# Freshwater Lake - Future Options Consultation

# Technical Reports by BOLA considering Option 2B

These Barrie Ormsby Landscape Architect (BOLA) reports provide potential technical solutions consistent with the general principles within Option 2B:

- **Option 2B – In-line treatment** – a system where water is treated in the lake using plants and other biological process in a wetland/reedbed system within the lake.

Disclaimer:
Given the preliminary nature of the assessment undertaken to date, the options presented are subject to further feasibility, site investigations and detailed design.

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# DELFIN ISLAND FRESHWATER LAKES, WEST LAKES

## Proposed Remediation and Water Recirculation Concept

*Prepared by: - Barrie Ormsby FAILA (Barrie Ormsby Landscape Architect)* May 2022

**(With Revised Recommendations 21.06.2022)**

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### Revised Recommendations (Report 21 June 2022)



### Report May 2022



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# REVISED REMEDIATION AND WATER RECIRCULATION RECOMMENDATIONS (21 June 2022)

Since the preparation of the original report "*Delfin Island Freshwater Lakes, West Lakes - Proposed Remediation and Water Recirculation Concept*", May 2022, prepared by Barrie Ormsby Landscape Architect (BOLA), further information has been obtained relating to the lake, which has some bearing on some of the proposed recommendations in this report. Accordingly, the recommendations have been revised.

These revised recommendations that follow are placed at the beginning of the above report, and the original report which follows has not been changed or altered for reasons of time constraints, etc.

The revised recommendations can be read as a 'stand-alone' document, but the discussions, information, etc, in the original report are still relevant and valid and useful in the consideration of these revised recommendations.

## 1. ADDITIONAL AVAILABLE INFORMATION

A report "Freshwater Lake Options Assessment" was prepared by WGA (Wallbridge Gilbert Aztec) at the request of the City of Charles Sturt, to enable Council to consider options for the remediation and upgrade of the existing freshwater lake in Delfin Island, West Lakes.

The report is a 'desktop study', understood to be based mainly on information from Council records and also anecdotal information from Council staff. It is understood that no field investigations, surveys or data collections were undertaken or required by Council as part of the preparation of this report.

The WGA report was obtained from the publically available agenda for a meeting of Council scheduled for Tuesday 14 June 2022, and provided to Barrie Ormsby Landscape Architect (BOLA) for review and comment, for the "Save the Ponds Group" (local concerned residents group).

This WGA report contains information that was not available to BOLA at the time that the above BOLA report was prepared.

Information from the WGA report of possible relevance to the above BOLA report of May 2022 includes the following: -

- Pond depths – originally assumed by BOLA at 600 to 800 mm, from measurements taken at the pond edges. Report states depths of 1.2 to 1.5 metres in the three main lakes. Since 'sludge/sediment' accumulates in the deepest part of a pond or lake, this influences possible options to manage or remove this sludge. This is assumed by WGA in their report.
- The total areas and water volumes of the lake system is larger than that estimated by BOLA, due to the lack of an accurate base map.

- Site map in the report shows the locations of outlets from the recharge bore into the lakes, and likely existing flow paths through the ponds.
- A water balance is provided in the report, showing total inflow (mainly from the recharge bore) and losses from the lakes due to both evaporation and seepage from the invert of the lakes. A static lake water volume is also shown.
- Bore salinity of 2,000 mg/litre (2,000 ppm).
- Some minor stormwater runoff into the lake from a carpark close to the northwest corner of the lake.
- A possible option to source lake recharge water from an existing MAR (managed aquifer recharge) located at the nearby West Lakes Golf Club, as an alternative to replacing/upgrading the existing bore.

The report proposes consideration of two (alternative) options to treat and clean the lake water: -

- Installation of a "Ocean Protect Filterra Biofilter" system, in which water is passed through an off-line (or out-of-lake) structure, where the water is cleaned by passing through a planted bioactive media, in a structure which is basically a concrete tank or trough, sized to suit, containing an organic media (with plants) through which the water flows.
- Alternatively, the installation of a "Floating Wetland", consisting of floating mats, planted with wetland vegetation, with the root system of the plants hanging down below the floating rafts into the water below. The roots provide a fine medium for the development of biofilms on the surface of the roots, which would react with and capture pollutants in the water passing through the roots.

(Comment: - Both systems would clean the lake water using the biological process inherent in any wetland water treatment system, including urban stormwater treatment wetlands. The different systems just use different ways of providing the medium and surfaces for the development of the essential biofilms (bacteria, algae, microorganisms, etc) to enable the biological processes to take place).

In addition, information has been provided to BOLA of a product called "TWC Block", from Marine Easy Clean Pty Ltd, which can be used "to restore the natural balance in an aquatic ecosystem by providing a favourable habitat for beneficial bacteria". The porous blocks, 1kg or 3.5 kg in size, contain bacteria, which over time, are able to restore the natural water cleaning process, and via bacterial remediation, reduce nutrient levels in the water, and degrade and so reduce/remove organic sludge (Refer section 5.2 this report).

## 2. PROPOSED REMEDIATION CONCEPT

The basis of any remediation concept revolves around two basic actions: -

- The establishment of a recirculating flow through all the ponds, so that water in all parts of the lake system are "turned over" regularly, minimising stagnant areas, and to direct water through whatever water treatment system (to capture and remove nutrients, suspended matter, etc) is established. (Refer Figure 2, original report)
- The installation of a water treatment facility that can improve water quality utilising the natural processes associated with wetland vegetation that are essential in capturing and removing pollutants from the water (possible options described as follows)

## 3. WATER TREATMENT OPTIONS

**3.1** The BOLA water treatment proposal envisages the construction of three appropriately sized shallow reedbeds, one in each of the West, East and North ponds, as shown in Figure 2.

The proposed recirculation system will direct flow from the West pond, through the initial reedbed in the West Pond, over the existing weir into the Central Pond. The flow then divides and flows into the East and North Ponds.

Extraction pumps in the East and North Ponds, located as shown at the downstream end of each pond, will return water back to the West Pond. Water extracted by the pumps will flow through the reedbeds which are located near the pumps, as shown in Figure 2.

The shallow reedbeds are essentially similar to reedbeds in urban stormwater treatment wetlands. Appropriately planted, they require very little maintenance once established.

However, either of the two water treatment option proposed for consideration in the WGA report could be integrated into BOLA recirculation concept.

**3.2** In the *Filterra Biofilter* system, water from pumped from the East and North Ponds could be diverted totally or partly into the biofilter, as required and depending on its design treatment flow capacity, with the treated water returned into the West Pond.

**3.3** The "*Floating Wetland*" system could be installed in place of the three reedbeds, in any suitable locations within the three ponds. It would be desirable to maximise the flow passing under each floating wetland mat, to minimise bypass and ensuring maximum contact between water flows and the roots dangling under the mats.

In terms of establishing a more natural and sustainable ecosystem in the lakes, the reedbed concept would be preferable, followed by the "floating wetland" system.

## 4. LAKE LINER

The WGA report provided an estimated annual water balance for the lake, indicating that, of a total annual outflow of 46.5 ML/a, 39 % was due to evaporation losses, and 61% was due to seepage. Their report estimated that re-lining the lake to minimise seepage losses would cost in the region of $1,000,000.

It is assumed that the lakes were originally lined with a compacted clay liner. The present condition and integrity of this liner is not known; this will need to be investigated before any work could be considered.

Some years ago, a considerable amount of the hard edging of the lake (originally asbestos) was replaced by steel sheet piling, driven into the bed of the lake. This would create a seepage path between the piling and the clay, which could possibly account for a proportion of the seepage losses. If possible, it would be desirable to determine exactly where seepage was occurring.


