LAKE ANNAN

SPECIFIC AREA PLAN OF MANAGEMENT

Adopted by
Camden Council
27 May 2014

15/7068

EXECUTIVE SUMMARY

Background

As with many riparian areas in Camden, Lake Annan is currently under stress from the impacts of surrounding urban land use and the development of urban release areas in the catchment. Active management is required to improve the ecological, aesthetic and recreation functions of the Lake.

The main concern for management is the quality of water discharging to Lake Annan. The existing gross pollutant trap (GPT) is not fulfilling its design objectives in providing adequate treatment of stormwater runoff to the Lake. This in combination with recent development in the catchment has placed additional pressure on the system.

The Vision

The Strategic Plan for Camden Council sets out a vision for what Camden will be like in the year 2040.

'*Camden will be a place that enjoys healthy urban and natural environments where the natural environment is protected and enhanced, open space is visible and accessible, public places and local neighbourhoods are attractive and vibrant places and the built and natural environment in the area complement and support one another.'* (refer Page 20)

'*Our community is able to access, enjoy and appreciate local natural assets and open spaces in a sustainable way, and these assets continue to be nurtured for future generations. In addition, our lifestyles and behaviours are improving not degrading our environment, and there is a high level of community involvement in environmental initiatives.'* (refer Page 22)

'*In 2040 our physical environment – both natural and built supports all aspects of our life in Camden. This will mean our natural systems are resilient and fully functional, and as a result provide for the health and wellbeing of the current and future populations through clean air, water, natural systems and diverse ecosystems.'* (refer Page 32)

'*The outcomes for Healthy Urban and Natural Environments will be achieved by focussing on:*

- *Improving the quality of our local rivers and waterways, and actively managing water throughout the area, including stormwater'* (refer Strategy 2.1.2, Page 34)
- *Provision and management of parks and natural open spaces which are accessible, connected and well-maintained to enhance community and environmental health, recreation and leisure opportunities, and appreciation of the local environment.'* (refer Strategy 2.4.1, Page 35)

Management Objectives

Objectives for the management of the Lake and its surrounding riparian environment are:

- To protect and enhance the biodiversity and ecological values of the lake, particularly in relation to water quality, native vegetation, and fauna habitat.
- To minimise long term maintenance costs.
- To maintain and enhance opportunities for passive recreational, cultural, social and educational pastimes and activities, without compromising ecological values.

- To conserve and enhance the scenic landscape qualities of the Lake.
- To encourage community involvement in the on-going management of the Lake and improve awareness of its existing potential ecological values.
- To promote monitoring of the Lake to evaluate and improve environmental outcomes.

Land to which this Plan Applies

This plan applies to Lake Annan and the surrounding riparian land and parkland, and incorporates the inlet and outlet structures of the Lake. The land parcels that fall under this plan are identified in Table 5 (Appendix 1) and shown in Map 2.

Plan Structure

The structure of this Plan of Management follows the provisions set out in the *Local Government Act 1993* for plans of management for 'community land'.

The management of Lake Annan will be in accordance with the specific management strategies that have been prescribed within this Plan.

The Lake and riparian buffer zone covered by this Plan were categorised 'natural area' and subcategory of 'wetland' when the original Plan of Management was adopted by Council on 28 July 2003 (refer Map 3, Appendix 1). The remainder of the land covered by this Plan was categorised 'park' (refer Appendix 1).

Scope

This Plan of Management specifies the manner in which Lake Annan and the associated riparian areas will be used and managed, and the objectives for that use and management. It also includes amendments to the original Plan of Management. The Plan may also be used to determine priorities for the use of resources and funds, and to guide the carrying out of works.

The major issues identified and addressed by this Plan are:

- Lake design;
- Water quality;
- Vegetation management;
- Erosion;
- Maintenance;
- Pest fauna;
- Recreation; and
- Community issues.

The Plan provides:

- a background to Lake Annan including an overview of the area, design intent of the Lake, past studies of the Lake and legislative context for the management of Lake Annan (Section 1);
- a vision and objectives for Lake Annan (Section 2);

- a discussion of the major issues identified for the management of Lake Annan (Section 3) and strategies developed to address each issue (Section 4);
- a masterplan prepared for improvement works at Lake Annan (Section 5); and
- an action plan for the implementation of management strategies. Performance measures have been identified for each action and actions have been categorised as low, medium or high priority to guide allocation of resources and funding (Section 6).

A Concept Maintenance Plan is provided in the report '*Concept designs for water quality treatment at Lake Annan'* prepared for Camden Council by Storm Consulting (Appendix 2).It sets out procedures by which Lake Annan can be maintained to a standard that ensures that it remains operational in accordance with the objectives of this Plan.

Recommendations

To maintain Lake Annan such that it functions in accordance with the objections of this Plan, appropriate stormwater treatment within the catchment is essential. Given the Lake is considered undersized relative to its catchment, the following management actions are considered essential:

1. Construction of water quality treatment devices including a constructed wetland within the Lake;
2. Replace the existing main Gross Pollutant Trap (GPT) so that it achieves optimum treatment of gross pollutants;
3. Install an appropriate water level control structure for maintenance requirements within the Lake;
4. Initiate and adhere to an appropriate maintenance regime, and allocate responsibility sand sufficient funding for this;
5. Develop a community education program for local residents;
6. Undertake bush regeneration to the island and native planting to enhance, and create additional riparian vegetation surrounding the Lake (which will also delineate between the open space 'park' area and the riparian 'natural area' buffer zone; and
7. Encourage and support education/interpretative and passive recreational activities by maintaining strategically placed signage and seating.

CONTENTS

Bringing engineering to life

Concept designs for water quality treatment at Lake Annan

Report Prepared for:
Camden council

Project No. 1485

Prepared by:
Storm Consulting Pty Ltd

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LAKE ANNAN

SPECIFIC AREA PLAN OF MANAGEMENT

BASIS FOR MANAGEMENT

SECTION ONE: INTRODUCTION

1.1 PURPOSE OF THE PLAN

Like many riparian areas in Camden, Lake Annan is currently under stress from the impacts of surrounding urban land use and the development of urban release areas in the catchment. Active management is required to improve the ecological, aesthetic and recreation functions of the Lake.

This Plan of Management specifies the manner in which Lake Annan and the associated riparian areas will be used and managed, and the objectives for that use and management. It provides amendments to the original Plan of Management adopted on 28 July 2003. The Plan may also be used to determine priorities for the use of resources and funds, and to guide the carrying out of works.

1.2 STRUCTURE OF THE PLAN

The structure of this Plan of Management follows the provisions set out in the *Local Government Act 1993* for plans of management for ‘community land’.

The management of Lake Annan will be in accordance with the specific management strategies that have been prescribed within this Plan.

1.3 CATEGORISATION

For the purposes of use and management, Lake Annan has been categorised as ‘natural area’ and ‘park’ according to provisions of the *Local Government Act 1993*. The Lake and riparian buffer zone fall under the category of ‘natural area – wetland’ and the land covered by this Plan which lies outside the riparian buffer zone falls under the category ‘park’ (refer Map 3).

The Lake and riparian buffer zone of Lake Annan is categorised for the purpose of this Plan as a constructed wetland.

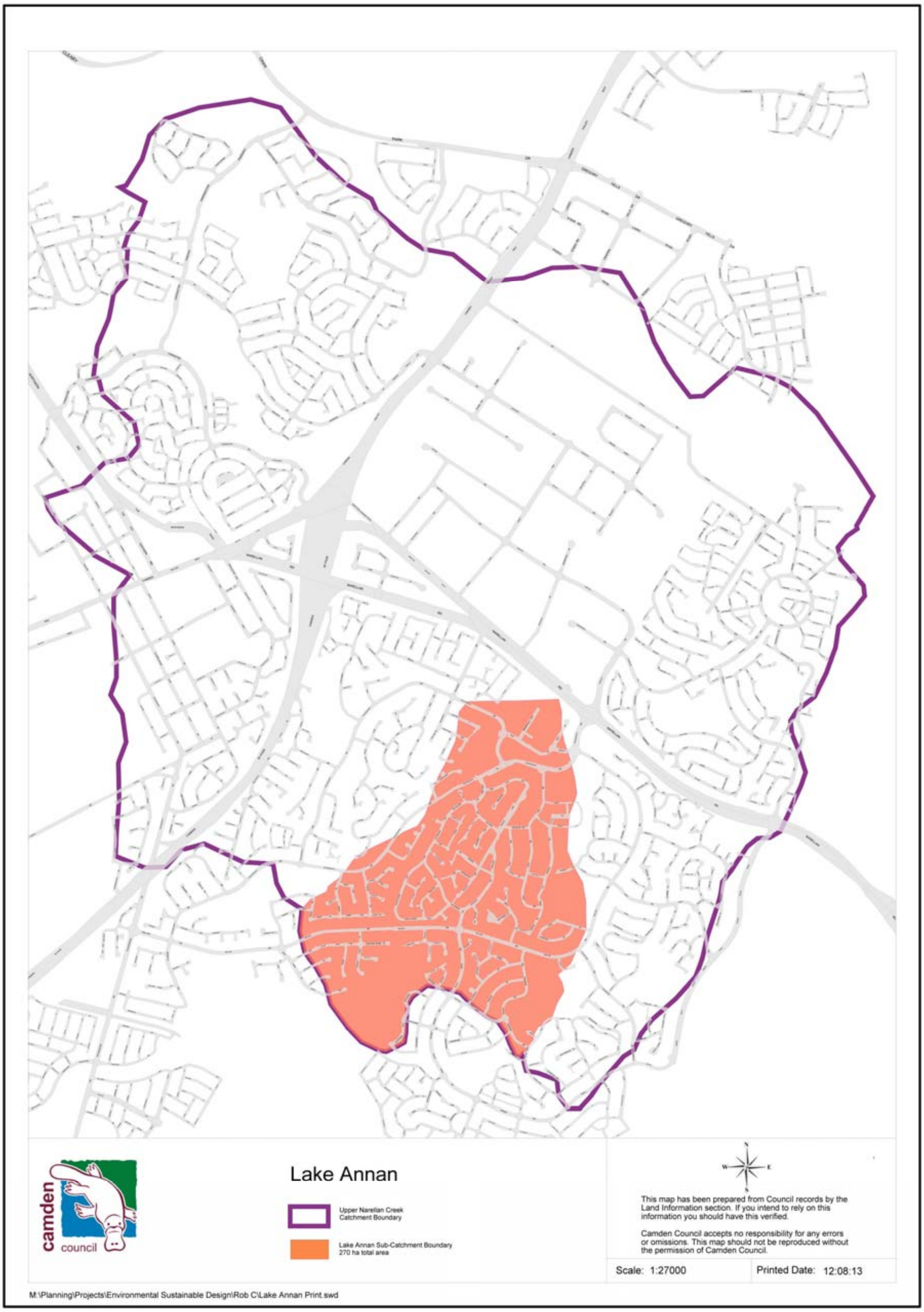
1.4 LAND TO WHICH THE PLAN APPLIES

This plan applies to Lake Annan and the surrounding riparian land and park land, and incorporates the inlet and outlet structures of the Lake. The land parcels that fall under this plan are identified in Table 2A (Appendix 2) and shown in Map 2. It should be noted that this plan, in some cases, covers only part of these land parcels (see Map 2).

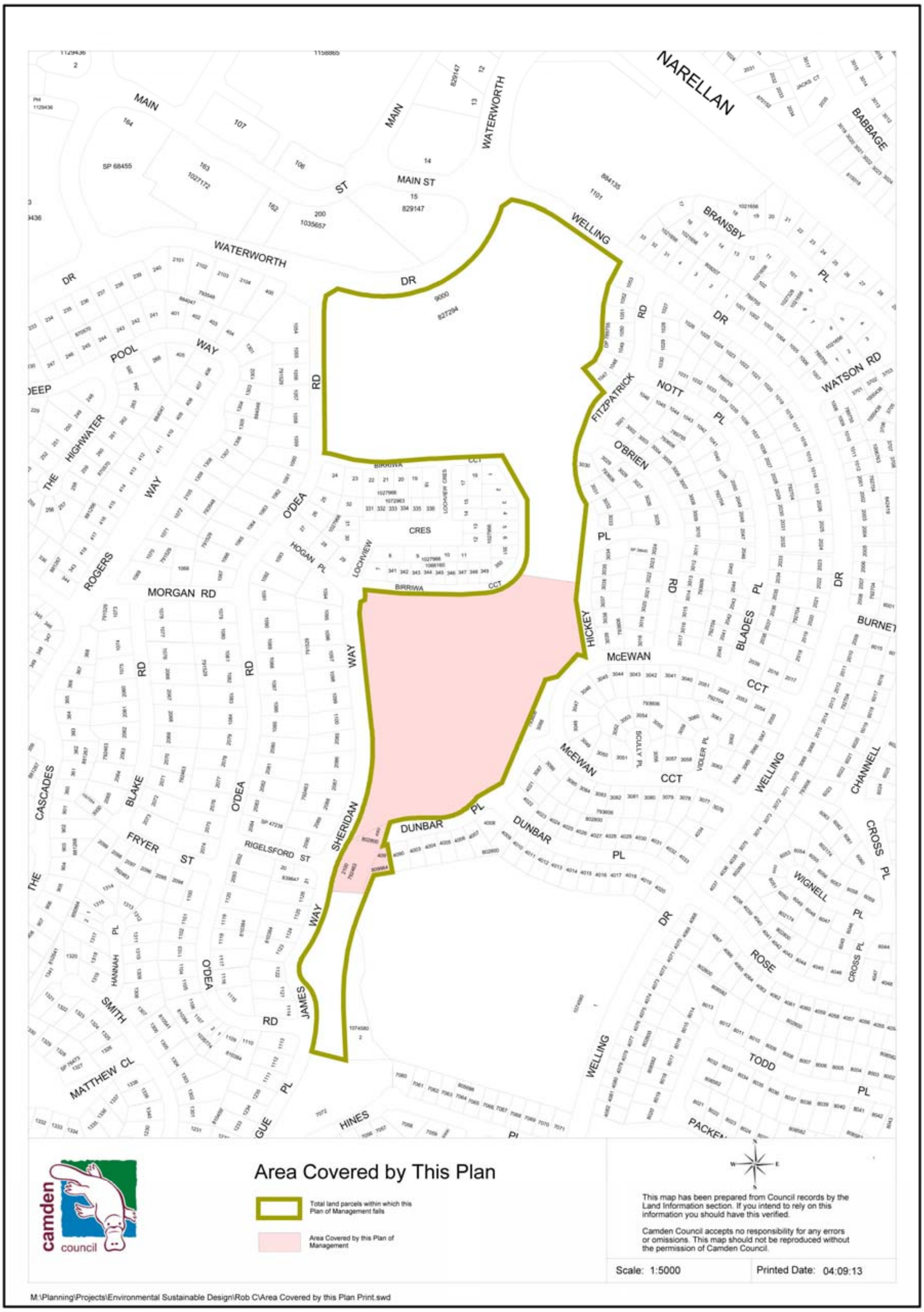
1.5 MANAGEMENT AUTHORITY, TENURE AND OWNERSHIP

The land is owned by Camden Council. For the purposes of this plan, the management authority is Camden Council.

MAP 1: LAKE ANNAN CATCHMENT



MAP 2: AREA COVERED BY THIS PLAN



1.6 BACKGROUND INFORMATION

1.6.1 Site and Surrounds

Lake Annan is located in the suburb of Mount Annan in the Camden Council LGA, approximately 52km South West of the Sydney CBD. Lake Annan is surrounded by residential housing and forms part of a public open space and drainage reserve (see Map 2).

1.6.2 Catchment Context

Lake Annan is located in the upper reaches of the Narellan Creek catchment (see Map 1) and is one of the most heavily urbanised sub-catchment of the Upper Nepean River. Remaining rural areas are rapidly being developed for residential, industrial and commercial land uses.

1.6.3 Soils and Geology

The catchment area of the lake is dominated by red and brown podzolic soils of the Blacktown soil landscape (Hazelton and Tillie, 1990). These soils are characterised by low fertility, low to moderate water holding capacity and low cationic exchange capacities. They are strongly acidic, with a high potential aluminium toxicity, dispersive and easily eroded.

1.6.4 Lake Annan Overview

The Lake is 2.7 hectares in size, which equates to 1% of its catchment area.

1.6.4.1 Design

Lake Annan was constructed in 1988 as a combined sedimentation and part macrophyte Water Quality Control Pond (WQCP) as part of a pilot scheme for reducing pollutant loads from stormwater runoff. Lake Annan has been constructed as an in-line water quality control pond within Narellan Creek. The lake was designed with the following components:

- basin storage volume of 55 ML;
- surface area of 2.7 hectares (approximately 1% of the total catchment area);
- average depth of 2 metres, maximum depth of 3.5 metres;
- a central island placed directly in line with the inflow to disperse the flow and reduce short-circuiting. The island also provides a refuge for native fauna and an additional lake edge for macrophytes;
- a Gross Pollutant Trap (GPT) located upstream of the Lake, designed to remove course sediment for floods up to the 3 month ARI flood event and so that velocities of floods up to the 1 year ARI event would not be sufficient to re-suspend sediment; and
- a spillway and trash rack at the downstream outflow of the Lake.

