Completion date: Completed (Environmental Management Program to be completed under Ministerial Conditions)

3.6 Seek to ensure the proposed 'Garden Island Highway' does not impact the thrombolites

If developed as planned, the Garden Island Highway will cut through the south west corner of Lake Richmond, and would result in direct impacts to some 16% of the thrombolites. The Recovery Team will liaise with relevant authorities to ensure impact to the thrombolites is considered in the planning of the highway.

Responsibility: the Department (Swan Coastal District); Recovery Team; City of Rockingham; Main Roads WA, DEP and DPI
Cost: \$1,000 pa
Completion date: Ongoing.

3.7 Conduct biological research

The 'health' or viability of the thrombolites has been established through a biological / petrographic study of the structures and this study indicated that they were healthy and that the same organism that formed them is still dominant.

The health of the thrombolites will be monitored through compositional and structure studies. Studies will also include identification of whether macro-algae occurs in the lake.

External funds have been obtained by the Rockingham Regional Environment Centre for some research on the community. A fauna survey of the lake has been done using funds from the World Wide Fund for Nature (WWF).

Responsibility: Recovery Team; the Department (Swan Coastal District); City of Rockingham; WRC
Cost: \$3,000 for Year 1 (microscope), \$1,000 p.a. for training and monitoring
Completion date: Ongoing.

3.8 Manage access to site

Ensure scientific and public access and research on the thrombolite community is undertaken in a coordinated and organised way with minimal disturbance and physical damage.

Responsibility: Recovery Team, City of Rockingham
Cost: \$1000 to develop protocol in Year 1, \$500 p.a. to manage system
Completion date: Ongoing.

3.9 Ensure drainage from adjacent lands does not impact the thrombolites

A drainage strategy is likely to include the containment of all drainage waters from proposed developments adjacent to the lake. The proponent of the new development on the eastern side of the lake will need to use water sensitive design to ensure maximum infiltration of rain water through the use of infiltration basins or soakwells and other systems including nutrient stripping basins if necessary.

There will be a Nutrient and Drainage Plan developed under Ministerial Conditions for the proposed development on land to the east of the lake. The consultant to the developer agrees that the development design will meet hydrological requirements.

The Water Corporation will install Trash Racks on drains if monitoring indicates that rubbish entering from drains is causing physical damage to the thrombolites.

Responsibility: DEP; WRC; Water Corporation; City of Rockingham; Recovery Team; the Department (Swan Coastal District); developers and managers of adjacent land
Cost: To be determined when drainage management plan is developed. Drainage costs to be covered by developers and land managers of land adjacent to the lake. (Cost of trash racks, if required, for two drains -\$24,000 in Year 1; \$3,000 p.a. for maintenance of trash racks)
Completion date: To be determined.

3.10 Ensure the microbial community is protected from physical damage

Actions will include erection of barriers to prevent vehicle access to the development site (to prevent rubbish dumping), placement of signs and construction of paths and boardwalks to prevent accidental crushing of thrombolites.

This action has been completed for sixty percent of the area of the thrombolites by the Rockingham Regional Environment Centre.

Responsibility: the Department (Swan Coastal District), Recovery Team; City of Rockingham; WAPC; and developers of land adjacent to the lake
Cost: \$33,000 for Years 1, 2 and 3
Completion date: Prior to development proceeding east of lake

3.11 Manage physical impacts to thrombolites through education

Continue to develop an education program through the use of information boards etc that explain the importance of the site and features.

Responsibility: Recovery Team; the Department (Swan Coastal District); City of Rockingham / Rockingham Regional Environment Centre, developers of land adjacent to the lake
Cost: \$2,000 p.a.
Completion date: Ongoing

3.12 Undertake ongoing monitoring of physical condition of thrombolites.

Ongoing monitoring will be undertaken using methods for monitoring condition, size and extent established under Recommendation 3.3. Such monitoring will include continuing assessment of the composition of the microbial community. The possibility of monitoring numbers of intact thrombolites along a transect to determine gross changes, and the use of photographic monitoring to measure the extent of physical crushing will be investigated.

