Cardno Willing

APPENDIX F

ASSESSMENT OF WATER MANAGEMENT OPTIONS
SEPTEMBER 2004

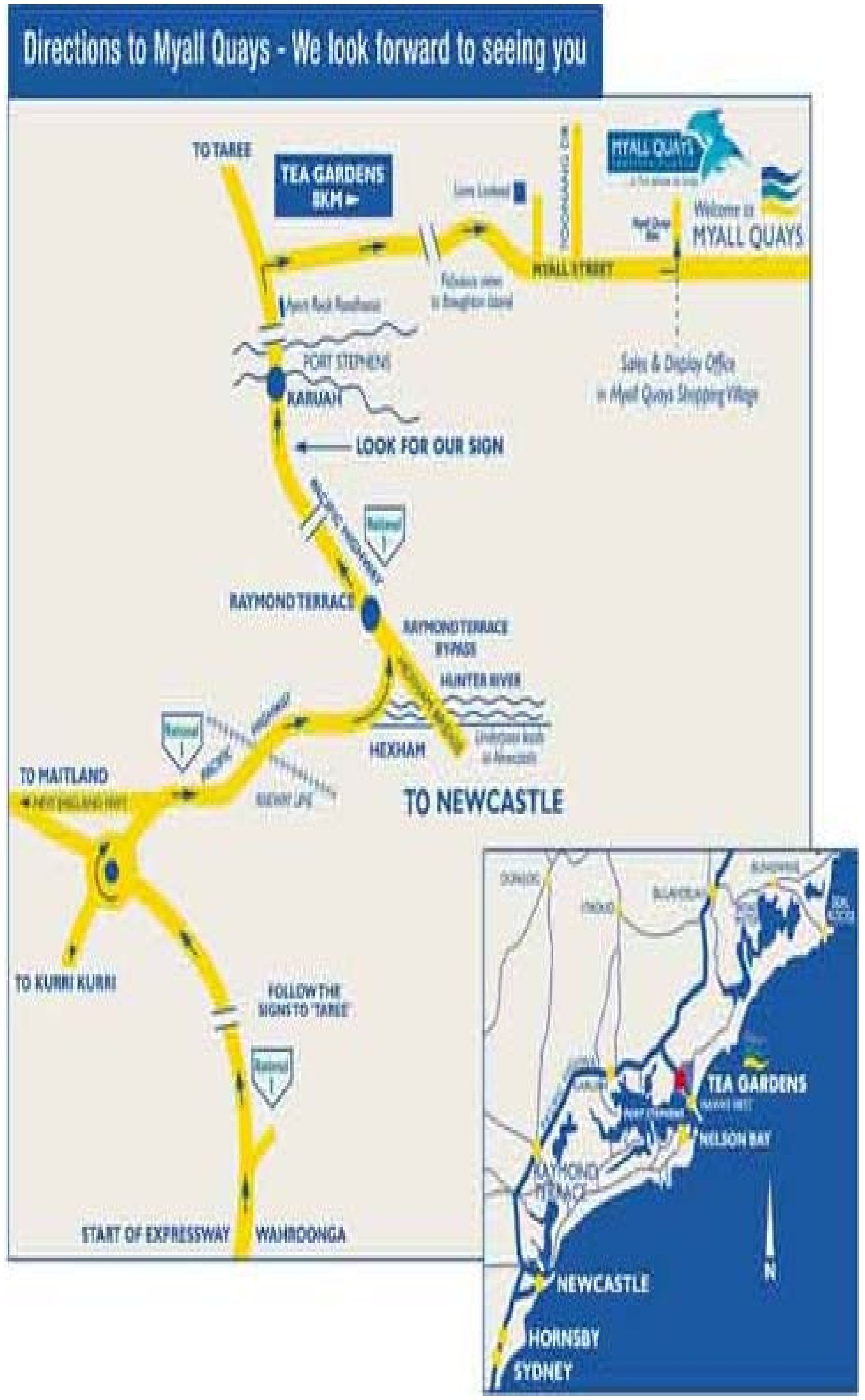
Myall Quays Development
Tea Gardens

Assessment of Water Management Options

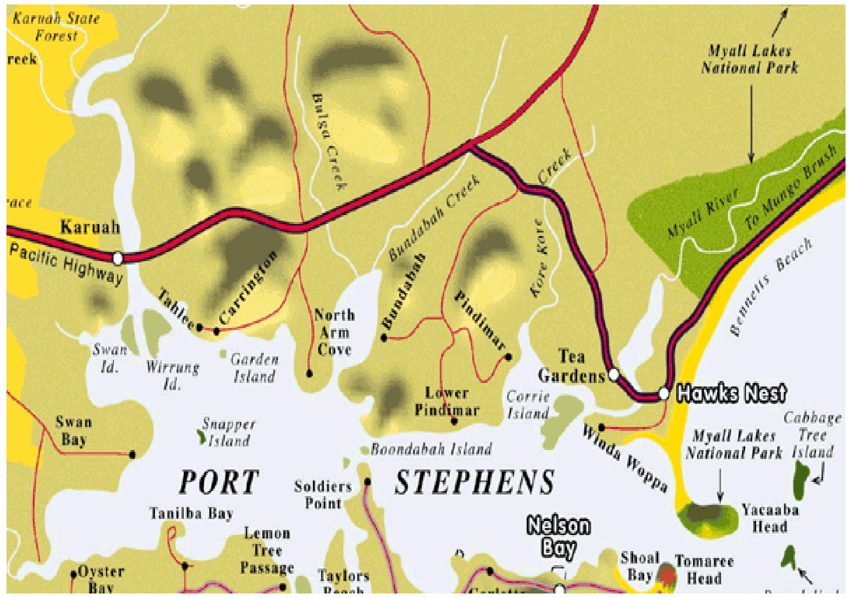
September 2004

Cardno

Background



Location of Myall Quays relative to Sydney and Port Stephens



Location map of Port Stephens. Tea Gardens can be seen on the North Shore adjacent to Hawks Nest on the beachfront.

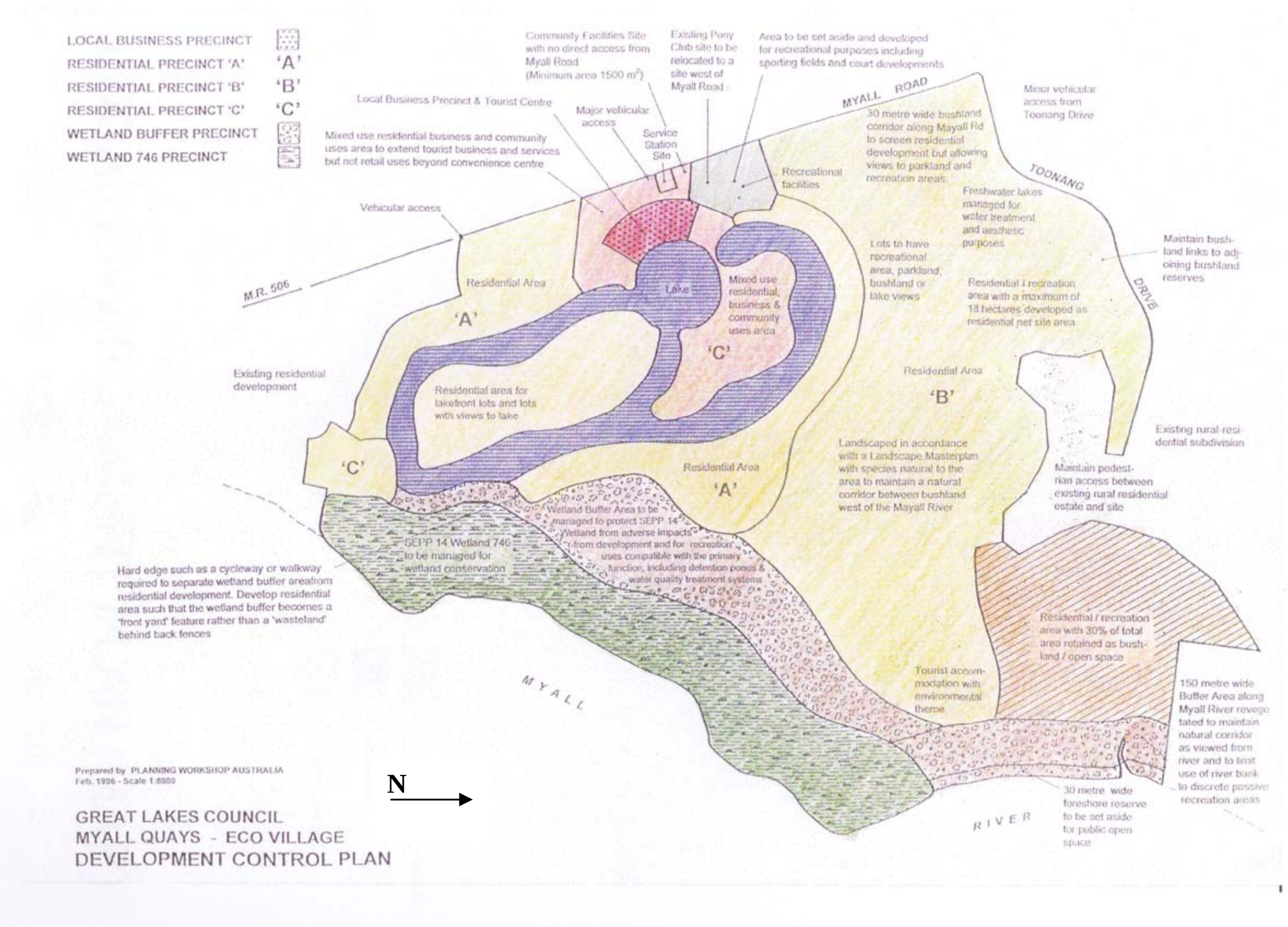
Aerial view of Tea Gardens depicting the development till 2000 of Myall Quays and its vicinity.

Site Location – Myall Quays

Myall Quays is located within the township of Tea Gardens. It is situated on the Mid North Coast of NSW, approximately 230 km north of Sydney. The Myall Lakes and Port Stephens catchment has an area of 370 km^2. Tea Gardens is located on the mouth of Myall River of Port Stephens just west of the popular holiday destination of Hawks Nest.

Myall Quays lies within the coastal zone adjacent to Myall River. It is bounded by various residential and other developments to all sides except to the east where the site is bounded by Myall River and SEPP 14 wetlands This site is approximately 230 ha and has a 2 km frontage to the Myall River / SEPP 14 wetland. The existing Myall Quays development features a 6 ha man-made tidally influenced detention lake. The SEPP 14 wetland is protected within a 7(a) Wetlands and Littoral Rainforest zone, which in turn is separated from the developable area of the site by a 7(b) Conservation Buffer zone.

Myall Quays is accessed from the main approach route to Tea Gardens / Hawks Nest, ie. Myall Road (approximately 9 km to the Pacific Highway). Much of the site was historically used as a major pine plantation, leaving a significant portion of the site currently cleared of vegetation. The site is very flat falling gently southward towards the existing detention lake.



History of the Site

In 1991 Crighton Properties Pty Ltd acquired the 230 ha site currently known as Myall Quays. A Local Environmental Study (LES) had been commissioned to consider the rezoning of the land for recreational, commercial, tourist and residential uses.

An adjoining 30 ha parcel of land, part of the 1991 purchase, was already zoned for residential development (Zone 2(a)). Since the purchase Crighton Properties have developed 220 high quality home sites.

The development of Myall Quays included the construction of a major detention lake that also helped to improve the quality of stormwater discharged to the Myall River. The water quality purposes were part of the 2(a) zoned development. The approval for the lake was obtained before the NSW Government's SEPP 50 (Canal Estates) was introduced.

A rezoning of the 230 ha rural land was gazetted in June 2000, pursuant to the LES. The majority of this land was zoned 2(f) accommodating a mix of residential, commercial and recreational uses. Under the Development Control Plan for the Myall Quays it was also proposed to extend the existing detention lake to create a 22 ha lake.

The previous use of this land was as a pine plantation. The majority of subject land cleared of vegetation was to allow the silviculture to proceed.

The Myall Quays – Eco Village – Development Control Plan opposite depicts the various land uses for this area. The Local Environmental Plan map shows the zoning of the site gazetted in 2000.

Current Development Proposal

The proposed project is for an extension of the Myall Quays development. It is proposed to construct additional housing, commercial, sporting and tourist facilities on the remaining 179 ha of the site. This is to include increasing the current lake to (refer schemes) as part of an integrated approach to stormwater management that both details and treats stormwater on the site. The strategy includes a number of additional stormwater ponds and rainwater tanks to harvest rainwater and support its reuse on approximately 600 new residential lots as well as a nine hole golf course.

Regional and Area Development
(Tea Gardens, Hawks Nest and other Crighton Developments)

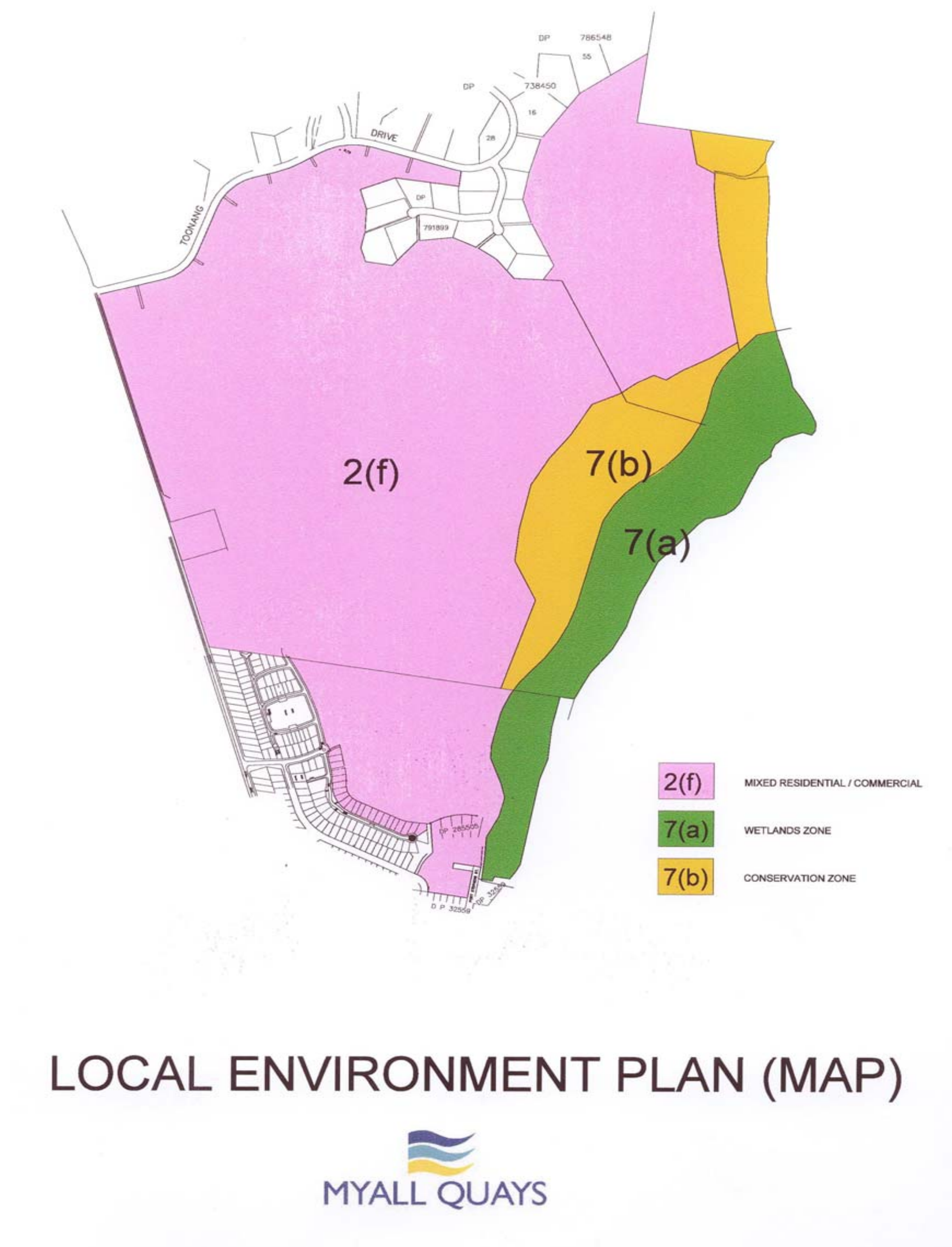
The dwindling opportunities for coastal development on the southern shores of Port Stephens, the creation of Myall Lakes National Park and the reduced travel times to Sydney have created a demand for land in the Tea Gardens and Hawks Nest area on the northern shore of Port Stephens. This area is growing quickly and is a popular holiday / retirement destination due to its close proximity to Sydney.

Both Tea Gardens and Hawks Nest are significantly developed areas providing a wide range of land uses and amenities including residential areas, commercial uses, recreational facilities, public amenities, holiday attractions, administration offices and related infrastructure. The Myall Quays site is bounded by Tea Gardens to the south, rural residential development to the north, residential / industrial development to the west and Myall River / Wetlands to the east.

A number of planning studies have been carried out in the Tea Gardens / Hawks Nest area in response to the need to protect its special character and the character of the surrounding area. The Tea Gardens and Hawks Nest urban areas at the time of the study (LES 1991) had the capacity to accommodate about 600 and 1,300 new residential lots respectively. The proposed project site could accommodate about 1,000 dwellings together with tourist developments, which would represent a significant development element in the local context. The development of Myall River Downs Estate and Tea Gardens Grange Lifestyle Resort are also providing greater residential capacity in the Great Lakes local government area.

There are various developments taking place in the Great Lakes local government area. Myall Quays is just one of several residential / commercial developments creating new estates to provide lifestyle properties in a sustainable environment.

Upgrades to major roads (Pacific Highway) are being undertaken providing efficient and convenient access to these destinations.



Local Environmental Plan

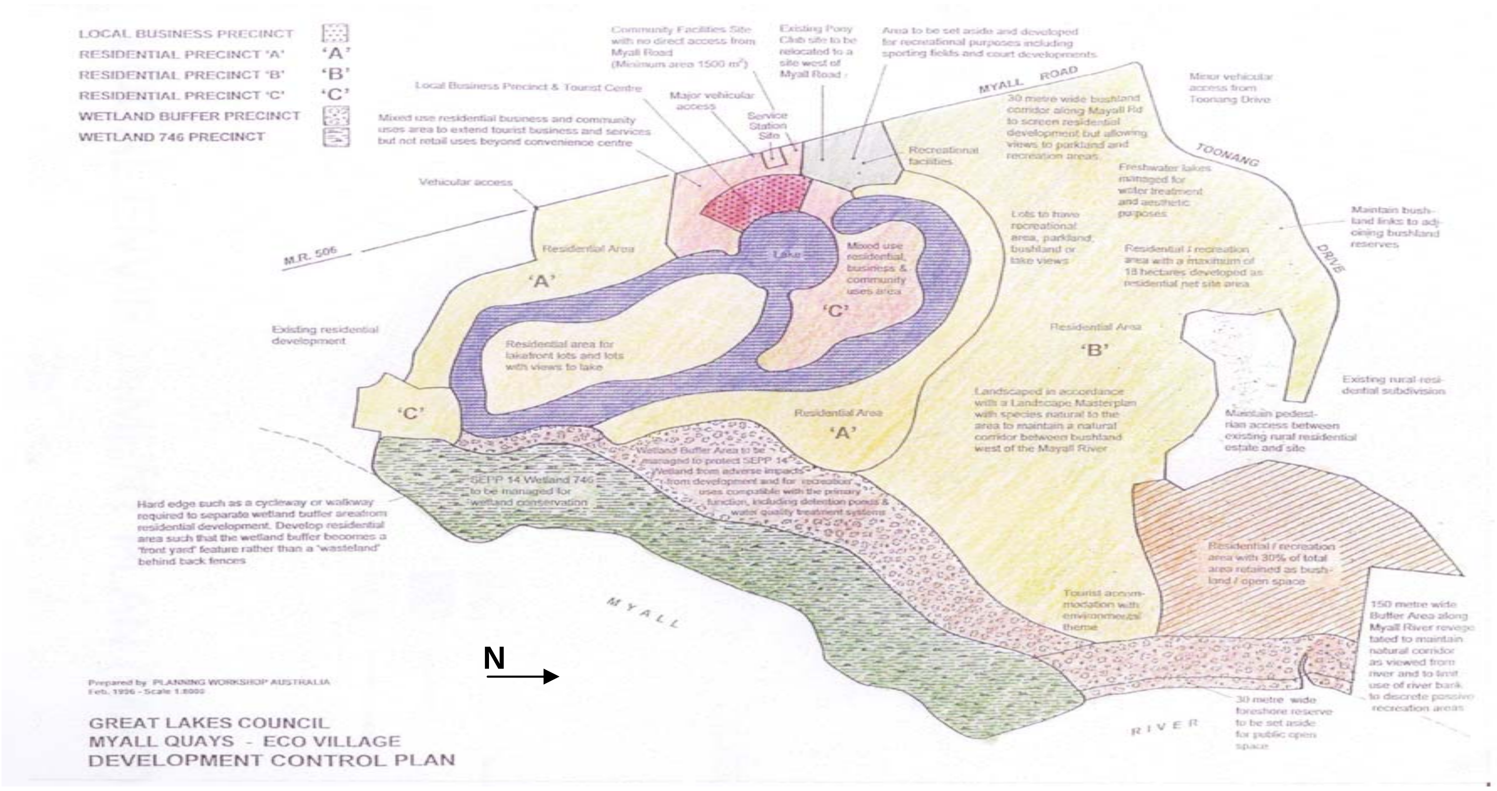
The current Local Environmental Plan (map) shows the different zoning of the proposed project site.

- The pink area 2(f) is zoned for mixed residential / commercial / recreational;
- The yellow area is 7(b) conservation zone; while
- The green area 7(a) wetland is the SEPP 14 wetlands fringing the Myall River.

Aerial view of Tea Gardens facing south east (2000)

View of existing lake and residences in background (2000)

Aerial view of Myall River facing south (2000)



Development Control Plan

The DCP gazetted in 2000 identifies the following precincts:

Local Business Precinct
- Local business precinct and tourist centre.

Residential Precinct A
- Residential Area

Residential Precinct B
- 30m wide bushland corridor along Myall Road to screen residential development but allowing views to parkland and recreation areas.
- Freshwater lakes managed for water treatment and aesthetic purposes.
- Lots to have recreational area, parkland, bushland or lake views.
- Residential / recreation area with a maximum of 18ha developed as residential net site area.
- Landscaped in accordance with a landscape masterplan with endemic species to maintain a natural corridor between bushland west of the Myall River.
- To provide a 100 m wide east / west wildlife movement corridor.

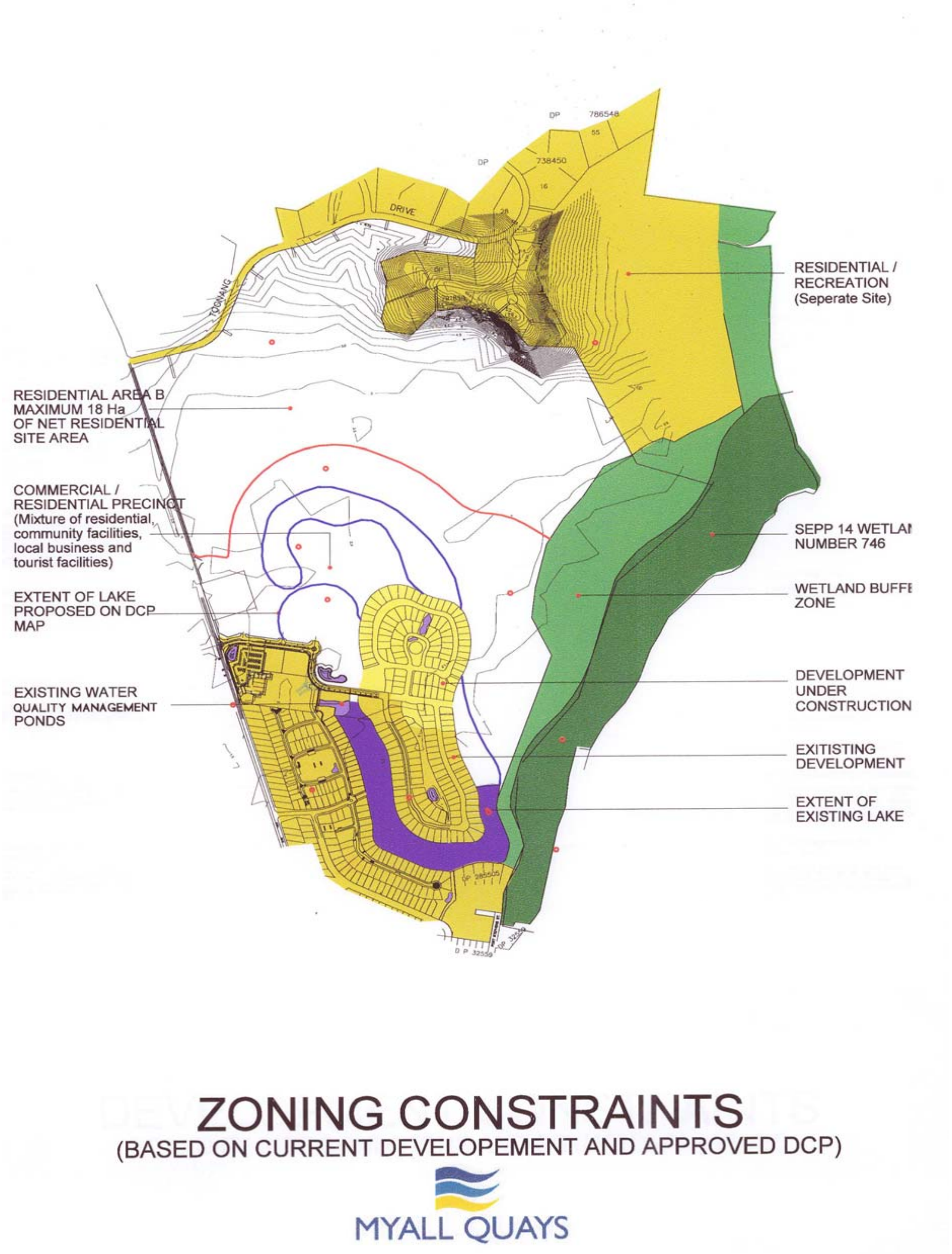
Residential Precinct C
- Mixed residential, business and community uses area to extend tourist business and services but not retail uses beyond convenience centre.
- Community facilities site with no direct access from Myall Road (minimum area 1,500 m^2).
- Major vehicular access.
- Service station site.
- Existing pony club to be relocated to a site west of Myall Road, with this area to be set aside and developed for recreational purposes including sporting fields and court development.
- Minor vehicular access from Toonang Drive.
- Maintain bushland links to adjoining bushland reserves.
- Maintain pedestrian access between existing rural residential estate and project site.
- Tourist accomodation with environmental theme.