The Lake system has five inflows and one outflow point, as follows:

- main inflow (from Narellan Creek) with a large GPT consisting of a permanently ponded sedimentation basin and trash rack;
- secondary inflow (from end of Hogan Place) fitted with a continuous deflective separation (CDS) unit;
- secondary inflow from the ‘T’ junction of Dunbar Place fitted with a CDS unit;

- two minor inflows (from the dead end of Dunbar Place and off Birriwa Circuit near the end of Hogan Place) that are not fitted with stormwater proprietary devices; and
- outflow (to Narellan Creek) with a large spillway and trash rack.

Additionally, macrophytes have sporadically established in a band approximately 2 metres wide around the perimeter, largely through natural processes and without deliberate planting (main species being Cumbungi, *Typha sp.* and Common Rush, *Juncus usitatus*).

1.6.5.2 Design Problems

Since construction (1988), Lake Annan has experienced a number of problems, which include:

- high nutrient loads contributing to algal blooms and odour in the warmer months;
- operation and maintenance of the upstream GPT;
- poor water clarity due to high turbidity;
- widespread loss of macrophyte plants;
- sediment build up;
- localised areas of erosion and bank scalding; and
- additional nutrient loads due to a large population of Australian White Ibis using the Island for breeding.

In addition, the Lake is considered undersized relative to its catchment.

1.6.5.3 Previous Studies

Lake Annan was the subject of a study concerning the performance of the Water Quality Control Pond (along with Currans Hill Pond) in the Upper Narellan catchment, commissioned by Camden Council (SMEC 1998). This study also identified measures that might readily and economically be adopted to improve water quality treatment, and was used to assess any savings that could be achieved in the proposed Harrington Park Water Quality Management System. Issues determined as a result of this study are summarised below:

- Operational problems of the major GPT which has been installed on-line of the major inflow to the Lake, as follows:
  - The GPT was installed on-line and due to concrete walls surrounding the GPT and housing the trash rack, the GPT has a permanent ponded area which has regularly become anaerobic, causing odour problems;
  - Pet animals have drowned in the permanently ponded area, which has raised safety concerns;
  - Stormwater spills over the trash rack causing the collected trash to be washed into Lake Annan and it is suspected that re-suspension of collected sediment also occurs on these occasions;
  - The low flow pipe that feeds the GPT has an invert level well below the permanent pond level. Consequently the low flow pipe is permanently inundated and during low flows this has resulted in sediment accumulating within the pipe, eventually blocking the pipe, which has caused ongoing maintenance problems. To help reduce this problem Council has cut a notch into the weir that controls the pool level in the GPT.

This has reduced the pool level so that only the bottom portion of the low flow pipe is permanently inundated. Sediment still settles in the bottom portion of the pipe.

- Macrophyte coverage is less than the design target of 30%, which was attributed to high turbidity. Turbidity was attributed to the predominance of dispersive clays in the catchment area, so that flows to the Lake contain high concentrations of colloidal particles that will not settle; and

- Elevated groundwater tables causing salinity problems observed around the perimeter of the pond.

Water Quality monitoring at the inlet and outlet structures of the Lake prior to May 2003 indicated that Lake Annan removes approximately 60% of the annual load of suspended solids and faecal coliforms and approximately 40% of total phosphorus and total nitrogen.

Management options recommended within the SMEC (1998) report were:

1. Increasing macrophyte zone; it was considered that the Lake's performance could be improved by increasing the coverage of macrophytes. Recommendations were to carry out earthworks to establish shallow zones between the existing island and the Lake perimeter. However, the expansion of macrophytes was not modelled to assess improvements in water quality from the proposed option.
2. Replacement of the GPT with a CDS unit to overcome all of the existing operational problems at an estimated cost of $150,000.
3. Alternatively, improve the existing GPT by constructing a bypass channel to effectively put the GPT offline, thus preventing re-suspension of sediment and spill of litter in large events. A small pump could also be installed to drain the GPT after flood events in order to reduce the tendency for sediment to accumulate in the upstream flow pipe.
4. Install a re-circulation system to improve the performance of the Lake and dosing with flocculants such as gypsum to assist in the settling out of fine colloids.
5. Planting trees and other suitable vegetation around the perimeter to maintain a lower groundwater table.

1.6.5.4 Community Consultation prior to the preparation of the original PoM

The following issues were raised during community consultation held in August 2001:

- Littering and dumping of grass clippings, shopping trolleys, etc;
- Vandalism and graffiti;
- Faeces not removed by owners of dogs using the area;
- Odours and aesthetics;
- Lack of linkage with pathways and formalised open space areas for use by visitors and Council contractors causing further degradation of lake verges;
- Lack of formal parking bays and unauthorised vehicular access;
- Lack of community education;
- Lack of water quality monitoring program;

- Lack of general maintenance, but in particular with regard to removal of trash and debris from GPTs and trash racks; and
- Ongoing impacts to water quality due to development in catchment and apparent lack of policing and enforcement of adequate sediment and erosion controls by developers.

1.6.5 Current Water Quality and Quantity Issues

1.6.5.1 Sediment

The sediment and lake bathymetric analysis which was undertaken in 2010 identified that the sediment is not contaminated, and that it could be re-used rather than disposed as landfill. While the bathymetric survey found there were 12,530 cubic metres of sediment, only 5,000 cubic metres of the sediment is solid sediment, the remainder being basically sludge. Therefore, potentially the 5,000 cubic metres of solid sediment can be used for benching in a constructed wetland or Water Sensitive Urban Design (WSUD) treatment where appropriate.

The sediment was also identified to contain high levels of phosphorus and nitrogen which would contribute to the outbreak of Blue-Green Algae during warm weather and dry periods.

1.6.5.2 Blue-Green Algae

Blue-Green Algae (*Cyano bacteria*) is present at Lake Annan in the warmer months and can build to a level that is toxic to humans and can be fatal to animals. A Blue-Green Algae outbreak can result from nutrient build-up in the Lake.

Camden Council has undertaken water quality testing of the Lake for Blue-Green Algae since February 2003 in the warmer months. There were 5 minor green alert periods in regards to the levels of toxic Blue-Green Algae in the initial period of testing in February/March 2003. In January and March 2009, and February 2010 there were major red alert periods in which the public was notified by signage and adjoining residents by letter, to not have contact with the water because of the potential for skin irritation and infection.

Consultants, GHD Pty Ltd, have undertaken water quality sampling, analysis and reporting in regards to stormwater entering and leaving Lake Annan since 2011. Results for Total nitrogen and Total phosphorus have been quite high and algal blooms observed.

1.6.5.3 Lake Y'andelora

A small part of the upper catchment of Lake Annan has had water quality issues partially addressed through the development in 2006 of Lake Y'andelora. The planting of macrophytes in Lake Y'andelora and the inclusion of an adjoining low flow in-stream swale to treat nutrients appear to be inadequate in treating the poor water quality issue.

There is also erosion at the in-stream swale on the upstream side of the Lake and there are no GPTs upstream of the Lake, which means there is excessive siltation of the Lake.

1.6.5.4 Pest Fauna

In the past pest fauna including Purple Swamp Hen, domestic ducts, carp and mosquito fish (Gambusia) have had a detrimental impact on the water quality and native fauna of the Lake. Since July 2006, poor water quality of Lake Annan has been exacerbated by the breeding colony of Australian White Ibis (Ibis) on the island at Lake Annan. The colony is also likely adding to the high phosphorus and nitrogen and is a public nuisance because of the size of the colony and the noise and odour generated.

Camden Council commenced detailed ibis population counts on 25 August 2009 with a population count of 1,109 Ibis (including chicks). Jacks Gully became a covered Waste Facility in late 2008, and the landfill was closed to putrescible wastes in 2009. The Ibis population subsequently dropped to an average peak of 700 birds in 2010, 2011 and 2012.

Camden Council developed a Management Plan for Australian White Ibis at Lake Annan to manage the Ibis population at Lake Annan and mitigate the public nuisance concerns. In accordance with the Management Plan, Council has undertaken oiling of the Ibis eggs and an ecological burn of abandoned nests.

Periodically there has been large numbers of Corellas (Cacatua sp.) at Lake Annan and they are presently in large numbers roosting on the island at night. They may at times also contribute to high phosphorus and nitrogen levels at the Lake.

1.6.5.5 Gross Pollutant Trap

Council engaged consultants, Optimal Stormwater, in early 2013 to investigate the retrofit of the existing main GPT or the installation of a new GPT to replace the existing main GPT at the inlet of Lake Annan. The proposed GPT was to be assessed on the following basis:

- Reliability of the solution;
- Available space for installation;
- Hydraulics of the solution;
- Suitability based on diversion chambers and depth to invert;
- Ease of maintenance and operation;
- Estimated cleaning frequency; and
- Capital and life cycle cost.

The GPT was to meet the minimum pollutant retention criteria provided in Table 1:

POLLUTANT	PERCENTAGE RETAINED
Gross Pollutants	80-100%
Coarse Sediment (> 0.5mm)	60-80%
Medium Sediment (0.1mm to 0.5mm)	50-70%
Fine Sediment (< 0.1mm)	40-60%

Table 1: Minimum Pollutant Retention Criteria

It is recommended that the GPT is to be moved further upstream to the existing GPT which will improve the function of the GPT and resolve most of the issues experienced with the existing GPT. This will also require the removal of the existing GPT.

1.6.5.6 Stormwater Harvesting

Council currently draws water from Lake Annan to irrigate Birriwa Reserve, Mount Annan. The average amount of water drawn over the last 12 months is:

- Spring/Summer – 127,500 litres/week x 27 weeks = 3,442,500 litres
- Autumn/Winter – 63,750 litres/week x 25 weeks = 1,593,750 litres
- Total per annum = 5,036,250 litres

Council has also connected Wandarrah Reserve, Mount Annan to Lake Annan for the purposes of irrigation, but at present the water from Lake Annan is not being utilised.

1.6.6 Requirements of Study to Prepare Concept Designs for Water Quality Treatment Devices at Lake Annan

Council engaged consultants, Storm Consulting, in May 2013 to prepare three concept designs for Water Quality Treatment Devices that addressed the water quality issued and in particular, reduced the concentration of fine particulate and dissolved pollutants in Lake Annan. The three concept designs were to incorporate water control treatments that include Water Sensitive Urban Design (WSUD) and Constructed Wetland Principles.

Additionally the design concepts were required to provide a design that retains a sufficient volume of water within Lake Annan during drought periods to allow the continued harvesting of water for irrigation Birriwa and Wandarrah Reserves. An option to be investigated and considered included the retention of significant areas of open water for aesthetic reasons, but the removal of the island.

The specific objectives for the original Lake Annan Plan of Management were required to be addressed in the concept designs an the constructed wetland was to be designed to retain nutrients, heavy metals, bacteria and other pollutants. The components of the constructed wetland were to include energy dissipation and sediment removal, flow spreader, macrophyte vegetation bans, open water and outlet control.

The above treatments needed to be considered for removal efficiency, maintenance requirements, social requirements, impacts and costs. Water quality and environmental flow standards to be met in regards to constructed wetlands are as per Council's Engineering Specifications.

To determine the expected performance of the water quality control treatment devices in each conceptual design, Storm Consulting was to undertake Model Urban Stormwater Improvement Conceptualisation (MUSIC) modelling incorporating the Lake Annan Catchment, including the Lake Y'andelora sub catchment. A comparative analysis of the Water Quality Treatment Devices was to be undertaken addressing the following criteria:

- The expected performance of each water quality control device to the catchment area and types of pollutant loads;
- The ease of access to and from each water quality control device for construction and maintenance purposes;
- The projected detail engineering design costs for each water quality control device;
- The projected capital and construction costs for each water quality control device;
- The projected landscaping costs for each water quality control device;
- A Concept Maintenance Plan for each water quality control device;
- The projected ongoing maintenance cost for each water quality control device; and
- A preliminary report recommending the optimum water quality treatment at Lake Annan.

SECTION TWO: STRATEGIC FRAMEWORK

Lake Annan was originally developed for scenic purposes but has been impacted by a range of issues including low water quality. To regain the scenic qualities of the Lake, a diverse and sustainable approach to design management is required.

2.1 THE VISION

The specific vision for Lake Annan is:

To create a sustainable, ecologically diverse aquatic and riparian environment that successfully integrates with the adjoining park areas and surrounding urban environment.

2.2 MANAGEMENT OBJECTIVES

Specific objectives for the management of Lake Annan and its surrounding riparian environment and parkland have been developed from and in addition to the core objectives for management of community land under the *Local Government Act 1993* (included in the Camden Riparian Areas Plan). These are:

- To protect and enhance the biodiversity and ecological values of the Lake, particularly in relation to water quality, native vegetation, and fauna habitat.
- To minimise long-term maintenance costs.
- To maintain and enhance opportunities for passive recreational, cultural, social and educational pastimes and activities, without compromising ecological values.
- To conserve and enhance the scenic landscape qualities of the Lake.
- To encourage community involvement in the on-going management of the Lake and improve awareness of its existing and potential ecological values.
- To promote monitoring of the Lake to evaluate and improve environmental outcomes.

LAKE ANNAN

SPECIFIC AREA PLAN OF MANAGEMENT

ISSUES AND STRATEGIES

SECTION THREE: MANAGEMENT ISSUES

Management of the land must take into account the Plan's objectives, that is, to manage the land in a way that protects the natural values of Lake Annan.

3.1 LAKE DESIGN

The initial design of Lake Annan has led to many of the problems inhibiting the function of the Lake. Such issues identified are as follows:

- Lake Annan is considered undersized to effectively undertake water quality control functions for the catchment it services, at only 1% of the catchment size.
- Catchment impacts of water quality and sedimentation are adversely affecting the Lake. Development in the upper catchment has exacerbated these problems.
- The Lake and inlet structure are built in-line to the drainage system, which affects the water quality control functions. The GPT is inefficient due to overtopping and remobilisation of nutrients/pollutants and collected sediment in high flows (see Section 1.6).
- The GPT design is poor and ineffective, with particular problems including the permanent pool, position of the low flow pipe, and no high flow bypass (see Section 1.6).

The design of Lake Annan and the GPT limit the effectiveness of the Lake as a water quality control pond for the catchment upstream. Additionally, there is an inherent conflict between the two functions of the Lake, as a water quality control pond and as an aesthetic element in the landscape.

Optimal Stormwater investigated the replacement of the GPT in June 2013 and identified that Council should take the GPT upgrading opportunity, to install a more effective, more reliable underground GPT that will not have the aesthetic and work, health and safety issues of a trap similar to the existing GPT.

It has been recommended by Optimal Stormwater that Council install a single P2018 CDS unit. It is also recommended for ease of construction, ease of cleaning, and the highest levels of functionality, the GPT should be moved upstream of the existing location.

Storm Consulting prepared a report in June 2013 that provided three Concept Design Options for water quality control treatment which included:

- Water Sensitive Urban Design treatment devices;
- A volume of water that is accessible for irrigation purposes; and
- One option which retained significant areas of open water for aesthetic reasons, and also the removal of the island.

The design components of the three Concept Designs, A, B and C are summarised below:

	DESIGN INTENT AND COMPONENTS	SIZE	COSTINGS
Concept A	Max flow path through reed bed. Open water retained. Island retained. Inlet zone for sedimentation.	9,228 m^2 12,442m^2 2,702m^2	Capital Investment: $695,000 20 Year Maintenance: $237,600 **Total Cost: $932,600**
Concept B	Island utilised as reed bed. Open Water retained. Inlet zone for sedimentation.	1,880m^2 20,645m^2 4,030m^2	Capital Investment: $481,000 20 Year Maintenance: $207,600 **Total Cost: $688,000**
Concept C	Three floating wetland substrates, one positioned at inlet, protected by cage. Most of open water retained (visuals retained). Island retained. Inlet zone for sedimentation. Permeable Reactive Barriers (flow filters through).	320m^2 2,702m^2	Capital Investment: $360,000 20 Year Maintenance: $287,600 **Total Cost: $647,000**

Table 2: Summary of Concept Designs

Capital cost is made up of detailed design cost, capital and construction cost, and landscaping cost.

The full report by Storm Consulting is provided in Section 8, Appendix 3 – Concept Designs for Water Quality at Lake Annan. A comparison and recommendation by Storm Consulting of the functionality of the Three Concept Design is as follows:

Concept Option A: Maximum Reed Bed - provides the best water quality improvement performance. However, it also has the highest cost of the three options and the additional cost does not appear to provide good value for money in relation to the additional treatment provided. It will also transform the Lake visually and have other associated risks. Storm Consulting do not recommend this option because of the design.

