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Stormwater Treatment + Wetland Functionality Report

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1	14 June 2010		TPS review
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4	6 July 2010	Peter Breen	Principal review

Rainbow Beach

Stormwater Treatment and Wetland Functionality Report

Prepared for

St. Vincent's Foundation (c/o TPS)

Prepared by

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Project No. 06502366.03

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Executive Summary

St Vincent's Foundation, as landowner and proponent, requested and received Director General's Requirements (DGRs) for Major Projects Concept Plan MP06-0085 and Project Application MP 07-0001. The DGRs were updated and reissued on 31 May 2010. Cardno Pty Ltd (Cardno) was engaged to prepare a Water Engineering and Environment Assessment to address potential hydrological impacts which have been raised by the DGRs, which has been further refined by AECOM (regarding stormwater treatment) and Water Research Laboratory of the University of NSW (WRL) (regarding groundwater assessment). Cardno's (2010) assessment included consideration of the existing hydrological and environmental site issues and constraints, and site management recommendations for hydrological, flooding and stormwater management. WRL's assessment of the groundwater identified that due to the poor quality of the groundwater resources, surface runoff is unlikely to have a detrimental impact on groundwater aquifers.

This report provides a review of the stormwater treatment strategy proposed for the site, including a discussion of the proposed stormwater treatment devices and the nature of the treatment train required to treat the urban runoff from all urban catchments within the Rainbow Beach Estate. Modelling parameters used to determine the size of treatment devices are presented, along with the footprints of the stormwater treatment wetlands and bioretention systems that will be required. Design recommendations are made to ensure that the detailed design of these devices will incorporate the features required for efficient water treatment. Design recommendations are also made to ensure that these devices will be robust and easy to maintain once established. These design recommendations will be important to the integrity and function of the stormwater treatment train and will ensure the sustainability of the open water wetland and Duchess Gully.Finally, an appraisal of the long-term maintenance costs for the Aquatic Features of the Central Corridor has been made.

This report references and augments the previous work by Cardno in the WEDGRA document. The adopted stormwater treatment measures proposed by Cardno and further developed by AECOM will ensure that water treatment measures proposed for Rainbow Beach Estate meet the requirements of the Port Macquarie-Hastings Council IWCM policy. The proposed treatment train will allow runoff from the development to be treated to meet the Port Macquarie Hastings Council's water quality objectives. Treated runoff will then be of suitable quality to be discharged to the open water wetland while ensuring the protection of the ecosystem health of the open water wetland and subsequently Duchess Gully. The use of a combination of swales, bioretention systems and constructed wetlands for stormwater treatment is considered most appropriate for the site and overall concept development.

1 Introduction

1.1 Proposed Development

In accordance with Port Macquarie-Hastings Council's 2004 Structure Plan, a mixed use development is proposed for the "Rainbow Beach Estate", a property owned by the St. Vincent's Foundation and located in Bonny Hills, on the mid-north coast of NSW. On behalf of St Vincent's Foundation, the landowner and proponent, Tierney Property Services (TPS) and Luke and Co. have prepared a Part 3A Concept Plan for the overall development. The proposed development includes a village centre, approximately 900 dwellings, 2 school sites, an eco-Tourist site and district playing fields.

A Part 3A Project Application has been prepared by AECOM for the Central Corridor, the major contiguous component of open space within the overall development. The Central Corridor incorporates the public open spaces such as the district sports fields, areas of native bushland and existing and proposed wetlands for amenity and stormwater treatment. This report pertains to the impacts of the development of the Central Corridor on groundwater and surface water resources.

1.2 Potential Impacts of Development on Groundwater and Surface Water Resources

Following the submission for draft test of adequacy of the project application (MP07-0001) Environmental Assessment for this development, the Department of Water and Energy (DWE, now the NSW Office of Water) had raised queries regarding the development of the Central Corridor and the subsequent impacts of stormwater runoff on the groundwater resources of this site (DWE, letter 21 May 2009). DWE requested a thorough investigation of groundwater impacts, since it was considered likely that treated stormwater runoff in the constructed wetland would readily mix with groundwater. Furthermore, there were concerns that three Endangered Ecological Communities of vegetation that occur on site would be affected by changes to the water table. Finally, DWE was concerned that the size of the constructed wetland and its construction posed a risk of liberating acid leachate from acid sulphate soils.

To resolve these concerns it was necessary to understand the quality and behaviour of the groundwater resources, to determine if they were likely to be impacted by treated stormwater runoff and the construction of the constructed wetland. The Water Research Laboratory (WRL) of the University of New South Wales were engaged by TPS on behalf of St Vincent's Foundation to undertake these groundwater investigations.

In addition, Port Macquarie-Hastings Council has raised certain queries regarding the stormwater treatment train and the use of wetlands. This report aims to address those queries.

AECOM have been engaged by TPS on behalf of St Vincent's Foundation to integrate and refine the results of the following studies:

- the groundwater studies undertaken by the WRL, and
- the Water Engineering and Environment DGR Assessments(WEDGRA) undertaken by Cardno (as revised in April 2010)

in order to produce a stormwater treatment strategy that meets the desired outcomes of the DWE (now NSW Office of Water) and Port Macquarie-Hastings Council, and that will sufficiently mitigate the impacts of urban development on the hydrology of the site with respect to the treatment of stormwater..

1.3 Purpose of the Stormwater Treatment and Wetland Functionality Report

St Vincent's Foundation has requested AECOM complete the Part 3A Project Application following the Department of Planning's Test of Adequacy process. The purpose of this report is to inform that process by specifically addressing the following:

- A review of the stormwater management strategy proposed in Cardno's Water Engineering and Environment DGR Assessments (WEDGRA, April 2010);
- A review of the assessment of the groundwater systems of the site (UNSW, Water Research Laboratory, March 2010) for those aspects that pertain to stormwater issues;
- Refinement of the stormwater management strategy and wetland designs to ensure that the impacts of urban development do not impact the groundwater or surface water resources of the site;
- Providing responses to the issues that were raised by the NSW Office of Water;
- Providing responses, where appropriate, to the issues that relate to water management that were raised by Port Macquarie-Hastings Council;

- Providing responses, where appropriate, to the issues that were raised by the Department of Planning in their Test of Adequacy process that relate to water management.

It is the intention that this report by AECOM be read in conjunction with the WEDGRA (Cardno) document and the Groundwater Study of WRL, and any new information provided is intended to provide additional detail to the stormwater treatment strategy originally proposed by the WEDGRA.

1.4 Stormwater Management Objectives

Water quality objectives for stormwater runoff treatment from the development adopted in the WEDGRA are in accordance with:

- Port Macquarie Hastings Council adopted criteria in accordance with Council's IWCM policy of September 2006 as amended in November 2007 (see Section 3.3). Port Macquarie-Hastings Council performance criteria was taken from Aus-Spec D7 Stormwater Management (AUS-SPEC 2003).

1.4.1 Port Macquarie-Hastings Council Requirements

The following load reductions must be achieved when assessing the post development sites treatment train (Comparison of unmitigated developed case verses developed mitigated case):

- 80% Reduction in Coarse Sediment (particles <= 0.5 mm)
- 50% Reduction in Fine Sediment (particles <= 0.1 mm)
- 45% Reduction in Total Nitrogen (TN) • 45% Reduction in Total Phosphorus (TP)
- 90% Reduction in Litter (sized 5mm or greater)
- 90% Reduction in Hydrocarbons, motor fuels, oils and greases

(All reductions are in terms of annual pollutant load)

1.5 Related and Supporting Studies

The information in this stormwater management strategy report is based on the following reports

- *Cardno (April 2010). Water Engineering and Environment DGR Assessments, Rainbow Beach Estate, Bonny Hills* (The WEDGRA). This report documents the proposed concept design for stormwater treatment on the site
- *Water Research Laboratory UNSW (March 2010). Groundwater Characterisation and Numerical Modelling for Rainbow Beach Estate.* This report documents the results of the groundwater investigations
- *The Ecology Lab Pty Ltd (2008). Aquatic Flora & Fauna Survey Rainbow Beach, Bonny Hills – St Vincents Foundation.* This report describes the condition and extent of aquatic flora and fauna, and water quality of the existing water bodies.

These documents are not attached to this report, however, they do form part of the supporting documentation for the Project Application Environmental Assessment.

2 Constraints for Stormwater Management

2.1 Policy Framework

2.1.1 Stormwater treatment

Council has adopted policy that requires that stormwater quality and quantity are treated to reduce the impacts of these parameters on downstream environments. Council's WSUD requirements are outlined in the document "Development Design Specification - D7 - Stormwater Management", Port Macquarie – Hastings Council 2004. This document requires that all developments meet the stormwater pollutant load reduction targets outlined in section 1.4.1. It also requires that detention facilities are installed to attenuate the change in peak flow rate to a level equal to the pre developed flow rate.

2.1.2 Potential groundwater use

Council policy precludes the use of groundwater as an alternative source for non-potable water demands. Council has stated that they will not consider the potential for groundwater aquifers beneath the Rainbow Beach Estate to be used as a source of potable water, citing the potential issues associated with extraction, including that due to the aquifer being impacted by the Bonny Hills Sewerage Treatment Plant (letter from Council to TPS, 23 October 2009) (Attached as Appendix X to the Environmental Assessment).

2.1.3 Reclaimed effluent supply

Council intends to establish a dual reticulation system to supply highly treated wastewater to the urban development for domestic toilet flushing and garden watering (letter from Council to TPS, 23 October 2009). Therefore, demands for domestic hot water could be met through water harvested in rainwater tanks, but the supply of treated wastewater obviates the need for harvested stormwater to meet many non-potable demands. Therefore, rainwater tanks were not included in modelling or calculations relating to stormwater treatment.

2.2 Groundwater

In order to win sufficient fill to raise the developable area out of areas subject to periodic inundation, a large constructed open water wetland is proposed. This open water wetland would intersect the groundwater water table and therefore there is the potential for urban stormwater to detrimentally impact the quality of the groundwater.

WRL (2010) has conducted an assessment of the groundwater aquifers that occur on site in order to determine the extent and quality of these groundwater resources

Three groundwater aquifers occur on site. These are:

1. West - Saturated organic/estuarine clays, which dominate the low lying regions to the west of the site
2. Centre - An unconfined aquifer within deposits of silty sands throughout low lying areas in the centre of the site
3. East – Perched freshwater aquifers within coastal dune systems in the east of the site, adjacent to the coast.

Water quality within the first two aquifers is of poor quality, typical of acid sulphate soils environments having high concentrations of iron and aluminium, and a low pH. Water would not be suitable for drinking, irrigation and does not fulfil beneficial usage categories of the relevant guidelines (WRL 2010).

Water quality in the third eastern perched aquifer of the dunes was found to have been impacted by the disposal of treated sewage effluent by infiltration into this dunal system. The eastern aquifer was found to have elevated concentration of nutrients and contamination from faecal coliforms. Although water quality satisfies the requirements for short-term irrigation, given the contamination, such usage is not recommended (WRL 2010).

WRL concluded that the existing aquifers are limited in extent and generally of poor quality.

The NSW Office of Water has assessed the likely impact of the design of the open water wetland and requires that appropriate WSUD be implemented to "efficiently handle the nutrients associated with (runoff from) the development" (Letter from NSW Office to Water to TPS 15/9/09).

A study by WRL (2010) indicates that the primary flow direction will be from groundwater to the open water wetland. The construction of the open water wetland is expected to result in a maximum possible drawdown of the water table by a depth of 0.8 metres in the vicinity of the wetland, causing groundwater to flow towards the wetland. This was estimated to be a very small volume, approximately 40 m^3 per day on average, equivalent to 3

% of the surface water flow through the open water wetland (averaged annually). This is largely the result of the very low hydraulic conductivity of the heavy clays in this area. Some infiltration of surface water may be possible after major runoff events but it is anticipated that the surface water will be of comparable or superior quality to the existing groundwater in the vicinity of the open water wetland (WRL 2010). Therefore there is limited opportunity for surface water runoff to impact the groundwater aquifers.

2.3 Sensitive Ecosystems

There are areas on site that contain Endangered Ecological Communities (EECs) as listed under the Threatened Species Conservation Act. These areas limit the footprint of the urban development and similarly the footprint of areas suitable for stormwater treatment devices.

The littoral rainforest located to the north-east of the site is supported by a perched aquifer. The impact of groundwater drawdown on this vegetation community was modelled by WRL. They found that due to the perched nature of this aquifer, it would not be affected by groundwater drawdown in the vicinity of the open water wetland, nor will it receive stormwater runoff from the urban development.

A second sensitive ecosystem that was considered is the habitat of the Wallum Froglet that lies adjacent to the north boundary of the existing lagoon. The groundwater at this location is 1.6 metres below ground (WRL 2010). The marshy conditions experienced on the surface are the result of impeded drainage – very thick clays retain localised runoff and rainfall in a broad depression. This issue is considered in further detail in a related report ("Assessment of the supporting hydrology of the Wallum Froglet Marshland at Rainbow Beach", AECOM 2010). This area is separated from the upper catchment by a catch drain and will not receive stormwater runoff from the proposed urban development.

2.4 Acid Sulphate Soils

The open water wetland has been designed to keep any excavation above the height that may cause drawdown and oxidation of the acid sulphate soil deposits. In addition, an Acid Sulphate Soil Management Plan has been prepared. Furthermore, modelling by WRL (WRL 2010) predicts that if, in the event that acidic leachate were to flow into the open water wetland, buffering and dilution from surface water inflows will be sufficient to maintain near-neutral pH levels. WRL considered that the good water quality in the existing lake was a robust test case for the model prediction.

2.5 Maintenance Requirements

Council has noted that it has concerns regarding the maintenance costs of managing a wetland with the potential for water quality problems, algal blooms and aquatic weed proliferation (letter from Council to TPS, 25 June 2009). Designs for wetlands must therefore demonstrate that these maintenance concerns are accommodated for or mitigated through the design.

3 Opportunities for Stormwater Management

3.1 Rainwater Tanks

Rainwater tanks can be used to meet non-potable demands for domestic hot water with a high reliability. However, the proposed supply of treated wastewater to the development for toilet flushing and irrigation obviates the need for harvested stormwater to meet these other non-potable demands.

It is anticipated that up to 50 percent of the lots at Rainbow Beach Estate may take up the opportunity to harvest water with rainwater tanks. However, since this is not a mandated requirement, the beneficial effect of rainwater tanks were not included in the stormwater quality modelling.

3.2 Swales

It is proposed to convey stormwater runoff from the urban development to the constructed stormwater treatment wetlands via swales. Swales confer several advantages to water management on site:

- Runoff is kept on the surface, making it easier to discharge from flat grades to the surface of a wetland.
- Coarse sediment is removed from runoff as it passes through the swale.
- Swales can also be designed as natural channels to reduce the maintenance burden of this landscape in addition to increasing the habitat value of these water conveyance corridors.