Wetland Buffer Precinct
- Wetland buffer area managed to protect the SEPP 14 wetland from adverse impacts from development and for recreation uses compatible with the primary function, including detention ponds and water quality treatment systems.
- 30m wide foreshore reserve to be set aside for public open space.
- Cycleway or walkway to separate buffer from residential area.

Wetland 746 Precinct
- SEPP 14 wetland 746 to be managed for wetland conservation.

The two DCP maps opposite depict the project location and a comparison of the lastest and original can be made.

ZONING CONSTRAINTS

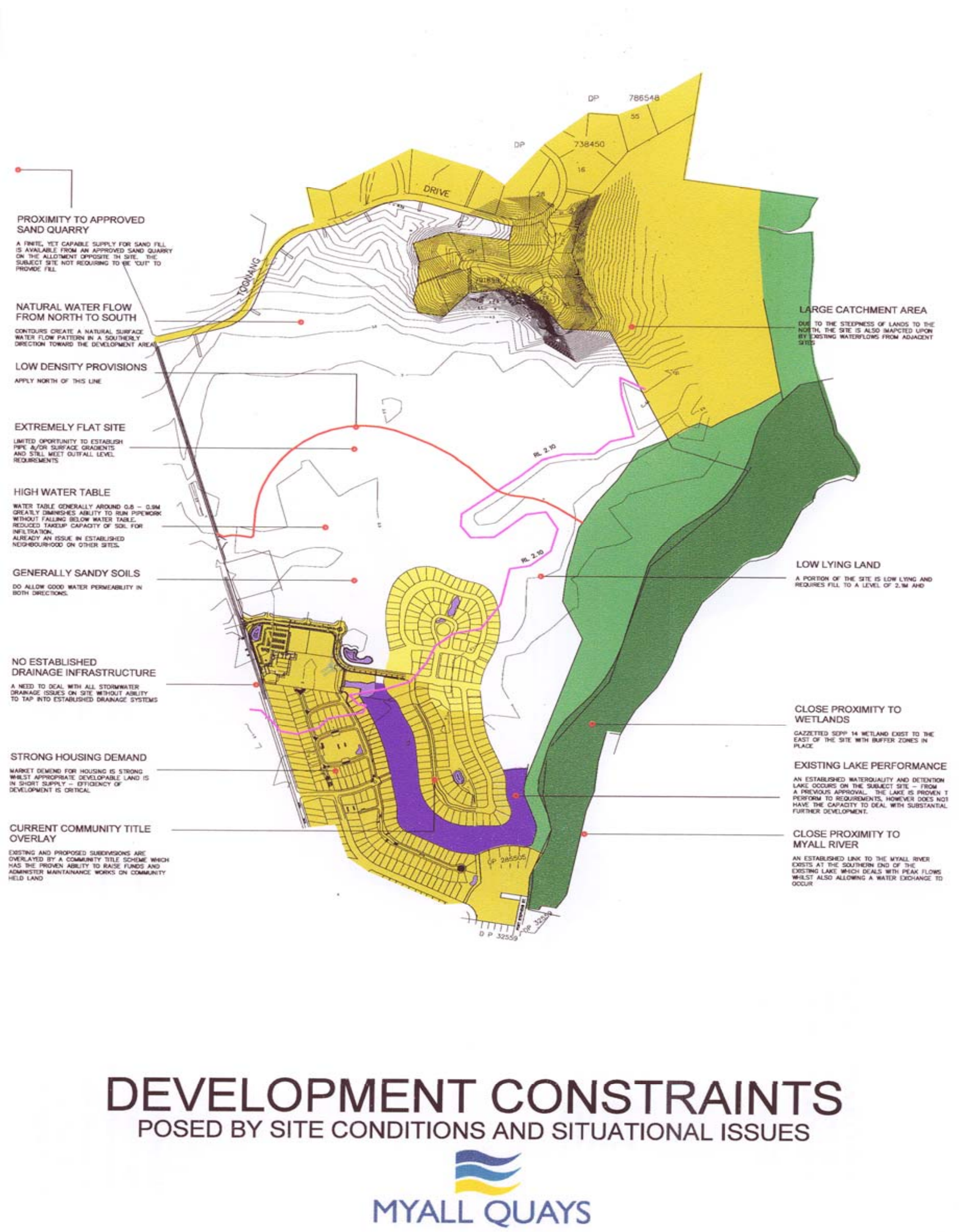


Zoning Constraints

The current zoning constraints include:

- Residential area B – a maximum 18 ha of net residential site area.
- Commercial / residential precinct – mixture of residential, community facilities and tourist facilities.
- Extent of lake proposed on DCP Map.
- Existing water quality management ponds / wetlands.
- Residential / recreation (separate site).
- SEPP 14 wetland number 746.
- Wetland buffer zone.
- Development under construction.
- Existing development.
- Extent of existing lake.
- Land set aside for water management, under Community Title.

ENVIRONMENTAL AND DEVELOPMENT CONSTRAINTS



ENVIRONMENTAL CONSTRAINTS

The environmental constraints include:

State Environmental Planning Policies

The following are the State Environmental Planning Policies (SEPP) which are presently identified as having influence on the Proposal:

SEPP 50 Canal Estates **-relevant due to detention lake**

This policy prohibits new 'canal estate' developments. The proposed extension of the present detention lake and associated waterbodies, however, are in accordance with the requirements of SEPP 50 because the lake extension is the minimum required to meet necessary drainage and water quality requirements. (refer clause 3 SEPP 50.

SEPP 71 Coastal Protection **-relevant as in coastal zone**

This policy aims to protect and manage the natural, cultural, recreational and economic attributes of the New South Wales Coast. This policy is relevant due to the proximity of the proposed development in relation to the coast.

SEPP 14 Coastal Wetlands **-relevant as designated SEPP 14 wetlands (7(a) zone) exists in the area**

This policy affects the proposed development, as there is a SEPP 14 wetland adjoining the eastern edge of the proposed development.

Local Planning Instruments

The two local planning instruments directly influence the proposal include the:

- Great Lakes Shire LEP 1996, and
- Myall Quays DCP No 22

Other constraints on the proposed project at Myall Quays include:

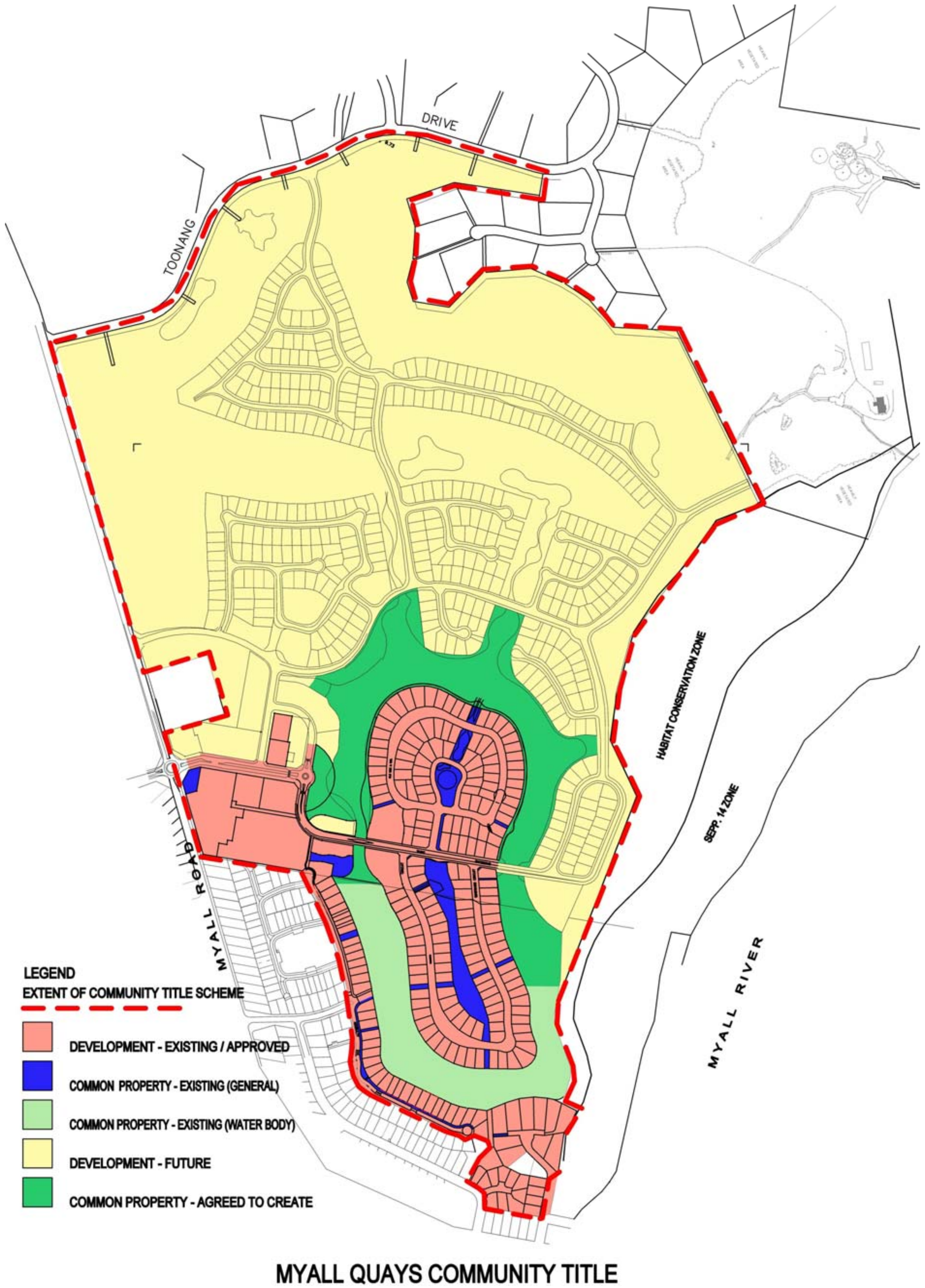
Floodplain – the site is low lying land and in part is flood prone. This constraints minimum ground and floor levels.

DEVELOPMENT CONSTRAINTS

The development constraints include:

- Natural water flow from north to south.
- Extremely flat site.
- Shallow water table that varies in response to rainfall.
- Generally sandy soils.
- Established drainage infrastructure in developed areas.
- External catchment area drains into the site.
- Low lying land that in part is subject to flood inundation.
- Designated conservation zone to protect existing SEPP 14 wetlands.
- Stormwater discharges through the wetlands to reach the Myall River.

Community Constraints



Community Constraints

Lands
Existing and proposed subdivisions are overlayed by a community title scheme, which has the proven ability to raise funds and administer maintenance works on community held land.

Title
The Community Titles Legislation in New South Wales provides for owners in a conventional land subdivision to share and manage a range of community facilities. The title to land incorporating these options is called 'Community Title'. The development will continue to be carried out as a Community Title subdivision. The community is 'collectively' responsible for the maintenance and well being of all commonly held property (including the water quality ponds and detention lake).

Existing Financial Model
The community contributes approximately $340 / year / household to the community association.

Budget
The total administration budget for this financial year based on the current number of members is $18,140, with $6,000 being allocated for water quality testing.

Extent
The community title currently applies to the entirety of the land hatched on the diagram, land cannot be added to the community title. Land cannot be subtracted from or reallocated a boundary without unanimous resolution from the community. The extent of community land (common property boundary) has already been agreed to and formalised by the community with information provided at the point of sale. This cannot be altered without unanimous resolution.

Issues
Community members have agreed to the allocation of common property in consideration of balancing the need for water quality and want of accessible open space against the cost of maintaining this space.

Water Quality Assessment

Water Quality Parameters

Salinity

What is salinity?
Salinity is a measure of salt content in water, for instance the salinity of seawater is 35 g/L (parts per thousand (ppt)). Typically salinity levels range from fresh at <1g/L to almost oceanic at >30g/L within an estuary. A value of 3g/L is taken as the salinity dividing fresh from saline waters.

Processes in estuaries – fresh water & salt water
The salinity distribution within coastal waterways reflects the relative magnitudes of fresh water, e.g. inflows from storms in comparison with the exchange of tidal waters. Salinity levels in an estuary fluctuate with tidal flows and with mixing of fresh water and marine water by wind and currents. Fresh water flows into coastal waterways are mainly episodic and are largely controlled by conditions in the catchment as well as rainfall patterns. Entrance size and sea level dictate the levels of exchange of marine water, and the level to which salinity can build up within a coastal waterway.

A decrease in fresh water flows will lead to elevated salinity whereas large influxes of freshwater will lower salinity levels.

Importance of salt regimes
Salinity varies in ranges from < 3 g/L (classified as freshwater), 3-20 g/L (hyposaline), 20-50 g/L (mesosaline) and 50 g/L (hypersaline). An increase of salinity above 3g/L is associated with a transition from freshwater species to saltwater species.It is important for salinity to remain between certain limits, to provide a suitable habitat for aquatic organisms to thrive (e.g. reproduce, feed, lifecycle).

The majority of aquatic organisms function optimally within a narrow range of salinity. When salinity varies above or below the optimum range an organism may lose the ability to regulate its internal ion concentration causing it to become susceptible to biotic pressures such as predation, competition, disease or parasitism. Shifting salinity distributions can affect the distributions of macro benthos as well as rooted vegetation (seagrasses) and sessile organisms. Salinity is also an important factor in the successful recruitment of larval and juvenile fish. Salinity factors influencing the proposal include

- **Salinities between 3 g/L and 20 g/L seem to exhibit greater species diversity and richness; and**
- **Increasing salinity levels above 20 g/L decreases both species richness and diversity.**

Salinity has more impact as a community determinant only where salinities approach those of freshwater.

Optimum range is between 3 g/L and 20 g/L

Dissolved Oxygen

What is Dissolved Oxygen?
Dissolved Oxygen (DO) is the measure of the amount of oxygen contained in water. **Oxygen has limited solubility in water usually ranging from 6 mg/L to 14 mg/L**. **ANZECC guidelines set default trigger at a range of 80 –110 % oxygen saturation for slightly disturbed estuarine environments**. Levels of 6 mg/L will fall within the recommended guidelines.

DO concentrations reflect the equilibrium between oxygen producing processes (eg photosynthesis) and oxygen consuming processes (eg decomposition of organic matter).

Processes in estuaries
DO concentrations can change as oxygen solubility varies with salinity, water temperature and atmospheric and hydrostatic pressure. The amount of plant and algal biomass, light intensity and water temperature influence DO consumption, and are subject to seasonal and diurnal (day/night) variations.

DO concentrations naturally vary over a twenty-four hour period due to tidal exchange and oxygen production by plants and algae during daylight (photosynthesis).

Nutrient enrichment enhances plant and algal growth often resulting in a mass influx of particulate organic matter. This can in turn result in masses of decomposing organic matter that consume oxygen particularly in bottom waters.

Tidal exchange can replenish coastal waterways with oxygen.

Significance of Dissolved Oxygen
Most aquatic organisms require DO to be within defined levels to support respiration and to support an efficient metabolism. Even short-lived anoxic (zero oxygen) or hypoxic (low oxygen) events can cause major ‘kills’ of aquatic organisms. Exposure to low oxygen concentrations can depress the immune system of a fish that elevates their susceptibility to diseases for several years.

The toxicity of a number of pollutants can double when DO is reduced from 10 mg/L to 5 mg/L. The death of sessile organisms and avoidance of low oxygen conditions by mobile organisms can also cause changes in the structure of biological communities. The depletion of oxygen in bottom waters or sediments can give rise to the release of nutrients and other pollutants into the water column and can initiate and sustain algal blooms.

Optimum range is between 80 % and 110 % oxygen saturation

Chlorophyll *a*

What is Chlorophyll *a*
Chlorophyll *a* is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Chlorophyll *a* concentrations are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters. High levels often indicate poor water quality and low levels often suggest good conditions. Elevated Chlorophyll *a* concentrations are not necessarily bad, however if they persist for long periods, the potential for algal blooms increases.

Processes in Estuaries
Chlorophyll *a* levels fluctuate naturally over time, with concentrations often being higher after rainfall due to the flushing of nutrients into waterways. Higher concentrations of Chlorophyll *a* are common during summer months when water temperatures and light levels are high.

Coastal lagoons, enclosed bays and microtidal waterways (mean tidal range < 2m) with limited flushing are susceptible to eutrophication (ie. high Chlorophyll *a* concentrations).

Tidal mixing is important in controlling algal biomass and lowering Chlorophyll *a* concentrations due to the reduced time algae undergoes photosynthesis. Changes to systems that decrease or increase flushing rates influence concentrations as flushing dilutes the nutrients available to plants. Slow moving or stagnant waters can concentrate nutrients and cause cell numbers to grow.

Significance of Elevated Chlorophyll *a* Concentrations
Elevated Chlorophyll *a* concentrations can indicate an increase in nutrients and increasing trends can indicate eutrophication of aquatic ecosystems.

The most pervasive system change which can lead to problems with constructed shallow lakes is the excessive influx of inorganic nutrients, either in soluble form or associated with organic matter, that lead to excessive algal growth.

Optimum levels less than 0.004 μg/ L for estuarine ecosystems and 0.005 μg/ L for fresh ecosystems

Nitrogen

What is Nitrogen?
Nitrogen (N) is a chemical element that is an essential building block for plant and animal growth. Nitrogen exists in water in inorganic and organic forms, and in dissolved and particulate states. Total nitrogen (TN) is a measure of all forms of dissolved and particulate nitrogen present in a water sample.

Enclosed bays, shallow coastal lagoons and other microtidal systems (mean tidal range < 2m) with limited freshwater inflows cannot readily flush nutrients and are particularly susceptible to nutrient build up and internal recycling.

Optimum levels less than 0.3 mg/ L for estuarine ecosystems and 0.35 mg/ L for fresh ecosystems

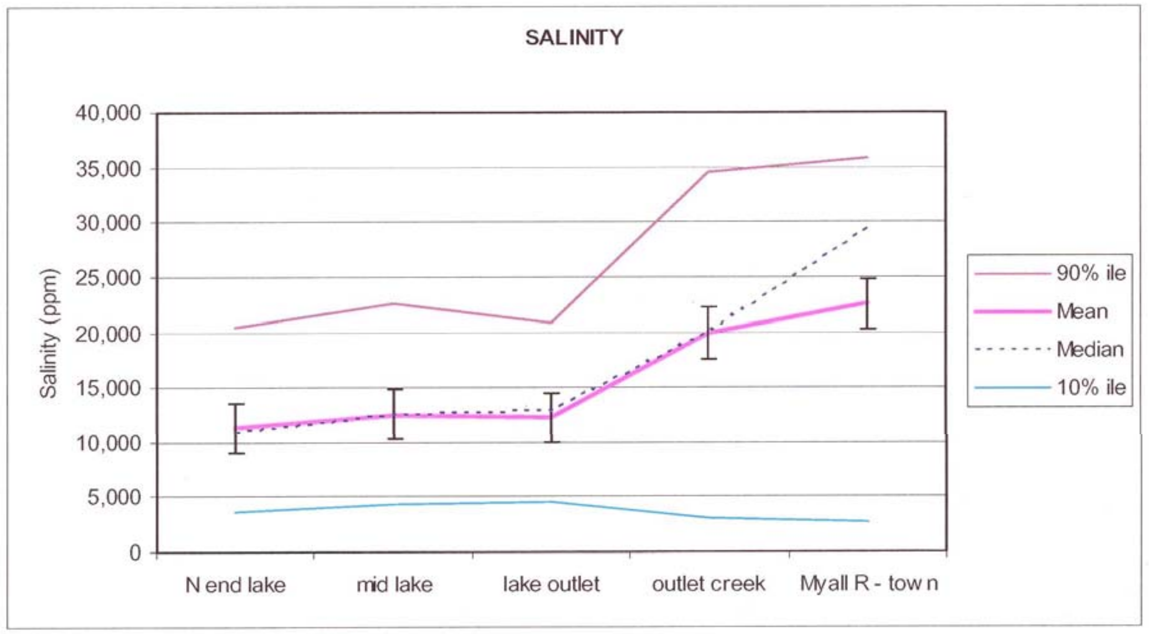
Phosphorous

What is Phosphorous?
Phosphorus (P) is a chemical element that is an essential building block for plant and animal growth. Phosphorus is found in waterbodies in dissolved and particulate forms. Total phosphorus (TP) is a measure of all the various forms of phosphorus (dissolved and particulate) found in water.

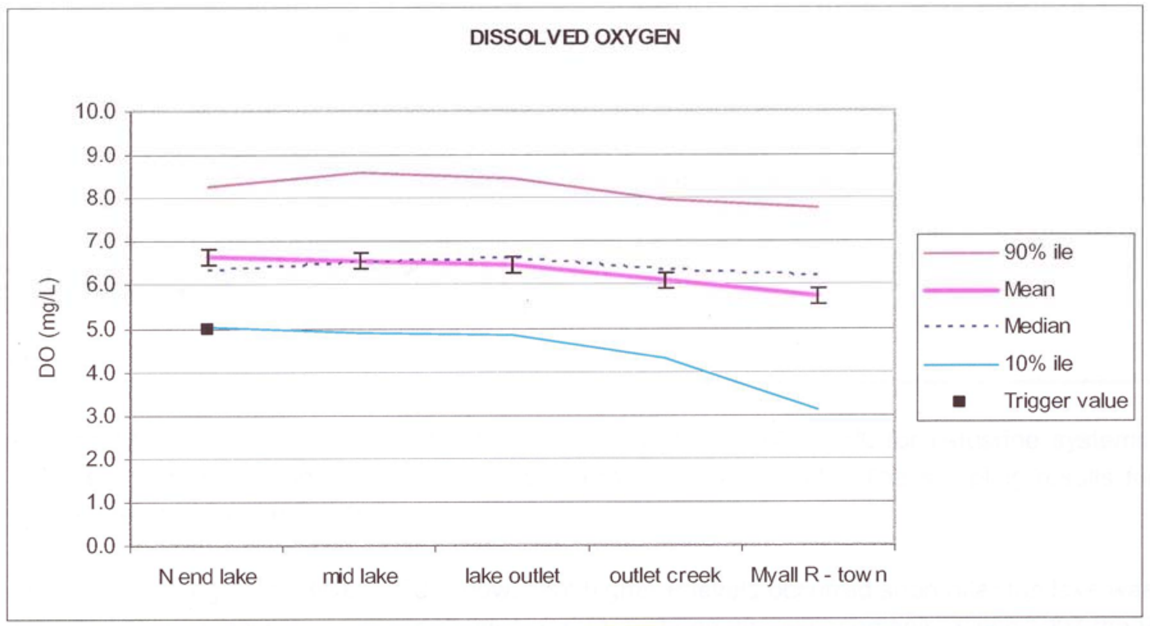
Enclosed bays, shallow coastal lagoons and other microtidal systems (mean tidal range < 2m) with limited freshwater inputs cannot readily flush nutrients and are particularly susceptible to nutrient build up and internal recycling.

Optimum levels less than 0.03 mg/ L for estuarine ecosystems and 0.01 mg/ L for fresh ecosystems

These graphs represent the various levels of salinity, dissolved oxygen and phosphate at the 5 sample locations.



Salinity Levels



Dissolved Oxygen Levels

Existing Conditions

The catchment under consideration is located on the eastern side of Myall Street and extends from Myall River northwards to high ground near Viney Creek Road. The total area of the catchment is approximately 272 ha.

Surface water drains partly toward the existing lake and partly toward the SEPP 14 wetlands on the eastern boundary of the site. The site is subject to both local and river flooding. Local flooding has been observed by the land owners and Council staff. This local flooding reflects the flat ground slopes and absence of natural drainage channels.

The impact of the existing development on flood flows was mitigated by constructing a detention lake to temporarily store floodwaters and to release it at a rate similar to pre-development conditions. A number of small retarding basins have also been build within the existing development to meet retardation requirements.