**Fig 1   Delfin Island Freshwater Lakes – Site Plan (not to scale)**

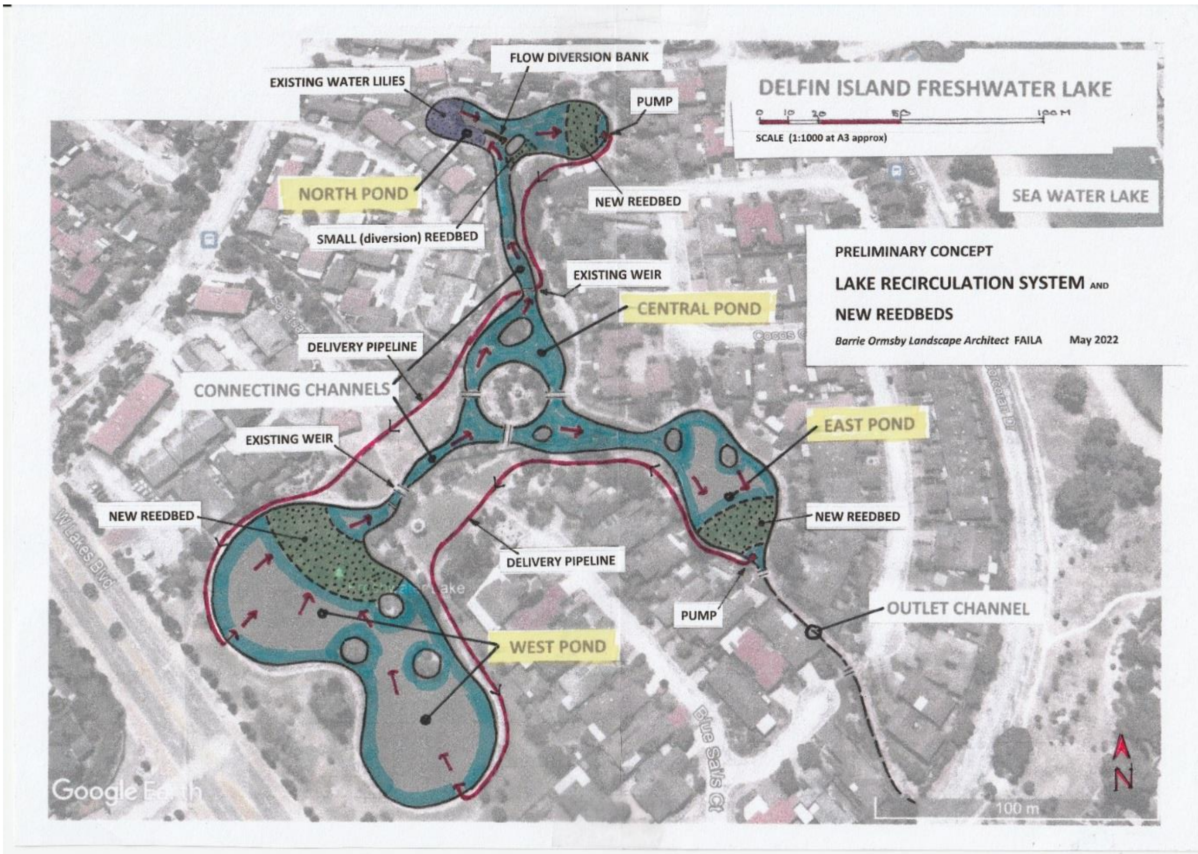


**Fig 2 – Delfin Island Freshwater Lakes – Concept - Lake Recirculation System and New Reedbeds**

Installing new lining to the lake, as described in the WGA report, would involve major earthworks and construction works and activities. All existing vegetation along pond edges and the extensive areas of waterlilies would need to be removed; it is presumed that the six existing islands would also be removed, for the installation of the liner. The work would also involve significant loss of amenity for some extended period, including the time taken to re-establish the landscape of the lake and surrounds. The work could be done in stages, one pond at a time, but this would extend the duration of the work considerably.

In considering the need for a new liner, a cost benefit study for installation of a new liner, compared to retaining the existing liner and the consequent ongoing costs (operational and environmental), would seem desirable.

The use of bore water to recharge the lake and subsequent loss of this water due to seepage to maintain a landscape and community asset (in this case, the Delfin Island lake), can be compared to the use of any water resource to provide and maintain any other community open space resource, such as grass/lawns and landscapes.

## 5. 1 SLUDGE REMOVAL

The WGA report provided an estimated cost to remove sludge from the lake in the order of $1,000,000, which is of serious concern to Council. It would be highly desirable if this cost could be avoided by the implementation of other alternative measures, as outlined/proposed in this report.

The sludge is likely to be concentrated in certain locations, particularly in the deepest parts of the ponds, and in backwater areas. An option to carry out a limited removal of sludge could possibly be carried out using a suction dredge, which would not involve draining the ponds.

The presence of the sludge is without doubt contributing to the poor water quality of the lake, particularly in combination with the carp population which would stir up the sludge, resulting in resuspension of nutrients and particulate matter, leading to algal blooms and low oxygen levels in the water.

This sludge would be of organic origin, from the decay of vegetable matter including leaf litter and wetland plants, and from faecal matter from water birds in particular. Faecal matter from birds also contributes nutrients to the water and sludge.

The sludge in wetlands and a pond system such as this is mainly organic in nature, and as such, under suitable conditions will be decomposed and degraded, so controlling or reducing its accumulation.

### **5.2** *TWC Block Treatment*

Information has been provided to BOLA during the preparation of this report, which would, on the information provided, be used immediately to begin the process of controlling and eventually removing the sludge, with a significant improvement in water quality.

The product from Marine Easy Clean Pty Ltd, based in WA, is in the form of bacteria-infused porous blocks (either 1.5 kg or 3 kg), which would be simply dropped into the water and distributed throughout the ponds. The number required (initial estimate 15 blocks) would be established in relation to the size and volume of the lake and the existing water quality conditions and specific pollutants.

The informant has used this product over a number of years to treat dams, lakes and ponds to treat water quality and sludge problems, with excellent results. The informant has been in touch with the company, who has confirmed the suitability of their product and treatment system to resolve the sludge and water quality issues in this situation.

This product could be deployed immediately before any other measures are implemented, with a suggested initial responses of cleaner water in 4 to 6 weeks and sludge reduction of 50% - 80% in the first 6 months (from information provided). The cost could be in the order of $15,000 per year for several years (verbal costing from informant via company)

I (BOLA) have no knowledge or experience of or with this product or company, but from the information provided, it would appear to offer an immediate answer to the very pressing and urgent issues relating to the remediation of the Delfin Island Lake.

This initial treatment using the TWC Block treatment should be followed by the installation of a water recirculation system, as described in this report (pumping from the East and North Ponds back to the West Pond), and the installation of some permanent water treatment and cleansing system (development of reedbeds as described, or either of the two options detailed in the WGA report).

The objective of these recommendations (the lake recirculation and water treatment system) is to establish an environmentally self-sustaining aquatic ecosystem, providing good water quality and habitat for aquatic fauna, and a system requiring limited maintenance requirements.

## 6. CARP REMOVAL

As detailed in the initial report, carp are detrimental to maintaining a good aquatic ecosystem, and a control program is essential, possibly on an on-going basis, to maintain the health of the lake. Expert advice should be sought to determine an appropriate strategy to control and/or remove carp.

## 7. LANDSCAPE IRRIGATION

The existing lake is essentially a closed system, with no effective or permitted outlet, so lake water and any pollutants in the water remains in the lake, with pollutants trapped within the lake, and accumulating over time.

The proposed recirculation and water treatment installations will offset and reduce pollutant levels and rates of accumulation. However, it would be desirable if there was some means of discharging water from the lake and replacing it with fresh clean water.

The original BOLA report (Section 5) proposed that existing source of water (presumed to be bore water) be replaced by using water from the lake itself, and re-directing the bore water that would otherwise be used for irrigation into the lake. The volume of water used from the bore for both the lake recharge and for landscape irrigation would not change, just a change in flow directions.

However, some constraints would have to be considered before this could be implemented, as follows:

- The lake water quality would need to be acceptable for irrigation use in a public place – at present water quality would not be acceptable, and so could only be implemented once all the recommended remediation works were operational and improving the water to an acceptable standard. As the report states, this could be some time before this would occur.

- The water from the existing bore in Corcoran Drive has a salinity of 2000 ppm, which may be too high for irrigation of the lawns and landscape. This may preclude this option, but if the landscape was already being irrigated using bore water (as assumed), then this may not be an issue. However, if the bore was replaced with a source from a Council operated MAR system (located ?, as suggested as an option by the WGA report, then using the low salinity water from this source would be of benefit to both the lake and the irrigation of the reserve.

## 8. WORKS/MATERIALS SCHEDULE

The works and materials involved in the implementation of the BOLA remediation concept (recirculation system and reedbeds) are listed in the following: -

1. Recirculating pumps – two required, can be either floating or submersible. Electrical supply to each pump, pump control/switching systems, flow control valves.

2. Pipe work - from recirculating pumps to West Pond (pipe routes as shown Figure 2): -

- From South Pond to West Pond – approx 280 m
- From North Pond to West Pond – approx 355 m

Trenching, reinstatement of lawns and landscape, path crossings, irrigation pipes, outlets to West Pond (2 off), etc, involved.

3. Delivery pipe from bore to West Pond – there is an existing pipe from the bore to the Pond, but the recirculation concept requires all recharge water from the bore to be directed to the West Pond, instead of some flow to the North Pond (lake 3 in WGA report). The existing pipe to West Pond (for possible increased flow rate) may need to be replaced or duplicated – length not known.

4. Pond water level, flow sensors, etc - existing instrumentation for the control of pumps, etc, may need to be replaced, upgraded, or new sensors required

5. Reedbeds - one each in three ponds – refer Figure 2 for locations

West Pond (all amounts quoted are approx)

- Area 1050 $m^2$
- Soils fill 1250 $m^3$
- Edging length 95 m (gabions average height 1.0 m)
- Pipes under reedbed x 2 (90 mm diam) – 50 m

South Pond

- Area 480 $m^2$
- Soils fill 550 $m^3$
- Edging length 60 m (gabions av ht 0.9 m)
- Pipes under reedbed x 2 (90 mm diam) – 35 m

North Pond

- Area 350 $m^2$
- Soils fill 450 $m^3$
- Edging length 70 m (gabions av ht 0.9 m)
- Pipes under reedbed x 2 (90 mm diam) – 25

Geotextile is required between gabions and soil in each reedbed, to prevent soil washing out into ponds. An explanation of the process for the construction/placing of soil in the reedbeds, and the function of the pipes under each reedbed is provided in Section 6.1 of the original BOLA report.