3.3 Constructed Wetlands

Constructed wetlands for stormwater treatment can work successfully in flat areas as very little grade difference is required to convey water through the wetland. They are ideal for locations where treatment is required at the bottom of the catchment as they can be easily scaled up to accommodate flows from large catchments. Wetlands are also complementary habitat for low-lying or flood prone areas and swampy habitats.

3.4 Bioretention Systems

Bioretention systems are highly adaptable in form and therefore are suited to distributed or streetscape systems, However, they are not amenable to end of pipe treatment of large catchments. In addition, as bioretention systems require sloping sites in order to discharge treated water below surface level, they are ideally suited for use in the upper urban catchments.

4 Stormwater Treatment Devices

The stormwater treatment strategy outlined in the WEDGRA (Cardno 2010) recommends that the following devices be used to treat stormwater:

- Rainwater Tanks
- Buffer Strips
- Swales
- Constructed Wetlands
- Bioretention Systems

The selection of these devices is appropriate to the site, and when designed as a treatment train they should provide adequate treatment of stormwater runoff from the Rainbow Beach Estate.

4.1 Stormwater Treatment Elements – Description

4.1.1 Rainwater Tanks

Rainwater runoff from roofs can be captured and used for toilet flushing, irrigation, washing machines and hot water systems. Rainwater tanks are of most benefit to stormwater treatment if they are plumbed into suitable devices that have a regular demand, for example, toilets, laundry or hot water (**Figure 1**).

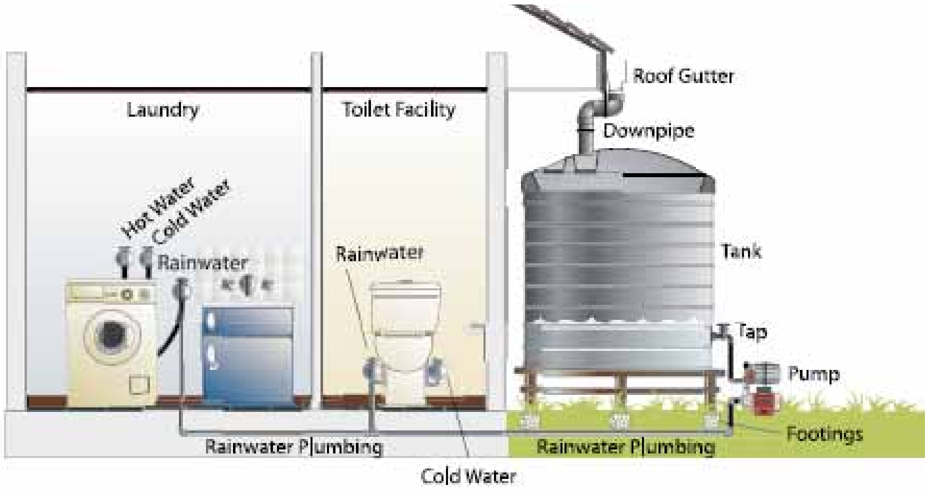

Figure 1: Typical configuration of a rainwater tank used to meet / supplement laundry and toilet water demands (ACT Government, 2006)

4.1.2 Vegetated Buffers

Buffer strips are intended to slow and filter flow from impervious surfaces to the drainage system. The key to their operation, like swales, is an even shallow flow over a wide vegetated area. The vegetation facilitates an even distribution and slowing of flow thus encouraging pollutant settlement. The vegetation also takes up some nutrients. Buffers are commonly used as a pre-treatment for other treatment measures. They may be located at the edge of a road, a carpark or a pedestrian area, for example and often incorporated on the outer edges of a swale.

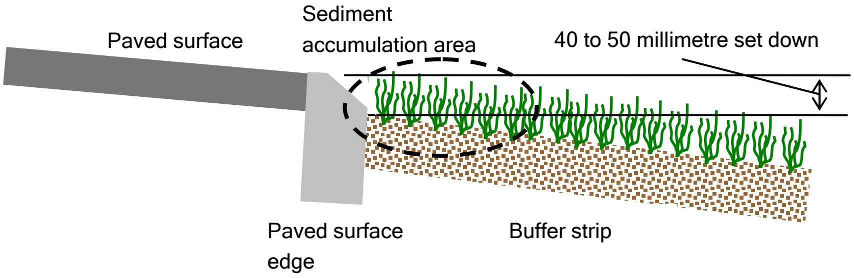

Figure 2 Typical buffer strip arrangement

4.1.3 Swales

Vegetated swales are both a stormwater conveyance and treatment mechanism. The key to their operation, is an even and shallow flow over a wide vegetated area. They are effective for removal of suspended solids, particularly coarse sediments, and will also reduce some phosphorus and nitrogen loads. Vegetated swales can be used instead of pipes to convey stormwater and provide a 'buffer' between the receiving water and the impervious areas of a catchment. They can be integrated with landscape features into parks and gardens and also into streetscape designs adding aesthetic character to an area.

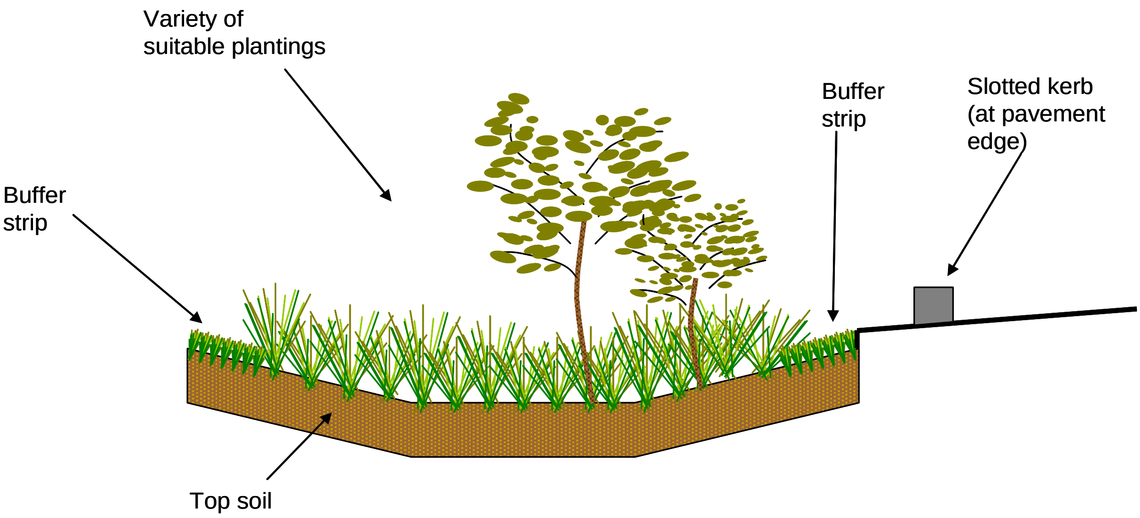

Figure 3 Typical swale configuration

4.1.4 Constructed Wetlands

Constructed surface flow wetland systems use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater. The wetland generally have the following elements (refer Figure 4):

- An inlet zone (which is basically a sediment basin).
- A macrophyte zone (a heavily vegetated area of different water depths to remove fine particulates and take up soluble pollutants).
- A high flow bypass channel (to protect the macrophyte zone).

Wetland systems can also incorporate open water areas. The wetland processes are engaged by slowly passing runoff through heavily vegetated areas where plants filter sediments and pollutants from the water. Biofilms that grow on the plants also absorb nutrients and other associated contaminants. Wetlands have additional benefits, in that they provide habitat for aquatic flora and fauna, and contribute substantially to the scenic amenity of public open spaces.

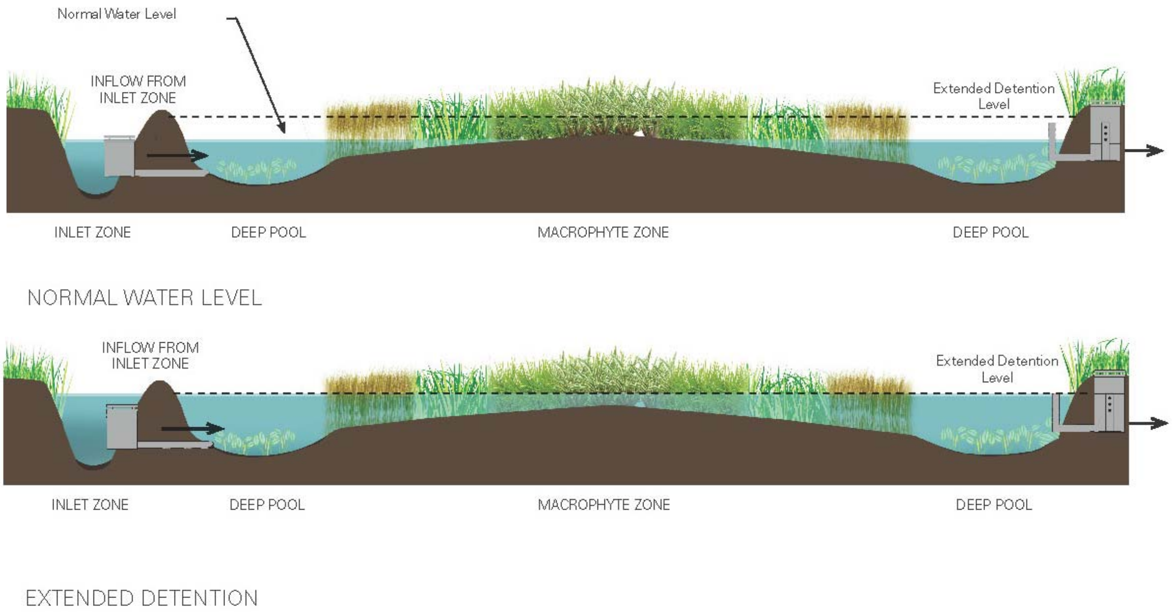

Figure 4 Long section of idealised conceptual stormwater treatment wetland at normal water level and with extended detention fully engaged (during a runoff event).

4.1.5 Bioretention Systems

Bioretention systems are vegetated filter systems designed to allow water to pool temporarily before percolating through the filter media. The filter media controls the flow rate of water through the system, as well as providing a growing media for the plants. The filtered water is directed via perforated pipes to the existing stormwater system, natural waterway or a detention basin for reuse.

Bioretention systems can be implemented in many sizes and shapes to fit different locations, for example, planter boxes, parks or streetscapes. It is important to have sufficient depth (normally at least 0.8 metres) between the inlet and outlet. Therefore bioretention systems may not be suitable at sites with shallow bedrock or other sites with depth constraints. Despite this, bioretention systems are a very flexible and effective treatment measure for dissolved nutrients.

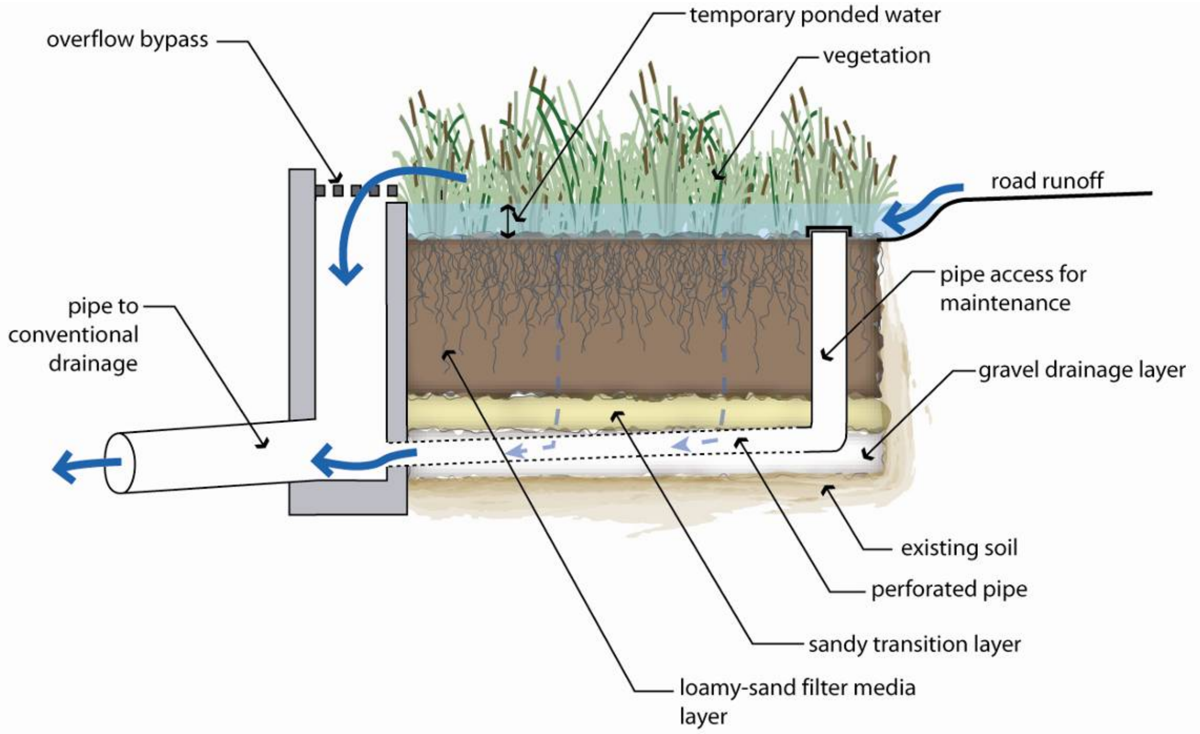

Figure 5 Typical configuration of a bioretention system

4.1.6 Constructed Open Water Wetland

The large constructed open water wetland will be deep (>1.5m), with emergent aquatic plants restricted to the margins because of water depth. For this reason, the large open water wetland is not considered part of the treatment train, but rather is considered to be the receiving environment that requires protection from poor quality runoff. However, in practice, the open water wetland will help protect Duchess Gully by contributing to stormwater detention during high flow events and by providing a buffer between the urban and treatment areas and the waterway. Such systems typically become colonised by submerged macrophytes that help stabilise the ecology of open water wetlands and further improve water quality, as is evident in the existing lagoon.

4.1.7 Treatment Train

The design of the stormwater management strategy takes into account the "treatment train", that is, the consideration of the connection of different devices along the flowpath of runoff such that primary, secondary and tertiary treatment processes take place in that order of priority (refer ARQ Chapter 4). These treatment processes are as follows:

- Primary level treatment:
  - screening of gross pollutants,
  - sedimentation of coarse particulates
- Secondary level treatment
  - sedimentation of finer particulates
  - filtration
- Tertiary level treatment
  - Enhanced sedimentation and filtration
  - Biological uptake
  - Adsorption onto sediments

The stormwater treatment train at Rainbow Beach Estate is structured in the following way:

Buffer Strips -► Swales -► Bioretention or Constructed Wetland Systems -►Constructed Open Water Wetland

The buffer strips provide primary level treatment, the swales provide secondary level treatment and the bioretention or treatment wetland systems provide tertiary level treatment. This order of treatment ensures that bioretention systems and treatment wetlands are protected from sediment that would clog or impair the function of these devices. This order of treatment also ensures that water of the highest possible quality is delivered to the constructed wetland, in order to protect the amenity and ecological values of the wetland.

