Lake Ainsworth Coastal Management Program

Stage 3 – Management Options Study

Final Report

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Front cover photo: Aerial view of Lake Ainsworth and adjacent Lennox Head coastline

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18-009 LAKE AINSWORTH COASTAL MANAGEMENT PROGRAM MANAGEMENT OPTIONS STUDY

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2	Final Report	K. Pratt, M. Howland	M. Howland	M. Howland	16 Aug 2019

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INTRODUCTION

Stage 3 of the coastal management program (CMP) process requires councils to identify actions that address coastal management issues in an integrated and strategic manner (OEH, 2019). The aim is to identify coastal management actions that address issues, reduce exposure to coastal hazards, and take advantage of opportunities, consistent with provisions in Section 14 and 15 of the *Coastal Management Act 2016* (CM Act). Councils also decide the priority of identified coastal management actions and propose integrated and strategic delivery pathways.

The Coastal Management Manual Stage 3 (OEH, 2019) outlines the following steps in completing Stage 3 of a CMP:

- Step 1 – Confirm the Strategic direction
- Step 2 – Identify Potential Management Options
- Step 3 - Evaluate Potential Actions
- Step 4 - Putting it together: including development of the business plan. Note that this step is to be completed as part of Stage 4: CMP Development.

Each step has been documented in the following sections.

STEP 1 – CONFIRM THE STRATEGIC DIRECTION

The purpose of a coastal management program is to set the long-term strategy for the coordinated management of land within the coastal zone with a focus on achieving the objects of the CM Act. The long term strategic direction for Lake Ainsworth is encapsulated by the Vision for the lake (Plate 1), local objectives (Table 1) and Coastal Management Area objectives applicable to Lake Ainsworth adopted from the CM Act (Table 2). The strategic direction has been confirmed through consideration of:

- The objectives of the *BSC Community Strategic Plan 2018 – 2028*;
- The relevant management objectives set out in the *Coastal Management Act 2016* and the objects of the *Marine Estate Management Act 2014*;
- The values, threats and management priorities identified in the Stage 1 Scoping Study (Hydrosphere Consulting, 2018) and Stage 2 Vulnerabilities and Opportunities Study (Hydrosphere Consulting, 2019) incorporating the findings of stakeholder consultation;
- The most important attributes for Lake Ainsworth nominated by the community and over 275 unique vision statements provided by the community in the Community Survey (refer Hydrosphere Consulting, 2019); and
- Lake Ainsworth CMP Steering Committee Workshops.

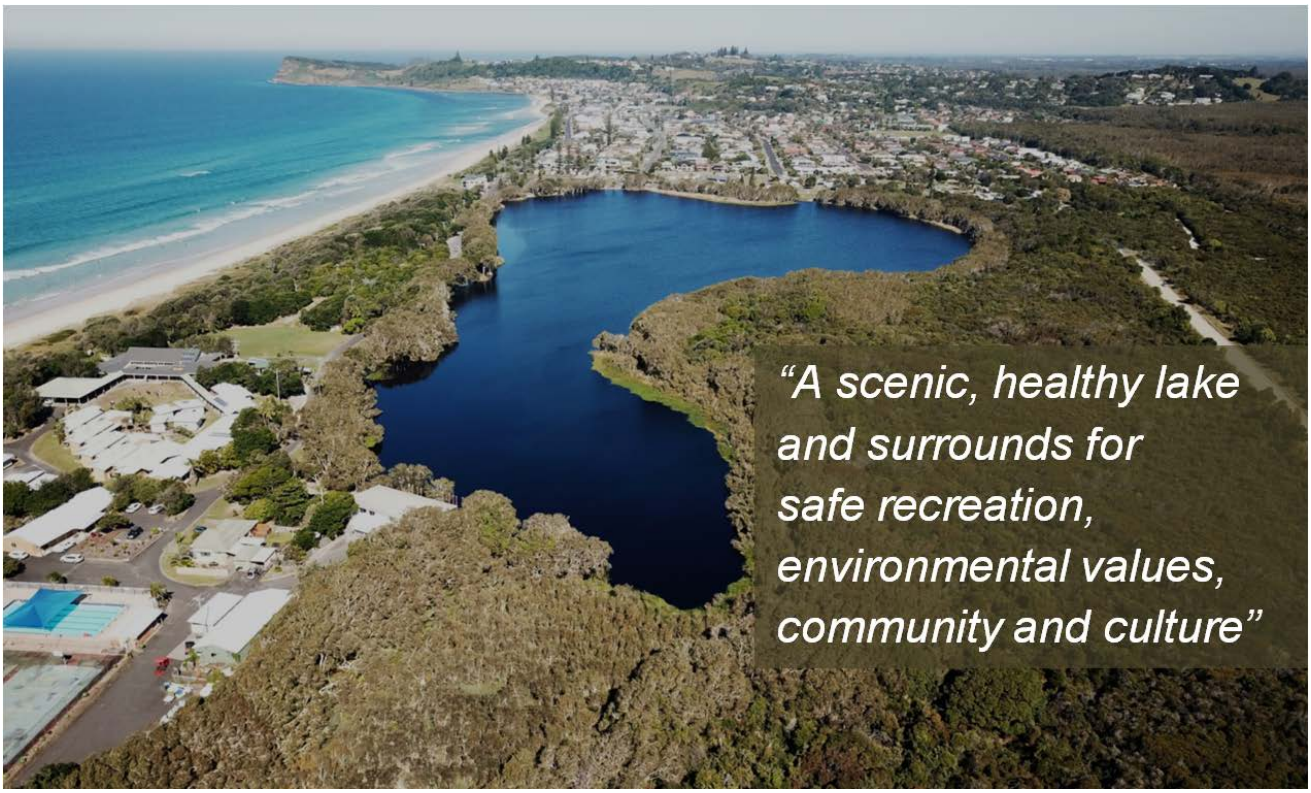

Plate 1: The long-term vision for Lake Ainsworth

Table 1: Lake Ainsworth community values and local management objectives

Values	Lake Ainsworth local management objectives
Environmental Values	
Water quality	1. To improve and maintain water quality and ecosystem health of the lake and surrounding habitats. 2. To reduce threats and improve the resilience of the lake to all current and future threats;
Natural habitats and biodiversity	3. To protect and enhance the coastal environmental values and natural processes of the lake and enhance natural character, scenic value, biological diversity and ecosystem integrity. 4. To encourage and support plans and strategies to improve the health and resilience of the lake and catchment area.
Recreational, Cultural and Community Values	
Scenic quality and amenity	5. To protect and enhance the recreational, scenic, social and cultural values of the catchment area. (also linked to objectives 1-4)
Public access to and use of the lake and foreshore	6. To improve and maintain public access and safety, facilities and infrastructure within the catchment area.
Education, engagement and public opinion	7. To actively engage with the public to achieve greater awareness, education and understanding of management issues and actions. 8. To support public participation in the coastal management and planning process.

Values	Lake Ainsworth local management objectives
Aboriginal cultural heritage and practice	9. To understand, protect and respect the aboriginal heritage value of the lake including aboriginal peoples' spiritual, social, customary and economic use of the catchment area.
Coastal risk and adaption to climate change	10. Identify coastal hazard risks and develop actions that increase the adaptive capacity of land managers, the community and natural systems to the predicted impacts of climate change, including increased storm intensity and sea level rise.
Economic Values	
Local economy, jobs and prosperity	11. To support integrated and co-ordinated coastal planning, management and reporting (achieving above objectives will contribute to local economic values through enhanced tourism and associated business activity)

Table 2: Coastal Management Area objectives adopted from the Coastal Management Act, 2016

Coastal Management Areas	Coastal Management Area Objectives
CMA1 – Coastal Wetlands and Littoral Rainforests[1]	1. To protect coastal wetlands and littoral rainforests in their natural state, including their biological diversity and ecosystem integrity. 2. To promote the rehabilitation and restoration of degraded coastal wetlands and littoral rainforests. 3. To improve the resilience of coastal wetlands and littoral rainforests to the impacts of climate change, including opportunities for migration. 4. To support the social and cultural values of coastal wetlands and littoral rainforests. 5. To promote the objectives of State policies and programs for wetlands or littoral rainforest management.
CMA2 – Coastal Vulnerability Area	6. Managing current and future risks from foreshore/bank erosion, coastal lake instability and tidal inundation. 7. Maintaining public access, use and amenity of foreshores. 8. Encourage land use that reduces exposure to coastal hazards over time. 9. Avoiding adverse impacts on adjoining land, resources and assets. 10. Maintaining essential infrastructure. 11. Improving the resilience of coastal communities.
CMA 3 – Coastal Environment Area	12. To protect and enhance the coastal environmental values and natural processes of the estuaries. 13. To enhance natural character, scenic value, biological diversity and ecosystem integrity. 14. To reduce threats to, and improve the resilience of the estuaries. 15. To maintain and improve water quality and estuary health. 16. To maintain the presence of natural features of foreshores. 17. To maintain and, where practicable, improve public access, amenity and use of estuary foreshores.

Coastal Management Areas	Coastal Management Area Objectives
CMA 4 – Coastal Use Area	18. To support sustainable coastal economies and ecologically sustainable development. 19. To protect and enhance the scenic, social and cultural values of the study area through: • appropriate type, size and scale of development; • providing adequate public open space and associated public infrastructure; and • avoiding adverse impacts of development on cultural and built environment heritage.

1. Objectives also apply to the 'proximity area' surrounding the vegetated area, to ensure that development near the coastal wetlands and littoral rainforest considers surrounding and downstream effects.

STEP 2 – IDENTIFY POTENTIAL MANAGEMENT OPTIONS

Where the risk assessments in Stages 1 and 2 of the CMP identified unacceptable risks, potential management options have been identified to address those risks. Broadly, the management options can be organised into five categories as described in OEH (2019):

1. Alert – includes coastal management actions that seek to 'watch and wait'. Such actions include monitoring change and setting thresholds, low regret responses and research to improve knowledge.
2. Avoid future impact – includes recommending proactive land use planning and encouraging new development only in locations of low risk.
3. Active intervention – includes coastal management actions that seek to protect assets or accommodate change in any of the coastal management areas, while maintaining current systems and values.
4. Planning for change – includes coastal management actions that seek to facilitate habitat migration and transformative changes to natural systems. For built areas, this includes planning to relocate or redevelop assets to consider the dynamic and ambulatory nature of the shoreline. It may be timed to commence as opportunities arise or when thresholds of exposure, impact and risk are exceeded.
5. Emergency response – includes coastal management actions to address residual risk in emergency situations.

Each management option is described in Appendix 1: Management Options, including information on key benefits and risks. In addition to management options considered for this CMP, Appendix 4 details additional management requirements identified to protect the lake from coastal hazard impacts (e.g. coastal recession, oceanic break-through, and wave run-up and dune overtopping). These management requirements are to be considered in development of the future Ballina Coastline CMP.

STEP 3 - EVALUATE POTENTIAL OPTIONS

The identified coastal management options have been prioritised through examining the feasibility, viability and acceptability of coastal management options. In doing this the following has been considered:

- Promoting and achieving the objects of the CM Act;
- Meeting the coastal management objectives within the coastal management areas;
- The environmental, social, cultural and economic context and potential impacts;
- The vulnerability and risks;

- The feasibility of coastal management actions: determined by effectiveness, practicality and reliability of the measure or technology;
- Viability of implementation: determined by anticipated cost, availability of resources, time and commitment and anticipated benefits; and
- The acceptability of the risks to the council, key stakeholders such as public authorities, and the community, including willingness to contribute to the upfront and ongoing maintenance costs.

Step 3.1 Management Options Assessment

The Stage 2 *Vulnerabilities and Opportunities Study* provided a preliminary screening of 69 potential management options to address issues identified through detailed study and stakeholder engagement. The outcome of this assessment was a refined list of options that should be considered as part of this Stage 3 options assessment.

This options assessment involved examination of a total of 38 options which were subject to a multi-criteria cost benefit analysis. The multi-criteria cost benefit analysis involved two parts as follows:

- Cumulative risk mitigation assessment – an assessment of the influence of the option on all threats to the lake, not just the direct threat addressed; and
- Cost benefit analysis considering a number of key criteria related to feasibility, viability and acceptability of the option.

Scores from the above two parts were combined to determine if the option should be recommended for implementation in the CMP. Each component of the assessment is detailed below.

1.1.1 Step 3.1.1 Cumulative Risk Mitigation Assessment

The cumulative risk mitigation assessment involved considering the direct and indirect impact of the option on each threat identified for the lake. Risks were identified through the risk assessment undertaken during the Stage 1 *Scoping Study* and updated as part of Stage 2 *Vulnerabilities and Opportunities Study.* The direct or indirect impact could be positive or negative, and scores were assigned on this basis (Table 3). For example, riparian restoration will have a direct positive influence on bank stability and is assigned a score of 2 for this threat. It will also enhance habitat values and increase aesthetic appeal indirectly and therefore is given a score of 1 for each of these threats. It will have no influence on the threat from ocean shoreline recession and so is scored a 0 against this threat.

Table 3: Risk Mitigation Scoring

Impact	Score
Direct negative	-2
Indirect negative	-1
No Influence	0
Indirect positive	1
Direct positive	2

The influence of each of the 38 options on mitigating all 24 risks was scored. The scores were then weighted according to the risk level of each risk as assigned during Stage 1 and updated in Stage 2 of the CMP.

Each influence score was multiplied by the weighting for that risk, then added to give a cumulative risk mitigation score.

Cumulative risk mitigation scores for the 40 options ranged from +92 (Option 39: Establish an integrated management group) to -30 (Option 5: Managed retreat). The cumulative risk mitigation score provided a clear overview of the likely influence of the various options on risks relative to Lake Ainsworth. The influence scores and cumulative risk mitigation score given to each option is provided in Table 6 of Appendix 2.

1.1.2 Step 3.1.2 Cost Benefit Analysis

The options were then assessed for costs and benefits against nine different criteria:

1. Effectiveness - being the ability of the option to reduce the risk for which the option has been designed or targeted, or alternatively, the provision of important data or knowledge about the target risk by the option;
2. Technical viability - to highlight where certain options may or may not be technically feasible or would require significant engineering (or other) investigations and construction / implementation capabilities;
3. Ecological sustainability – to identify options with potential for negative or positive environmental impacts in either the short or long term;
4. Legal / Approval Risk - to highlight the legislative and approval requirements (or impediments) to implementing an option within the current legal framework;
5. Capital costs to implement the option initially;
6. Ongoing costs per annum;
7. Cost-benefit distribution (private vs public benefit);
8. Community/Stakeholder Acceptability –based upon general feedback from the local community and stakeholders received so far; and
9. Meeting Coastal Management Objectives - promoting and achieving the objects of the CM Act, and meeting the coastal management objectives.

The scoring system for the above criteria is outlined in Table 4. Each of the criteria were given equal weighting. The total score for each option was therefore based on a direct addition of scores against each criteria. Scores for the options ranged from 9 (a number of options including Option 23: Backfill exposed tree roots and Option 2: Riparian vegetation enhancement for erosion control) to a score of -1 (Option 12: Draining and/or treatment of nutrient-rich benthic waters; and Option 15: Constructed wetlands). The high CBA scores were generally assigned to options with a high chance of success, low technical difficulty, relatively low cost, and a high level of community and stakeholder support.

The outcomes of the cost benefit analysis for each option against each criteria is provided in Table 7 of Appendix 3.

Table 4: Cost Benefit Analysis Criteria Scoring System

Score:		**-1**	**0**	**1**
Feasibility	Effectiveness (in addressing direct risks)	Option is unlikely to be effective / substantially reduce targeted risks	Option will not necessarily reduce targeted risk(s) but will provide important knowledge / data about the risk OR Option will bring a minor reduction in the targeted risk(s)	Option will be very effective in eliminating/ reducing/ remediating its target risk(s)

Score:		-1	0	1
	Technical Viability	Is unlikely to be technically viable without substantial engineering (or other) design investigation and capabilities for implementation	Is likely to be technically viable at the site, but would require further investigations to clarify	Is technically viable at the site / location
	Ecological sustainability	Option is likely to have a negative impact on environmental values either directly or indirectly or impacts are unknown	Not expected to have any influence on environmental values	Expected to have a net positive impact on environmental values
	Legal/ Approval Risk	Will require an EIS to implement; There is a residual risk that approval will not be obtainable for the proposed works / strategy	Will require government approvals (e.g. REF) to be implemented	No or minimal government approvals required to implement
Viability	Capital Costs	Very expensive (>$300,000)	Moderately expensive ($100,000 - $300,000)	Limited cost (<$100,000)
	On-going costs	Very expensive (>$150,000 p.a.)	Moderately expensive ($25,000 -$150,000 p.a.)	Limited cost (<$25,000 p.a.)
	Cost-benefit distribution (public vs. private)	100% private benefit	50% public, 50% private benefit	100% public benefit
Acceptability	Community/ Stakeholder Acceptability	Unlikely to be acceptable to community and politically unpalatable; Extensive community education, endorsement by Minister(s) and Council required	Would be palatable to some, not others (~50/50 response); Briefing to Councillors, GM and community education required	Is very politically palatable, acceptable to community; Minimal education required
	Meeting CM objectives	Doesn't not meet any CM objectives	Meets one of the CM objectives	Meets multiple (>1) CM objectives

Step 3.2 Overall Outcome

The cumulative risk mitigation score provided an indication of an option's ability to mitigate more than one risk, directly or indirectly. However, this score does not indicate how costly or viable it is to implement such an option or the level of community and stakeholder support.