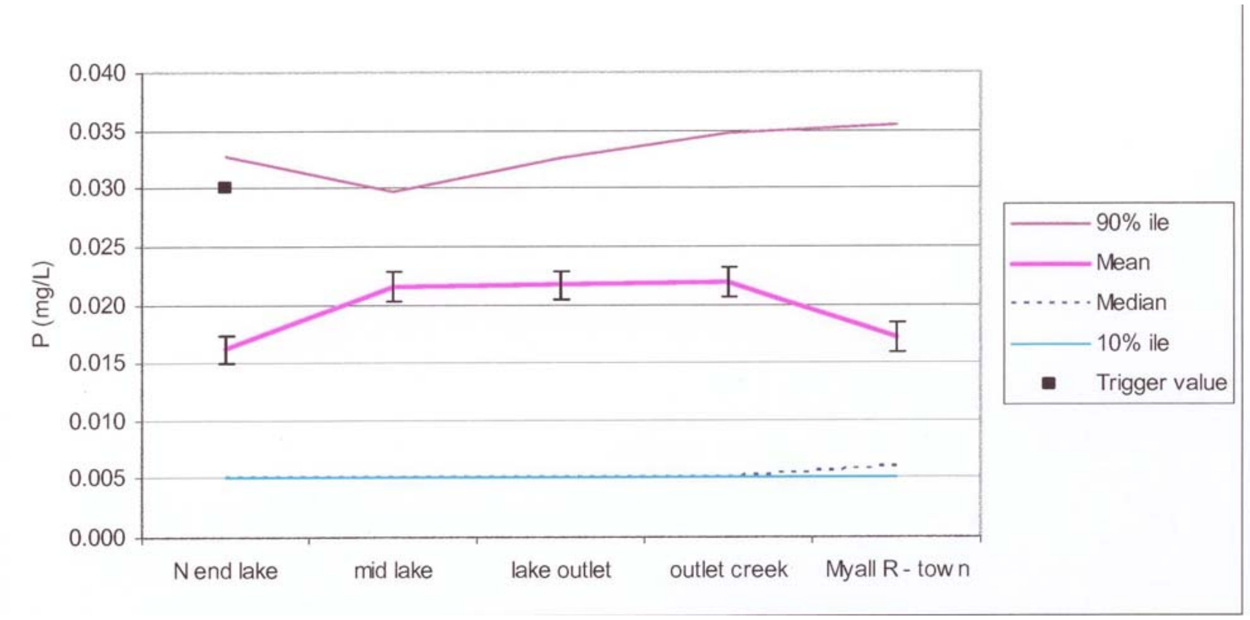
Water Quality Management

The primary aim for the existing management of water quality is to protect the SEPP 14 wetland by directing the runoff from the catchment to a tidally flushed lake. This is also supported by a number of smaller ponds and wetlands located within the residential areas.

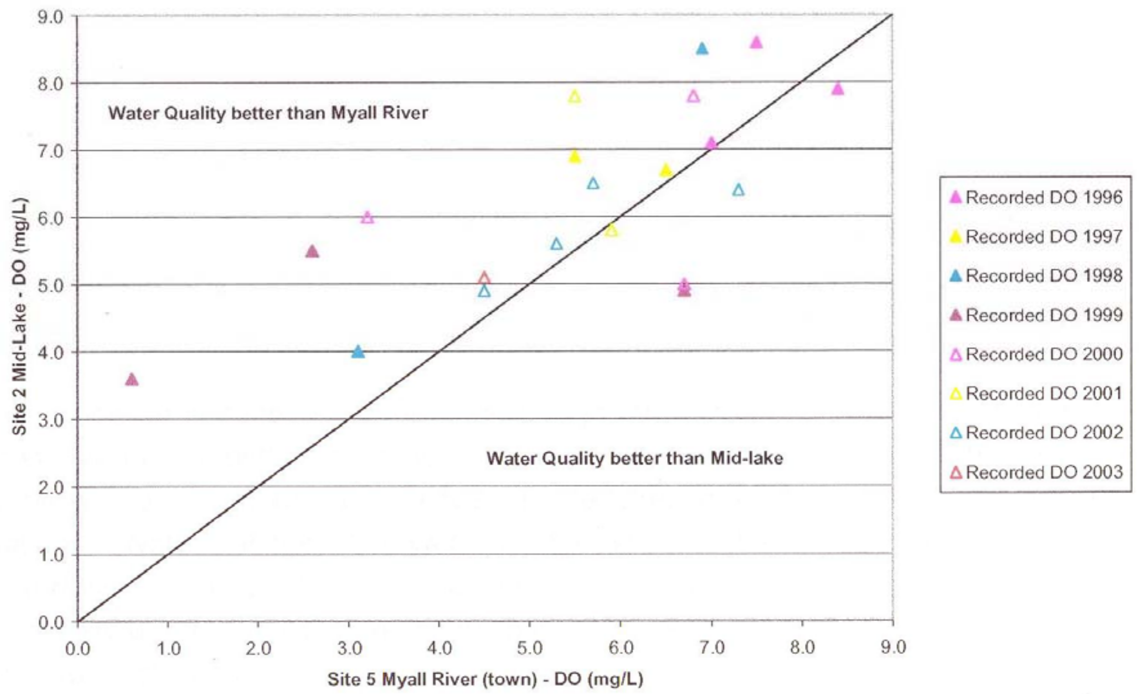
Water quality impacts on the lake at Myall Quays are due to event-driven loads from runoff, decay of in-lake algae and releases from sediments. Tidal inflows can also impact on water quality. The stormwater runoff impacts can be expected to increase with urban development in the northern part of the project site unless remedial measures are provided and / or the lake is increased in size.

The Water Quality Objectives include:

- The lake and ponds meet microbiological standards for bacterial content and pathogens.
- The lake and ponds be free of nuisance organisms such as algal scums and odours, midges and aquatic worms.
- Visual clarity and colour, physical appearance of lake / pond and discharged water to be clear and colourless.
- pH within range 5.0-9.0.
- Toxic chemicals meet standard for untreated drinking water.
- Surface films such as oil and petrochemicals should not be visually noticeable nor detected by odour.
- Sustain a healthy ecosystem.
- Free of trash and debris.
- Free of mosquito related health risks and irritants.
- Free of nuisance macro aquatic plants.



Phosphorous Levels



Comparison of monitored DO levels in Myall Lake and Myall River

Water Quality Monitoring

A water quality monitoring programme was established in 1996 firstly by the developer, and more recently taken over by the Myall Quays Community Association. Hunter Water Laboratories is contracted to collect and analyse samples at 5 locations every 3 months.

Salinity

The sampling indicates that the lake water is brackish, consisting of a mean salinity of 12 g/L, which is approximately one third of the salinity of seawater. There is variability in the salinity concentration due to both catchment (freshwater) runoff as well as the influence of tides and varying salinity in the Myall.

Dissolved Oxygen (DO)

The mean DO level within the lake for the sampling period is 6.6 mg/L, with a 10th percentile level of 4.9 mg/L. The 4.9 mg/L level is just below the recommended ANZECC trigger value of 5.0 mg/L for freshwater fish.

Nutrients

The adopted ANZECC 2000 trigger value for Phosphorus (P) is 0.03 mg/L for estuarine systems. Most of the samples have been below the recommended value, with a mean of 0.02 mg/L. Higher P levels occurred soon after the lake was constructed, possibly due residual P released from exposed soil.

The ANZECC 2000 trigger value for Nitrogen (N) is 0.3 mg/L for estuarine systems. The samples measured have generally been low, contributing to the overall good water quality in the existing lake.

Most chemical indicators are below the ANZECC 2000 trigger values. There is 90% of the catchment that is undeveloped, with the existing treatment measures in the southern part of the catchment seemingly assisting with maintenance of good water quality with the existing lake.

Water Quality of Lake in Comparison with the Myall River

The DO levels measured within the Myall Quays Lake and the Myall River have been compared. The Hunter Water Laboratories data shows the ANZECC high quality guidelines for DO are not currently met at all times, in either the lake or river (Copeland Ave Wharf). This data shows the DO levels in the existing lake are often better that in the Myall River.

Water Quality and Retardation Summary Table

Scheme	Water Quality Summary								Retardation Summary				
									Additional Detention Basin(s)*				
	BASIX	Additional Neighbourhood Ponds	Saline Lake		Freshwater Lake / Wetland		Outlet Channel to Myall River		Included**		Additional Required***		Total Additional Detention (ha) [a+b]
			Area (ha)	Ave Depth (m)	Area (ha)	Ave Depth (m)	Times existing width	Deepening of existing connection to river (m)	Area (ha) [a]	Ponding Level (mAHD)	Area (ha) [b]	Ponding Depth (m)	
0			6	2.06			x 1	0.00					
1	√		6	2.06			x 1	0.00					
2	√	√	6	2.06			x 4	0.30			12	0.72	12
3	√	√	13.5	1.8			x 2	0.10	7.5	0.92	3	1.22	10.5
4	√		6	2.06	12	1.5	x 1.6	0.09	12	0.74			12
5	√		8	2.06	6.5	1.65	x 1.8	0.09	6.5	1.22			6.5
6	√		6	2.06	16	0.25	x 1.6	0.09	16	0.37			16

* Additional basin(s) required over and above existing detention lake (6ha) to limit post-development Local peak 100 yr ARI outlet to existing peak outflow.

** Retardation achieved through Water Quality management initiatives

*** Additional basin(s) required over and above the retardation achieved through the Water Quality management initiatives

Myall Quays Water Management Schemes

0. **Existing conditions**.
1. **Do nothing** – keep the current waterbody as it is without increasing the size (but with BASIX implemented).
2. Existing lake with **increased tidal flushing** and additional dry basins.
3. **Extended tidally flushed lake**.
4. Existing lake (saline) **and new freshwater lake(s)** incl. Basin.
5. **Partially extended saline lake and new freshwater lake**.
6. Existing lake and **new wetlands**.
7. Existing lake and **dry swales**.

Notes:

i. BASIX included in all new developments in schemes 1 - 6.
ii. All schemes aim to maintain the water quality regime in the existing lake and to not increase the local 100yr ARI peak outflow to the Myall River.

CRIGHTON PROPERTIES

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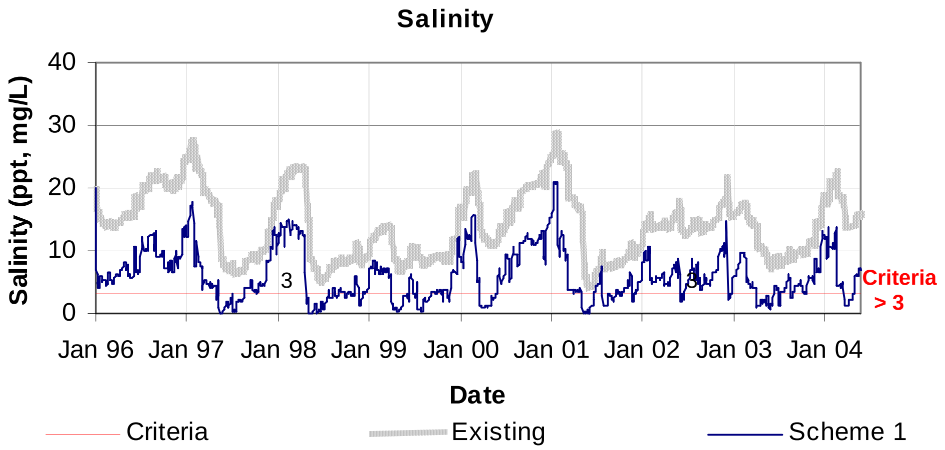
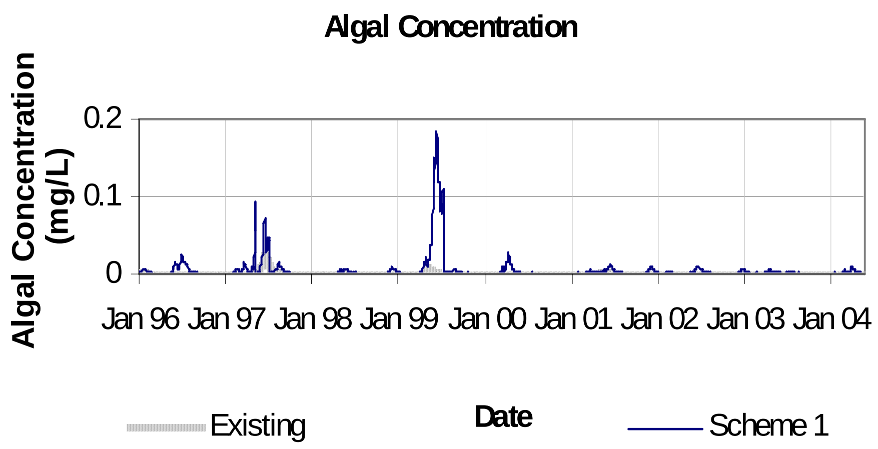
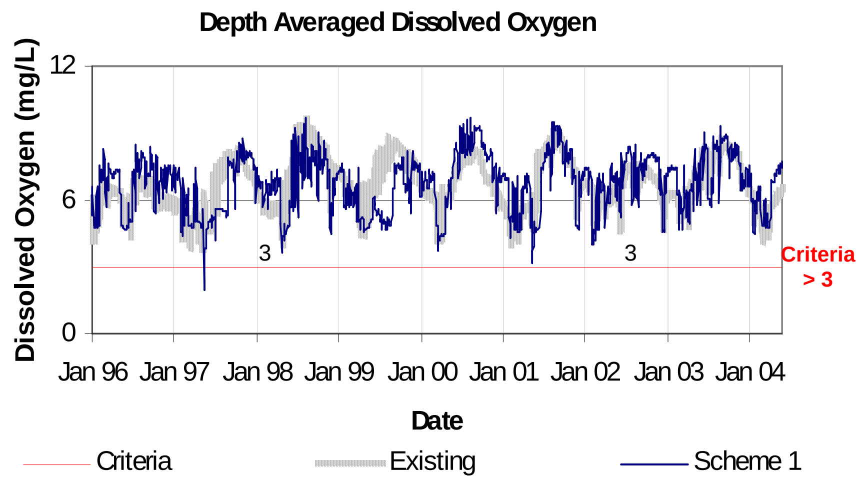
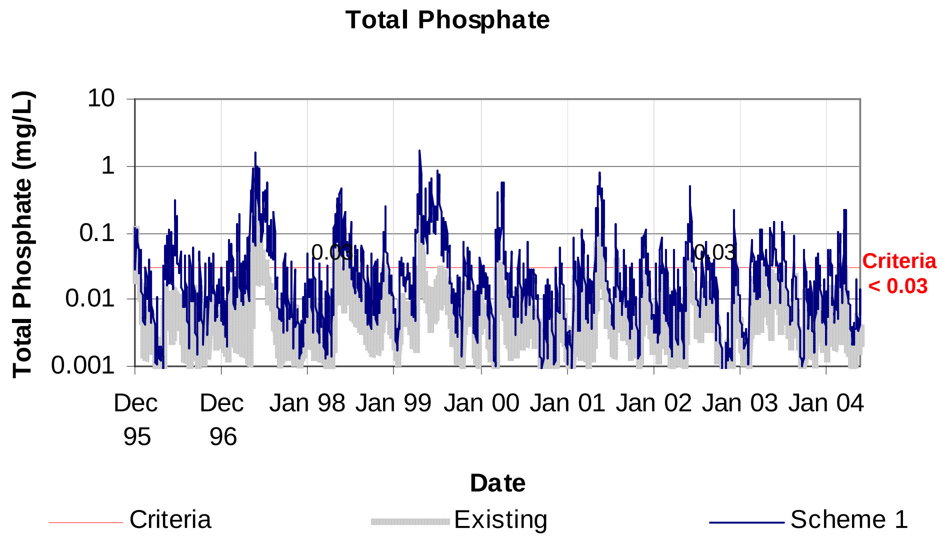


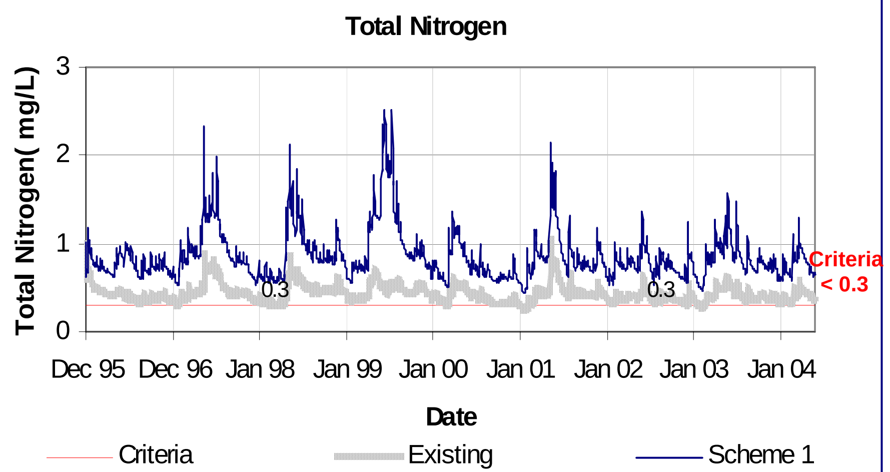
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	0
Total WQ Area [a]	6 ha
Outlet Channel Details	
Outlet Width	x 1
Outlet Depth	-
Retardation Details	
Total Available [=a]	6 ha
Additional Required	
Total	









Scheme 1

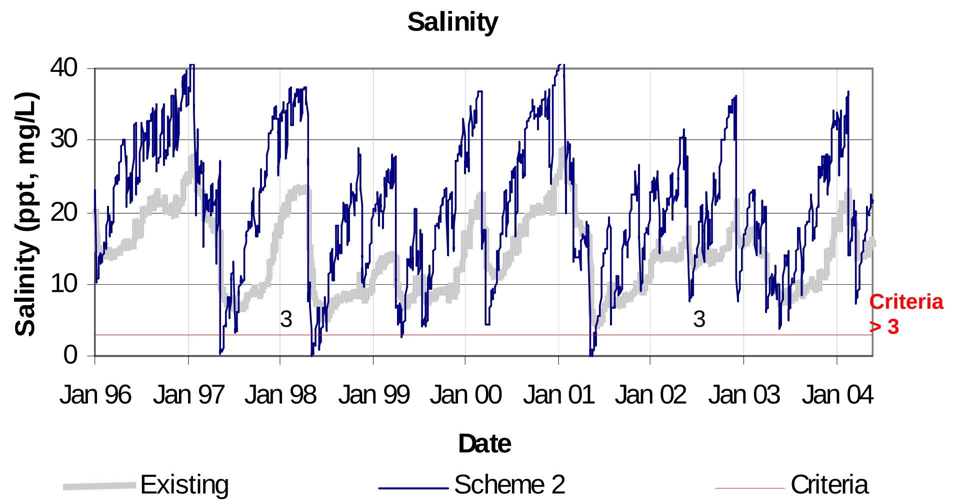
This scheme represents the implementation of the proposed development without any additional work to manage stormwater quantity or quality except the installation of measures to meet the requirements of BASIX for all new residential properties. This is the "Do Nothing" scheme. All stormwater flows to be piped into existing lake or discharged directly to wetland.

Strengths

- Least cost

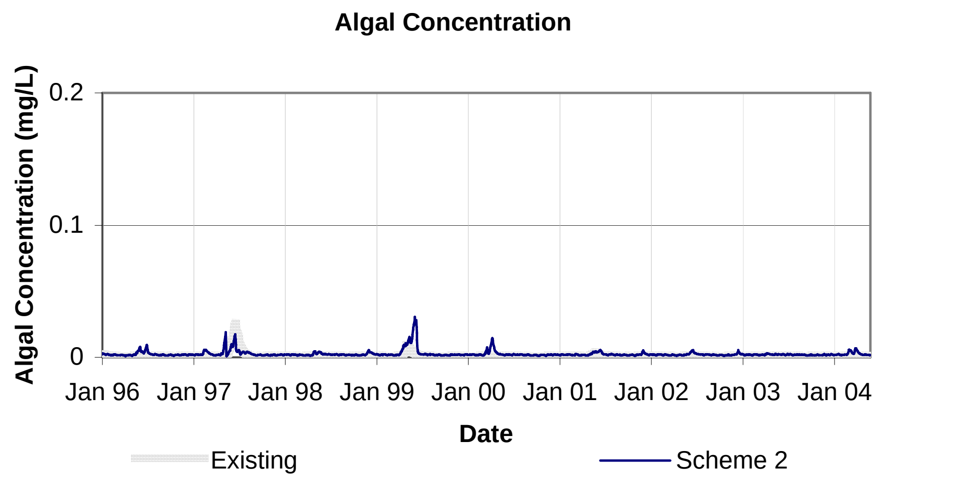
Weaknesses

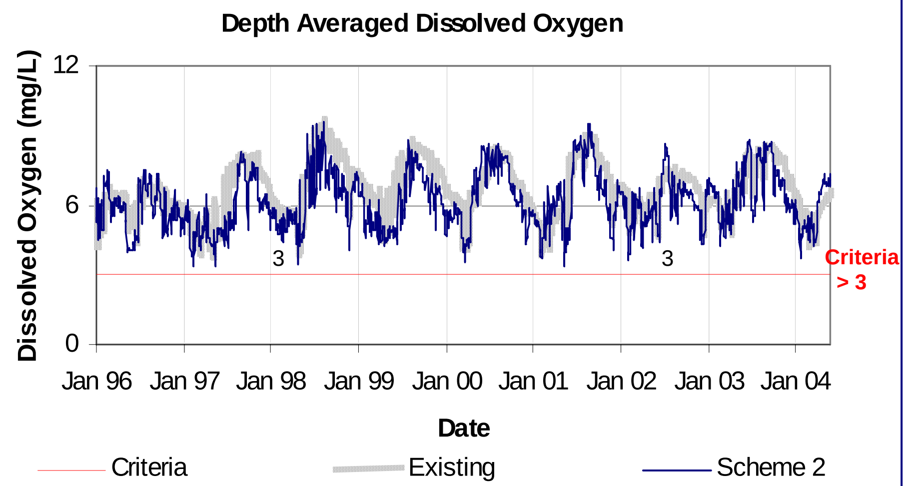
- No measures to mitigate the impact of the proposed development with respect to stormwater quantity or quality.
- Greatest potential impact on existing detention lake water quality and ecosystems ceases to function satisfactorily.
- Greatest potential impact on SEPP 14 wetlands.
- Does not meet the requirements of the Great Lakes Councils Stormwater Quality DCP.
- Highly likely to result in algal blooms, scour and discharge of pollutants.
- Inability to provide pipe gradients and surface water flow paths without importing vast quantities of fill and raising land some 1 – 1.5 m.

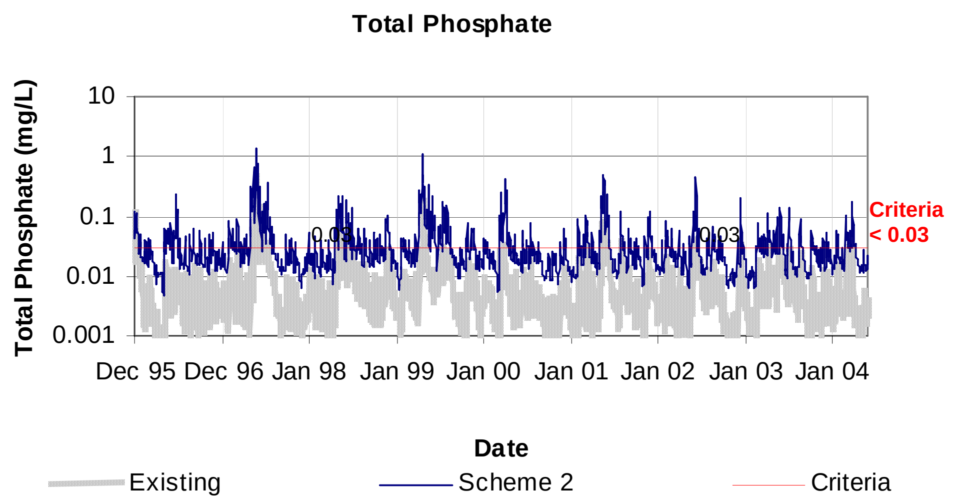


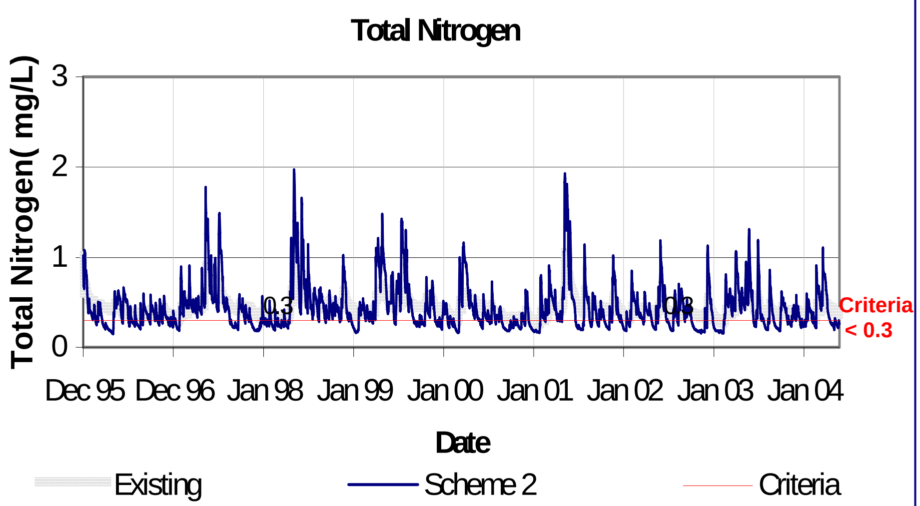
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	0
Total WQ Area [a]	6ha
Outlet Channel Details	
Outlet Width	x 4
Outlet Depth	0.3 m
Retardation Details	
Total Available [=a]	
Additional Required	0
Total	12 ha









Scheme 2

This scheme attempts to mitigate the adverse impacts of scheme 1 by increasing tidal flushing to combat water quality impacts and the provision of dry basins to help address detention and nutrient control.