4.2 Modelling Parameters and Design features

The stormwater management strategy proposed by Cardno in the WEDGRA is considered generally appropriate for the site given the level of detail that was available at the time. As a consequence of the new information available from the WRL groundwater investigations, and in order to address the concerns of the DWE regarding the design of the stormwater management features of the Rainbow Beach Estate, the stormwater management strategy proposed in the WEDGRA was reviewed and additional design detail considered where it was necessary to address the Department's concerns.

The quality of runoff from the development was modelled by Cardno using the MUSIC software package. Many of the initial modelling parameters used in Cardno's models were based on the catchment characteristics recommended by the Gold Coast City Council. These are applicable and appropriate for the coastal environment of Rainbow Beach Estate. MUSIC was used to complete initial modelling of the development to confirm that the water quality objectives defined by Port Macquarie Hastings Council (refer Section 3.1) for runoff from the site (to the water bodies) could be achieved. MUSIC was then used by Cardno to derive the runoff, sediment, and nutrient inputs to the Pond model from each of the three water bodies.

The meteorological template used was 6 minute timestep data from the Port Macquarie region for the years 1966 to 1970 inclusive. Monthly evapotranspiration data from the region was also used. Simulations over this period produced an annual rainfall of 1125 mm and annual potential evapotranspiration of 1318mm.

As a result of the review, the modelling parameters used in the assessment of stormwater treatment were further refined to ensure that the design of the proposed treatment measures was:

- in agreement with the design principals documented in Australian Runoff Quality – A guide to Water Sensitive Urban Design, and the Constructed Wetlands Manual, Vols 1 & 2, DLWC (1998), and
- complementary to the proposed landscape masterplan.

The following sections provide design recommendations to ensure efficient stormwater treatment, and describe the refinements made to the MUSIC models provided by Cardno in order to accommodate these design recommendations.

4.2.1 Gross Pollutant Traps

Gross Pollutant Traps (GPTs) were not considered to be an ideal treatment measure for the site. GPTs are very efficient at removing litter, coarse sediment and oil and grease, and are ideally suited to industrial or commercial catchments where these pollutants are likely to be a problem. These pollutants are not likely to be an important component of a stabilised urban catchment at Rainbow Beach. GPTs also require frequent monitoring and maintenance, whereas the measures proposed below have lower monitoring and maintenance requirements.

It is recommended that sedimentation basins be used in place of GPTs in association with each of the constructed wetlands for stormwater treatment. Where bioretention systems are used, sediment forebays should be designed into the inlet zone. Sediment basins have been used successfully by AECOM in other projects (e.g. Lynbrook Estate, Victoria, a successful and one of the oldest examples of a stormwater treatment train system).

4.2.2 Rainwater Tanks

Given the popularity and benefits of rainwater tanks for households, it is expected that rainwater tanks for capture of roof stormwater runoff will installed on at least 50% of households of the Rainbow Beach Estate. However, Port Macquarie Hastings Council IWCM policy does not mandate the use of rainwater tanks and therefore, without an explicit demand on the rainwater tanks, it cannot be assumed that they will be empty when needed. For this reason and to be conservative in the modelling of stormwater treatment, rainwater tanks were not included in the modelling of the treatment of stormwater pollutants.

4.2.3 Vegetated Buffers

Vegetated buffer strips were retained in the modelling as described in the WEDGRA (Cardno 2010).

4.2.4 Swales

The proposed stormwater treatment swales were modelled as per the WEDGRA, but the design was adjusted to provide a wider swale base by increasing the batter slopes to a 1:4 slope. Swales have not been depicted on the masterplan for the site because their design will be strongly influenced by the urban design (not yet undertaken). Additionally, the swales can vary in width to provide temporary detention and attenuation of flood flows, and to encourage the engagement of the swale benches by flood waters. This diversity in width will increase diversity of habitats along the swale.

The key to the effective operation of swales is the provision of an even and shallow flow over a wide vegetated area. Urban catchments often exhibit a trickle base flow as a result of household water use throughout the catchment. The swales proposed for the Rainbow Beach Estate are large swales draining runoff from large catchments (up to several hectares). These swales are therefore likely to be subjected to trickle baseflows and large stormflows. To accommodate these conditions it is proposed to design the swales as naturalised drainage lines (an example is provided in Figure 6). Important features of the proposed design include:

- A low flow channel to accommodate baseflows. Limiting baseflows to a small channel allows wetter preferring vegetation to thrive in this channel, and to exclude weeds that commonly establish in urban waterways.
- A wider benched area provides sufficient room to convey large urban flows.
- Stability of the swale is ensured through dense plantings of native groundcover species.
- Maintenance of the swale is minimised by designing the swale as a largely self-sustaining native ecosystem. This ecosystem requires no mowing or trimming and can be managed through low-impact bush regeneration techniques.

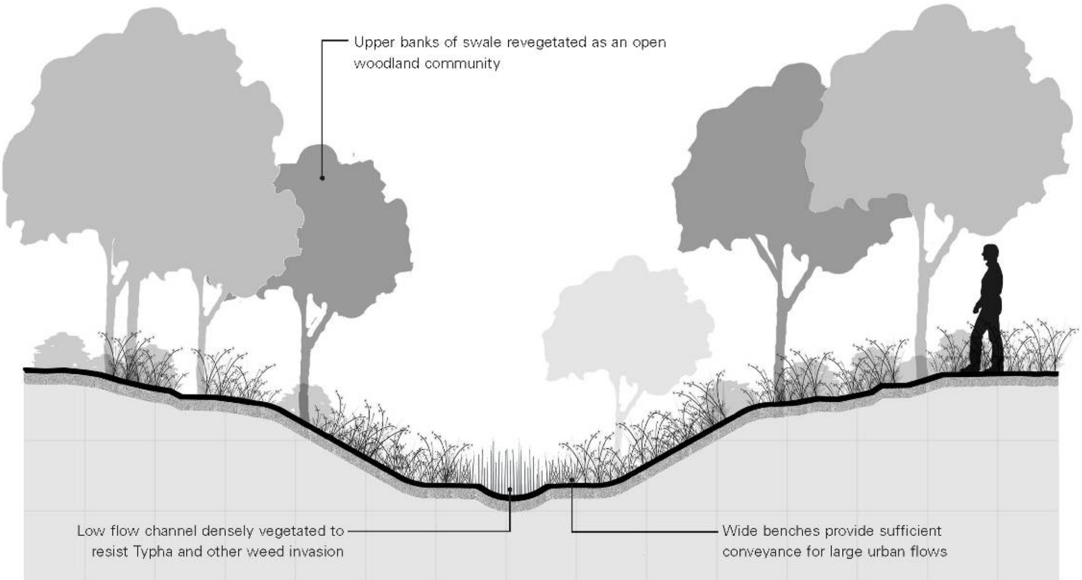

Figure 6 Cross section of a swale designed as a stable, naturalised flow path

Figure 7 Example of existing naturalised swale at Rainbow Beach Estate

A successful template for this style of swale design already exists at the south-eastern corner of the site (Figure 7). This swale has been built on site for the purpose of conveying stormwater runoff from the existing urban development to the existing lagoon. The swale is stabilised with cobbles and planted out with native grasses and sedges to complement the neighbouring bush. As the grasses and sedges mature and increase in density, they provide greater stability to the swale and are increasingly able to exclude weeds from establishing.

4.2.5 Constructed wetlands for stormwater treatment – Modelling parameters

The modelling of the treatment wetlands for stormwater treatment was refined. The following design parameters were applied to the constructed wetland treatment nodes of the MUSIC modelling provided by Cardno (WEDGRA, Table 28):

Parameter	Details
Inlet pond volume (m^3)	Set at approximately 10% of the area of the macrophyte zone. Required to trap sediment and dissipate flow energy.
Macrophyte zone surface area (m^2)	Set at the area required to meet the pollutant reduction targets set by Council. Wetland extent was mostly driven by area required to meet TN removal of 45%.
Extended detention (m)	Set at 0.5m. Deeper than this puts the health of the aquatic vegetation at risk by potential drowning during extended wet periods.
Average Depth (m)	Set at 0.3m. Deeper than this puts the health of the aquatic vegetation at risk by potential drowning during extended wet periods.
Permanent pool volume (m^3)	Calculated based on average depth.
Equivalent outlet pipe diameter (mm)	Set to control the notional detention time at 72 hours. Detention times shorter than this are unlikely to provide adequate pollutant removal in practice. Detention times longer than this require a larger footprint to treat the same proportion of runoff..

For the wetlands parameters (presented in WEDGRA Table 28) - the following parameters were amended:

- extended detention - was reduced from 1 - 2 m and fixed at 0.5 m. setting a high extended detention height returns high pollutant removal rates in computer modelling, however depths of inundation greater than 0.5 m can drown vegetation during prolonged wet spells, or may be too deep often enough that vegetation grows poorly and provides poor water treatment.
- Permanent pool volume - set at 0.3 m. A deep permanent pool increases the model's residence time for water and produces good modelled pollutant removal estimates. However, if the average depth is deeper than this, vegetation is unlikely to grow well, resulting in poor water treatment.
- Outlet pipe diameter - set for each wetland such that the notional detention time is approximately 72 hours. Large outlet pipe diameters improve the modelled efficiency of the wetland by allowing more run-off to pass through. However, if the detention time is less than 72 hours there is insufficient time available for wetland treatment processes to take place.

Applying these modelling parameters to the existing models resulted in the need to increase the footprint of the proposed treatment wetlands. The maximum wetland footprints required for the proposed masterplan are listed in the following table:

Catchment + Wetland Name	Wetland Area (m^2)
W1a	960
W1b	800
W1c	4050
W1d	1620
W1e	4750
W2	9000
W3	9000
W4a	2200
W4b	1650

Since the potential footprints of the proposed wetlands are constrained in many locations, and not sufficiently large to meet Council's water quality criteria, additional treatment will be required. This additional treatment can be provided through the inclusion of bioretention systems located higher in the catchments (discussed in section 4.1.5).

4.2.6 Constructed wetlands for stormwater treatment – Design recommendations

Design recommendations are provided here to inform the wetland detailed design. The inclusion of these design principles is recommended to ensure that wetland designs are efficient in their function as water treatment devices, and to ensure that the wetlands protected from potentially damaging flows, are easy to maintain and have low maintenance requirements. The figures that accompany these design recommendations represent a concept design applied to wetland W1d (Figure 9 and Figure 10).

Sedimentation basin - In order to protect the macrophyte zone of the wetlands from smothering by sediment, all stormwater treatment wetlands will have a sedimentation basin built just upstream of the macrophyte zone (refer Figure 10). All flows are directed to the sedimentation basin prior to entering the wetland. The sediment basin will be designed to trap particles sized 125 um and above (fine sand and larger). Particles of this size are less likely to be contaminated by heavy metals or other chemicals. Therefore, sediment that is removed from the sediment basin during desilting operations (approximately once every 5 years) is unlikely to require disposal as contaminated material. To make excavation of the sedimentation basin easier, the base of the basin will be lined with cobbles so that the excavator operator can sense when they have reached the bottom (refer Figure 11).

Sediment storage - the sediment basin will be designed such that half of the sediment storage volume will be full in approximately 5 years. It is recommended that the sediment basins are emptied when half full. The sediment basins will be lined with cobbles or rip-rap material so that the operator of an excavator can easily detect the base of the sediment basin during clean out.

Flow control - All flows will be directed to the sedimentation basin (refer Figure 10). In the sedimentation basin, a pit with an orifice outlet will allow flows less than the 1 year Annual Recurrence Interval to discharge to the macrophyte zone. Flows larger than this could potentially cause erosion or disruption to the biofilm growth on the macrophytes that are responsible for a large part of the water quality treatment. Flows larger than the 1 year Annual Recurrence Interval will bypass the macrophyte zone and will be discharged directly to the waterway, or open water wetland. The residence time within each of the wetland macrophyte zones is controlled by a pit fitted with a riser outlet to ensure a residence time of 72 h.

Open water - In the macrophyte zone, water is initially discharged into a pool of open water (refer Figure 10). This allows the flow energy to dissipate and flows to spread out evenly.

Length width ratio - The macrophyte zone has a large length to width ratio, much greater than 1:5. This ensures efficient treatment by minimising any locations of stagnant water or preferential flow paths.

Bands of dense vegetation - Water flows through bands of dense vegetation (indicated conceptually on Figure 10). These ensure good water treatment as water is dispersed across the full width of the wetland, maximising the interaction between the water, the vegetation and the sediment. Different depths are used to promote different treatment processes (refer also).

- Shallow marsh - In shallow areas, organic litter is trapped and broken down, and pollutants such as phosphate are removed through sediment absorption reactions.
- Deep marsh - In deeper areas enhanced sedimentation and nitrogen removal through denitrification takes place.
- Open water - In the open water preferential flow paths are disrupted and UV disinfection takes place. Deep water also provides habitats and drought refuges for aquatic fauna. Treated water is discharged from an open water zone so that the outlet pipe can be located away from vegetation. The outlet pipe it is also submerged to keep it free from floating organic debris.

Figure 8 Constructed wetland showing densely planted vegetation in bands shortly after establishment (left) and after establishment, adjoining open water (right). Dense planting promotes efficient water filtration, and resists erosion and weed infestation (design and construction supervision by AECOM).

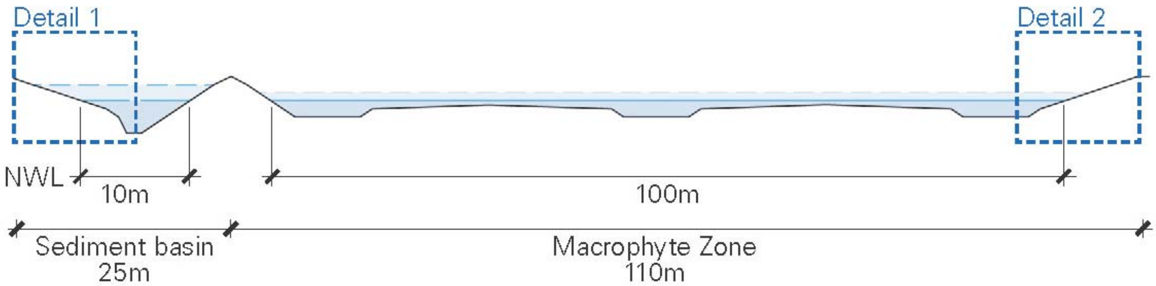

Figure 9 Long section of constructed wetland W1d. Note varying water depths along the wetland.

Riser outlet - the outlet is a staged riser that controls the release of water from the wetland to ensure a notional detention time for water treatment of approximately 72 hours. 72 hours is needed to give biological processes sufficient opportunity to remove dissolved compounds from the water column.