The cost-benefit analysis provided an indication of the financial, technical or other constraints or opportunities associated with each option, including the effectiveness of the action in meeting its aims.

The combination of cumulative risk mitigation score and cost benefit analysis score was then weighted according to the ability of the option to mitigate priority risks. The resulting outcome was a score that allowed for ranking of options and determination of which options to implement through the CMP.

The overall outcome for each option against these thresholds is provided in Table 7 of Appendix 3. Based upon the total multi criteria (cumulative risk mitigation and cost benefit) assessment, 27 options were

recommended for implementation. These are shown in Table 5 below. The options that were not recommended based on this assessment are not included in the following table, however, more information on these are available in Appendix 1 (Management Options) and details of scoring is provided in Appendix 3 (Cost-Benefit Analysis).

Table 5: Ranked management options recommended for implementation as part of the CMP

Option No.	Management Option	Description	Risk(s) directly addressed	Final Score (CTMS[1] + CBA[2])*RW[3]
5	Trial modifications to artificial aeration	Conduct a trial to test the effects of modifying the aeration program on lake water quality and specifically the incidence of blue green algae blooms. During the trial it will be necessary to carefully monitor water quality including dissolved oxygen levels at the sediment-water interface.	Blue Green Algae blooms, Nutrient enrichment	84
15	Trial sediment treatment	Dosing of water column and/or sediment coating to bind phosphorus and make in unavailable for plant/algae uptake. Involves stages of trials and in-lake treatment.	Blue Green Algae blooms, Nutrient enrichment	64
1	Beach nourishment with a geofabric container beach sill	Sand nourishment with installation of geofabric containers along the beach face (i.e. parallel to the shoreline) to act as sills to maintain minimum beach levels and reduce the rate of sediment loss from the beach.	Foreshore erosion of the lake	41
21	Backfill exposed tree roots	Backfill exposed roots of Paperbark trees along foreshore with suitable sediment.	Riparian vegetation disturbance, Risks to native flora and fauna, Foreshore accessibility and public safety	39
38	Establish an integrated management group	Establish an integrated management group responsible for overseeing the implementation, monitoring and review of the Lake Ainsworth CMP.	Barriers to effective management	37
30	Review of public safety risk assessment	Review of the risk assessment undertaken as part of this study once the Lake Ainsworth Foreshore Improvement Works program has been finalised.	Foreshore accessibility and public safety,	34

Option No.	Management Option	Description	Risk(s) directly addressed	Final Score (CTMS[1] + CBA[2])*RW[3]
34	Management of future parking arrangements	Address continued community concern regarding lack of sufficient parking spaces during peak times.	Car parking adequacy for current and future demand, Foreshore accessibility and public safety	32
32	Restrict overnight parking along foreshore	Explore options to restrict parking between hours of 1am and 5am along the lake foreshores including: signage; ranger policing; and lake CCTV surveillance.	Car parking adequacy for current and future demand, Foreshore accessibility and public safety	32
2	Riparian vegetation enhancement for erosion control	Enhancement/expansion of riparian vegetation as primary bank erosion control.	Foreshore erosion of the lake, Foreshore accessibility and public safety, Riparian vegetation disturbance	30
18	Litter management/ recycling	Ensure adequate provision/emptying of general waste bins, particularly during peak visitation. Provision of recycling bins.	Risks to aesthetic quality, Risks to native flora and fauna	29
31	Greater acknowledgement of Aboriginal Heritage	Work with traditional owners to identify culturally appropriate ways to better acknowledge the indigenous history of the lake. May include signage and be linked to education campaign.	Impacts on Aboriginal cultural practices and heritage, Insufficient public education	28
39	Monitoring Program	On-going tracking and assessment of CMP implementation as well as investigation of identified key ecosystem components to provide better information and inform effective management.	Barriers to effective management, linked to all risks	28
22	Grass species selection for open space areas to minimise bare areas	Use of suitably durable grass type for high use areas (couch proven inadequate) with effective weed guard to separate grassed areas from native vegetation.	Foreshore erosion of the lake, Risks to aesthetic quality, Risks to native flora and fauna, Riparian vegetation disturbance	27
4	Flood Planning	Future development and actions to consider potential future flood risk.	Localised freshwater flooding	27
20	Riparian vegetation management	Enhancement/ maintenance/ restoration of natural fringing vegetation around lake through protection of sensitive areas and weed management	Riparian vegetation disturbance, Risks to native flora and fauna	27

Option No.	Management Option	Description	Risk(s) directly addressed	Final Score (CTMS[1] + CBA[2])*RW[3]
25	Wildlife/ turtle crossing warning signs on Camp Drewe Road	Crossing signs to alert drivers of potential wildlife crossing at known locations.	Risks to native flora and fauna	26
24	Traffic management Camp Drewe Road	Consider wildlife, public safety.	Cars and public safety, Risks to native flora and fauna	24
33	Encourage alternative transport to the lake	Provide facilities/services to encourage alternative transport to cars (e.g. bike racks, mobility scooter parking; provide a shuttle bus service through town to the lake).	Car parking and public safety, Foreshore accessibility and public safety	23
29	Manage increasing use of the western side of the lake	Develop and implement an overall concept for the western side of the lake in order to appropriately protect environmental and cultural values while managing increasing visitor pressures.	Foreshore erosion of the Lake, Car parking adequacy for current and future demand, Foreshore accessibility and public safety, Cars and public safety, Risks to aesthetic quality, Riparian vegetation disturbance, Risks to amenity and enjoyment (e.g. overcrowding, insufficient/degraded facilities), Impacts on Aboriginal cultural practices and heritage	23
17	Stormwater treatment/ improvement	Constructed wetlands/ bio retention/ GPTs/ filters/ swales etc. to slow stormwater flows and treat water before reaching the lake.	Nutrient enrichment, Stormwater impact on Lake Ainsworth, Spills and contamination	21
19	Develop and implement local Cane Toad management strategy	Assessment of cane toad management options	Exotic aquatic fauna	20
27	Biological Control	Salvinia weevil (*Cyrtobagous salviniae*) is released at the lake as needed and is an ongoing management tool.	Aquatic weeds or unnatural growth, Risks to native flora and fauna,	20
28	Replace boom used in aquatic weed management	The boom in place at the lake is current damaged and needs to be replaced.	Aquatic weeds or unnatural growth, Risks to native flora and fauna,	20

Option No.	Management Option	Description	Risk(s) directly addressed	Final Score (CTMS[1] + CBA[2])*RW[3]
36	Education campaign	Multi-faceted campaign to educate and promote understanding of the natural attributes of the lake, sensitivities and key issues and encouraging low-impact use/practices to protect the lake. May involve: installation of attractive and engaging signage at key locations; leaflets/flyers; webpage; posters; information days/activities; school programs; educational videos etc. Include information on health risks of exposure to cyanobacteria blooms.	Insufficient public education, Stormwater impact on Lake Ainsworth Nutrient enrichment Blue Green Algae blooms Spills and contamination Exotic aquatic fauna	20
12	Aquatic weed harvesting	Continue removal of aquatic weeds from the lake.	Nutrient enrichment, Aquatic weeds or unnatural growth	18
37	Review blue green algae alert/ lake closure signage	Review the current signage including text, images, symbols as well as placement and sizing to ensure effective communication of public health risks.	Insufficient public education, Blue Green Algae blooms	18
35	Dog Access	Review current dog access arrangements, ensure effective communication of restrictions and to mitigate impacts from dogs on recreational amenity and water quality.	Threats to aesthetic quality, Threats to native flora and fauna, Faecal coliforms and Enterococci (microbiological risk to human health) Blue Green Algae blooms, Nutrient enrichment Car parking adequacy for current and future demand Foreshore accessibility and public safety	17

[1.] CTMS – Cumulative Risk Mitigation Score;[2.] CBA – Cost Benefit Analysis Score;[3.] RW – Risk Weighting

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Appendix 1. MANAGEMENT OPTIONS

Potential management options identified during Stage 1 and Stage 2 of the CMP are discussed below. The aim is to provide background information and clear discussion of key benefits and risks that will and assist Council, the community and stakeholders to evaluate potential options and select the most effective solutions to identified issues affecting Lake Ainsworth.

2. BANK EROSION

Option 1: Beach nourishment with geofabric container beach sill

Risk (s) to be addressed:	**Foreshore erosion of the lake**
Risk Rating:	**High**

Option Description

Nourishment of the lake's recreational beaches with clean sand and installation of buried geofabric containers along beach faces (i.e. parallel to the shoreline) to act as sills to maintain minimum beach levels and reduce the rate of sand loss. This option combines engineering principles of battering, renourishment, and reshaping. It is intended that typically a single sill is installed underwater (at say 2-3m depth) to stabilise the submerged lower slopes of the beach. This would reduce the loss of sand to deeper water and improve the retention of sand used for nourishment of the upper beach. Although installed below the typical depths utilised by people for recreation, safety signage may be required at beach access points to make beach users aware of the presence of the sills and any associated terracing. The standard containers are available as either rectangular bags or a sausage-like form (Figure 1).

Why implement this option? What are the benefits?

This option will ameliorate erosion, and re-instate safe access to the water. It will provide improved recreational beach widths under most water level conditions and greatly improve visual amenity. Use of geofabric containers is one of the safest and 'user friendly' options in an area of high recreational use as the sills would be largely buried and the same sand used for nourishment could be used to fill the containers.

Minimal turbidity issues are anticipated during construction as there is minimal disturbance of lake sediments. Nourishment could also include infilling around exposed tree roots to improve tree health and protect riparian vegetation (refer Option 23: Backfill exposed tree roots).

What are the potential implementation issues and key risks?

The cost to import nourishment material (suitable clean sands) is high. Utilisation of scraped sand from the lake would be much more cost effective and should be considered where this is appropriate and can be achieved without negative impact on environmental and aesthetic values. The size and placement depth of geofabric containers requires further design to achieve the most effective configuration. Trials are currently underway at the lake which will help inform further design. Sill(s) are to be located away from the key recreational use elevations, but may present a potential trip hazard and a hazard to swimmers (sudden small drop off resulting in unexpected submergence) when water levels are very low.

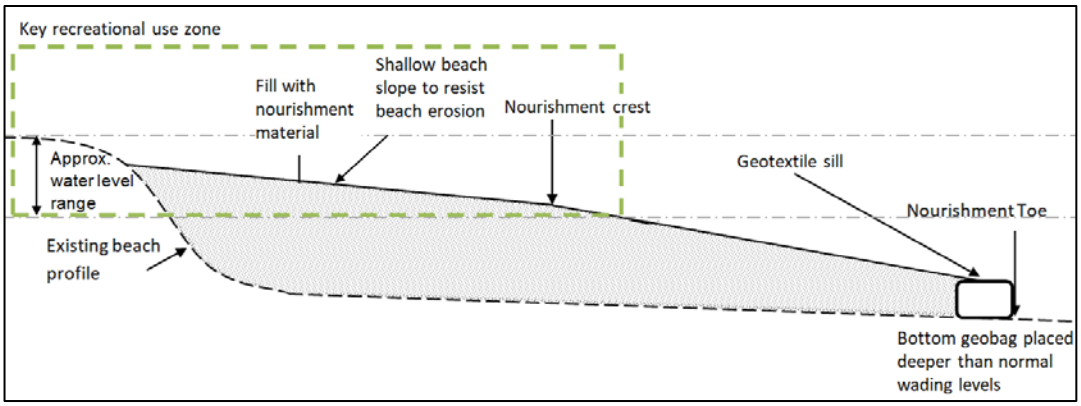

Figure 1: Example of nourishment profile using geotextile sills on lake beaches

Option 2: Riparian vegetation enhancement for erosion control

Risk (s) to be addressed:	**Foreshore erosion of the lake** **Foreshore accessibility and public safety** **Riparian vegetation disturbance**	
Risk Rating:	**High**	**Medium**

Option Description

Enhancement and/or expansion of riparian vegetation for bank erosion control. Past riparian revegetation work in the 1990's has been successful in protecting banks against erosion however; adjacent bare areas have been left to erode into a series of small inlets along the eastern shoreline (Plate 2). This option would select areas for further riparian revegetation and/or enhancement along shorelines for greater erosion protection in combination with other erosion mitigation methods (e.g. Option 1: Beach nourishment with geofabric container beach sill). While it would appear logical to revegetate at least some of the small eroding inlets along the eastern shoreline, areas for revegetation will need to balance access requirements with bank protection and ecological values. Provision for managing access to these areas will need to be considered as part of the design of works.

Foreshore Improvement Works along the southern and eastern foreshores of the lake include vegetation management, coupled with bank erosion amelioration works and provision of formal access pathways and ramps. Once works are complete, it will be necessary to assess areas to determine whether further revegetation, including potential closure of some small inlets is desirable (refer Option 40: Monitoring Program).

Why implement this option? What are the benefits?

Native vegetation provides natural bank protection while enhancing ecological values and scenic and recreational amenity (e.g. habitat, shading etc.). Increased shading of the water may enhance habitat for native species and discourage aquatic weed growth. Vegetated banks can also provide separation of lake beaches and provides a sense of a more secluded space for recreation.

What are the potential implementation issues and key risks?

By setting aside additional areas for revegetation, there is potential for concentration of pedestrian impacts in adjacent non-vegetated areas. Careful planning of revegetation areas is required with consideration of the managed access points (Plate 2) and specifically use of access ramps to cater for this increased impact. Another risk is that increasing riparian vegetation could reduce the visual connection between parkland areas and the water.

Plate 2: Past revegetation efforts have succeeded in protecting banks from erosion along eastern shoreline of the lake, while adjacent bare areas have continued to erode forming inlets

Option 3: Managed retreat

Risk (s) to be addressed:	**Foreshore erosion of the lake**
Risk Rating:	**High**

Option Description

Managed retreat permits bank erosion to continue unabated, while managing any safety or environmental concerns. This limited intervention option is really only viable where there is room for this to occur without negative impacts on recreational use, access, infrastructure and ecological values etc. For these reasons it is only appropriate on the western and northern shorelines of the lake where largely intact riparian vegetation and fringing reed beds provide natural protection against erosion. Erosion has been classified as predominantly stable or minor at these locations owing to these natural protections.

Why implement this option? What are the benefits?

Managed retreat is a low cost or no cost option and allows 'natural' processes to proceed. This option does not introduce infrastructure that would require maintenance or could further detract from the visual amenity and natural ambience of the western/northern shorelines.

What are the potential implementation issues and key risks?

Should substantial changes occur in these areas such as increasing visitor use or loss of riparian vegetation and /or fringing reed beds, managed retreat may no longer be a suitable option. It will be necessary to monitor erosion in these areas and implement adaptive management as needed.

Plate 3: Intact riparian vegetation and fringing reeds along western shoreline

3. FLOODING

Note there are several flooding related management options including Option 12: Draining and/or treatment of nutrient-rich benthic waters, and Option 13: Enhanced flushing that are discussed in Section 3.

Option 4: Flood planning

Risk (s) to be addressed:	**Localised freshwater flooding**
Risk Rating:	**Medium**

Option Description

Stage 2 of the CMP has identified freshwater flooding as an issue that will continue to periodically affect Lake Ainsworth and potentially increase in severity with climate change. Future development in the catchment and all options implemented as part of the CMP will need to consider the potential future flood risk. This is considered a key part of overall management of the lake now and into the future. To assist in planning, the Lake Ainsworth catchment should be included in the review of the *Ballina Floodplain Risk Management Plan* (BMT WBM, 2015). In addition, emergency management plans for Camp Drewe and the Lake Ainsworth Sport and Recreation Centre should be updated with future flooding risk and contingencies for the potential closure of Camp Drewe Road due to flooding.

Why implement this option? What are the benefits?

Considering the future flood risk will ensure any development or management option is suitable for the location and/or is adaptive to changing risk.

What are the potential implementation issues and key risks?

No risks have been identified in taking this precautionary approach.