Strengths

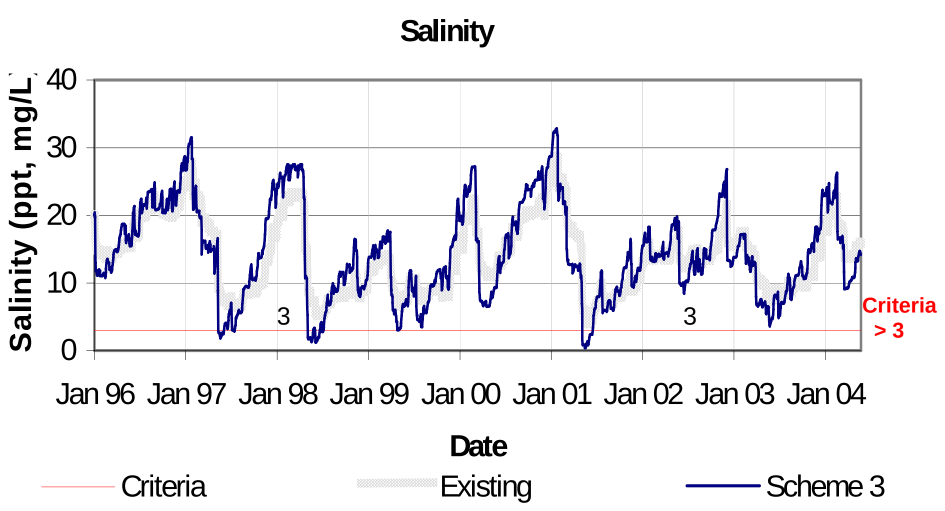
- Low cost.

Weaknesses

- Greatest change in the salinity regime in the existing lake.
- Greatest vulnerability to poorer water quality in the Myall River.
- Channel works have greatest impact on SEPP 14 wetland and conservation zone (massive increase in flows).
- Overall lake level significantly lowered
- Impact on the aesthetics of the existing lake.
- Additional dry retarding basins need to be above wet rainfall year groundwater levels.
- Even minimum grades on swales and basins lead to significant additional filling of new lots (1 – 1.5 m).

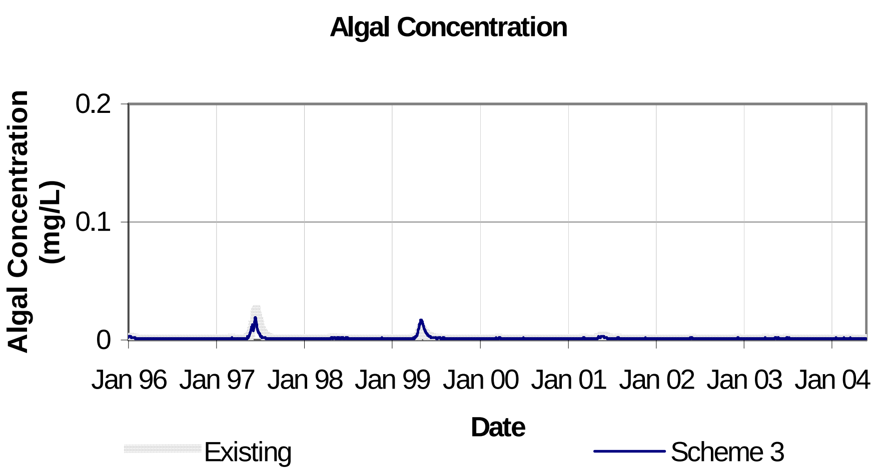
CRIGHTON PROPERTIES

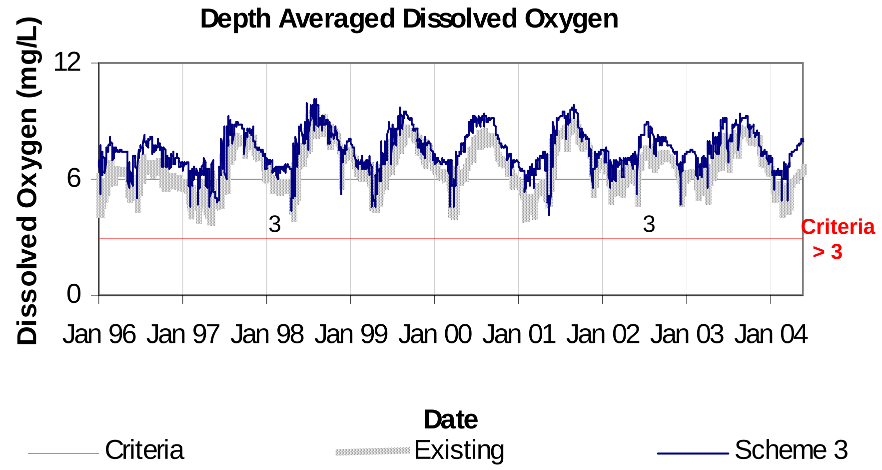
Cardno

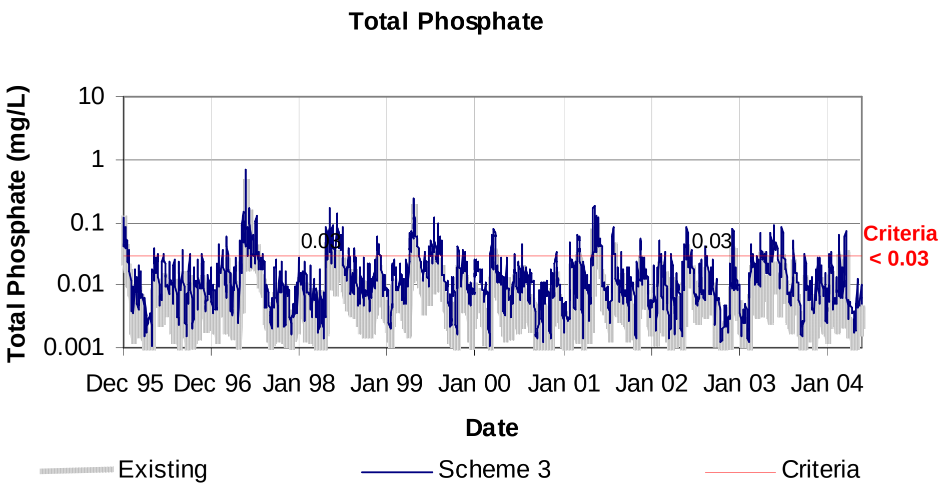


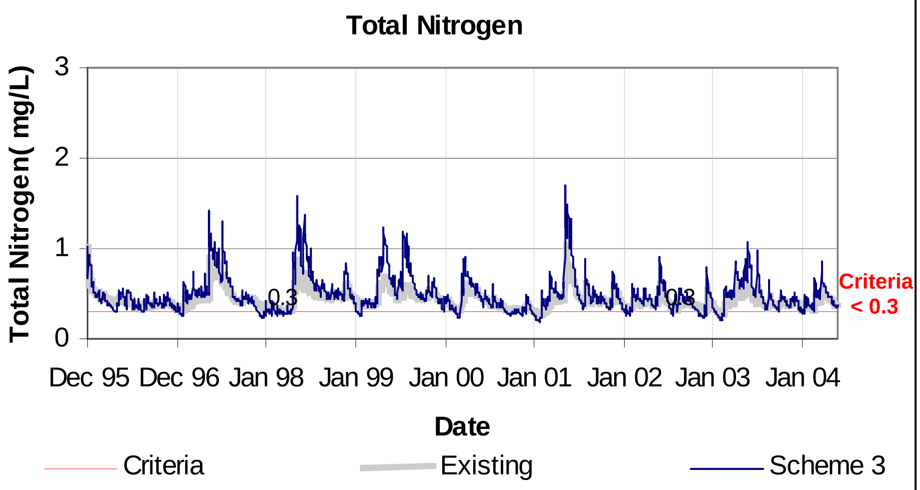
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	7.5 ha
Additional Freshwater Area	0
Total WQ Area [a]	13.5 ha
Outlet Channel Details	
Outlet Width	x 2
Outlet Depth	0.10 m
Retardation Details	
Total Available [=a]	
Additional Required	3 ha
Total	16.5 ha









Scheme 3

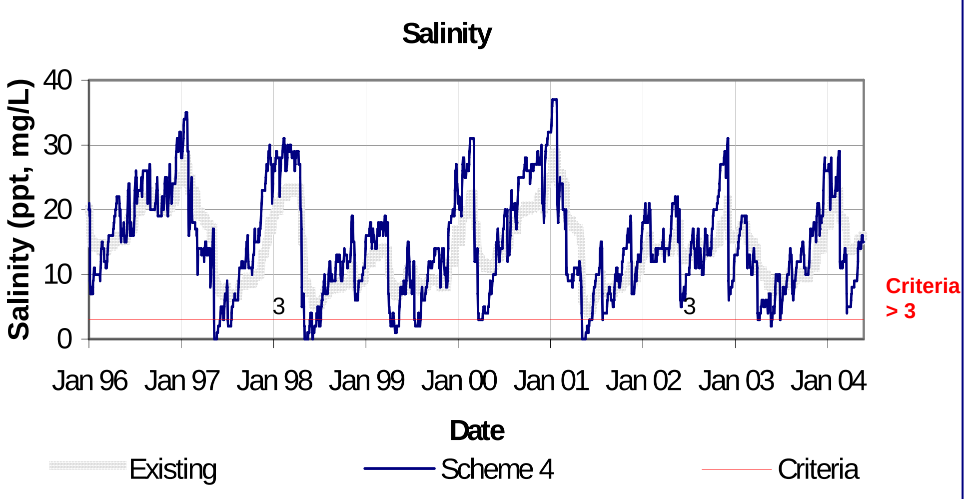
This involves the extension (by 7.5 ha) of the existing lake to give a tidally flushed lake with water quality comparable to existing conditions. The extended lake would also partially meet the requirements for additional active detention storage.

Strengths

- Tidal flushing assists water quality throughout the system.
- Expansion of established ecosystem (fish habitat etc)
- Benefits to existing lake quality due to final shape (improved circulation)
- Allows greater area to be serviced at water level (not requiring pipe gradients or fill).
- Aesthetic benefits.
- Most efficient land use with respect to site density.
- Extracted material could be used for shaping golf course and public areas.
- Minimum fill required over site generally (close to natural levels).
- Established proven Community Title arrangements to ensure on-going maintenance.
- Facilitates the drainage of the new developments with minimal fill.
- Desensitises water body to quality fluctuations.
- Lower long term maintenance costs.

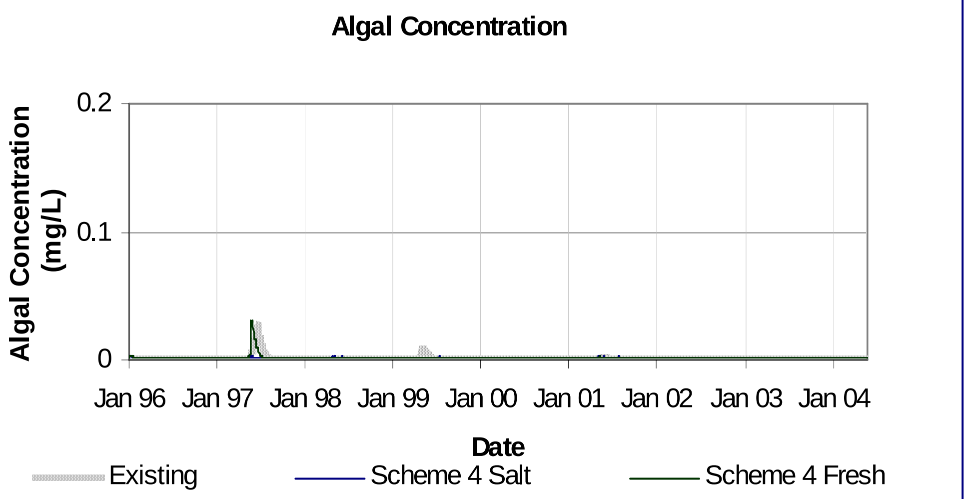
Weaknesses

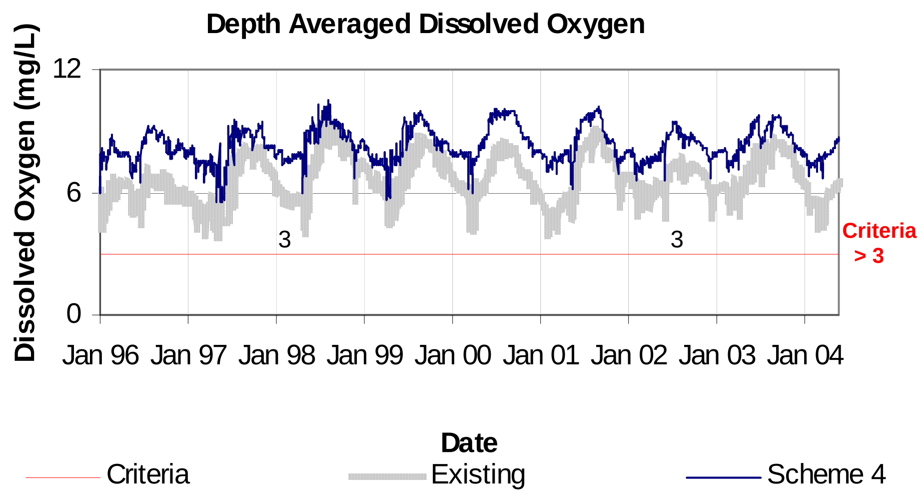
- Higher capital cost.
- Potential local impact on SEPP 14 wetland and conservation zone due to channel works.
- Single water body, reduces degree of security from contamination.
- Still requires additional detention.

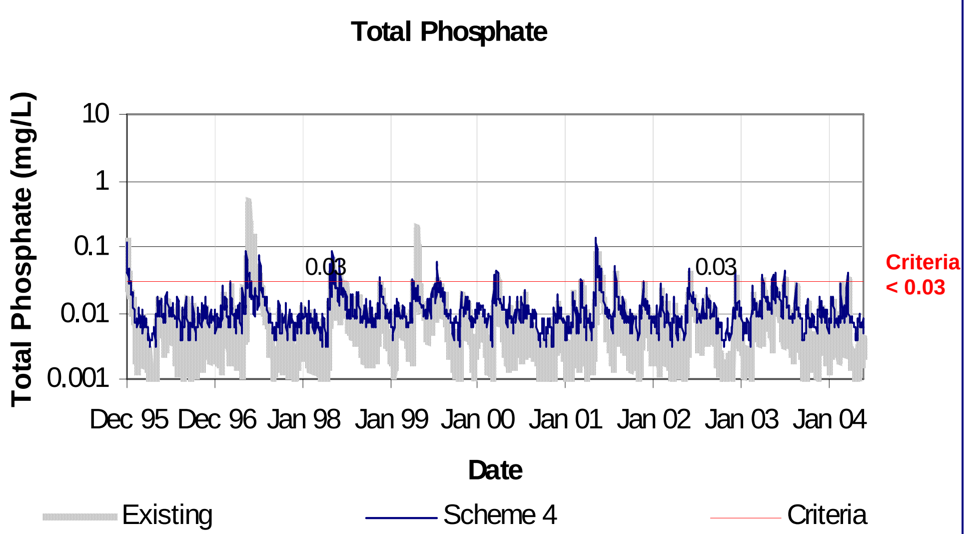


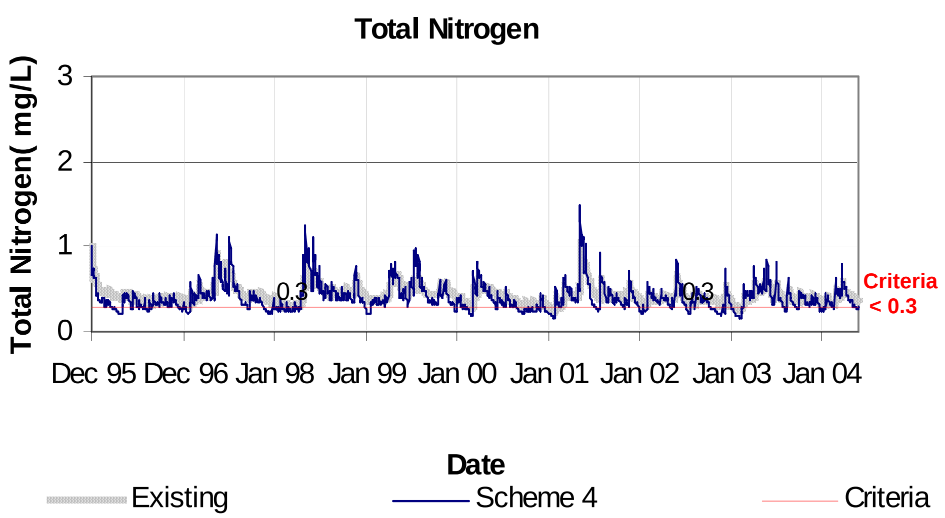
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	12 ha
Total WQ Area [a]	18 ha
Outlet Channel Details	
Outlet Width	x 1.6
Outlet Depth	0.09 m
Retardation Details	
Total Available [=a]	
Additional Required	0
Total	18 ha









Scheme 4

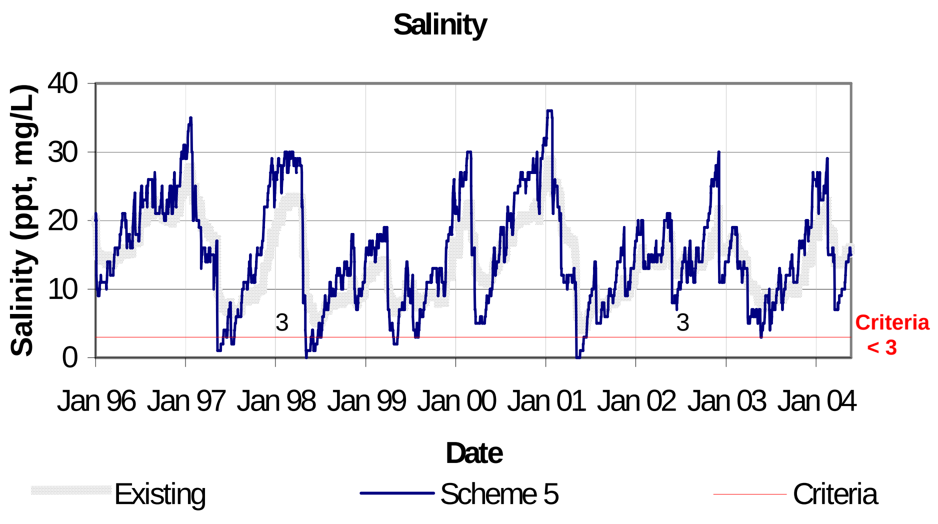
Under this scheme a separate freshwater lake (12 ha) and / or equivalent area of water bodies would be constructed to treat stormwater from the new development prior to its discharge into the existing detention lake. This lake would be a window lake with an expected average water level slightly higher than the existing tidally flushed lake. The additional lake / pond(s) would also include active storage to partially meet the retardation requirements.

Strengths

- Ponds could be constructed sequentially.
- Ponds could be located where required (when required).
- Dual role of water quality and partial detention.

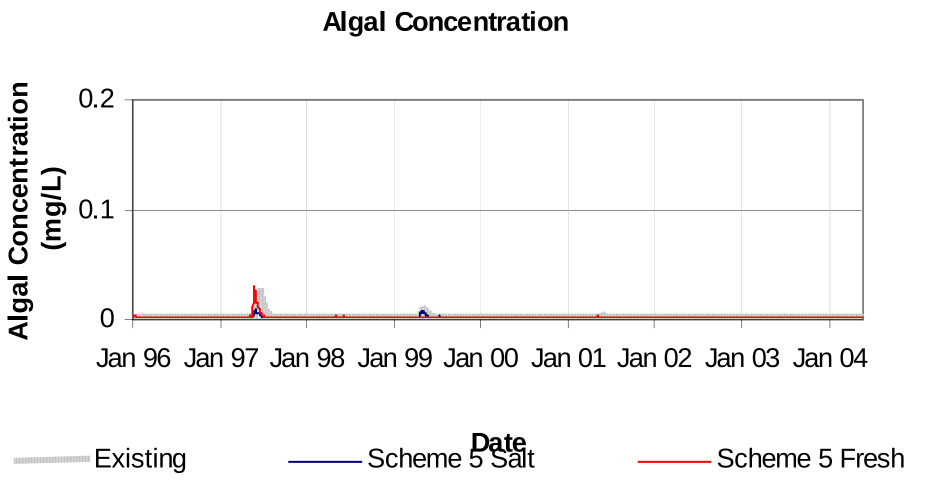
Weaknesses

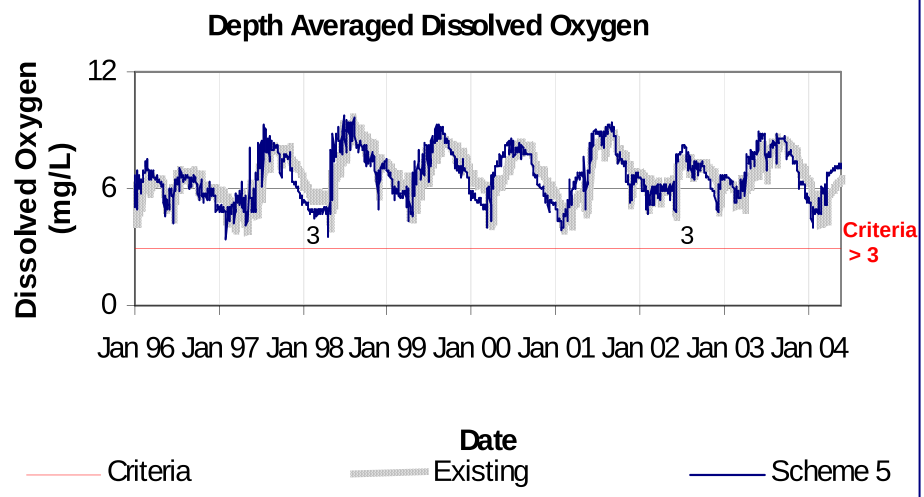
- No tidal flushing provided to limit potential of algal blooms.
- The size of a freshwater lake / pond greater than a tidally flushed lake (i.e. not as space efficient).
- The raised water levels in a freshwater lake / pond, impacts on the hydraulics of drainage swales (slight loss of fall potential).
- A number of different ponds to service and maintain.
- Higher overall land take in comparison with other schemes.
- No assistance to the established brackish ecosystem.
- Inherent circulation issues in ponds.