Concept Option B: Replace Island with Reed Bed - is a good option if removing the island is a preferred strategy. Storm Consulting note that without a large ibis population that the island could be revegetated to make it more attractive, so the issue is whether the bird population can be controlled. The bird population is created by the operation of open landfills in the Sydney region. All landfills are identified to close within a few years.

Concept Option C: Floating Wetlands; has the least impact on visual quality of the lake while also providing relatively good water quality improvement. The reported water quality improvement is understated because Storm Consulting have not factored in the ongoing effect of the Permeable Reactive barrier to lock up Phosphorus over time, thereby preventing algal blooms in the lake. This option is somewhat experimental, but there is research and applications in Australia to be guided by.

The key risk factors identified by Strom Consulting that ought to inform a decision to select an option are as follows:

- **Climate Resilience;** will fluctuating water levels affect the viability of the reed beds, especially if water levels drop below the reed bed base for extended periods. The other issue is in a general sense, will fluctuating water levels be too much for the reed bed plants to bear.
- **Reed Bed Resilience;** will sediment carry over from the inlet sediment zones clog up the reed beds, particularly at their leading edge, which would require clean-out periodically. Note the water quality modelling shows that only about half the sediment load is retained in the inlet sediment zones, and so the remainder would travel through the reed beds.
- **Bird Predation of Planted Reed Beds;** waterfowl have a habit of preferring small plants and they can devastate planted areas. There are two typical ways to prevent this from occurring, i.e. bird netting and planting more mature plants which the birds do not prefer. Neither cost is included in the cost estimates.

These three risk factors apply to Concepts A and B only. Option C is immune to each issue because the reed beds are supported by a floating substrate and protected by a bird cage.

Recommended Option

Storm Consulting has recommended Option C for implementation based on the following summary of findings:

- Minor Impact on the visual appearance of the lake;
- Retention of the island and its biodiversity (which can be enhanced);
- Lowest capital cost;
- Lowest cost over 20 years of operation (includes construction);
- Not affected by fluctuating water levels;
- Not affected by sediment overloading;
- Not affected by bird predation of planted areas; and
- Ability to be easily retrofitted with additional water quality improvement in a staged manner.

The preferred Water Quality Treatment Concept C is provided in Section 5: Masterplan.

3.2 WATER QUALITY

Lake Annan faces the following water quality issues:

- Sedimentation of unknown quantities impacts on the storage volume and water quality as a result of on-going development in the catchment. A potential further loss in water volumes is yet to occur (from further upstream development planned).
- Nutrients are remobilised in the current GPT because of the wet bottom design and are being fed into the Lake in soluble form. Nutrients are also being fed into the Lake attached to sediment remobilised by storm events.
- Turbidity has resulted in poor water clarity caused by fine colloidal material from catchment soils.
- Algal growth in the form of filamentous green algae and blue-green algae indicate excess nutrient levels in the Lake.

Excess sediment and nutrients in the Lake are resulting in poor water quality and algal growth. Actions to improve water quality must be implemented in order to enhance environmental values e.g. habitat provision, and aesthetic amenity of the Lake.

Optimal Stormwater utilised MUSIC modelling to determine pollutant removal with the CDS Unit P3018. The modelling identified the following pollutant removal.

	TOTAL SUSPENDED SOLIDS	GROSS POLLUTANTS	TOTAL NITROGEN	TOTAL PHOSPHOROUS
% Removal	78%	92%	0%	57%
Load Removed (kg/year)	82000	23000	0	162

Table 3: Pollutant Removal Expected with the CDS Unit P3018

Taking into account the characteristics of the catchment and the interactions between flow and pollution transport, Optimal Stormwater is of the opinion the actual removal for gross pollutants would be expected to be 80% to 85% and around 60% to 70% for total suspended solids. The installation of a second similar CDS unit would expect an additional 5% to 10% increase in pollution removal outcomes and a 70% increase in cost. This is considered a poor cost benefit outcome to Council.

The Concept Designs for Water Quality Treatment at Lake Annan prepared by Storm Consulting in June 2013 assumed the effective trapping of gross pollutants in the upstream catchment and their routine removal to ensure ongoing removal efficiency remains high.

Storm Consulting found that widespread removal of the existing sediments from the lake is considered unfeasible. Where earthworks are proposed, lake sediments may be capped with imported sandy soil / spoil. Where sediments remain exposed on the lake bed, chemical stabilisation is required to prevent ongoing release of phosphorus.

In respect of the three Concept Designs for Water Quality Treatment, the following reductions in pollutants were identified:

	% REDUCTION		
POLLUTANT	**Concept A**	**Concept B**	**Concept C**
Total Suspended Solids	67%	58 %	55%
Total Phosphorus	45%	39%	28%
Total Nitrogen	15%	11%	2%
Gross Pollutants	55%	54%	55%

Table 4: Water Quality Performance of Water Quality Treatment Options

Storm Consulting has indicated that literature on the performance of floating wetlands is scarce but they can be up to ten times more effective than a conventional reed bed for the same unit area based on increased density of the root system, increased surface area contact of the roots in the water and "biofilms" on the roots that promote bacteria which improves water quality. For the purpose of the study, Storm Consulting adopted an efficiency of five times (5X) that of reed beds and also identified the following matters for consideration in dealing with water quality in the Lake Annan Catchment.

MUSIC modelling is not fully applicable to floating wetlands as it does not perceive there to be shallow water levels as occurs in a reed bed. The 2% reduction indicated for Total nitrogen may therefore be conservative. However the target pollutant is phosphorous, with nitrogen levels not being as important in the development of algal blooms. There is the potential to incorporate additional floating wetlands subject to monitoring and assessment of the initial installed floating wetlands.

Lake Annan (2.7 ha) and Lake Y'andelora (1.8 ha approx. area) represent 1.7% of the contributing catchment and to achieve best practice water quality performance, a constructed wetland should be 3% of the catchment.

Lake Annan and Lake Y'andelora is therefore highly unlikely to achieve best practice water quality treatment. In this regard Council may need to look at additional water quality treatment options in the catchment such as rain gardens in some of the existing drainage swales in the catchment.

3.3 VEGETATION MANAGEMENT

Native vegetation and aquatic macrophytes perform roles in water quality control, fauna habitat and visual amenity of the lake. Issues are as follows:

- Macrophyte coverage in the Lake is sparse and does not achieve the design intent of 30%. In addition, die off of macrophytes has been observed. Impaired light penetration as a result of high turbidity is believed to have been the reason for loss of macrophytes. Waterfowl was thought to have contributed to the suppression of growth by feeding on any new green shoots as they emerge.
- Terrestrial weeds such as Kikuyu (*Pennisetum clandestinum*) encroach into the macrophytes at the edge of the Lake and competes with our natives.
- Aquatic weeds (noxious and other serious weeds) have the potential to dominate open water and marsh zones of the Lake. These are potentially insurmountable to control both economically and physically if a large infestation occurs.

- The island and its bushland remnant with supplementary planting potentially provided valuable fauna habitat. However, the flora and fauna of this island has been impacted heavily since July 2006 by the Ibis population. Approximately 50% of the vegetation has died and the Australian White Ibis population has generally excluded other fauna utilising the island to habitat.
- The riparian zone around Lake Annan lacks a substantial native riparian edge vegetation community as required by the objectives for the management of this zone.

Aquatic macrophytes in the past been under stress die to impacts from water quality and water birds in the Lake, and coverage is well below the design intent of 30% if the Lakes surface. The buffer zone around Lake Annan lacks a substantial native riparian edge vegetation community to function in water quality protection, erosion control, habitat provision, aesthetic amenity and education in accordance with the objectives of this Plan and management of wetlands under the Local Government Act.

3.4 EROSION

The lake shores have minor erosion in the form of scalds and sheet runoff leading into the Lake, and undercutting of the bank. The erosion is pronounced on the south and east banks. The island is displaying active erosion on the northern bank which requires repair. Erosion of the southern and eastern banks is not serious enough to warrant repair in isolation. Erosion should be repaired concurrently with earthworks in these locations. The northern bank of the island requires repair to arrest erosion that is occurring.

3.5 MAINTENANCE

Wetlands constructed and occurring naturally within an urban environment suffer from a number of constraints placed upon them by disturbance within the contributing catchment. Consequently a wetland in an urban environment cannot be expected to perform as a natural system without regular maintenance. Operation and maintenance must ensure that:

- The wetland operates as designed and the objectives are met;
- The active lifespan of the wetland is extended, delaying the need for a major retrofit or decommissioning;
- Operational staff are allowed to make informed decisions and ensure new staff can effectively manage the wetland; and
- Money is saved by providing the mechanism through which problems such as weed infestations can be detected in the early stages. This often results in solutions that are much cheaper and simpler to implement that later remedial action (DLWC 1998).

Maintenance issues for Lake Annan include the following:

- Maintenance is currently limited to mowing, litter collection, removal of rubbish and removal of dead Ibis from the island.
- Mowing is undertaken close to the edge of the Lake in some sections and native plantings on the edge of the Lake in other sections are not maintained.
- Council outsources the design and determination of maintenance of the wetland.
- GPT maintenance and inspections are scheduled and undertaken every 3 months; however there has not been consistent auditing to see if the schedule achieves optimum results.

- In high flow rain events the trash rack at the main inlet of the main GPT overtops and trapped litter is released into the Lake.
- There will be some continued sedimentation of the Lake and it will be required to be surveyed in the future to determine if and what level of de-silting is required.

Additionally the redesign and construction of a constructed wetland will require general maintenance to be undertaken, including:

- Removal of accumulated sediment and debris from inlet sediment zones.
- Replanting of denuded areas of macrophyte planting.
- Repair of erosion/scour of embankments, or undermining of rockwork.
- Replacement of permeable reactive barrier in Concept C.

A wetland in an urban environment cannot be expected to perform as a natural system, without regular maintenance, due to the ongoing catchment impacts. Current maintenance practices at Lake Annan are currently limited and not in accordance with the objectives for the management of the Lake in terms of enhancing native vegetation, habitat provision and water quality functions. Clear delineation of maintenance responsibilities and adequate resources are required to effectively manage Lake Annan, so as to enhance its environmental and parkland functions.

3.6 PEST FAUNA

Pest fauna likely to impact on the various ecological and aesthetic functions of Lake Annan are as follows:

- Purple swamp hen *(Porphyrio porphyrio)* nesting and feeding activities have substantially damage aquatic macrophytes in the past when the macrophytes were being established.
- Domestic ducks in large number have in the past had an impact on the performance of the Lake, in particular water quality functions.
- Carp *(Cyprinus carpio)*; anecdotal evidence in the past indicated the presence of Carp in Lake Annan, however it is considered that there are no carp present in the Lake due to low water quality. Carp are suspected of generating high turbidity when food in the water column is scarce (i.e. winter) by sucking soft plant matter and detritus from the substratum. An investigation is required to confirm whether carp are present in the Lake.
- Mosquito fish *(Gambusia holbrook)* is virtually impossible to control/eradicate in an open space system such as Lake Annan but is classified as a *Threatening Process under the Threatened Species Conservation Act 1995*. It is considered that there are no Mosquito fish present in the Lake due to low water quality. An investigation is required to confirm whether Mosquito fish are present in the Lake.
- Mosquitoes are a potential public health issue in constructed wetlands such as Lake Annan.
- Companion animals such as dogs and cats may have an impact on native fauna and their habitat and there are also potential water quality issues from dog faeces.
- Feral animals such as foxes and cats may also be present and potentially impacting on the use of the site by native fauna.
- Australian White Ibis will continue to impact on water quality and vegetation on the island whilst numbers are high.

Pest fauna in Lake Annan and the surrounding riparian areas may be having a detrimental impact on the water quality and native fauna use of the Lake.

3.7 RECREATION

Recreational use of Lake Annan is predominantly passive and includes picnicking, walking dogs, cycling, walking, and children's' free play. The Lake's amenities are mostly used by local residents and generally meet current recreational uses. It is not expected the Lake will be suitable for primary contact after the proposed measures are undertaken.

The path at Lake Annan is not continuous so people are unable to do a complete walk around the Lake other than having to use part of the road system.

3.8 COMMUNITY ISSUES

Community awareness is vital for the ongoing success and functioning of Lake Annan. Currently there are a number of obstacles preventing this and issues were raised by concerned residents during the community consultation process prior to the adoption of the original Plan of Management on 28 July 2003:

- Lack of understanding of catchment issues and impacts; ecological processes, values and functions amongst the community. In particular, many residents are not aware of the weed and nutrient issues related to residential gardening practices, and the tipping of grass clippings.
- Community perception; a proportion of the community appear to place no value or are unaware of the values of Lake Annan, which is observed, for example, by littering and vandalism.
- The aesthetic amenity of Lake Annan is compromised by various things such as odours from stagnant water, poor water quality, dog faeces and unsightly stormwater infrastructure.
- Views onto the Lake are important to residents and extensive planting has been undertaken with no shrub planting in order to maintain views.

Lake Annan is valued greatly by much of the community as an open space resource. However, lack of awareness of the ecological values and the adverse effects that human activities in the catchment may have on the wetland and waterways in general has contributed to compromise of the visual amenity and ecological functioning of the wetland.

SECTION FOUR: MANAGEMENT STRATEGIES

A range of clearly defined strategies are required to address the diverse range of issues. The three principal strategies relate to Lake Design, Water Quality and Vegetation Management. All strategies have detailed actions set out in Section Six.

4.1 LAKE DESIGN

To improve functioning of the Lake, the following design issues need to be addressed:

- **Concept Designs for Water Quality Treatment**

Construct Water Treatment Concept Design – Option C as prepared and recommended by Storm Consulting.

- **Replace GPT**

Install a single P3018 CDS (Continuous Deflective Separator) Unit as recommended by the consultant Optimal Stormwater. The P3018 is the largest diameter CDS Unit available.

- **Remove Existing GPT**

After the replacement GPT is installed, remove the existing GPT prior to the installation of the floating wetlands and associated water quality treatment devices.

- **Water Level Control**

Install water level control mechanism for the purpose of aquatic plant establishment, water quality and regular maintenance (macrophyte maintenance, required weed removal, wetting and drying cycle which assists in natural regeneration) and infrequent maintenance (sediment removal, major noxious weed infestations and any infrastructure repair).

4.2 WATER QUALITY

Undertake monitoring of the constructed wetlands developed as per Option C to ensure they meet the Total phosphorous removal as per Table 3.1 (Water Quality Performance of Options – Storm Consulting) refer Appendix 2.

Undertake monitoring of the newly constructed GPT to ensure it is removing 80% to 90% of the mean annual load of total gross pollutants at this source as per the findings of Optimal Stormwater (24 June 2013).

Undertake maintenance of Lake Annan, the constructed wetlands and the GPT (see section 4.5).

Investigate the feasibility of implementing water quality treatment upstream of Lake Annan.

4.3 VEGETATION MANAGEMENT

- **Terrestrial Weeds**

Incorporate weed eradication as part the riparian landscaping and incorporate in the Council’s annual Bush Regeneration program.

- **Aquatic Weeds**

Monitor weeds regularly as part of maintenance inspections. If they occur develop a site specific aquatic weed removal program and incorporate in the Council's overall aquatic weed program.

- **Island Bushland Refuge**

When the population of Australian White Ibis is below 50 birds, undertake enhancement of the vegetation to maximise biodiversity and habitat/refuge.

- **Riparian Edge Zone**

Complete and maintain a full planting of a 3 metre wide strip of native grasses and forbs around the edge of the Lake.

4.4 EROSION

Undertake rehabilitation of erosion of the southern and eastern banks concurrently with the earthworks in these locations when the constructed wetlands works are undertaken.

4.5 MAINTENANCE

- **Maintenance Regime**

Implement a regular maintenance regime for Lake Annan and the constructed wetland following the maintenance manual developed by Storm Consulting (refer Appendix 2).

- **Maintenance Responsibility and Staff Skills**

Identify Maintenance Responsibility and required Staff Skills, including training.

- **Maintenance Practices**

Formalise open space (park) and riparian (natural area) zones and develop a maintenance plan for the riparian zone and implement appropriate maintenance. This will also prevent mowing of native grasses and macrophytes growing around the Lake edge.

- **GPT Maintenance**

Implement a maintenance plans for the main GPT and the two minor GPTs.

- **Litter Collection**

Prevent litter entering Lake Annan via stormwater. Remove litter regularly from the GPT.

4.6 PEST FAUNA

- **Purple Swamp Hen**

If Purple Swamp Hen numbers are high and causing excessive environmental damage liaise with the NSW National Parks and Wildlife Service (NPWS) with regard to limiting Purple Swamp Hen numbers. Develop an agreed policy and process for management of the species. If any adverse impacts on macrophyte establishment and growth is observed, trapping and relocation may need to be undertaken in consultation with the NPWS.

- **Australian White Ibis**

Council continue to implement the Management Plan for Australian White Ibis (AWI) at Lake Annan, including monitoring a potential population that may shift to the island at Lake Y'andelora within the Lake Annan catchment or to the island at Harrington Park Lake. Additionally the population should be monitored regularly at Lake Annan as there is a tendency for the AWI to return to their original breeding site within 2 to 3 years of original dispersal.