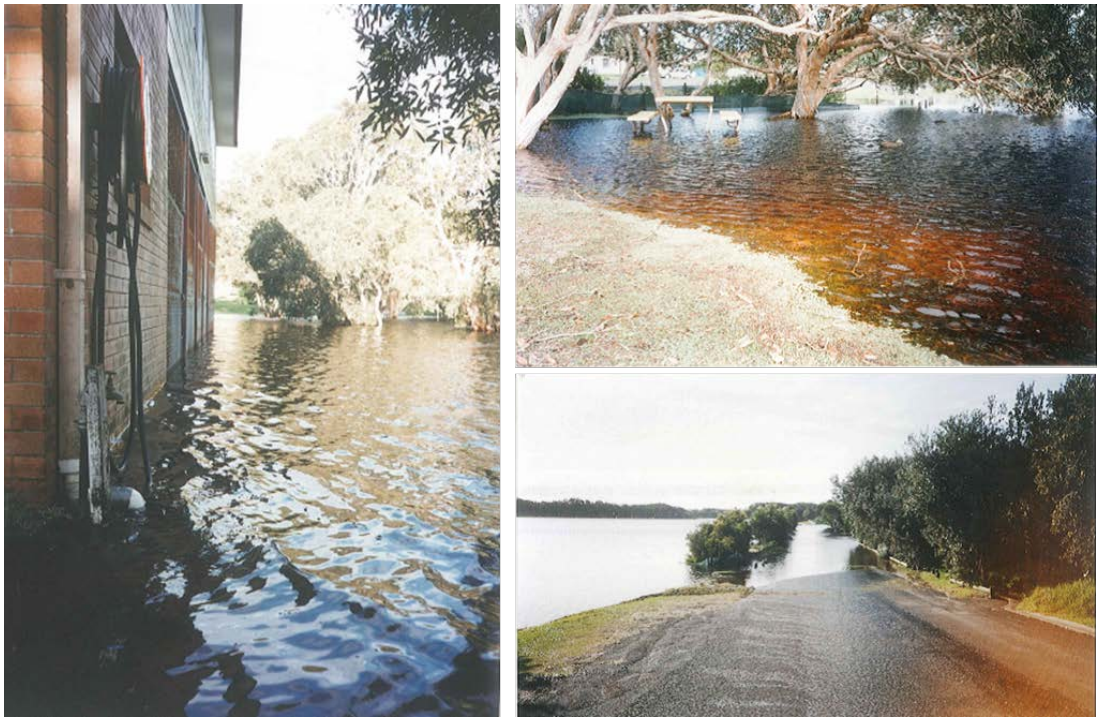

Plate 4: Flooding around the lake in June/July 1999 – Left: Sport and Recreation Boat Shed; Top Right: picnic area in south east corner; Bottom Right: Eastern Road (Source: BSC, 1999)

4. WATER QUALITY

Option 5: Trial modifications to artificial aeration

Risk (s) to be addressed:	**Blue Green Algae blooms** **Nutrient enrichment**
Risk Rating:	**High**

Option Description

Conduct a trial to test the effects of modifying the aeration program on lake water quality and specifically the incidence of blue green algae blooms. The following modifications are proposed:

1. Trial spring/ summer aeration program with continuous operation (24 hour aeration, opposed to the current program where aerators operate 12 hours overnight). It is also recommended that a gradual start-up procedure be tested in spring to observe the effect on water quality conditions in the initial aerator operation period (i.e. aim to allow acclimation and avoid a major turnover event). Monitoring will be required to assess the effectiveness of modifications. Assessing dissolved oxygen levels at the sediment/water interface at a number of locations around the lake will be critical to determining the effectiveness of the modified regime and identifying the 'zone of influence' for the aerators. Overall water quality and specifically nutrient/algae conditions will also be assessed.
2. Based on the results of the initial trial above, further management is to be recommended. This may include:

- Continuation of the modified regime if water quality improvements were observed;
- Consider the need for additional diffusers spaced around the lake (if the 'zone of influence' of current aerators is considered inadequate); or
- If above modifications do not improve conditions, consider turning off the aerators for a trial period.

A monitoring program (developed as part of Option 40: Monitoring Program) will be designed to assess water quality conditions throughout the trial period incorporating measurements of blue green algae, surface water quality and water quality at depth (profiles).

Why implement this option? What are the benefits?

Review of the current aerator program completed as part of Stage 2 studies indicated that the aerators may be having a negative impact on overall water quality. The short-term trial conducted in 2018/2019 found that despite artificial aeration in the lake (12 hours/day), a low dissolved oxygen zone was still detected at the sediment/water interface creating conditions suitable for phosphorus release from sediments to the overlying water. Additionally, artificial aeration was found to be very effective at mixing the entire water column, however this is also believed to be a mechanism for transport of nutrients released from sediment to surface layers where algal growth occurs in the presence of sunlight. It is believed that this continued cycling of nutrients contributes to algal blooms and ongoing eutrophication of the lake. Trial modifications to the current aerator program will allow for assessment of water quality under different regimes and ultimately inform the best aerator regime for the lake, or support the decision to cease aeration altogether.

What are the potential implementation issues and key risks?

There will be increased operational costs to run the aerators 24 hours a day. Monitoring costs will also be incurred to properly evaluate the lake's response to modified aerator operation. Turning off the aerators as part of a secondary trial presents a risk of oxygen depletion at depth. A naturally occurring mixing event (due

to severe wind/rainfall event) may cause a large dissolved oxygen crash if a large volume of anoxic water is brought to the surface. The level of impacts are unknown, however they could be significant with regard to aquatic ecology (e.g. potential for fish kill in a worst case scenario). Monitoring of water conditions will be essential to detect any worsening conditions and potential for a large turnover event. Any such event could be mitigated by modifying the operation of the aerators if needed.

Option 6: Continue aerator program

Risk (s) to be addressed:	**Blue Green Algae blooms**
Risk Rating:	**High**

Option Description

This option is to continue the current program which involves aerators being operational between spring and autumn at Lake Ainsworth for 12 hours in a 24 hour cycle. The aim of artificial aeration is to completely mix the entire water column using compressed air released into bottom waters.

Why implement this option? What are the benefits?

Stage 2 studies indicated that the aerators may be having a negative impact on overall water quality and therefore continuing the current program is considered to have minimal (if any) benefit.

What are the potential implementation issues and key risks?

The key risk is that continuing the artificial aeration program in its current regime may be facilitating nutrient cycling from sediments to surface waters thus fuelling continued eutrophication and algal growth. In the absence of successful management to prevent nutrient release from sediments (refer Section 4, Sediment management options) continued aeration may facilitate continued long-term decline of water quality in the lake. If sediment management options are implemented and successful, there would be no reason to continue artificial aeration of the lake.

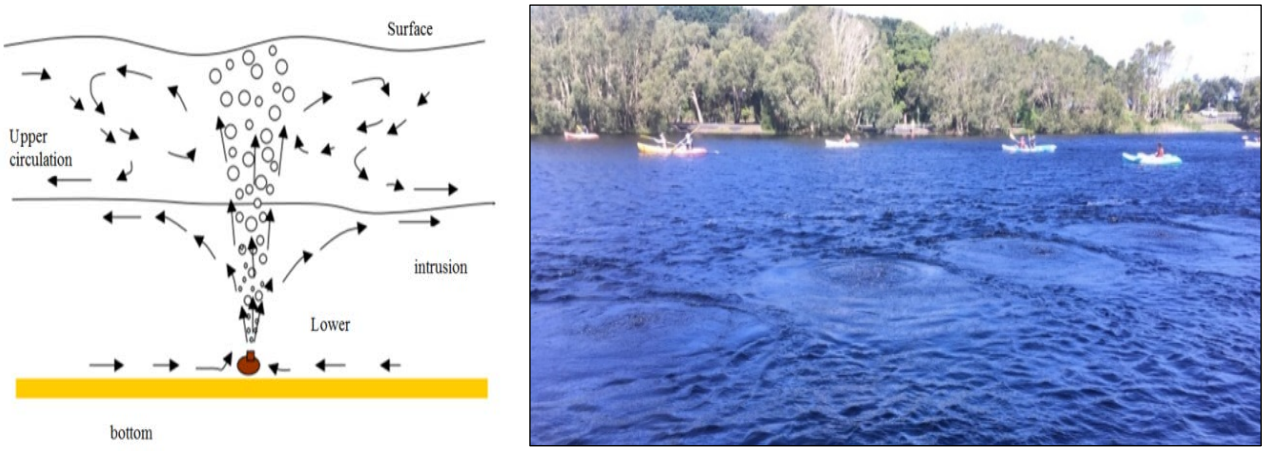

Figure 2: Left: Typical bubble plume function (Source: Brookes et al., 2008); Right: Aerators in lake

Option 7: Vertical mechanical mixers/surface mixers

Risk (s) to be addressed:	**Blue Green Algae blooms**
Risk Rating:	**High**

Option Description

A large impeller mounted on a raft draws water from the surface and transports it through a tube to desired depth. The aim is to transport cyanobacteria into deeper water thereby inducing light limitation.

Why implement this option? What are the benefits?

This option directly addresses algal blooms and therefore should have immediate effect. It doesn't rely on reducing nutrients or managing sediments and would only be used when there is a bloom is developing, therefore reducing operational costs. Typically they are used in made-made waterbodies such as water supply dams, where they have been found to be effective at controlling algal blooms (Brookes *et al.,* 2008).

What are the potential implementation issues and key risks?

This option only treats the symptoms (algal blooms) and does not address the underlying causes (high nutrients, sediments etc.). When the algae dies and sinks to the bottom, it will decompose adding to the sediment sludge layer and releasing nutrients which are likely may be recycled again to water column. Therefore it is not considered to be an effective long-term solution. Start-up costs are likely to be high and there will be significant on-going operational and maintenance requirements and costs. Additionally, there are safety concerns with deployment of a raft-mounted device in a lake used for recreation as well as aesthetic impacts.

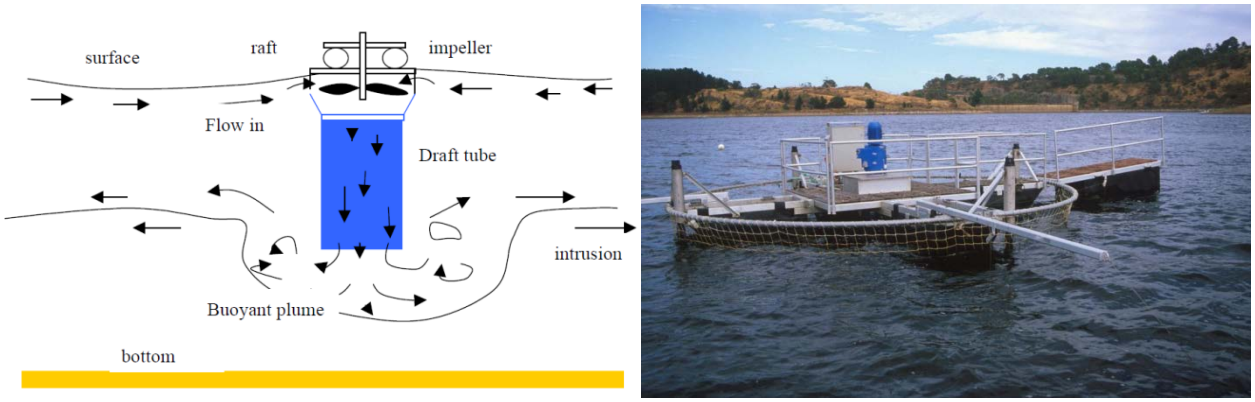

Figure 3: Left: Surface mechanical mixer function (Source: Brookes *et al.,* 2008); mixer deployed at Myponga Reservoir, SA (Sherman *et. al*., 2010)

Option 8: Pure oxygen injection

Risk (s) to be addressed:	**Blue Green Algae blooms** **Nutrient enrichment**
Risk Rating:	**High**

Option Description

Hypolimnetic oxygenation involves the injection of pure oxygen to bottom waters to prevent nutrient release from sediments. Pure oxygen released as very small bubbles so that stratification is preserved and the surface layer would remain intact thus avoiding transport of nutrients to surface for algal growth.

Why implement this option? What are the benefits?

This option has a potential advantage over bubble plume aerators in that oxygen injection increases oxygen at the water sediment interface but due to stratification being maintained, nutrients from bottom waters are not transported to surface.

What are the potential implementation issues and key risks?

Hypolimnetic oxygenation without mixing requires a higher level of specialised capital equipment than whole-lake aeration. This option has high start-up and ongoing costs involving construction of oxygen pipelines and reticulation grid as well as tank holding areas. It requires on-site liquid oxygen tanks which are likely to be expensive, require a large storage area and are potentially hazardous (Plate 5).

Plate 5: Two 20,000 gallon liquid oxygen tanks installed at Russell Dam, South Carolina as part of large-scale oxygen injection project

Option 9: Fountains

Risk (s) to be addressed:	**Blue Green Algae blooms**
Risk Rating:	**High**

Option Description

Fountains enhance surface mixing with the aim of preventing buoyant blue green algae blooms. A series of large fountains would be required across the lake to provide enough surface mixing to prevent blooms.

Why implement this option? What are the benefits?

May prevent buoyant surface blooms near mixing area. Could be operated only when needed (i.e. bloom development) thus reducing operational costs.

What are the potential implementation issues and key risks?

Several fountains or very large fountains and ongoing operational and maintenance costs would be required for adequately mixing the surface water layer to prevent surface blooms. Fountains are not an effective oxygenation strategy as surface waters are generally close to 100% oxygen saturation. They consume a lot of energy relative to their effects on mixing surface waters and may have high operational costs due to energy demand. In addition, the noise and visual aesthetics created by fountains is unlikely to be acceptable in a natural setting like Lake Ainsworth.

Plate 6: Example of in-lake fountain at Torrens Lake, Adelaide South Australia (source: http://sahistoryhub.com.au/things/torrens-lake-fountain)

Option 10: Draining and/or treatment of nutrient-rich benthic waters

Risk (s) to be addressed:	**Blue Green Algae blooms** **Nutrient enrichment** **Localised freshwater flooding**	
Risk Rating:	**High**	**Medium**

Option Description

Removal and/or treatment of nutrient-rich hypolimnetic (bottom) waters during thermal stratified conditions. Removal would occur by way of pumps drawing water from intake(s) near the lake bottom. Disposal options for the water would involve discharge outside of the lake basin (e.g. to the ocean, Council sewerage system), or treatment followed by disposal. Treatment options include passive treatment in constructed wetlands and settling ponds, or employment of other wastewater technologies. Treated water could then be returned to the lake or potentially discharged outside of the lake basin (e.g. to the ocean).

Why implement this option? What are the benefits?

This option allows for the direct removal of nutrient laden waters from the bottom of the lake. Additionally, dependent on timing of withdrawals, reduced water levels may mitigate climate change/flooding impacts.

What are the potential implementation issues and key risks?

The key issue is management of the extracted water. Ocean disposal is unlikely to be suitable particularly into the adjacent Cape Byron Marine Park. Treatment options such as wetlands and settling ponds are constrained by a lack of space for potential treatment areas nearby. There is also likely to be significant capital and ongoing costs in establishing and maintaining treatment (refer Option 15: Constructed wetlands). Discharge to the Council sewerage system for treatment at the Lennox Head Wastewater Treatment Plant is a potential option, but is unlikely to be cost-effective, or catered for in the current design of the sewage system.

Due to the high sediment nutrient load, release of nutrients from sediment is likely to continue and therefore to be effective in the long term, this option would need to continue indefinitely until the sediment nutrient store is depleted.

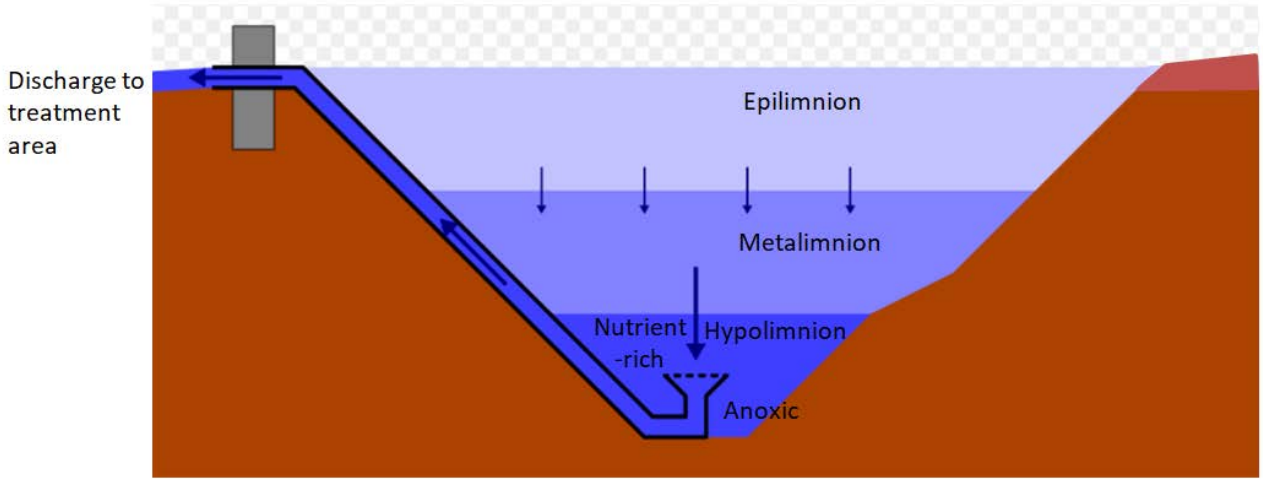

Figure 4: Pumping of Hypolimnetic lake water for treatment

Option 11: Enhanced flushing

Risk (s) to be addressed:	**Nutrient enrichment** **Localised freshwater flooding**	
Risk Rating:	**High**	**Medium**

Option Description

Similar to Option 12: Draining and/or treatment of nutrient-rich benthic waters, this option would utilise a spillway or drain pipe(s)/ dune infiltration network to allow for drainage of surface water when the lake reaches high water levels. Due to high nutrient concentrations and the potential for floating scums, aquatic weeds and algal blooms, it may be necessary to treat the water before it can be released to the environment.