6. Reedbed planting

Approx 10,000 plants at 5 plants per $m^2$. A suggested species list is provided in Section 6.2of the orifinal report.

# ORIGINAL REPORT (May 2022)

## SUMMARY

This report provides detail of a proposal for works to remediate several issues relating to the maintenance and management of the Delfin Island Freshwater Lake, otherwise known as the Delfin Island duck ponds. The layout of the ponds and the overall site is shown in Figure 1, and the proposed scheme is shown in Figure 2.

A significant feature of the existing pond system is that it is a “closed” system, in that it does not have any overflow or operating outlet, so that the water in the ponds is contained within the ponds, such that any pollutants, particulate matter and sediment, etc, in the pond water can and does accumulate, with no processes (natural or mechanical) of any significance that could reduce the level of pollutants. This is resulting in poor water quality, with algae growth, suspended matter in the water, and accumulating sediment.

Water is only lost from the pond system through evaporation losses and possibly by leakage to the subsoil; these losses are made up by rainfall and water pumped from a deep aquifer bore.

Pollutant input to the pond water would appear to be mainly from faecal matter from the waterbird population of the ponds, as well as decaying vegetable matter (leaf litter, plants, etc).

It does not appear that stormwater runoff from the surrounding residential area, except possibly from the surrounding parkland, is discharged to the pond.

*The three principal elements of the proposed works, as described in Section 4 of the report, are: -*

- Development of a recirculation system for the ponds, by installing pumps in the North and East Ponds, pumping water from these two ponds and discharging it into the West Pond, and allowing this water to flow back and recirculate through the pond system.
- Constructing and establishing three main reedbeds, one in each of the West, North and East Ponds, so that the recirculating water will flow through the reedbeds, so that the reedbeds can filter and clean the water.
- Reconfiguring the irrigation system of the surrounding landscape, so that, instead of the irrigation system drawing its water supply directly from an existing deep aquifer bore, the water for irrigation is extracted from the West Pond. The water in the West Pond is then replenished from the bore to maintain the operating water level in the pond.

*<u>This integration of the pond recirculating system and the irrigation system is the key element in the proposed scheme, as this will result in water in the ponds being gradually replaced with clean bore water. The reedbeds will reduce pollutant levels before it is used for irrigation, and any remaining pollutants in the water used for irrigation (nutrients, particulate material, etc) will be applied to and absorbed by the soil of the irrigated areas.</u>*

Over time, the continual process of removal of pollutants by the filtering reedbeds as water is continually recirculated through the ponds and reedbeds, the extraction of water from the West Pond for irrigation, and the continual replacement of the water used for irrigation, it is expected that the levels of pollutant in the pond water will stabilise at a very low level, so that the water will be much cleaner, with minimal algae and suspended particulate matter in the water.

The issue of sediment (sludge) in the ponds would seem to be of considerable concern to Council, as removing this sediment may be difficult and incur a very significant cost. (It is not known what the existing build-up/depth of sediment is within the ponds).

It is suggested in this report that sludge removal should not be carried out as part of any initial remediation work; the need for this to be done is then to be assessed (in terms of water quality and actual amount of sediment) at some time after the main works (as listed above) have been completed and have been operating for some period of time.

It is noted that urban water treatment wetlands, of which there are numerous examples in Adelaide, can and do produce clean water, suitable for reuse, even though all wetlands would have significant sediment loads, however, this does not prevent the wetland from functioning efficiently (in producing good quality and clean water).

It is quite possible, that after the remediated pond system has been established and has been operating for some time, that sediment is no longer accumulating in the ponds, the water quality is acceptable (water has become clear) and the appearance of the ponds have improved substantially, and the need to carry out major de-silting works is assessed as no longer necessary, even if sediment remains in the ponds.

However, there are (as reported) numbers of carp in the ponds. These fish have a significant detrimental impact on water quality, as their bottom-feeding habit stirs up sediment, re-suspending sediment that clouds the water and releasing nutrients which can lead to algae blooms.

It is recommended that a carp removal or control program be undertaken, if not to remove them completely, then to remove all large breeding fish. Carp could also affect the plants in the proposed reedbeds.

## 1. BACKGROUND

The "Freshwater Lake" on Delfin Island, West Lakes, also known as the Delfin Island duck ponds, was constructed in the 1970's as a key water feature of the landscape of the West Lakes Delfin Island Development, and much appreciated by residents and visitors.

Council (City of Charles Sturt) is reviewing the present operation and maintenance of the freshwater lake, and initially proposed four options for consideration in a public flyer: -

1. *Maintain the lake in its current form and continue with existing maintenance and management practices.*
2. *Maintain the lake in its current form with improvements to permanently enhance lake performance and quality, operations and management.*
3. *Reduce or change the size and shape of the water body and increase the amount of terrestrial (land) open space as a result.*
4. *Have no lake, and make the entire reserve terrestrial (land) open space.*

Following a well-attended public meeting and a presentation to Council by two members of a resident's group, it is understood that Council has resolved that Options 3 and 4 would be "set-aside" and not considered further.

Barrie Ormsby FAILA (Barrie Ormsby Landscape Architect) was invited by a committee of local residents, who are concerned by possible changes to the existing lake or its removal, to view and assess the existing lake and its management, and provide comment and advice as to possible actions that could be implemented that would maintain and possibly enhance the existing lake, desirably with greater environmental benefits than the current lake provides (as per Option 2).

Following a meeting with a number of residents and subsequent inspection/assessment of the lake system, a report was prepared by Barrie Ormsby: - "*Delfin Island Freshwater Lakes, West Lakes, Review of Proposed Council Options for Future of Freshwater Lake Operations and Management*", dated 22nd March 2022. (Referred to in this report as the 'first report").

This first report examined the merits and impacts of each option, and concluded that Option 2: - (*Maintain the lake in its current form with improvements to permanently enhance lake performance and quality, operations and management*) would seem to be the most desirable option, and was strongly favoured by residents and others.

The report went on to describe the elements of a scheme that could provide the desired outcomes of environmental improvement and improved water quality, while retaining and possibly enhancing the existing visual and recreational amenity of the site.

The recommendations of this first report were based on (anecdotal) information provided by local residents, on observations made during two visits to the Freshwater Lake, and on Barrie Ormsby's considerable experience gained through a long involvement in the design, construction, planting and management of many urban and non-urban wetland systems, ponds and waterbodies.

The following report provides a more detailed description of a practical concept for Option 2, which is believed will achieve the desired environmental, management and aesthetic outcomes for the lakes.

## 2. EXISTING FRESHWATER LAKE SYSTEM AND SITE DESCRIPTION

The lake consists of three separate ponds, connected by relatively narrow channels to a central pond, which contains a circular island with a shelter and seating. An overflow and outlet channel runs from the East Pond to and under Corcoran Drive, to a small stormwater (?) pond at the corner of Corcoran Drive and Sir John Marks Drive, which then can drain via a stormwater pipe into the very large salt water West Lakes lake system. (Refer to site plan (Figure 1) below for pond locations and naming, etc).

It is assumed that the overflow/outlet channel as shown only operates as an (if needed) overflow for the lake, and is not currently used to drain or discharge water from the lake. It is also understood that water from the ponds is not permitted to be discharged into the salt water lakes, presumably due to the poor water quality (nutrients, pathogens, etc) of the lake water.

It is understood that the water in the freshwater lake is maintained by pumping from a bore (presumably from a Tertiary (deep) aquifer). It is also assumed that any drainage of stormwater/runoff from the surrounding streets and residential development into the ponds is very limited, if any.

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From observation, it would appear that the water supply (from the bore) to the lake system is discharged into the west pond, which then flows over a weir into a narrow channel which connects to the remainder of the ponds. Difference in water level as observed between the West Pond at this weir and the remainder of the system is approx 300mm.

From very rough calculations, the pond system is estimated to have a volume in the order of 6,000 $m^3$, based on average depths in the order of 500 to 800 mm (average 700 mm) (as determined by a limited number of measurements at the edges of the ponds), and assumed roughly level inverts.


**FIG 1   Delfin Island Freshwater Lakes – Site Plan (not to scale)**

The water in the ponds is visually poor with a dark greenish colouration, and visibility into the water column is limited to roughly 300 mm or less, indicating a significant suspended material and algae load, which obscures the bottom of the ponds.

As observed, water from the West Pond (refer Fig 1) flows over the existing weir into the Central Pond and then into the North and East Ponds. As there are no outlets for the North or East Ponds, water in these two ponds is effectively stagnant.

A more complete description of the lakes and their condition is provided in the first report.

