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CONSTRUCTED WETLAND MANAGEMENT PLAN CYGNIA COVE ESTATE, WATERFORD - CONDITION 6, MINISTERIAL STATEMENT NO. 692/EPA ASSESSMENT NO. 1467

Prepared for:

The Trustees of the Christian Brothers in WA Inc.
c/- Richard Noble and Company
Level 1, 189 Hay Street
SUBIACO WA 6008

Report Date: 13 August 2008
Project Ref: 2007/122, V3

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13 August 2008

The Trustees of the Christian Brothers in WA Inc.
c/- Richard Noble and Company
Level 1, 189 Hay Street
SUBIACO WA 6008

Attention: Mr Alex Gregg

Dear Alex,

RE: Constructed Wetland Management Plan Cygnia Cove Estate, Waterford - Condition 6, Ministerial Statement No. 692/EPA Assessment No. 1467

Enclosed is Version 3 of the Wetland Management Plan for the proposed constructed wetland to be created at the Cygnia Cove Estate, Waterford. This Management Plan has been prepared in accordance with the requirements of Condition 6 contained in Ministerial Statement No. 692. It also incorporates those comments discussed with relevant regulatory authorities.

Please contact the undersigned on (08) 6462 7900 or Paul_Zuvela@coffey.com if you have questions regarding the content of this report.

For and on behalf of Coffey Environments Pty Ltd

Paul Zuvela
Manager (Environmental Planning)

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1 ea	ENVIPERT00213AA_Wetland Management Plan_002_pz_V3	Version 3	13 August 2008	• The Trustees of the Christian Brothers of WA Inc. • City of South Perth • Swan River Trust • Department of Environment and Conservation • Department of Water	PZ

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1 INTRODUCTION

1.1 Background

The Trustees of the Christian Brothers in WA Incorporated (the Proponent) propose to develop their land at Waterford for a residential subdivision to be known as Cygnia Cove Estate (formerly known as East Clontarf).

The development of Cygnia Cove Estate has been planned as part of the Proponent's strategy to generate funds for the on-going maintenance of the Clontarf Campus as well as other community services provided by The Christian Brothers in both Western Australia and South Australia.

The site has historically been used for farmland (grazing and market gardens), pine plantation and building infrastructure. The farm paddocks originally extended to the periphery of the wetlands and the swamp areas were fenced to prevent stock gaining access and becoming bogged in the mud. Rubble in the form of brick fragments, concrete blocks, glass, ceramic tiles, metal sheets, rods and asbestos cement sheeting fragments have also been dumped on the site.

The subdivision has been formally assessed (Public Environmental Review) by the Environmental Protection Authority (EPA) and approval was granted by the Minister for the Environment. The Ministerial approval for the subdivision of the subject land was granted subject to a number of conditions as outlined in Ministerial Statement No. 692. One of the conditions requires that the Proponent shall design and construct an artificial wetland for the purposes of Black Swan (*Cygnus atratus*) breeding habitat as an off-set to the development on some of the existing Resource Enhancement Wetland on the subject land. The constructed wetland will link with the portion of the existing wetland being retained and the Canning River.

1.2 Purpose and Scope

The Proponent has commissioned Coffey Environments (formerly ATA Environmental) to prepare a Wetland Management Plan for the constructed wetland. This Wetland Management Plan fulfils the Ministerial requirements.

The wetland design has been developed by a multi-disciplinary team consisting of TABEC (civil engineers), JDA (consultant hydrologists), Bamford Consulting Ecologists (ecologist), Plan E (landscape architects) and Coffey Environments (environmental consultants).

1.2.1 Ministerial Statement No. 692 Condition 6: Wetland

6.1 Within 12 months following subdivision/development approval, the Proponent shall substantially commence construction of an approximately 1.8ha wetland shown in Figure 1 of Schedule 1 as Public Open Space, to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority (EPA).

This wetland shall include the following:

- Black Swan breeding habitat;
- Revegetation with local indigenous species;
- Landform re-contouring;

- Establishment and maintenance of wetland connection to Clontarf Bay and the Canning River;
- Weed control measures;
- Water quality and quantity monitoring; and
- Contingency measures to maintain or improve water quality of water flowing into Clontarf Bay and the Canning River.

6.2 Prior to the commencement of construction of the wetland required by condition 6-1, the Proponent shall prepare a Wetland Management Plan which includes the identification of species to be used in revegetation works on site, to the requirements of the Minister for the Environment on advice of the EPA.

6.3 The Proponent shall implement the Wetland Management Plan required by condition 6-2.

6.4 The Proponent shall make the Wetland Management Plan required by condition 6-2 publicly available.

A Wetland Management Plan for the retained portion of the existing wetland upstream of the proposed constructed wetland site has been prepared by Coffey Environments (2008a) and is separate to this report.

1.3 Location

The site is located approximately 8km southeast of the Perth Central Business District (Figure 1) and is bound by the Canning River to the south, Manning Road to the north, Centenary Avenue to the east and the Clontarf Campus to the west.

The constructed wetland will be located on the western side of the existing drainage channel in the southwest portion of the proposed subdivision (Figure 2).

2 EXISTING ENVIRONMENT

2.1 Climate

The area has a Mediterranean climate with mild wet winters and hot dry summers. The hottest months are January and February and rain falls primarily in the winter months. Long term average rainfall is approximately 860mm (based on Bureau of Meteorology's Perth Regional Station, 1880 to present). The annual average rainfall has decreased significantly since the mid-1970s.

Seasonal wind patterns consist of a moderate south-easterly during the mornings in summer, with a moderate south-westerly in the afternoon. The winter pattern reflects synoptic flow. For example, north-westerly wind would be expected following a cold front.

2.2 Topography

Topographic contours range from 0mAHD (Australian Height Datum) immediately adjacent to Clontarf Bay to approximately 2.5mAHD in the northern portion of the proposed wetland site (Figure 2). The site slopes downwards on a gentle grade from north to south towards Clontarf Bay.

2.3 Geomorphology and Surface Geology

Environmental geology mapping of the site shows that a large part of the site is considered part of the Canning River floodplain (Jordan, 1986).

A geotechnical assessment of the site was undertaken by Coffey Geosciences (2000). The constructed wetland site is low-lying adjacent to the Canning River foreshore. The soil is generally medium dense sand over clayey sand, sandy clay and clay of the Guildford Formation.

2.4 Soil Contamination

ATA Environmental has previously investigated soil and groundwater contamination at the site, as described in the following reports:

- *Environmental Assessment, East Clontarf, Manning* (ATA Environmental, 2001). ATA Environmental Report 2000/179. Prepared for The Trustees of the Christian Brothers, January 2001.
- *Preliminary Assessment, East Clontarf, Manning* (ATA Environmental, 2002). ATA Environmental Report 2002/47. Prepared for The Trustees of the Christian Brothers, May 2002.
- *Remediation Report, Asbestos Contamination, Clontarf Aboriginal College, Manning* (ATA Environmental, 2002). ATA Environmental Report 2002/122. Prepared for The Trustees of the Christian Brothers, September 2002.
- *Detailed Soil/Groundwater Contamination and Preliminary Acid Sulphate Soils Investigation, Sampling and Analysis Program* (ATA Environmental, 2002). ATA Environmental Report 2002/147. Prepared for The Trustees of the Christian Brothers, December 2002.

- *Preliminary Acid Sulphate Soils Investigation, East Clontarf, Manning* (ATA Environmental, 2003a). ATA Environmental Report 2003/115. Prepared for The Trustees of the Christian Brothers,
  August 2003.

- *Detailed Soil and Groundwater Investigation, East Clontarf, Waterford* (ATA Environmental, 2003). ATA Environmental Report 2002/92. Prepared for The Trustees of the Christian Brothers, December 2003.

The contamination investigations found that parts of the Cygnia Cove Estate site have been used for uncontrolled rubbish dumping in the past and contamination associated with the uncontrolled fill is present. However, there was no evidence of contamination at the proposed wetland site. This was confirmed during the drilling program undertaken as part of the acid sulphate soils investigations.

2.5 Acid Sulphate Soils

Majority of the proposed wetland site is mapped in the updated Western Australian Planning Commission's (2007) *Planning Bulletin No. 64 Acid Sulphate Soils* as High to Moderate risk of Acid Sulphate Soils (ASS) occurring within 3m of the natural surface level.

(2008) Environments has undertaken a site specific ASS investigation at the proposed wetland site and found ASS present between 1.75m and 3m below existing surface level. The results obtained exceed the Department of Environment and Conservation's (DEC) Action Criteria. Other locations in the Cygnia Cove Estate were also were found to exceed DEC Action Criteria.