- **Domestic Ducks**

Discourage the release of domestic water fowl and feeding of ducks. Impounding of domestic ducks may need to be considered, followed by destruction if not claimed.

- **Carp and Mosquito Fish**

Undertake an investigation to confirm whether Mosquito fish or Carp are present in the Lake when the Lake is drained at the time of the construction of wetlands and associated works. If present consult Fisheries NSW and develop an eradication program prior to construction being undertaken. After the construction of wetlands, undertake monitoring program to determine whether the population of the species still exist or has re-established. If species repopulate the Lake, develop an eradication program in consultation with the NSW Fisheries.

- **Mosquitoes**

Promote diverse habitats for predators and seed predators into the system (e.g. larvivorous fish), and retrofit with water level control device.

- **Companion Animals**

Educate residents on responsible pet ownership and the potential impacts of companion animals on the ecological functions of riparian systems.

- **Feral Animals**

Assess as required presence and abundance of feral foxes, cats and rabbits and assess impacts. Where rabbits and feral cats reach problematic numbers, put suppression measures in place.

4.7 RECREATION

Develop a continuous path system to create a loop around the lake.

4.8 COMMUNITY ISSUES

- **Community Awareness**

Develop a community education program and facilitate local community involvement to develop a sense of ownership and understanding of catchment management issues such as pollution and sediment reduction.

- **Signage**

Maintain signage to:

- Improve safety; and
- Inform users of prohibited activities e.g. dumping of litter, garden rubbish, grass clippings and appropriate behaviour (e.g. removal of dog faeces).

Install signage to:

- Interpret the environmental values and functionality of the Lake, and surrounding riparian environment.

- **Community Perceptions**

Establish Lake Annan Community Working Group, develop liaison with Council, and develop Community Education Program and undertake a field day to present the Concept Design for Water Quality Treatment – Option C to the community. In addition undertake regular policing of the area to deal with issues as they arise.

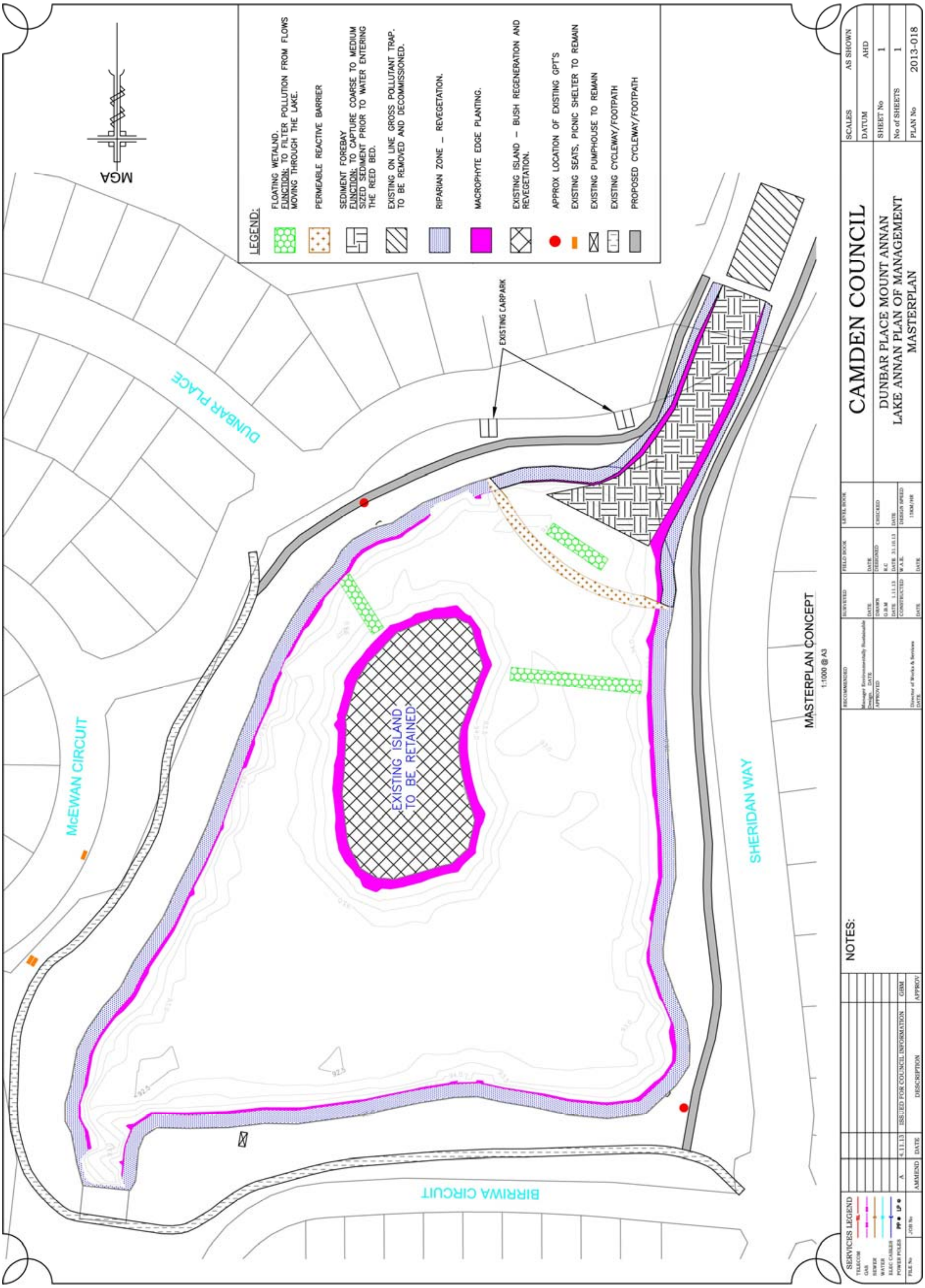
LAKE ANNAN

SPECIFIC AREA PLAN OF MANAGEMENT

IMPLEMENTATION

SECTION FIVE: MASTERPLAN

FIGURE 1: SITE ANALYSIS



SECTION SIX: ACTION PLAN

6.1 APPLICATION OF MANAGEMENT POLICIES AND GUIDELINES

The management strategies and actions specified by this Plan are to be taken into consideration by Council when making management decisions. Council is responsible for implementing and reviewing the provisions of this Plan.

6.2 ACTION PLAN SCOPE

This plan (overleaf) specifies:

- Actions specific to each strategy;
- Performance measures for which the action can be measured; and
- Priorities for actions.

Priorities have been set according to Council's 2040 plan and associated Delivery Program.

6.3 PERFORMANCE TARGETS AND PRIORITIES

The Plan establishes a performance regime that sets strategic action and tracks progress over an initial 5 year period.

The basis of performance monitoring is the extent to which strategic actions are implemented and whether they are undertaken according to the priority of the plan.

- High Priority Actions should be commenced within 1 year from the adoption of this plan and completed within 2 years.
- Medium Priority Actions should be commenced within 2 years from the adoption of this plan and completed within 3 years.
- Low Priority Actions should be commenced within 4 years of the adoption of this plan and completed within 5 years.

Evaluation of achievement of the Action Plan is to be undertaken by Council's Environmentally Sustainable Design section on an annual basis. Performance of the Plan in relation to Lake Annan will be based on the extent to which the implementation of the strategic actions actually achieve the stated outcomes and meet the objectives and performance criteria identified in the Plan.

6.4 REVIEW OF PLAN

The Plan of Management applies for a period of five (5) years commencing on the date of its adoption by Council, after which period the Plan must be reviewed and updated.

Council should commence a review of the Plan at least one year prior to the date on which it lapses. The review is to include all relevant background information, including updated ecological information and details of proposed works and expenditure.

6.5 ENDORSED ACTIVITIES

In accordance with the provisions of s. 36 of the *Local Government Act 1993,* the activities and improvements endorsed under this Plan include:

- Detailed design and installation of Water Quality Treatment Devices including constructed wetland at Lake Annan;
- Replacement of the main GPT;
- Installation of interpretive and other signage;
- Macrophyte planting;
- Other recommendations noted on the Masterplan; and
- Those items listed in the Action Plan.

STRATEGY: LAKE DESIGN

NO.	ACTION	PERFORMANCE MEASURE	PRIORITY
1	**Mitigate Catchment Impacts**		
1a	Commission detailed design for Water Quality Treatment Devices as per Option C prepared by Storm Consulting Pty Ltd.	Design commissioned, undertaken, put to Council for approval.	H
1b	Undertake a Review of Environmental Factors and seek all necessary licences.	Review of Environmental Factor completed, amelioration measures adopted, necessary licences obtained and Water Quality Treatment Devices including Constructed Wetland approved.	H
1c	Construct Water Quality Treatment Devices as per detailed designs.	Water Quality Treatment Devices including Constructed Wetland constructed.	H
1d	Investigate feasibility of implementing water quality treatment upstream of the Lake, e.g. Rain Gardens in existing drainage swales, Water Sensitive Urban Design embellishment of inlets to Lake Y'andelora.	Where feasible Water Quality Treatment Devices, designed, assessed, approved and installed upstream of Lake Annan.	M
1e	Investigate feasibility of installing additional floating wetlands.	Monitoring, assessment and adequate performance of existing installed floating wetlands.	L
2	**Replace Main GPT at Lake Annan**		
2a	Commission detailed designs for replacement of main GPT.	Design commissioned, undertaken, put to Council for approval.	H
2b	Undertake a Review of Environmental Factors and seek all necessary licences.	Review of Environmental Factor completed, amelioration measures adopted, and necessary licences obtained and GPT approved.	H
2c	Install new main GPT as per detailed design.	GPT installed.	H
2d	Remove existing GPT and reconstruct the inlet zone to the Lake.	Existing GPT removed.	H

3	**Water Level Controls**		
3a	Prepare designs for an adjustable control weir and outlet pipe to allow water level to be controlled for maintenance purposes. Pipeline could be routed around the ends of the abutments if it is not feasible to construct through the main embankment.	Design commissioned, undertaken, put to Council for approval, and changes put into place.	H

STRATEGY: WATER QUALITY

NO.	ACTION	PERFORMANCE MEASURE	PRIORITY
4	**Assess Sediment Volume and Quantity**		
4a	Undertake annual sediment survey of inlet sediment zone.	Survey commissioned and undertaken.	M
4b	Remove sediment when it accumulates to average depth of 0.5 metre across sediment deposition zone.	Sediment removed.	M
4c	Undertake bathymetric survey in 2018.	Survey commissioned and undertaken.	L
4d	Obtain sediment core samples and analyse for sediment grading, phosphorus, metals and level of contamination.	Survey commissioned and undertaken.	L
5	**Algae**		
5a	Undertake weekly monitoring algae in warmer months.	Monitoring undertaken.	M
6	**Water Quality Monitoring**		
6a	Maintain water quality testing on a regular basis using physiochemical and undertake biological monitoring using macro invertebrates.	Physiochemical testing maintained. Detailed water quality monitoring records compiled and available for use to guide management decisions.	M

STRATEGY: VEGETATION MANAGEMENT

NO.	ACTION	PERFORMANCE MEASURE	PRIORITY
7	**Macrophytes**		
7a	Prepare a macrophyte planting plan. Note: Positioning and extent of coverage to be informed by storm standards.	Plan prepared for macrophyte planting to areas designated in the Masterplan.	H
7b	Undertake plantings of macrophytes and underwater plants.	Plantings in place, monitored, maintained and replaced as required.	H
8	**Terrestrial Weeds**		
8a	Undertake weed removal/eradication on riparian edge.	Weeds eradicated as per Council's annual Bush Regeneration program.	M
9	**Aquatic Weed**		
9a	Monthly inspections as per maintenance regime.	No aquatic weeds present.	M
10	**Island Bushland Refuge**		
10a	Undertake enhancement of the vegetation on the island when the Australian White Ibis population is at a manageable level.	Vegetation restored, regular bushland maintenance carried out on the island as per Council annual Bush Regeneration Program.	L
11	**Riparian Edge Zone**		
11a	Undertake native grass and forb planting on 3 metre strip edge of the lake.	Native vegetation buffer established in the riparian zone for full edge of the Lake.	M

STRATEGY: EROSION

NO.	ACTION	PERFORMANCE MEASURE	PRIORITY
12	Undertake rehabilitation of the eroded northern, southern and eastern banks concurrently with the earthworks in these locations when the constructed wetland works are undertaken.	Eroded banks rehabilitated upon completion of the constructed wetlands.	M

STRATEGY: MAINTENANCE

NO.	ACTION	PERFORMANCE MEASURE	PRIORITY
13	**Maintenance Plan**		
13a	Formalise open space and riparian zones as per Masterplan to designate zones for maintenance.	Clear delineation between open space and riparian zones. Edge clearly defined.	M
13b	Develop detailed Maintenance Plan for the Lake based on the Concept Maintenance Plan developed by Storm Consulting and the detailed design.	Lake being maintained to optimum level.	M
14	**GPT Maintenance and Inspections**		
14a	Develop a maintenance and monitoring plan for the main GPT and the two minor GPTs.	GPTs being cleaned and maintained to optimum level.	M
15	**Maintenance Responsibility and Staff Skills**		
15a	Identify maintenance responsibilities of staff and undertake training for all current maintenance and management staff with regard to management of riparian areas.	Training undertaken.	M
16	**Lake Maintenance Regime**		
16a	Implement maintenance regime and allocate responsibility, funds and equipment required for maintenance as per maintenance manual.	Regular maintenance and inspection regime in place.	M
17	**Litter Collection**		
17a	Refer to Actions 2, 4 and 17.	Litter and debris absent from the Lake and surroundings.	M

STRATEGY: PEST FAUNA

NO.	ACTION	PERFORMANCE MEASURE	PRIORITY
18	**Purple Swamp Hen**		
18a	Monitor bird impacts during macrophyte establishment and take actions to minimise impact on macrophyte establishment as required.	Monitoring in place; impacts on macrophytes minimised.	M
19	**Domestic Ducks**		
19a	As per Action 21 above.	Monitoring in place; impacts on macrophytes and water quality minimised.	L
20	**Australian White Ibis**		
20a	Continue to implement the Management Plan for AWI, including a potential population shift to Lake Y'andelora.	The population of Australian White Ibis at Lake Annan and its catchment is decreasing.	H
21	**Carp Monitoring**		
21a	At time of draining Lake for construction of wetland, undertake a baseline fish survey to determine Carp population size.	Baseline fish survey completed.	H
22	**Carp Management**		
22a	If present develop and implement an eradication and monitoring program.	Carp removed from the Lake. and being monitored.	H
23	**Mosquito Fish**		
23a	At time of draining Lake for construction of wetland, undertake a baseline fish survey to determine Mosquito fish population size.	Baseline fish survey completed.	M
23b	If present develop and implement an eradication and monitoring program.	Mosquito fish removed from the Lake. and being monitored.	M
23c	After constructed wetland is completed, introduce native predators of Gambusia, to offer some control.	Native Gambusia predators introduced to the Lake.	M

24	**Mosquitoes**		
24a	Control if present in nuisance numbers at Lake Annan.	No mosquito pest problem evident.	L
25	**Companion Animals**		
25a	Educate residents on responsible pet ownership.	Education program in place.	L
26	**Feral Animals**		
26a	Control if present.	No feral animal problem evident.	L

STRATEGY: RECREATION

NO.	ACTION	PERFORMANCE MEASURE	PRIORITY
27	Maintain recreation facilities.	Facilities are usable.	M
28	Complete path system to create a loop.	Community satisfaction.	L

STRATEGY: COMMUNITY ISSUES

NO.	ACTION	PERFORMANCE MEASURE	PRIORITY
29	**Community Awareness/Perceptions**		
29a	Establish ‘Lake Annan’ Community Working Group.	Working Group established.	M
29b	Incorporate Working Group into development of Community Education Program and develop liaison with Council.	Improved communication and relations between the local community and Council.	M
29c	Develop Community Education Program.	Community awareness of environmental issues improved.	H
29d	Organise field day to present the Concept Plan for Water Quality Treatment to the community.	Field day presentation carried out.	H
29e	Install interpretive and other signage as necessary.	Signage installed.	M
29f	Council officers to regularly police the area in order to discourage littering, rubbish dumping and vandalism. Enforce with appropriate penalties.	Fines issued for illegal rubbish dumping, littering, vandalism. The above actions become less prevalent.	M

LAKE ANNAN

SPECIFIC AREA PLAN OF MANAGEMENT

SUPPLEMENTARY INFORMATION

SECTION SEVEN: BIBLIOGRAPHY

Boyden & Partners (1999) Stormwater Management Plan for the Upper Nepean River Catchment. Final Report prepared by Boyden and Partners Pty Ltd, Thornleigh NSW.

Camden Council (1990) Camden Local Environment Plan No. 47. Adopted 3 August 1990.

Camden Council (1999) Camden 2025: A Strategic Plan for Camden. Adopted 13 December 1999.

Department of Foreign Affairs and Trade (1988) Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment. Australian Treaty Series 1981 No. 6. Entry into force 30 April 1981, Canberra.