Responsibility: the Department (Swan Coastal District); Recovery Team; City of Rockingham; WRC; WAPC; developers of land adjacent to the lake
Cost: Costs of developing program \$1,000 for Year 1, then \$1,000 for monitoring in Year 4
Completion date: Ongoing

3.13 Conduct baseline water quality studies

Water Corporation currently monitors chemicals, major nutrients, pH, salinity and pesticides in the exit point of the major drains and in three sites in the lake. Smaller drains will also be monitored to determine if these represent a risk to lake water quality.

Water quality parameters will be correlated with occurrence of any changes that occur in the community. This will help to determine water quality requirements of the thrombolites. Nutrient status is likely to be the most important determinant of the health of the thrombolites (L. Moore personal observation).

The possibility of including seepage studies such as measurements of flow rates and quality in the reef area in the full Recovery Plan will be investigated. Comparison with water quality data for the groundwater and lake waters may help determine causes of any algal blooms. Such research would help to determine the water and nutrient budgets for the lake.

Responsibility: the Department (Swan Coastal District); Recovery Team; City of Rockingham; Water Corporation; WRC; WAPC; and developers of land adjacent to the lake
Cost: \$33,750 for Year 1
Completion date: Ongoing

3.14 Monitor water quality and hydrology

Baseline and ongoing monitoring of the limnological status of the lakewaters and groundwaters will be undertaken. Data will ideally include ionic composition, nutrient levels, nutrient input and flow rates through the drains and collection of water level and water quality information from the lake middle and edges adjacent to thrombolites and from monitoring bores in adjacent areas of interest.

'Investigation levels' of nutrients will be developed as soon as possible and incorporated into a full Recovery Plan, if developed. 'Investigation Levels' are the nutrient levels that will trigger a full nutrient balance study of the lake. 'Investigation' levels for other water quality parameters that trigger detailed research to ascertain the causes and likely implications of reduced water quality, before the 'minimum' criteria are reached will also be developed and included in the full Recovery Plan, if developed.

Baseline and ongoing monitoring data on water level and quality are already available for the lake (Kenneally *et al.* 1987). The Water Corporation is undertaking monthly monitoring of nutrient levels in major drains into the lake and from the lake itself.

Responsibility: Water Corporation; WRC; Recovery Team, City of Rockingham; DEP; WAPC and developers and managers of adjacent land

Cost: To be determined following analysis of baseline monitoring data (between \$12,000-\$33,000)

Completion date: Ongoing

3.15 Ensure hydrological regimes are not altered outside the range of normal fluctuations

Liaison with developers of adjacent lands will help to ensure any adjacent developments do not alter the hydrological balance ie. abstraction reducing groundwater input to the lake, reducing lake levels in summer or altering the flow pattern in the lake. The adequacy and appropriateness of current investigation of water level measurements needs to be assessed. Groundwater flows will also be measured, and specific actions initiated if flow rates decline below a certain level.

Criteria that can trigger fuller investigation will be established and incorporated into the full Recovery Plan, if developed.

These and other hydrological issues will be considered in the Nutrient and Drainage Plan to be produced for the development on land to the east of the lake.

Baseline and ongoing monitoring data on water levels are already available for the lake (Kenneally *et al.* 1987; B. Goodale, personal observation). Thrombolites are currently uncovered for about one month each year. The period of inundation of the thrombolites will continue to be monitored. The TAG will determine criteria and levels for investigation during the implementation of this interim recovery plan.

Responsibility: the Department (Swan Coastal District), Recovery Team, City of Rockingham; Water Corporation; WRC; DEP; land managers and developers of land adjacent to the lake

Cost: \$1,000 pa

Completion date: Ongoing.

3.16 Manage water quality

There will be liaison with land managers to respond to results of water monitoring as appropriate eg diverting stormwater from the lake if input drainage water quality declines significantly; closing sluice gates or limiting groundwater abstraction rates if saltwater intrusion occurs.

The results of water quality research and the drainage management plan for the proposed development adjacent to the lake will be incorporated into a management strategy developed under this Action.

Strategies to manage water quality developed under this IRP will be incorporated into the full Recovery Plan, if developed. Contingency plans will also be incorporated into the full Recovery Plan.