Excavator access pad - access for an excavator and a flat pad for desilting and sediment dewatering is provided alongside the sediment basin (shown on Figure 10). Based on discussions with Port Macquarie Hastings Council, Council has excavators with an 8 m reach. Therefore, to facilitate sediment cleanout, sediment basins will be designed with a maximum width of 12 m across the normal water level (NWL). This is narrow enough to permit the excavator to remove most of the stored sediment with each cleanout cycle. The access pad will be planted with hardy native grasses and sedges. Some supplementary landscape repair and additional planting may be required after desilting operations (once every 5 years). If Council's machinery changes, then based on a clean out frequency of 5 years, short term hire of machinery may be required (expected duration 1 to 2 days).

Safety Features - Council's guidelines *(Hastings Council Auspec-1 D07 Stormwater Management 2004)* provide design guidance regarding safety of the wetland edges as follows:

> *All edges to waterbodies and wetlands shall have safety benches of at least 1.5m to 3.0m wide from the normal top water level except where transitions to culverts or waterways occur. Safety benches shall have maximum slopes of 1 in 8 for the first 1.5m to 3.0m, a transition to 1 in 5 over 0.5m (min.) prior to steeper grades up to 1 in 3. The safety bench shall be densely planted with emergent macrophytes to preclude access.*

The designs for all the water bodies meet these requirements.

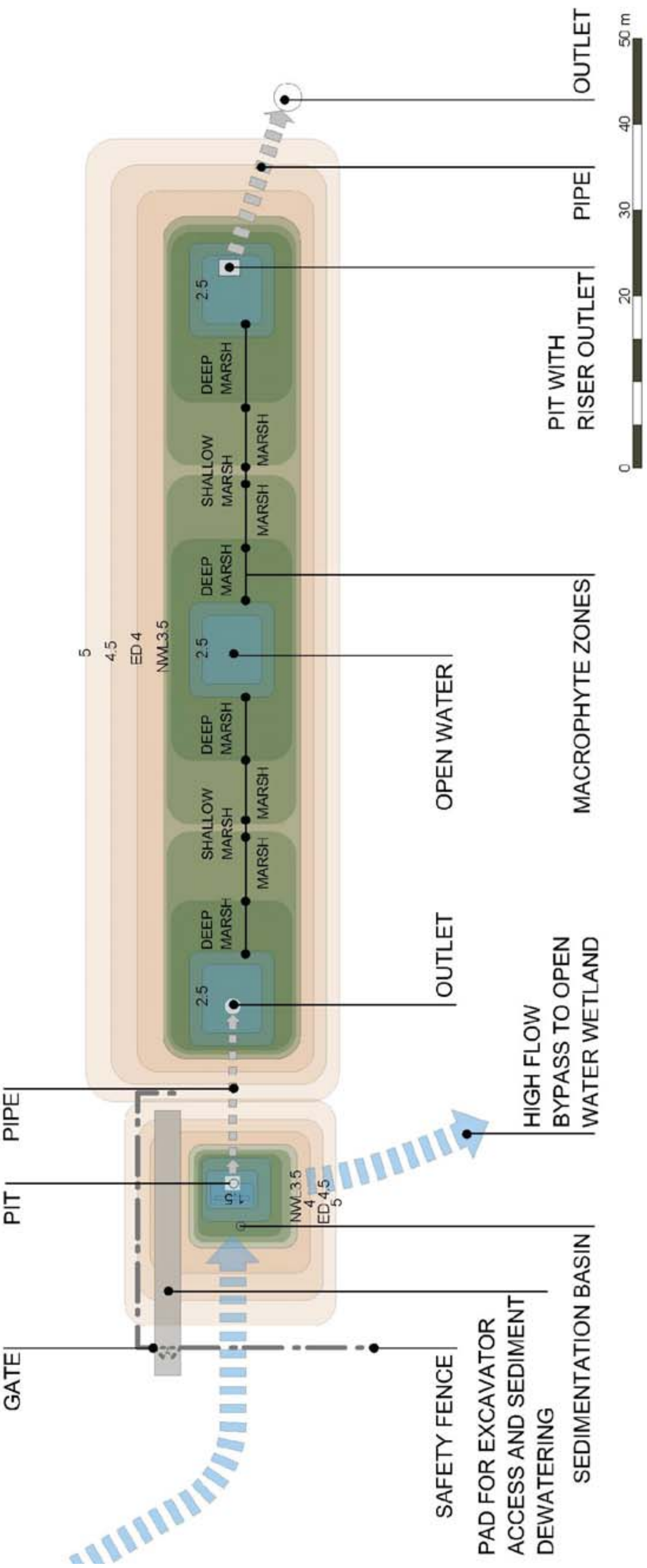

Figure 10 Concept diagram in plan view of constructed wetland W1d

Safety fence - in order to provide access for the excavator close to the sedimentation basin. Steeper batter slopes are required near the water (1:3 grade). Therefore, fencing and/or specific and appropriate planting around the excavator work area is recommended to deter the public from accessing this area (refer Figure 11).

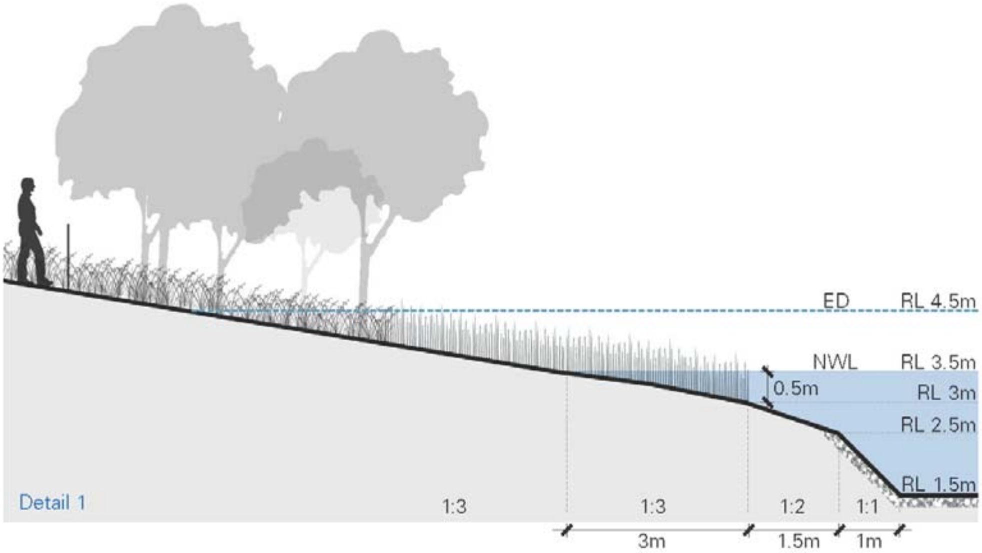

Figure 11 Detail of batter slopes near excavator access of sedimentation basin. Note safety fence and dense batter slope planting

All other sediment basin, wetland and pond slopes will be designed to Council's criteria and densely planted with grasses, sedges and shrubs (Figure 12). These plants will act as a deterrent to public access. A constructed wetland for stormwater treatment exists on site. Batter planting around this wetland acts as a very efficient deterrent to public access.

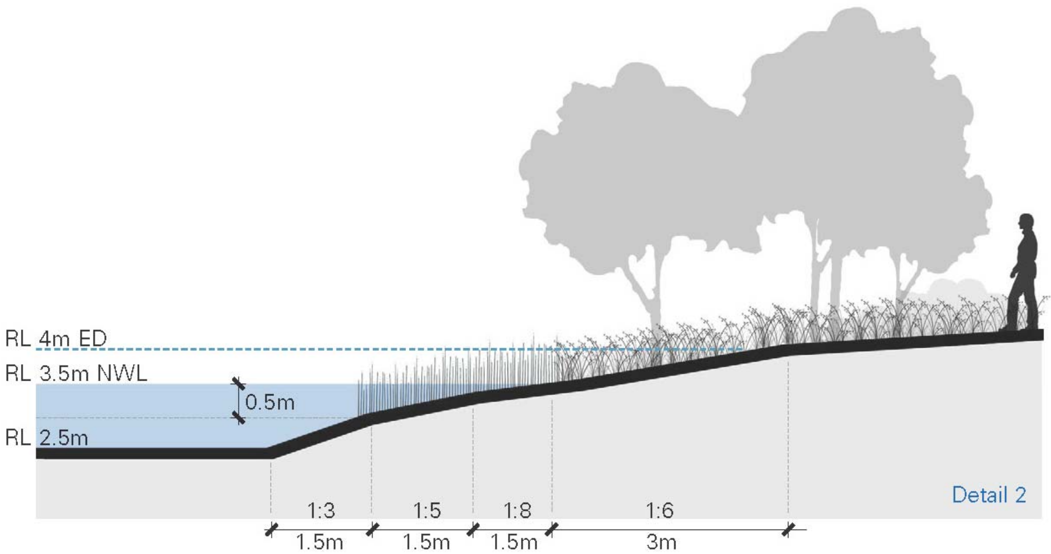

Figure 12 Batter slopes of water bodies as designed to Council's criteria. Note safety bench near water's edge (1:8 slope) and dense batter slope planting.

Figure 13 Existing constructed wetland for stormwater treatment at Rainbow Beach Estate. Note the dense edge planting that deters ingress towards the water.

Weed Resistance – Dense planting in and around the wetland provides better resistance to weed establishment and is an important mechanism for minimising the ongoing maintenance requirement during the plant establishment period and beyond. Dense planting also assists in stabilising the landscape against potentially scouring flows (refer). A generic list of aquatic plant species recommended for use in the stormwater treatment wetlands is provided in Table 1. Plant densities should be at least 12 plants/m2 (batters and ephemeral zone) to no less than 6 plants/m2 (deep marsh). AECOM noted from the site inspection that the planting and maintenance regime undertaken by the resident bush regenerator (Wildthings Native Gardens) is appropriate and has been successful to date in suppressing Torpedo Grass and other problematic weeds. The bush regenerator has noted that plants propagated from local provenance stock have grown more successfully than imported material. Therefore, local provenance stock should be used if available.

Figure 14 Dense macrophyte planting within a constructed wetland for stormwater treatment. 10 years after establishment the wetland is very resistant to weed invasion (AECOM project, Lynbrook Estate, Victoria).

Table 1 Plant species recommended for use in constructed wetlands for stormwater treatment

Wetland Zone	Depth relative to Normal Water Level
Littoral Zone *Consult current bush regenerator for recommendations of species demonstrated*	**0.2**
Ephemeral Zone *Baloskion tetraphyllum* *Baumea juncea* *Baumea teretifolia* *Bolboschoenus caldwellii* *Bolboschoenus medianus* *Carex appressa* *Carex fascicularis* Chorizandra sphaerocephala *Cladium procerum* *Cyperus polystachyos* *Ficinia/Isolepis nodosa* *Fimbristylus dichotoma* *Gahnia clarkei* *Imperata cylindrica* *Juncus continuus* *Juncus polyanthemus* *Juncus prismatocarpus* *Juncus usitatus* *Persicaria decipiens* *Schoenus brevifolius*	**0 to +0.2**
Shallow Marsh *Eleocharis equisetina* *Baumea rubiginosa* *Baumea teretifolia* *Carex fascicularis* *Chorizandra sphaerocephala* *Eleocharis acuta* *Juncus continuus* *Juncus polyanthemus* *Lepyrodia muelleri*	**0 to -0.2**
Marsh *Baumea rubiginosa* *Lepironia articulata* *Baumea articulata* *Eleocharis sphacelata*	**- 0.2 to -0.35**
Deep Marsh *Baumea articulata* *Eleocharis sphacelata*	**-0.35 to -0.5**
Open Water *Vallisneria spp.* *Potamogeton javanicus* *Chara spp.*	**-0.5 to -1.0**

Note: this list is intended to provide the reader with an indication of the types of plants that may be used in constructed wetlands. It is indicative only and final planting plans may need to accommodate other site factors. Plant densities should be at least 12 plants/m2 (batters and ephemeral zone) to no less than 6 plants/m2 (deep marsh).

4.2.7 Constructed wetlands for stormwater treatment – Analysis of inundation and drawdown

An assessment of wetland inundation and drawdown was conducted for the stormwater treatment wetlands proposed for Rainbow Beach. Successful water quality treatment in the wetland is dependent on the successful growth of aquatic macrophytes. These are in turn dependent on the flooding and drying hydrology of the wetland. To assess the flooding and drying hydrology of the stormwater treatment wetlands, inundation frequency curves were produced. These permit an appraisal of the designs to determine if the proposed wetland bathymetry or planting plans need to be modified to accommodate for a drier or wetter situation. Inundation frequency curves were generated for all of the proposed wetlands. The inundation frequency curves were generated from output from music (flux files). These files were imported into and processed by the River Analysis Package software (RAP). RAP assesses and graphs summaries of the proportion of time that the wetland water level is above and below its designed normal water level.

An ideal frequency of inundation for a stormwater wetland will show that:

- less than 10% of the time the water level is greater than 0.2 m above NWL
- at least 90% of the time the wetland will not experience significant water level drawdown below the NWL.

Inundation frequency curves are presented in Figure 15, Figure 16,Figure 17,and Figure 18. All wetlands, with the exception of W4b, show appropriate inundation frequency curves. These wetlands will not need further specific design consideration. W4b shows that the water level is higher than 0.2 m at least 30% of the time. This is due to the large catchment above this wetland. Much of the run-off from this catchment is partially treated by bioretention systems. However, the partially treated run-off is directed to the wetlands to ensure that the water is fully treated to Council standards. Therefore this wetland experiences longer periods of inundation than a wetland conventionally sized for a smaller catchment. To address this, the planting plan for this wetland will need special consideration. It is recommended that the shallow marsh zones be planted with species listed for use in the marsh and deep marsh areas.