Why implement this option? What are the benefits?

This option will seek to reduce flooding at the lake and increase nutrient export through enhanced outflows.

What are the potential implementation issues and key risks?

Such a system may allow seawater ingress back to lake which would alter the freshwater ecology and could have significant negative effects on water quality and flora and fauna. If relying on passive draining of water to the east through dunes, it will not be effective during high tides and high seas when the hydraulic gradient is not positive in this direction. This aspect will only increase with sea level rise.

Ocean disposal without treatment is unlikely to be suitable particularly into adjacent Cape Byron Marine Park considering high nutrient concentrations and the potential for floating scums, aquatic weeds and algal blooms.

Plate 7: Coastal dune system separating the lake from Seven Mile Beach and Cape Byron Marine Park

Option 12: Aquatic weed harvesting

Risk (s) to be addressed:	**Nutrient enrichment** **Aquatic weeds or unnatural growth**	
Risk Rating:	**High**	**Medium**

Option Description

This concept involves harvesting aquatic weeds from the lake to control outbreaks and remove nutrient load. For any nutrient removal to be achieved it will be necessary to remove harvested plants from the catchment. If plant material is left to decompose on banks or even within the lakes hydrological catchment, the released nutrients may return to the lake through runoff or groundwater flow.

Aquatic weeds (primarily water hyacinth) are currently manually removed from the lake by Lennox Head Landcare volunteers and staff and students from the Lake Ainsworth Sport and Recreation Centre when outbreaks occur. BSC assist in removal and disposal of the harvested plants and it is recommended that this continue to support this action. This is generally implemented to prevent negative impacts on native flora and fauna, recreational use and visual amenity.

Why implement this option? What are the benefits?

Aquatic weed harvesting is an important part of ongoing weed management to improve recreational opportunities and aesthetics at the lake. Nutrient removal is viewed as a complimentary aspect to this management option; however, to date there has not been any detailed estimations of the impact of removal on the nutrient load within the lake.

Recent studies from other locations offer some insight into the likely nutrient removal capacity of water hyacinth harvest. The two main studies both quantified nutrient removal associated with large scale harvest of water hyacinth: Lake Dianchi, China (Wang *et al*., 2012) and a shallow urban lake in Minnesota, USA (Bartodziej *et al*., 2017). The studies had differing results with a removal rate of 1.4 kg TP/tonne of fresh biomass reported by Wang *et al*. (2012) and 3.1 kg TP/tonne reported by Bartodziej *et al*. (2017). AWACs (1996) estimated that the net total phosphorus load to Lake Ainsworth (comprised mainly of sediment releases) was 91.4 kg/year. Based on these numbers, and taking an average removal rate from the two studies, it would be necessary to remove in excess of 470,000 kg per annum (470 tonnes, wet weight) of water hyacinth to remove the net annual phosphorus load from the lake. Based on current regeneration rates of water hyacinth, it is unlikely that there would be enough biomass to meet these targets. Therefore weed harvesting is unlikely to have any appreciable impact on nutrient levels in the lake in any reasonable timeframe.

What are the potential implementation issues and key risks?

Manual weed harvesting is labour intensive, requiring a high level of effort to harvest and dispose of plants. Currently, this option relies on the willingness and ability of volunteers to complete the work, which cannot be guaranteed into the future.

Water hyacinth can harbour contaminants such as heavy metals (Gonzalez *et al.,*1990) which may make safe disposal problematic. Disposal of weeds to registered waste facility required. If left to decompose on lake shore, rotting vegetation can create aesthetic issues (odour, visual) and nutrients and contaminants potentially re-introduced to lake.

Option 13: Constructed wetlands

Risk (s) to be addressed:	**Blue Green Algae blooms** **Nutrient enrichment**
Risk Rating:	**High**

Option Description

Constructed wetlands are natural treatment systems consisting of a series of shallow, densely-planted, man-made ponds that help filter water through physical and biological processes. They provide a natural way to treat and remove pollutants from water and are typically used to treat stormwater, or for tertiary (final) treatment of wastewater prior to discharge to the environment. This option involves constructing a separate wetland treatment system(s) allowing for treatment of lake water. Lake water would be pumped to the constructed wetland for treatment, and drained passively back to the lake.

Why implement this option? What are the benefits?

Reduce nutrients in water through 'natural' plant uptake while providing habitat features and amenity, depending on design.

What are the potential implementation issues and key risks?

The key issue is the generally low nutrient removal rates offered by constructed wetlands (particularly for phosphorus) considering the magnitude of nutrient load in the lake. Previous study has reported removal rates of between 100-200g N/m^2/yr and 10-20g P/m^2/yr for various types of constructed wetlands (Vymazal, 2007). Based on these figures and the net phosphorus load in the lake modelled by AWACs (1996), a minimum of 1 ha treatment wetland would be required to remove the net phosphorus load from the lake each year. As discussed for other options, there is limited space available for a treatment area this size. There is also the continued replenishment of nutrients to the water column from sediments (as discussed above) and therefore treatment through a wetland would need to continue until the sediment nutrient supply was exhausted. Constructed wetlands have a limited effective life particularly with regard to phosphorus removal that relies largely on sediment burial, and many renewals of such a system would be required to treat the phosphorus load in the lake. Both capital and on-going operational costs are high for constructed wetlands. Construction and operational costs for a 1ha wetland over 10 years was estimated to be in excess of $500,000 not including costs associated with land acquisition and environmental approvals.

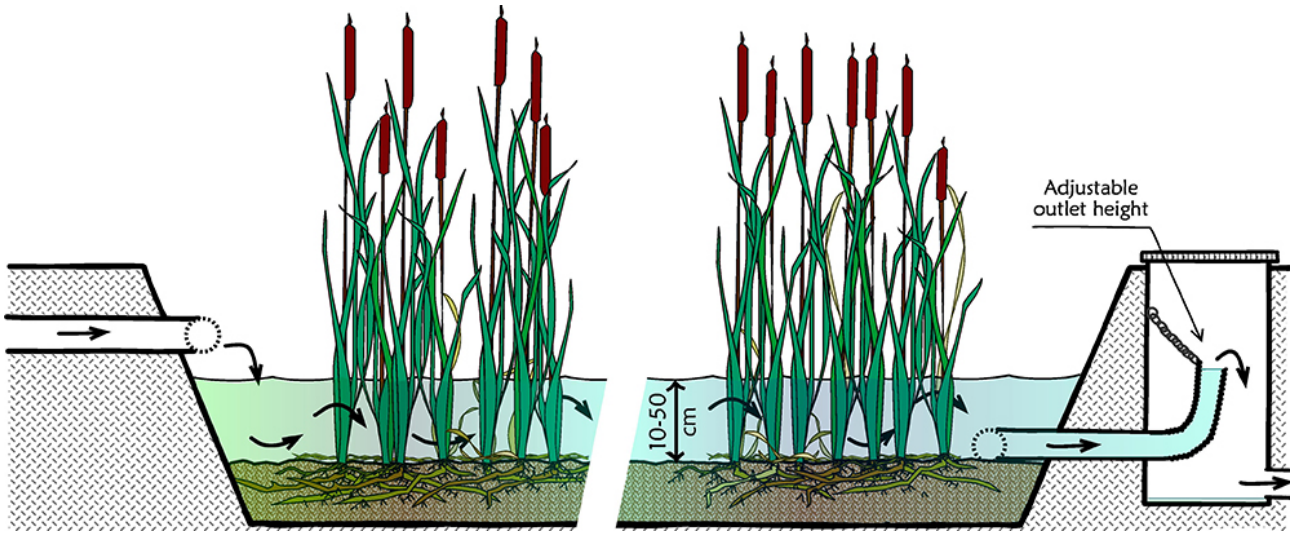

Figure 5: Surface flow constructed wetland system (Source: Water and Carbon Group, 2019)

5. SEDIMENT MANAGEMENT

The internal cycling of nutrients and particularly phosphorus from lake sediments was confirmed during Stage 2 of the CMP as the primary factor exacerbating blooms of blue green algae. Methods to reduce phosphorus release from sediments include: physical approaches - such as artificial destratification, aeration, enhanced lake flushing (discussed in Section 3), dredging; geochemical approaches—such as the application of alum and iron as flocculation agents, and other products that are applied as a surface barrier over sediments to prevent phosphorus release. The use of flocculation agents such as alum and iron has been investigated previously and are considered unsuitable due to the potential for negative ecological and public health impacts. Sediment removal (dredging) and sediment barrier options are explored further below.

Option 14: Sediment removal (dredging)

Risk (s) to be addressed:	**Blue Green Algae blooms** **Nutrient enrichment** **Localised freshwater flooding/ altered lake hydrology and water balance**
Risk Rating:	**High**

Option Description

This option involves dredging (removal) of nutrient rich sediment layers from deep sections of lake. Based on recent survey of sediments and previous assessment of depths by AWACs (1996), the total volume of the organic rich mud layer is estimated to be approximately 240,000m^3. Due to the nature of sediments (high nutrient and carbon content, acidic, elevated levels of lead and mercury) it is highly likely that treatment would be required followed by disposal at a licensed facility. Treatment options could involve the use of geotextile bags to dewater and treat the dredged sediment slurry prior to transport of dried sediment to a disposal facility. Typically, dewatering and treatment would need to occur in a nearby bunded area with appropriate management and disposal of leachate so as not to cause adverse environmental impacts. Based on recent local examples involving treatment of dredged sediments, it is estimated that a treatment area of over 14 ha would be required to treat all the sediment at one time, which is slightly larger than the size of the lake itself. A smaller-scale and longer-duration option would be required to reduce the treatment space requirements.

Why implement this option? What are the benefits?

Sediment removal would directly address the primary source of nutrients to the water column and therefore reduce the susceptibility of the lake to algal blooms. By reducing the impermeable sludge layer, groundwater outflow from the lake may be enhanced which could assist in mitigating the effects of climate change and specifically sea level rise which is predicted to increase the risk of localised flooding.

What are the potential implementation issues and key risks?

There are significant limitations associated with this option including:

- Very high costs for dredging, treatment and disposal of such a large volume of contaminated sediment. Initial estimates indicate dredging costs would be in the region of $29M (based on a rate of $120/m^3 for dredging, treatment and disposal, incurred by other local dredging projects).
- Limited space available for treatment area. There is very little open space in the immediate vicinity of the lake that would be suitable for treatment.

- Leachate from geobags is likely to be nutrient rich, acidic and potentially contaminated with lead or mercury. If not managed and treated effectively, leachate could return to lake through seepage and have negative environmental consequences.
- Dredging and disposal of sediments will require EPA licencing and have associated costs for such a large volume.
- The number of truck movements required to remove dredged sediment through the main roads in Lennox Head would need to be considered.
- There is a risk of resuspension of sediments during dredging which may resulting in release of nutrients, and contaminants to the water as well as high turbidity and subsequent effects on biota and human health.
- There is also potential for dredging to interfere with groundwater processes, which could have negative implications for the lake such as very low water levels.

Plate 8: Top: Iluka boat harbour dredging; Bottom: Geobag deployment (Source: https://www.geofabrics.co/news/solid-waste-removal)

Option 15: Trial sediment treatment

Risk (s) to be addressed:	**Blue Green Algae blooms** **Nutrient enrichment**
Risk Rating:	**High**

Option Description

This option involves trial application of a phosphorus binding agent (e.g. Phoslock™) to determine the effectiveness of this approach in reducing bioavailable phosphorus in the water column and also reduce the on-going release of phosphorus from sediments. The trials will be important to better understand the potential risk of any unintended effects specific to Lake Ainsworth. Trials are likely to involve a combination of laboratory tests and simulated lake environments using sediment and water from the lake (i.e. out-of-lake 'test-tube' studies). A second stage of trials could involve a small-scale in-lake study where areas of the lake are isolated to test how the treatment effects water quality. 'Mesocosms' have been used for this purpose in Lake Tuggeranong in the ACT, which are essentially like giant bottomless plastic bags that isolate the water column from the lake surface to the lake bottom (ACT Healthy Waterways, 2019) (see Plate 9). The trials would determine aspects such as application rates, timing and evaluation of potential impacts. If stage 1 and 2 trials were positive, the next step would be lake application.

Typical lake application would involve binding agent granules or slurry being directly added to the water via a barge or boat. The compound is designed to settle out through the water column binding phosphate and eventually collect as a thin (< 2mm) layer over sediments creating a barrier layer and preventing further phosphorus release. An alternative to lake application could be the use of an out-of-lake treatment cell, where lake water is pumped for treatment and returned to the lake with reduced phosphorus load.

An example of a treatment compound commonly used for this purpose is Phoslock™, an absorbent clay-based substance that was developed by the CSIRO in the early 2000's to combat waterway eutrophication. It is a modified natural product made up of the naturally occurring rare earth mineral lanthanum (typically 5%) and a modified bentonite clay material (typically 95%). The mechanism of phosphorus removal by Phoslock™ involves the reaction of phosphate anions with lanthanum leading to formation of a single insoluble species of lanthanum phosphate, or rabdophane (Douglas *et al.* 2004)(Plate 9). Phoslock™ is used widely around the world to combat eutrophication however, treatment can have mixed success depending on site characteristics and it is crucial to understand if this will be an effective and safe treatment for Lake Ainsworth specifically.

Why implement this option? What are the benefits?

Phosphorus binding agents can be highly effective at reducing dissolved phosphorus and locking up sediment phosphorus under appropriate conditions and doses, thus improving water quality and reducing the duration and severity of blue green algae blooms. Arkhurst *et al.,* (2004) conducted laboratory trials using sediment cores from Lake Ainsworth to test the effectiveness of a lanthanum modified bentonite clay (a compound prepared for the study similar to Phoslock™). They found that the compound was very effective at reducing the concentration of phosphorus in cores (reduced by 90%) and was also very effective at reducing the release of phosphorus from bottom sediments. This is consistent with several large-scale fields trials from other locations showing a substantial reduction in phosphorus released from bottom sediments when applied as a thin barrier layer (Douglas & Adeney, 2001; Robb *et al.,* 2003).

The key advantage of treating sediments in-situ is that it avoids removal which is expected to be highly problematic at Lake Ainsworth (refer Option 16: Sediment removal (dredging)).

Phoslock™ has been the subject of extensive testing and has applied to over 200 environments worldwide. In most environments it is considered to have low eco-toxicological and human health risks (Copetti *et al.,*

2016), and is approved for use in drinking water for humans. Specific potential risks identified with reference to Lake Ainsworth are discussed below.

What are the potential implementation issues and key risks?

The potential risks of using a phosphorus binding agent include: the effects on colour and water clarity following application; smothering of benthos; release of La^{+} ions to water which may affect aquatic organisms; and potential increase in dissolved iron concentrations in water (Kickey and Gibbs, 2009; Arkhurst *et al.,* 2004; Reitzel, *et. al.,* 2017).

The Arkhurst *et al.,* (2004) study found a marked increase in dissolved iron concentrations in water as a result of the application of the lanthanum modified bentonite clay, to levels that were in excess of ANZECC guidelines. The authors acknowledged that the release of iron into the water column may have been enhanced by the excessive concentration of $LaCl_2$ being used in the preparation of modified clay, and that while the modified clay used was based on the Phoslock™ technology, it might not be representative of current Phoslock™ applications.

During application, the water has a milky appearance as the binding agent is distributed. However, it generally settles out of suspension and is visually undetectable within a few hours and up to a maximum of a couple of weeks following application. Granular application (rather than as a slurry) of binding agents has the advantage of rapidly settling after application which reduces water clarity issues and allows for more accurate distribution of the product (Kickey and Gibbs, 2009).

There is also some indication from the previous study that high dissolved organic carbon (DOC) can slowdown phosphate removal by Phoslock™, however researchers concluded that the negative impact was overcome within a few days (Dithmer, *et al*., 2016). Lake Ainsworth has high DOC (~19mg/L) and this effect may be expected in the short-term. Another recent study found that lanthanum was shown to be released from Phoslock™ in soft water lakes with high humic acid concentration (Reitzel, *et al.,* 2017). Lake Ainsworth is a humic lake and the water is generally soft (median $CaCO_2$ 22.5 mg/L reported by AWACs, 1996). Therefore, if this option is to proceed it will be essential to ensure thorough testing of alkalinity/water hardness prior to real-lake application in order to fully assess the risk.

Another factor to consider is the longevity of treatment effectiveness and the cost of repeat application. Factors such as bioturbation by bottom dwelling aquatic biota need to be considered in assessment of potential longevity. Given that Stage 2 study of lake water quality (Hydrosphere Consulting, 2018) has indicated that catchment input of nutrients is relatively low and stormwater management and education is also recommended to further reduce external loads, sediment treatment is expected to have a reasonably long-life, however further investigation is required to fully understand ongoing management requirements and associated costs.