Responsibility: Recovery Team; the Department (Swan Coastal District); City of Rockingham; Water Corporation; WRC; DEP; relevant land managers and developers of land adjacent to the lake
Cost: To be determined as a result of monitoring actions in this IRP
Completion date: Ongoing

3.17 Provide information to surrounding landholders to ensure actions on their lands do not impact the thrombolites

Such information will aim to minimise fertiliser use, avoid use of chemicals that may be toxic to the community and ensure other threatening processes are mitigated. A pamphlet that includes this information will be provided to people who purchase land adjacent to the lake. The Environmental Management Plan for the development to the east of the lake also addresses this issue.

Responsibility: Recovery Team; Rockingham Regional Environment Centre; City of Rockingham; the Department (Swan Coastal District); liaison with surrounding landholders
Cost: \$2,000 in Year 1 and Year 4
Completion date: Ongoing

3.18 Collect baseline information and ongoing monitoring data for buffer vegetation

Density, root mass, and the width of the vegetation buffer will be important in controlling sheet flow and inhibiting the movement of sediment into the lake. Although weeds may also contribute to these processes, some species such as couch grass also invade the area between the thrombolites. This results in sediment being trapped around the thrombolites, and sediment and weeds may smother the structures. Weeds should therefore be controlled in the vegetation adjacent to the lake (see 3.18).

Flora monitoring data, collected every second year will include weed levels, plant species diversity, species composition of flora. Two plots in the buffer area should be sufficient. Baseline data on the vegetation condition and a vegetation map has been produced by the Rockingham Regional Environment Centre.

Responsibility: Recovery Team; the Department (Swan Coastal District); Rockingham Regional Environment Centre; City of Rockingham
Cost: \$1,000 in Years 1, 3 and 5 for flora monitoring
Completion date: Ongoing

3.19 Rehabilitate adjacent plant communities

A strategy to rehabilitate degraded areas of the sedgeland and other adjacent plant communities that provide a buffer for the wetland containing the thrombolites will be designed and implemented. The strategy will include carefully designed and monitored weed control - taking extreme care not to impact the thrombolites, and replanting as necessary (eg. where visitors have impacted the plant communities). Data from DEP (1997) may help provide a list of appropriate species for use in rehabilitation.

Responsibility: the Department (Swan Coastal District), Recovery Team, City of Rockingham; land managers and developers of adjacent land
Cost: \$100,000 for Year 1, \$30,000 p.a. thereafter
Completion date: Ongoing.

3.20 Design and implement Fire Management Strategy to sustain the vegetation buffer

3.20.1 Liaise with adjacent developer and City of Rockingham to develop and implement an approved fire management strategy

The strategy will allow for the natural development of the sedgeland and adjacent plant communities that provide a buffer for the thrombolites. It should include an annual fire monitoring and reporting schedule.

There is a need for research into the effect of fire on the vegetation that provides a buffer for the thrombolites and on sediment levels entering the lake etc and the implications for management. A fire history map of the area, which is updated annually, is also required.

These issues will be considered in a general sense in the Management Plan for the Rockingham Lakes Regional Park.

Responsibility: the Department (Swan Coastal District), Recovery Team, City of Rockingham; adjacent developer / landholders and Fire and Emergency Services Authority of Western Australia (FESA)
Cost: \$850 to develop fire management strategy in Year 1
Completion date: Year 2.

3.20.2 Liaise with adjacent landholders and FESA to ensure fire suppression strategy in adjacent areas does not impact community

The strategy for fire suppression procedures will be to minimise physical and chemical impacts on the thrombolites eg avoidance of the use of chemicals that adversely impact the thrombolites and avoidance of construction of new tracks for use in fire suppression.

Responsibility: the Department (Swan Coastal District); Recovery Team; FESA; City of Rockingham; liaison with adjacent landholders
Cost: Costs of all liaison included in Action 3.4
Completion date: Ongoing.

3.21 Report on success of management strategies for the thrombolite community

Reporting will be part of annual reports prepared by the Recovery Team. Annual reporting to the Department; City of Rockingham; Rockingham Regional Environment Centre on success of overall strategies to maintain or improve condition of the thrombolite community. Report to be presented as part of or complementary to the full recovery plan for community.

Responsibility: the Department (Swan Coastal District), Recovery Team, City of Rockingham
Cost: \$2,000 p.a.
Completion date: End of Year 3

3.22 Write a full Recovery Plan, if required

At the end of the five-year term of this Interim Recovery Plan, the need for further recovery actions will be assessed. If the community is still ranked as Critically Endangered at that time the need for a full Recovery Plan or to update this IRP will be assessed.