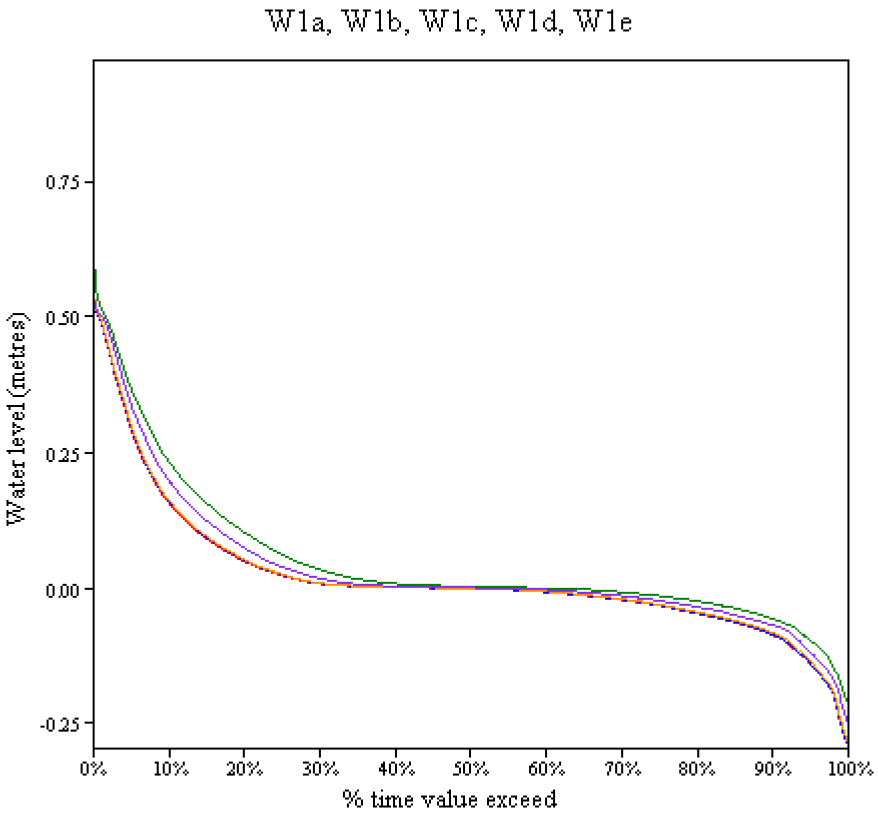

Figure 15 Wetland Inundation Frequency Curves for W1a, W1b, W1c, W1d, and W1e. Inundation behaviour for all of these wetlands is suitable for the successful growth of aquatic macrophytes i.e. <10% above 0.2m, no significant drawdown greater than 90%.

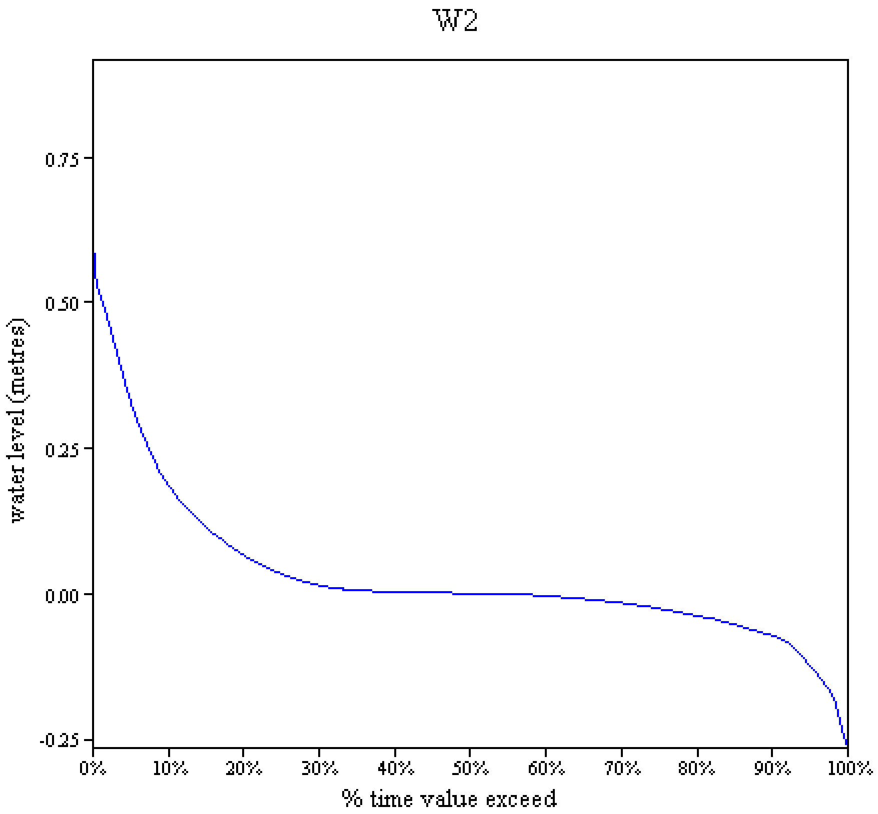

Figure 16 Wetland Inundation Frequency Curve for W2. Inundation behaviour for this wetland is suitable for the successful growth of aquatic macrophytes i.e. <10% above 0.2m, no significant drawdown greater than 90%.

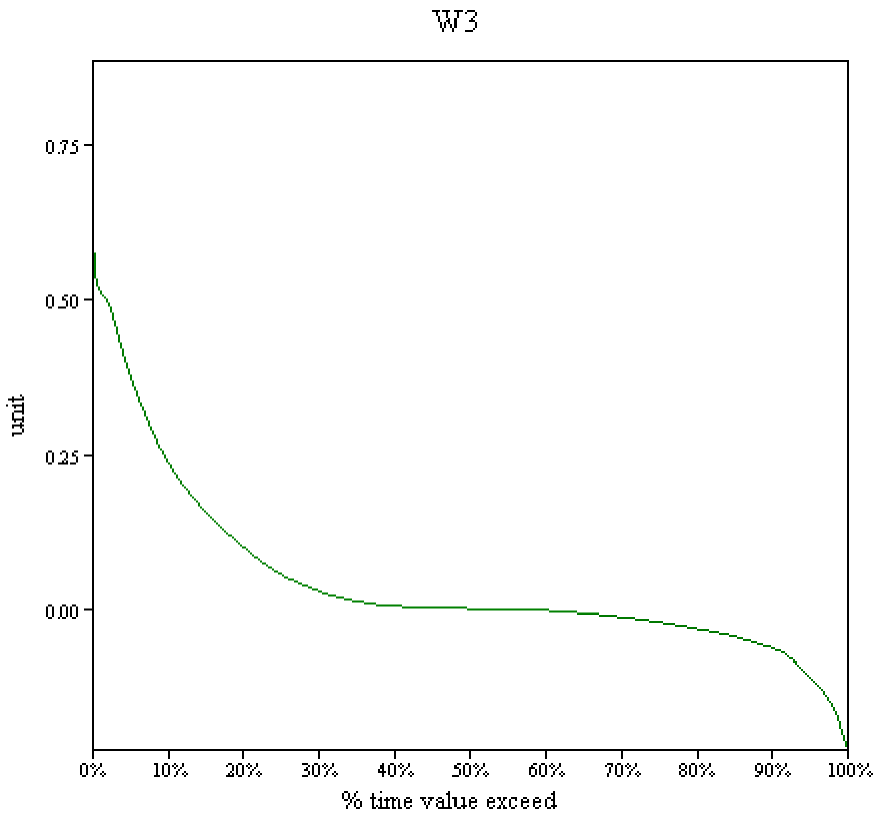

Figure 17 Wetland Inundation Frequency Curve for W3. Inundation behaviour for this wetland is suitable for the successful growth of aquatic macrophytes i.e. <10% above 0.2m, no significant drawdown greater than 90%.

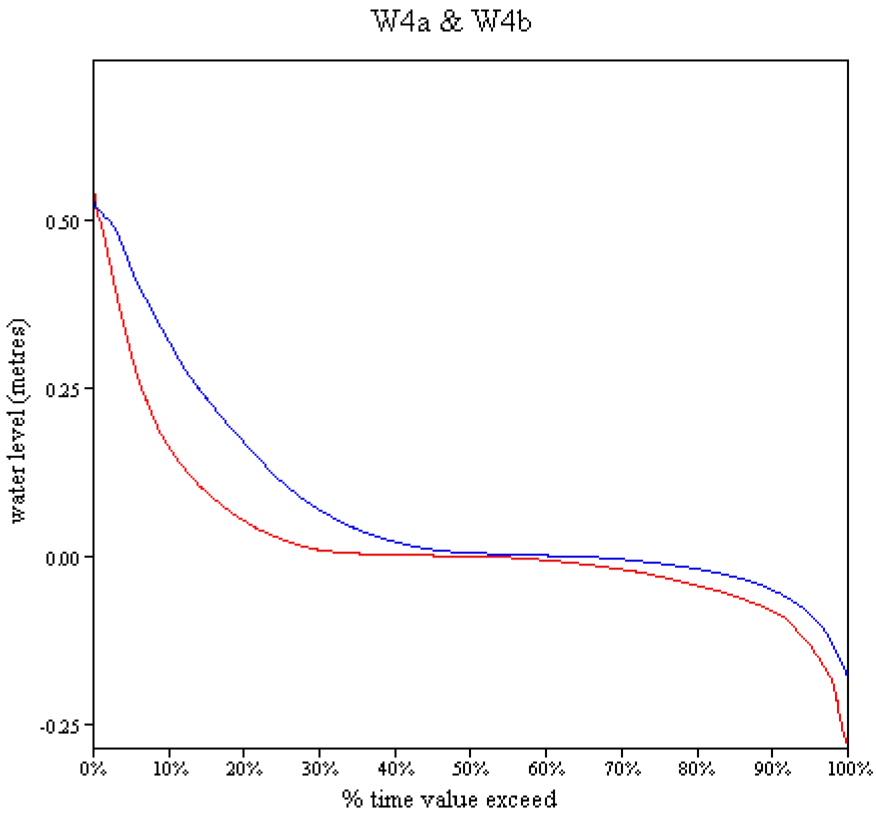

Figure 18 Wetland Inundation Frequency Curve for W4a (bottom line, red) and W4b (top line, blue). Inundation behaviour for W4a is suitable for the successful growth of aquatic macrophytes i.e. <10% above 0.2m, no significant drawdown greater than 90%. W4b shows that inundation is greater than 0.2 m approximately 30% of the time. This wetland will need special design consideration to ensure good plant growth and survival.

4.2.8 Existing stormwater treatment wetland at Rainbow Beach Estate

A constructed wetland for stormwater treatment was built at Rainbow Beach in 2005 to treat stormwater from the existing urban development (refer Figure 19). The wetland has been successfully established provides efficient treatment of stormwater runoff. An inspection by AECOM of this wetland concluded that this stormwater treatment wetland appears to deliver good quality water to the existing lagoon, because the lagoon exhibits several indicators of a healthy open water wetland system. These include:

- Dense growth of the submerged macrophyte *Vallisneria nana*. The presence of this plant indicates that the water is mostly clear as it allows for light to penetrate to the bottom of the lagoon. It also indicates that the water quality in the lagoon is of good quality. If the water quality was poor (i.e. high in nutrients), it would be expected that algal epiphytes would smother the leaves of *Vallisneria nana*, reducing the vigour of its growth.
- Clear water – if the water quality was poor (i.e. high in nutrients), then it would be expected to support the growth of planktonic algae, which would reduce water clarity and give the water a greenish colour.

An analysis of the measured water quality parameters for samples taken from the lagoon during the period 2005 to 2007 undertaken by Cardno (2010) concluded that the water quality in the lagoon was suitably protected by the treatment wetland as the lagoon water quality was good, and suitable for providing a recreational environment and habitat resources. Cardno also assessed water quality at the inlet and outlet of the constructed wetland. They determined that Total Nitrogen and Total Phosphorus concentrations were reduced by 70 to 90 %. These data validate our visual assessment of the efficient function of the existing stormwater treatment wetland.

Figure 19 Exiting constructed wetland for stormwater treatment at Rainbow Beach. Note the dense growth of aquatic macrophytes in the foreground, with open water and the discharge outlet in the background (Photo taken June 2010).

4.2.9 Bioretention Systems – Modelling parameters

Bioretention systems need to be located in the upper urban catchments in order to take advantage of the grade or hydraulic head (approximately 1m depth) required to allow water to percolate through the filter media and to be discharged back to the stormwater network. Bioretention systems are also much better suited as a treatment distributed treatment system rather than a large “end-of-pipe” system as there may be difficulties evenly distributing stormwater over the surface of the media if they are bigger than $300m^2$ in area. Bioretention systems were sized to complement the treatment provided by the treatment wetlands.

The following design parameters were applied to the bioretention system treatment nodes of the MUSIC modelling:

Parameter	Details
Extended detention (m)	Set at 0.3 or 0.2 m depending on location of bioretention system. A smaller height of extended detention would be required in system incorporated into the streetscape, greater heights would be appropriate for large bioretention basins.
Surface Area (m^2)	Set at the area required to meet the pollutant reduction targets set by Council. Surface of filter media extent was mostly driven by area required to meet TN removal of 45%.
Exfiltration Rate (mm/h)	Set at zero. This is conservative and assumes that the bioretention system will be lined. The bioretention systems may not need to be lined, and if so, water treatment will be better than expected.
Filter Area (m^2)	Same as Surface Area
Filter depth(m)	Set at 0.6 m. Does not include depth of transition and drainage layers (additional 0.3 m, 0.9 m total)
Filter median particle diameter (mm)	0.5
Sat hydraulic conductivity (mm/h)	100
Depth below underdrain (%)	Set at zero. Drainage media was not counted towards the depth of filter media that provides a filtration function.
Overflow weir width (m)	10

The extent of bioretention areas required to complement the treatment wetlands and needed to meet the water quality targets for Rainbow Beach Estate are as follows:

Catchment + Bioretention System Name	Bioretention Area (not inc. batters) m^2
W4a BR a	450
W4a BR b	750
W4a BR c	850
W3 BR a	800
W3 BR b	150
W1e BR a	350
W1e BR b	150

Bioretention systems have not been depicted on the masterplan for the site because their design will be strongly influenced by the urban design (not yet undertaken). These will be located as distributed systems within the streetscape or in areas of public open space.

A list of plant species recommended for use in the bioretention systems is as follows:

Shrubs
Leptospermum spp.
Callistemon spp.
Melaleuca quinquenervia
Melaleuca styphelloides
Melaleuca linearifolia

Sedges & grasses
Carex apressa
Juncus usitatus
Lomandra longifolia
Lomandra hystrix
Imperata cylindrica
Ficinia nodosa
(sedges and grasses should be planted at a density of 12 plants/m2)

Note: this list is intended to provide the reader with an indication of the types of plants that may be used in bioretention systems. It is indicative only and final planting plans may need to accommodate other site factors.

4.2.10 Open Water Wetland

The constructed open water wetland was not modelled as part of the stormwater treatment train because this element is considered to be the receiving environment that requires protection from polluted runoff. Design elements that influence the sustainability of this water body are described in section 5.1. The open water wetland does provide storage for flood detention, adding to the protection of Duchess Gully.

4.2.11 Treatment Train

The stormwater treatment devices modelled as the treatment trains treating runoff from the Rainbow Beach Estate were all successful at meeting or exceeding the water quality target load reductions set by Council for the following modelled parameters:

- 80% Reduction in Total Suspended Sediment (TSS)
- 45% Reduction in Total Nitrogen (TN)
- 60% Reduction in Total Phosphorus (TP)

(All reductions are in terms of annual pollutant load)

The treatment trains proposed for each wetland catchment are shown in the following figures (Figure 20, Figure 21, Figure 22, Figure 23, Figure 24, Figure 25, Figure 26,
Figure 27). Note that the location of swales and bioretention systems are not shown on the masterplan because the location and form of these will be subject to detailed urban design at a later stage.