## 3. DISCUSSION

The first report ("*Delfin Island Freshwater Lakes, West Lakes, Review of Proposed Council Options for Future of Freshwater Lake Operations and Management*", dated 22nd March 2022) provided suggestions to achieve the desired environmental outcomes as per Option 2; that is, "*Maintain the lake in its current form with improvements to permanently enhance lake performance and quality, operations and management".*

To achieve a permanent enhancement of lake performance and quality, etc, as desired, will require, in particular, a significant improvement in water quality and a reduction of the rate of sedimentation. If this can be achieved, then the operation and management of the lake system can be made easier and more self-sustaining. At the same time, the visual amenity of the lake would be improved.

Three specific elements were suggested in the first report that would enable this desired improvement in water quality to be achieved, as follows: -

- The establishment of a recirculating flow through all the ponds (this enables water to be directed through and treated by flow through reedbeds in each pond),
- The establishment of three main reedbeds to capture and remove nutrients from the water, and to capture and retain suspended solids within the reedbeds (as sediment), which would reduce the rate of sedimentation elsewhere in the pond system).
- Utilise the water in the ponds as the source of irrigation water for the surrounding landscape, with the water withdrawn from the ponds replaced by clean aquifer water from the existing bore.

*<u>This third (dot point) proposed action will be of particular benefit, if not essential, to achieve the desired water quality improvement and the other objectives.</u>*

The existing lake and pond system is essentially a "closed system", with no regular overflow or outlet, so that the only water losses are due to evaporation and possible seepage losses to the subsoil. As such, the ongoing discharge of pollutants and accumulated sediments into the ponds will accumulate over time, leading to worsening water quality.

Nutrients in the water will in particular lead to the growth of algae (as shown by the existing greenish discoloration of the water), with resulting poor visual quality.

There are no mechanisms, natural or otherwise, in the existing operation of the lake system (other than very infrequent and costly de-silting of the ponds), that can reduce or control the accumulation of pollutants in the water and particularly the amount of sediments on the bottom of the ponds.

By comparison, adequately designed and established urban stormwater wetlands, with considerable pollutant loads in the inflowing stormwater, and with accumulated sediments on their inverts, can and do achieve good water quality on a continuing basis.

The intent of the proposed actions; that is, recirculation of water through the ponds and the establishment of reedbeds, is to replicate the water quality enhancement processes that occur in these urban wetlands, within the Delfin Island lake system.

There are a number of key pollutant removal/retention/transformation processes occurring in wetlands and wetland reedbed systems, including: -

- Sedimentation, particularly within reedbeds,
- Fine particulate filtration by reedbeds, and
- Nutrient uptake by sediments and soils, biofilms (layers of bacteria and micro-organisms on submerged plant and other surfaces), and by the plants (macrophytes),
- Disinfection of bacteria and other pathogens by sunlight in open water areas.

The recirculation of the pond water through adequately sized reedbeds will reduce pollutant loads in the first place, then extracting/removing water from the ponds for irrigation, and replacing this water used for irrigation with clean bore water, will, in combination, effect a significant and ongoing improvement in water quality.

Constructed urban stormwater treatment wetlands, designed specifically to reduce and remove pollutants from urban runoff and to produce clean water suitable for reuse, typically can have approx 25% of open water and 75% of reedbeds (surface area).

Given the unique visual and aesthetic characteristics of the Delfin Freshwater Lakes, and the expectations of the local residents, the conversion of the existing attractive generally open water lake system to one of ponds with extensive reedbeds would be unlikely to be publically acceptable or aesthetically desirable.

Again, given the unique circumstances of a closed pond system, with steady but limited inputs of pollutants (mainly organic nutrients and matter of faecal from the birdlife of the ponds, and leaf and vegetable litter), the continual recirculation of water through the ponds and reedbeds, the extraction of water from the ponds for irrigation, and replenishment of the ponds with clean bore water, it is considered unnecessary to establish large areas of reedbeds in the pond system.

## 4. LAKE REMEDIATION/ RECIRCULATION CONCEPT

A schematic concept for a recirculation system for the ponds is shown in Figure 2.

The three principal elements of the recirculation concept as shown are: -

- Establishment of shallow reedbeds in each of the three main ponds,
- Installation of two pond extraction pumps at suitable locations as shown at the downstream ends of the North and East Ponds.
- Delivery pipelines to take water from the pumps to discharge into the West Pond, at two separate locations.

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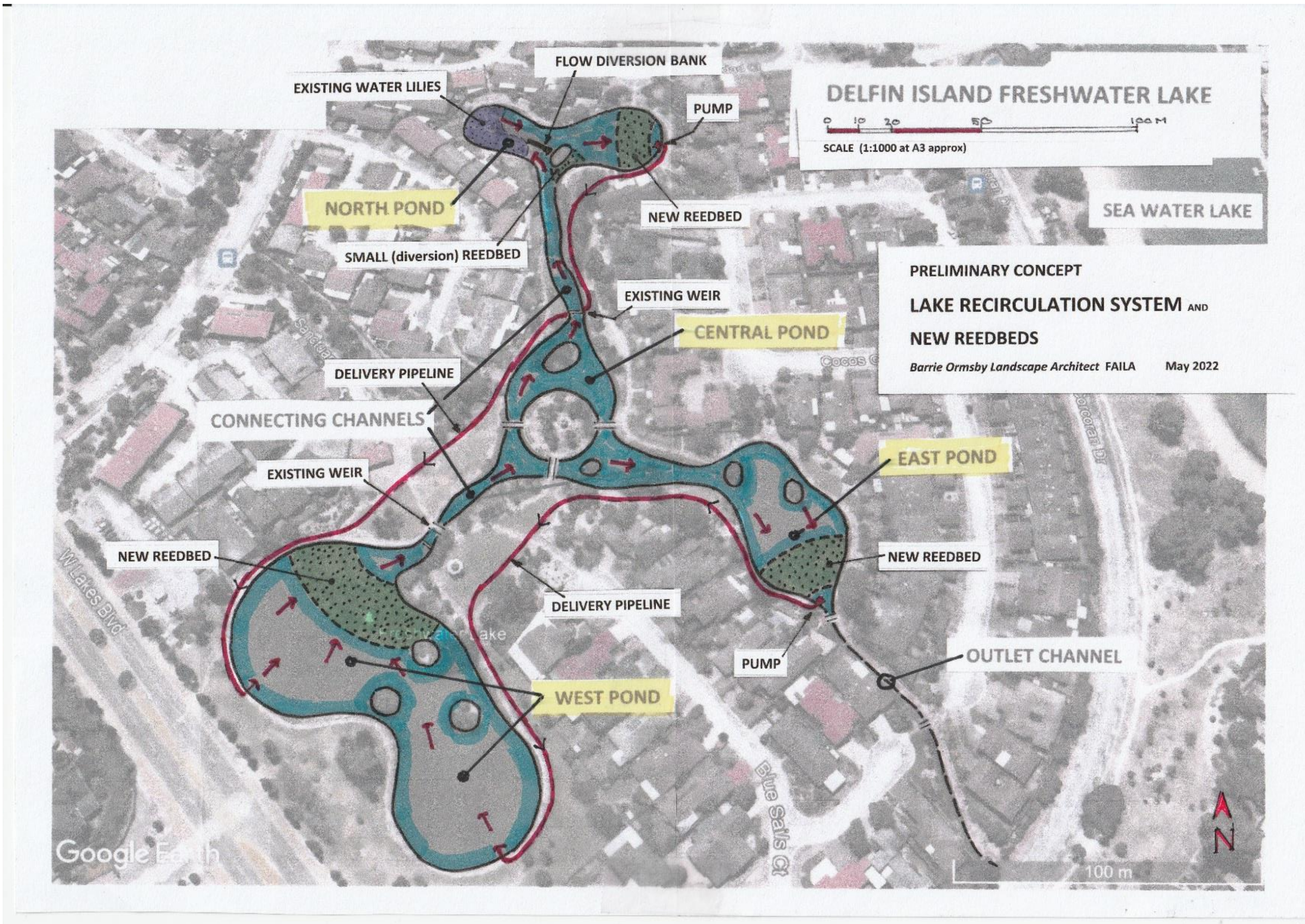


**Fig 2 – Delfin Island Freshwater Lakes – Concept - Lake Recirculation System and New Reedbeds**

In addition, a flow diversion bank and a small flow diversion reedbed is shown in the North Pond to direct most of the inflow into and through the existing area of well-established waterlilies in the northern lobe of this pond. This will minimise any short-circuiting of this area of pond; water would otherwise flow directly to the south end of the pond.

Arrows show the direction of flow through the ponds, and in the pipelines.

The outflow pipelines from each pump are shown as separate lines, with each discharging separately into the West Ponds. This is likely to be the most cost effective layout and could be more simple and flexible to operate.

Because it is a large pond, it is desirable that the pumped discharge from the other two ponds into the West Pond occurs at least at two locations (as shown), so that inflow is distributed more evenly throughout the pond. The existing location of the bore water discharge into West Pond is not known, and extraction of water from this pond for irrigation could be from any point in the pond.