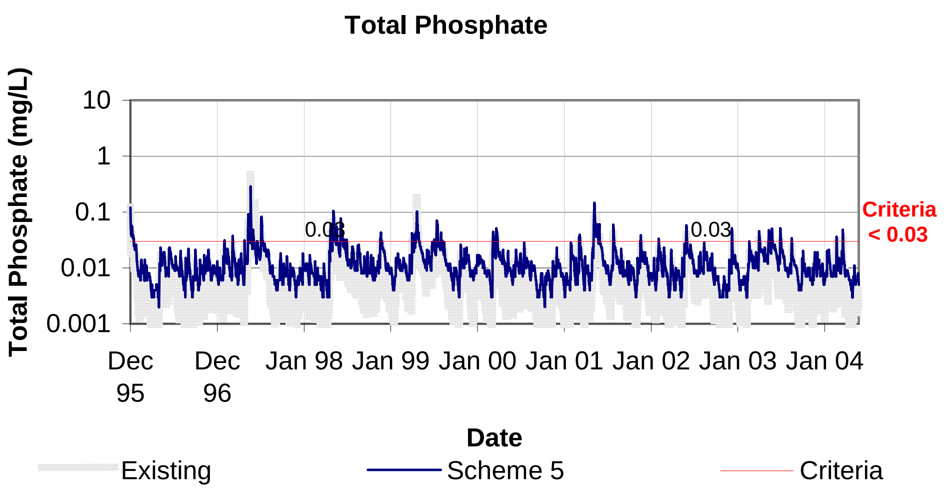


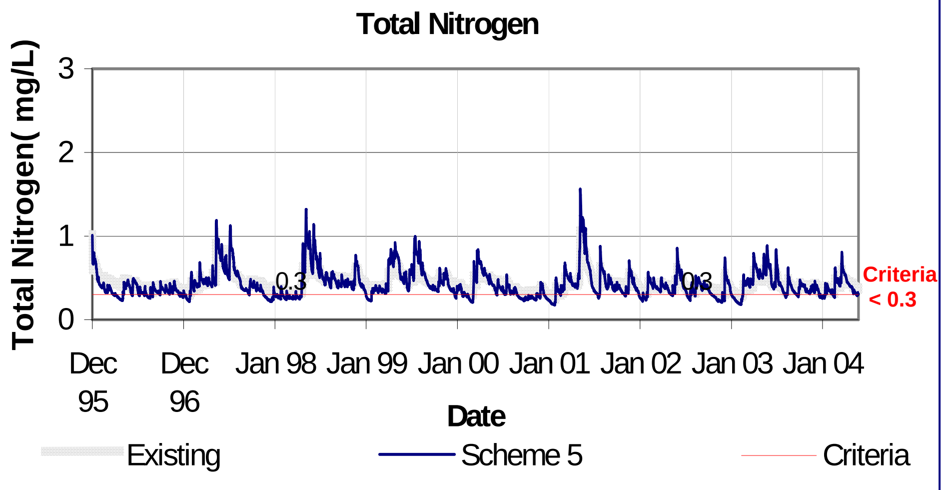
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	2 ha
Additional Freshwater Area	6.5
Total WQ Area [a]	14.5 ha
Outlet Channel Details	
Outlet Width	x 1.8
Outlet Depth	0.09 m
Retardation Details	
Total Available [=a]	
Additional Required	0
Total	14.5 ha









Scheme 5

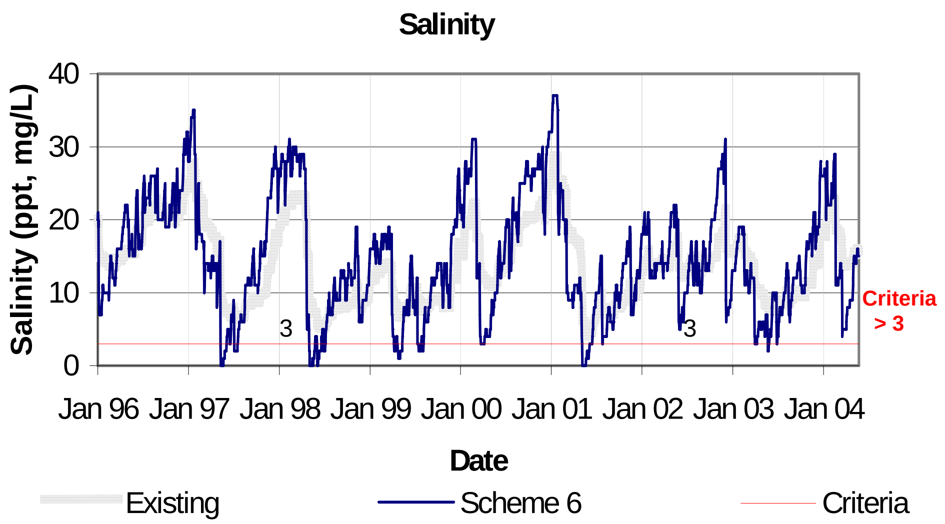
This scheme is a combination of schemes 3 and 4. It would comprise the extension of the western arm of the existing tidally flushed lake as well as the construction of an additional freshwater lake or chain of ponds (total extension).

Strengths

- The extended tidally flushed lake is able to reduce the size of the separate freshwater lake / ponds.
- Ponds could be constructed sequentially.
- Land take is less than other "split lake" schemes.
- Potential to integrate with open space strategy.
- Moderately increased tidal flushing.
- Better protection is afforded by discharging commercial runoff to brackish catchment.

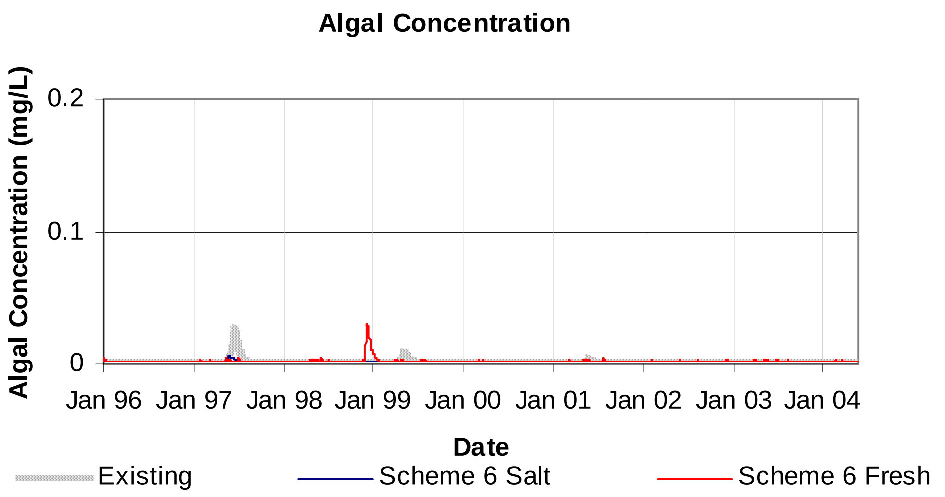
Weaknesses

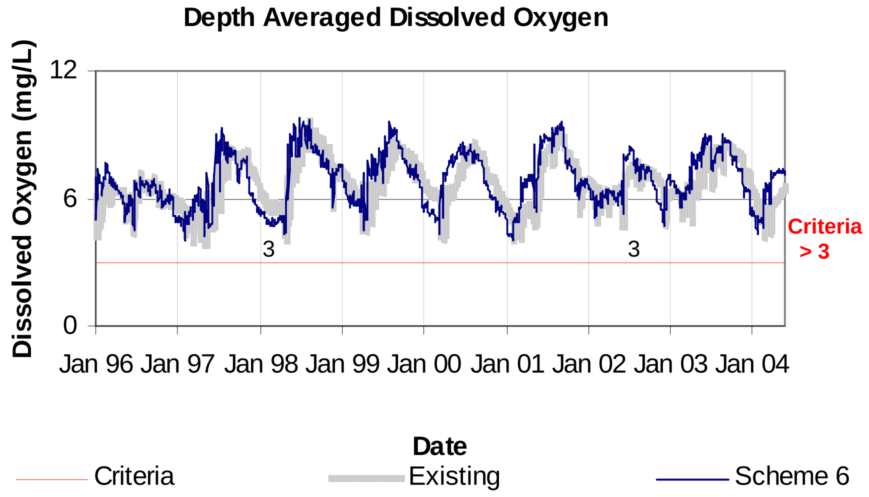
- The raised water levels in a freshwater lake / pond(s) impact on the hydraulics of the drainage swales.
- Need to maintain multiple water bodies.
- Local impact on SEPP 14 wetlands and conservation zone due to outlet channel works.

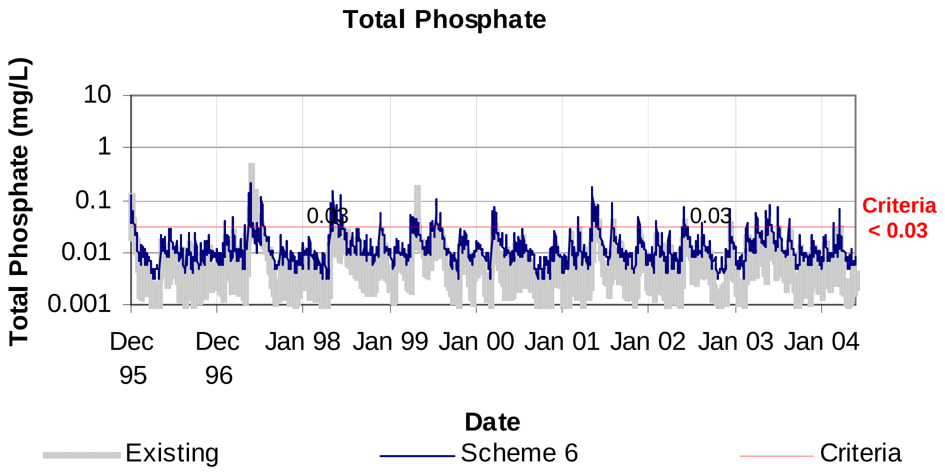


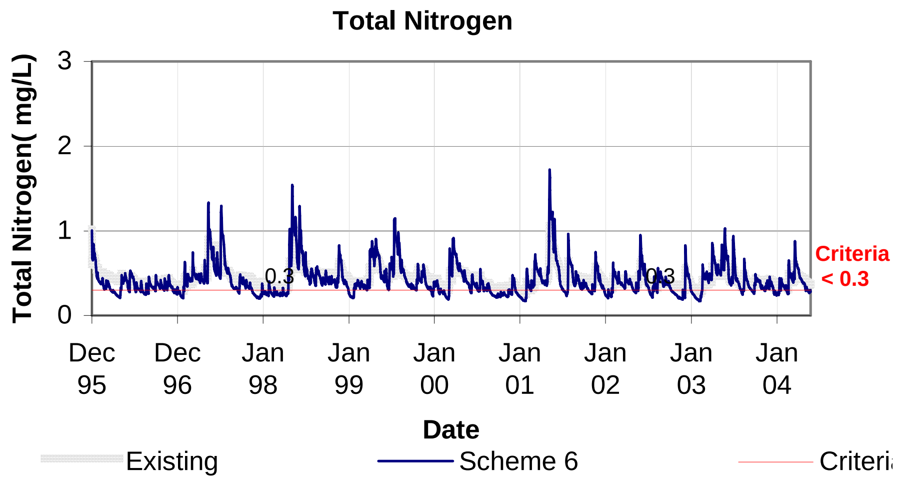
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	16 ha
Total WQ Area [a]	22 ha
Outlet Channel Details	
Outlet Width	x 1.6
Outlet Depth	0.09 m
Retardation Details	
Total Available [=a]	
Additional Required	16 ha
Total	22 ha









Scheme 6

This is also a variation on Scheme 4. Instead of an additional shallow lake / pond(s) additional shallow lined wetlands would be constructed.

Strengths

- Wetlands could be constructed where required (when required).
- Dual role of water quality and detention.
- Moderate increase in tidal flushing.

Weaknesses

- Wetland would need to be lined to maintain water within the wetlands.
- Large area of wetlands may pose a health risk to residents through increased potential for mosquito breeding.
- Land take is greater than other schemes.
- The level of the wetlands likely to impact on the hydraulics of drainage swales
- Need to incorporate open water zones within the wetlands to assist predation on mosquitoes
- Aesthetic impacts.
- Local impact.
- Lined wetlands susceptible to drying out.
- Increased fire risk (see the Map below with the APZ required – in red).

SWALES

What is a Swale?
Swales are linear broad shallow channels that provide for stormwater collection and conveyance. Swales may be grass-lined or densely vegetated and / or landscaped. While swales provide for stormwater transportation, they also contribute to the removal of gross pollutants, such as litter and coarse sediment, from stormwater runoff.

In urban areas, swales may be used as an alternative to the conventional street naturestrip or in central median strips of roads, through to runoff collection points in car park areas. Hydraulically swales can reduce run-off volumes and peak flows. Current designs involve the use of grass or other vegetation (such as rushes) to carry out this function. Examples of their current use are in road medians and verges, car park run-off areas, parks and recreation areas.

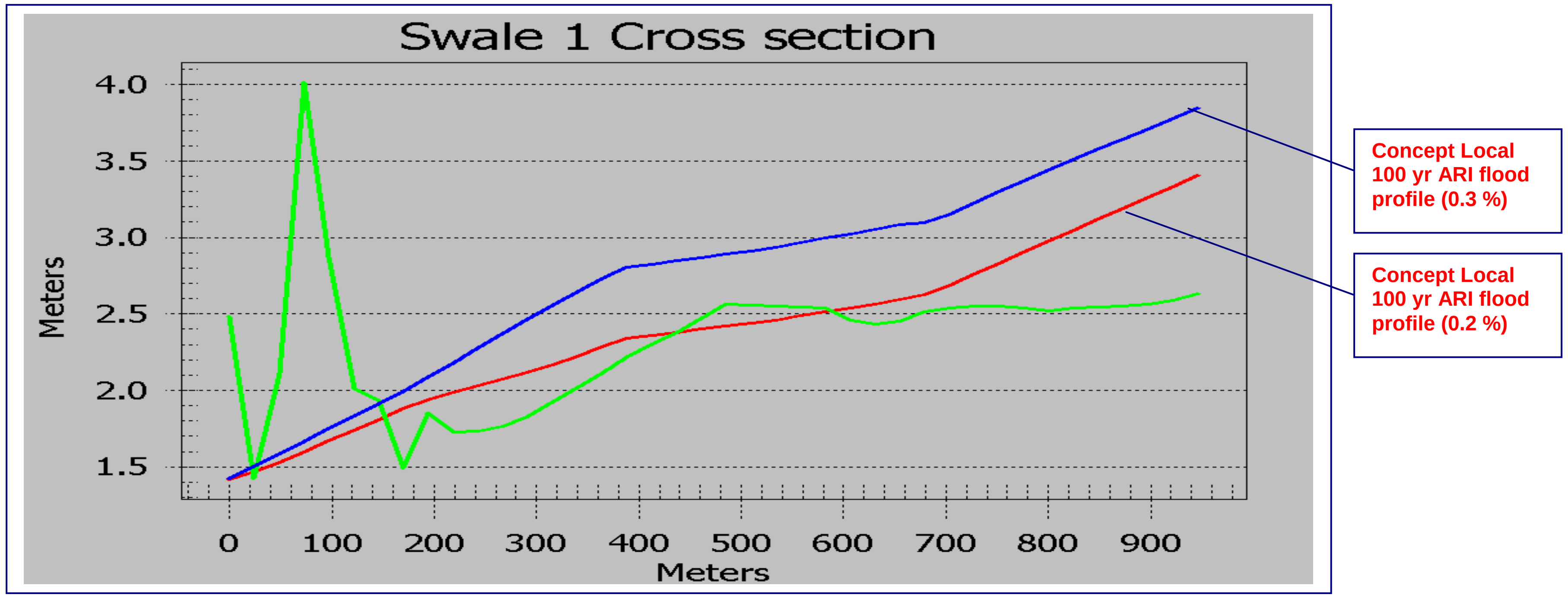
Swales initially immobilise pollutants, by binding them to organic matter and soil particles. Settling, filtration and infiltration into the subsoil achieve ultimate pollutant removal. Certain pollutants, such as hydrocarbons, may be digested and processed by the soil microorganisms in the filter strip. Consequently, adequate contact time between the run-off and the vegetation and soil surface is required to optimise pollutant removal.

Swale design for Myall Quays
Swales design purpose is to carry varying flows. The design for Myall Quays development is to incorporate grassed swales, approximately 6 m wide. Minimum gradient 0.2%

Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	0
Total WQ Area [a]	6ha
Outlet Channel Details	
Outlet Width	x 4
Outlet Depth	0.3 m
Retardation Details	
Total Available [=a]	
Additional Required	swales
Total	

Swale Cut and Fill Cross Section



Scheme 7
This scheme is effectively scheme 2 with the benefit of swales. This scheme attempts to mitigate the adverse impacts of scheme 1 by increasing tidal flushing to combat water quality impacts and the provision of dry basins to help address detention and nutrient control.

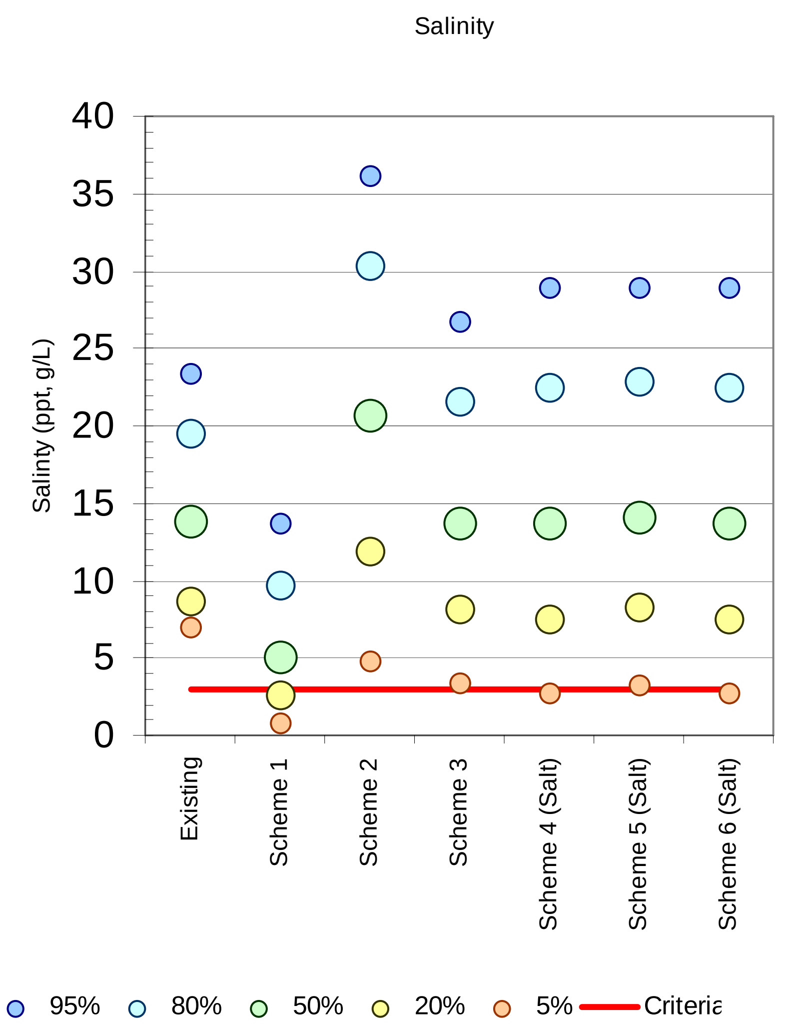
Strengths
- Can reduce and delay storm run-off,
- Retains particulate pollutants close to source,
- More aesthetically appealing than kerb and gutter, and
- Relatively inexpensive to construct.

Weaknesses
- Limited removal of fine sediment and dissolved pollutants,
- Requires larger land area that kerb and gutter, with certain activities restricted (i.e. car parking),
- Sunny aspect is required for plant growth, limiting its application in shaded areas,
- Regular inspections are required; and
- Even at minimum gradient (0.2%) swales result in massive fill required at upper end of catchment.

Salinity

The plot of salinity compares modelled existing conditions (calibrated using recorded data) with the various schemes considered for the Myall Quays development. The values (5%, 20%, 50%, 80% and 95% percentile) for the probability of exceedence of the salinity in a tidally flushed lake (either existing or extended) is depicted for pre-existing conditions, existing conditions as well as Schemes 1 – 6. Schemes 3 to 6 have salinity levels (within hyposaline range) to support a more diverse ecosystem compared to that of scheme 2. Scheme 2 has levels with the 80%ile reaching relatively high salinity levels, which limits the species diversity and richness. Scheme 0 is similar to schemes 3 to 6. Scheme 1 is modelled depicting relatively low salinity levels.

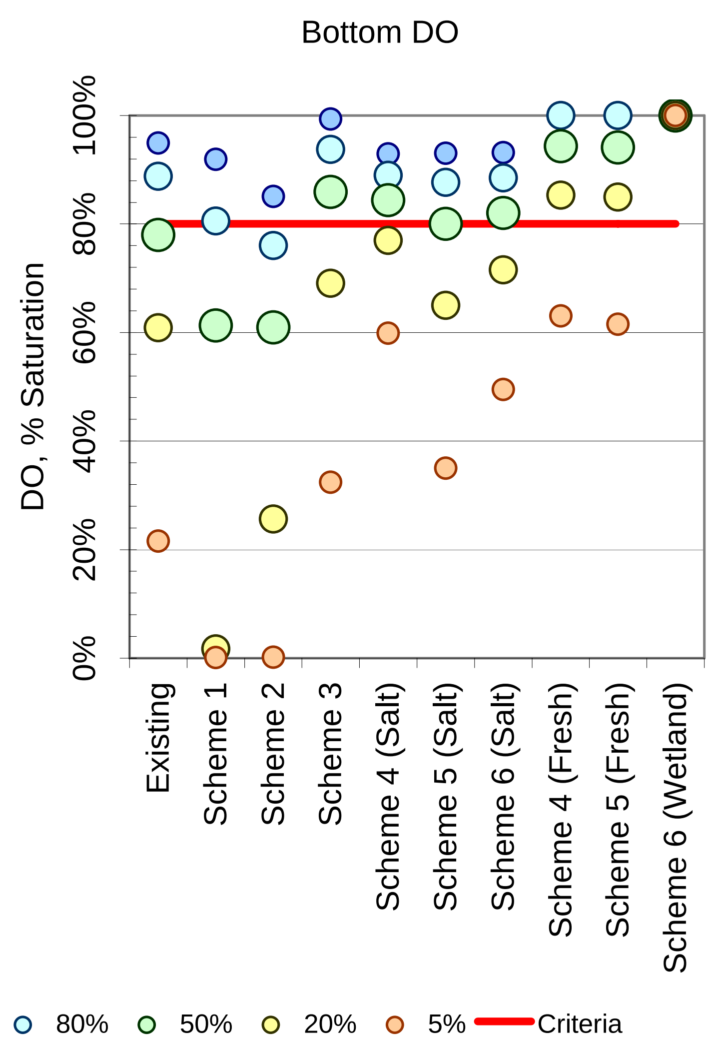
Rank	Scheme
1	0
7	1
6	2
2	3
3	4
3	5
3	6



Dissolved Oxygen

The DO concentrations measured in the existing lake include readings of both bottom and surface waters. The levels in bottom waters tend to be lower dissolved oxygen. Scheme 3, 4 and 5 have a high percentage of DO levels in the optimal range (80% to 110%) to support a healthy ecosystem than other schemes.

Rank	Scheme
5	0
7	1
6	2
4	3
2	4
3	5
1	6



Chlorophyll *a*

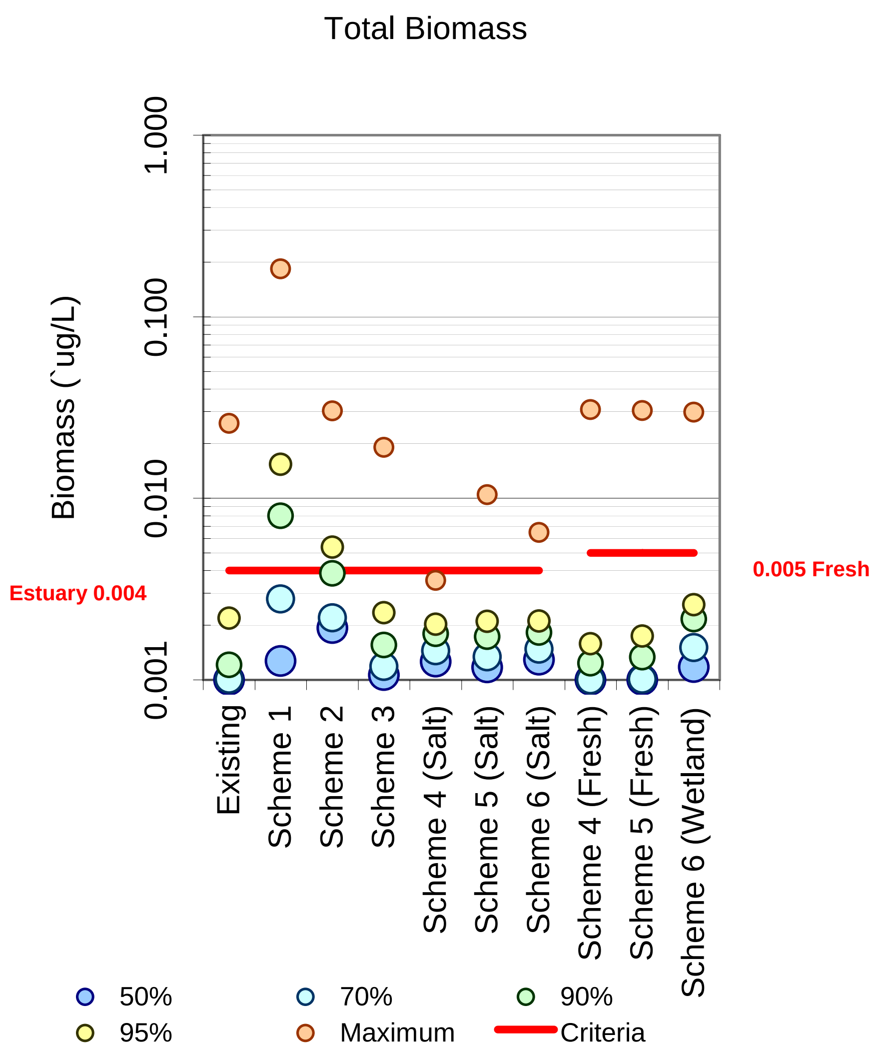
The Chlorophyll *a* concentrations in Myall Quays detention lake vary at certain times of the year. Modelling of the different options for the proposed development are represented, with certain schemes showing less dramatic variations.

ANZECC (2000) Trigger Values for Chlorophyll *a*

	Chlorophyll *a*
Fresh	5 µg/L
Marine	1 µg/L
Estuary	4 µg/L

Scheme Ranking for Chlorophyll *a*

Rank	Scheme
4	0
7	1
6	2
5	3
1	4
3	5
2	6



Nitrogen

The ANZECC(2000) trigger values for TN are shown in the table below.