Department of Foreign Affairs and Trade (1981) Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment. Australian Treaty Series 1981 No. 6. Entry into force: 30 April 1981, Canberra.

Department of Land and Water Conservation (1998) The Constructed Wetlands Manual. Department of Land and Water Conservation New South Wales.

Department of Urban Affairs and Planning (1997) Sydney Regional Environmental Plan No. 20 Hawkesbury Nepean River (no. 2-1997)(SREP 20). DUAP, Sydney.

Department of Urban Affairs and Planning (1997) The Action Plan of the Hawkesbury Nepean Environmental Planning Strategy 1997. DUAP, Sydney.

Hazelton, P.A & Tille, P.J (1990) Soil Landscapes of the Wollongong – Port Hacking 1:100 000 Sheet. Soil Conservation Service of NSW, Sydney.

Fallding, M., Kelly, A., Bateson, P & Donocan, I (2001) The Biodiversity Planning Guide for NSW Local Government. NSW National Parks & Wildlife Service, Hurstville, Sydney.

Land & Environment Planning & Environs Australia (2001) Biodiversity Planning Guide for NSW Local Government, Prepared by NSW National Parks and Wildlife Service, Hurstville.

Optimal Stormwater (2013) GPT Concept Design For Lake Annan, Mount Annan, Prepared for Camden Council by Optimal Stormwater Pty Ltd.

SMEC (1998) Upper Narellan Creek Water Quality System Assessment. Final Draft. Prepared for Camden Council, by SMEC Australia Pty Ltd.

Storm Consulting (2013) Concept designs for water quality treatment at Lake Annan, Prepared for Camden Council, by Storm Consulting Pty Ltd.

SECTION EIGHT: APPENDICES

APPENDIX 1: SCHEDULE OF LAND PARCELS

This plan of management applies to part or all of the following parcels of land. The area of land to which the plan applies in indicated in Map 3. The following information has been obtained from the Council of Camden – Land Register (Section 53 if the *Local Government Act 1993*).

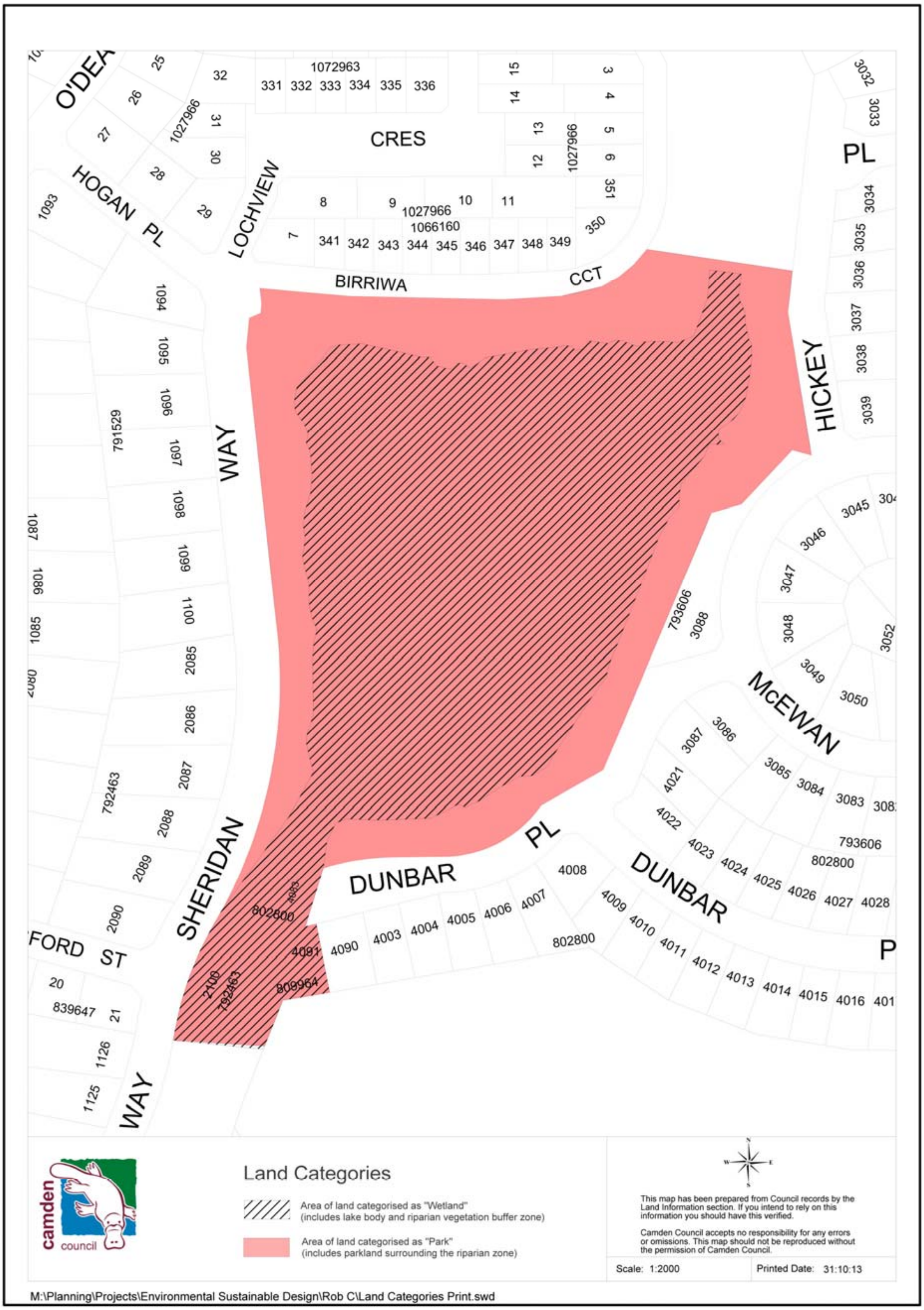
Table 5: Schedule of Land Parcels

NAME	LOCATION	LOT NO.	DP NO.	LAND DESCRIPTION	USES[2] (CURRENT)	CATEGORY[1]	SUB-CATEGORY	ZONING	CERTIFICATE OF TITLE
Lake Annan	**MOUNT ANNAN**								
	O'Dea Road	9000	827294	Public Reserve	Open Space, Playing Fields, Drainage	Park, Natural Area	Wetland		C250
	McEwan Circuit	3088	793606	Public Reserve	Open Space, Drainage	Park			C098
	Dunbar Place	4083	802800	Public Reserve	Open Space, Drainage	Natural Area	Wetland		
	Dunbar Place	4091	809964	Public Reserve	Open Space, Playing Fields, Drainage	Natural Area	Wetland		C260
	Sheridan Way	2100	792463	Public Reserve	Open Space, Drainage	Natural Area	Wetland		C097

[1]Note: Categorisation applies only to whole or part of lots that fall within the area to which this Plan applies. Refer to Map 3 for boundaries.

[2]Uses for categorised land is to be "open space" and "drainage", except Lot 3088 DP 793606 which is to be open space only.

MAP 3: LAND CATEGORISATION PLAN



APPENDIX 2: CONCEPT DESIGNS FOR WATER TREATMENT AT LAKE ANNAN

REPORT PREPARED FOR CAMDEN COUNCIL

BY STORM CONSULTING PTY LTD

DATED 26 JUNE 2013

(INCLUDES SECTION 3.7 CONCEPT MAINTENANCE MANUAL)

Concept designs for water quality treatment at Lake Annan

Report Prepared for:
Camden council

Project No. 1485

Prepared by:
Storm Consulting Pty Ltd

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1.0 INTRODUCTION

1.1. Background

Lake Annan is a purpose-built urban lake in the suburb of Mt Annan South in Camden local government area. The lake was designed to provide an ornamental backdrop to a residential subdivision. While the Lake is still attractive and provides amenity, it also experiences water quality problems and these contribute to a loss of amenity of residents and users of the lake.

This report summarises the findings of a project which seeks to address the water quality problems in Lake Annan to restore or improve its amenity.

1.2. Context

Lake Annan has a catchment area of 270Ha and the Lake is 2.7Ha in area, i.e. the lake represents 1% of catchment area. In the centre of the lake is a 0.3Ha refuge island which is inhabited by birds – dominated by white ibis at the time of writing.

Council on 28 July 2003 adopted a Specific Plan of Management for Lake Annan (PoM). The Plan of Management applied for a period of 5 years and according to its recommendations, is due for revision in 2012-13.

Design problems identified by Lake Annan at the time of adoption of the PoM included:

- The lake is undersized according to its catchment size
- The operation and maintenance of the upstream Gross Pollutant Trap is difficult (primarily because no access provision was made into the GPT)
- Poor water quality due to high turbidity
- Widespread loss of macrophyte plants
- Sediment builds up within the lake
- Localised areas of erosion and bank scalding around the embankments of the lake
- Excess sediment and nutrient in the lake

Various actions recommended in the PoM have been implemented, including the following key items and activities:

- Installation of 2 small CDS units on smaller stormwater inlets to the lake
- A study to retrofit/replace the upstream GPT
- Ongoing water quality testing, including algal levels
- Lake bed bathymetry and sediment layer bathymetry

Despite this, water quality and amenity problems remain in Lake Annan.

1.3. Objectives

The findings of this report are intended to provide the basis for updating the Lake Annan PoM. A Plan of Management will incorporate water quality recommendations which show a concept design and other related works and investigations required to advance or implement it. Costings of the works and activities is provided, including maintenance requirements.

In addition, Council will need to consult with the community about the recommendations that are to feature in the revised PoM. In order to consult with the community, Council requires the development of three different concept designs that will enable the community to provide comment on.

The concept designs are intended to address water quality treatment and to reduce the concentration of fine particulate and dissolved pollutants in Lake Annan. The proposed concepts cannot impede the continued use of water from Lake Annan for irrigation purposes in downstream Council Reserves.

In developing concept designs, the specific objectives of the PoM need to be addressed, including:

To protect and enhance biodiversity and ecological values

- Minimise long term maintenance costs
- Maintain or enhance recreational, cultural, educational and amenity opportunities
- Conserve or enhance scenic landscape outcomes
- Promote monitoring to evaluate and improve environmental outcomes

1.4. Scope

The scope of work conducted in undertaking this project includes the following:

- Desktop investigations – reviews of background material and data supplied by Council for Lake Annan. This includes Lake and sediment bathymetry, water quality results, stormwater network diagram, previous PoM, and a range of other resources.
- Site – investigations – a site and catchment inspection with Council staff to discuss issues, constraints and opportunities for Lake Annan.
- Discussions with suppliers of water and sediment treatment technologies
- Discussions with a construction contractor experienced in lake works to discuss construction methodologies
- Discussions between consultant and Council staff to discuss various issues and constraints

All this background information has been collated and processed prior to undertaking a critical analysis, leading to the development of concepts.

2.0 KEY FINDINGS

Table 2.1 provides a summary of the key water quality related findings and their implications for Lake Annan.

Table 2.1: Key findings influencing the improvement of water quality in Lake Annan

Finding	Implication
Gross pollutant trapping strategy Two minor inflows to the lake have CDS GPTs fitted to them which are effective at trapping coarse pollutants. The major inflow to the Lake has a poorly functioning GPT and this has resulted in the ongoing release of pollution to the lake. Council is seeking to retrofit or replace this GPT.	All concept designs have been developed assuming the effective trapping of gross pollutants in the upstream catchment, and their routine removal to ensure ongoing removal efficiency remains high.
Lake Sediments The lake has accumulated sediments on its bed over years of operation. The sediments are a source of Phosphorus in the lake and this drives algal growth and water quality problems. There is about 12,530m3 of sediment on the base of the pond. At least 7,500m3 of this is classified as sludge, which is typically encountered in urban lakes. This sludge is impossible to work with in an engineering sense (i.e. earthworks). It is also difficult to separate the sludge from other more useful sediments. The accumulation of sediments in the Lake is demonstrated in Figure 2.1 (over page) showing how sediments enter principally at the main inflow and they are mixed and distributed through the Lake.	Widespread removal of sediments from the lake is considered unfeasible. Where earthworks are proposed, lake sediments may be capped with imported sandy soil/spoil. Where sediments remain exposed on the lake bed, chemical stabilisation is required to prevent ongoing release of Phosphorus. Promotion of sedimentation and its ongoing removal should be a key feature of the main inflow to the lake.
Lake water level The lake has a single outlet in the north-eastern end. Essentially the lake overflows when full. Therefore the lake has a variable level depending on inflows, outflows and evaporation. Council draws 3,000- 6,000m^3 of water from the lake each year, depending on need. Council advises that typical water level variability is in a range of 200-300mm below the top water level for the lake. Note that previous macrophyte plantings have been lost from the lake. If this was caused in part by fluctuating water levels, then the adoption of reed beds as a solution may not be feasible. Bird predation is also an issue.	This range of water level fluctuation makes it feasible to introduce reed beds to the lake, and the ideal depth of water in reed beds is 300mm. The ongoing use of the Lake for irrigation water has little noticeable impact on lake water levels, e.g. a 200m^3 irrigation event would result in a fall in water level of <1mm across the lake.
Island and birds The island in the lake is vegetated and a colony of white ibis is present in numbers up to 1100. This is damaging the vegetation on the island, and the birds are contributing high amounts of faecal matter to the. The faecal matter is high in Phosphorus and in a soluble form which is perfect for stimulating algal growth. Council are actively reducing ibis numbers through egg manipulation (under licence).	Numbers of ibis (or other avifauna) need to be kept at manageable levels as per recommendations of Plan of Management

Finding	Implication
Bank erosion The lake shores have minor erosion in the form of scalds and sheet runoff leading into the Lake, and undercutting of the bank. This erosion is pronounced on the south and east banks. The island is displaying active erosion on the northern bank which requires repair	Erosion of the southern & eastern banks is not serious enough to warrant repair in isolation. However, if earthworks are proposed in these locations then this erosion should be repaired concurrently. The northern bank of the island requires repair to arrest the erosion that is occurring.
Carp Council's brief states that carp have been known to inhabit the lake. Carp have a type of feeding behaviour that dislodges sediment and associated Phosphorus, thereby promoting algal blooms	Investigation required to confirm presence of carp in the lake – feeding bread or meat at the water's edge may confirm this. All carp should be removed from the lake when lake works occur.

Figure 2.1: Lake inflow sediment plume distribution behaviour. Note how sediments enter primarily from the main inflow and the flows move this sediment through the lake. Note also the presence of submerged plants in the northern section of the lake - conferring water quality improvement (this should be retained).

3.0 CONCEPT DESIGN OPTIONS

3.1. Design criteria

The Brief states that the concept designs developed need to comply with the following:

1. For Constructed wetlands:
    - *Australian Runoff Quality*
    - *The Constructed Wetlands Manual* (DLWC 1998)
    - *Managing urban stormwater using constructed wetlands* (CRC for Catchment Hydrology)
2. Camden Council Design Specifications:
    - Designed to retain nutrients, heavy metals, bacteria and other pollutants
    - Components to include: energy dissipation, sediment removal, flow spreader, macrophyte vegetation bands, open water, outlet control.
    - Consideration given to pollution removal efficiency, maintenance requirements, social requirements, impacts and costs

Council has also set design criteria for the water quality treatments. However, this project seeks to retrofit an existing pond and the water quality benefit derived will be reported for what it can achieve, and not necessarily comply with any design criteria.

3.2. Description of concept options

Three concept options have been devised for consideration by Council and the community. The options are in Appendix A as annotated design drawings. The options are listed and described as follows:

Concept A: Maximum Reed Bed	Design intent – provide maximum flow path through reed bed to polish flows. Open water retained in northern Lake. Island retained. Components – inlet zone for sedimentation, reed bed for filtering

Reed bed

Sediment pond

Concept B: Reed Bed to Replace Island

Design intent – take advantage of the opportunity afforded by the island to create a reed bed with minimal earthworks, balanced with flow polishing and retention of open water

Components – inlet zone for sedimentation, reed bed for filtering

Sediment pond

Island reed bed (ours set below water level, and much larger)

Concept C: Floating Wetlands

Design intent – provide intensive treatment at the main stormwater inlet where sediments accumulate, and independent of lake water levels. Largely retains the existing (open water) visual qualities of the lake. Plants protected from bird predation (bird cage barrier supplied). Island retained.

Components – inlet zone demarcated, Permeable Reactive Barrier (flow filters through), floating wetland substrates tethered to lake and planted out.

Sediment pond

Permeable Reactive Barrier

Floating wetland

Bird cage to protect plants

3.3. Water quality performance of options

The modelling software used to determine the water quality performance of each of the proposed options is MUSIC v5 (the Model for Urban Stormwater Improvement Conceptualisation). This model was developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH) and is a standard industry model for this purpose.

The adopted modelling approach compares the residual pollutant load being discharged into the open water of the lake, rather than at the receiving node (lake outlet). This approach has been adopted as the objective of these concept designs is to address the water quality and reduce the concentration of fine particulate and dissolved pollutants in Lake Annan.