*Critical Design Parameters*

It will be essential to determine three parameters for the design of the system as shown: -

- The desirable recirculation rate of the pond water through the ponds (and hence the turnover time of the total volume of water in the system), and,
- The optimum area of each reedbed to achieve the desired water quality, which will relate to the rate of flow through each reedbed, and,
- The demand (varying seasonally) for irrigation water that will be extracted from the pond system. There will be in effect a complete replacement of the water in the pond system on a regular but variable basis, which will depend on the total volume of water in the pond system and the rate at which water is used for irrigation (which will vary from a maximum in the peak of summer to minimal during winter)

*Note that no attempt has been made to quantify these parameters in developing this concept.*

The size and area of each reedbed as shown in Figure 2 is indicative only, and it may be found that they should be larger than shown. However, their location in each pond (at the outlet end of each pond) as shown is important for the function of the reedbeds and the water quality enhancement processes.

## 5. INTEGRATION OF POND RECIRCULATION AND LANDSCAPE IRRIGATION SYSTEMS

The proposal, as outlined in the first report, is that water be extracted from the pond system and used for irrigation of the surrounding landscape, rather than irrigation supply being provided directly from the bore as at present. The water extracted from the pond(s) for irrigation would then be replaced by bore water, as irrigation withdrawal occurs.

This is considered to be a significant and important component to maximise the improvement of water quality in the ponds, and possibly minimise some of the current issues with the maintenance and appearance of the ponds.

As stated before, the existing system of ponds is essentially a closed system, with no outlet (except possibly for surcharge due to rain or flooding events), and topped up from the bore to offset any losses due to evaporation or seepage.

The consequence of a closed pond system such as this is that any pollutants, particularly nutrients (from bird excreta, fertilisers applied to the landscape, and decomposition of organic matter), and any salts from the bore water, can become concentrated which could (and do) result in algae blooms and poor water quality.

By using water from the ponds for irrigation rather than irrigating directly with bore water, the water in the ponds would gradually be removed and replaced by clean bore water, with any nutrients and contaminants remaining in the pond water after treatment by the reedbeds being removed with the irrigation water.

The location of the existing bore within the reserve and details of the irrigation system is not known. It is assumed that the bore also discharges into the West Pond at some point. Extraction of water from the pond system for irrigation should occur from the West Pond, as it has the largest static capacity/volume of any of the ponds, and so extraction of water for irrigation would have less impact on the water level in the pond at any specific time or period. Possible drawdown of the water level would depend on the balance between the bore discharge rate to the pond and the pumping/extraction rate from the pond to the irrigation system (assuming that irrigation and pumping into the pond would occur at the same time). Any draw-down would be expected to be relatively minimal, with the water level restored to normal on a daily basis.

The operation of the bore pump into the pond would be automatically controlled by a water level sensor in the pond. Recharge of the ponds could operate continuously (24 hours/day) if needed, but irrigation would presumably be limited to night time hours to minimise evaporation losses and to minimise nuisance to park users. The operation of the irrigation system could remain as at present, controlled by irrigation controller(s) as at present.

It is likely that the irrigation system is supplied by water from the bore under pressure by the bore pump. If this is so, then a separate pump will be needed to extract water from the pond and supply the irrigation system.

The irrigation extraction system and the pond recharge should be inter-connected so that, if extraction from the pond is interrupted for whatever reason (inadequate water quality, maintenance of the ponds, etc), then irrigation can continue as required directly from the bore.

## 6. REEDBEDS

As stated before, this is a “closed” system (unlike a stormwater wetland), with limited and relatively regular nutrient input (from birds, decaying vegetable matter, etc) (unlike stormwater wetlands), and with water in the system being replenished with bore water to replace losses (evaporation, etc). The extraction of water from the pond system for irrigation purposes, particularly during summer, will have a significant beneficial impact on water quality by removing pollutants from the system.

As shown, each of the proposed three main reedbeds are located at the downstream end or outlet of each of the main ponds (refer Figure 2). Water will flow into each reedbed along a wide/broad edge, and flow slowly though each reedbed. In the West Pond, the reedbed will discharge into an outlet channel leading to the Central Pond, and in North and East Ponds the reedbeds will discharge into a small area of open/deep water at the end of the pond, from which water will be pumped to the West Pond as shown.

The higher the recirculation rate, the larger the pumps and pipeline capacity will need to be, with increased running costs, etc. Some control to vary pumping rates may be desirable to reduce or increase the recirculation rate, depending on the water quality at any particular time.

The efficiency of the reedbeds in removing pollutants and improving water quality is dependent on the amount and duration of contact of the water with the surfaces of the plants and soils in the reedbeds. For this reason, it is essential that flow velocity through the reedbed is as low as possible, to maximise this contact time and particularly to minimise both disturbance of the biofilms on the surfaces of the plants, etc, and to minimise disturbance and re-suspension of captured sediments within the reedbeds.

Note that the existing narrow channels that connect the three main ponds, two of which have previously been planted with reeds, are not suited to become effective reedbeds, as any suitable recirculation rate determined for the system would result in excessively high velocity though the very restricted flow cross-section of the channels, particularly when planted with wetland plants.

The two pumps could also be useful to de-water the ponds if needed, eg, for maintenance purposes.

The wetland vegetation creates the physical and biological conditions required for the successful removal of finely graded particles and associated pollutants. Emergent vegetation will minimise wind-generated turbulence, allowing sediments to settle. The submerged stems and leaves of the plants provide a surface for the establishment of 'biofilm', such as bacteria and algae, which will capture/remove both fine particles and dissolved pollutants from the water column. The root systems of the vegetation binds and stabilises deposited particulates, protecting them against re-suspension, and modifying and stabilising pollutants in these sediments and the soil of the reedbeds.

For the reedbeds to be effective, it is essential that they are sized and designed to maximise their performance, and that they are planted with suitable plant species. It is also essential the flow velocity through the reedbeds is low enough to eliminate or minimise any possible re-suspension of sediments or loss of biofilm from within the reedbed.

## 6.1 Reedbed Design and Construction

The reedbeds are the key to the remediation of the lake and improving water quality, reducing the accumulation of sediments (sludge) in the ponds, and establishing a more sustainable ecosystem in the lakes, so it is essential that they are designed, constructed and planted to current best practice.

The three reedbeds are shown at the outlets of each pond. The reedbed in the West Pond is located at the outlet from the pond into a channel, while the reedbeds in the North and East Ponds are located close to the pump extraction locations, as shown in Figure 2.

The reedbeds should generally be constructed with a good quality loamy, low salinity soil (not clay or sand). The water depth above the reedbeds should be in the order of 100 to 200 mm below normal operating water level.

The layout of each reedbed must be designed to ensure "plug flow" through the reedbed, with a consistent length of flow (from inlet edge to outlet edge) through the reedbed to ensure that preferential flow paths do not develop.

The selection of species and the layout of the planting should also aim to minimise the development of preferential flow paths through the reedbed, which can lead to poor performance. The objective in the design of the planting design is to achieve a consistent density of plant stems below the water surface.

Soil should be contained at each edge of each reedbed by a rock or gabion wall or similar construction, to prevent erosion of the edges of the reedbeds or slumping of soil from the reedbed into the open water areas. The edges can be formed of any suitable material, such as rock-filled gabions, quarry rock or brick (besser block could be quite suitable). These edges, regardless of the material, will virtually 'disappear' from sight once plants grow and the edge material becomes coated by algae as all underwater surfaces do.

It is recommended that (one or two) pipes (say 90/100 mm diam stormwater uPVC), be installed under each reedbed, at or just above the invert of the ponds, to allow flow between ponds when water levels are below the level of the soil in the reedbeds. This will enable water levels to equalise either side of the reedbed, which is particularly important when filling ponds after lowering water levels or when emptying (eg, for maintenance, etc).

The installation of small diameter pipes under the reedbed is intended to avoid or minimise any erosion or channelling of the soil surface, particularly during the first filling after construction, as this can lead to the development of gutters and preferential flow paths. (A 'preferential flow path" allows a localised rapid flow path to develop through the reedbed, with other areas of the reedbed thus receiving less flow and becoming less effective, so reducing the overall performance of the reedbed).

Small pipes installed in this way under reedbeds carry minimal flow when the ponds are at normal operating water levels with water flowing through the reedbeds, and so do not detract from the function of the reedbeds in cleaning the water flowing through the reedbed vegetation.

The soil placed in a reedbed should <u>initially be over-filled, then compacted to a compaction equivalent to a natural undisturbed soil (approx 70% compaction), then graded off accurately to design levels.</u> This compaction will minimise any settlement after the reedbed is planted and flooded, and make planting easier.

Loose uncompacted soil in a reedbed is liable to settle after flooding, and can easily be eroded and washed away when the bed is first flooded, particulary if water has to flow across the surface of the bed when being first filled.