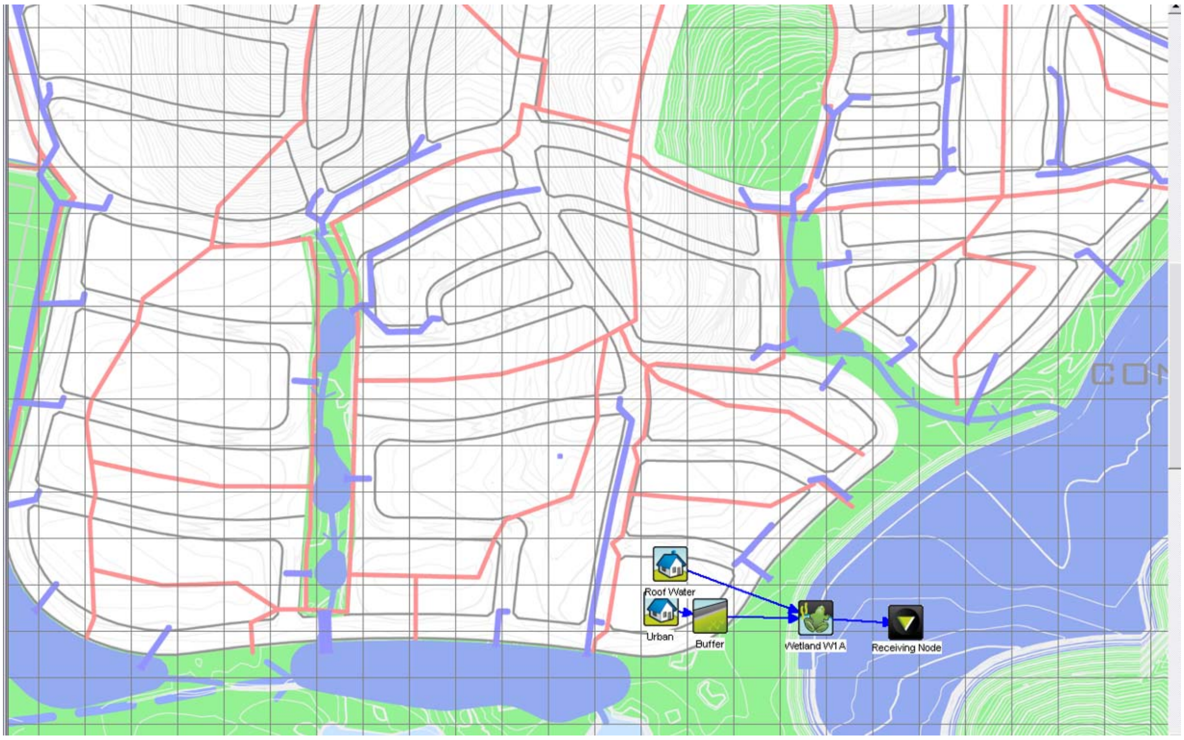

Figure 20 Wetland W1a

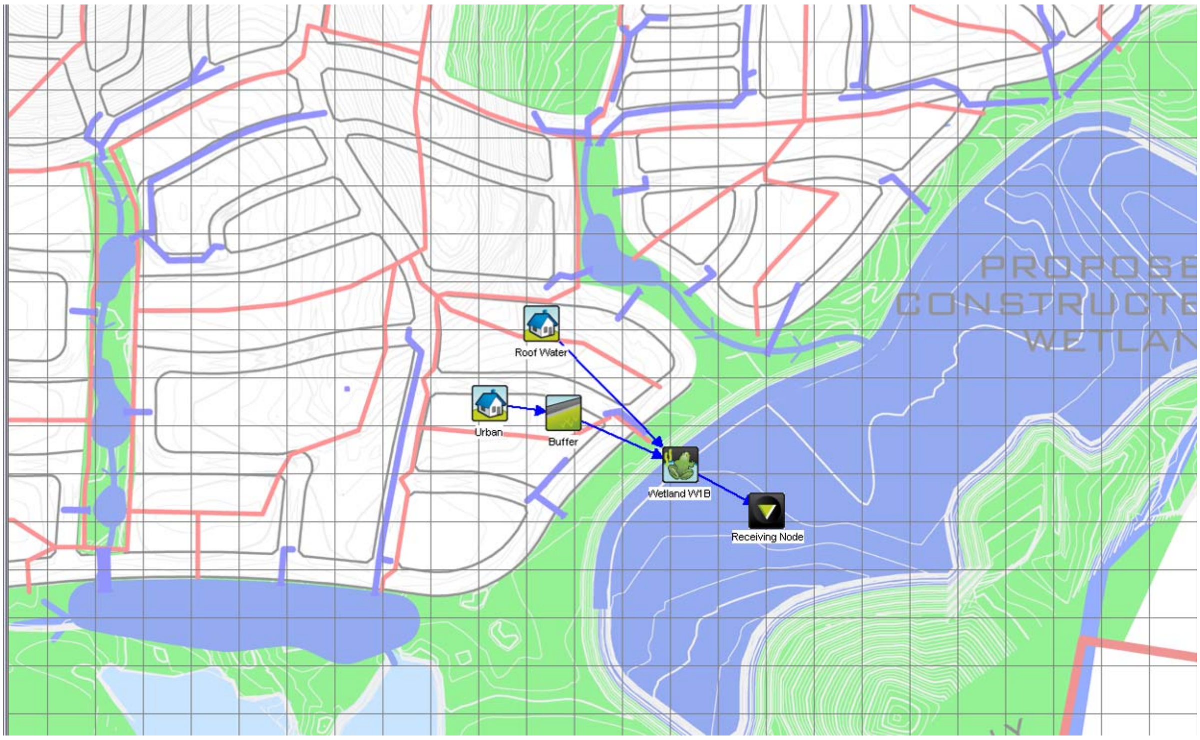

Figure 21 Wetland W1b

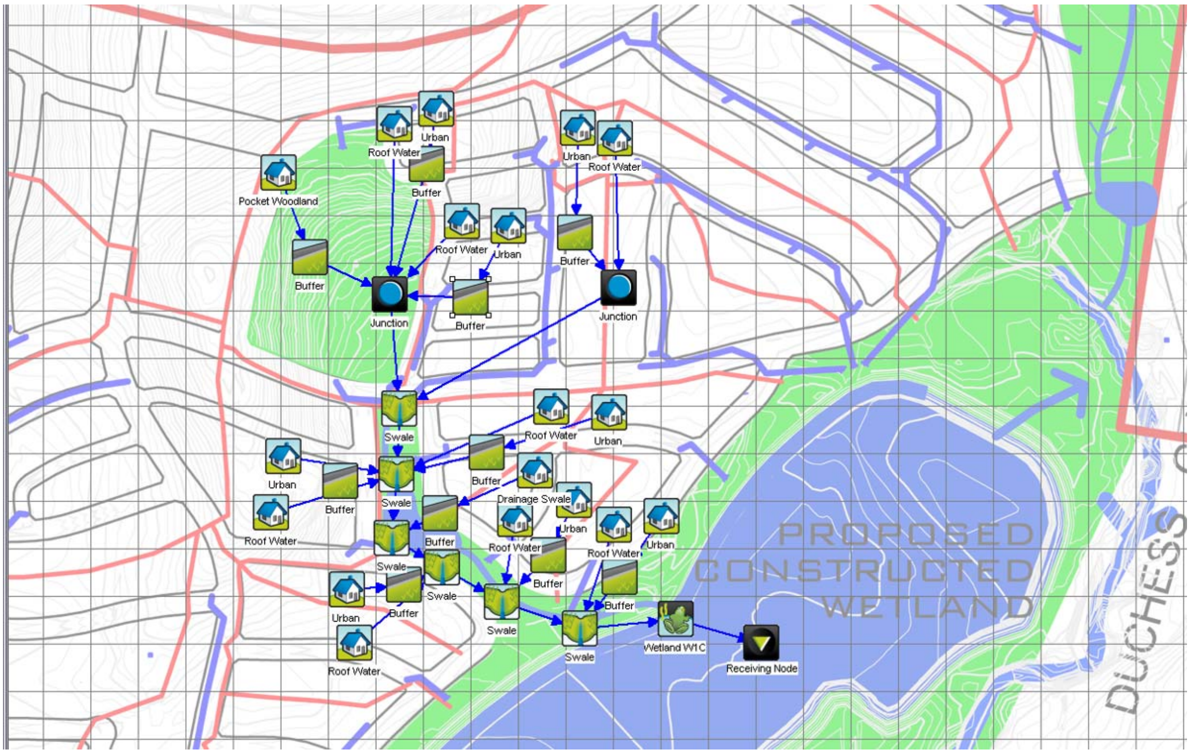

Figure 22 Wetland W1c

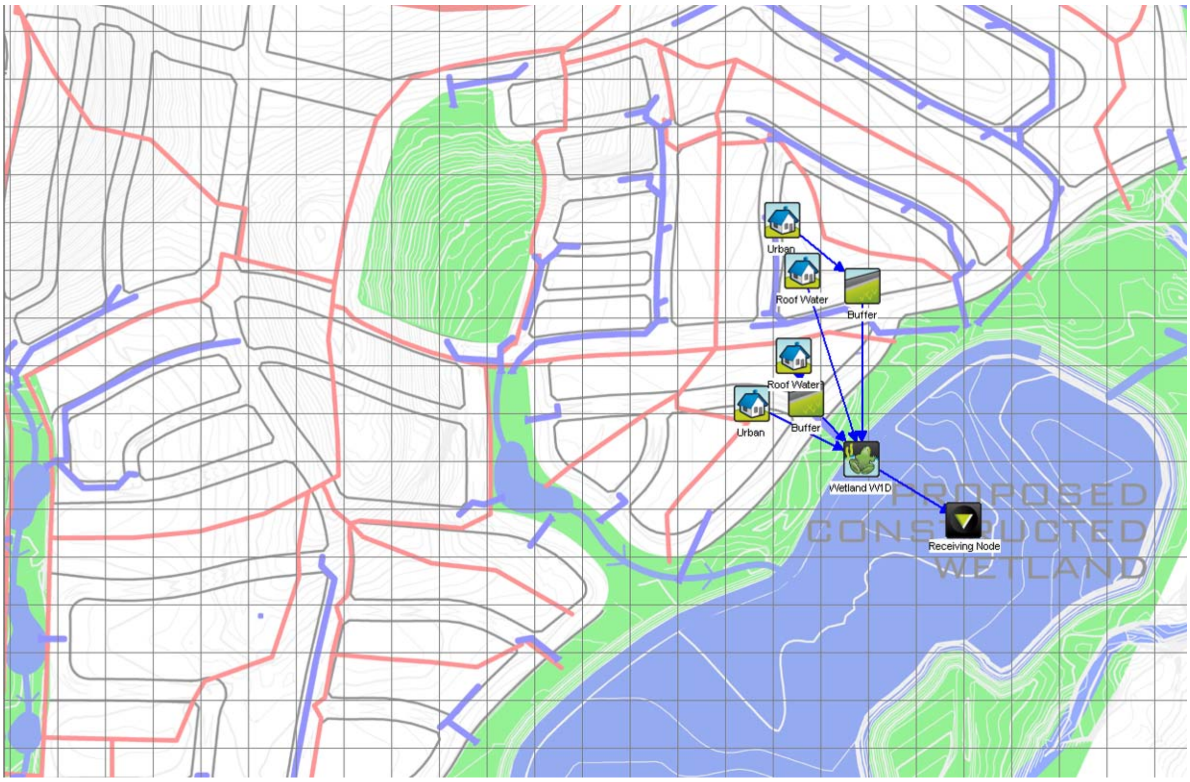

Figure 23 Wetland W1d

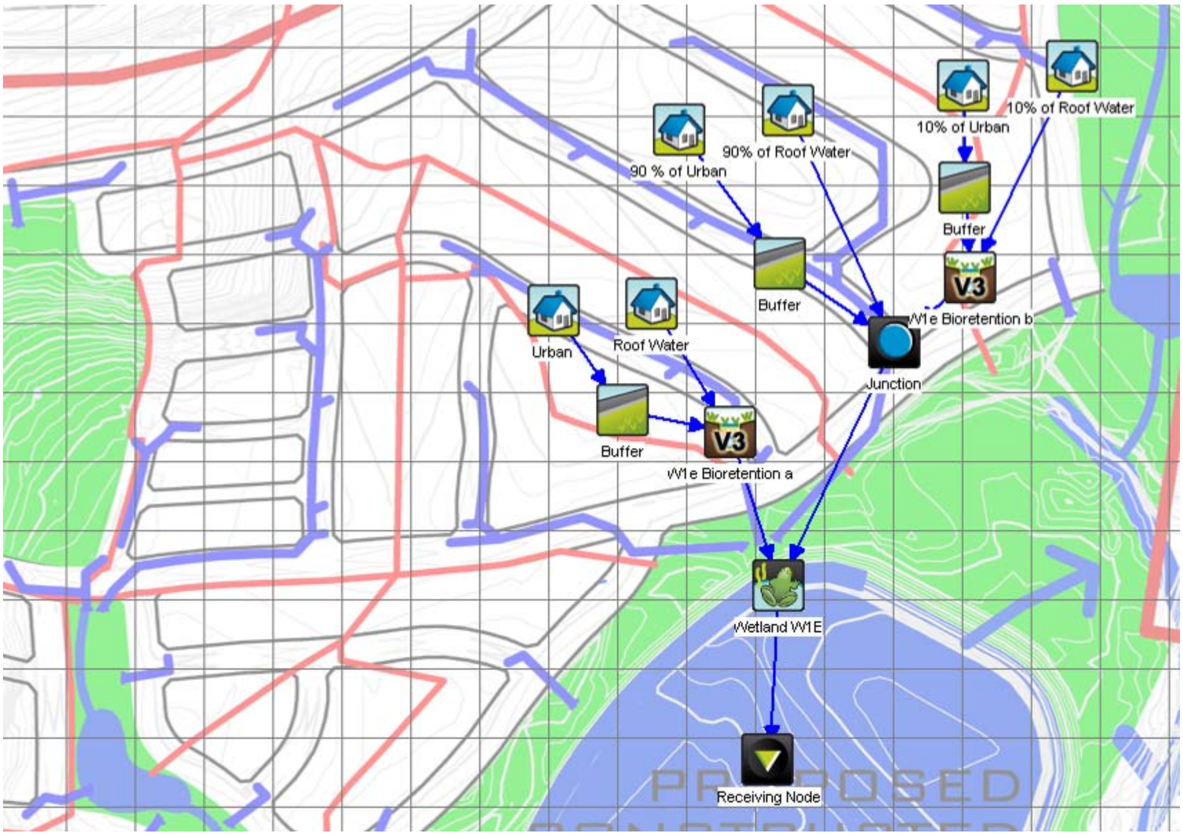

Figure 24 Wetland 1e

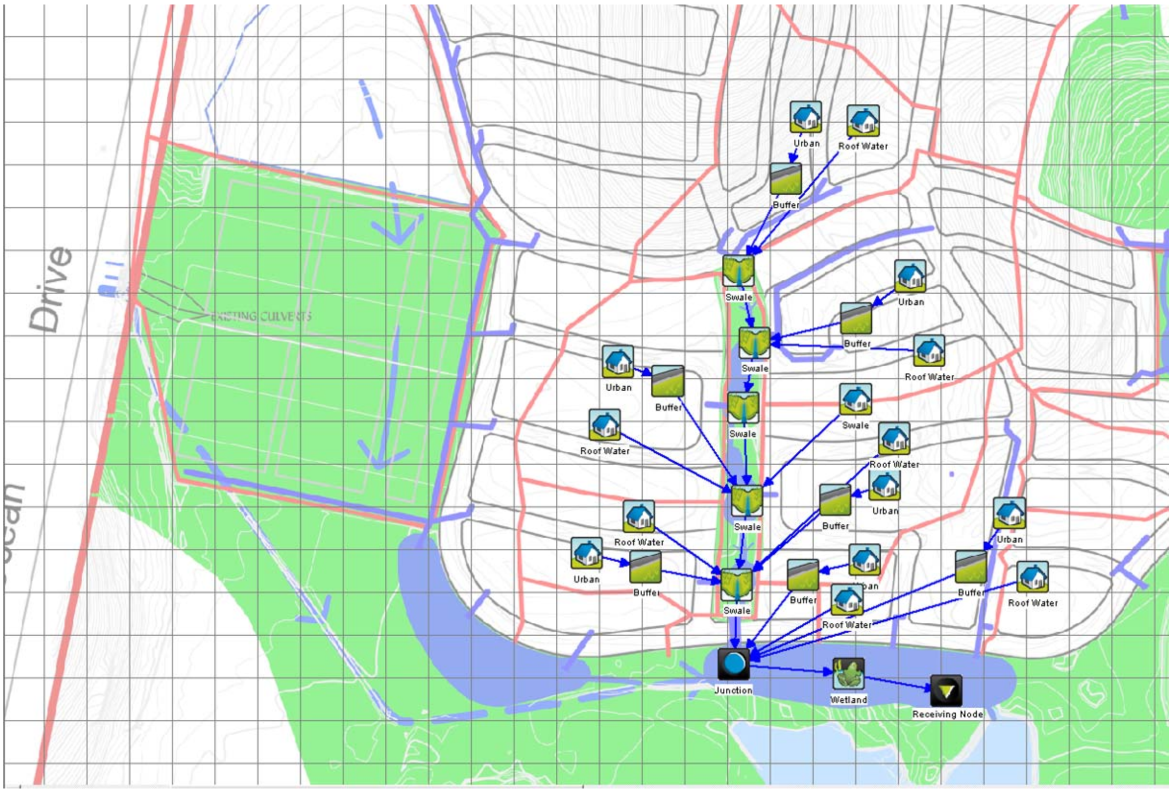

Figure 25 Wetland W2

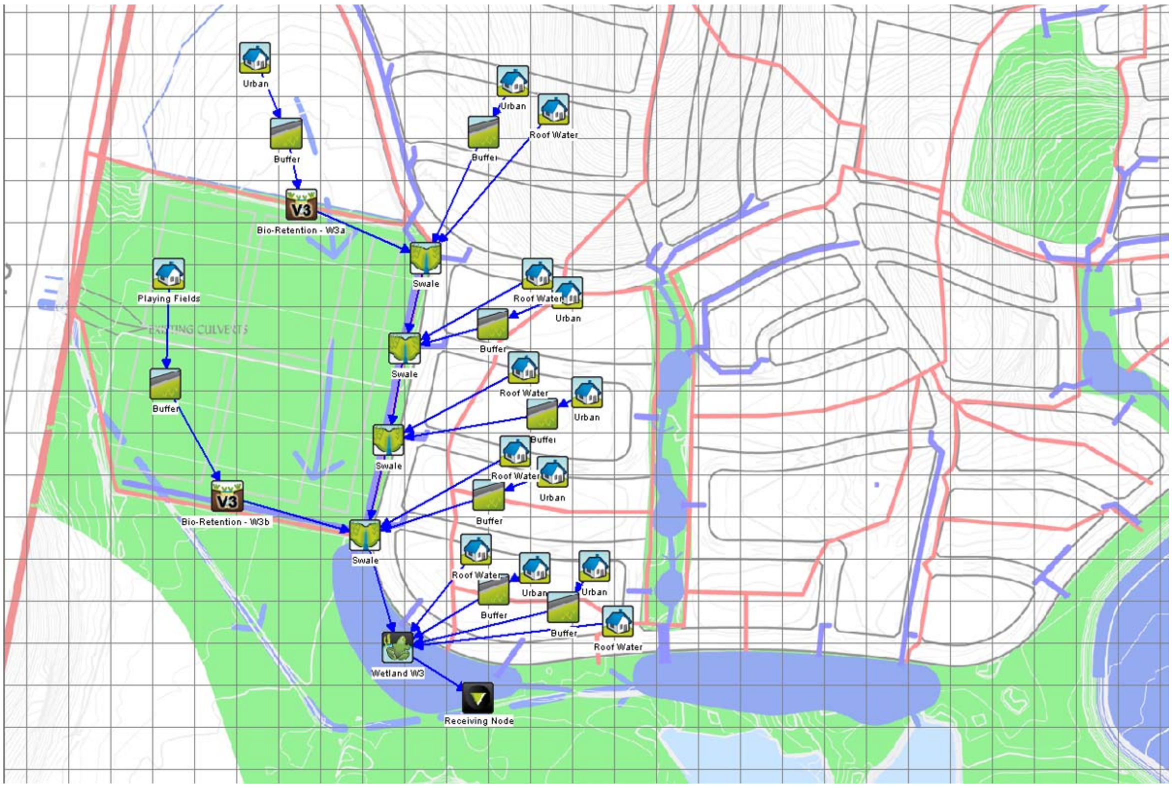

Figure 26 Wetland W3

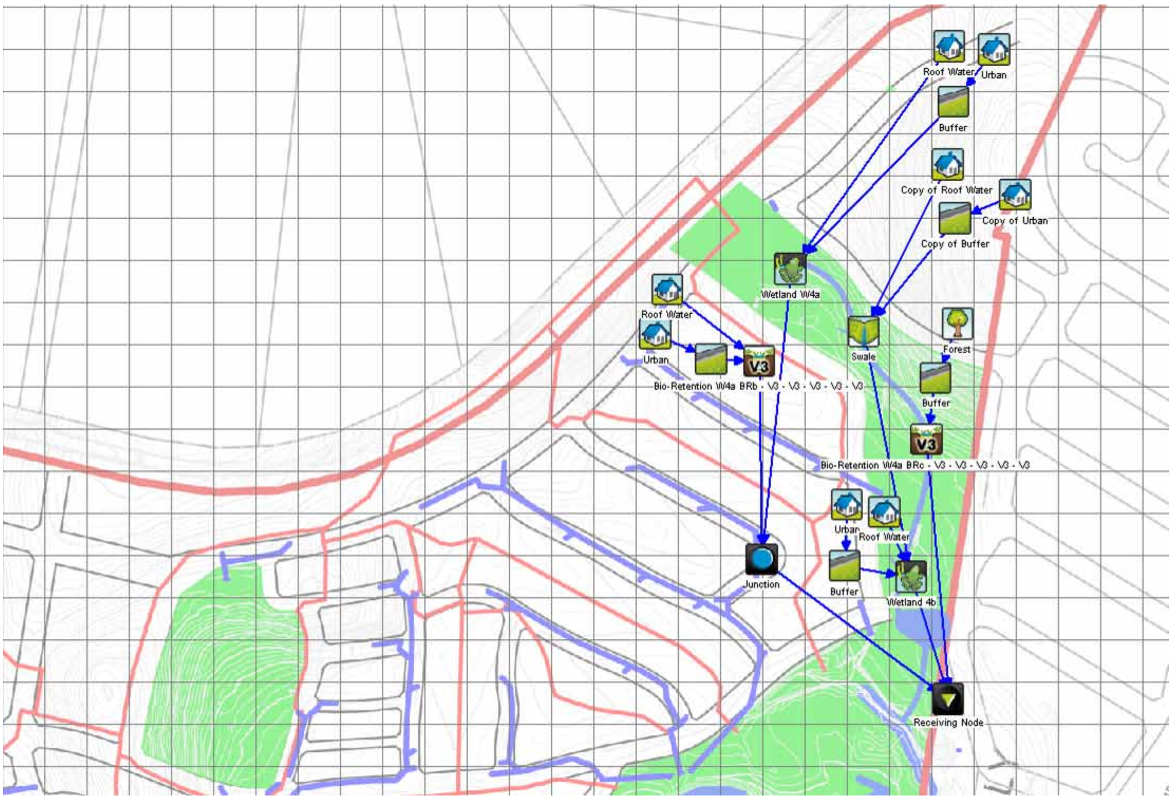

Figure 27 Wetlands W4a & W4b

5 Stormwater Treatment – Discussion of Impacts and Specific Issues

5.1 The constructed open water wetland

5.1.1 Impact of acid groundwater on wetland pH

Groundwater modelling was conducted by WRL (2010) to estimate the risks of poor quality groundwater to the sustainability of the open water wetland. Modelling was based on the following parameters:

- WRL calculated that steady state groundwater inflow to the wetland is approximately 40m3/day. However for the purposes of conservative modelling they assumed that inflow was twice this value, therefore 80 m3/day or 29.2 ML per year.
- From Cardno's calculations it can be estimated that the average annual runoff to the open water wetland was approximately 850 ML per year (average of 2300 m^3/day, based on a catchment area of 354 Ha, with average annual runoff of 240mm) (Table 18, Cardno 2010).

Therefore groundwater inputs to the site are on average 3% of the stormwater inputs (29.2ML/850ML).

WRL (2010) modelled the impact of acid groundwater on the pH of the open water wetland for several scenarios, including highly conservative scenarios that assumed that the stormwater influx was only 320 m3/day (or 14% of the average). The modelling predicted that for all scenarios, the acidity of the water in the open water wetland would remain close to neutral and would be of an acceptable quality.

5.1.2 Impact of groundwater nutrients on wetland water quality

The impact of nutrients associated with the groundwater influx into the open water wetland was estimated as follows:

Average concentrations of Total Nitrogen and Total Phosphorus from groundwater samples recorded from the groundwater bores in proximity to and upstream of the open water wetland were collated, and an overall average calculated as follows:

Groundwater bore	Groundwater concentration (mg/l)	
	TN	TP
LC11/1	2.42	0.07
GW3	2.028	0.5768
GW4	0.459	0.1239
GW6	1.158	0.026
GW7	1.897	0.135
Average of all sites	1.5924	0.18634
Annual Load (kg per year)	46.50	5.44

These values were then compared to the average annual load of Total Nitrogen and Total Phosphorus expected to enter the open water wetland from the Rainbow Beach Estate and the external catchments. The average annual load expected to be delivered to the open water wetland was derived from the MUSIC model for the Rainbow Beach and external catchments supplied by Cardno. This model gave the following results:

	TN (kg/year)	TP (kg/year)
Nutrient load discharged to Open Water Wetland	6590	634

These loads were then compared to the expected nutrient loads likely to be delivered into the Open Water Wetland by surface runoff as follows:

	TN kg/year	TP kg/year
Surface Water Annual load	6590	634
Groundwater Annual Load	46.50	5.44
Groundwater load as % of surface water load	0.71%	0.86%

The load of nutrients discharged to the open water wetland from groundwater is less than 1% of the load of nutrients discharged to the wetland from surface water. Given the very small magnitude of these nutrient loads, nutrients in groundwater are not expected to detrimentally impact on the water quality of the open water wetland.

5.1.3 Expected Water Quality of the Proposed Open Water Wetland

It is expected that the proposed open water wetland will maintain good water quality after the development of the Rainbow Beach Estate. Cardno modelled the water quality in the existing lagoon and proposed open water wetland using the water quality model POND (Cardno 2010). The POND model water quality modelling for the existing lagoon accurately predicted the existing water quality conditions for the existing wetlands. The POND models predicted that the open water wetland will maintain good water quality after the development of the Rainbow Beach Estate.