1.4 Hydrology

1.4.1 Surface Water

JDA (2004) reported that approximately 12.2ha of the Cygnia Cove Estate is estimated to drain to the existing wetland upstream of the proposed constructed wetland site. The remaining 6.3ha of the Cygnia Cove Estate (including the proposed constructed wetland site) is estimated to drain directly to the Canning River.

The Cygnia Cove Estate also receives surface drainage from external catchments as follows:

- Manning Road and Conlon Street catchment of approximately 6.9ha which discharges to into the north-western area of the wetland via piped drainage. The extent of this catchment area is indicative only as it is based on topographic data.

- Centenary Avenue catchment (26.0ha), which includes urban areas to the east of Centenary Avenue and north of Manning Road. These areas discharge into the Cygnia Cove Estate via piped drainage under Centenary Avenue into the eastern region of the wetland.

- Two smaller catchments to the west (1.0ha) and southeast (1.5ha), which may discharge into the Cygnia Cove Estate from impervious areas as diffused overland flow.

- On this basis, JDA (2004) estimate that the total estimated upstream area draining into Cygnia Cove Estate is 35.4ha, of which 33.9ha drains into the existing wetland and is discharged to the Canning River through a 750mm diameter culvert from the existing wetland into a trapezoidal channel.

- The flow rate discharging from the existing wetland was estimated by JDA during field work on 10 November 2002 and 31 December 2002 to be approximately 20L/s. However, in January 2007, JDA measured the flow rate to be 10L/s. This reduction is probably due to the significant decline in rainfall during 2006. In April 2008, Coffey Environments measured the flow rate discharging from the culvert as 22.46L/s, and in May 2008 the flow rate was 24.23L/s. The proponent will continue to collect monthly pre-development flow rate data until September 2008.

- Assuming 35% rainfall run off from the 46.1ha catchment and 790mm/year rainfall, the estimated annual average surface runoff is approximately 127,000m^3/year, corresponding to 4L/s, which is less than the observed discharge (JDA, 2004). It is therefore, considered unlikely that surface drainage is sustaining the observed discharge from the existing wetland to the Canning River.

- Coffey Environments has collected two surface water samples from the existing drainage channel with both samples analysed by a NATA accredited laboratory for a range of parameters. Due to the proximity of the Canning River, the results have been compared to the guidelines for Aquatic Ecosystems (for Fresh Waters, including Lowland Rivers values where available, from ANZECC and ARMCANZ, 2000). The results show that surface water quality is good, although exceedances in mercury and zinc levels were recorded. Explanation of these exceedances is provided below:

- Mercury levels were analysed at a detection limit of 0.0002 mg/L which exceeds the Freshwater Guidelines criterion of 0.00006 mg/L. Current NATA certified methods are not able to achieve detection limits that will determine exceedance of the Freshwater Guideline criterion for Mercury. The *Australian Drinking Water Guidelines* (2004) nominate a health criterion of 0.001 mg/L, which is greater than the detection limited used for the analysis of the surface water samples from the Cygnia Cove Estate site.

- The Freshwater Guideline criterion for zinc is 0.008 mg/L. The unfiltered sample collected from the river side of the culvert in the existing drainage channel recorded a value of 0.007 mg/L which is less than the Freshwater Guideline criterion. The filtered sample recorded a level of 0.016 mg/L. The unfiltered sample collected from Clontarf Bay recorded a level of 0.009 mg/L, while the filtered sample recorded a level 0.014 mg/L. The application of Freshwater Guidelines to the sample collected from Clontarf Bay is not appropriate due to the salinity levels of the River being (at the time of sampling) at estuarine or marine levels. The criterion for marine waters for zinc is 0.015 mg/L. The difference in the filtered vs. unfiltered results suggests possible contamination associated with the filters used in the laboratory. In addition, the Australian Drinking Water Guidelines state that there is insufficient data to set a criterion based on health considerations. However, *"based on aesthetic considerations (taste), the concentration of zinc in **drinking water** should be less than 3 mg/L."* The *Australian Drinking Water Guidelines* (2004) also state that *"in major Australian reticulated supplies, the concentration of zinc ranges up to 0.26 mg/L, with a typical concentration of 0.05 mg/L*."

- The proposed wetland site is located outside of the 100 year flood zone for the Canning River.

1.4.2 Groundwater

The site lies on the northern bank of the Canning River within the Cloverdale groundwater flow area of the superficial formation aquifer (Davidson, 1995). The superficial formation extends down to approximately 25m below AHD and is underlain by the Leederville Formation aquifer which is approximately 300m thick. Davidson (1995) indicates an upward head between the

two aquifers indicating that the area is one of groundwater discharge from the Leederville to the superficial aquifer.

The direction of groundwater flow in the superficial formation is essentially south towards the Canning River.

Groundwater salinity beneath the site is described by Davidson (1995) as fresh (<1,000mg/l) although salinity increases along the Canning River foreshore due to mixing with higher salinity river water.

Coffey Environments has installed and monitored (quarterly basis) a bore located at the proposed wetland site. The bore was installed in March 2006 and sampling commenced during the same month following development and settling of the bore. Samples have been analysed for the following suite of parameters:

- A suite of metals (As, Ba, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Zn);
- Organochlorine (OC) and organophosphate (OP) pesticides;
- Total Petroleum Hydrocarbons (TPHs);
- Benzene, toluene, ethylbenzene, and xylenes (BTEX);
- Polycyclic aromatic hydrocarbons (PAHs);
- Inorganic parameters (pH, conductivity, total suspended solids (TSS), acidity, alkalinity, carbonate, hydroxide, chloride, sulphate, and hardness); and
- Nutrients (ammonia-N, NO_x-N, total Kjeldahl nitrogen, total nitrogen, and total phosphorous).

Due to the proximity of the Canning River, the results have been compared to the guidelines for Aquatic Ecosystems (for Fresh Waters, including Lowland Rivers) values where available, from ANZECC and ARMCANZ (2000). The results indicate the following:

Metals

The following analytes exceeded the Aquatic Ecosystems criteria in one or more rounds (considering the data for filtered samples from the March 2006 round only):

- aluminium;
- selenium; and
- zinc.

Organics

There are no Aquatic Ecosystems guidelines for these parameters:

- No OP pesticides, OC pesticides, BTEX compounds, TPHs or PAHs were detected.

Inorganics

- Monitoring by Coffey Environments recorded groundwater salinity readings between 0.5mS/cm and 1.2mS/cm.
- Samples from the bore fell outside the recommended range of pH for two rounds.
- Total phosphorus concentrations exceeded the guideline on two occasions.

The depth to groundwater from the bore at the proposed wetland site ranged from 0.89m (in September 2006) to 1.31m (in December 2006) below existing surface level. JDA (2004) estimated that there is likely to be minimal seasonal variation in the groundwater level in the vicinity of the proposed wetland. This is largely due to the wetland in the north receiving a high groundwater discharge such that the water level in the wetland itself is constant all year. This factor combined with the constant 0m AHD average river level in Canning River means that between the two, the groundwater level will therefore have minimal seasonal variation.

1.5 Vegetation

1.5.1 Vegetation Description

Most of the constructed wetland site has been cleared of native vegetation as a result of infilling to create a sports field with Kikuyu Grass maintained on the surface.

The drain from the existing upstream wetland to the river east of the constructed wetland site consists of planted *Eucalyptus* trees including River Red Gum, Swamp Mahogany and Lemon-scented Gum. An examination of historic aerial photographs indicates that these trees were planted between 1968 and 1978. These trees will be retained in the proposed wetland design.

The Canning River foreshore area contains a narrow zone of *Juncus kraussii* ranging in width from 10m to 30m from the edge of the river. Low Samphire *(Halosarcia halocnemoides)* shrubland also occurs in patches along the foreshore.

1.5.2 Vegetation Condition

The vegetation condition at the proposed wetland site is classified as Completely Degraded according to the vegetation condition rating of Keighery as applied in Bush Forever (Government of Western Australia, 2000) due to the absence of native vegetation. The site is located adjacent to the Clontarf campus' playing fields.

1.6 Fauna

The proposed wetland site offers few faunal values due to the absence of habitat. The planted Eucalypts along the drainage channel east of the site provide some habitat values for local birds and it is intended that these will be retained.

Black Swans are known to visit the site to access freshwater being discharged from the existing drainage channel.

The construction of a wetland and revegetation with native species will provide improved habitat values and will support a more diverse faunal assemblage.