## 6.2 Reedbed Plant Selection and Planting

The selection of suitable species of wetland plants is critical to the efficient functioning of the reedbeds. There are two basic growth forms of emergent (have leaves/stems above the surface) wetland plants: -

- Species that grow as clumps or tussocks, often forming dense tussocks, the density of stems within the clump which can restrict or prevent the flow of water through them, and,
- Spreading species, which spread by means of underground rhizomes or above ground stolons. These species can spread over large areas, usually with fairly uniform density of stems or growth.

In a reedbed planted with clumping species, water will flow around the clumps, with much reduced contact between water and plant surfaces. Planting of reedbeds for water quality functions should primarily utilise spreading species, with possibly only a few widely spaced/scattered clumping species, if desired, for aesthetic and plant diversity purposes.

Suitable spreading species could include:

| SPECIES | COMMON NAME | HEIGHT |
|---|---|---|
| *Centella cordifolia* | Centella | To 30 cm |
| *Eleocharis acuta* | Spike rush | 30 – 50 cm |
| *Hydrocotyle verticillata* | Shield pennywort | To 10 cm tall |
| *Marsilea drummondii* | Nardoo | Up to 30 cm tall |
| *Marsilea mutica* | Nardoo | Floating leaves |
| *Schonoplectus pungens* | Club rush | 30 – 60 cm |
| *Triglochin procerum* | Water ribbons | Long strap floating leaves |
| *Triglochin striatum* | Streaked arrowgrass | 10 – 20 cm |
| | | |

When planting seedlings into reedbeds, it is essential that they be planted so that not more than half of the stem or leaf is submerged (except for *Triglochin procerum and Marsillea mutica*, which are submergent species – can grow under water) – if planted too deep, the plant can drown. (Emergent wetland plants rely on their above water level stems to 'breathe'). Water levels can be manipulated to provide the correct depth of water when planting and while plants are becoming established, particularly if the plants are small.

The planting density can be suited to the availability of plants (and budget), but a spacing of 40 to 50 cm apart should be sufficient to achieve good cover of most species within a few months (depending on the time of planting).

Some waterbirds may graze on and disturb newly planted wetland plants; if this occurs, it may be necessary to exclude birds by covering with temporary netting.

Some of the existing areas of reeds in the narrow channels have been planted with *Schoenoplectus validus* (river club-rush), which is considered unsuitable in these narrow channels and in this site, as it is quite tall and dense growing, and can obstruct flows.

The northern end of the North Pond has established areas of a water lily (species not known, most likely not native). It is reported these were planted a number of years ago, probably initially just a few plants, and which have since spread to cover much of this part of the pond. It has probably been able to establish in any accumulated sediment in the bottom of this pond.

This area of water lilies has been reported to have better water quality than the other ponds. If this is so, the beneficial impact of this established vegetation on water quality in this area of the pond would likely be due to the capture of pollutants from the water by biofilm on the plants stems and leaves, the plants and leaves which cover the surface of the water creating conditions that encourage sediment to settle out, and the plant roots helping to retain and oxidise organic matter in the sediments.

Some other small areas of the ponds the water lily has recently been planted by Council, initially covered by wire cages.

Note: Environmental Enhancement

The proposed construction of a limited extent of reedbeds is primarily for water treatment purposes. They will provide some additional but limited habitat diversity for the lake system.

However, if it considered that greater aquatic habitat and environmental diversity in the ponds would be desirable, then additional work could be undertaken to achieve this. In particular, additional areas of reedbed planting could be established, with a wider selection of plant species and varying water depths.

These could be as separate isolated areas within the ponds, located around some of the existing islands, or along existing pond edges.

The existing islands, of which there are eight, and which generally have established trees and palms, appear rather artificial and not particularly sympathetic to the overall lake landscape. The appearance of these could be enhanced by establishing reedbeds and reedbed plantings around the islands. The reedbeds could be informal in shape to create visual interest, and a number of different species planted, including taller species, to provide diversity of habitat.

## 7. SEDIMENT (SLUDGE) and CARP

### 7.1 Sediment/Sludge

The estimated cost and difficulty of removing the existing sediment/sludge load from the ponds is reportedly a major concern of Council, and it is believed that the sludge is responsible for the very poor water quality of the lakes.

The sludge in wetlands and a pond system such as this is mainly organic in nature, and as such, under suitable conditions will be decomposed and degraded, so controlling or reducing its accumulation.

However, the proposed recirculation of water through the ponds and reedbeds, the impact of the reedbeds (or alternative treatment systems) in capturing particulate matter from the water flowing through the reedbeds, is intended to reduce the rate of accumulation of sediment while improving water quality and hence the appearance of the ponds. It may be possible to achieve this with the existing sediment remaining in place.

It is suggested that the construction of the reedbeds or alternative treatment systems, the installation of the two pumps and recirculating pipework, be completed before any works to remove sediment from the ponds are contemplated. The new system should then be operated for an extended period, possibly one or two years, to assess the performance of the new system, the resulting water quality, whether the sediment is detrimental to water quality, and any change to sediment loads in the ponds.

Stormwater wetlands naturally build up organic sediment (sludge) in the invert of any wetland over time, but still operate satisfactorily to produce clean water. Decay of the organic matter in the sediments consumes any oxygen present in the sediment, so that the sediments become anoxic (without oxygen), resulting in smells, etc, but this may not cause a problem if the sediment is not disturbed.

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However, if the sediment is stirred up and mixed with the water in the pond or wetland, then the nutrients in the sediment can trigger the growth of algae, which mixed with the re-suspended sediment, will result in discoloured water with reduced water quality.

## 7.2 Carp.

Carp can grow to 1.0 m in length or more, and can breed prolifically. They are bottom feeders, stirring up mud and sediments, which usually results in poor water quality, as described above.

It will be highly desirable to remove carp from the ponds, or at least to reduce the numbers of the larger breeding fish, by whatever practical means possible. Expert advice should be sought on this, but options could include encouraging fishing, carrying out netting, electro-fishing, or by draining the ponds (possibly one at a time) and manually removing fish. Installing fish screens between ponds could assist in managing the numbers of larger fish in each pond, and prevent them moving between ponds.

The weir at the outlet of the West Pond will prevent carp from moving from the lower ponds into the West pond, so if carp are removed from this pond, it should remain free of carp.

It is known that the ponds also contain River Murray Rainbow Fish (7 to 9 cm), which are a very desirable native species that control mosquito breeding. Also present in the ponds are two (South Australian) species of native turtles.

During any action to remove carp, consideration must be given to avoid any detriment impact on these desirable species and any other aquatic life present.

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# DELFIN ISLAND FRESHWATER LAKES, WEST LAKES

## Proposed Remediation and Water Recirculation Concept

### (With Revised Recommendations 21.06.2022

*Prepared by: - Barrie Ormsby FAILA (Barrie Ormsby Landscape Architect)* May 2022

## ADDITIONAL RECIRCULATION OPTIONS – 7 July 2022

### INTRODUCTION

The report "*Delfin Island Freshwater Lakes, West Lakes - Proposed Remediation and Water Recirculation Concept*", dated May 2022, and consolidated with "*Revised Recommendations*" dated 21.06.2022, provided a concept (refer Figure 2) for the recirculation of the lake water through the three main ponds (West, North and South Ponds), and the installation of shallow reedbeds in each of these ponds.

This report provides three additional options to achieve the desired recirculation of water through the lake system and directing these flows through new reedbeds. These three options reduce the need for new infrastructure by making use of existing infrastructure, particularly the existing borelines.

A general Site Plan is shown in Figure 1, showing the naming of the ponds, as used in this and other reports prepared by BOLA.


**Fig 1 Delfin Island Freshwater Lakes – Site Plan (not to scale)**

The original concept to recirculate water through all the ponds and the proposed reedbeds, is shown in Figure 2, and the additional options are shown in Figures 3, 4 and 5.

(Site plans for Options B, C and D in this report are taken from site plan in the WGA report).