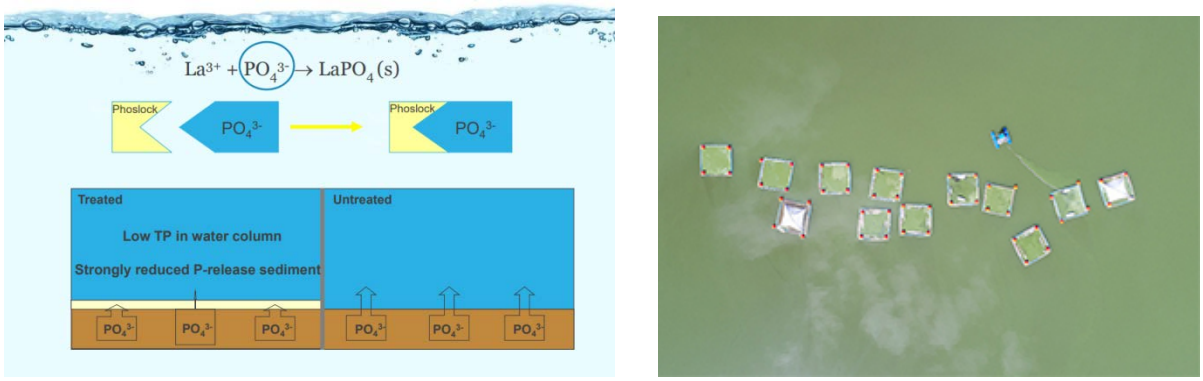

Plate 9: Left: Simplified diagram of how Phoslock™ works (Source: PET, 2019); Right: Aerial view of treatment mesocosms deployed at Lake Tuggeranong, ACT (Source: ACT Healthy Waterways, 2019)

Based on preliminary discussions with industry representatives, it is estimated that a total cost of approximately $200,000 would be expected to be incurred for this option. This consists of approx. $10,000 for stage 1 out-of-lake 'test-tube' studies; approx. $30,000 for isolated in-lake mesocosm trials; and approx. $160,000 for full in-lake application. Monitoring of water quality post-application will be required to determine on-going effectiveness and whether follow up treatment is necessary. The longevity of treatment is not known at this stage and would be informed by initial trials.

Given the demonstrated ability of phosphate binding agents to remove phosphorus, it would appear warranted to further investigate its potential application at Lake Ainsworth. To manage the identified risks it will be essential to conduct further laboratory testing with current Phoslock^{TM} products to confirm effectiveness and safety prior to real-lake application.

Option 16: Sediment capping using clean sands

Risk (s) to be addressed:	**Blue Green Algae blooms** **Nutrient enrichment**
Risk Rating:	**High**

Option Description

An alternative to an active geochemical barrier is the use of a passive physical barrier (e.g. sand, gravel or clay) to cap sediments. This option would involve establishing a layer of clean sand (>0.1m) over the nutrient rich muds located in the deepest parts of the lake creating a physical barrier to prevent sediments releasing nutrients back to water column. Clean sand of medium to fine grained texture that matched the naturally occurring substrate would be required. Initial calculations based on a minimum 0.1m capping layer over the organic-rich mud layer with clean sands would equate to approximately 6,000m^3 of sand required at a cost of approximately $600,000 (for sand purchase alone, not including placement in the lake). It would require approximately 300 truckloads ('truck and dog' size) to deliver the required sand (potentially 6 weeks of 10 trucks per day 5 days a week). The potential techniques that could be used to place the capping sand include: discharge from a barge, hopper dredges, and pipelines; and surface spreading techniques (Bailey *et al.*, 2005).

Why implement this option? What are the benefits?

The appeal of this option is that it is a 'natural' solution that does not involve introduction of compounds that may not naturally occur in the lake.

What are the potential implementation issues and key risks?

There are many unknowns with this option including how effective it will be at preventing phosphorus release from sediment and the longevity of treatment when considering disturbance effects due to bioturbation etc. Depending on the quality of material, some increase in turbidity would be expected as sand is distributed through the water column.

This is also a very high cost option, depending on volume of sand required and local availability and method of placement. Additionally, the number of truck movements required through the main roads in Lennox Head would need to be considered.

It also carries a high level of technical difficulty in distributing the sand to provide a consistent coverage at the required thickness to be effective. Trials would be required to determine the volumes required to guarantee coverage, sedimentation rates, bioturbation and groundwater influence to examine longevity of treatment.

6. CATCHMENT MANAGEMENT

Option 17: Stormwater treatment/ improvement

Risk (s) to be addressed:	**Nutrient enrichment** **Stormwater impact on Lake Ainsworth** **Spills and contamination**		
Risk Rating:	**High**	**Medium**	**Low**

Option Description

This option involves implementing water sensitive strategies within the catchment with the aim of slowing stormwater flows, directing flows away from erodible banks and treating runoff water prior to discharge to the lake. The majority of high priority stormwater management issues along the eastern and southern foreshores have been addressed through the Lake Ainsworth Foreshore Improvement Works, either complete along the southern section or underway along the eastern foreshore. These works include the installation of water sensitive features such as parking bays with turfcell reinforced turf, grassed swale drains, bio-retention basins and swales for stormwater treatment and infiltration. For the remaining catchment areas including the Lennox Head Sport and Recreation Centre and Reflections Holiday Park, and Camp Drewe Road stormwater treatment and improvement is to be considered during the design and upgrade of any roads and parking facilities.

Why implement this option? What are the benefits?

Stormwater control and treatment reduces ongoing inputs of nutrients and pollutants to the lake. It also reduces the erosive potential of stormwater thus offering greater protections against bank erosion. Modern stormwater treatment devices are often incorporated into landscaping elements and can enhance the aesthetic value of an area as well as providing habitat where native species are utilised.

What are the potential implementation issues and key risks?

The main limitation of implementing stormwater controls is the high capital cost involved to retrofit existing infrastructure. Where works are planned to install new or upgrade existing roads and parking areas, the costs to incorporate water sensitive design elements are reduced and shared across the total capital works. There are also ongoing maintenance costs associated with stormwater control devices that need to be accounted for to ensure optimal treatment efficiency. Lifecycle costs are available for the various stormwater treatment devices to estimate ongoing costs.

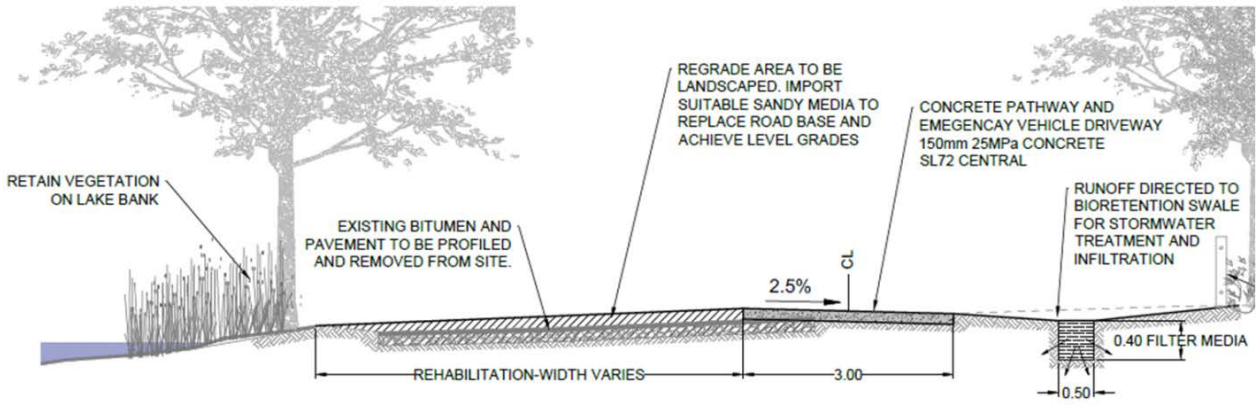

Figure 6: Planned stormwater control and treatment along eastern foreshore as part of foreshore improvement works (Source: BSC, 2018)

Option 18: Litter management/recycling

Risk (s) to be addressed:	**Threats to aesthetic quality** **Threats to native flora and fauna**
Risk Rating:	**Medium**

Option Description

Community feedback during the survey indicated a level of concern about litter and waste being left behind by visitors including takeaway food containers/cups, bottles, cigarette butts, bags of dog faeces and nappies. Of particular concern was periodic overflowing of bins during peak times and a lack of recycling bins at the lake. To address these concerns it is recommended that adequate bins are provided at key locations as part of the foreshore improvement works, including general waste and recycling bins. During peak times such as long weekends and school holiday periods, consider increased frequency of rubbish collection and placement of a small temporary skip bin (with cover) on site to reduce the likelihood of overflow and litter polluting the lake environment. Option 37: Education campaign will include key messages about litter and potential for impacts on the lake and reminders about what items are suitable for recycling bins.

Why implement this option? What are the benefits?

Improving waste management on site will assist in reducing litter impacting on amenity, water quality and wildlife. Increased recycling opportunities will have positive off-site impacts in reducing waste going to landfill.

What are the potential implementation issues and key risks?

Limited risks have been identified. The costs of extra bin provision, rubbish collection and education are considered minor. The placement of bins will be important to maximise their use and reduce the effects on amenity (e.g. scenic appeal, odours etc.) There is always a risk of contamination of recycling bins and clear signage with illustrations will be required to reduce this risk.

Plate 10: Overflowing bins during peak visitation (Source: Lennox Head Wildlife Watchers, 2018)

7. FLORA AND FAUNA

Option 19: Develop local cane toad management strategy

Risk (s) to be addressed:	**Exotic aquatic fauna**
Risk Rating:	**Medium**

Option Description

This option involves development of an integrated local Cane Toad Management Strategy for the lake. The Stage 2 Vulnerabilities and Opportunities Study identified a number of options for cane toad control at Lake Ainsworth and while it will be very difficult to eradicate cane toads completely, there are potential population control methods available including: trapping adults and tadpoles; manual removal; and enhancing native predators through broader ecosystem health improvements (e.g. water quality improvements and enhancing native riparian vegetation).

The implementation of any control options would have to be carefully considered, particularly in context of the current distribution of cane toads within Ballina Shire. It is unlikely one method alone would be effective but the implementation of a suite of methods may be effective at controlling cane toad numbers. For example, survival and recruitment could simultaneously be reduced by manual removal and trapping of both adults and tadpoles and discouraging breeding by increasing riparian vegetation, while applying suppressor pheromones and encouraging potential native predators of toads in and around the lake.

Why implement this option? What are the benefits?

Reducing Cane Toad numbers will reduce their undesirable impacts including: poisoning, injuring and killing native fauna such as higher order predators such as snakes, large lizards and quolls; poisoning, injuring and killing pets; preying on native fauna; and potentially carry diseases that can be transmitted to native frogs and fishes.

What are the potential implementation issues and key risks?

Many of the potential options (i.e. trapping and manual removal) are labour intensive and would require dedicated staff time and/or a high level of community participation. Trapping presents a potential for impacts on non-target species and regular monitoring of traps is necessary to mitigate this risk.

Plate 11: Cane Toad (*R. marina*) (Source: Australian Museum, 2019)

Option 20: Riparian vegetation management

Risk (s) to be addressed:	**Riparian vegetation disturbance** **Threats to native flora and fauna**
Risk Rating:	**Medium**

Option Description

This option involved enhancement, restoration and maintenance of natural fringing vegetation around lake. This includes revegetation for erosion control discussed in Option 2: Riparian vegetation enhancement for erosion control, as well as general maintenance, weed control and enhancement of foreshore vegetation for all foreshores. Further planting of native reed beds along lake foreshores is also considered appropriate in some areas to assist in ongoing erosion control, managing access, enhancing habitat value and minor nutrient uptake.

Why implement this option? What are the benefits?

Riparian vegetation offers a number of ecosystem functions and values that include bank stability and maintenance of soil structural integrity, land use buffering, water quality filtering, lowering of water temperature (via shading), providing fisheries habitat (root masses and fallen logs/ trees), food source (from litter fall), providing terrestrial habitat, community/ recreational and intrinsic values, and scenic amenity. Vegetated banks with and without exclusion fencing can also provide a natural deterrent to foreshore access in environmentally sensitive areas where the aim is to minimise disturbance (e.g. western side).

What are the potential implementation issues and key risks?

It will be important to strike the right balance between ecological and aesthetic benefit and providing safe access to the lake. It will be necessary to consider the concentration of pedestrian access and effects on neighbouring areas and potential impacts on overall space available for public recreation. Weed control methods need to be consistent with ecological values and community expectations.

Plate 12: Riparian vegetation along western foreshore

Option 21: Backfill exposed tree roots

Risk (s) to be addressed:	**Riparian vegetation disturbance** **Threats to native flora and fauna** **Foreshore accessibility and public safety**
Risk Rating:	**Medium**

Option Description

Backfill exposed roots of mature Broad-leaved Paperbark trees along the south-east foreshore with suitable sand. Ideally the sand should match the natural substrate and have minimal nutrient/fertiliser content. Providing vegetation cover over the placed sediment either as turf or native groundcovers will assist in preventing movement of the placed material either through pedestrian access or wind action. Temporary fencing may be required to prevent pedestrian access in the short term to allow vegetation to establish. This option can be integrated with the nourishment of the lake's beaches (refer Option 1: Beach nourishment with geofabric container beach sill).

Why implement this option? What are the benefits?

The main aim is to improve tree health and prevent dieback of these significant trees, thus maintaining and improving visual and recreational amenity, habitat values and cultural significance. The Broad Leaved Paperbark trees have been identified as culturally significant 'Song Trees' by local aboriginal representatives.

It will also remove trip hazards created by the exposed roots which was raised by the community as a key concern for public access safety (Plate 13).

What are the potential implementation issues and key risks?

The erosive processes that lead to sediment loss around root zones are likely to continue. Over time, ongoing foot traffic, water level changes and wind action may erode the placed sand. It will therefore be essential to monitor these areas and implement maintenance as required to protect trees.

As discussed in Option 1: Beach nourishment with geofabric container beach sill, the cost to import suitable clean sands is high and sand scraping should be investigated as an alternative source where appropriate and can be achieved without adverse environmental or aesthetic impacts.

Plate 13: Exposed roots of mature Broad-leaved Paperbark trees along the south-east foreshore

Option 22: Grass species selection for open space areas to minimise bare areas

Risk (s) to be addressed:	**Foreshore erosion of the Lake** **Threats to aesthetic quality** **Terrestrial weeds** **Riparian vegetation disturbance** **Threats to native flora and fauna**		
Risk Rating:	**High**	**Medium**	**Low**

Option Description

There are several bare ground areas along foreshores particularly in high use zones in the south-eastern corner, where shading is also affecting grass cover. This option involves the selection of suitably durable grass type for high use areas along the lake foreshore. Feedback from the community indicates that the standard couch turf species has proven inadequate and other options should be explored. Initial research conducted by Lennox Landcare suggests species such as Empire Zoysia or Kenda Kikuyu might be more suitable. Zoysia grass is able to withstand heat, droughts and high levels of foot traffic, with a number of new varieties that are shade tolerant and have high salt resistance. Kenda Kikuyu is hard-wearing and quick growing, but is not very shade tolerant. The suitability and availability of these and potentially other grass cover species should be investigated further.

Why implement this option? What are the benefits?

Maintain grass cover in recreation areas not only enhances aesthetics and recreational values but also protects against erosion. Weed guards reduce invasion of grass into native vegetation areas which can be very problematic to exclude due to their high growth rates.

What are the potential implementation issues and key risks?

Whatever grass is selected, it is unlikely to achieve complete cover at all times and in all locations considering the high use areas and incidence of drought that will occur at some time. Grass selection is likely to include some trade-offs between strengths and weaknesses. For example, Zoysia grass has many of the benefits outline above but is slow growing, so if bare patches were to develop during high use and/or drought periods, it may take some time to re-establish. In contrast, Kikuyu is quick to repair, but because it is fast growing it can become a problem if it spreads into natural areas. It is also not very tolerant of shade, preferring full sun or light shade. The ability for grasses to spread via wind-dispersed seed and impacts on nearby natural vegetation areas should also be considered.

It will be important to provide adequate weed guards/ edging to separate turfed areas from natural riparian vegetation and revegetation areas. Edging should extend down into the soil to prevent the spread of underground grass runners invading natural areas.

Plate 14: Areas of bare grass in high traffic recreation areas

Option 23: Underground replacement or relocation of power lines

Risk (s) to be addressed:	**Ocean shoreline recession, breakthrough and saline intrusion (short-term and long-term)** **Riparian vegetation disturbance** **Threats to native flora and fauna**	
Risk Rating:	**High**	**Medium**

Option Description

Liaise with power authorities to request removal of the overhead powerlines between the Sport and Recreation Centre and Lennox Surf Club and either relocate to a position where they can be maintained more readily without damaging dune vegetation (i.e. along the access pathway) or placed underground. The overhead powerlines currently cross through approx. 150 m of native dune vegetation south the Sport and Recreation Centre and approx. 270m of vegetation bordering the eastern side of the lake (Plate 15). The native vegetation will continue to grow and at some stage will require trimming to prevent potential power outages or bushfires caused by vegetation coming into contact with powerlines. There is currently no access through this area to conduct regular maintenance of the lines.

Why implement this option? What are the benefits?