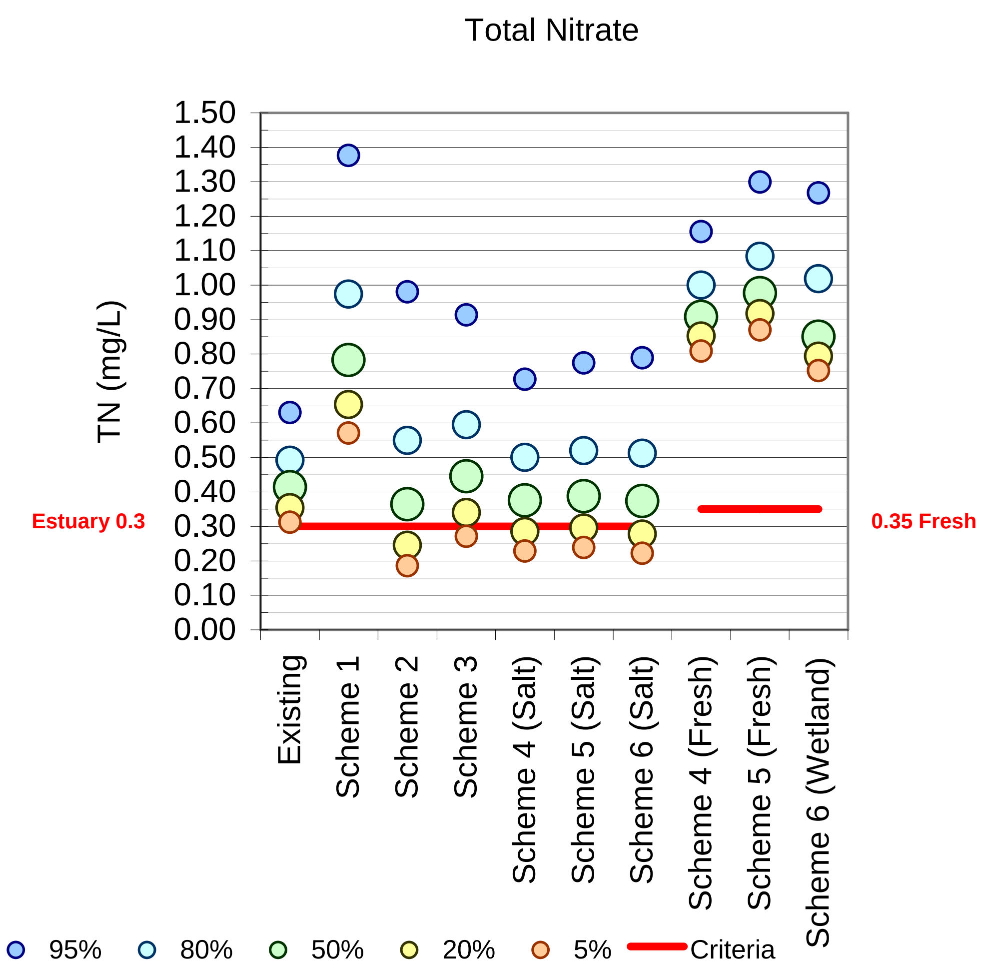
ANZECC (2000) Trigger Values for Nitrogen

	Total Nitrogen (TN)
Fresh	0.35mg/L
Marine	0.12mg/L
Estuary	0.3mg/L

Scheme Ranking for Nitrogen

Rank	Scheme
2	0
4	1
3	2
1	3
5	4
7	5
6	6

Implementation of new management measures and the appropriation of a higher site specific target monitored using community funding means water quality in the existing and proposed lake / pond(s) will meet the recommended ANZECC (2000) guidelines. The higher standard is desirable as the nutrient status of water quality would not encourage algal blooms, phytoplankton blooms and midge outbreaks etc that occur in eutrophic or high nutrient waters. The observed levels in the existing lake have generally been low. This appears to be contributing to the overall good water quality.



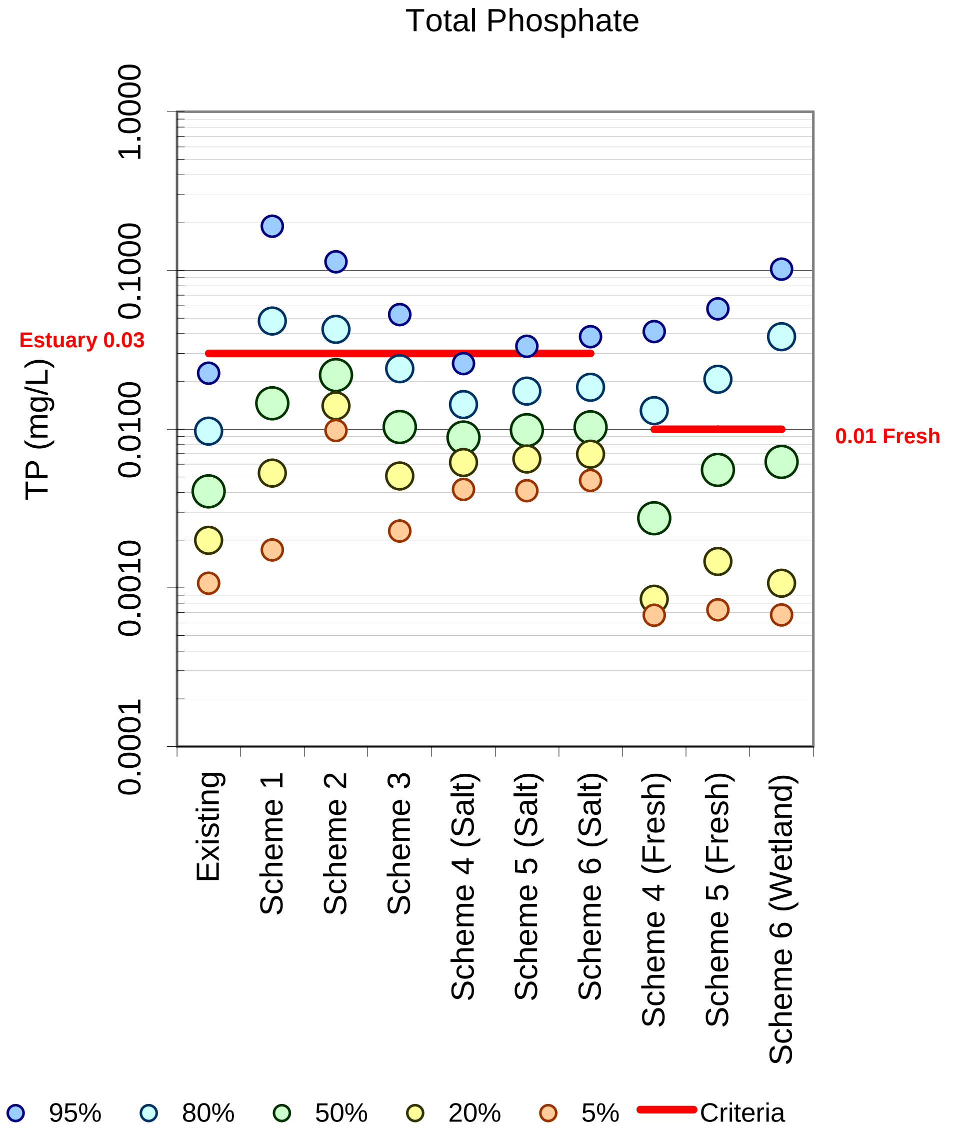
Phosphorus

The ANZECC(2000) trigger values for (80%ile) TP are shown in the table below.

	Total Phosphorus (TP)
Fresh	0.01 mg/L
Marine	0.025 mg/L
Estuary	0.03 mg/L

Rank	Scheme
1	0
7	1
6	2
2	3
3	4
4	5
5	6

The TP levels in the lake at Myall Quays are generally low. The mean value for the existing lake is 0.02 mg/L. The phosphorous concentrations have declined since 1997 to consistently low values, contributing to the overall very good water quality.



Summary

Summary of Qualitative Assessment of Schemes

Criteria	Weight	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5	Scheme 6	Scheme 7
Water Quality								
Salinity	0.2	2	4	3	2	3	3	2
Dissolved Oxygen	0.2	1	1	4	4	4	4	3
Algae	0.2	1	3	4	4	4	4	3
Total Nitrogen	0.2	1	4	4	1	1	1	3
Total Phosphorous	0.2	2	2	3	3	3	3	3
Environmental Impacts								
Impact on existing water body	0.4	1	2	4	4	4	4	4
Impact on SEPP 14 wetlands	0.3	2	3	4	4	4	4	4
Impact on Myall River	0.1	2	3	4	4	4	4	4
Impact on Ground Water	0.2	2	2	3	3	3	4	1
Viability								
Loss of potential lots	0.3	3	4	5	3	3	1	1
Aesthetic/Health	0.1	2	2	4	4	4	1	1
Landtake for Basins	0.2	1	4	5	4	4	4	2
Landtake for Ponds / Wetlands	0.2	1	4	5	4	4	4	2
Filling	0.2	5	4	5	3	4	2	1
Weighted Total Score		5.50	9.00	12.30	10.10	10.50	9.40	7.60
Rank		7	5	1	3	2	4	6

Criteria / Score	1	2	3	4	5
Salinity	Extremely Low	Low	Meets the Criteria	Good	Extremely Good
Dissolved Oxygen	Extremely Low	Low	Meets the Criteria	Exceeds Criteria	Extremely Good
Algae	Highly Elevated	Elevated	Meets the Criteria	Lower than Criteria	Extremely Good
Nutrients	Highly Elevated	Elevated	Meets the Criteria	Lower than Criteria	Extremely Good
Impact on existing water body	Negative Impact	Some Negative Impact	No Impact / No Change	Some Improvement	Positive Impact
Impact on SEPP 14 wetland	Significant Negative Impact	Some Negative Impact	Slight Negative Impact	Minimal Impact	No Impact / No Change
Impact on Myall River	Significant Negative Impact	Some Negative Impact	Slight Negative Impact	Minimal Impact	No Impact / No Change
Impact on Ground Water	Significant Negative Impact	Some Negative Impact	Slight Negative Impact	Minimal Impact	No Impact / No Change
Loss of potential lots	Significant loss of lots	Loss of lots	Slight loss of lots	Minimal loss of lots	No net loss of lots
Aesthetic/Health	Significant Negative Impact	Negative Impact	No Impact / No Change	Positive Impact	Significant Positive
Landtake for Basins	Greatest landtake	Additional landtake	Some landtake	Contained within public open space	Excellent
Additional Water Area	Greatest landtake	Additional landtake	Some landtake	Contained within public open space	No additional area required
Filling	Most volume of fill required	Additional fill required	Some additional fill	Minimal additional fill	No Impact / No Change

APPENDIX G

GROUNDWATER ASSESSMENT
OCTOBER 2007

GROUNDWATER ASSESSMENT

Crighton Properties
Riverside Development, Tea Gardens

GEOTLCOV23225AA-AD
26 October 2007

Coffey Geotechnics Pty Ltd ABN 93 056 929 483
8/12 Mars Road Lane Cove West NSW 2066 Australia

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

26 October 2007

Crighton Properties
PO BOX 3369 Tuggerah
NSW 2259

Attention: Mr Peter Childs

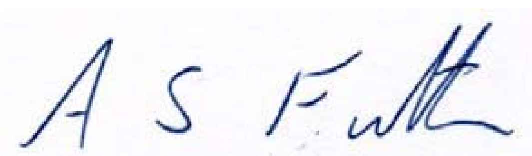
Dear Sir

RE: Groundwater Assessment, Riverside Development, Tea Gardens.

Coffey Geotechnics is pleased to present our groundwater study for the Riverside Development, Myall Quays.

We trust that our report meets your requirements. If you have any questions regarding the report, please do not hesitate to contact the undersigned or either Jessica Northey and Andy Fulton.

For and on behalf of Coffey Geotechnics Pty Ltd



Andrew Fulton

Senior Hydrogeologist

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Executive Summary

A groundwater study and modelling program was undertaken to assess the groundwater aspects of concept layout for the proposed Riverside development. The development includes housing and a man made lake which has been constructed to provide a storm water detention structure and to aid water quality management.

The site is located to the west of the Myall River and is bounded to the west by Myall Road and Toonang Road. The ground surface generally slopes down gently south-east towards the river with ground levels typically below 3mAHD. A series of sand ridges trending roughly north-south are present across the site. An elevated bedrock outcrop, rising to about 25mAHD, is present at the northern end of the site. Elevated bedrock levels are also present at the north-western limit of the site.

The sandy aquifer local to the development is contained within a discrete area and groundwater users further a field are not likely to be affected by activities at the Riverside development site. The shallow rock levels to the north of the site provide a barrier to groundwater inflow. The sand aquifer is expected to extend to the south and west of the site and be in hydraulic contact with the waters of the Myall River to the south, Wobbegong Bay and Pindimar Bay (Port Stephens) to the south-west and Kore Kore Creek to the west.

Losses from the groundwater system occur due to seepage to the Myall River and evapotranspiration from areas of shallow water table. Rainfall infiltration forms the main groundwater recharge mechanism and previous monitoring results from the bores over the site show marked groundwater level response to rainfall events. Lower groundwater levels recorded recently are likely to be the result of lower than average rainfall which has occurred on the Mid North Coast of NSW in recent years.

Groundwater modelling that was conducted in an earlier investigation phase was built upon and used to simulate the expected impacts from the proposed development. The modelling indicated that the extension of the lake and the introduction of a series of stepped freshwater lakes will cause localised drawdown on the north-western most extremity of the extended lake by up to 0.75 m. There was negligible impact indicated from the modelling on the wetland area fringing the Myall River.

Groundwater quality monitoring indicates that quality has remained relatively stable when recent results were compared to earlier testing periods. Groundwater quality is generally below the key criteria for protection of species in marine water with the exception of some metal concentrations. Groundwater from monitoring bores closer to the Myall River tends to be characterised by higher EC and a similar anion to cation ratio to seawater, suggesting the dilution of seawater is occurring as a result of rainfall recharge from the catchment.

Groundwater quality was compared to the Australian Drinking Water Guidelines (NHMRC, 2004) and is not potable due to concentrations of a range of analytes exceeding the drinking water guidelines. Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and outside the lower criterion for drinking water of pH 6.5. Groundwater near the Myall River has elevated levels of electro-conductivity, anions and cations that do not meet the criteria for drinking water. Elevated ammonia concentration found in some bores also renders groundwater unsuitable for potable use due to the exceeding of ANZECC guidelines. Groundwater away from the Myall River may be considered for irrigation purposes, however high concentrations of phosphorus have the potential to result in bio-clogging of irrigation equipment.

An assessment of potential acid sulfate soils was undertaken at the site (Coffey 2007 GEOTSGTE20248AA-AE) which indicated elevated levels of total potential sulfidic acidity and peroxide oxidisable sulfur were present in the samples tested. It was considered that the potential acid sulfate soils were likely to be present in the area. The lake extension will cause groundwater level reductions on the north-western tip of the lake extension to fall slightly below levels interpreted to have acid soil producing potential. However, the area affected and the exceedance of criteria is considered to be limited for the predicted resulting groundwater levels.

The groundwater results from the current monitoring round suggest that the reclaimed water from treatment facilities in the area may be suitable for irrigation of open spaces and gardens within the development area subject to a small reduction in total nitrogen concentrations. This reduction may be achieved through a combination of treatment and dilution of the reclaimed water with water of higher quality.

The results of this study as presented has show that groundwater levels within are not significantly affected by the proposed development proposed . Groundwater quality results indicate that the groundwater form the aquifer at Riverside is not suitable for potable use although it is possible that reclaimed water can be used for irrigation purposes provided appropriate treatment is undertaken. Groundwater quality results also indicate that the groundwater is generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations.

1 INTRODUCTION

This report presents the results of a groundwater study and modelling program undertaken to assess the latest concept layout for the proposed Riverside development (the Site) at Tea Gardens (Figure 1) on local groundwater movements. Coffey Geotechnics Pty Ltd (Coffey) was commissioned to undertake the project by Crighton Properties to address the issues noted in the amended Director-General's Environmental Assessment Requirements (Ref.: MP 06_0010, dated 29 December 2006) for the site, in particular:

- Analysis of groundwater quality of the site;
- Interception and use of groundwater;
- Potential for impact on existing groundwater with respect to the latest concept layout for the development;
- Beneficial uses of groundwater; and
- The potential impact of reuse of reclaimed water and the quality required to minimise impact on groundwater.

Mr Peter Childs of Crighton Properties commissioned the works in March 2007 in response to a Coffey proposal (Ref: GEOTLCCOV22325AA, 6 March 2007). Cardno Willing (Cardno) are consultants to Crighton Properties and they have provided information in relation to the proposed development.

2 PROPOSED DEVELOPMENT

It is understood that Crighton Properties has commenced development at the site in accordance with the current Local Environment Plan (LEP) zonings – mixed residential/commercial 2(f), wetlands 7(a) and a conservation zone 7(b). The development is approximately 230ha in size and comprises residential areas, a commercial area, open space recreational areas, wildlife corridors and buffer zones and the lake.

The development features a large lake partially encircling an existing residential development. Development approval has been granted for a portion of the development at the south of the site including housing and a man made lake (about 6.5ha in area) which has been constructed to provide a storm water detention structure and as a water quality management measure.

The proposed development will involve extending the existing lake and construction of housing and open space recreational areas. This is the latest concept layout for the proposed Riverside development considered in this report. Along the eastern boundary of the development, a natural wetland area separates the site from the Myall River. This wetland is recognised under State Environment Planning Policy No. 14 (SEPP 14) as Wetland No. 746 and consists of seagrass tidal mud flats containing fringing mangroves along the river bank.

3 PREVIOUS INVESTIGATIONS AT THE SITE

Coffey has previously undertaken a groundwater assessment of the site in 2004 (Ref: E12752/3-AF) to assess the impact of an earlier development proposal at the site. The report included groundwater level and groundwater quality monitoring, acid sulfate soil testing and the development of a numerical groundwater model.

The groundwater assessment reported on the results from a network of fourteen monitoring bores, four of which were installed by Coffey in the vicinity of the lake (Bores 21 to 24). Rainfall was assessed to be the main groundwater recharge mechanism and groundwater level was found to respond rapidly to rainfall events. During periods of low rainfall, groundwater levels gradually fall as seepage towards the Myall River and the lake occurs.

Previous monitoring of groundwater level indicated the area is underlain by a shallow watertable, particularly in the eastern part of the site in the vicinity of the wetlands and the Myall River. The watertable was found to be slightly deeper (0.5 to 1m) in the northern and western parts of the site.

Groundwater quality monitoring, undertaken in 2004, indicated that there had been little change in groundwater quality between the 1995 and 2004 monitoring rounds. Groundwater in the vicinity of the Myall River is characterised by higher salinity, with decreasing salinity as distance to the river increases. Groundwater quality was assessed to be unsuitable for drinking purposes but was considered to be potentially suitable for irrigation purposes.

An assessment of potential acid sulfate soils was also undertaken at the site (Coffey 2007 GEOTSGTE20248AA-AE). The laboratory results indicated elevated levels of total potential sulfidic acidity and peroxide oxidisable sulfur were present in the samples tested. It was considered that the potential acid sulfate soils were likely to be present in the area.

A steady state groundwater model was established for the site to predict groundwater level conditions for the proposed development. It was assessed that groundwater level would decrease slightly to the north of the lake and that groundwater direction in the area would change slightly, with groundwater discharging to the constructed lake.

4 GEOLOGICAL AND HYDROLOGICAL CONDITIONS

The geological and hydrological conditions at the site were presented in Coffey's earlier report (Ref.: 12752/3-AF, dated 23 December 2004) and are summarised below.

4.1 Topography and Geology

The site is located to the west of the Myall River and is bounded to the west by Myall Road and Toonang Road. The ground surface generally slopes gently south-east towards the river with ground levels below 3mAHD. A series of sand ridges trending roughly north-south are present across the site. An elevated bedrock outcrop, rising to about 25mAHD, is present at the northern end of the site. Elevated bedrock levels are also present at the north-western limit of the site.

Soils in low lying areas are generally silty sand and topsoil overlying fine to medium grained sand containing cemented layers (coffee rock) and peaty bands. Basement rock occurs at a depth of 10m to 20m over much of the site, rising steeply at the northern end of the site forming an outcrop. A surface clay layer of 1m to 2.5m thickness exists at the north-west of the site accompanied by an underlying layer of peat.

The sand aquifer is underlain by basement sandstone at a depth of up to approximately 20m. Sand thickness varies from 0m in the elevated areas in the north of the site to about 20m at the southern limit of the proposed development.

4.2 Surface Water Conditions

The catchment of the site is limited to the north by a ridge outcrop, and to the south-west by Myall Road. The catchment is largely contained within the site area except for a comparatively small area to the north and north-west. With the exception of the portion at the south of the site that has already been developed, there is little natural development of surface drainage features and the sandy surface soils generally result in a high level of rainfall infiltration to the groundwater system. As a result, significant surface runoff is unlikely except during periods of high rainfall when groundwater levels rise to near the ground surface and recharge is rejected.

The site contains several low natural sand ridges which tend to channel runoff in the western half of the site from north to south. Runoff from the eastern margin of the site tends to flow to the east towards the SEPP 14 wetlands and the Myall River.

Much of the site runoff including runoff from the contributing catchment north of Toonang Road flows to the lake at the south of the site before discharging through the drain to the Myall River. The invert level of this drain is at approximately 0.64 mAHD. During high tide, saline water from the Myall River flows through the drain and the adjacent low lying area to the detention lake. The water in the lake is therefore brackish.

4.3 Groundwater Conditions

The subsurface sands form an aquifer characterised by moderate to high transmissivity, previously estimated at 200m^2/day, which is present over much of the development site and over the SEPP 14 wetland area. Previous groundwater levels indicated shallow water tables are present over the site. generally within 1m of the surface and at the western limit of the SEPP 14 wetlands and Myall River, groundwater levels are within 0.5m of the ground surface. Groundwater flow is south-east toward the Myall River and groundwater is relatively fresh in the main body of the sand aquifer. There is a secure town water supply well to the north of the area and currently groundwater is not used except for minor home irrigation.

The shallow rock levels to the north of the site provide a barrier to groundwater inflow from that direction. The sand aquifer is expected to extend to the south and west of the site and be in hydraulic contact with the waters of the Myall River to the south, Wobbegong Bay and Pindimar Bay (Port Stephens) to the south-west and Kore Kore Creek to the west.

During periods of low rainfall, losses from the groundwater system will occur due to seepage to the Myall River and evapotranspiration from areas of shallow water table. Evapotranspiration losses from the water table reduce with increasing depth of the water table in a non-linear fashion (Coffey Partners International, 1996).

Rainfall infiltration forms the main groundwater recharge mechanism. Previous monitoring results from the bores over the site show marked groundwater level response to rainfall events.

The aquifer is in contact with saline water in the Myall River and also in contact with the brackish water in the lake in the south of the site. This results in the development of an interface between high quality fresh groundwater and saline water. The depth of the fresh/salt water interface is a function of the density difference between fresh and salt water and the height of the groundwater surface. For seawater, this depth can be estimated using the Ghyben-Herzberg approximation to be about 40 times the height of the groundwater table above average sea water surface (Fetter 2001).

The proposed development involves the extension of the existing lakes on the western side and a series of stepped freshwater lakes on the eastern side. Evaporation from these lake extensions would be greater than evapotranspiration losses from the water table over a similar area. These increased evaporative losses are expected to be balanced in part by the reduced evapotranspiration losses that would accompany covering part of the ground surface for residential development.

4.4 Climate – Rainfall and Evaporation

Historical rainfall and evaporation was obtained from the Bureau of Meteorology. Daily rainfall measurements recorded at the Bureau of Meteorology weather station No#61054 at Nelson Bay along with summary statistics of monthly data. The climate data is included in Appendix A of Coffey's earlier report (Ref.: E12752/3-AF, dated 23 December 2004).

5 FIELD INVESTIGATIONS

5.1 Previous Investigation

Field investigations were previously undertaken by Coffey in April 2004. The field work included extending the bore network by adding four groundwater bores, monitoring of groundwater levels and the collection of soil and groundwater samples for laboratory testing.

5.2 Current Investigation

Field work for the current investigation was undertaken on 29 and 30 March, 2007. The field work included:

- Monitoring groundwater levels in accessible bores (bore 3 and Bore 7 could not be accessed);
- Groundwater samples were collected from a selection of the monitoring bores, in accordance with the following protocols:
    - Prior to purging, the groundwater levels were measured in each bore;
    - Purging of the bores prior to sampling using a plastic bailer, until pH and electrical conductivity (EC) readings stabilised (minimum of 3 well volumes purged);
    - Samples were collected using a plastic bailer;
    - Samples were poured into appropriately preserved laboratory-supplied containers and placed in a cooler box filled with ice immediately after collection.

The samples were then dispatched to ALS, a NATA accredited laboratory under chain of custody conditions.

The groundwater samples were analysed for a range of parameters including pH, EC, total dissolved solids (TDS), total hardness, total alkalinity as $CaCO_3$, major cations and anions (including sodium, calcium, magnesium, potassium, chloride and sulfate), ammonia, nitrate, nitrite, total Kjeldahl nitrogen (TKN), heavy metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc and mercury), biological oxygen demand (BOD) and total organic carbon (TOC).

The locations and levels of the groundwater bores were surveyed by Tattersall Surveyors.

6 RESULTS

6.1 Groundwater Level Monitoring

A network of twelve groundwater monitoring bores (Bore 1 to Bore 12) was installed by DJ Douglas & Partners in 1994 and four monitoring bores (Bore 21 to Bore 24) were installed by Coffey in 2006. Four of the bores (Bore 1, Bore 2, Bore 3 and Bore 7) had been destroyed or lost between the current and previous monitoring rounds. The remaining available bores formed a network for Coffey's 2007 monitoring program.