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**0RIGINAL CONCEPT (as per Report dated May 2022 and 21.06.2022)**

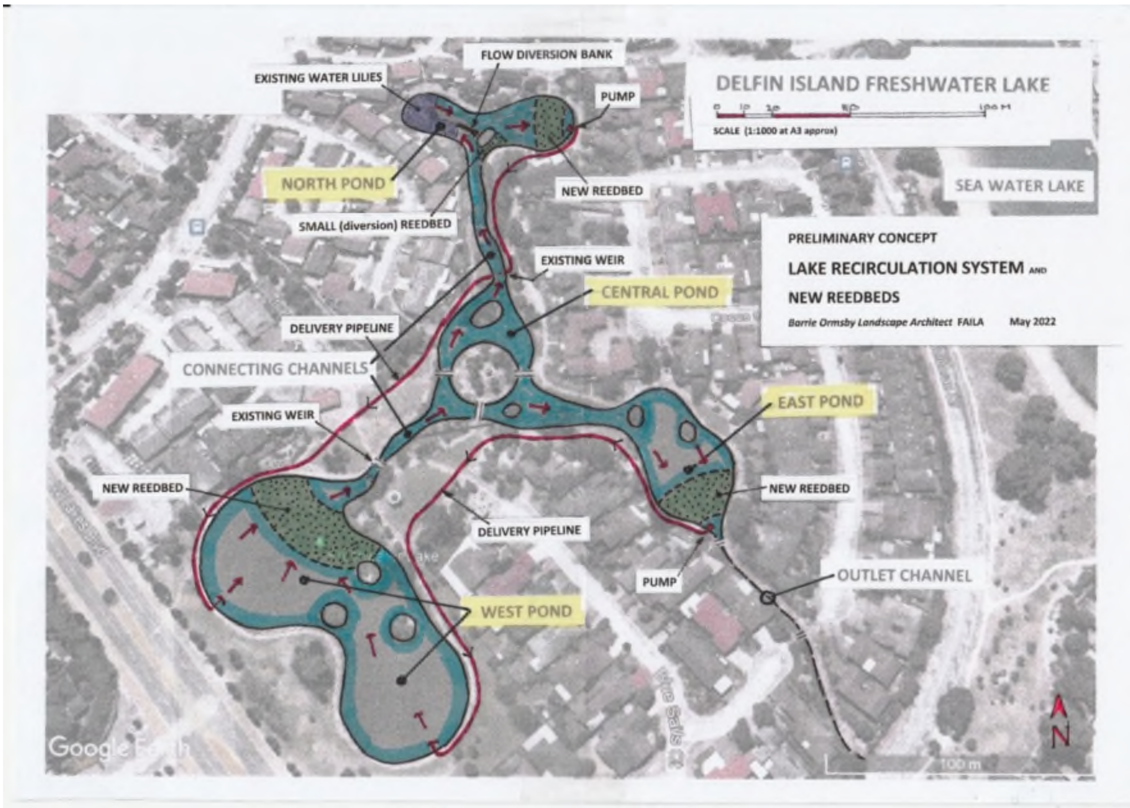


**Fig 2 – Delfin Island Freshwater Lakes – Concept - Lake Recirculation System and New Reedbeds (from BOLA report dated 21.06.20220 (plan <u>not</u> to scale)**

The main elements of this concept (Figure 2 as above) are:-

- The installation of shallow reedbeds in each of the West, East and North Ponds, as shown,
- The installation of extraction pumps at the ends of the South and North Ponds, and,
- Separate delivery pipelines from the two pumps to West Pond, discharging at different locations in West Pond, as shown.
- All lake/pond recharge from the bore is discharged into the West Pond.
- Water pumped from the East and North Ponds into the West Pond circulates through the reedbed in the West Pond, flowing through the Central Pond into both East and the North Ponds, where the water will flow through the reedbeds in these ponds, and thence be pumped back to the West Pond.

This concept will now in this report be referred to as “Concept A”.

Three variations of this “Concept A” have now been developed, as ‘Option B” and “Option C”, with “Option D” consolidating some aspects of Option B and C. Each is described in more detail in this report.

These concepts are intended to make better use of existing infrastructure, particularly the existing borelines, which are used to recharge the lake system with water from the bore in Corcoran Drive. These borelines discharge into both the West Pond and the North Pond, with control/isolation valves that can direct the bore water to either pond, or to both, as needed.

**OPTION B (Refer Figure 3)**

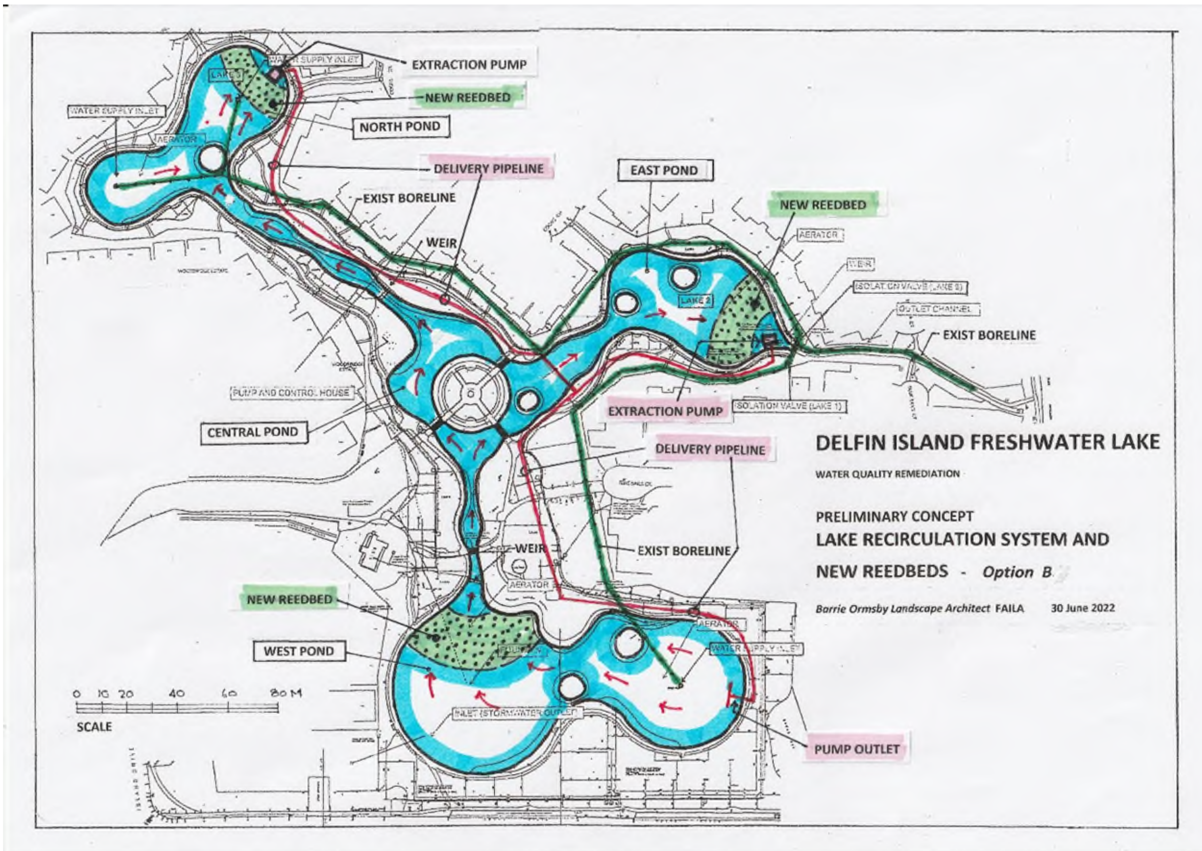


**Figure 3 – Option B**

Concept B has reedbeds similar to the original concept (refer Figure 2) in the three ponds, and the direction of flow through the ponds remains the same.

Two extractor pumps (either submersible or floating) will extract water from the East and North Ponds as before, but the delivery pipelines will join at a point near the Central Pond, and then flow to the West Pond, discharging at the south end of West Pond, as shown Figure 3. This reduces the length of new delivery pipeline required, and with less disruption to the landscape of the reserve.

The boreline from the recharge bore in Corcoran Drive divides close to the south end of the East Pond, with isolation valves to direct water to either the West or North Ponds, or both, as required.

In this concept, water from the recharge bore will normally be directed to the West Pond as in the original recirculation concept, and the existing boreline to the North Pond will not be used for recharge. However, the existing boreline to the North Pond and its outlets will remain, if needed.

Water in West Pond will flow over the existing weir at the outlet of West Pond, into the Central Pond, then flow will go into the East and North Ponds. Water flow into the North pond will need to flow over the existing weir in the narrow channel between Central and North Ponds (see Figure 3). This means that the water level in the Central and East Ponds may be higher than in the North Pond, unless the water level in both ponds is set so that the weir is submerged by a small amount.

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**OPTION C (Refer Figure 4)**