Relocation of the powerlines will reduce vegetation damage from ongoing maintenance and reduce bushfire risk at this location. Native dune vegetation has a very important role in stabilising coastal dunes and protecting the coastline from coastal hazards including ocean shoreline recession, breakthrough and saline intrusion.

What are the potential implementation issues and key risks?

Previous requests to Essential Energy have been unsuccessful due to prohibitive costs associated with this option (over $440,000 quoted in 2015).

Plate 15: Existing powerlines through dune vegetation along eastern side of lake

Option 24: Traffic management Camp Drewe Road

Risk (s) to be addressed:	**Cars and public safety** **Threats to native flora and fauna**
Risk Rating:	**Medium**

Option Description

The community has raised concerns over cars travelling at high speeds along Camp Drewe Road, particularly since surface was sealed in 2018. This option involves review of appropriate treatments consistent with best practise to improve the road safety for Camp Drewe Road. It also involves review of policing and enforcement of speed limits.

Why implement this option? What are the benefits?

Slowing traffic to appropriate speeds will reduce wildlife road-kill incidents and address public safety concerns.

What are the potential implementation issues and key risks?

There is a risk that traffic management will be ineffective. There are also moderate capital and on-going costs associated with provision and maintenance of road treatments, policing and enforcement.

Option 25: Wildlife/ turtle crossing warning signs on Camp Drewe Road

Risk (s) to be addressed:	**Threats to native flora and fauna**
Risk Rating:	**Medium**

Option Description

Review and improve wildlife crossing signs along Camp Drewe Road to alert drivers of potential wildlife crossing at known locations. This will involve assessment of potential nesting areas and known crossing locations to be able to locate signage effectively. Consultation with the community, and particularly wildlife groups in Lennox will assist in implementation. This option is linked to Option 26: Traffic management Camp Drewe Road, particularly with regard to any road treatments which should be cognisant of wildlife crossing areas. Education regarding this issue and management efforts should be included in Option 37: Education campaign.

Why implement this option? What are the benefits?

This option raises awareness and reminds the community and visitors of the presence of native fauna and the need for care to be taken to avoid road kill.

What are the potential implementation issues and key risks?

The main risk is that drivers will ignore signage regardless of placement and design. To be effective it will be necessary to implement the suite of actions described including traffic control and enforcement measures, education and promotion in the media.

Option 26: Aquatic weed harvester

Risk (s) to be addressed:	**Aquatic weeds or unnatural growth** **Threats to native flora and fauna**
Risk Rating:	**Medium**

Option Description

Use of a barge-mounted aquatic weed harvesters, compactors and removal services to more efficiently remove aquatic weeds from the lake. This option may only be required where weeds are unable to be managed through manual harvest.

Why implement this option? What are the benefits?

Mechanical harvesting allows for efficient removal of large areas of aquatic weeds. Weeds can be offloaded directly to a compactor truck without contact with ground. The volume of bulk waste is reduced as water is squeezed out by compactor loading process.

What are the potential implementation issues and key risks?

Mechanical harvesting of large infestations has been effective at other locations, although costly. As a guide, it takes between 600 and 900 hours to harvest one hectare of dense water hyacinth (NSW Weedwise, 2019).

There are also risks to aquatic fauna, specifically eels and turtles depending on the method used. These species were encountered in large numbers during previous use of cutting conveyor belt harvester model at the lake. Removal of fauna also reduced efficiency and increased cost of hire.

Plate 16: Aquatic weed harvester (Source: http://www.aquaticweedharvester.com.au/gallery.html)

Option 27: Biological control

Risk (s) to be addressed:	**Aquatic weeds or unnatural growth** **Threats to native flora and fauna**
Risk Rating:	**Medium**

Option Description

The Salvinia Weevil (*Cyrtobagous salviniae*) is originally from south-eastern Brazil and was introduced into Australia by the CSIRO in 1980 to combat the growing threat of Salvinia.

Salvinia weevil is currently released at the lake as needed and is an ongoing management tool. This management is on-going and is managed by NSW DPI. It has been deemed to be largely successful but cannot control Salvinia in isolation during high growth periods. Physical removal is also required for effective management.

Why implement this option? What are the benefits?

Continuation of this management option provides ongoing control of the problem.

What are the potential implementation issues and key risks?

No negative side-effects have been identified to date.

Plate 17: Left Salvinia at Lake Ainsworth; Right: Salvinia weevil (Source: NSW Weedwise, 2019)

Option 28: Replace boom used in aquatic weed management

Risk (s) to be addressed:	**Aquatic weeds or unnatural growth** **Threats to native flora and fauna**
Risk Rating:	**Medium**

Option Description

When required, a boom is used in the northern section of the lake to contain Salvinia to prevent this weed from choking the waterway until manual removal can be undertaken (EnviTE, 2007). Currently, the boom is broken and requires replacement. This option seeks to replace the boom to allow ongoing control of aquatic weeds.

Why implement this option? What are the benefits?

Allows for effective weed control when high densities occur.

What are the potential implementation issues and key risks?

Low risk to boats and recreational users as it is located in the far northern end of the lake away from public recreation areas.

8. COMMUNITY USES

Option 29: Manage increasing use of the western side of the lake

Risk (s) to be addressed:	**Foreshore erosion of the Lake** **Car parking adequacy for current and future demand** **Foreshore accessibility and public safety** **Cars and public safety** **Threats to aesthetic quality** **Riparian vegetation disturbance** **Threats to amenity and enjoyment (e.g. overcrowding, insufficient/degraded facilities)** **Impacts on Aboriginal cultural practices and heritage**			
Risk Rating:	**High**	**Medium**	**Low**	**Unknown**

Option Description

Increased use of the western side of the lake is a key community concern, including parking along Camp Drewe Road and ad hoc access to the western foreshore via various informal pathways existing in the bushland. This option develops an overall concept for the western side of the lake in order to appropriately protect environmental and cultural values while managing increasing visitor pressures. The following elements are to be considered in development of the overall concept:

- The majority of the western side should be preserved as an ecological and cultural heritage protection zone. This zone will provide for enhancement of ecological and cultural heritage values with minimal disturbance. Opportunities for nature appreciation and education would be promoted here.
- Provision for creating more formalised access in the south-western corner. This area would provide a combination of ecological protection and additional passive recreational opportunities. It acknowledges the likelihood of increased use of the western side of the lake and seeks to manage and confine access to this corner while protecting the remaining western side as an ecological protection zone.
- During community consultation as part of Stage 2 of the CMP it was clear that the community desired the western side of the lake to remain as natural as possible maintaining visual amenity from the popular recreational areas on the southern and eastern vantage points. Therefore, it is proposed that formal access is restricted to the south-west corner of the western side and is to be in keeping with low-impact, natural-looking access (i.e. no concrete and bitumen).
- Informal parking along Camp Drewe Road will also need to be restricted to manage visitor numbers and access to the western shoreline (refer Option 36: Management of future parking arrangements)..
- Rationalise access to the western side of the lake by selecting a preferred access path and formalising this route, while closing off and revegetating the remaining tracks. This may involve removal of existing fencing and provision of formal tracks with fencing as required to direct pedestrians away from sensitive areas (e.g. lake edges).
- There is also opportunity for pedestrian/shared path facilities along Camp Drewe Road with the purpose of providing separation between pedestrians and traffic and potentially increased amenity for dog walkers, bike riders etc.

Why implement this option? What are the benefits?

This approach seeks to preserve the relatively 'untouched' ecosystem along the western shoreline and protect Aboriginal places and sites, while providing formalised access to a limited section in order to reduce impacts resulting from concentrated use.

What are the potential implementation issues and key risks?

It may prove difficult to completely protect the western side. Any structures put in place to restrict access may be subject to vandalism. This is confounded by the fact that this area is largely out of sight and therefore difficult to regulate. It will also be important to consult with Aboriginal stakeholders regarding any potential impacts on Aboriginal heritage.

Plate 18: Existing pathway in south-west corner of lake with broken fencing

Option 30: Review of public safety risk assessment

Risk (s) to be addressed:	**Foreshore accessibility and public safety**
Risk Rating:	**Medium**

Option Description

The Lake Ainsworth Foreshore Improvement Works program will address the majority of risks identified during the Stage 2 public safety risk assessment. It will be necessary to review and update the risk assessment once the Lake Ainsworth Foreshore Improvement Works program has been finalised. Based on the results of the updated assessment, actions can be directed towards any remaining risk areas.

Why implement this option? What are the benefits?

This option allows for assessment and identification of any residual public safety risks.

What are the potential implementation issues and key risks?

None identified.

Option 31: Greater acknowledgement of Aboriginal Heritage

Risk (s) to be addressed:	**Impacts on Aboriginal cultural practices and heritage** **Insufficient public education**	
Risk Rating:	**Medium**	**Unknown**

Option Description

This option would seek to work with traditional owners to identify culturally appropriate ways to better acknowledge the indigenous history of the lake. Consultation with the range of stakeholders identified during Stage 2 will be important to reflect the diversity of groups and agree on the best way forward. Options could include dedicated signage, educational materials and field days to allow for appropriate acknowledgement. This option is linked to Option 37: Education campaign for promotion and dissemination of information. Protecting the western side of the lake is also considered important in terms of cultural significance of this area (Option 31: Manage increasing use of the western side of the lake).

Why implement this option? What are the benefits?

Throughout the community engagement conducted as part of the CMP, the broader community has expressed a strong desire to know more about the indigenous history and significance of the lake. Sharing knowledge will improve understanding of the cultural significance of the area and enhance values for the community and visitors. A greater community understanding of cultural heritage values is also likely to increase the effectiveness of measures to protect cultural heritage at the lake.

What are the potential implementation issues and key risks?

There may be a risk in getting agreement on appropriate actions between different stakeholders. A detailed consultation program should be undertaken to reduce this risk.

Option 32: Restrict overnight parking along lake foreshore

Risk (s) to be addressed:	**Car parking adequacy for current and future demand** **Foreshore accessibility and public safety**	
Risk Rating:	**High**	**Medium**

Option Description

The availability of parking close to the lake will continue to be a key issue during peak visitation periods. Overnight and long-term parking along the lake foreshores was identified by the community as a key factor in exacerbating the issue. To address this it is recommended that parking be restricted between 1am and 5am along the lake foreshores. To be effective, this option must include education and enforcement provision including: signage; ranger policing; and lake CCTV surveillance. Traffic regulatory signage for timed parking will be subject to the approval of the traffic committee.

Why implement this option? What are the benefits?

This option will discourage long-term parking and free-up public parking spots for lake users. It will discourage Holiday Park customers from parking in public spaces along foreshore and also discourage illegal camping.

What are the potential implementation issues and key risks?

Enforcement may be difficult, outside of normal working hours for rangers; however CCTV offers a means to remotely monitor parking. Signage and CCTV may be subject to vandalism. This option may prove expensive with ongoing out of hours surveillance and/or CCTV monitoring.

Plate 19: Southern road parking area during upgrade works in 2018 (BSC, 2019)

Option 33: Encourage alternative transport to the lake

Risk (s) to be addressed:	**Car parking adequacy for current and future demand** **Foreshore accessibility and public safety**	
Risk Rating:	**High**	**Medium**

Option Description

Provide facilities/services to encourage alternative transport to the lake. This may include provision of bike racks and mobility scooter parking. Another option suggested by the community is to provide a regular shuttle bus service through town to the lake, which may also assist in relieving traffic congestion through Lennox Head in general. Promotion through the Option 37: Education campaign will be essential to raise awareness of these additional services and facilities and promote use.

Why implement this option? What are the benefits?

These options will seek to reduce congestion, parking pressure and vehicle use in general meaning lower carbon emissions, pollution and increased safety. It also encourages exercise and community connectivity with associated increased health benefits.

What are the potential implementation issues and key risks?

Generally these options will only be effective for residents of Lennox Head, or those visitors staying in Lennox Head. Visitors travelling from elsewhere will generally still drive to lake. Cost-effectiveness also needs to be considered particularly during periods of low visitation.

Plate 20: Encourage alternative transport to the lake (Source: BSC, 2017a)

Option 34: Management of future parking arrangements

Risk (s) to be addressed:	**Car parking adequacy for current and future demand** **Foreshore accessibility and public safety**	
Risk Rating:	**High**	**Medium**

Option Description

Car parking was a key contention during the exhibition of the Foreshore Improvement Works Review of Environmental Factors (REF). The community is concerned about a lack of parking at the lake during peak times resulting in more cars parking along Camp Drewe Road and subsequently greater use of the western side of the lake as well as increased parking by lake users extending into town. There were also concerns raised about the distance required to walk from new parking areas to the lake particularly for disabled people and those carrying children and equipment.

Council has provided additional formalised parking spaces adjacent to the Holiday Park and along Ross Street and improved parking along the Southern Road to offset the parking spaces lost through the eastern road closure. The REF notes that while parking is considered adequate for current usage throughout the year, it should be anticipated that during peak times excess parking will at times spill onto Camp Drewe Road and the adjacent residential areas (BSC, 2017b). With increasing population and tourism pressures into the future, this effect is only likely to increase.

This option will monitor car parking patterns following the eastern road closure with a focus on assessing parking along Camp Drewe Road and into suburban areas of Lennox Head and subsequent impacts on environmental values, amenity and public safety. It will also track the effectiveness of Option 34: Restrict overnight parking along lake foreshore. It is recommended that monitoring is conducted over a year to capture seasonal changes in demand. It will be implemented as part of Option 40: Monitoring Program. Based on the results of monitoring, recommendations regarding additional management can be made. Results will also inform parking arrangements to be determined along Camp Drewe Road as part of Option 31: Manage increasing use of the western side of the lake.

Why implement this option? What are the benefits?

The information will evaluate the extent of the problem and assist in directing further management effort.

What are the potential implementation issues and key risks?

Community perception that nothing is being done to address concerns in the short-term.

Option 35: Dog Access

Risk (s) to be addressed:	**Threats to aesthetic quality** **Threats to native flora and fauna** **Faecal coliforms and Enterococci (microbiological risk to human health)** **Blue Green Algae blooms, Nutrient enrichment** **Car parking adequacy for current and future demand** **Foreshore accessibility and public safety**	
Risk Rating:	**High**	**Medium**

Option Description

During community and stakeholder consultation the issue of dog access to the lake was raised on a number of occasions. Dog walking is a popular activity in the area and is currently permitted 'on leash' along the eastern pathway to gain access to the off leash dog exercise area on Seven Mile Beach (Figure 7). Access to the beach is also permitted 'on leash' north of the Lennox Head SLSC and a waste bag dispenser and waste bin is provided at this location. No dogs are permitted in the lake or on foreshores and immediate reserve. Dog access is also provided north of the lake at the 4wd access track to Seven Mile Beach with waste bag dispenser and waste bin provided at this location.

Some community members have indicated that the current zones can be confusing due to the close proximity of permitted 'on leash' areas along the eastern foreshore to 'no dogs' areas in the lake and foreshores. Concerns have been raised that dogs are being allowed 'off-leash' along lake foreshores and to swim in the Lake despite signage. There were also many reports of dog faeces being left behind which may contribute to water quality decline and microbiological risk to human health.

Management of dogs in public places is regulated by the *BSC Companion Animal Management Plan* (BSC, 2017) prepared in accordance with the *NSW Companion Animals Act 1998.*

This option involves review of current dog access arrangements at the lake as documented in the *BSC Companion Animal Management Plan* (BSC, 2017) and consideration of the following:

- Continue to provide dog access north of the Lennox Head SLSC to Seven Mile Beach;
- Consider removal of the on leash area along the eastern side of the lake and dog access to the north, making all lake foreshore areas and immediate surrounds 'dog free';
- Encourage dog walkers who drive to Seven Mile Beach to access the off-leash area of beach via the horse track at the end of Camp Drewe Road (north of 4wd track) where parking is plentiful
- Continue to provide dog poo bag dispensers and waste bins at suitable access points to the off-leash area at Seven Mile Beach and other locations.

Why implement this option? What are the benefits?

Making all lake foreshore areas and immediate surrounds 'dog free' would remove any current confusion due to close proximity of the different zones and allow for clearer enforcement of restrictions by rangers. The benefits would include a reduction in the number of dogs in the lake and foreshore areas, reducing the inputs of urine and faeces to the lake and reduced impacts on native wildlife at the lake. If more dog walkers who drive to Seven Mile Beach, park at the end of Camp Drewe Road instead of the lake, this will reduce parking pressure around the lake. Providing dog poo bins and bags should help to reduce the amount of dog poo left behind, it is also a clear visual reminder that dog owners are expected to clean up after their dog.

What are the potential implementation issues and key risks?

The main risk is that some dog owners will ignore restrictions and signage regardless of placement and design. To be effective it will be necessary to reinforce any changes with education and promotion in the media, and enforcement measures. There is likely to be community opposition to any changes to the current access arrangements.