One round of groundwater level monitoring was undertaken from the existing monitoring network using a dip meter. Table 1 presents a summary of groundwater monitoring data from the previous and current monitoring rounds.

The depth to groundwater at the site has decreased since April 2004 at all locations with the exception of Bore 21. Groundwater level ranges from 0.5m to 1.7m below ground surface and tends to be shallower in the vicinity of the Myall River and the lake (Bores 4, 10, 21, 22, 23 and 24) and deeper further from the river (Bores 5, 8, 9, 11 and 12). The shallow groundwater conditions at the site will limit the capacity of the groundwater system to accept rainfall recharge.

Previous groundwater level data collected by automatic loggers indicates that the measured groundwater levels respond to rainfall events. Groundwater levels measured in March 2007 are typically 0.3 m lower than corresponding levels measured in April 2004. The largest reductions were recorded for Bore 11 (reduction of 0.87 m) and Bore 12 (reductions of 1.1 m). These monitoring bores are in elevated ground and are the two bores most distant from the existing lake of the bores for which comparisons could be made.

As groundwater levels respond to prevailing climatic conditions that a decrease in groundwater levels would be experienced during periods of lower than average rainfall. Lower than average rainfall has been experienced on the mid central coast of NSW in recent years. It is most likely that this is the cause of groundwater level decreases observed.

TABLE 1: GROUNDWATER LEVEL MONITORING

Location	Bore Depth Below Ground (m)	Screened Depth Interval (m)	Elevation of TOC* (mAHD)	Water Depth (m) below TOC	**Water Level (mAHD)**	Water Depth (m) below TOC	**Water Level (mAHD)**	Water Depth (m) below TOC	**Water Level (mAHD)**
				7 April 2004		11 May 2004		29 March 2007	
Bore 2	5.0	2.5 – 4.5	~2.300	Destroyed		Destroyed		Destroyed	
Bore 3	5.0	2.5 – 4.5	0.842	0.544	0.298	0.610	0.232	Bore not found	-
Bore 4	10.0	7.5 – 9.5	2.663	1.519	1.144	1.735	0.928	1.84	0.823
Bore 5	5.0	2.5 – 4.5	3.038	0.995	2.043	1.587	1.451	1.735	1.303
Bore 6	5.0	2.5 – 4.5	1.463	0.695	0.768	-		Bore not found	-
Bore 7	5.0	2.5 – 4.5	3.841	1.025	2.816	1.760	2.081	Bore not found	-
Bore 8	5.0	2.5 – 4.5	2.584	0.270	2.314	0.810	1.774	1.05	1.534
Bore 9	6.0	3.5 – 5.5	3.512	1.401	2.111	1.632	1.880	1.855	1.657
Bore 10	5.0	2.5 – 4.5	1.851	0.750	1.101	1.015	0.836	1.31	0.541
Bore 11	5.0	2.5 – 4.5	4.074	1.512	2.562	2.135	1.939	2.385	1.689
Bore 12	5.0	2.5 – 4.5	3.835	1.127	2.708	1.715	2.120	2.18	1.655
Bore 21	3.0	1.0 – 3.0	2.213	-	-	1.435	0.778	1.4	0.813
Bore 22	3.0	1.0 – 3.0	2.276	-	-	1.400	0.876	1.45	0.826
Bore 23	3.1	1.1 – 3.1	2.370	-	-	1.440	0.930	1.61	0.760
Bore 24	3.0	1.0 – 3.0	2.068	-	-	1.387	0.681	1.44	0.628

** Measured from the top of the casing (TOC) including extension pipes where added*

6.2 Groundwater Quality

6.2.1 Current Monitoring Round

Laboratory results from the groundwater bores selected for analysis are presented in Table LR1 in Appendix A. The laboratory reports are included in Appendix B. A summary of the results are presented below in Table 2.

TABLE 2: SUMMARY OF LABORATORY RESULTS (mg/l unless otherwise stated)

SAMPLE ID	ANZECC Marine (slightly to moderately disturbed system)		NHMRC Human Health Guidelines		ANZECC Irrigation and General Use (moderately sensitive crops)		Bore 4	Bore 9	Bore 12	Bore 21
SAMPLE DATE							29/03/07	30/03/07	29/03/07	29/03/07
GENERAL PARAMETERS										
pH (pH Unit)			6.5-8.5	7			5.32	3.99	5.02	5.62
EC (µS/cm)							202	178	268	15500
Total Dissolved Solids			500	7			155	200	1210	11500
Total Hardness			200	7			23	14	29	2040
MAJOR ANIONS										
Sulfate as SO_4^{2-}							10	13	22	702
Chloride			250	7	175-350	3	50.4	34.4	64.6	**5300**
Bicarbonate Alkalinity							14	26	6	92
Total Alkalinity							14	26	6	92
MAJOR CATIONS										
Calcium							2	<1	2	126
Magnesium							4	3	6	420
Sodium			180	7	115-230	3	29	15	39	**2650**
Potassium							<1	4	4	65
HEAVY METALS										
Arsenic	0.0023	2	0.007	6	0.1	4	<0.001	<0.001	<0.001	0.002
Cadmium	0.014	1	0.002	6	0.01	4	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.0486	1	0.05	6	0.1	4	<0.001	<0.001	<0.001	0.002
Copper	0.003	1	2.0	6	0.2	4	<0.001	<0.001	<0.001	0.001
Lead	0.0066	1	0.01	6	2.0	4	<0.001	<0.001	<0.001	<0.001
Nickel	0.2	1	0.02	6	0.2	4	<0.001	<0.001	<0.001	<0.001
Zinc	0.023	1	3.0	7	2.0	4	0.085	0.017	0.009	<0.005
Mercury	0.0007	1	0.001	6	0.002	4	<0.0001	<0.0001	<0.0001	<0.0001
NUTRIENTS										
Ammonia as N			0.5	7			0.212	0.545	0.303	0.934
Nitrite as N			3	6			<0.010	0.028	0.027	<0.010
Nitrate as N			50	6			0.034	<0.010	0.039	0.027
Nitrite + Nitrate as N							0.034	0.034	0.066	0.027
TKN					5.0	4	0.9	2.5	3	**12.1**
Total Phosphorus					0.05	5	**0.14**	**1**	**0.76**	**1.38**
Reactive Phosphorus							0.017	0.799	0.036	0.035

[shaded] Concentration exceeds the respective ANZECC (2000) Marine Water Guideline for slightly to moderately disturbed systems

[boxed] Concentration exceeds the respective human health guideline NHMRC (2004) for drinking water

5 Concentration exceeds the respective ANZECC (2000) Irrigation Water Guideline for moderately sensitive crops/long term use

1 ANZECC (2000) Marine Water Guidelines for protection of 90% of species in slightly to moderately disturbed systems

2 Low reliability trigger level

3 ANZECC (2000) Guidelines for irrigation - moderately sensitive crops

4 ANZECC (2000) Guidelines for irrigation - long-term trigger value

5 To minimise bioclogging of irrigation equipment only

6 Human Health Guidelines (NHMRC, 2004)

7 Aesthetic Guidelines (NHMRC, 2004)

\- Not Analysed

TABLE 2 (CONT): SUMMARY OF LABORATORY RESULTS (mg/l unless otherwise stated)

SAMPLE ID	ANZECC Marine (slightly to moderately disturbed system)		NHMRC Human Health Guidelines		ANZECC Irrigation and General Use (moderately sensitive crops)		BORE 22	BORE 23	BORE 24	Lake
SAMPLE DATE							29/03/07	29/03/07	29/03/07	30/03/07
GENERAL PARAMETERS										
pH (pH Unit)			6.5-8.5	7			6.05	5.6	5.46	5.83
EC (µS/cm)							1610	234	2730	182
Total Dissolved Solids			500	7			1350	212	2250	129
Total Hardness			200	7			123	39	300	33
MAJOR ANIONS										
Sulfate as SO_4^{2-}							39	6	344	12
Chloride			250	7	175-350	3	**430**	58.7	**800**	37.4
Bicarbonate Alkalinity as $CaCO_3$							102	28	26	23
Total Alkalinity as $CaCO_3$							102	28	26	23
MAJOR CATIONS										
Calcium							11	3	31	8
Magnesium							23	7	54	3
Sodium			180	7	115-230	3	**283**	31	**551**	22
Potassium							7	1	24	2
HEAVY METALS										
Arsenic	0.0023	2	0.007	6	0.1	4	0.001	<0.001	0.006	<0.001
Cadmium	0.014	1	0.002	6	0.01	4	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.0486	1	0.05	6	0.1	4	0.007	<0.001	0.005	<0.001
Copper	0.003	1	2.0	6	0.2	4	<0.001	<0.001	0.001	0.005
Lead	0.0066	1	0.01	6	2.0	4	<0.001	<0.001	<0.001	<0.001
Nickel	0.2	1	0.02	6	0.2	4	<0.001	<0.001	0.003	0.001
Zinc	0.023	1	3.0	7	2.0	4	<0.005	0.008	0.016	0.029
Mercury	0.0007	1	0.001	6	0.002	4	<0.0001	<0.0001	<0.0001	<0.0001
NUTRIENTS										
Ammonia as N			0.5	7			0.655	0.179	0.893	<0.010
Nitrite as N			3	6			0.087	<0.010	0.013	<0.010
Nitrate as N			50	6			<0.010	0.013	0.013	0.02
Nitrite + Nitrate as N							0.037	0.013	0.026	0.02
TKN					5.0	4	7.2	2.5	**9.3**	0.7
Total Phosphorus					0.05	5	**0.79**	**0.32**	**1.12**	**0.08**
Reactive Phosphorus							0.095	-	0.062	<0.010

(shaded) Concentration exceeds the respective ANZECC (2000) Marine Water Guideline for slightly to moderately disturbed systems

(boxed) Concentration exceeds the respective human health guideline NHMRC (2004) for drinking water

5 Concentration exceeds the respective ANZECC (2000) Irrigation Water Guideline for moderately sensitive crops/long term use

1 ANZECC (2000) Marine Water Guidelines for protection of 90% of species in slightly to moderately disturbed systems

2 Low reliability trigger level

3 ANZECC (2000) Guidelines for irrigation - moderately sensitive crops

4 ANZECC (2000) Guidelines for irrigation - long-term trigger value

5 To minimise bioclogging of irrigation equipment only

6 Human Health Guidelines (NHMRC, 2004)

7 Aesthetic Guidelines (NHMRC, 2004)

\- Not Analysed

The results indicate that:

- Groundwater chemistry has not changed significantly since the previous monitoring round in 2004 (Ref: E12752/3-AF). The 2004 report indicated that groundwater chemistry had not changed significantly since the groundwater quality monitoring undertaken in 1994/1995. A comparison table showing the 2004 and 2007 results is presented Table LR2 in Appendix A.
- The results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations.
- Evidence of significant heavy metal contamination in the groundwater samples was not observed however the concentrations of zinc, chromium and copper slightly exceed the guidelines in some samples.
- Groundwater from monitoring bores closer to the Myall River tend to be characterised by higher EC and a similar anion to cation ratio as seawater, suggesting the dilution of seawater is occurring as a result of rainfall recharge from the catchment.
- Groundwater quality was compared to the Australian Drinking Water Guidelines (NHMRC, 2004) and is not potable due to concentrations of a range of analytes exceeding the drinking water guidelines. Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and below the criteria for drinking water of pH 6.5. Groundwater near the Myall River (including Bores 21, 22, 24) has elevated levels of EC, anions and cations (due to the interaction of groundwater with seawater in this area) that do not meet the criteria for drinking water. Groundwater in Bores 9, 21, 22 and 24 are not potable due to the concentration of ammonia exceeding the ANZECC guidelines.
- Groundwater away from the Myall River may be considered for irrigation purposes, however high concentrations of phosphorus have the potential to result in bioclogging of irrigation equipment (ANZECC 2000).

Groundwater quality is such that treatment would be required to allow potable use given the limited extent of the aquifer and the constraints on usage rates which would need to be imposed to avoid saltwater intrusion and the impacts on wetland areas. Consequently, Coffey consider the groundwater resource unsuitable for development as a significant potable supply.

Major cation and anion analytical results for the groundwater samples were plotted on a Piper Trilinear Diagram (Figure 3). The Piper diagram provides a visual method of assessing the relative proportion of the major ions in the groundwater. The positions of the sample points in the diamond field facilitate interpretation of water types relative to one another.

The Piper Diagram indicates that all the groundwater samples are characterised by sodium chloride type waters with lesser concentrations of magnesium and alkalinity. There is little variability in the relative proportion of the major ions, indicating a similar source of groundwater across the site. The water from the lake shows a slightly higher concentration of calcium and alkalinity than the groundwater at the site.

Figure 4 shows the sodium/chloride ratio in the groundwater and pond water samples relative to the seawater dilution line. All samples generally plot along the seawater dilution line indicating an atmospheric source of salt in locations further away from the Myall River and interaction with seawater as the source of salt in the bores closer to the River.

A Wilcox Diagram can be used to classify water for its suitability for irrigation by plotting the sodium adsorption ratio (SAR) of samples against their EC value. Figure 5 shows a Wilcox Diagram for groundwater at the site. Groundwater in the majority of bores away from the Myall River (Bores 4A, 12 and 23) show low salinity and sodicity hazard, suggesting these waters are suitable for irrigation purposes. However, it should be noted that the water in the lake is influenced by the tide and salinity will vary with time depending on the amount of rainfall recharge to the lake both directly as rainfall and via groundwater discharge into the lake. Bore 9, to the north of the detention basin, shows a high salinity hazard but a low sodicity hazard. This water may suitable under specific conditions including salt tolerance of the vegetation and permeability and drainage of the soil. Groundwater from bores close to the Myall River (Bores 22 and 24) show a high salinity hazard and high sodicity hazard, indicating water from these locations would be unsuitable for irrigation.

Table 3 shows the various potential uses of groundwater in each bore. The results indicate that it is generally select parameters, namely pH, ammonia and salinity (or TDS) that are limiting the potential use of the groundwater rather than a wide range of parameters. Consequently, some treatment of groundwater with respect to these parameters is likely to increase the number of potential uses of the groundwater across the Site. It is also noted that groundwater away from the Myall River tends to have greater potential usability, primarily due to lower salinity (or TDS) and lower concentrations of sodium and chloride.

TABLE 3: POTENITAL USES OF GROUNDWATER

	Bore 4A	Bore 9	Bore 12	Bore 21	Bore 22	Bore 23	Bore 24	Pond	Comments
Maintenance of Ecosystem	× due to zinc	✓	✓	✓	✓	✓	× due to arsenic	× due to copper and zinc	
Drinking water supply	×	×	×	×	×	×	×	×	Due to low pH and high concentrations of TDS, Na, Cl and / or NH_3
Irrigation, parks, gardens	✓	✓	✓	× due to NO_3, Na and Cl	× due to Na and Cl	✓	× due to NO_3, Na and Cl	× variable quality	Bioclogging of irrigation equipment due to high P may occur
Stock watering	✓	✓	✓	× due to TDS	✓	✓	× due to TDS	✓	
Primary* recreation contact	× due to NH_3	× due to pH and NH_3	× due to NH_3	× due to NH_3 and hardness	× due to NH_3	× due to NH_3	× due to NH_3	✓	

NO_3: nitrate; Na: sodium; Cl: chloride; NH_3: ammonia; TDS: total dissolved solids; P: phosphorus

** Concentrations of Na and Cl were detected above the water quality guidelines for recreational purposes, however these concentrations are due to groundwater interaction with seawater and are not considered to limit the use of groundwater for recreational purposes.*

Based on the assessment described above and set out in Table 3, the highest beneficial uses for groundwater in some locations are for irrigation and ecosystem maintenance.

7 ASSESSMENT OF THE POTENTIAL FOR USING RECLAIMED WATER FOR IRRIGATION

It is understood that there is the potential to use reclaimed water from a nearby water treatment plant to irrigate open spaces (parks, gardens, lawns etc) at the site. Many water needs can be satisfied using reclaimed recycled water as long as it is adequately treated to ensure water quality is appropriate for the proposed use (NSW DEC, 2004).

For the purposes of this report, effluent is considered to be wastewater from the collection or treatment systems associated with sewerage works, processing industries (livestock, wood, paper or food), intensive livestock, aquaculture or agricultural industries.

In assessing the suitability of waters for irrigation use, water quality characteristics that affect the catchment condition and downstream water quality must be considered. The water quality guidelines recommended for irrigation purposes are listed in the *Environmental Guidelines: Use of Effluent by Irrigation* (NSW DEC, 2004) and ANZECC (2000). A summary table of relevant water quality characteristics is presented as part of Table LR1 in Appendix A. Environmental performance objectives that apply to the use of reclaimed water by irrigation include the protection of surface waters, groundwater and lands and public health risk.

Nutrients

Nutrients in effluent such as nitrogen, phosphorus and sulfur are generally beneficial to plant growth and may reduce the need for fertiliser application. Nitrogen, phosphorus and sulfur need not be removed from effluent where it can be shown that the land management system effectively uses these nutrients both in the short and long term.

Nitrogen

Nitrogen (N) can be present in organic and mineral forms, including ammonia (NH_3) ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-). The relative amount of each of these forms depends on the original constitution of the wastewater, and the treatment and stabilisation processes used.

Mineral forms of nitrogen are readily transformed into other mineral forms. Some mineral forms such as nitrate, nitrite and ammonia can be taken up by plants. Nitrate is also readily leached to groundwater. High concentrations of nitrate can nourish unwanted plants and algae.

Phosphorus

Phosphorus (P) concentrations in municipal sewage plants are between 0.5 and 10 mg/L depending on the extent of P removal processes used. Phosphorus contained in effluent exists in many forms but is normally expressed as total P.

The major P removal mechanisms in effluent irrigation systems are uptake by vegetation, and soil sorption by chemical precipitation and adsorption to soil particles. Soil sorption of P (P sorption capacity) is an immobilisation reaction that renders phosphorus unavailable for plant uptake and varies widely from low levels in sandy soils to high levels in strongly weathered clay soils. Soil sorption capacity can be taken into account when developing a nutrient budget for soils irrigated with reclaimed water.

Most Australian soils have the capacity to immobilise phosphorus (P) in soil thereby making it unavailable for plant growth, however this capacity can vary with depth. In general, sandy soils have a very low sorption capacity. If the effluent has a higher P content than can be absorbed by the growing plant, then it will be necessary to estimate the P sorption capacity of the soil to determine the risk of P leaving the irrigated site during the life of the irrigation scheme thereby potentially contaminating ground and surface waters. The form of P in the effluent and the pH of the soil may also affect the mobility of P in soil.

Table 4 shows the range of potential P sorption capacities measured from sandy Sydney Basin soils and coastal soils. Table 4 indicates that sandy soils from coastal dune systems have a low capacity for P adsorption, suggesting that there may be more P applied during irrigation with reclaimed water than can be removed by soil adsorption and crop uptake. In this situation, assessments of P sorption capacity should be made. If application of P exceeds this threshold, both runoff and leaching of phosphorus to surface and groundwater may occur.

TABLE 4: PHOSPHORUS ADSORPTION POTENTIAL OF NSW SOILS (1M DEPTH)

Location	Soil parent material	Soil classification	Total P sorption capacity(kg/ha)	P sorption capacity (critical) (kg/ha)
Sydney Basin	Hawkesbury sandstone	Soloth	5,440	2,700
Sydney Basin	Hawkesbury sandstone	yellow earth	13,600	4,600
Coastal	Sand dune	Siliceous sand	25-130	25-36

7.1 Groundwater

When using reclaimed water to irrigate open spaces, the quality of the underlying groundwater must not be downgraded to the extent that the resource is not able to support its most sensitive beneficial use (NSW DEC, 2004). With regard to the groundwater results from the current monitoring round, the most sensitive beneficial use of the groundwater is for irrigation purposes and maintenance of ecosystems in selected locations (see Table 3).

Where supporting technical advice has not been obtained, effluent should not be applied to land where the depth to groundwater table is considered to be less than 10 metres or where the irrigation area is located less than 1000 metres from a town water supply bore. Water quality objectives for the groundwater (i.e. water quality needed to protect beneficial uses of groundwater) should also be considered (NSW DEC, 2004). It is noted that groundwater was shallower than 10m across the site during the previous and current monitoring rounds.

7.2 Surface water

The quality of streams and rivers in the catchment of an effluent irrigation scheme must not be downgraded (i.e. relevant water quality objectives need to be taken into account). There is a risk that surface waters may be degraded by poorly designed or managed effluent irrigation schemes, particularly where effluent with high quantities of nutrients, salt, pathogens or other contaminants is being irrigated. Potential impacts on current and future downstream water users and resources need to be considered, for example, wetlands that may be located downstream (NSW DEC, 2004).

7.3 Reclaimed Water Quality

A sample of the reclaimed water was not available to undertake testing of the soil, however, Mid Coast Water provided Coffey with data showing average water quality of treated water from a treatment plant. Coffey understands that the water quality information provided is indicative of the reclaimed water that may be used for irrigation of open spaces and gardens in the Riverside development. Table 5 shows an indicative concentration of the reclaimed water that may be used for irrigation purposes compared to the ANZECC Guidelines for irrigation and the protection of marine ecosystems.

TABLE 5: WATER QUALITY OF RECLAIMED WATER

Parameter	Indicative Concentration (mg/L)	ANZECC Guidelines for Irrigation (long term use) (mg/L)	ANZECC Guidelines for marine ecosystems (90% protection) (mg/L)
pH	6.8	4.5-9.0	-
Total Phosphorus	2.2	0.05*	-
Nitrogen (Ammonia)	1	-	1,200
Nitrogen (Nitrate)	5	-	0.7^
Total Nitrogen	6.4	5	-

* for bio-clogging of irrigation equipment only
^ low reliability trigger value
\- no guidelines available

Indicative ammonia concentration in the reclaimed water is 1mg/L, well within the ANZECC guidelines for the protection of marine ecosystems. There are no guidelines for ammonia concentrations in irrigation water. The concentration of ammonia in groundwater is generally low as it adsorbs to soil particles and is not readily leached from soils. Consequently, the concentrations of ammonia in the reclaimed water are unlikely to pose any constraints on using the water for irrigation purposes.

The indicative concentration of nitrate in reclaimed water is 5mg/L and total nitrogen 6.4mg/L (Table 6). Nitrate, the dominant form of nitrate in the reclaimed water, is soluble in water and can move freely through the soil to the water table in recharge derived from irrigation water. The concentration of nitrogen marginally exceeds the ANZECC Guidelines for long-term irrigation (up to 100 years), however is significantly lower than the nitrogen concentrations for short term use (up to 20 years) of 25-125mg/L. It should be noted that a site assessment should be undertaken before using the guidelines for short-term irrigation.

The indicative concentration of total phosphorus in the reclaimed water is 2.2mg/L. Compared with nitrate, phosphate is less mobile in soil-water and groundwater and tends to bind to soil particles. However, if the soil becomes saturated with phosphate there is a chance of phosphate reaching groundwater. As the soils at the site are highly sandy, the phosphorus adsorption capacity is likely to be low, in the range of 25-36kg/ha (see Table 4). The ANZECC guidelines for irrigation indicate a trigger value of 0.05mg/L for phosphorus, however this is with respect to bio-clogging of irrigation equipment. The ANZECC guidelines (2000) recommend total phosphorus concentrations for freshwater lakes and reservoirs to be below 0.01mg/L and 0.025mg/L for NSW east flowing coastal rivers. It is recognised that the lake is likely to show tidal influence, so that criteria for coastal rivers is considered more appropriate. Indicative phosphorus concentration recorded in testing of groundwater quality sampled from the bores in April 2007 range from 0.14 mg/L to 1.38mg/L. There are no guidelines for phosphorus for the protection of marine ecosystems.

A NATA-accredited laboratory was commissioned to develop a water sample with similar concentrations of nitrate, phosphorus and pH to those anticipated for reclaimed water from treatment facilities in the area. This water was then used as a leaching agent for three soil samples collected from the site. Leachate tests were undertaken in accordance with the Australian Standard Leaching Procedure (ASLP) method, using the laboratory- produced reclaimed water as the leaching agent. Table 6 shows the concentrations of the lab-produced reclaimed water and the concentrations of anaytes in the leachate water.

TABLE 6: LEACHATE WATER QUALITY USING MANUFACTURED RECLAIMED WATER

Parameter	Manufactured reclaimed water	HA01 Topsoil 0-0.1m	HA01 Subsoil 0.4-0.5m	HA02 Topsoil 0-0.1m	HA02 Subsoil 0.4-0.5m	HA03 Topsoil - 0.1m	HA03 Subsoil 0.4-0.5m
pH	6.6	5.4	5.3	4.9	5.6	5.3	5.0
Total Phosphorus (mg/L)	2.5	ND	0.8	ND	0.5	ND	ND
Nitrate (mg/L)	4.7	5.0	4.8	5.3	5.0	4.6	4.6

ND: Not detected, detection limit 0.1mg/L

The concentration of nitrate in the leachate water from all samples is similar or greater than the concentration of nitrate in the lab-produced reclaimed water (4.7mg/L). This indicates that the potential for nitrate adsorption on the soil is low and the travel time of nitrate through the soil is likely to be similar to the rate of water through the soil.