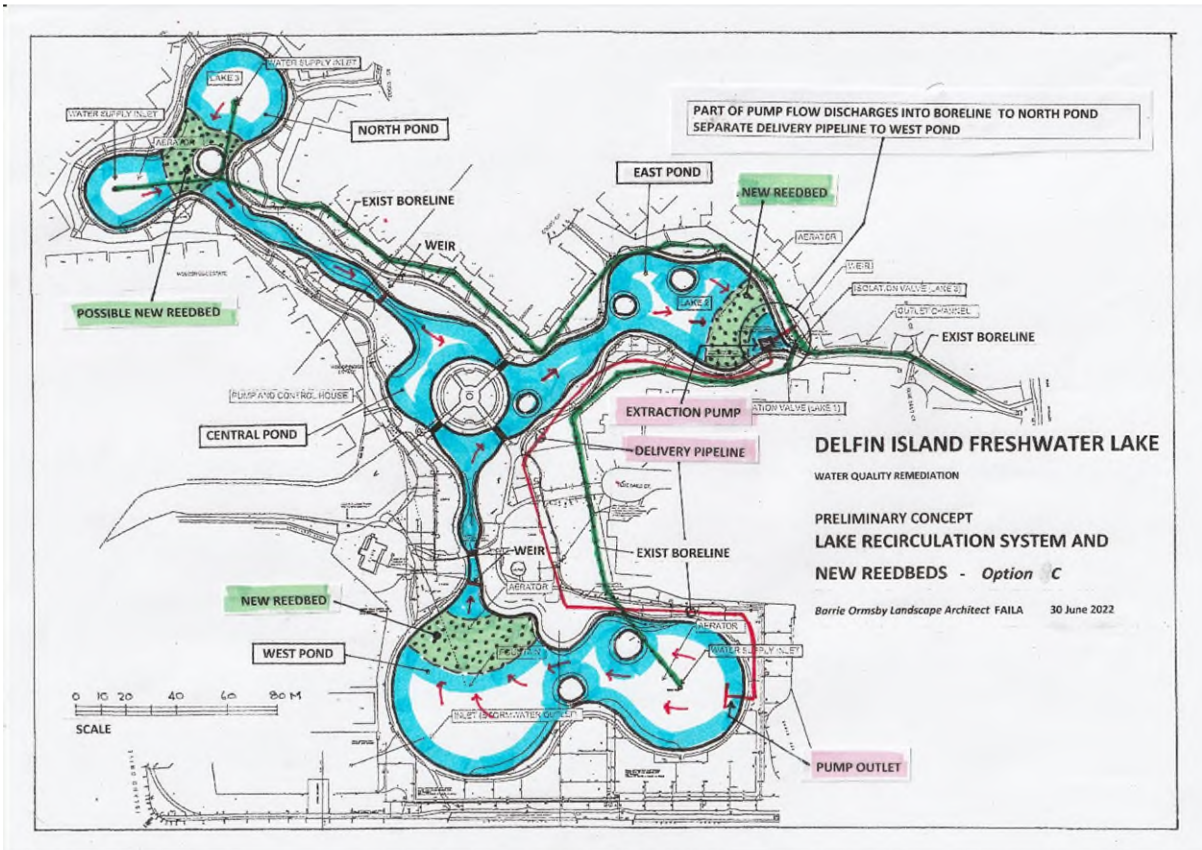


**Figure 4 – Option C**

The size (diameter) and flow capacity of the borelines from the end of North Pond to West Pond is not known. It may be possible to divert the flow from the extraction pump in East Pond into the boreline to the West Pond, so using this boreline for both recharge (from the bore) and the recirculation flow from the South Pond. This would only be possible if the capacity of the existing boreline had sufficient capacity.

This option would remove the need to install a new delivery pipeline from East Pond to West Pond, with a cost saving and reduced disturbance to the landscape.

A back-flow prevention valve would need to be installed in the boreline back to the bore to prevent lake water flowing back to the bore.

The particular benefit of this option is the reduction of the number of extraction pumps from two in Option B to one in this option, and the elimination of the need for a new electrical connection/supply to a pump in the North Pond.

The elements of Concept C are as follows:-

- Reedbeds installed in West and East Ponds only, with a small reedbed at the outlet of the North Pond if considered necessary,
- An extraction pump (floating or submersible) is installed at the south end of the East Pond only, which discharges into West Pond via a new delivery pipeline, at one location only, and with the route of the delivery pipeline from the pump to the West Pond as shown in Figure 4,
- A proportion of the output of the extraction pump is discharged into the boreline to the North Pond, as shown,
- The existing borelines are retained, with recharge from the bore into both West and North Ponds, through the existing borelines and pond outlets.
- The direction of flow between the North and Central Ponds in the narrow channel is reversed, compared to Concept B, with water from the North Pond flowing to the extraction pump in the East Pond.

A small proportion of the outflow from the extraction pump is directed into the existing boreline that feeds to the North Pond, as shown, with a backflow prevention valve installed to prevent backflow to the bore.

This allows the North Pond to be part of the pond recirculation and treatment system, so that water from the North Pond will be directed through the reedbed water cleansing system.

If the North Pond does not receive water from the extraction pump, it would only be able to receive bore water via the boreline. This would reduce water turnover and recirculation in and through this pond (particularly in winter), which would effectively isolate this pond from the rest of the recirculation and water treatment system, with possible adverse consequences for water quality.

If found to be desirable, a small reedbed could be created at the outlet of the North Pond, as shown, to enhance water treatment of outflow from this pond. Alternatively, the size/area of the reedbed in the East Pond could be increased to offset the absence of this reedbed in North Pond.

## OPTION D (Refer Figure 5)

This option is a consolidation of elements of Concepts B and C, but is only possible if the required flows for the overall pond/lake system, that is, bore recharge inflows (which would vary in response to seasonal and weather conditions), and the required rate of recirculating flows through all ponds (to achieve and maintain water quality), can be carried within the capacity of the existing borelines.

In this context, it is noted that the recharge bore and the extraction/recirculation pump may not need to be operated at the same time, with the bore operating as recharge demand requires (to offset evaporation and seepage losses, and the recirculation pump operating for much longer each day, but not necessarily on a continual basis, depending the prevailing water quality and the need to pass water through the treatment reedbeds.

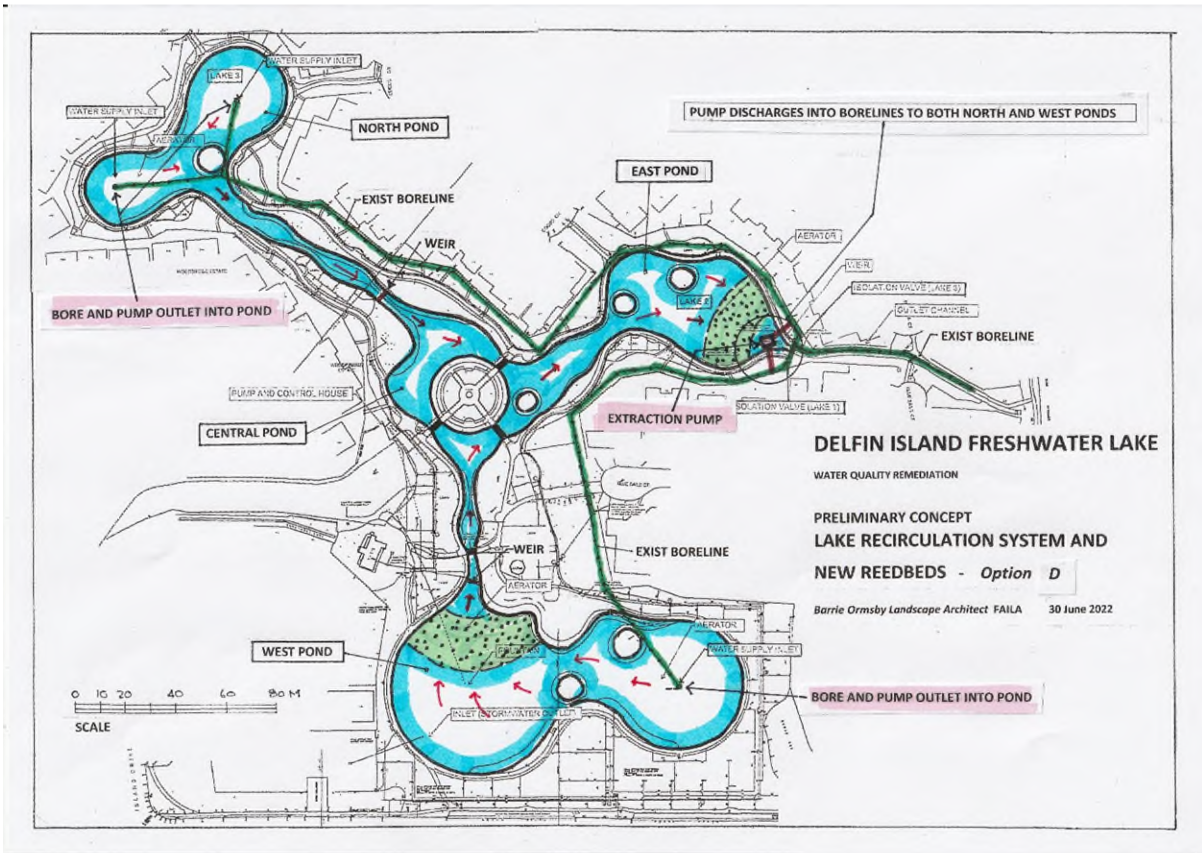


**Figure 5 – Option D**

The elements of this concept then are as follows: -

- Reedbeds installed in West and East Ponds, and possibly at the outlet of North Pond (as shown in Figure 4),
- An extraction pump (floating or submersible) installed at the south end of the East Pond (as in Option C and shown in Figures 4 and 5),
- The flow from the extraction pump diverted into the existing borelines adjacent to the extraction pump, so that flows from the pump are directed to both the West Pond and the North Pond. Backflow prevention valves installed to prevent any pond water being pumped back to the bore, and isolation/control vales installed so that the extraction/recirculation flow can be proportioned between ponds as necessary (possibly in proportion to the water volumes of North and West Ponds).

This option will provide recirculating flows through all ponds, with bore recharge into both the West and North Ponds, and all flows directed through reedbeds, but with minimal disturbance to the landscape (except for the installation of electrical supply to the extraction pump, which is common to all options).