The protection of the water quality of the open water wetland is provided through several design measures:

- All catchments draining from the Rainbow Beach Estate have stormwater treatment devices that will treat runoff to Council's required standards.
- Baseflows from the existing lagoon are to be routed through the open water wetland to re-instate the discharge point of this catchment to Duchess Gully. The water from this lagoon is known to be of good quality as determined by our field inspection and the results reported in the WEDGRA (Table 14, Cardno 2010). Routing of baseflows through the open water wetland will aid the circulation of water in the open water wetland, and will decrease the residence of water in this waterbody. Minimising the residence time of water in the open water wetland reduces the risk that algal blooms may occur.
- Flood flows from the external catchments from large storm events are conveyed from existing lagoon to discharge directly to Duchess Gully and will not flow into the open water wetland. Bypassing the wetland in this way protects the wetland from high sediment loads that may be associated with flood waters.
- All other flows from local catchments will pass through sedimentation basins prior to discharge to the Open Water Wetland.
- Stratification is unlikely to be persistent in this water body due to the shallow depth. In shallow water, the stratification breaks down most nights as cold water sinks. Additionally, there are no deep holes that help maintain stratification. Stratification can be problematic in lakes if anaerobic conditions are created at depth. Persistent anaerobic conditions at depth may lead to the release of nutrients from the sediments to the water column. These nutrients can support the proliferation of algae leading to algal blooms.
- Stratification is also unlikely because the orientation of the wetland axis aligns with dominant spring and summer winds (SW & NE, refer to Appendix C for wind roses). The orientation of the wetland along this axis provides the wind a long fetch that allows sufficient wind and wave energy to promote turbulence, currents and mixing of the water column. These winds occur at a time when the open water wetland would be most prone to algal blooms – during spring when rainfall is lowest leading to the longest residence times, and during summer when water temperatures and consequently algal growth rates, are highest.
- The benthos of the wetland will be planted with submerged aquatic macrophytes. These grow well in the adjacent existing lagoon and are also expected to grow well in the proposed wetland. These help to maintain the water quality by stabilising trapped sediment, and oxygenating the sediment, thus preventing the anaerobic conditions that lead to nutrient releases.

5.1.4 Design recommendations

Several design recommendations are made to ensure that the finished landscape is robust and stable:

- The bottom contours of wetland should be kept higher than the potential acid sulphate soils in order to prevent the possible oxidation of acid sulphate soil material.
- Wave-caused erosion may be an issue along the south-western shore. Resistance to erosion should be addressed by lining this shore of the lake with cobbles. The cobbles will act to dissipate the wave energy. The cobbles should be backfilled with suitable soil and interplanted with vegetation.
- Weed invasion to the wetland should be managed by blocking the passage of weeds to the water via the littoral zone. Many emergent aquatic weeds that are problems in wetlands (such as Typha or Torpedo grass) have very small seeds that germinate only on moist, exposed soil. The small size of the seed does not have the resources to grow through existing mulch or plant material, or to germinate under water. Therefore, the spread of these weeds can be suppressed by dense planting around the wetland edges that excludes weed propagules from the ephemerally wet lake shore. Weed spread is prevented through shading and competition for space and resources. The experience of the resident bush regenerator (Wildthings Native Gardens) indicates that this design recommendation is achievable.