1.7 Aboriginal Heritage Values

The Canning River is a recognised heritage site which includes the entire length of the Canning River and associated creeks, tributaries and springs. Consultation and on site meetings with representatives of the local Aboriginal community confirmed that the Canning River is a site of major cultural and spiritual significance to traditional and contemporary Nyungars. The subject land was identified as part of hunting, collecting and fishing ground of significance to the Nyungar people.

Other sites on or near the Cygnia Cove Estate site were identified. However, these are located outside of the proposed wetland area.

The proponent has received a Section 18 clearance under the *Aboriginal Heritage Act 1972.* Section 18 clearance is required where there is potential for an activity to disturb a recorded site.

1.8 Site Opportunities and Constraints

The proposed wetland site presents the following opportunities and constraints:

- Adjacent areas are known Black Swan habitat;
- The selected site is degraded and is in need of rehabilitation;
- Acid sulphate soils are present at 1.75m to 3m;
- Depth to groundwater is less than 2m which may result in difficulties to achieve adequate compaction;
- A continuous flow of freshwater from the upstream wetland flows down the drainage channel;
- The densely vegetated upstream wetland provides some water quality treatment function; and
- Bush Forever Site No. 333 is adjacent to the proposed wetland.

3 BLACK SWANS (*CYGNUS ATRATUS*)

Black Swans (*Cygnus atratus*) can be seen on a number of suburban waterways in the Perth Metropolitan area. They generally are found wherever there is suitable habitat and can be found in all states of Australia with some birds occasionally straying to southern New Guinea (Blakers *et al.*, 1984). Despite the historical, cultural and symbolic significance of Black Swans in the Perth region, the birds have not fared well since European settlement on the Swan River (ATA Environmental *et al.*, 2000).

Environmental features that are important for Black Swans include:

- Safe roosting areas;
- Access to freshwater; and
- Access to shallow, fairly sheltered water where the birds can graze on submerged aquatic plants.

3.1 Habitat Requirements

The following information has been adapted from ATA Environmental *et al.* (2000).

3.1.1 Water Salinity

The salinity of a wetland is not a critical factor in determining its suitability as habitat for swans. Black Swans occur on fresh and saline lakes, swamps and rivers, on estuaries and occasionally at sea. However, Black Swans do need to drink relatively fresh water each day.

3.1.2 Water Depth

The depth of water available to Black Swans is important as the birds forage extensively on submerged aquatic plants and the depth needs to be suitable for reaching available food resources. The preferred water depth is within the 0.5m to 1.5m range.

3.1.3 Food

Black Swans feed exclusively on plants but by accident may ingest aquatic invertebrates. Apart from grazing on submerged plants, Black Swans also graze on plants around the margins of wetlands including cultivated lawn (Kikuyu is a favourite food), algae and rushes. Commonly utilised submerged plants include Sea Wrack (*Halophila ovalis*), Pondweed (*Potamogeton crispus*, *P. ochreatus* and *P. pectinatus*), and introduced Water Couch-grass (*Paspalum distichum*), as well as other plants including young shoots of Bulrush (*Typha* spp.) (indigenous and introduced species), seeds of Tall Spike Rush (*Eleocharis sphacelata*) and sedges (Cyperaceae).

3.1.4 Nesting Sites

Important factors in nest site selection are water level, availability of suitable materials for nest construction, and proximity to feeding areas.

The water level is considered one of the most important elements of preferred nest sites of Black Swans. Studies have shown nests are constructed in a range of water depths from 300mm to 965mm and it is suggested that water depth around a nest must be at least 300mm for Black Swans to initiate nesting. Black Swans generally breed during winter and spring,

with a peak in the number of nests occurring in late winter. An increase in the intensity of rainfall sufficient to create suitable nesting habitat and to increase the available food supply, is the initial factor that induces reproductive behaviour in Black Swans.

Black Swans tend to build nests to ensure the eggs are about 200mm or a little less above the water level. Black Swans are therefore most likely to breed in wetlands that will have a predictable winter rise and spring fall in water levels rather than tidal areas or positions that have fluctuating water levels in spring.

Black Swans will only nest at locations where suitable nesting materials can be found. Nest building continues throughout the incubation period and the nest requires considerable quantities of vegetation even when old nest mounds are refurbished.

A variety of materials are used for nest construction. Materials such as reeds, samphire, aquatic plants, sticks and bark are collected mainly from the immediate vicinity of the nest. The bowl of the nest is lined with down feathers when incubation starts. Old nests are commonly refurbished by the addition of fresh nest building material at the start of the breeding season.

Black Swans nest in a wide variety of wetland habitats. Reed beds are probably the most common site for Black Swan nests in fresh water wetlands in the south-west of Western Australia, and samphire beds are the most common site in saline wetlands. Islands are often preferred as nest sites by Black Swans compared with swamp vegetation. The suitability of islands as nest sites is affected by size, the depth of surrounding water, proximity to feeding areas, surrounding visibility and topography.

The proximity of a source of fresh water to nesting areas is an important factor for nesting since cygnets require freshwater daily. There is limited information regarding the distance cygnets will travel to a freshwater source. Cygnets bred on saline wetlands however, must travel several hundreds of metres from the nest to freshwater soaks shortly after hatching. The conditions encountered during the journey to the freshwater source though, may limit the attractiveness of a particular site for breeding (i.e. if windy and choppy conditions separate the potential nesting area and the freshwater source then the swans may not be inclined to breed at that location).

The density of nests appears to be determined by the availability of important ecological requirements such as food and suitable nest sites. Black Swans nest both in large colonies with many pairs of breeding birds, and as solitary pairs at some distance from the next nearest nest. Solitary pairs maintain a territory around the nest in the order of a hectare, but in colonies, the distance between nests can be as little as 2.4m. It appears the density of Black Swan nests, given a suitable depth of water and proximity to feeding areas, depends on the distribution of materials suitable for the construction of nests. Colonies are established where there is abundance of materials or on islands where the space is limited. An adequate supply of food and the preferred depth of water, but limited nesting materials usually result in a single nest.

Artificial nests constructed from several old car tyres that are held in position with wooden stakes, filled with sand and topped with twigs, have been found to be utilised by Black Swans for nesting.

3.1.5 Take-Off and Landing Requirements

Black Swans need a relatively large area from which to take-off, as they have to run across water in order to get airborne. There is no specific length of water required for taking-off but a distance of at least 50m is considered adequate. The birds typically face into the wind during take-off. In contrast, landing requires a length of water of only a few metres. It is probable that the Black Swans will move overland to Clontarf Bay for take-of in preference to taking off from, the constructed wetland.

3.1.6 Other Wetland Features

An area of open land adjacent to a wetland, or very shallow water, is an essential habitat requirement for Black Swans to enable daily preening. Preening is characteristically followed by a period of sleep, which usually takes place on land, and therefore safe habitat away from disturbance is required.

Wetland shorelines, island and sandbars need to enable easy access for the swans to and from the water for roosting and preening. Gradients need to be gentle enough to facilitate both adult swans and cygnets to enter and exit the water if nesting is to occur at a site. It is estimated that the slopes be about 1 in 6 or gentler, particularly where breeding occurs to ensure suitable access for cygnets.

The area around a wetland where swans are flying should be free of obstructions to avoid swans being injured or killed through collision with obstacles such as power lines.

3.2 Analysis of Requirements

In summary, the critical features of ideal habitat for Black Swans are:

- A large area of water between 0.5m to 1.5m in depth.
- Abundant food in the form of aquatic plants.
- A continuous supply of fresh water for drinking.
- An area of land adjacent to the water that is large enough for swans to roost and preen, easily accessed from the water and secure from humans and dogs.

The availability of these features will determine the number of swans in an area and the length of time that they remain there. More swans are expected to be present where a large area of water of preferred depth with food plants is available. If no fresh water or land for preening is available, the swans will fly out to a source each day or may not use the habitat if an equivalent habitat that has all these features is available as an alternative. If the food resources are seasonal, swans will be present only when there is sufficient supply.

All of the above habitat features should be provided at a given location on a continuous basis in order to attract Black Swans and encourage swans to be present throughout the year.

Other features that are desirable but not essential include:

- A sufficient length of water oriented toward the direction of prevailing winds to enable swans to take off and leave an area easily.
- A lack of obstacles such as powerlines in the vicinity of the habitat.
- Shelter from windy and rough conditions.

- Conditions and materials required for nesting.