The MUSIC modelling has been undertaken in accordance with the Draft NSW Design Guidelines and Council's modelling criteria.

Table 3.1 summaries the performance of the three water quality options. Note that the % reduction shown for each concept is a comparison of the residual pollutant load being discharged into the lake. Therefore, it shows the impact of the proposed in-lake structures only.

Table 3.1: Water quality performance of options

Pollutant	Existing	Concept A		Concept B		Concept C*	
		Residual load (kg/ann)	% reduction	Residual load (kg/ann)	% reduction	Residual load (kg/ann)	% reduction
Total Suspended Solids	149,000	49,600	(67%)	49,100	(58%)	66,900	(55%)
Total Phosphorus	277	151	(45%)	169	(39%)	199	(28%)
Total Nitrogen	2,250	1,920	(15%)	2,010	(11%)	2,210	(2%)
Gross Pollutants	5,410	2,430	(55%)	2,470	(54%)	2,430	(55%)

*** Important information on the performance of Option C (floating wetlands).** Option C was modelled for the combined performance of the sediment inlet zone plus the effect of floating wetlands. Literature on the performance of floating wetlands is scarce and is reported that they can be up to ten times more effective than a conventional reed bed for the same unit area. For the sake of conservatism, we have adopted an efficiency of five times (5x) that of reed beds. The enhanced performance per unit area is based on several factors, including:

- The increased density of the root system
- The increased surface area of contact of the roots in the water – acting as a hydroponic system
- The growth of "biofilms" on the roots causing "biological seeding" of the lake with bacteria that promote water quality improvement and pond health

The low performance for Total Nitrogen reduction is because the MUSIC model perceives there to be no shallow water level as occurs in a reed bed. Therefore, this aspect of treatment is excluded, however, in reality it is probably much higher than the 2% retention indicated. Note also, that the target pollutant is Phosphorus, with Nitrogen levels not being as important in the development of algal blooms.

The performance of the Permeable Reactive Barrier (PRB) is not included in the modelling. PRBs comprise blast furnace waste material (slag) which is very high in calcium and semi-porous in nature with high surface area of contact. As water permeates through it, calcium is dissolved from the slag and this forms a strong bond with available (dissolved) Phosphorus and Calcium phosphate [$Ca_3(PO_4)_2$] is formed. This precipitates to the lake bottom.

Most of the Australian research on PRBs is being conducted by Dr Iradg Yassini, University of Wollongong. Dr Yassini has worked on the installation at Catalina Golf Course in Batemans Bay in which a PRB + 50m^2 floating wetland was introduced to reduce the amount of Phosphorus entering a 1Ha reservoir. Early results show Total Phosphorus in the reservoir has reduced by 68%. In addition, the Australasian (Iron and Steel) Slag Association produced an industry funded report titled *An assessment of iron and steel slag for treatment of stormwater pollution* (Matthew Taylor, 2006). It discusses: types of slag (with recommendations); the trace levels of impurities (which he says are not leachable and so would have little or no impact on the lake ecosystem); and the fact that they alter pH (which occurs now in Lake Annan with algal blooms).

Because PRBs results in enhanced sedimentation and precipitation of Phosphorus, they are an effective measure to make Phosphorus entering the lake unavailable to algae. Note, however, that the slag actually dissolves in the process of water passing through it, and needs to be replaced after a 10 year period. The presence of the PRB also "doses" the lake with Calcium as it dissolves all the time, and this will have the effect of binding dissolved Phosphorus in the lake over the medium-long term. We consider that the effect of the PRB will enhance the performance of this option such that the assumed 5x performance ratio (as compared to typical reed beds) is highly conservative for Phosphorus in particular.

Note PRBs are known to cause pH rises by one pH unit in water bodies. This represents no harm to lake biota.

3.4. Comparison of results to best Practice standards

The Draft NSW water quality criteria for pollutant retention are as follows:

- Total Suspended Solids (TSS): 85% retention
- Total Phosphorus (TP): 65% retention
- Total Nitrogen (TN): 45% retention

The modelled performance of the three options falls well short of these criteria, with Concept Option A performing the best of the three at 67/45/15% respectively for TSS, TP and TN.

Together, Lake Annan (2.7Ha in area) and Lake Y'Andalora (1.8Ha approx. area) represent 1.7% of the contributing catchment area. The rule of thumb for a constructed wetland in a catchment to achieve best practice water quality performance is 3%. Therefore, Lake Annan can never achieve best practice with a typical retrofit of wetland features.

Therefore, designs have not sought balance water quality treatment performance with the practicalities of construction and issues of lake aesthetics.

3.5. Cost and performance analysis of options

Table 3.2 shows a comparison of the three concept options for Lake Annan.

Table 3.2: Comparative analysis of options

Criteria	Concept Options		
	A.Max. Reed Bed	**B. Replace Isl w Reed Bed**	**C.Floating Wetlands***
Key design factors	Max flow path through wetland Reed bed area = 9,228m^2 Open water retained = 12,442m^2 Inlet zone for sedimentation = 2,702m^2	Island utilised as reed bed Reed bed area = 1,880m^2 Open water retained = 20,645m^2 Inlet zone for sedimentation = 4,030m^2	Three floating wetland substrates (320m^2) Most open water retained (2.4Ha) Island retained = 1,880m^2 Inlet zone (defined by Permeable Reactive Barrier) for sedimentation = 2,702m^2
Water quality performance (% retention of pollutant)	TSS: 67% TN: 15% **TP: 45%**	TSS: 58% TN: 11% **TP: 39%**	TSS*: 55% TN*: 2% **TP*: 28%**
Construction access #	Most difficult	Moderately difficult	Easiest
Maintenance access	Inlet zone access is easy Access to extensive reed bed is on foot	Inlet zone access is easy Access to moderately sized reed bed is on foot	Inlet zone access is easy Access to floating wetlands is by canoe (easy)
Detailed Design Cost	$50,000	$50,000	$35,000 (Less earthworks and no planting plan required)
Capital & Construction Cost	$405,000& Install water level control structure in weir $15,000 Erosion repair on north shore of island $15,000 Phoslock application 10,000 Civil/earthworks for sed zone and reed bed $400,000	$341,000& Install water level control structure in weir $15,000 Phoslock application $20,000 Create inlet swale from old GPT to lake edge $30,000 Civil/earthworks for sed zone and reed bed $276,000	$226,000& Install water level control structure in weir $15,000 Erosion repair on north shore of island $15,000 Supply/Install permeable reactive Barrier $40,000 Civil/earthworks for sed zone $156,000
Landscaping Cost	$240,000 (9,0000$m^2$ reed bed, plants @ 6/m^2= $216,000, plus other general landscaping)	$90,000 (1,880$m^2$ reed bed, plants @ 6/m^2 = $62,500 , plus inlet swale $10,000, plus other general landscaping)	$100,000 (320$m^2$ floating wetland = $93,500, plus other general landscaping)

* TSS= Total Suspended Solids; TN=Total Nitrogen; TP=Total Phosphorus; # Access within lake to create inlet zone & reed bed limited by sludge consistency of sediments, so most area of sediments affected results in increased difficulty; & Assumes no cut is removed from site, is incorporated into earthworks, or onto banks of lake; @ Floating wetland quote by Harris Environmental Consulting, Jamberoo; ' composting cost used for sediment disposal – will be more if landfilling is required, refer Table 3.6.

Criteria	Concept Options		
	A.Max. Reed Bed	B. Replace Isl w Reed Bed	C.Floating Wetlands*
Total Capital investment	**$695,000**	**$481,000**	**$360,000**
20 yr maintenance cost[1] (see Table 3.6)	$237,600 $120,000 general maintenance $117,600 sediment composting (2 episodes)	$207,600 $90,000 general maintenance $117,600 sediment composting (1 episode)	$287,600 $60,000 general maintenance $117,600 sediment composting (2 episodes) $40,000 replace permeable reactive barrier (2 episodes)
Total cost over 20 yrs	**$932,600**	**688,600**	**647,600**

All costs ex gst and subject to contingency -10%-+20%

3.6. Constructability issues

When assessing each concept design option for the lake, it is important to consider issues of constructability. The following tables describe the construction sequencing and methods for each of the options.

Table 3.3: Concept A - Maximum Reed Bed construction

Sequence of works	Method	Comment
Install temporary water diversions in lake. Work initially to create the reed bed on the eastern side of the island, followed by the inlet zone then western reed bed.	Construct temporary earthworks, use pumps as required, install erosion and sediment controls.	Sections of the lake can be isolated such that works can occur within them. The most difficult challenge will be working at the major stormwater inlet where flows are high.
Drain area of works Manage aquatic fauna	Use pumps to keep the works area relatively dry. Use sump drainage points within the works area where rainfall runoff can flow to	Important to select drier periods to conduct works, if possible. As water levels fall, the collected water may contain concentrated nutrients. This water could be run over a grassed area to filter it before it runs back into the lake. Any stranded aquatic fauna as a result of water drawdown will need to be relocated into the main body of the lake.
Allow time for sediments to dry out	Use pumps to keep the sediment layer dry.	Continue to maintain dry work space with pumps.
Import earth/spoil to create earthworks	Earthmoving equipment, trucks and excavators, etc.	Continue to maintain dry work space with pumps.
Import rock to provide scour protection	Earthmoving equipment, trucks and excavators, etc.	Continue to maintain dry work space with pumps.
Import and place planting media to create reed beds and other planted areas	Earthmoving equipment, trucks and excavators, etc.	Continue to maintain dry work space with pumps.

Sequence of works	Method	Comment
Plant reed bed zones and other planted areas	By hand	Irrigate the plants until established (can use pumped lake water for this purpose) Raise water levels to max 1/3 height of the smallest stems until established. Note: Timing of planting is very important with best results resulting from spring planting. Therefore, construction should be scheduled for completion in mid-September. Note also that pre-ordering and growing of plants is required – allow a lead time of one year for plant ordering.
Remove temporary earthworks and connect works back to the lake	Earthmoving equipment	Rehabilitate all temporary works, as required

Table 3.4: Concept B - Reed Bed to Replace Island construction

Sequence of works	Method	Comment
Reed bed		
Install temporary earthworks to gain access to island.	Construct temporary earthworks, using earthmoving equipment, trucks and excavators, etc.	Ensure works are outside the main inlet flows
Clear and grub vegetation from the island	Earthmoving and tree grubbing machinery	Potential to mulch the vegetation for use in landscaping around the lake. Otherwise remove to waste disposal or recycling facility
Earthworks to create reed bed, including temporary earthworks to isolate reed bed from lake	Earthmoving equipment, trucks and excavators, etc.	Retain useful spoil for other earthworks at the inlet zone as required. Recycle excess spoil off site. Maintain dry work space with pumps.
Import rock to provide scour protection	Earthmoving equipment, trucks and excavators, etc.	Continue to maintain dry work space with pumps.
Import and place planting media to create reed beds and other planted areas	Earthmoving equipment, trucks and excavators, etc.	Continue to maintain dry work space with pumps.
Plant reed bed zones and other planted areas	By hand	Irrigate the plants until established (can use pumped lake water for this purpose) Raise water levels to max 1/3 height of the smallest stems until established Note: Timing of planting is very important with best results resulting from spring planting. Therefore, construction should be scheduled for completion in mid-September. Note also that pre-ordering and growing of plants is required – allow a lead time of one year for plant ordering.

Sequence of works	Method	Comment
Inlet zone		
Install temporary water diversions at inlet	Construct temporary earthworks, install erosion and sediment controls.	
Earthworks to create inlet zone	Earthmoving equipment, trucks and excavators, etc.	Remove sediments from inlet zone footprint. Reuse if possible, or remove for disposal Cut to create bed levels Use spoil, from removal of island to create embankments, if suitable.
Import rock to provide scour protection	Earthmoving equipment, trucks and excavators, etc.	
Import and place planting media for planted areas	Earthmoving equipment, trucks & excavators, etc.	Continue to maintain dry work space with pumps.
Plant out planted areas	By hand	Irrigate the plants until established (can use pumped lake water for this purpose) Raise water levels to 1/3 height of the smallest stems.
Remove temporary water diversion and connect works between inlet zone and reed bed	Earthmoving equipment	Rehabilitate all temporary works, as required

Table 3.5: Concept C - Floating Wetland construction

Sequence of works	Method	Comment
Inlet zone		
Install temporary water diversions at inlet	Construct temporary earthworks, install erosion and sediment controls.	Create coffer dam to enable a dry working site.
Earthworks to create inlet zone	Earthmoving equipment, trucks and excavators, etc.	Remove sediments from inlet zone footprint. Reuse if possible, or remove for disposal Cut to create bed levels
Install Permeable Reactive Barrier	Earthmoving equipment, trucks and small excavators, etc.	
Remove temporary water diversion and connect works between inlet zone and reed bed	Earthmoving equipment	Rehabilitate all temporary works, as required
Floating wetlands	Manually on banks	
Supply to site, and assemble	Manually on banks	

3.7. Concept Maintenance Plans

Table 3.6 shows the maintenance requirements with associated costings for each of the three Concept options.

The largest cost is sediment removal which we have assumed will cost: 1. $100/m^3 for handling and processing (recycling); or 2. $250/m^3 for removal and landfilling (plus $5,000 each episode for testing and lab analysis).

It is likely that disposal of the removed sediments at landfill will be required at some time. In this eventuality, testing of the material will be required and an assessment is made against the *Classification of Liquid and Non-liquid Wastes* Guideline by the Environment Protection Authority. The cost supplied in Table 3.6 for landfilling assumes the wastes are classified as General Solid Waste, or better.

Table 3.6: Concept Maintenance Plan for the three Lake Annan water quality improvement options

Activity	Method	Frequency	Cost*
Remove accumulated sediment and debris from inlet sediment zones	Remove when sediment accumulates to Ave depth of 0.5m across Sediment deposition Zone. Commence works in a dry period with low/no inflows to lake Lower lake water levels to below that of inlet zone embankment. Pump water out of inlet zone and into Lake to expose sediments. Install erosion and sediment controls. Excavator enters the sediment zone on a stabilised access ramp (rip-rap). Remove and stockpile sediments within inlet zone (at edges). Wait to dry. Using excavator, transfer dried sediments into trucks for disposal	**Concept A:** 65t/ann ÷ 1.8t/m^3 = 36m^3/ann. Sediment accumulation volume is 300m^3, so will be **cleaned out once every 8 years** **Concept C: cleaned out once every 7 years**, based on same volume as Concept A but enhanced sedimentation conferred by floating wetland and Permeable Reactive Barrier	**Composting:** $58,800 per clean-out, (based on 420t @ $30/t removal + $90/t disposal + $20/t transport) **Landfilling:** $80,600 per clean-out, (based on 420t @ $30/t removal + $130/t disposal + $20/t transport + lab testing of sediments ($5,000)
		Concept B: 70t/ann ÷ 1.8t/m^3 = 39m^3/ann. Sediment accumulation volume is 600m^3, so will be **cleaned out once every 15 years** Note the volume of sediment accumulation in Concept B is twice that of Concepts A & C.	**Composting:** $117,600 per clean-out, (based on 840t @ $30/t removal + $90/t disposal + $20/t transport) **Landfilling:** $159,200 per clean-out, (based on 840t @ $30/t removal + $130/t disposal + $20/t transport + lab testing of sediments ($8,000)
General maintenance of works	Replant denuded areas of plantings – lower lake water levels to do so. Weeding occurs while doing this. Repair erosion/scour of embankments, or undermining of rockwork.	Annually Concept A: Concept B: Concept C:	 $6,000 $4,500 $3,000

Activity	Method	Frequency	Cost*
Replace Permeable Reactive barrier	Lower lake water level Import slag to site. Create Barrier using small earthmoving machinery.	Concept C only, every 10 years	$40,000 each time

*Costs of sediment composting and landfill disposal supplied by Envirocivil (Peter Day, 0412 232859).
*all costs ex gst
*Transport cost for sediment disposal is set at $20/tonne throughout. This may vary.

3.8. Non-structural options for managing water quality

The design options will provide treatment of lake inflows to varying degrees based on the effectiveness of the inlet sediment zones and reed beds/wetlands. However, a key issue for the lake is the accumulation of vast quantities of sediment across the entire lake bed.

During dry sequences, and especially in warm conditions, the sediments can give up their Phosphorus to the water column. This occurs via a complex suite of chemical processes occurring in the lake and sediments. The result is that algae are able to take advantage of this released Phosphorus and algal blooms result. This makes the lake unsightly, and leads to odours, and conditions unfavourable to other fauna and plants. Certain blue-green algae can also release toxins into the water when they die.