Responsibility: the Department (Swan Coastal District and WATSCU) through the Recovery Team
Cost: \$17,500 in Year 5 if required
Completion date: Year 5.

Table 1: Summary of costs for each recovery action

Recovery Action	Year 1	Year 2	Year 3	Year 4	Year 5
Establish a Recovery Team	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000
Establish a Technical Advisory Group	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000
Clarify the extent and condition of the community	\$5,000		\$1,000		\$1,000
Map Critical Habitat		\$2,000			
Agree on a suitable native vegetation buffer area	\$5,000	\$5,000	\$5,000	\$5,000	\$5,000
Seek to ensure the proposed 'Garden Island Highway' does not impact	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000
Conduct biological research	\$4,000	\$1,000	\$1,000	\$1,000	\$1,000
Manage access to site	\$1,500	\$500	\$500	\$500	\$500
Ensure drainage from adjacent lands does not impact the thrombolites	\$24,000	\$3,000	\$3,000	\$3,000	\$3,000
Ensure microbial community is protected from physical damage	\$33,000	\$33,000	\$33,000	-	-
Manage physical impacts to thrombolites through education	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000
Undertake ongoing monitoring of physical condition of thrombolites	\$1,000			\$1,000	
Conduct baseline water quality studies	\$33,750	-	-	-	-
Monitor water quality and hydrology	To be determined				
Ensure hydrological regimes are not altered	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000
Manage water quality	To be determined				
Provide information to surrounding landholders	\$2,000			\$2,000	
Collect baseline information and ongoing monitoring data for buffer vegetation	\$1,000		\$1,000		\$1,000
Rehabilitate adjacent plant communities	\$100,000	\$30,000	\$30,000	\$30,000	\$30,000
Develop and implement an approved fire management strategy	\$850				
Liaise with adjacent landholders and Fire and Rescue service	-	-	-	-	-
Report on success of management strategies	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000
Write full Recovery Plan, if required					\$17,500

Summary of costs over five years

Year 1	\$220,100
Year 2	\$83,500
Year 3	\$83,500
Year 4	\$51,500
Year 5	\$68,000
Total	\$506,600

ACKNOWLEDGMENTS

The critically endangered status of the microbial community at Lake Richmond was identified under the Australian Nature Conservation Agency (now Environment Australia) funded project entitled "Identifying and conserving threatened ecological communities in the South West Botanical Province" (English and Blyth 1997).

The following people provided valuable advice and assistance in the preparation of this Interim Recovery Plan;

Angus Davidson	Previously Water and Rivers Commission
Steve Appleyard	Water and Rivers Commission

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GLOSSARY

Aeolian: brought in by the wind

Aragonite: a particular form of calcium carbonate that is chemically identical to calcite but differs in crystallisation, a higher specific gravity and less marked cleavage.

Benthic: from the bottom of the sea or a lake

BMC: Benthic microbial community

Chemoautotrophic microbes: microbes that are capable of producing complex organic nutritive substances from simple inorganic substances such as carbon dioxide

Chemoheterotrophic microbes: microbes that rely upon complex organic compounds to produce their own organic constituents

Cyanobacteria: “blue green algae” - photosynthetic bacteria

Eschericia coli: a common bacteria used to indicate fecal contamination in waterways

Eukaryotes: organisms whose cells have a nuclear membrane, membranes around their internal structures, and divide by mitotic division eg fungi, protozoa and higher animals and plants

Evapotranspiration: the return of water vapour to the atmosphere by evaporation from land and water surfaces and from water produced by vegetation

Holocene: from the last 10,000 years of geological history

Lithified: composed of stone

Macroalgae: larger algae having a complex structure eg seaweed

Microalgae: microscopic simple algae eg diatoms

Microenvironment: within the minute immediate environment

Petrography: the scientific description and classification of rocks

Prokaryotes: organisms that have no nuclear membrane or membrane around their internal cellular structures eg blue-green algae and bacteria

Quindalup Dune System: the dune system located nearest the coast around Perth, consisting of white sands

Thrombolite: a structure produced by the growth and metabolic activity of microbes and which has a clotted internal framework