Figure 7: Current dog access arrangements at the lake (BSC Community Connect, July 2019)

9. EDUCATION

Option 36: Education campaign

Risk (s) to be addressed:	**Stormwater impact on Lake Ainsworth** **Nutrient enrichment** **Blue Green Algae blooms** **Insufficient public education** **Spills and contamination** **Exotic aquatic fauna**		
Risk Rating:	**High**	**Medium**	**Low**

Option Description

To develop a multi-faceted campaign to educate and promote understanding of the natural attributes of the lake, sensitivities and key issues and encouraging low-impact use/practices to protect the lake. Issues to be covered include:

- Education about fertiliser use/ garden waste management/ compost etc. for all catchment land managers and residents to the south of the lake.
- Sensitivity of lake ecosystems, need for protection etc.
- Groundwater/ surface water interactions, emphasising the link between what is added to the surface of land (e.g. fertiliser, manure, herbicides, pesticides etc.) and what can be transported through groundwater flows to the lake.
- Impacts of dogs on native wildlife and water quality.
- Types of fertiliser, application rates, timing with rainfall etc.
- Information on health risks of exposure to cyanobacteria blooms and revised signage.
- Sunscreen pollution:
    - Key risks of sunscreen to human health, water quality and wildlife.
    - Encourage use of more environmentally friendly sunscreen; wear UV resistant clothes instead (e.g. rash shirt etc.); avoid hottest part of day; apply sunscreen 20 mins before swimming etc.
- Pest fish species education - An educative program coupled with facilities for accepting unwanted aquarium fish. Information could include relevant pest species identification information, impacts of aquarium fish releases to the wild, dumping of aquarium fish is prohibited and alternatives to dumping aquarium fish.
- Native wildlife present in the area, habitat values and key risks including discussion of what the community and visitors can do to conserve wildlife (i.e. Camp Drewe Road wildlife crossing).
- Results of Option 40: Monitoring Program components.
- Indigenous cultural heritage and significance.

Educational programs should target the local community as well as visitors to the area and may involve (but are not limited to):

- Installation of attractive and engaging signage at key locations around the lake.

- Leaflets/flyers/letterbox drop;
- Webpage;
- Posters;
- Information days/activities;
- School programs; and
- Educational videos.

Why implement this option? What are the benefits?

Education can lead to positive changes in behaviour. By informing the community about the values of the lake and its unique ecosystem components and sensitivities, the aim is to foster a higher level of respect and stewardship, translating into careful use that is cognisant of human impacts and their ramifications. There are a number of areas where the general community may simply be unaware of the negative consequences of actions such as over fertilising lawns, sunscreen pollution, the impact of abandoned fishing line and litter on wildlife and dumping of aquarium fish species. By raising these issues and explaining the impacts the campaign will seek to reduce negative impacts while increasing community understanding and appreciation of the lake.

What are the potential implementation issues and key risks?

There is always a risk that education effort may not be effective in engaging all lake users. Members of the community that are already engaged and have a good understanding of the lake are the most likely to take part in educational campaigns. The challenge will be to reach those community members who typically would not engage with educational campaigns. People may become desensitised when over-exposed to educational material. A multi-faceted approach is needed canvassing a variety of media platforms to maximise exposure and capture interest. Excessive or unattractive signage may also detract from the aesthetics of natural areas and careful design and placement of signs as well as removal of reductant existing signage should be considered.

Plate 21: Examples of current signage at the lake

Option 37: Review blue green algae alert/ lake closure signage

Risk (s) to be addressed:	**Blue Green Algae blooms** **Insufficient public education**	
Risk Rating:	**High**	**Medium**

Option Description

Review the current signage including text, images, symbols as well as placement and sizing to ensure effective communication of public health risks. Recommend improvements to signage to more effectively communicate public health risks associated with BGA blooms as well as complimentary actions to promote and educate about the risks of blooms. This option is linked to Option 37: Education campaign which includes further information of the risks of exposure to blue green algae toxins.

Why implement this option? What are the benefits?

Better communication of risks associated with blooms with a view to reducing those swimming during high risk periods.

What are the potential implementation issues and key risks?

There will always be a residual risk that people will chose to ignore the signs. This may be especially true for those community members who have swum in the lake during closures for many years without any perceived effects.

Plate 22: Blue Green Algae alert signage at the lake

10. MANAGEMENT AND GOVERNANCE

Option 38: Establish an integrated management group

Risk (s) to be addressed:	**Barriers to effective management**
Risk Rating:	**High**

Option Description

Establish an integrated management group responsible for overseeing the implementation, monitoring and review of the Lake Ainsworth CMP.

The Lake Ainsworth catchment area is comprised mainly of Crown land managed by different appointed trustees (land managers) including: BSC, DI Lands, NSW Crown Holiday Parks Land Managers, and NSW Office of Sport. Some freehold land exists north of the lake owned and managed by Jali LALC and also small section of freehold residential land is located along the southern border of the catchment. Land Management arrangements were documented and mapped as part of the Stage 1 Scoping Study of this CMP (Hydrosphere Consulting, 2018). In addition to these official land managers and property owners, other organisations and government agencies have a role in the management of Lake Ainsworth and the surrounding catchment including: North Coast Local Land Services (LLS); Office of Environment and Heritage (OEH); Lennox Head Landcare; and Ballina Coastal Committee.

The 2002 Lake Ainsworth Management Plan identified '*Lack of management structure'* as a high priority issue for the lake and recommended the following management actions:

- Formulate a Memorandum of Understanding between responsible agencies.
- Review Memorandum of Understanding and agency performance every two years.
- Arrange funding for the various management actions.
- Monitor performance of plan.

The Scoping Study (Hydrosphere Consulting, 2018) determined that these actions were incomplete or not undertaken and the relevant committees formed previously had now been dissolved.

The Lake Ainsworth CMP Steering Committee formed to oversee the development of this CMP comprises all land managers in the immediate vicinity of the lake and foreshores and has worked effectively together to discuss issues and concerns and formulate management direction. It is recommended that this group continues to oversee the subsequent stages of the CMP implementation and review. It will be necessary to appoint key roles such as Chairperson and Secretary to organise and host meetings, distribute minutes and oversee group administration. As a minimum, meetings should be held on a bi-annual basis, and more frequently as required to discuss implementation milestones, funding and emerging issues etc.

Why implement this option? What are the benefits?

Coordinated and cooperative management is essential for ongoing and effective management of the lake.

What are the potential implementation issues and key risks?

There is always a risk that membership on management committees will wax and wane over the years. Participation is dependent on the motivation and willingness of individuals to attend meetings and contribute positively to discussions and decision making processes. The existing Lake Ainsworth CMP Steering Committee has proved to be an effective and committed group during development of the CMP and based on this, the risk of ineffective management is considered low.

11. MONITORING

Option 39: Monitoring Program

Risk (s) to be addressed:	**Barriers to effective management** **Linked to all threats**
Risk Rating:	**High**

Option Description

To develop a multi-discipline monitoring program for the lake incorporating ongoing tracking and assessment of CMP implementation as well as investigation of identified key ecosystem components to provide better information and inform effective management.

Components for inclusion are:

- Water quality – ongoing monitoring of water quality to allow for assessment of changes as a result of management actions
- Aerator trial monitoring – associated with changes to the aerator program. A monitoring program will be designed to assess water quality conditions throughout the trial period and measure the success of trials. Assessing dissolved oxygen levels at the sediment/water interface at a number of locations around the lake will be critical to determining the effectiveness of the modified regimes and identifying the 'zone of influence' for the aerators. Overall water quality and specifically nutrient/algae conditions will also be assessed.
- Blue Green Algae - continuation of current monitoring in line with NHMRC guidelines and existing BSC processes.
- Water level - continuation of current monitoring via the automatic water level recorder managed by MHL on behalf of OEH.
- Sediment extent - it is proposed that the extent of the Organic Rich Mud sediment be assessed every 5 years by repeating the methodology implemented as part of Stage 2 of the CMP. This will provide information about relative rates of sedimentation over time. If reductions in algal blooms are achieved through other management actions, monitoring sediment extent will allow for an assessment of whether reduced algal blooms reduces the rate of sedimentation.
- Hydrology and groundwater – conduct groundwater monitoring in the catchment to replicate that undertaken as part of the 1996 processes study and allow for assessment of current groundwater conditions and more accurate modelling of groundwater outflows and lake water balance completed as part of Stage 2.
- Erosion - monitor the performance of the lake foreshore erosion controls and conduct timely maintenance as required. Formal assessment by repeating the Erosion Assessment conducted as part of Stage 2 studies is recommended annually. The current Foreshore Improvement Works along the southern and eastern foreshores of the lake include formalised pedestrian pathways and wheelchair accessible ramps to the water, coupled with bank erosion amelioration works. It will be necessary to monitor the new access points created to ensure access is functioning as intended, and if necessary trigger maintenance or further work as required (refer Option 42: Monitoring Program and Option 33: Review of public safety risk assessment). There is also a need to monitor future access pressure on the western side following closure of the eastern road to minimise/mitigate any worsening of erosion.

- Riparian Vegetation - Once Foreshore Improvement Works are complete, assess areas to determine whether further revegetation, such as restoration of some of the small inlets along the eastern shoreline is desirable to further protect against erosion.
- Investigations of sunscreen pollution – design a monitoring program to provide further information on the nature of sunscreen pollution and potential impacts on ecology and particularly nutrient concentrations. Monitoring could involve testing lake water for chemicals of concern, assessing the nutrient composition of common sunscreens and/or physical assessment of sunscreen slicks on the lake surface.
- Investigate sources of Enterococci (faecal contamination)- determine whether wildlife/dogs or human waste is source of faecal matter to the lake. There are a suite of methods are available for this purpose known as microbial source tracking (MST). Many methods rely on signature molecules such as DNA sequences of host-associated microorganisms.
- Increasing use of the Western side – monitor visitor numbers, access points and subsequent impacts on bank erosion, ecosystem values, cultural heritage and amenity. It is recommended that monitoring be conducted over 1 year to capture seasonal variation. Results will be used to assist in developing concept design for western side (refer Option 31: Manage increasing use of the western side of the lake).
- Parking - monitor car parking patterns following the eastern road closure with a focus on assessing parking along Camp Drewe Road and into suburban areas of Lennox Head and subsequent impacts on environmental values, amenity and public safety. It will also track the effectiveness of Option 34: Restrict overnight parking along lake foreshore. It is recommended that monitoring is conducted over a year to capture seasonal changes in demand. The information will assist in evaluating the extent of the problem and potential further management options.
- Assessment of wildlife populations and impact of Camp Drewe Road – This will involve monitoring of all wildlife road fatalities/injuries along Camp Drewe Road with a particular focus on turtles. A register of community sightings should also be established and advertised to encourage community members to share information. Details to be captured include species name/common name, approximate age (e.g. juvenile/adult), date of observation, observation type (e.g. fatality, injury) location (GPS coordinates if possible), photograph, and details of outcome (e.g. transported to vet/ wildlife carer in the case of injury, or disposal in the case of fatality). The location of turtle nesting sites and crossing locations should be determined to assist in placement of any future traffic control structures and signage. It would be ideal to monitor over 1 year to capture seasonal changes, and may potentially be a suitable post-graduate student study.

Why implement this option? What are the benefits?

Monitoring is considered a key part of overall management of the lake allowing adaptive management measures to be implemented as required. Regular monitoring will allow land managers to address small issues before they get bigger and more problematic/expensive to resolve. Monitoring of management actions such as erosion controls is essential in maintaining safe access at all times. Investigation of issues helps to better understand the level of issues and priority for management.

What are the potential implementation issues and key risks?

The cost of monitoring needs to be considered and assessed in terms of the benefit derived from outputs. The monitoring goals, sample collection strategies, and methods of analysis used in monitoring must be well defined in advance to obtain robust results. Monitoring must be conducted and reported in a timely fashion for consideration in ongoing management. For most components it will be necessary to make the results available to the public and therefore needs to be written in plain English suitable for a broad range of readers.

Appendix 2. CUMULATIVE RISK MITIGATION SCORE

Table 6: Cumulative Risk Mitigation Score (CRMS) weighted according to risk rating of threat (refer Step 3.1.1 Cumulative Risk Mitigation Assessment for details and scoring system)

		Threats	Blue Green Algae blooms	Nutrient enrichment	Ocean shoreline recession, breakthrough and saline intrusion (long-term)	Foreshore erosion of the Lake	Car parking adequacy for current and future demand	Barriers to effective management	Impacts on Aboriginal cultural practices and heritage	Foreshore accessibility and public safety	Cars and public safety	Threats to aesthetic quality	Ocean shoreline recession, breakthrough and saline intrusion (short-term)	Wave run-up and dune overtopping	Localised freshwater flooding	Faecal coliforms and Enterococci (microbiological risk to human health)	Altered lake hydrology and water balance	Stormwater impact on Lake Ainsworth	Exotic aquatic fauna	Aquatic weeds or unnatural growth	Riparian vegetation disturbance	Threats to native flora and fauna	Threats to amenity and enjoyment (e.g. overcrowding, insufficient/degraded facilities)	Insufficient public education	Spills and contamination	Terrestrial weeds	
No.	Option	Risk Rating	High	High	High	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	Cumulative Risk Mitigation Score (CRMS)
1.	Beach nourishment with a geofabric container beach sill		0	0	0	2	0	0	1	2	2	2	0	0	0	0	0	0	0	0	2	0	2	0	0	0	48
2.	Riparian vegetation enhancement for erosion control		0	0	0	2	0	0	1	0	0	2	0	0	0	0	0	1	0	1	2	1	1	0	0	2	40
3.	Managed Retreat		0	0	0	-1	0	0	-1	-2	0	-1	0	0	0	0	0	0	0	0	-2	0	-1	0	0	0	-30
4.	Flood Planning		0	0	0	0	0	1	0	2	0	2	0	0	2	0	1	1	0	0	0	0	1	0	0	0	34
5.	Trial modifications to artificial aeration		2	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	1	2	0	0	0	57
6.	Continue aerator program		-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	-22
7.	Vertical mechanical mixers/surface mixers		1	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	1	0	0	-1	0	0	0	5
8.	Pure oxygen injection		2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	37
9.	Fountains		1	0	0	-1	0	0	0	-1	0	-2	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-10
10.	Draining and /or treatment of nutrient-rich benthic waters		2	2	0	0	0	0	0	0	0	-1	0	0	1	0	1	0	0	1	0	-1	0	0	0	0	41

No.	Option	Risk Rating	Blue Green Algae blooms	Nutrient enrichment	Ocean shoreline recession, breakthrough and saline intrusion (long-term)	Foreshore erosion of the Lake	Car parking adequacy for current and future demand	Barriers to effective management	Impacts on Aboriginal cultural practices and heritage	Foreshore accessibility and public safety	Cars and public safety	Threats to aesthetic quality	Ocean shoreline recession, breakthrough and saline intrusion (short-term)	Wave run-up and dune overtopping	Localised freshwater flooding	Faecal coliforms and Enterococci (microbiological risk to human health)	Altered lake hydrology and water balance	Stormwater impact on Lake Ainsworth	Exotic aquatic fauna	Aquatic weeds or unnatural growth	Riparian vegetation disturbance	Threats to native flora and fauna	Threats to amenity and enjoyment (e.g. overcrowding, insufficient/degraded facilities)	Insufficient public education	Spills and contamination	Terrestrial weeds	Cumulative Risk Mitigation Score (CRMS)
		Threats	High	High	High	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	
11.	Enhance flushing		2	2	-1	0	0	0	0	0	0	-1	0	-1	1	0	-1	0	1	0	0	-1	-1	0	0	0	24
12.	Aquatic weed harvesting		1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	27
13.	Constructed wetlands		1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	23
14.	Sediment removal (dredging)		2	2	0	0	0	0	0	0	0	-1	0	0	1	0	-2	0	0	0	0	0	0	0	-2	0	31
15.	Trial sediment treatment		2	2	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	2	0	1	2	0	0	0	59
16.	Sediment capping using clean sands		2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	42
17.	Stormwater treatment/ improvement		1	1	0	2	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	1	0	0	2	0	45
18.	Litter/recycling		0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	1	1	2	1	0	0	24
19.	Develop local Cane Toad management strategy		0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	2	2	0	0	0	24
20.	Riparian vegetation management		0	0	0	1	0	0	0	1	0	2	0	0	0	0	0	0	0	0	2	2	1	0	0	2	34
21.	Backfill exposed tree roots		0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	1	0	0	2	2	2	0	0	0	36
22.	Grass species selection for open space areas to minimise bare areas		0	0	0	2	0	0	0	2	0	2	0	0	0	0	0	1	0	0	2	-1	2	0	0	2	39