Therefore, despite any works at inlets to control ongoing treatment, the sediments can still cause water quality problems in the lake. There are several options available to manage this, including:

- **Submerged aerators** – these cause mixing of the water column and provide oxygen to the water to prevent chemical processes that lead to algal blooms. They are devices that sit on the bottom of the lake and compressed air is supplied to them from the lake bank via a conduit. These have a high capital costs and a power source would be required to run the air compressors and pumps. One of these is present in Lake Annan, but anecdotally it is not very effective. Their use is not recommended and the existing system in the Lake could be decommissioned after any of the design options are implemented.
- **Surface aerators** – there are two types designed to provide aeration of the water, i.e. surface agitators (e.g. like those used in rice paddies and fish farms in Asia), or fountains/water features where the water used for the jet may be sourced from a stagnant part of the lake. A fountain would add significant visual appeal to the lake and could be considered if other measures are only partially effective.

- **Stabilisation of sediments** – this is where chemicals or mineral materials are broadcast over the lake or sediments with the intent of binding Phosphorus such that it is not released into the water column. One commercially available product is Phoslock which is applied as slurry to the water. Another option is to apply Iron Sulphate with lime. Both of these solutions rely on the application of chemicals to a water body, and this would be considered an activity that requires a license under NSW law. It is recommended to proceed with Phoslock application if Concept Options A or B are selected for implementation. This option is not considered necessary for Option C because it will provide ongoing dosing of the lake with calcium which binds with Phosphorus and makes it unavailable to algae.

Storm

4.0 SUMMARY AND CONCLUSION

4.1. Summary of findings

The analysis of options provided in Section 3 provides relatively reliable feedback to Council and the community upon which to base a decision of which Concept option to proceed with. Table 4.1 presents a summary of several key issues that will facilitate the decision-making process.

Table 4.1: Comparative analysis of options

Criteria	Concept Options		
	A.Max. Reed Bed	B. Replace Island with Reed Bed	C.Floating Wetlands*
Total cost over 20 yrs	$932,600	$688,600	$647,600
Key Pollution Retention	TSS: 67% TP: 45%	TSS: 58% TP: 39%	TSS: 55% TP*: 28% *Ignores ongoing effect of PRB to lock up Phosphorus
Impact on visual appearance of Lake	**Huge impact** – complete transformation	**Major impact** – island lost and significant transformation	Relatively **minor impact**
Safety for lake users	**Potential for people to access the lake on earthworks used to create inlet zones.** Typically these are submerged which would prevent access. Also a rip-rap scour protection is shown on some of these batters. When water levels in the lake fall in drought, some areas of exposed rip-rap could result. The intent is to use a soil/rock matrix into which plants would be grown to prevent access.		
Irrigation water availability	**In any of the options, water availability for irrigation from the lake is unaffected**		
Requirement for non-structural options	**Yes**, sediment stabilisation required (Phoslock).	**Yes**, sediment stabilisation required (Phoslock).	**No**
Permits from OEH required for construction	**Yes**, for Phoslock application (see row above)	**Yes**, for Phoslock application (see row above)	**Yes**, for addition of Permeable Reactive Barrier
Climate resilience	**Risk** of drought sequences resulting in drying out of reed beds	**Risk** of drought sequences resulting in drying out of reed beds	**No issues**, floating wetlands unaffected by water level changes
Reed bed resilience	**Risk** of sediment carry-over to reed beds, requiring clean-out and re-planting	**Risk** of sediment carry-over to reed beds, requiring clean-out and re-planting	**No issues**, floating wetlands unaffected
Bird resilience	**Risk** of birds eating planted wetland plants	**Risk** of birds eating planted wetland plants	**No issues**, built-in bird protection.
Experimental approach	**No**	**No**	**Somewhat,** but based on scientific principles with several Australian applications (Dr Iradg Yassini, University of Wollongong)

4.2. Ability to amend or combine options

While every effort has been made to quantify and qualify the performance of the options in relation to their water quality performance, the fact remains we are dealing with a natural system that is highly variable in its performance in space and time. The lake responds to what is occurring in its catchment which a water quality model may not always be able to account for. Therefore, if an option is selected and implemented, there is still a chance that water quality problems will remain within Lake Annan. This would be easily recognised by the presence of ongoing algal blooms.

Similarly, Council may wish to adopt a staged or optimised approach to works in any given option to gauge the success.

Therefore, Council needs to know what options they have to, a) provide enhanced performance after an option has been implemented, or b) stage works. Table 4.2 shows how this may be approached by Council.

Table 4.2: Ways to amend, stage or combine options

Concept	Amend	Combine
Option A	Only create sediment zone on main stormwater inlet, consider adding the northern one later Reduce area of reed bed Install fountain in northern end of lake	Floating wetland in inlet sediment zone Permeable Reactive Barrier in inlet zone
Option B	Exclude minor inflow (Dunbar Place) from inlet sediment zone to make it smaller Install fountain in northern end of lake	Floating wetland in inlet sediment zone Permeable Reactive Barrier in inlet zone
Option C	Increased area of floating wetland Install fountain in northern end of lake	Add a reed bed after inlet sediment zone

4.3. Conclusions

It is very clear that **Concept Option A: Maximum Reed Red** provides the best water quality improvement performance. However, it also has the highest cost of the three options and the additional cost does not appear to provide good value for money in relation to the additional treatment provided. The fact that it will also transform the lake visually and have other associated risks means that we do not recommend this option. If Council were to proceed with Option A, we recommend amending the design to omit the inlet zone and wetland at the northern inflow, and reducing the area of reed bed coverage. Both these amendments will save costs while balancing water quality performance.

Concept Option B: Replace Island with Reed Bed is a good option if removing the island is a preferred strategy. We note that without a large ibis population that the island could be revegetated to make it more attractive, so the issue is whether the bird population can be controlled. Council advise that the bird population is created by the operation of nearby landfills which are due for closure in the medium-long term. If Council were to proceed with Concept Option B, we recommend reducing the size of the inlet zone by removing the inflow from Dunbar Place. This will save costs while not greatly affecting water quality performance.

Concept Option C: Floating Wetlands has the least impact on visual quality of the lake while also providing relatively good water quality improvement. The reported water quality improvement is understated because we have not factored in the ongoing effect of the Permeable Reactive barrier to lock up Phosphorus over time, thereby preventing algal blooms in the lake. This option is somewhat experimental in nature, but there is research and applications in Australia to be guided by.

The **key risk factors** that ought to inform a decision to select an option are as follows:

- **Climate resilience** – will fluctuating water levels affect the viability of the reed beds, especially if water levels drop below the reed bed base for extended periods. The other issue is in a general sense, will fluctuating water levels be too much for the reed bed plants to bear.
- **Reed bed resilience** – will sediment carryover from the inlet sediment zones clog up the reed beds, particularly at their leading edge, which would require clean-out periodically. Note the water quality modelling shows that only about half the sediment load is retained in the inlet sediment zones, and so the remainder would travel through the reed beds.
- **Bird predation of planted reed beds** – waterfowl have a habit of preferring small plants and they can devastate planted areas. There are two typical ways to prevent this from occurring, i.e. bird netting and planting more mature plants which the birds do not prefer. Neither cost is included in the cost estimates.

These three risk factors apply to **Concepts A and B only**. Option C is immune to each issue because the reed beds are supported by a floating substrate, protected by a bird cage.

4.4. Recommendation

We recommend Option C for implementation based on the following summary of findings:

- Minor impact on the visual appearance of the lake
- Retention of island and its biodiversity (which can be enhanced)
- Lowest capital cost
- Lowest cost over 20 years of operation (includes construction)
- Not affected by fluctuating water levels
- Not affected by sediment overloading
- Not affected by bird predation of planted areas
- Ability to be easily retrofitted with additional water quality improvement in a staged manner

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APPENDIX A
Concept Option Drawings

1485 -C01

LAKE ANNAN WATER QUALITY
CONCEPT DESIGN
LAKE ANNAN, DUNBAR PLACE, MOUNT ANNAN

LOCALITY PLAN
NOT TO SCALE

SHEET INDEX	
SHEET	DESCRIPTION
C01	COVER PAGE AND SHEET INDEX
P02	LAYOUT PLAN
P03	CONCEPT A - MAXIMUM REED BED
P04	CONCEPT B - REED BED TO REPLACE ISLAND
P05	CONCEPT C - FLOATING WETLANDS
D06	TYPICAL SECTIONS

Rev.	Revision Description	Designed	Date
B	FINAL CONCEPT DESIGNS	TH	26.06.13
A	CONCEPTS FOR COUNCIL REVIEW	TH	17.06.13

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LAKE ANNAN WATER QUALITY
CONCEPT DESIGN
LAKE ANNAN, DUNBAR PLACE, MOUNT ANNAN
Cover Page and Sheet Index

Date 26.06.13 Drawing No. 1485 -C01 Sheet 01 of 06

1485 -P02

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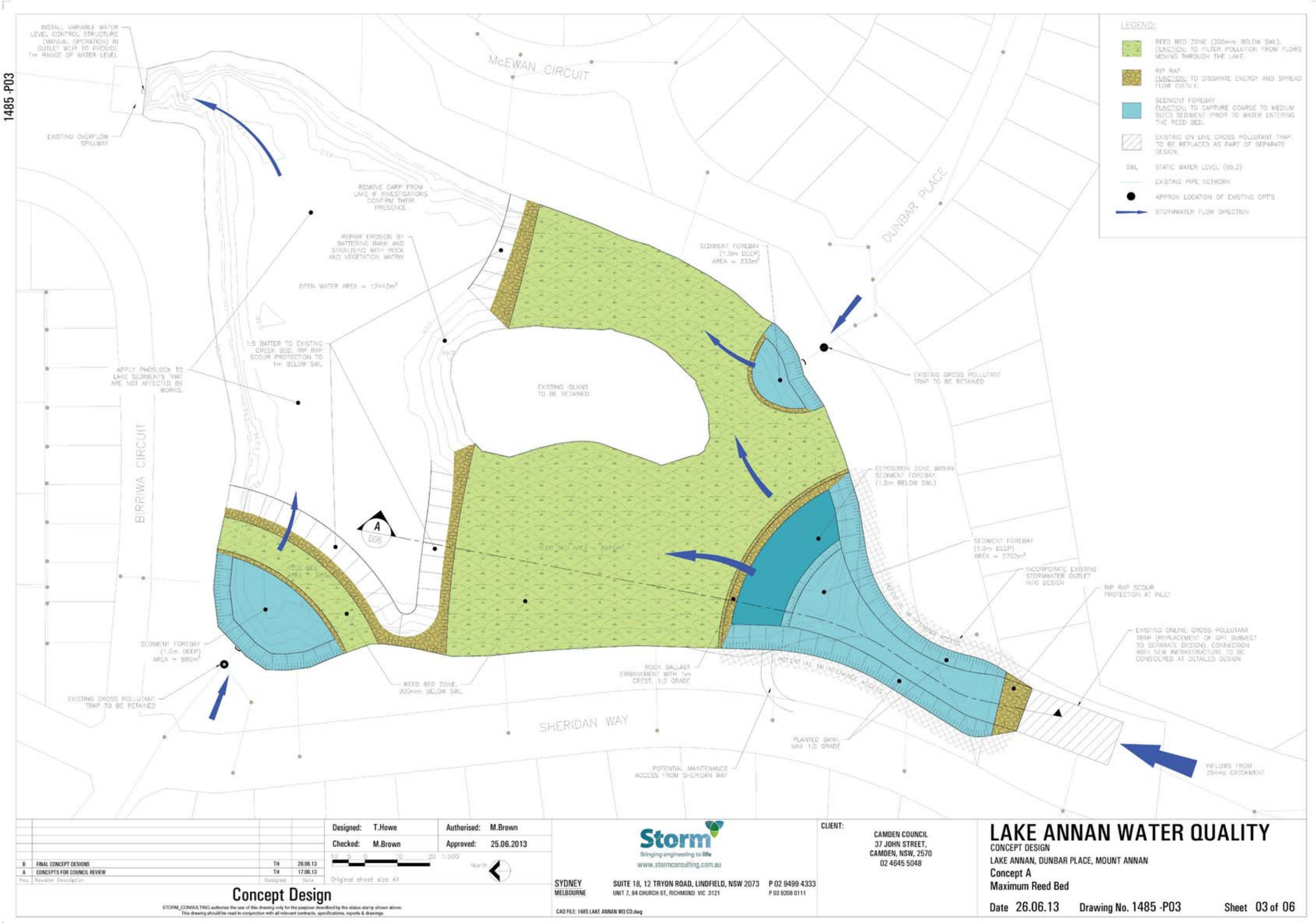
LAKE ANNAN WATER QUALITY

CONCEPT DESIGN
LAKE ANNAN, DUNBAR PLACE, MOUNT ANNAN
Layout Plan

Date 26.06.13 Drawing No. 1485 -P02 Sheet 02 of 06



1485 -P03
LEGEND:
REED BED ZONE (300mm BELOW SWL). FUNCTION: TO FILTER POLLUTION FROM FLOWS MOVING THROUGH THE LAKE.
RIP RAP. FUNCTION: TO DISSIPATE ENERGY AND SPREAD FLOW EVENLY.
SEDIMENT FOREBAY. FUNCTION: TO CAPTURE COARSE TO MEDIUM SIZED SEDIMENT PRIOR TO WATER ENTERING THE REED BED.
EXISTING ON LINE GROSS POLLUTANT TRAP, TO BE REPLACED AS PART OF SEPARATE DESIGN.
SWL STATIC WATER LEVEL (95.2)
EXISTING PIPE NETWORK
APPROX LOCATION OF EXISTING GPT'S
STORMWATER FLOW DIRECTION
McEWAN CIRCUIT
DUNBAR PLACE
BIRRIWA CIRCUIT
SHERIDAN WAY
INSTALL VARIABLE WATER LEVEL CONTROL STRUCTURE (MANUAL OPERATION) IN OUTLET WEIR TO PROVIDE 1m RANGE OF WATER LEVEL
EXISTING OVERFLOW SPILLWAY
REMOVE CARP FROM LAKE IF INVESTIGATIONS CONFIRM THEIR PRESENCE
REPAIR EROSION BY BATTERING BANK AND STABILISING WITH ROCK AND VEGETATION MATRIX
OPEN WATER AREA = 12442m²
1:5 BATTER TO EXISTING CREEK BED. RIP RAP SCOUR PROTECTION TO 1m BELOW SWL
APPLY PHOSLOCK TO LAKE SEDIMENTS THAT ARE NOT AFFECTED BY WORKS.
EXISTING ISLAND TO BE RETAINED
SEDIMENT FOREBAY (1.0m DEEP) AREA = 333m²
EXISTING GROSS POLLUTANT TRAP TO BE RETAINED
DEPOSITION ZONE WITHIN SEDIMENT FOREBAY (1.5m BELOW SWL)
SEDIMENT FOREBAY (1.0m DEEP) AREA = 2700m²
INCORPORATE EXISTING STORMWATER OUTLET INTO DESIGN
RIP RAP SCOUR PROTECTION AT INLET
EXISTING ONLINE GROSS POLLUTANT TRAP (REPLACEMENT OF GPT SUBJECT TO SEPARATE DESIGN). CONNECTION WITH NEW INFRASTRUCTURE TO BE CONSIDERED AT DETAILED DESIGN
INFLOWS FROM 354Ha CATCHMENT
SEDIMENT FOREBAY (1.0m DEEP) AREA = 880m²
EXISTING GROSS POLLUTANT TRAP TO BE RETAINED
REED BED ZONE 200mm BELOW SWL
ROCK BALLAST EMBANKMENT WITH 1m CREST. 1:2 GRADE
POTENTIAL MAINTENANCE ACCESS
PLANTED BANK MAX 1:5 GRADE
POTENTIAL MAINTENANCE ACCESS FROM SHERIDAN WAY
A D06
B FINAL CONCEPT DESIGNS TH 26.06.13
A CONCEPTS FOR COUNCIL REVIEW TH 17.06.13
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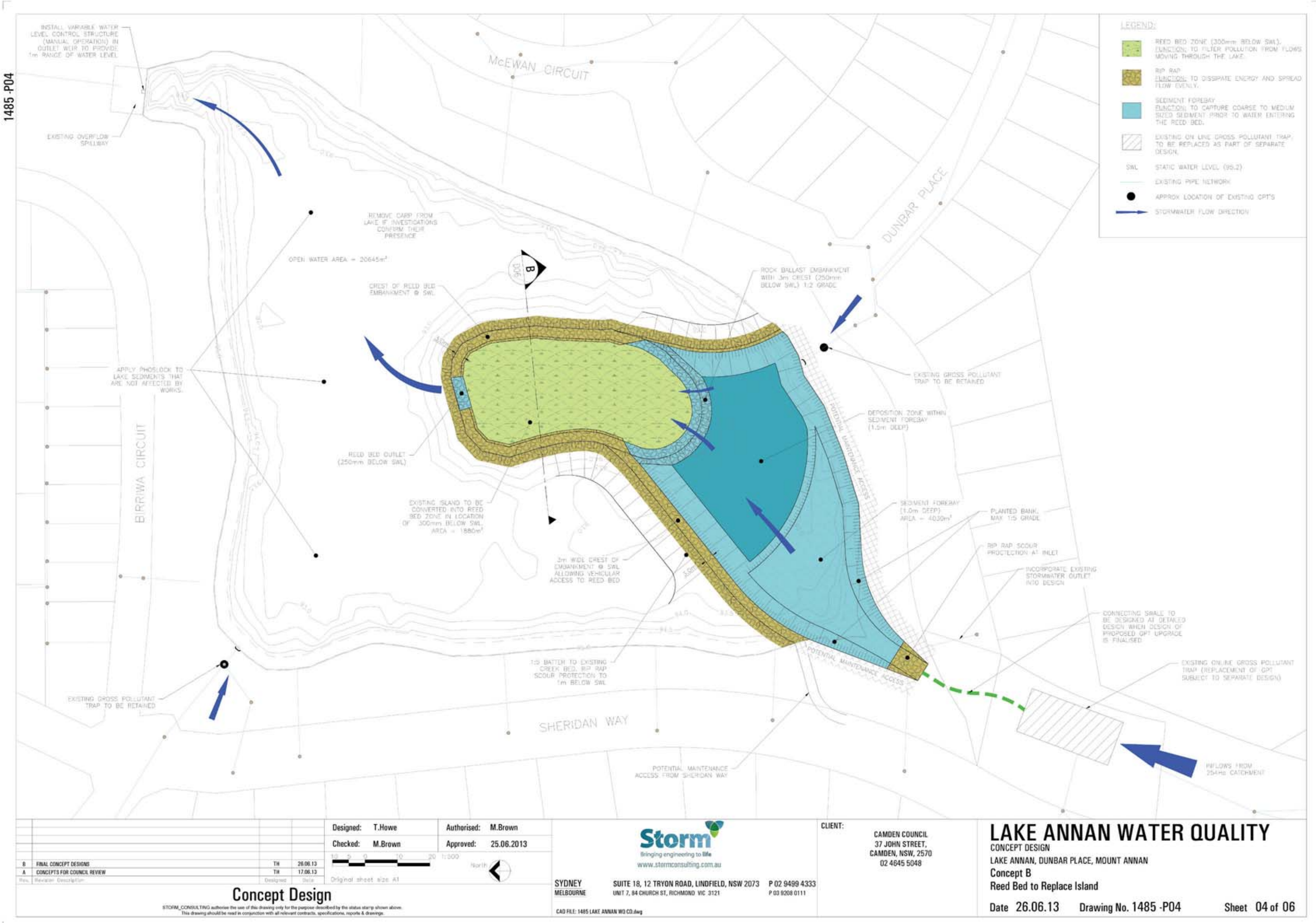
LAKE ANNAN WATER QUALITY
CONCEPT DESIGN
LAKE ANNAN, DUNBAR PLACE, MOUNT ANNAN
Concept A
Maximum Reed Bed
Date 26.06.13
Drawing No. 1485 -P03
Sheet 03 of 06