Black Swans are expected to remain in an area that supports the important features but is not suitable for nesting as there is always a large number of non-breeding birds. Nesting habitat is therefore not essential but an additional attraction for an area especially if suitable habitat is limited in the region.

The important features of nesting habitat are:

- Materials suitable for nest construction.
- Water depth from 0.3m to 1m or on islands.
- Proximity to feeding habitat.

The quantity and area of suitable materials and depth of water will determine the number of nests that are constructed. Artificial nests may be used to create a nesting population if natural materials are not available or to supplement such materials. Reinforcement of the edges of steep shorelines around wetlands or on islands and sandbars should be provided to avoid significant shoreline erosion from regular access to the nest.

Nesting habitat in areas where there is a limited food supply may require the swans to fly to a food source each day and lead their cygnets to a food source once they hatch. There is a significant potential for cygnets to be killed or separated from their parents during this trip especially if the swans have to cross roads to reach the feeding area.

Table 1 provides a summary of all of the key habitat features and requirements for encouraging Black Swans to inhabit an area.

TABLE 1

CRITICAL HABITAT REQUIREMENTS

Description	**Preferred Conditions**
Water Depth	0.5m to 1.5m preferred.
Food	Reach to a depth of about 1m.
Drinking Water	Need to drink relatively fresh water (<1500mg/L TSS, preferably <500mg/L TSS) each day. If no local source, swans typically fly off to a source each evening.
Flight	
Take Off	Facing into wind. Distance of 50m adequate.
Landing	Only a few metres required. Areas around a wetland where swans are flying into and

Description	Preferred Conditions
	out of should be free of obstruction e.g. power lines.
Nesting	During winter and spring, with peak in late winter.
Nest Site Selection	
Water Level	Appears water depth around a nest must be at least 0.3m for swans to start nesting; water level needs to be relatively constant.
Nest Location	Black Swans only nest at locations where suitable nesting materials can be found. Most nests located where density of reed spikes between 500/m^2–1,500/m^2. These densities are very high and would be achieved (at the lower density) approximately two years after the completion of the revegetation program. It should be noted that successful Black Swan breeding has occurred in other areas of the Perth metropolitan region where spike densities are not as high.
Nesting Material	Reed beds – freshwater wetlands. Samphire beds – saline wetlands. Artificial nests.

Figures 3 and 4 outline the concept plan and concept sections for the wetland, incorporating those features described in the above sections.

4 CONSTRUCTED WETLAND DESIGN

4.1 Design Objectives

Ministerial Statement No. 692 requires that the Proponent shall design and construct an artificial wetland for the purposes of Black Swan breeding habitat. The constructed wetland is to cover an area of 1.8ha and include:

- Black Swan breeding habitat;
- Revegetation with local indigenous species;
- Landform re-contouring;
- The establishment and maintenance of wetland connection to Clontarf Bay and the Canning River;
- Weed control measures;
- Water quality and quantity monitoring; and
- Contingency measures to maintain or improve water quality of water flowing into Clontarf Bay and the Canning River.

The DEC has advised Coffey Environments that the primary design objective for the constructed wetland is to create Black Swan breeding habitat and that the design of the wetland and the drainage system needs to achieve this. With this in mind, it should be noted that some of the wetland objectives as outlined in Ministerial Statement No. 692 conflict with each other. For example, it is specified that existing water quality should be maintained or improved. However, it is anticipated that the addition of a number of water birds to this wetland will add nutrients to the water body with potential to adversely influence ambient water quality.

4.2 Design Process

The wetland design process has involved input from a multi-disciplinary project team comprised of Coffey Environments, Bamford Consulting Ecologists, TABEC, JDA Consultant Hydrologists and Plan E. The over-riding objective of Black Swan habitat has driven the design process with other wetland objectives being considered as second tier objectives. Figure 5 illustrates the proposed finished levels for the wetland, the proposed locations for the two weir structures and weir design details.

4.3 Design Constraints and Opportunities

The following factors were taken into consideration in the concept design for the Cygnia Cove Estate constructed wetland:

- Wetland area to occupy an area of approximately 1.8ha.
- Wetland design to maintain the hydrological regime supplying fresh water to Clontarf Bay and the Canning River.
- Freshwater discharge along existing drainage channel is to be maintained.

- Revegetation of proposed wetland is to link with existing wetland further north to provide a wildlife corridor with Clontarf Bay and the Caning River.
- Revegetation to utilise indigenous plant species.
- The proximity of the wetland site to Clontarf Bay raises the potential for 'backflow' from the Canning River into the wetland resulting in possible temporary changes to salinity levels in the proposed wetland. Changes to salinity may have potential to affect plant survival.
- Existing groundwater contain levels of phosphorous that exceeded recommended guidelines for Aquatic Ecosystems on two occasions.
- JDA (2004) estimated that there is little seasonal variation in groundwater levels across the site.
- If excavation occurs below groundwater level, there will be groundwater inputs into the wetland.
- Acid sulphate soils have been identified at 1.75m to 3m below existing surface level.

4.4 Wetland Sizing

Generally, the larger the wetland the better, as it will provide a greater opportunity to incorporate a range of habitat features. However, the proximity of the constructed wetland to Canning River provides benefits in terms of provision of habitat.

4.5 Hydrological Considerations

Coffey Environments has recorded depths to groundwater ranging from 0.89m (in September 2006) to 1.31m (in December 2006) below existing surface level. This information suggests that there is possibility for exchanges between groundwater and the wetland. However, it is anticipated that the constant inflow of water into the wetland is likely to create sufficient head to minimise this exchange.

JDA (2004) estimated that there is likely to be minimal seasonal variation in the groundwater level in the vicinity of the proposed wetland. This combined with the constant inflow of water from the upstream wetland, will result in the creation of a permanent waterbody.

There is no relevant water level data for Clontarf Bay in the Department of Water's data sets. To address this paucity of data, JDA installed a water level recorder in Clontarf Bay on 12 October 2006. This recorded continuously logged water levels at 5 minute intervals until 21 November 2006. The water level (and logger position) was surveyed to MGA 94/AHD to enable water level readings to be converted. Data collected was compared with data collected by the Department for Planning and Infrastructure (DPI) at Barrack Street Jetty during part of the investigation period and JDA determined that there was strong correlation between recorded water levels in Clontarf Bay (as recorded by JDA) and in the Swan River at Barrack Street (as recorded by DPI).

JDA determined that a design top water level for the constructed wetland of 0.4mAHD would be feasible and would not interfere with the outflow from the culvert at the discharge point of the existing wetland. This level will not interfere with the existing culvert upstream which is at 0.53mAHD. Although a water level of 0.4mAHD would result in an estimated 5% exceedance, that is there would be back flow from the Canning River to the proposed wetland approximately 5% of the time. To eliminate potential impacts associated with the back flow of

water from the Canning River into the wetland, it is proposed to set the top water level of the proposed wetland to 0.85mAHD. This will also require raising the upstream culvert at the discharge point for the existing wetland by approximately 0.45mAHD from 0.53mAHD to 0.98mAHD. JDA investigated the possible impacts of raising the existing culvert by temporarily blocking the existing culvert to an approximate elevation of 0.78mAHD and observing the results. The full results are provided in Appendix A. A continuous recording water level recorder was installed upstream of the existing wetland outlet culvert and flow measurements were conducted at the downstream end of the culvert. The upstream end of the culvert was blocked to an approximate height of 0.78mAHD resulting in the stoppage of flow through the culvert. The water level up stream of increased up to and above the board used to block the culvert. Flow measurements were made when it was observed to have reached a steady state (approximately 20 minutes after blocking the culvert). Flow measurements were repeated once the flow rate was observed to have reached a steady state. Prior to unblocking the culvert, volumetric flow analysis was repeated to confirm previously recorded flow rates. The culvert was unblocked.

The results from the investigation determined that the flow rate was the same before and after blocking of the culvert, thus no significant impact on flow from the existing wetland would be expected. The flow rate was only affected during the period it took for the modified system to reach a steady state. JDA determined that the impact of blocking the culvert on the area of inundation would result in a rise of the water level in the existing wetland by approximately 0.03m corresponding to a surface area of 40m^2 and the area of increased groundwater elevation is inferred to be similar.

Based on the hydrological investigations completed, the top water level of the constructed wetland is proposed to be 0.85mAHD. This can be achieved by constructing the wetland outlet (i.e. a weir) to the Canning River at 0.85mAHD to maintain that level. This is set at a level that is above 95% of tides. JDA recommended that the weir not be set any higher due to the potential effect upstream (Appendix A). It should be noted that the weirs and wetland are designed to accommodate for the occasional peak tides and storm surges.