No.	Option	Risk Rating	Blue Green Algae blooms	Nutrient enrichment	Ocean shoreline recession, breakthrough and saline intrusion (long-term)	Foreshore erosion of the Lake	Car parking adequacy for current and future demand	Barriers to effective management	Impacts on Aboriginal cultural practices and heritage	Foreshore accessibility and public safety	Cars and public safety	Threats to aesthetic quality	Ocean shoreline recession, breakthrough and saline intrusion (short-term)	Wave run-up and dune overtopping	Localised freshwater flooding	Faecal coliforms and Enterococci (microbiological risk to human health)	Altered lake hydrology and water balance	Stormwater impact on Lake Ainsworth	Exotic aquatic fauna	Aquatic weeds or unnatural growth	Riparian vegetation disturbance	Threats to native flora and fauna	Threats to amenity and enjoyment (e.g. overcrowding, insufficient/degraded facilities)	Insufficient public education	Spills and contamination	Terrestrial weeds	Cumulative Risk Mitigation Score (CRMS)
		Threats	High	High	High	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	
23.	Underground replacement or relocation of power lines between Sport and Recreation Centre and Lennox Surf Club.		0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	0	0	17
24.	Traffic management Camp Drewe Road		0	0	0	0	1	0	0	2	2	1	0	0	0	0	0	1	0	0	1	2	1	0	0	0	37
25.	Wildlife/ turtle crossing warning signs on Camp Drewe Road		0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	2	0	2	0	0	10
26.	Aquatic weed harvester		0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	2	1	0	0	0	21
27.	Biological Control		0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	2	1	0	0	0	21
28.	Replace boom used in aquatic weed management		0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	2	1	0	0	0	21
29.	Review of public safety risk assessment		0	0	0	1	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	20
30.	Greater acknowledgement of Aboriginal Heritage		0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	16
31.	Manage increasing use of the western side of the lake		0	0	0	2	2	0	2	2	2	2	0	0	0	0	0	1	0	0	2	2	2	1	0	1	73
32.	Restrict overnight parking along foreshore		0	0	0	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
33.	Encourage alternative transport to the lake		0	0	0	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24

		Threats	Blue Green Algae blooms	Nutrient enrichment	Ocean shoreline recession, breakthrough and saline intrusion (long-term)	Foreshore erosion of the Lake	Car parking adequacy for current and future demand	Barriers to effective management	Impacts on Aboriginal cultural practices and heritage	Foreshore accessibility and public safety	Cars and public safety	Threats to aesthetic quality	Ocean shoreline recession, breakthrough and saline intrusion (short-term)	Wave run-up and dune overtopping	Localised freshwater flooding	Faecal coliforms and Enterococci (microbiological risk to human health)	Altered lake hydrology and water balance	Stormwater impact on Lake Ainsworth	Exotic aquatic fauna	Aquatic weeds or unnatural growth	Riparian vegetation disturbance	Threats to native flora and fauna	Threats to amenity and enjoyment (e.g. overcrowding, insufficient/degraded facilities)	Insufficient public education	Spills and contamination	Terrestrial weeds	
No.	Option	Risk Rating	High	High	High	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	Cumulative Risk Mitigation Score (CRMS)
34.	Management of future parking arrangements		0	0	0	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	26
35.	Dog Access		1	1	0	0	1	0	0	0	0	0	0	0	0	2	0	1	0	0	0	2	0	0	0	0	39
36.	Education campaign		1	1	0	1	1	0	1	1	1	1	0	0	0	1	0	1	1	1	1	1	1	2	1	1	69
37.	Review blue green algae alert/ lake closure signage		0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	16
38.	Establish an integrated management group		1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	92
39.	Monitoring Program		1	1	0	1	1	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	65

Appendix 3. COST-BENEFIT ANALYSIS

Table 7: Cost Benefit Analysis (refer Step 3.1.2 Cost Benefit Analysis for details and scoring system)

Option No.	Management Option	Threat(s) directly addressed	Cumulative Risk Mitigation Score		Feasibility				Total Feasibility Score	Viability			Total Viability Score	Acceptability		Total Acceptability Score	Final CBA Score	Overall Outcome	
			Weighted according to risk rating (see CRMS table)	Scaled CRMS	Effectiveness (in addressing direct threats)	Technical Viability	Ecological sustainability	Legal/ Approval Risk		Capital Costs	On-going costs	Cost-benefit distribution (public vs. private)		Community/ Stakeholder Acceptability	Meeting CM objectives		CBA	(CRMS + CBA)* RW	Recommendation *R=Recommended, NR=Not Recommended
5	Trial modifications to artificial aeration	Blue Green Algae blooms, Nutrient enrichment	57	4	1	1	1	1	**4**	1	0	1	**2**	1	1	**2**	8	84	R
15	Trial sediment treatment	Blue Green Algae blooms, Nutrient enrichment	59	4	1	1	1	1	**4**	1	-1	1	**1**	0	1	**1**	6	64	R
1	Beach nourishment with a geofabric container beach sill	Foreshore erosion of the lake	48	3	1	0.5	1	1	**3.5**	0	1	1	**2**	1	1	**2**	7.5	41	R
21	Backfill exposed tree roots	Riparian vegetation disturbance, Threats to native flora and fauna, Foreshore accessibility and public safety	36	3	1	1	1	1	**4**	1	1	1	**3**	1	1	**2**	9	39	R
38	Establish an integrated management group	Barriers to effective management	92	5	1	1	0	1	**3**	1	1	1	**3**	1	1	**2**	8	37	R
30	Review of public safety risk assessment	Foreshore accessibility and public safety,	16	2	1	1	0	1	**3**	1	1	1	**3**	1	1	**2**	8	34	R
34	Management of future parking arrangements	Car parking adequacy for current and future demand, Foreshore accessibility and public safety	26	2	0	1	0	1	**2**	1	1	1	**3**	1	0	**1**	6	32	R
32	Restrict overnight parking along foreshore	Car parking adequacy for current and future demand, Foreshore accessibility and public safety	24	2	0	1	0	1	**2**	1	1	1	**3**	1	0	**1**	6	32	R
2	Riparian vegetation enhancement for erosion control	Foreshore erosion of the lake, Foreshore accessibility and public safety, Riparian vegetation disturbance	40	3	1	1	1	1	**4**	1	1	1	**3**	1	1	**2**	9	30	R
18	Litter management/ recycling	Threats to aesthetic quality, Threats to native flora and fauna	24	2	1	1	1	1	**4**	1	1	1	**3**	1	1	**2**	9	29	R
31	Greater acknowledgement of Aboriginal Heritage	Impacts on Aboriginal cultural practices and heritage, Insufficient public education	73	4	0	1	0	1	**2**	1	0	1	**2**	1	1	**2**	6	28	R
39	Monitoring Program	Barriers to effective management, linked to all threats	65	4	1	1	0	1	**3**	1	-1	1	**1**	1	1	**2**	6	28	R

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			Weighted according to risk rating (see CRMS table)	Scaled CRMS	Effectiveness (in addressing direct threats)	Technical Viability	Ecological sustainability	Legal/ Approval Risk		Capital Costs	On-going costs	Cost-benefit distribution (public vs. private)		Community/ Stakeholder Acceptability	Meeting CM objectives		CBA	(CRMS + CBA)* RW	Recommendation *R=Recommended, NR=Not Recommended
22	Grass species selection for open space areas to minimise bare areas	Foreshore erosion of the lake, Threats to aesthetic quality, Threats to native flora and fauna, Riparian vegetation disturbance	39	3	1	1	0	1	**3**	1	1	1	**3**	1	1	**2**	8	27	R
4	Flood Planning	Localised freshwater flooding	34	3	1	1	0	1	**3**	1	1	1	**3**	1	1	**2**	8	27	R
20	Riparian vegetation management	Riparian vegetation disturbance, Threats to native flora and fauna	34	3	1	1	1	1	**4**	1	0	1	**2**	1	1	**2**	8	27	R
25	Wildlife/ turtle crossing warning signs on Camp Drewe Road	Threats to native flora and fauna	10	2	0	1	1	1	**3**	1	1	1	**3**	1	1	**2**	8	26	R
24	Traffic management Camp Drewe Road	Cars and public safety, Threats to native flora and fauna	37	3	1	1	1	1	**4**	1	0	1	**2**	1	0	**1**	7	24	R
33	Encourage alternative transport to the lake	Car parking and public safety, Foreshore accessibility and public safety	24	2	0	1	1	1	**3**	1	0	1	**2**	1	1	**2**	7	23	R
29	Manage increasing use of the western side of the lake	Foreshore erosion of the Lake, Car parking adequacy for current and future demand, Foreshore accessibility and public safety, Cars and public safety, Threats to aesthetic quality, Riparian vegetation disturbance, Threats to amenity and enjoyment (e.g. overcrowding, insufficient/degraded facilities), Impacts on Aboriginal cultural practices and heritage	20	2	1	1	1	1	**4**	0	0	1	**1**	1	1	**2**	7	23	R
17	Stormwater treatment/ improvement	Nutrient enrichment, Stormwater impact on Lake Ainsworth, Spills and contamination	45	3	1	1	1	1	**4**	1	1	1	**3**	1	1	**2**	9	21	R
19	Develop local Cane Toad management strategy	Exotic aquatic fauna	24	2	1	1	0	1	**3**	1	0	1	**2**	1	0	**1**	6	20	R
27	Biological Control	Aquatic weeds or unnatural growth, Threats to native flora and fauna,	21	2	1	1	1	1	**4**	1	1	1	**3**	1	1	**2**	9	20	R
28	Replace boom used in aquatic weed management	Aquatic weeds or unnatural growth, Threats to native flora and fauna,	21	2	1	1	1	1	**4**	1	1	1	**3**	1	1	**2**	9	20	R

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			Weighted according to risk rating (see CRMS table)	Scaled CRMS	Effectiveness (in addressing direct threats)	Technical Viability	Ecological sustainability	Legal/ Approval Risk		Capital Costs	On-going costs	Cost-benefit distribution (public vs. private)		Community/ Stakeholder Acceptability	Meeting CM objectives		CBA	(CRMS + CBA)* RW	Recommendation *R=Recommended, NR=Not Recommended
36	Education campaign	Insufficient public education,Stormwater impact on Lake Ainsworth Nutrient enrichment Blue Green Algae blooms Spills and contamination Exotic aquatic fauna	69	4	1	1	1	1	**4**	1	0	1	**2**	1	1	**2**	8	20	R
12	Aquatic weed harvesting	Nutrient enrichment, Aquatic weeds or unnatural growth	27	2	0	1	1	1	**3**	1	1	1	**3**	1	1	**2**	8	18	R
37	Review blue green algae alert/ lake closure signage	Insufficient public education, Blue Green Algae blooms	16	2	1	1	0	1	**3**	1	1	1	**3**	1	1	**2**	8	18	R
35	Dog Access	Threats to aesthetic quality Threats to native flora and fauna Faecal coliforms and Enterococci (microbiological risk to human health) Blue Green Algae blooms, Nutrient enrichment Car parking adequacy for current and future demand Foreshore accessibility and public safety	39	3	0	1	1	1	**3**	1	1	1	**3**	0	1	**1**	7	17	R
26	Aquatic weed harvester	Aquatic weeds or unnatural growth, Threats to native flora and fauna,	21	2	1	1	1	1	**4**	1	-1	1	**1**	1	1	**2**	7	16	NR
23	Underground replacement or relocation of power lines between Sport and Recreation Centre and Lennox Surf Club.	Riparian vegetation disturbance, Threats to native flora and fauna, Ocean shoreline recession, breakthrough and saline intrusion (short-term and long-term)	17	2	-1	1	1	1	**2**	-1	1	1	**1**	1	1	**2**	5	14	NR
16	Sediment capping using clean sands	Blue Green Algae blooms, Nutrient enrichment	42	3	0	1	0	0	**1**	-1	-1	1	**-1**	1	0	**1**	1	13	NR
8	Pure oxygen injection	Blue Green Algae blooms, Nutrient enrichment	37	3	0	0	1	0	**1**	0	0	1	**1**	-1	0	**-1**	1	13	NR
9	Fountains	Blue Green Algae blooms	-10	1	0	0	-1	0	**-1**	1	0	1	**2**	0	0	**0**	1	11	NR
3	Managed Retreat	nil	-30	0	-1	1	0	1	**1**	1	1	1	**3**	0	0	**0**	4	4	NR
14	Sediment removal (dredging)	Blue Green Algae blooms, Nutrient enrichment, Localised freshwater flooding, altered lake hydrology and water balance	31	3	1	0	-1	-1	**-1**	1	-1	1	**1**	0	0	**0**	0	3	NR

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			Weighted according to risk rating (see CRMS table)	Scaled CRMS	Effectiveness (in addressing direct threats)	Technical Viability	Ecological sustainability	Legal/ Approval Risk		Capital Costs	On-going costs	Cost-benefit distribution (public vs. private)		Community/ Stakeholder Acceptability	Meeting CM objectives		CBA	(CRMS + CBA)* RW	Recommendation *R=Recommended, NR=Not Recommended
6	Continue aerator program	nil	-22	0	-1	1	-1	1	**0**	1	0	1	**2**	0	0	**0**	2	2	NR
11	Enhance flushing	Blue Green Algae blooms, Nutrient enrichment, Localised freshwater flooding	24	2	0	0	-1	-1	**-2**	1	0	1	**2**	0	0	**0**	0	2	NR
13	Constructed wetlands	Blue Green Algae blooms, Nutrient enrichment	23	2	-1	1	-1	-1	**-2**	0	-1	1	**0**	1	1	**2**	0	2	NR
7	Vertical mechanical mixers/surface mixers	Blue Green Algae blooms	5	1	0	0	-1	0	**-1**	0	0	1	**1**	0	0	**0**	0	1	NR
10	Draining and /or treatment of nutrient-rich benthic waters	Blue Green Algae blooms, Nutrient enrichment, Localised freshwater flooding	41	3	1	0	-1	-1	**-1**	-1	0	1	**0**	0	0	**0**	-1	-5	NR

Appendix 4. COASTAL HAZARD CONSIDERATIONS FOR THE FUTURE BALLINA COASTLINE CMP

Coastal hazard issues relevant to Lake Ainsworth

The continued recession of Seven Mile Beach and increased risk of erosion as a consequence of climate change (i.e. sea-level rise and storm events) has the potential to result in periodic or permanent opening of Lake Ainsworth to the sea. This has been identified as a key issue in the *Coastal Zone Management Plan for the Ballina Shire Coastline* (CZMP, GeoLINK, 2016). Oceanic breakthrough to the lake would substantially alter the ecosystem functions of the waterbody and surrounding habitats by changing the salinity, water chemistry and water level regime of the waterbody.

Weather events resulting in storm surges and abnormal waves have the potential to overtop the bordering dune system along Seven Mile Beach at points of low elevation (i.e. beach access tracks). This could result in saline input into Lake Ainsworth, localised flooding along the eastern side of the catchment, localised erosion along the dune system and lake foreshore, and disruption of public use via impeded access. Investigations as part of Stage 2 of this CMP indicated that the risk of significant wave run-up and over-wash of salt water to Lake Ainsworth during heavy seas is currently low, but will increase with continued sea level rise. The highest risk site is at the Surf Club, where risks can be mitigated by temporary minor works as required.

Actions currently proposed as part of the Ballina Coastline CZMP

Extension of current sea walls along Seven Mile Beach and beach nourishment to provide continuous shoreline protection is recommended in the existing certified CZMP (GeoLINK, 2016). The CZMP recommends protection of landward assets (rather than a 'retreat' option) for the section of coast between Byron Street and the Sport and Recreation Centre. Consideration as part of Stage 2 of this CMP has confirmed that this option is the best option for long-term protection of Lake Ainsworth.

The Emergency Action Subplan detailed in the CZMP (GeoLINK, 2016) sets out a plan for coastal emergencies including responsibilities and actions to prepare for and manage wave run-up and dune overtopping events in Lennox Head north of Byron Street. The actions focus on preventing entry of seawater into buildings, and damage to infrastructure. There is currently no mention of actions (e.g. sand-bagging) to prevent over wash to Lake Ainsworth.

Additional measures to the Ballina Coastline CZMP required to protect the lake

The coastline CZMP protection strategy is regarded as sound and fully compatible with the on-going management requirements for Lake Ainsworth. As part of this CMP, a number of additional measures relevant to the ongoing protection of Lake Ainsworth and have been identified which should be considered as part of the future coastline CMP development:

1. The coastline CZMP suggests that any sea wall option protecting Lake Ainsworth could be located further landward than in other areas, however it would be advantageous to protect as much of the dune system as practical, for ecological, aesthetic and risk mitigation purposes. Therefore a more easterly alignment is advocated.
2. Any works along Seven Mile Beach will need to consider groundwater outflows from Lake Ainsworth through the dunes and ensure no adverse impacts on lake hydrology (e.g. restriction of outflows, flooding impacts etc.)

3. A response strategy to extreme swell/high water conditions should be formulated to combat the potential for wave run-up and marine over-wash into the Lake Ainsworth basin. It is considered that the only notable risk at current is the Surf Club access ramp area and that a short-term emergency response in this area would be feasible and effective. Given the good accessibility and the proximity to the Surf Club (Plate 26) which itself would also warrant protective measures, a strategy to deploy short-term defences such as sand bags to prevent over wash into the lake and foreshore areas would likely do much to mitigate any current risk associated with wave run-up. This would be best dealt with by incorporating into the coastline CMP Emergency Action Subplan.
4. There is a need for a detailed evaluation of future wave run-up risk associated with sea level rise.
5. Further analysis and correction of discrepancies in recent LiDAR data to ensure an accurate monitoring of coastline sand reserves to the east of Lake Ainsworth. For future acquisition, particular focus should be placed on proper discrimination and classification of LiDAR returns to ensure appropriate analysis can be undertaken.

Plate 23: Aerial image of the dunes separating the lake from the Pacific Ocean

Plate 24: Aerial view of Surf Club and potential over-wash areas 1 and 2