1485 -P04
LEGEND:
REED BED ZONE (300mm BELOW SWL). FUNCTION: TO FILTER POLLUTION FROM FLOWS MOVING THROUGH THE LAKE.
RIP RAP. FUNCTION: TO DISSIPATE ENERGY AND SPREAD FLOW EVENLY.
SEDIMENT FOREBAY. FUNCTION: TO CAPTURE COARSE TO MEDIUM SIZED SEDIMENT PRIOR TO WATER ENTERING THE REED BED.
EXISTING ON LINE GROSS POLLUTANT TRAP, TO BE REPLACED AS PART OF SEPARATE DESIGN.
SWL STATIC WATER LEVEL (95.2)
EXISTING PIPE NETWORK
APPROX LOCATION OF EXISTING GPT'S
STORMWATER FLOW DIRECTION
McEWAN CIRCUIT
DUNBAR PLACE
BIRRIWA CIRCUIT
SHERIDAN WAY
INSTALL VARIABLE WATER LEVEL CONTROL STRUCTURE (MANUAL OPERATION) IN OUTLET WEIR TO PROVIDE 1m RANGE OF WATER LEVEL
EXISTING OVERFLOW SPILLWAY
REMOVE CARP FROM LAKE IF INVESTIGATIONS CONFIRM THEIR PRESENCE
OPEN WATER AREA = 20645m²
CREST OF REED BED EMBANKMENT @ SWL
APPLY PHOSLOCK TO LAKE SEDIMENTS THAT ARE NOT AFFECTED BY WORKS.
REED BED OUTLET (250mm BELOW SWL)
EXISTING ISLAND TO BE CONVERTED INTO REED BED ZONE IN LOCATION OF 300mm BELOW SWL. AREA = 1880m²
3m WIDE CREST OF EMBANKMENT @ SWL ALLOWING VEHICULAR ACCESS TO REED BED
1:5 BATTER TO EXISTING CREEK BED, RIP RAP SCOUR PROTECTION TO 1m BELOW SWL
ROCK BALLAST EMBANKMENT WITH 3m CREST (250mm BELOW SWL) 1:2 GRADE
EXISTING GROSS POLLUTANT TRAP TO BE RETAINED
DEPOSITION ZONE WITHIN SEDIMENT FOREBAY (1.5m DEEP)
SEDIMENT FOREBAY (1.0m DEEP) AREA = 4020m²
PLANTED BANK, MAX 1:5 GRADE
RIP RAP SCOUR PROTECTION AT INLET
INCORPORATE EXISTING STORMWATER OUTLET INTO DESIGN
CONNECTING SWALE TO BE DESIGNED AT DETAILED DESIGN WHEN DESIGN OF PROPOSED GPT UPGRADE IS FINALISED
EXISTING ONLINE GROSS POLLUTANT TRAP (REPLACEMENT OF GPT SUBJECT TO SEPARATE DESIGN)
INFLOWS FROM 354Ha CATCHMENT
POTENTIAL MAINTENANCE ACCESS
POTENTIAL MAINTENANCE ACCESS FROM SHERIDAN WAY
EXISTING GROSS POLLUTANT TRAP TO BE RETAINED
B
D06
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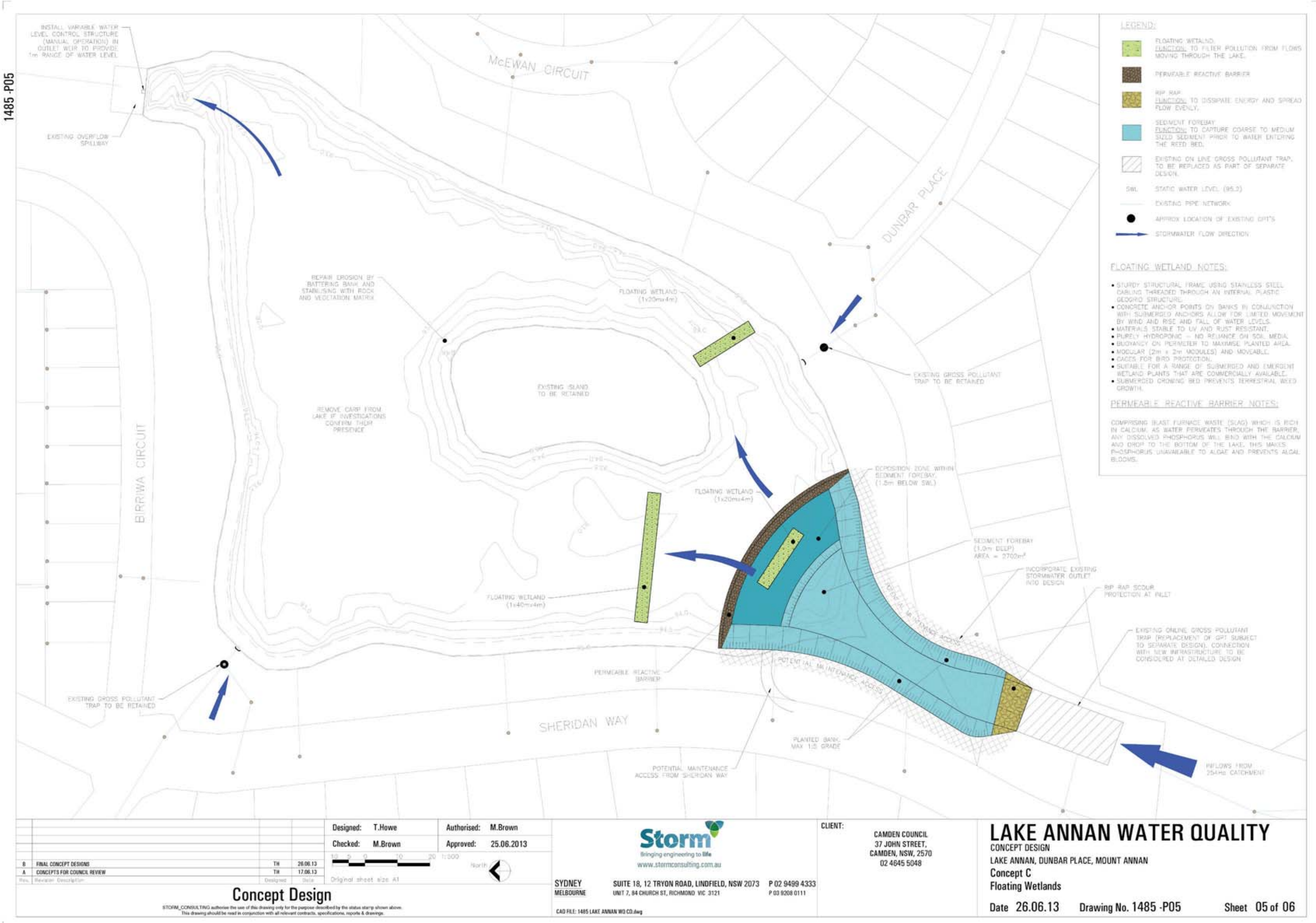
CONCEPT DESIGN
LAKE ANNAN, DUNBAR PLACE, MOUNT ANNAN
Concept B
Reed Bed to Replace Island
Date 26.06.13
Drawing No. 1485 -P04
Sheet 04 of 06



1485 -P05
INSTALL VARIABLE WATER LEVEL CONTROL STRUCTURE (MANUAL OPERATION) IN OUTLET WEIR TO PROVIDE 1m RANGE OF WATER LEVEL
EXISTING OVERFLOW SPILLWAY
McEWAN CIRCUIT
DUNBAR PLACE
BIRRIWA CIRCUIT
SHERIDAN WAY
REPAIR EROSION BY BATTERING BANK AND STABLISING WITH ROCK AND VEGETATION MATRIX
REMOVE CARP FROM LAKE IF INVESTIGATIONS CONFIRM THEIR PRESENCE
EXISTING ISLAND TO BE RETAINED
FLOATING WETLAND (1x20mx4m)
FLOATING WETLAND (1x20mx4m)
FLOATING WETLAND (1x40mx4m)
EXISTING GROSS POLLUTANT TRAP TO BE RETAINED
EXISTING GROSS POLLUTANT TRAP TO BE RETAINED
DEPOSITION ZONE WITHIN SEDIMENT FOREBAY (1.5m BELOW SWL)
SEDIMENT FOREBAY (1.0m DEEP) AREA = 2700m²
INCORPORATE EXISTING STORMWATER OUTLET INTO DESIGN
RIP RAP SCOUR PROTECTION AT INLET
EXISTING ONLINE GROSS POLLUTANT TRAP (REPLACEMENT OF GPT SUBJECT TO SEPARATE DESIGN). CONNECTION WITH NEW INFRASTRUCTURE TO BE CONSIDERED AT DETAILED DESIGN
INFLOWS FROM 354Ha CATCHMENT
PERMEABLE REACTIVE BARRIER
POTENTIAL MAINTENANCE ACCESS
POTENTIAL MAINTENANCE ACCESS FROM SHERIDAN WAY
PLANTED BANK MAX 1:5 GRADE
LEGEND:
FLOATING WETALND. FUNCTION: TO FILTER POLLUTION FROM FLOWS MOVING THROUGH THE LAKE.
PERMEABLE REACTIVE BARRIER
RIP RAP FUNCTION: TO DISSIPATE ENERGY AND SPREAD FLOW EVENLY.
SEDIMENT FOREBAY FUNCTION: TO CAPTURE COARSE TO MEDIUM SIZED SEDIMENT PRIOR TO WATER ENTERING THE REED BED.
EXISTING ON LINE GROSS POLLUTANT TRAP, TO BE REPLACED AS PART OF SEPARATE DESIGN.
SWL STATIC WATER LEVEL (95.3)
EXISTING PIPE NETWORK
APPROX LOCATION OF EXISTING GPT'S
STORMWATER FLOW DIRECTION
FLOATING WETLAND NOTES:
• STURDY STRUCTURAL FRAME USING STAINLESS STEEL CABLING THREADED THROUGH AN INTERNAL PLASTIC GEOGRID STRUCTURE.
• CONCRETE ANCHOR POINTS ON BANKS IN CONJUNCTION WITH SUBMERGED ANCHORS ALLOW FOR LIMITED MOVEMENT BY WIND AND RISE AND FALL OF WATER LEVELS.
• MATERIALS STABLE TO UV AND RUST RESISTANT.
• PURELY HYDROPONIC – NO RELIANCE ON SOIL MEDIA.
• BUOYANCY ON PERIMETER TO MAXIMISE PLANTED AREA.
• MODULAR (2m x 2m MODULES) AND MOVEABLE.
• CAGES FOR BIRD PROTECTION.
• SUITABLE FOR A RANGE OF SUBMERGED AND EMERGENT WETLAND PLANTS THAT ARE COMMERCIALLY AVAILABLE.
• SUBMERGED GROWING BED PREVENTS TERRESTRIAL WEED GROWTH.
PERMEABLE REACTIVE BARRIER NOTES:
COMPRISING BLAST FURNACE WASTE (SLAG) WHICH IS RICH IN CALCIUM. AS WATER PERMEATES THROUGH THE BARRIER, ANY DISSOLVED PHOSPHORUS WILL BIND WITH THE CALCIUM AND DROP TO THE BOTTOM OF THE LAKE. THIS MAKES PHOSPHORUS UNAVAILABLE TO ALGAE AND PREVENTS ALGAL BLOOMS.
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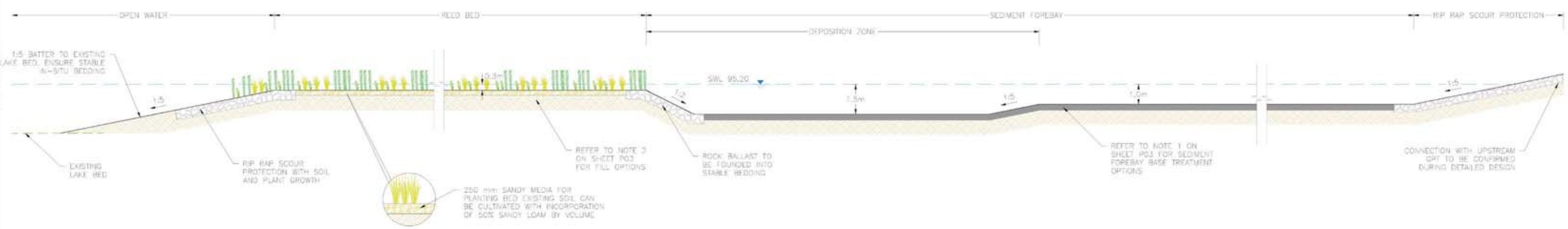
LAKE ANNAN WATER QUALITY
CONCEPT DESIGN
LAKE ANNAN, DUNBAR PLACE, MOUNT ANNAN
Concept C
Floating Wetlands
Date 26.06.13
Drawing No. 1485 -P05
Sheet 05 of 06

1485 -D06



TYPICAL SECTION CONCEPT A & B,
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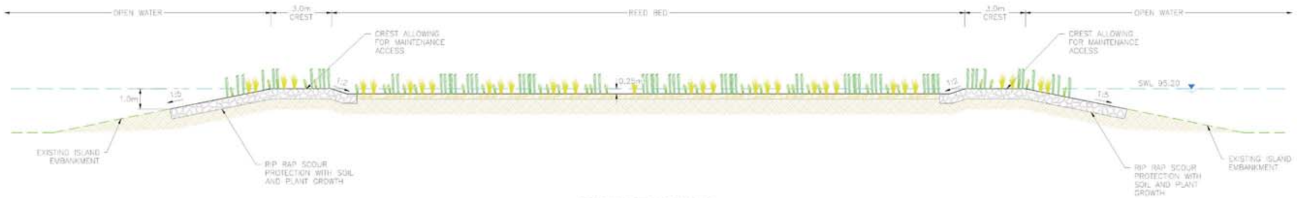

TYPICAL SECTION CONCEPT B,
1:100 @ A1

CONCEPT C EXAMPLE,
FLOATING REED BED

CONCEPT C EXAMPLE,
PERMEABLE REACTIVE BARRIER

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LAKE ANNAN WATER QUALITY

CONCEPT DESIGN
LAKE ANNAN, DUNBAR PLACE, MOUNT ANNAN
Typical Sections

Date 26.06.13 Drawing No. 1485 -D06 Sheet 06 of 06