4.6 Simplified Water Balance

TABEC estimated the storage volume of the wetland to be 1,612m^3 with a top water level of 0.85mAHD. A constant inflow of 10L/s into the constructed wetland would result in a total daily through-flow of 864m^3. The constant inflow into the wetland will ensure that the proposed wetland will be a permanent water body. Based on these calculations, the total volume of the wetland will be exchanged in less than two days. However, the continuous flow of water (from groundwater sources) will be split between the existing drainage channel and the proposed wetland, resulting in an exchange period in the wetland being less than four days.

Optimal reported performance occurs for a retention time of 24 to 40 hours (CSIRO, 1999). The proposed exchange period is less than four days based on a constant inflow of 5L/s into the constructed wetland. This arrangement exceeds the preferred 24 to 40 hour period. Therefore, contingency measures designed to prevent algal growth and the proliferation of mosquitoes and midges (such as use of aeration units) may be needed.

Under a low-, or no-flow regime, some emergent plant species may grow into deeper water, and as a consequence, may require some future management.

The top water level of 0.85mAHD has been selected to prevent back flow from Clontarf Bay due to tidal movements. The water level will be controllable by altering the discharge weir structure to lower the outlet combined with the diversion of wetland inflows to the existing drainage channel to allow draining of the wetland for maintenance and plant establishment.

4.7 Configuration

4.7.1 Shape and Key Features

The design for the proposed wetland includes an irregularly shaped shoreline to maximise the length and variety of the shoreline (Figures 3 and 5). The general slopes proposed are on a gentle grade (1V:6H) providing a gradual change in water depth and thereby encouraging the development of a gradual zonation of plant species (Figures 3, 4 and 5).

Water depth will vary throughout the wetland, however depth will primarily comply with the preferred water depth for swans which is in the 0.5m to 1.5m range (Figure 5).

Islands in open water provide visual and habitat variety. Several islands suitable for Black Swan breeding and roosting are provided in the proposed design (Figures 3, 4 and 5). These islands are not accessible from the shoreline to provide Black Swans with security from attack by predators such as cats and dogs. The islands will be low in profile (less than 30cm higher than normal open water level). They have been positioned to maintain good water circulation, while being positioned to encourage usage by Black Swans.

4.7.2 Water Regime

Assuming continuous inflow of water into the wetland, there will be little fluctuation in water depth thereby providing a stable habitat. As indicated in earlier sections, the flow rate being discharged from the upstream wetland was measured in February 2007 at 10L/sec while it was measured at 18L/sec in 2000 and 20L/sec in 2002. The earlier measurements were taken in November and December respectively, while the more recent measurement was made in February. In April and May 2008, Coffey Environments recorded a flow rate of 22.46L/sec and 24.23L/sec respectively. It is probable that the recorded reduction in flow rate is a result of reduced rainfall.

A significant reduction in flow rate will have consequences for the operation and management of the proposed wetland. The planting layout and plant selection are based on a permanent water body. Black Swans require freshwater and are known to utilise the freshwater discharged through the existing drainage channel. The loss of this water source will compromise the operation and ecological function of this wetland system. Alternative water sources would be needed if this system was to be maintained as a permanent waterbody in prolonged low or no flow conditions. For example, bore water could be used to artificially maintain water levels, however this should not be viewed as a sustainable solution in the longer term.

4.7.3 Positioning and Flow Path

The wetland design proposed is based on re-diverting some of the existing water flow from the upstream wetland through the constructed wetland in order to maximise the hydraulic flow path and optimise interaction of flows with the various functional treatment components (Figure 5). The balance of the water flow will continue to discharge to Clontarf Bay via the existing drainage channel.

Water flowing into the wetland will be split at the junction of the existing drainage channel and the wetland inlet using weir structures at the inlet and outlet zones of the constructed wetland (refer to Figure 5). The weirs will consist of a drop-in (bolt in place) metal plate that will enable the water level in the wetland to be altered. Stone pitching will be constructed at the inlet and outlet zones for scour protection. Approximately 50% of the flow will flow into the wetland and the remaining 50% discharged via the existing drainage channel. Storm events will by-pass the wetland and discharge via the drainage channel to Clontarf Bay. The proposed wetland will discharge to the lower section of the drainage channel and then to Clontarf Bay. This design approach fulfils the EPA's requirements as outlined on page 5 of the EPA's (2004) *Bulletin No. 1156 East Clontarf Residential Development: Trustees of the Christian Brothers of WA Inc. Report and Recommendations of the EPA*.

Water moving through the wetland will pass through densely vegetated areas prior to being discharged as a method of pollutant removal. It should be re-iterated that the primary objective for the constructed wetland is to create Black Swan habitat and that the wetland has not been designed as a stormwater treatment wetland. It is expected that the rehabilitation of the wetland upstream from the proposed wetland will assist in the treatment of water entering the constructed wetland. The connectivity between these wetlands will be maintained as depicted in Figure 6. The approach to urban water management in the wider Cygnia Cove Estate is to infiltrate stormwater at source where possible. The management of stormwater in Cygnia Cove Estate will be in accordance with the Department of Environment's (2004) *Stormwater Management Manual for Western Australia*.

4.8 Water Quality and Expected Performance

The quality of the wetland water will initially be determined by the quality of the water flowing into the wetland. It is predicted that, once developed, the Cygnia Cove Estate is unlikely to have a significant impact on water quality entering the constructed wetland due to the emphasis on infiltration of stormwater at source, small gardens, use of native species in landscaped areas, and the emphasis on low nutrient inputs in landscaped areas. The proposed drainage system and its management (as documented in the *Drainage, Nutrient, Irrigation and Water Quality Management Plan* prepared by Coffey Environments, 2007) incorporates structural device (e.g. gross pollutant traps) and non-structural (e.g. street sweeping practices) to capture and remove gross pollutants. This approach, coupled with the densely vegetated retained wetland upstream of the proposed constructed wetland will substantially reduce sediment inputs into the constructed wetland.

The water quality for the constructed wetland could potentially be influenced by additional inputs into the wetland from other sources. However, the treatment function provided by the wetland will assist in water quality maintenance or improvement.

Plant growth is largely determined by water quality and the successful establishment of species relies on salinity levels, pH and nutrient levels. Poor water quality can restrict which species of plants can become successfully established thereby affecting habitat diversity. For example, there is a range of emergent plant species that will tolerate brackish water, although there is only a few that will tolerant environments that are more saline.

Black Swans require access to freshwater. It is therefore preferred that a freshwater environment is provided to maximise opportunities for use by the swans. The water flowing into the wetland is from the same source that is currently utilised by Black Swans in the general area.

The creation of waterbird habitat may result in increased nutrient input arising from bird excrement and food sources. The extent of the potential impacts on water quality of the wetland is not known. However, this is an important consideration when determining benchmarks for the measuring wetland performance.

4.9 Vegetation Design

A Landscape Concept Master Plan (Figure 6) has been developed by Plan E with species selection and input by Coffey Environments. The basic requirement for attracting Black Swans is to provide those plants that provide key habitat requirements. For example, it is important that species selection include plant species that provide shelter, nesting opportunities as well as foraging habitat such as submerged aquatic plants. The ovals west of the proposed wetland site will provide some food for Black Swans who are known to eat grasses as a part of their diet.

Future development of the Cygnia Cove Estate will result in increased public access to the foreshore reserve area and the proposed wetland site. The design aims to create an iconic natural resource, restoring the degraded landscape to create an environment that encourages use by Black Swans as well as creating an attractive recreational node. Although the core wetland area will be fenced with a 1.5m high dog-proof fence, dense plantings around the wetland margins will also assist in discouraging unwanted intrusion into the wetland area, assisting to create a refuge for Black Swans.

The proposed wetland is located between the existing wetland to the north and Clontarf Bay/Canning River to the south. The landscape design aims to restore and enhance the ecological connection between the existing wetland and Clontarf Bay/Canning River.

4.9.1 Selection of Vegetation Types and Species

Ministerial Statement No. 692 requires that revegetation of the proposed wetland utilises indigenous species. Tables 2, 3, 4, 5 and 6 list those species considered suitable for planting in the wetland and surrounding areas. Tables 3, 4, 5 and 6 refer to the planting zones shown in Figure 7. The numbers of each species should be considered indicative at the time of preparing this report. Future monitoring should be based on actual numbers of species planted.

Plant materials of local provenance will be used wherever practicable. The City of South Perth has defined local provenance as meaning plant stock of Western Australian origin.