The concentration of phosphorus in the leachate water is consistently significantly below the concentration of phosphorus in the lab-produced reclaimed water. Phosphorus was not detected in any of the topsoil samples and one of the subsoil samples after the leaching procedure and at low concentrations in the remaining two of the subsoil samples. These results indicate the soil at the site has the capacity to adsorb phosphorus present in reclaimed water and that the travel time of phosphorus through the soil is very slow. These initial results show that with respect to phosphorus, reclaimed water may be used for irrigation purposes. However, Coffey recommend further testing when samples of reclaimed water proposed for irrigation use are available.

The groundwater results suggest that the reclaimed water may be suitable for irrigation of open spaces and gardens within the development area subject to a small reduction in total nitrogen concentrations. This reduction may be achieved through a combination of treatment and dilution of reclaimed water with water of higher quality.

The concentration of pathogens is also an important effluent quality consideration in terms of public health, which affects the way effluent should be reused and managed on-site. Treatment would need to occur as required to meet relevant health standards.

8 NUMERICAL MODELLING OF GROUNDWATER IMPACTS

The Riverside development lies in an area with a shallow groundwater table that has the potential to be impacted by the proposed changes to the development. A groundwater model was established using MODFLOW, a finite difference groundwater simulation program, during the 2004 monitoring period, based on the level of understanding of the hydrogeological conditions in the vicinity of the site at that time. Following calibration against measured groundwater levels, the model was used to predict groundwater level conditions for the proposed development to assist in the assessment of potential groundwater impacts of the proposed development.

The model was adapted to incorporate changes to the development and was carried out under steady state conditions with a view to assessment of groundwater levels under typical rainfall conditions.

8.1 Model Establishment

The groundwater model was set up using MODFLOW, a finite difference groundwater simulation program. The MODFLOW program was developed by the US Geological Survey and is widely used for groundwater analysis. A steady state model was prepared to represent average conditions across the site.

A finite difference grid was set up to model groundwater behaviour in the Riverside area leading out to Myall River. The following assumptions and modelling choices were made in establishing the model:

- The base grid size of 50m x 50m was maintained. This was considered sufficiently fine to provide a reasonable representation of the site and the layout of the proposed development. The lake areas within the development were refined to a grid size of 25m x 50m. The extent of the model domain is presented in Figure 9.
- Constant head conditions were adopted along the eastern, southern and western boundaries (representing Myall River, Pindimar Bay and Kore Kore Creek, respectively). The constant head boundaries were set to be 0.045mAHD, consistent with the average water level in the Myall River adjacent to the development. A no flow boundary following a surface water divide was adopted along the northern boundary of the model.
- The model was established in one layer, from surface levels to bedrock.
- Given the consistent surface conditions across the site, a uniform net rate of groundwater infiltration from rainfall was adopted over more of the site. The exception to this is a small area in the north western corner of the site where bedrock outcrops. As rainfall recharge will be very limited in this area, the rate of groundwater infiltration from rainfall was much reduced.
- A uniform net rate of evapotranspiration was adopted across the site – This was considered reasonable given the proximity of the water table to the ground surface. Evaporation was assumed to occur when the water table approaches the ground surface and was assumed to reduce with depth to zero at a depth of 2m. This assumption was based on a study which assessed the change in the rate of groundwater decline with depth to the water table during periods of low rainfall from the monitoring data from Bore 4 (Coffey, 1996).
- Sand aquifer conditions were considered uniform within the model domain. The depth to bedrock varies across the site from outcrops of rock at the ground surface to depths of approximately 17m below ground surface. Previous field investigations have been undertaken

across the site down to bedrock levels. The assumed bedrock contours and depths to rock are adopted are shown on Figure 10.

- Ground surface levels were based on the Port Stephens 1:25000 topographic map and survey data from Tattersals, and are shown in Figure 11.
- The aquifer was modelled as having a specific storage of $0.00001m^{-1}$, a specific yield of 0.1, an effective porosity of 0.2 and a total porosity of 0.35 – These values are considered to be typical values for a sandy aquifer.
- The water level at the lake was set at 0.64mAHD, as advised by Cardno. The lake was modelled as a highly permeable layer, with a permeability of 200000m/day to represent uniform head levels within the lake.
- Changes to original model include extension of constant head cells in north-western extent of model to enable a more effective contouring of groundwater levels in this area.

8.2 Model Calibration

The groundwater model was previously calibrated during the 2004 monitoring round by testing a range of values of permeability, evapotranspiration rate and infiltration (recharge) rate. These parameters are considered to have the highest level of uncertainty. The calibration of the model is discussed in Coffey's previous report (Ref: E12752/3-AF). Details of calibration results are provided in Appendix C.

During the calibration trials, a steady state calibration in reasonable agreement with measured groundwater levels was obtained (predevelopment conditions). The groundwater level contours for modelled conditions under present conditions are shown in Figure 12. Table 7 presents a comparison of groundwater levels obtained for the calibration analysis compared with the range of measured groundwater levels at the observation wells.

Minor disagreements with recent monitored groundwater levels and modelled results were present in observation wells (Bores 9, 11 and 12) in the northern parts of the site, with the largest disagreement of about 0.5m between the calibrated level and the measured level at Bore 9. It is considered that these minor disagreements may be contributed to localised (shallow rock) or seasonal conditions and/or limitations of the model. Given that the modelled groundwater levels agreed with the measured levels at the key locations (Bores 5, 10, 11), it is considered that, overall the model has been successfully calibrated for the development area.

TABLE 7 – COMPARISON OF CALIBRATED GROUNDWATER LEVELS WITH OBSERVATIONS

Observation Well	Measured Range of Groundwater Levels (mAHD) – April/May 2004	Calibrated Groundwater Level (mAHD)	Average Groundwater Levels (mAHD) – April/May 2004	Groundwater Levels (mAHD) – April 2007	Comments on the Calibrated Level vs Measured Range
BORE 3	0.18 to 0.29	0.34	0.23	Bore not found	NA
BORE 4	0.66 to 0.87	0.97	0.76	0.823	Slightly lower, but within ±0.5m
BORE 5	1.55 to 2.14	1.81	1.85	1.303	Slightly lower, but within ±0.5m
BORE 6	0.34	0.42	~0.30	Bore not found	NA
BORE 7	2.03 to 2.77	2.91	2.40	Bore not found	NA
BORE 8	1.79 to 2.33	1.61	2.06	1.534	Slightly lower, but within ±0.5m
BORE 9	1.78 to 2.01	1.21	1.89	1.657	Slightly higher, but within ±0.5m
BORE 10	0.78 to 1.04	0.87	0.91	0.541	Slightly lower, but within ±0.5m
BORE 11	1.94 to 2.57	1.94	2.25	1.689	Slightly lower, but within ±0.5m
BORE 12	2.08 to 2.66	1.85	2.37	1.655	Slightly lower, but within ±0.5m

The modelled groundwater level contours show that groundwater flows across the site in a south-easterly direction towards Myall River. In general, groundwater levels from recent monitoring round were lower than those used to calibrate the groundwater model. However, water levels from recent monitoring are all within 0.5 m of calibrated values and the model is estimated to be representative of the groundwater system. The adopted model parameters following calibration trials are summarised in Table 8.

TABLE 8 – ADOPTED MODEL PARAMETERS – CALIBRATED MODEL

Parameter	Adopted Value	Source / Comment
Aquifer permeability	Horizontal permeability = 8m/day Vertical Permeability = 8m/day	Consistent with results reported by DJ Douglas & Partners (1994b). Typical value for relatively clean sand.
Rainfall infiltration (recharge) rate for general sandy area	2.0mm/day	Consistent with the calibrated value of the previous model established by Coffey Partners International (1996), i.e. approximate 60% of average rainfall. Consistent with sandy soil in an undeveloped environment.
Rainfall infiltration (recharge) rate for the clayey area in the north-western part of site	0.5mm/day	Typical permeability and recharge value for clayey soil. Comparable with the value adopted (0.2mm/day) in the Coffey Partners International (1996) model. Groundwater level contours are not sensitive to the value adopted.
Evapotranspiration rate	2.5mm/day	Approximately 50% of the pan evaporation rates from Williamtown weather station.

Site groundwater recharge may contain a proportion of hillslope runoff on the northern boundary of the model domain where exposed bedrock forms the model boundary however insufficient data were available to reliably assess the amount contributed from that source. For the purposes of this assessment, groundwater recharge from infiltration was taken as being uniformly distributed. Impacts calculated from predictive modelling will be conservatively high because any contribution from hillslope runoff was distributed over the model domain rather than application of this runoff at the northern extremities of the sand aquifer (and therefore comprised to minimal extent by development).

8.3 Assessment of Groundwater Levels of Post Development

Following the calibration, groundwater modelling was carried out to assess the impacts of the proposed development on the groundwater system. Typical conditions were modelled using steady state analysis.

A total of seven schemes were initially investigated in the Riverside Master plan for the proposed development. The current development is a development of Scheme 5. Scheme 5 involves a partial extension of the existing lake to 8 ha and a series of freshwater lakes covering approximately 6.5 ha. The extended lake would be approximately double the size of the existing lake, covering approximately 14.5ha. The proposed development would also include construction of a series of single dwelling residential housing and open space recreational areas (including some isolated small ponds).

Under post development conditions for the current proposal the following assumptions were made for the modelling:

- The water level of the extended lake will remain the same at 0.64mAHD;

- Rainfall infiltration (and recharge) and evapotranspiration rates will remain the same, including the proposed housing and open space recreational area;
- Small ponds of the open space recreational areas are considered insignificant to the overall hydrogeological impacts; and
- General ground surface levels will not be dramatically altered.

Figure 13 presents modelled post-development (extended lake) groundwater levels for typical conditions. Figure 14 shows the modelled reduction in groundwater level associated with the extended lake only proposed development. The modelled results are summarised as follows:

- Under typical conditions, modelled post-development groundwater levels in the northern, eastern and southern parts of the site are similar to those for pre-development (Figure 12).
- Groundwater levels to the north of the existing lake will be lowered by up to about 0.75 m due to the extension of the lake. The effects of the lake are especially visible within the area surrounding the North West extension of the lake.
- Groundwater flow will be induced towards the lake extension due to a change in groundwater gradients in the vicinity of the lake extension.
- Groundwater levels along the SEPP 14 wetlands are assessed to be similar to the existing levels, with a small decrease in groundwater level (approximately less than 0.1m drawdown) on the western edge of the SEPP 14 wetland area.
- Groundwater generally flows in a south easterly direction. However groundwater to the west and north of the extended lake will tend to flow towards the extended lake. As a result, general groundwater flow directions in the area will change slightly and a higher volume of groundwater will be discharged into the lake.

The modelled results are generally comparable with the modelled results presented in Coffey Partners International (1996).

8.4 Flow Budgets

Flow budgets were conducted for the areas representing the proposed subdivision to the north of the lake and the area which encompasses the existing and extend lake. This enabled mass balance calculations to be conducted for the purpose of estimating return of nutrients of potential irrigation of treated water. Table 9 lists the flow budgets for the zones as indicated in Figure 15. The flow budget was calculated with errors of less than 0.01%.

Zone 1 (Z1) encompasses the majority of the model domain with Zone 2 (Z2) occupying the area in which additional development is planned to occur. Zone 3 (Z3) represents the area of the existing lake and the planned lake extension.

TABLE 9: FLOW BUDGETS FOR THE STEADY STATE MODEL

Budget Component	Average Daily Flow Rate (ML/day)	
	IN	OUT

Ponds			
	Rainfall Recharge	1.31	
	Evapotranspiration		0.66
Z1 to Z3	Baseflow In	0.62	
Z2 to Z3	Baseflow In	0.23	
Z3 to Z1	Baseflow Out		0.55
New Development Area (irrigated)			
Z1 to Z2	Baseflow In	0.08	
Z2 to Z1	Baseflow Out		0.06
Z2 to Z3	Baseflow Out	0.23	
	Rainfall Recharge	0.52	
	Evapotranspiration		0.30
Rest of Model Domain			
	Baseflow In	17.93	
	Baseflow Out		17.93
	Rainfall Recharge Evapotranspiration	17.2	15.55

8.5 Geometry of the Freshwater / Saline Water Mixing Zone

As part of the proposed development, the existing lake is to be extended on the western side and there is also the introduction of a series of stepped freshwater lakes on the eastern side. Much of the site runoff will flow to this lake. The lake is hydraulically linked to the Myall River by a drain. The invert level of this drain is at approximately 0.64 mAHD. During high tide (tidal water levels above 0.64 mAHD), saline water from the Myall River flows through the drain and the adjacent low lying area to the lake. At other times, the lake either discharges by surface flow back through the drain (while lake water levels are above 0.64mAHD) or by groundwater flow generally towards the river. Cardno have previously advised that the water level in the lake generally fluctuates around an average elevation of approximately 0.64 mAHD.

The lake accepts groundwater flow from up gradient parts of the aquifer, and also accepts surface water runoff and saline water from the river. The 50 percentile concentration of total dissolved solids for lake water is 12,800 mg/L (Cardno 2007) and given the input of river water, is brackish. A concentration of 20,000 mg/L was used in this analysis. The periodic tidal action will create a fluctuating water table at the lake edge which will create a typical saltwater / freshwater mixing zone observed in coastal systems.

To assess the geometry of the saltwater / freshwater interface that will be created by the presence of the lake, a simple species transport simulation was conducted for a cross-section through the lake representing the general hydrogeological conditions to the west of the lake. The simulation assumes the following:

- Long-term steady state hydrogeological conditions immediately west of the lake;
- No groundwater extraction;
- Average concentration of total dissolved solids (TDS) for lake water is 20,000mg/L (about 60% of the average TDS of seawater, to incorporate mixing with water from fresher water sources). This concentration was chosen to provide a conservative basis for assessment. Measured lake water quality is typically of much lower salinity;
- Average TDS concentration in groundwater is 240mg/L (average of results for seven groundwater samples analysed in 2004);
- Average TDS concentration in rainwater is 10mg/L;
- Instantaneous and complete mixing of fresh and salt water in the lake;
- Maximum tidal height of 0.8mAHD, based on the average tidal range at Fort Denison in Sydney;
- Calibrated aquifer parameters, with a rainfall recharge rate of 1mm/day;
- Dispersivity of 0.001m for TDS over a time period of 6 hours.

Results of the simulation are shown in Figure 18. The concentration contours are a general indicator of typical conditions which may arise based on the above assumptions. The contours also incorporate a simple Ghyben-Herzberg analysis (Ghyben, 1889; Herzberg, 1901) (assuming a TDS concentration of 20,000mg/L for the lake) to account for density-driven flow. The interpreted contours are therefore an assessment of the potential geometry of the long-term saltwater/freshwater interface that may be created by the lake. The contours assume no groundwater abstraction.

Interpreted contours indicate that pre-development aquifer conditions are probably maintained at a distance of 100m from the lake edge. If groundwater abstraction takes place, this will draw the contours away from the lake edge. As this assessment has used a high salinity concentration (20,000 mg/L), the actual scenario is expected to be more conservative.

8.6 Acid Sulfate Soil

An assessment of potential acid sulfate soils was undertaken at the site (Coffey 2007 GEOTSGTE20248AA-AE). The laboratory results indicated elevated levels of total potential sulfidic acidity and peroxide oxidisable sulfur were present in the samples tested. It was considered that the potential acid sulfate soils were likely to be present in the area.

Groundwater modelling indicates that the lake extension will cause groundwater level reductions by approximately up to 0.75. To date there is no indication of the potential for sulfate production in the area but a number of bores were drilled within close proximity of the lake extension. Several test holes were drilled and the soils tested for the potential to produce acid sulfate soils. BH37 is located in the area where the maximum drawdown has been predicted and the results of SPOCAS analysis indicate that from 2 m below surface, samples tested exceed the Acid Sulfate Soil Management Advisory Committee (ASSMAC) action criteria. The potential to produce acid soils increased with depth with the interval 2.0 – 2.5 m just exceeding the criteria.

Groundwater levels in this area are approximately 1.5 m below surface and a 0.75 m groundwater level decline will lower groundwater levels into this zone however, the area affected would be restricted to the 0.75 m drawdown contour indicated in Figure 14.

A comparison of pH from previous investigations conducted in April 2004 with recent results collected in March 2007 indicates that there has been no discernable change in groundwater pH. This suggests that even with the groundwater level reductions assessed to be affected by lower than average rainfalls in the last few years, there has been no additional increase in acid production resulting from the drying of acid producing soils.

9 DISCUSSION

9.1 Groundwater Levels and Flow Directions

The results from the current monitoring round indicate groundwater levels have decreased across the majority of the site since 2004, when development at the site commenced. The decrease in groundwater levels has been in the order of 0.1mAHD to 0.2mAHD in the majority of wells and a maximum of 0.47mAHD. Groundwater levels respond to prevailing climatic conditions and the decrease in groundwater levels experienced are likely to be the result from lower than average rainfall which has occurred on the mid central coast of NSW in recent years.

Groundwater modelling indicates that groundwater level contours are altered in the vicinity of the lake extension with the greatest impact at the north-western most point of the proposed lake extension. This will induce groundwater flow towards the lake within the vicinity of the lake which will act to prevent the intrusion of saline water into the aquifer from Myall River and brackish water from the lake.

The enclosed nature of the groundwater system within the localised riverside area limits the potential impacts on other groundwater users further afield.

9.2 Groundwater Quality

Laboratory results from the groundwater bores selected for analysis indicate that groundwater quality has not changed significantly since the last monitoring round in 2004. The results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC guidelines, with the exception of some metal concentrations. Groundwater from monitoring bores closer to the Myall River tend to be characterised by higher EC and a similar anion to cation ratio as seawater, suggesting the dilution of seawater is occurring as a result of rainfall recharge from the catchment.

All groundwater samples are characterised by sodium chloride type waters with lesser concentrations of magnesium and alkalinity. There is little variability in the relative proportion of the major ions, indicating a similar source of groundwater across the site.

9.3 Groundwater Modelling

Groundwater modelling of post-development with an extended lake indicates that groundwater levels for typical conditions in the northern, eastern and southern parts of the site are similar to those for pre-development. Groundwater levels to the north of the existing lake will be lowered by up to about 0.75 m due to the extension of the lake. The effects of the lake are especially visible within the area surrounding the North West extension of the lake. Groundwater to the west and north of the extended lake will tend to flow towards the extended lake. As a result, general groundwater flow directions in the area will change slightly and a higher volume of groundwater will be discharged into the lake.

Groundwater levels along the SEPP 14 wetlands are assessed to be similar to the existing levels, with a marginal decrease in groundwater levels (less than 0.1m drawdown) on the western edge of the SEPP 14 wetland area.

9.4 Geometry of the Freshwater / Saline Water Interface

Interpreted contours indicate that pre-development aquifer conditions are probably maintained at a distance of less than 100m from the lake edge which is well within the riverside concept plan and project site. If groundwater abstraction takes place, this would draw the contours away from the lake edge.

10 CONCLUSIONS

10.1 Groundwater Levels

Influence of the Lake Extension

The results of the groundwater modelling study for the proposed Riverside development site are presented. The results indicate that there will be negligible impacts to the wet land area and groundwater decline will be limited to a fall of approximately 0.75 m in the vicinity of the lake extension.

The lake extension will cause groundwater level to fall slightly below levels interpreted to have acid soil producing potential. However, the area affected is considered to be limited and the exceedance of criteria of ASSMAC slight for the predicted resulting groundwater levels.

On the basis of these results, Coffey does not consider that the proposed extension of the lake would adversely affect site groundwater outside the proposed lake extension.

10.2 Groundwater Quality and Impact of Development on Potential Future Use as a Potable Water Source

Groundwater quality is not considered to be potable due to concentrations of a range of analytes exceeding the drinking water guidelines (ANZECC 2000). Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and below the criteria for drinking water of pH 6.5. Groundwater near the Myall River (including Bores 21, 22, 24) has elevated levels of EC, anions and cations (due to the interaction of groundwater with seawater in this area) above the criteria for drinking water. Groundwater in Bores 9, 21, 22 and 24 are not potable due to the concentration of ammonia exceeding the ANZECC (2000) guidelines.

The groundwater results indicate that it is generally select parameters, namely pH, ammonia and salinity (or TDS) that are limiting the potential use of the groundwater rather than a wide range of parameters. Consequently, some treatment of groundwater with respect to these parameters is likely to increase the potential uses of the groundwater across the Site. It is also noted that groundwater away from the Myall River tends to have greater potential usability, primarily due to lower salinity (or TDS) and lower concentrations of sodium and chloride.

Groundwater quality is such that treatment would be required to allow potable use given the limited extent of the aquifer and the constraints on usage rates which would need to be imposed to avoid saltwater intrusion and the impacts on wetland areas. Consequently, Coffey consider the groundwater resource unsuitable for development as a significant potable supply.

10.3 Groundwater Quality and Impact of Development on Adjacent Ecosystems

Groundwater quality results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations. Groundwater quality modelling indicates that the salt water interface would not be significantly affected by the development and groundwater level modelling indicates that there will be little impact within the wetland area. Groundwater level changes resulting from the proposed development are assessed to be below 0.25 m beyond 300 m from the development and 0.1 m within the wetland area. Changes of this magnitude would be within the existing groundwater level variability and are therefore considered unlikely to adversely affect adjacent ecosystems.

10.4 Re-use of reclaimed water

A laboratory developed a water sample with similar concentrations of nitrate, phosphorus and pH to the reclaimed water data supplied by Mid Coast Water. This water was used as a leaching agent for three soil samples collected from the site.

The concentration of nitrate in the leachate water was similar or greater than the concentration of nitrate in the lab-produced reclaimed water. This indicates that the potential for nitrate adsorption on the soil is low and the travel time of nitrate through the soil is likely to be similar to the rate of water through the soil.

The concentration of phosphorus in the leachate water was consistently significantly below the concentration of phosphorus in the lab-produced reclaimed water. These results indicate the soil at the site has the capacity to adsorb the phosphorus present in the reclaimed water and that the travel time of phosphorus through the soil is very slow.

These initial results show that with respect to phosphorus, the reclaimed water may be used for irrigation purposes. However, Coffey recommend further testing when a sample of reclaimed water from Mid-Coast Water is available. Table 10 provides groundwater quality and indicative concentration parameters for key chemical constituents.

The groundwater results from the current monitoring round suggest that the reclaimed water may be suitable for irrigation of open spaces and gardens within the development area subject to a small reduction in total nitrogen concentrations. This reduction may be achieved through a combination of treatment and dilution of the reclaimed water with water of higher quality.

TABLE 10: GROUNDWATER QUALITY AND INDICATIVE CONCENTRATION FOR KEY CHEMICAL CONSTITUENTS

Parameter	Average in Groundwater (mg/L)	ANZECC guidelines (mg/L)	Indicative conc. from STP (mg/L)
Nitrate	0.02	0.7	5
Ammonia	0.53	1200	1
Total Phosphorus	0.79	0.05	2.2

Based on the signature of key chemical constituents present above, three re-use options are presented as possible scenarios for the use of re-used water for the purposes of irrigation:

1. Treatment of the reclaimed water to meet health standards including pathogens. The reclaimed water may be used for irrigation if 10% of the reclaimed water is mixed with 90% of fresh water.
2. Treatment of the reclaimed water to limit NO_3 to an average concentration of 0.7mg/L. If this level of treatment is obtained on an average basis, 100% of the reclaimed water may be used for irrigation purposes, assuming partial uptake of nutrients by vegetation.
3. Treatment of the reclaimed water to limit NO_3 to an average concentration of 1.4mg/L. If this level of treatment is obtained on an average basis, a mixture of 50% of reclaimed water and 50% of fresh water may be used for irrigation.

Calculations of the average time required for the groundwater to migrate from the development area to the lake or river indicated that the groundwater moves at a rate of approximately 10 m/year. This is based on an assumed hydraulic conductivity of 8 m/day, a porosity of 35 % and a groundwater gradient of 0.12 %. The leaching tests indicate that nitrate will move at a similar rate to the groundwater and that phosphorus will move at a significantly slower rate.

Given this low rate of groundwater movement, Coffey consider that the irrigation impacts can be considered on a time averaged basis. With respect to use of reclaimed water for irrigation purposes, it is considered that irrigation of parks and open spaces within the development is unlikely to adversely impact groundwater or the water in the lake if one of the above treatment options is employed. Appropriate monitoring of irrigated areas should however be employed to ensure key indicators remain within relevant guidelines.

11 RECOMMENDATIONS

Monitoring of the groundwater system is recommended to confirm the findings of this report following development and initiation of any proposed water re-use program. Coffey recommend that a monitoring plan be developed to check performance of the groundwater system. This would include:

- Monitoring of irrigation water and groundwater quality;
- Irrigation water application rates and timing; and
- Soil testing

12 LIMITATIONS

The findings contained within this report are the result of discrete/specific sampling methodologies used in accordance with normal practices. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site. Under no circumstances, however, can it be considered that these findings represent the actual state of the site at all points.

13 REFERENCES

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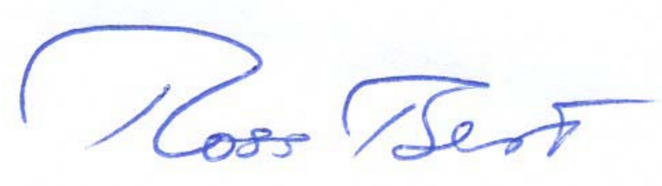
For and on behalf of Coffey Geotechnics Pty Ltd



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