5.1.5 Habitat features of the Open Water Wetland

The open water wetland will be designed with features to provide aquatic habitat. These include (refer also Figure 28):

- An undulating edge on the eastern shore to create habitat diversity, with steeper and shallower batters in different areas
- Placement of salvaged logs to provide fish and bird habitat
- Fringing aquatic and terrestrial vegetation (refer Figure 29)
- Open water for use by birds and pelagic fish
- Fringing vegetation will provide habitat for wading birds, perching areas, fish habitat, invertebrates (insects & crustaceans).
- The wetland shore will be vegetated with plants with proven resistance to torpedo grass, to be based on site experience from the current bush regenerator (Wild Things Native Gardens).

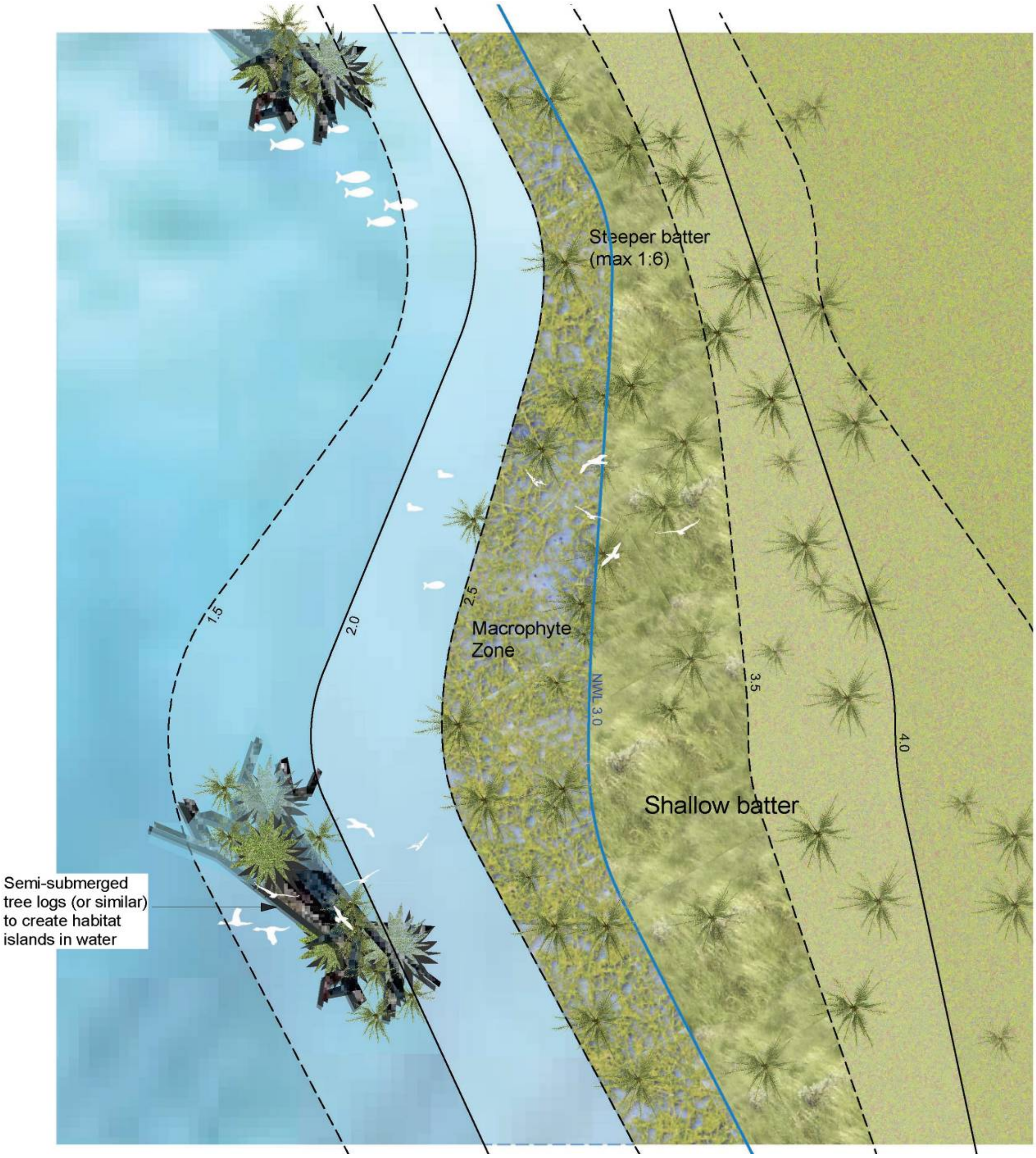

Figure 28 Design of the eastern shore of the proposed open water wetland with features such as undulating shoreline, macrophytes, logs, and fringing vegetation to improve the habitat value of this area.

Figure 29 Regenerating aquatic habitat along the edge of the existing lagoon.

5.3 Wallum Froglet Marshland

The Wallum Froglet habitat is on a marshland on perched clay. This marshland is unlikely to be influenced by groundwater and will not receive stormwater from urban areas. Part of a small catchment that feeds runoff to the Wallum Froglet habitat will be lost to accommodate the new constructed wetland. An equivalent area of catchment will be created to the north of the Wallum Froglet habitat. The catchment area after development of the site will be approximately the same as currently exists.

Potential impacts of the development on the Wallum Froglet Marshland a considered in a separate report: “Assessment of the supporting hydrology of the Wallum Froglet Marshland at Rainbow Beach” (AECOM 2010).

5.4 Maintenance requirements

Council are concerned that proposed wetlands have the potential for water quality problems and algal blooms and aquatic weed proliferation. A meeting was held on the 1st June 2010 attended by Port Macquarie Hastings Council, AECOM, TPS and St Vincent’s Foundation staff to discuss the proposed wetland designs. It is anticipated that the meeting and this report appropriately addresses the concerns of Council regarding the wetland designs.

Council Comment (from Port Macquarie-Hastings Council in a letter to TPS dated 25 June 2009):

> *“The main concerns in relation to the smaller proposed wetlands are the ongoing maintenance costs including the potential for water quality problems, algal blooms and aquatic weed proliferation. While it is acknowledged that the Cardno report indicates the existing lake is free of weeds this is unlikely to be the case when development is intensified. The proposed wetlands ponds W2 and W3 appear unnecessary and would contribute to further maintenance costs. lt is strongly recommended that consideration be given to combining the two existing small systems E1 and E2 with proposed W2 and W3 to provide a single more management system. Ultimately three larger systems (E3, W1 and a new combined system) would be cheaper and simpler to maintain financially and practically. Alternatively, all of the proposed small wetlands should be incorporated into part of the existing lake (i.e. the south eastern end), lt may be possible to reduce the footprint of proposed wetland (W1) with this modification to the existing ponds.”*

Notes in response:

- Wetlands are sized according to footprint required for each catchment to achieve adequate pollutant removal from stormwater runoff.
- The location of wetlands is determined mostly by topography and appropriate locations for wetland inlets and outlets, and with consideration of other existing site constraints such as vegetation or other land uses. Consolidation of some of the wetlands may be possible during the detailed design phase. This will require the cut and fill design to be revisited in order to consolidate some of the catchments. This is most likely to be possible for the catchments that feed the wetlands W1a, W1b, W1c or W1d.
- Water quality problems in the treatment wetlands for stormwater treatment (namely: W1a, W1b, W1c, W1d, W1e,W2, W3, W4) are unlikely to occur as these wetlands will be heavily vegetated and designed specifically for the purpose of water quality improvement.
- Algal blooms are unlikely to occur in these wetlands, and the dense emergent macrophyte plantings normally provide sufficient shade to control the growth of algae in the water column of the wetland.
- Aquatic weed proliferation is also controlled through dense macrophyte plantings. Dense plantings assist in excluding the establishment of weed propagules through competition for resources such as light and space. Effective weed management requires regular monitoring and the early removal of weed propagules from the wetlands soon after they become apparent.

Council Comment:

"The proposed stormwater quality edge treatment on the northern edge of the wetland is not desirable. It is unlikely this narrow strip will function in reality given the likely low detention times and poor hydraulic efficiency. In addition, the layout has ongoing maintenance and access issues. An alternative solution is required."

Notes in response:

- The wetlands that comprise the proposed stormwater quality edge treatment on the northern edge of the wetland (W1a to W1e) have been sized according to footprint required for each catchment to achieve adequate pollutant removal from stormwater runoff (as determined by MUSIC modelling). The wetland design parameters include detention times of 72 hours, and width to length ratio of greater than 1:5, as specified by Hastings Council (2003). These parameters ensure that wetlands will be designed to provide optimal pollutant removal.
- Maintenance access has been resolved through the provision of a vegetated bund to the eastern edge of all of the wetlands W1a to W1e. This bund will allow access for bush regenerators or similarly skilled personnel to undertaken regular weeding and monitoring of the wetland inlet and outlet structures.

5.5 Surface Water Monitoring

The WEDGRA (Appendix C, Cardno 2010) provides the following recommendations in the Surface Water Monitoring Plan.

Surface water quality in the wetlands flow zone should at all times be suitable for –

- Sustainability of the coastal floodplain ecosystem
- Passive recreation use
- Irrigation of native vegetation species

Measured surface water quality should comply with the criteria given in **Error! Reference source not found.**, at the 90 percentile level (refer to ANZECC 2000).

Table 2 Surface Water Quality Compliance Criteria

Parameter	Surface Water Quality Trigger Value
PH	6.5 to 7.5
Turbidity	1 – 20 ntu
Chlorophyll a	0.005 mg/L
Salinity	0.02 – 0.03 mS/cm
Dissolved Oxygen	90 – 100 % saturation
Total Nitrogen	0.35 mg/L
Total Phosphorus	0.01 mg/L

Surface water should be sampled in the existing western tributary lagoons and the proposed constructed wetlands (the open water wetland) flow zone at suitable locations near the centre of the water bodies and at sufficient depths to characterise the vertical profile. Each location and depth should be sampled in accordance with the schedule outlined in Table 3.

Table 3 Surface Water Sampling Schedule

Project Stage	Frequency	Tests
Pre-construction	Fortnightly (for 2 months); then Monthly if consistent (**)	• Turbidity • Conductivity / Salinity • Temp (temperature) • pH • DO (dissolved oxygen) • ORP • Total N, P
	Monthly (*)	• Chlorophyll a
Construction	Weekly	• Turbidity • Conductivity / Salinity • Temp • pH • DO
	Monthly	• Chlorophyll a • ORP • Total N, P
Operational	Quarterly	• Turbidity • Conductivity / Salinity • Temp (temperature) • pH • DO (dissolved oxygen) • ORP • Total N, P • Chlorophyll a

Notes:
(*) Pre-construction quarterly tests should provide at least three sets of samples over six months prior to construction activities on site.
(**) Pre-construction fortnightly tests can be reduced to monthly frequency if results over two months show consistent data.

The water quality values given in Table 2 are not intended to be used as threshold values, rather they should be used in conjunction with professional judgement to provide an assessment of a waterbody. Exceedance of these values implies only that a *potential* risk exists and that continued monitoring is recommended to ensure that there is no decline in water quality values over time.

Some flexibility should be considered in the use of the trigger values presented in Table 2. These are derived from the ANZECC (2000) guidelines designed to protect “slightly disturbed ecosystems” from detrimental change, whereas they are being applied to waterbodies that would fall in the category of “highly disturbed ecosystems”. The wetlands are considered highly disturbed because they are artificially constructed, and will be fed by urban catchments that are highly altered in comparison to their natural state. Therefore, monitoring results that approach or meet the criteria may indicate relatively good ecosystem health, considering the artificial nature of the wetlands and catchments.

6 Conclusion

The surface water management strategy proposed by Cardno (2010) has been slightly modified and is logical and practicable and appropriate for the proposed development at Rainbow Beach. Additionally, groundwater studies for the site have concluded that due to the poor quality of the groundwater resources of the site, surface runoff is unlikely to detrimentally impact the quality of the aquifer (WRL 2010). AECOM have built upon that work by Cardno and this report provides greater detail sufficient to guide the detailed design of the treatment devices appropriate to the stormwater treatment train at Rainbow Beach Estate. The recommendations made herein are designed to ensure that the aquatic features of the Central Corridor will:

- provide adequate treatment for stormwater runoff from the development
- protect the water quality of the open water wetland and Duchess Gully to ensure that the ecosystem health of these features is sustained.
- incorporate features that facilitate maintenance
- provide an attractive, robust and relatively low maintenance landscape, and
- provide habitat that complements the habitat provided throughout the Central Corridor.

The strategy outlined by Cardno and refined in this report presents no technical challenges to achieving compliance with Council's WSUD criteria for the protection of the surface water and groundwater environments. The strategy outlined by Cardno (2010) and the additional groundwater investigation and report by WRL (2010) also addresses the concerns raised by the NSW Office of Water. The design recommendations made in this AECOM report will minimise the future maintenance requirements and should help to overcome any uncertainties that regulatory authorities may have regarding the maintenance of stormwater treatment devices.

7 References

ACT Government 2006, Rainwater tanks – Guidelines for residential properties in Canberra, available online at www.actpla.act.gov.au/data/assets/pdf_file/0003/3378/**tank**s.pdf

Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) (ANZECC). Available here: http://www.mincos.gov.au/publications/australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality

Cardno (April 2010). Water Engineering and Environment DGR Assessments, Rainbow Beach Estate, Bonny Hills (The WEDGRA).

Engineers Australia (2006) AUSTRALIAN RUNOFF QUALITY: A guide to Water Sensitive Urban Design. Chapter 4: Water Sensitive Urban Design. National Committee for Water Engineering ,231pp. Editor-in-Chief: T.H.F.Wong.

Hastings Council (2003) Aus-Spec D7 Stormwater Management (AUS-SPEC 2003).

Melbourne Water (undated) Constructed Wetland Systems Design Guidelines for Developers. Available at: http://www.clearwater.asn.au/resources/324_1.pdf

Taylor, A.C *(2005) Structural Stormwater Quality BMP Cost / Size Relationship Information From the Literature. Version .3 Cooperative Research Centre for Catchment Hydrology. Urban Stormwater Quality Program. Available here:* www.toolkit.net.au/Tools/DownloadPublication.aspx?id=1000020

Taylor, A.C. (2003). An Introduction to Life cycle Costing Involving Structural Stormwater Quality Management Measures. Technical Paper. Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria. Available at: www.catchment.crc.org.au (August 2004).

The Ecology Lab Pty Ltd (2008). Aquatic Flora & Fauna Survey Rainbow Beach, Bonny Hills – St Vincents Foundation.

Water Research Laboratory, University of NSW (March 2010). Groundwater Characterisation and Numerical Modelling for Rainbow Beach Estate.