TABLE 2

POSSIBLE SUITABLE AQUATIC PLANTS

Species	Common Name
Potamogeton ochreatus	Pondweed
Potamogeton pectinatus	Pondweed

TABLE 3

RECOMMENDED SPECIES FOR DRYLAND REVEGETATION (CW1)

Scientific name	Common name	Form	Height	Planting	Density	Estimated number
Acacia saligna	Coojong	Shrub	6	Tubestock	1000cts	70
Adenanthos cygnorum	Woolly bush	Shrub	3	Tubestock	700cts	60
Allocasuarina humilis	Dwarf sheoak	Shrub	1.5	Tubestock	600cts	60
Anigozanthos manglesii	Mangles kangaroo paw	Shrub	0.5	Tubestock	300cts	680
Bossiaea eriocarpa	Common brown pea	Shrub	1	Tubestock	500cts	360
Conospermum stoechadis	Common smokebush	Shrub	2	Tubestock	500cts	260
Conostylis aculeata	Prickly conostylis	Herb	0.5	Tubestock	300cts	680
Conostylis candicans	Grey cottonhead	Herb	0.5	Tubestock	300cts	1170
Gompholobium tomentosum	Yellow pea	Herb	1	Tubestock	600cts	60
Hakea prostrata	Harsh hakea	Shrub	3	Tubestock	600cts	260
Hardenbergia comptoniana	Native wisteria	Creeper	0.5	Tubestock	800cts	50
Hemiandra pungens	Snakebush	Shrub	0.5	Tubestock	500cts	40
Hibbertia racemosa	Stalked guinea flower	Herb	0.3	Tubestock	600cts	50

Scientific name	Common name	Form	Height	Planting	Density	Estimated number
Hovea pungens	Devil's pins	Herb	0.5	Tubestock	450cts	450
Hovea trisperma	Common Hovea	Shrub	0.5	Tubestock	450cts	450
Jacksonia furcellata	Grey stinkwood	Shrub	4	Tubestock	800cts	150
Jacksonia sternbergiana	Green stinkwood	Shrub	4	Tubestock	800cts	50
Kennedia prostrata	Scarlet runner/postman	Creeper		Tubestock	800cts	40
Olearis axillaris	Coastal daisy bush	Herb	1.5	Tubestock	500cts	80
Patersonia occidentalis	Western Patersonia	Shrub	0.5	Tubestock	400cts	390
Philotheca spicata	Pepper and salt	Shrub	1.2	Tubestock	500cts	380
Banksia attentuata	Candle Banksia	Tree	8	45Lt-100Lt bag	n/a	3
Banksia grandis	Bull Banksia	Tree	8	45Lt-100Lt bag	N/a	3
Banksia ilicifolia	Swamp Banksia	Tree	10	45Lt-100Lt bag	N/a	3
Banksia menziesii	Firewood banksia	Tree	10	45Lt-100Lt bag	N/a	3
Corymbia calophylla	Marri	Tree	35	45Lt-100Lt bag	N/a	3
Eucalyptus marginata	Jarrah	Tree	30	45Lt-100Lt bag	N/a	3
Macrozamia riedlei	Zamia	Shrub	2	Transplant	N/a	5
Nuytsia floribunda	Christmas tree	Tree	8	Transplant	N/a	2
Xanthorrhoea preissii	Grass tree	Shrub	3	Transplant	N/a	5

TABLE 4

RECOMMENDED SPECIES FOR UPPER EMBANKMENT REVEGETATION (CW2)

Scientific name	Common name	Form	Height	Planting	Density	Estimated number
Acacia pulchella	Prickly Moses	Shrub	2	Tubestock	700cts	400
Astartea fascicularis		Shrub	1.5	Tubestock	500cts	600
Anigozanthos viridis	Green kangaroo paw	Shrub	0.5	Tubestock	400cts	825
Dampiera linearis	Common Dampiera	Shrub	0.5	Tubestock	400cts	825
Kunzea ericifolia	Spearwood	Shrub	3	Tubestock	600cts	450
Kunzea recurva		Shrub	1.5	Tubestock	600cts	450
Kunzea glabrescens	Spearwood	Shrub	4	Tubestock	600cts	450
Hypocalymma angustifolium	White myrtle	Shrub	1	Tubestock	600cts	500
Melaleuca preissiana	Modong	Tree	10	Tubestock	1000cts	100
Pericalymma elipticium	Swamp tea tree	Shrub	1	Tubestock	600cts	300
Taxandria linearifolia		Shrub	5	Tubestock	500cts	300
Viminaria juncea	Swishbush	Shrub	5	Tubestock	500cts	500
Banksia littoralis	Swamp Banksia	Tree	10	45Lt-100Lt bag	N/a	5
Casuarina obesa	Swamp Sheoak	Tree	10	45Lt-100Lt bag	N/a	10
Eucalyptus rudis	Flooded Gum	Tree	15	45Lt-100Lt bag	N/a	5
Melaleuca preissiana	Modong	Tree	10	45Lt-100Lt bag	N/a	5
Melaleuca rhaphiophylla	Swamp Paperbark	Tree	8	45Lt-100Lt bag	N/a	5

TABLE 5

RECOMMENDED SPECIES FOR UPPER EMBANKMENT INFILL (CW3)

Scientific name	Common name	Form	Height	Planting	Density	Estimated number
Acacia pulchella	Prickly Moses	Shrub	2	Tubestock	700cts	150
Astartea fascicularis		Shrub	1.5	Tubestock	600cts	250
Anigozanthos viridis	Green kangaroo paw	Shrub	0.5	Tubestock	500cts	300
Dampiera linearis	Common Dampiera	Shrub	0.5	Tubestock	400cts	380
Kunzea ericifolia	Spearwood	Shrub	3	Tubestock	700cts	180
Kunzea recurva		Shrub	1.5	Tubestock	700cts	180
Hypocalymma angustifolium	White myrtle	Shrub	1	Tubestock	800cts	150
Melaleuca preissiana	Modong	Tree	10	Tubestock	1000cts	60
Pericalymma elipticium	Swamp tea tree	Shrub	1	Tubestock	1000cts	60
Schoenoplectus validus	Lake club rush	Sedge	2.5	Tubestock	500cts	200
Taxandria linearifolia		Shrub	5	Tubestock	700cts	150
Viminaria juncea	Swishbush	Shrub	5	Tubestock	700cts	100
Banksia littoralis	Swamp Banksia	Tree	10	45Lt-100Lt bag	N/a	3
Casuarina obesa	Swamp Sheoak	Tree	10	45Lt-100Lt bag	N/a	1
Eucalyptus rudis	Flooded gum	Tree	15	45Lt-100Lt bag	N/a	1
Melaleuca preissiana	Modong	Tree	10	45Lt-100Lt bag	N/a	1
Melaleuca rhaphiophylla	Swamp Paperbark	Tree	8	45Lt-100Lt bag	N/a	1

TABLE 6

RECOMMENDED SPECIES FOR LOWER EMBANKMENT AND SUBMERGED VEGETATION (CW4)

Scientific name	Common name	Form	Height	Planting	Density	Estimated number
Carex appressa	Tall sedge	Sedge	1.5	Tubestock	500cts	185
Carex fascicularis	Tassel sedge	Sedge	1	Tubestock	500cts	185
Baumea articulata	Jointed twig rush	Sedge	2.5	Tubestock	500cts	185
Baumea juncea	Bare twig rush	Sedge	1	Tubestock	500cts	185
Baumea rubiginosa	River twig rush	Sedge	1	Tubestock	500cts	185
Baumea vaginalis	Sheath twig sedge	Sedge	1.5	Tubestock	500cts	185
Eleocharis acuta	Common spike-rush	Sedge	0.9	Tubestock	500cts	185
Juncus kraussii	Shore Rush	Rush	1.2	Tubestock	500cts	185
Juncus pallidus	Pale rush	Sedge	1.5	Tubestock	500cts	185
Leptocarpus laxus (syn diffusus)				Tubestock	500cts	185
Lepidosperma longitudinale	Pithy Sword-sedge	Sedge	2	Tubestock	500cts	185
Meeboldina scariosa	Velvet rush	Rush	1.5	Tubestock	500cts	185
Banksia littoralis	Swamp Banksia	Tree	10	45Lt-100Lt bag	N/a	1
Casuarina obesa	Swamp Sheoak	Tree	10	45Lt-100Lt bag	N/a	1
Eucalyptus rudis	Flooded gum	Tree	15	45Lt-100Lt bag	N/a	1
Melaleuca preissiana	Modong	Tree	10	45Lt-100Lt bag	N/a	1
Melaleuca rhaphiophylla	Swamp Paperbark	Tree	8	45Lt-100Lt bag	N/a	1

It should be noted that species selection would ultimately be determined by availability and refinement of the wetland concept design. The lack of availability of certain plant species in nurseries may require that some transplanting from nearby wetlands occur.

4.9.2 Planting Configuration

The proposed planting configuration will follow a typical profile of wetland plant communities as depicted in Plate 1. Vegetation in the wetland and in particular in areas of water flow will be planted where each row will be offset from the adjacent row. This will help to optimise sedimentation and possible nutrient stripping. Plantings will not be limited to the wetland area, but include the dryland buffer areas surrounding the wetland. As shown in Figure 6, the constructed wetland has been designed to integrate with the existing upstream wetland and the Canning River foreshore to function as an integrated system.

Emergent vegetation comprising of selected sedges and rushes will be planted around the margins of the wetland and on islands. Wetland dependent shrubs and trees will be planted densely behind the sedges and rushes around the wetland grading into dryland plantings. Reed plantings on the islands will be increased to a density of approximately 30 per m^2 to provide a higher spike density to encourage black swan nesting. Achieving the nominated preferred spike density at planting will be difficult to achieve. Over time, it is expected that spike density will increase as the system becomes self-sustaining. It should be noted that Black Swans have successfully bred in other areas of the Perth metropolitan region where spike densities are lower than the 500 to 1,500 per m^2.

Dense plantings of shrubs and trees will help shade the water column and assist in reducing the occurrence of algal blooms through reduced photosynthesis from reduced availability of sunlight. However, it should be noted that overstorey species should not be planted in areas that could affect Black Swan flight paths in the future.

The preferred planting time occurs in the spring to autumn period for sedges and rushes. However, other wetland dependent and dryland species will be planted during winter through to early spring depending on seasonal conditions. Dryland species may require watering during the first summer to maximise survival rates and encourage plant establishment.

4.10 Materials and Colour Palette

Colours and materials used at the site will be consistent with the site's proximity to Clontarf Bay as well as reflective of the historical and cultural significance of the general area. Materials selected will enhance the identity of the area while linking to the future urban landscape. Suitable materials include natural timbers, limestone, concrete and steel. Selected materials will need to be robust enough to withstand local environmental conditions and potential high public usage and require minimal maintenance.

4.11 Safety

Public health and safety in constructed wetlands is important throughout the whole life of the wetland. Issues such as bank stability, risks of drowning and mosquito breeding are the main issues that need consideration. Managing these issues is more important where the wetland is located in close proximity to residential areas or areas likely to attract significant numbers of people.

To protect the public health and safety a risk management approach will be required. To minimise potential risks to public health and safety the following strategies will be implemented:

- Gentle grade (1V:6H) on banks;
- Defined pedestrian access located away from the core wetland area, although access to the wetland for maintenance purposes will be provided for through a lockable gate;
- Minimal, low-impact lighting along the dual use path for night time pedestrian safety;
- Dog-proof fencing to prevent dog and human access to the wetland core; and
- Signage advising of potential risks associated with wetland (e.g. deep water zones, mosquitoes, faecal contamination from waterbirds etc).

4.12 Construction

4.12.1 Construction Specification and Detailed Drawings

Detailed construction specifications and engineering diagrams will be prepared for the site by the proponent's civil engineers (TABEC). The engineering specifications and diagrams will contain information relating to (but not limited to) stone pitching for scour protection (at inlets and outlets), embankment design, earthworks plan and sections. Drawings depicting the proposed weir structures details are provided in Figure 5.

The contractor will be required to ensure erosion measures are implemented to prevent sediment export to Clontarf Bay during earthworks associated with the construction of the wetland and re-contouring.

Prior to the commencement of site works, the wetland area will be pegged with particular reference to wetland boundaries and the location of required structures. The boundary between the foreshore reserve and the proposed wetland will be temporarily demarcated with flagging prior to commencement of site works to ensure that construction activities do not encroach into the foreshore reserve.

The sides and base of the wetland are critical to the wetland's performance. The wetland bed will be lined with limestone and sealed by compaction (to 92% in public open space areas) using conventional earthmoving equipment. However, achieving a high level of compaction may be difficult given the depth to groundwater. Where compaction cannot be achieved, localised dewatering may be required. Compacted limestone has been selected to provide additional buffering capacity against any potential acid sulphate soils.

A suitable planting medium will be spread over the compacted limestone base of the wetland to enable planting.

4.12.2 Timing of Earthworks

Earthworks for the wetland site will be timed with the bulk earthworks program for the first stage of the subdivision. It is anticipated that earthworks for stage 1 of the subdivision will commence in October 2008. It is anticipated that the earthworks required for the constructed wetland will be completed quickly.

4.12.3 Acid Sulphate Soils Management and Dewatering

The design top water level for the wetland will be set at 0.85m AHD. To accommodate Black Swan habitat requirements, the depth of the wetland will vary (refer to Figure 5). However the base of the wetland at its deepest point will be -0.35m AHD (Figure 5). At the deepest point, it is estimated that the existing ground level is at 1.5m AHD. This will require depth of disturbance to be approximately 1.85m AHD which will intersect (albeit in a small area) with the identified acid sulphate soils horizon (which commences from approximately -0.25m AHD at). Therefore, construction and dewatering activities will need to consider acid sulphate soils management. Coffey Environments (2008b) details the proposed approach for the management of acid sulphate soils at the Cygnia Cove Estate. The management of acid sulphate soils during construction of the wetland site will be in accordance with the Acid Sulphate Soils Management Plan. Earthworks will be conducted as quickly as possible to minimise the duration of dewatering and to minimise the opportunity for oxidisation of acid sulphate soils present at the site. Management options include the removal and treatment (liming) of acid sulphate soils material with treated material reused elsewhere in the Cygnia Cove Estate (subject to testing of material), or appropriate disposal of acid sulphate soils material.

A dewatering license application prior to the commencement of earthworks will be submitted by the contractor. However, it is proposed that dewatering using spears with effluent being pumped to a dosing tank and then infiltrated. It is not anticipated that extensive periods of dewatering will be required.

5 WETLAND MANAGEMENT AND MAINTENANCE

5.1 Wetland Management

The management of a constructed wetland typically involves monitoring (water quality, habitat, flora and in this case fauna), inspection of structures and embankments and maintenance.

A monitoring program is needed to determine whether the wetland is meeting its objectives, to identify problems and to provide information for improving the wetland design process and operation.

Regular inspections are needed to check that all components in the wetland are functioning correctly. Inspections will inform the maintenance program by identifying areas that need modification or repair.

Maintenance should be responsive to undesirable wetland changes.

5.2 Access and Education

The constructed wetland is located adjacent to the Canning River foreshore reserve. Plan E's Concept Master Plan (Figure 6) depicts a dual use path (DUP) meandering to the north and west of the constructed wetland. The constructed wetland area will only be accessible to pedestrians via the DUP. There is potential to link this DUP into the regional cycle network along the Canning River foreshore.

Dog-proof fencing (1.5m high post and rail fence with black cyclone fencing infill) will be constructed around the perimeter of the wetland to prevent pedestrian and dog access into the wetland proper. This is important to provide visiting birds, in particular Black Swans, with a feeling of safety and security.

The creation of an artificial wetland habitat offers an opportunity to educate the public about wetland dynamics and the inter-relationship between fauna and their environment. Education and awareness can be achieved through a number of avenues such as the installation of interpretive signage and possible field visits for special interest groups. Signage will be installed in strategic locations (refer to Figure 6 for indicative locations) advising the public of the importance of the wetland, Black Swan requirements and the importance of controlling incompatible activities (e.g. dog exercise) near key habitat areas.

The preparation of this Wetland Management Plan will also facilitate awareness of the potential value of the site for Black Swans. As part of the Ministerial requirements, this Wetland Management Plan must be made publicly available. Once endorsed, the City of South Perth may consider making this Wetland Management Plan available in their local libraries and via their website.

5.3 Vegetation Management and Weed Control

It is anticipated that some plant deaths will occur. A well implemented revegetation program may result in approximately 10% plant deaths in the first year and 5% in the second year. Vegetation establishment will be monitored for the first two years and where necessary, new plantings will be initiated to augment remaining vegetation. Infill planting may be required, if unacceptable mortality rates occur, and should be back to densities that will ensure that the completion criteria are achieved.

Where wetland plants are being used to remove nutrients from wetlands, the leaves and accumulated sediment will be periodically harvested and removed from the wetland floor. This prevents accumulation and recycling of nutrients within the system. It is generally only phosphorous that is a problem in nutrient accumulation, as it has no gaseous phase, unlike carbon and nitrogen which may be cycled back into the atmosphere as carbon dioxide and gaseous nitrogen through chemical and biological breakdown.

Critical to the establishment of vegetation in the wetland areas is the control of weed species. While there are a number of weed species currently present at the site, bulk earthworks will negate the requirement to undertake preliminary weed control. However, weed monitoring and control will be required on completion of proposed earthworks. A bimonthly inspection of the wetland area post-construction during the two year maintenance period will be undertaken by the Proponent to assess the species and density of weeds and when appropriate, weed eradication will be initiated. It is essential that manual methods of control (removal, brush cutting etc) be the preferred method of control. However, if chemical control is required, then herbicides (such as glyphosate bi-active) suitable for use in and adjacent to aquatic ecosystems will be used.

Table 7 outlines relevant vegetation management and weed control actions.

TABLE 7

VEGETATION MANAGEMENT AND WEED CONTROL OBJECTIVE AND ACTIONS

Objective	**Zone/Component**	**Function**	**Management Activity**
Vegetation/Habitat Establishment	Reed beds, littoral areas and open water areas	• Provides diversity of flora • Provides habitat for Black Swans • Optimal water depth for Black Swans	• *Encourage wildlife opportunities* – control domestic pets; • *Weed control* – conduct bimonthly inspections and remove exotic species as required; • *Vegetation inspection* – conduct inspections to identify plant deaths and requirement for plant harvesting;
	Wetland structures (e.g. weirs)	• Outlet/inlet structures allow water level control for plant establishment, weed control and pest control	• *Lower or raise water levels* – allow plant establishment and weed control;

5.4 Black Swan Management

Black Swans are currently present on the Swan and Canning Rivers in low numbers and Clontarf Bay attracts up to 60 Black Swans in autumn with much smaller numbers for the remainder of the year (ATA Environmental *et al.*, 2000). The birds feed in the river and have attempted to breed in Clontarf Bay in the past (ATA Environmental *et al.*, 2000). Critical to encouraging Black Swans to use the proposed wetland will be the installation of a 1.5m high dog proof fence to create a safe area for the swans.

There is some indication that swans may return to areas they are familiar with or return to the same location to breed in successive years. The preferred method is for the natural attraction of swans and other wildlife to the site without interference. However, it might be possible to actively enhance black swan usage of the site if necessary. For example, it might be feasible to release swans that have been in care following abandonment while young or injury and subsequent recuperation. Alternatively, swans bred in captivity could be introduced to habitat areas. Birds released on-site may disperse to alternative habitat, or they may choose to remain at the site.

Black Swan use of the wetland will be monitored (refer to Section 5.7.1) to identify issues that may be inhibiting swans from using the wetland.

5.5 Mosquito and Midge Management

While wetlands provide habitat for a range of vertebrate and invertebrate fauna, some of these, when in large numbers, can become pests and pose a potential disease risk for people. Of particular concern are mosquitoes and midges.

5.5.1 Mosquitoes

Mosquitoes can significantly restrict the enjoyment of outdoor activities. Some species, of mosquitoes are known as vectors for serious diseases such as Ross River Virus and Australian Encephalitis. The larval and pupal stages of the mosquito life cycle are aquatic, feeding on microscopic organisms, decaying vegetation or bottom detritus, however it is only the adult mosquito that is regarded as a pest. Adult female mosquitoes require a blood meal in order to obtain the necessary protein required to produce a large numbers of eggs (usually between 100–500 eggs).

The majority of mosquito species are active for only part of the year, and this is often determined by the seasonal availability of breeding sites. Other species breed opportunistically, following rains, or in artificial wetlands such as drains or stormwater basins. Mosquitoes are most prolific in very temporary water bodies, such as tidal salt marshes. Within a particular habitat, other factors such as sunlight or shade, the presence or absence of emergent vegetation and prevailing winds may be important.

5.5.2 Midges

Midges (chironomids) are non-biting insects that occur in all wetlands. In large numbers, they are considered a nuisance and can affect the amenity of nearby residences. Large numbers usually only occur in nutrient rich water bodies where there is excessive algal growth and algal blooms. Algal blooms typically occur in warm periods when water temperatures are high and there is sufficient light to permit growth. The decomposition of algal material provides food for midge larvae that prefer to feed on three main forms of algae: benthic (within sediments),

phytoplankton and epiphytic. Midges are generally attracted to lights and can be found to swarm near houses in the evening, creating nuisance values for residents close to wetlands.

5.5.3 Mosquito and Midge Control Objectives

The objectives of the mosquito and midge control program are to:

- Reduce residents exposure to disease carrying mosquitoes;
- Minimise the use of chemicals for the control of mosquitoes;
- Control mosquitoes using the most cost effective and environmentally safe methods available; and
- Educate the community about mosquitoes, mosquito borne diseases and mosquito prevention.

5.5.4 Risk Assessment Matrix

The Midge Research Group of Western Australia (2006) has developed a risk assessment matrix for the purposes of assessing design characteristics of proposed and existing constructed water bodies with a view to identifying which elements of the design may contribute to the number of nuisance midge and mosquitoes.

The Midge Research Group of Western Australia (2006) acknowledges that the risk matrix does not provide a guarantee that nuisance problems will not arise. The risk matrix has been applied to the proposed constructed wetland design with the results show in Table 8.

TABLE 8

CHIRONOMID MIDGE AND MOSQUITO RISK ASSESSMENT MATRIX

Element	Risk rating description	Score
Hydrology of the Water Body	Water body does not dry out but water level remains constant (Risk Rating 2).	2
Location of the Water Body to Residential Areas	Nearest resident is located between 50m and 100m from waters edge (Risk Rating 5).	5
Form of the Water Body	Less than 50% of the water body's edge is hard vertical edge (Risk Rating 4).	4
	Shape of the water body is simple in order to facilitate good water circulation (Risk Rating 1).	1
Wind Related Parameters	The long axis of the water body is perpendicular to known prevailing wind directions (Risk Rating 2).	2
	Surrounding land level with water body preventing surface runoff entering and maximising potential wind action (Risk Rating 1).	1
Depth of the Water Body	Between 60cm and 2m (Risk Rating 2).	2
Mechanical Circulation	Volume of water body circulated every 24 hours or longer (Risk	2

Element	Risk rating description	Score
	Rating 2).	
Aquatic Vegetation	Emergent vegetation in small stands parallel to predominant wind direction (Risk Rating 2).	2
Terrestrial Vegetation	Buffer vegetation mainly planted down wind of the water body or surrounding entire water body and with clear open space provide between buffer vegetation and nearest residence (Risk Rating 1).	1
In-flow Water Quality	In flow water has minimal levels of nutrients (Risk Rating 1).	1
Engineering Considerations	In-built ability to 'draw down' or lower the water level mechanically (Risk Rating 1).	1
	Sufficient access for personnel and machinery to undertake routine maintenance or implement control measures (Risk Rating 1).	1
	TOTAL SCORE	**25**

Table 8 indicates that the proposed design of the constructed wetland is considered as borderline low risk to medium risk. Low risk is defined as a water body which is unlikely to produce midge or mosquitoes in sufficient numbers so as to create a nuisance or pose a health risk (Midge Research Group of Western Australia, 2006). Medium risk is defined as a water body with increased probability of midge or mosquito breeding so as to create a problem with the likely requirement for monitoring and maintenance to minimise risks for increased midge and mosquito populations (Midge Research Group of Western Australia, 2006).

5.5.5 Strategies for Managing Mosquitoes and Midges

Mosquito numbers vary between seasons and years. A major contributing factor to this is the amount of rainfall received, or the height and frequency of tidal inundation. While it is not possible to eliminate all mosquitoes, it is important to take measures to reduce the risk of people being bitten by infected mosquitoes (EPA, 2000).

With respect to the wetland design, there are a number of design elements and maintenance strategies that can be utilised to minimise the risks associated with mosquitoes and midges. Typically, these relate to vegetation management, water circulation and water quality.

Vegetation Management

Vegetation is important for utilising nutrients in the water, thereby reducing the potential for algal blooms occurring. However, excessive vegetation establishment can provide protected areas for larvae to hide from predatory species.

The decomposition of plant material during senescence can be a source of nutrients in wetlands. In addition, due to the rhizomatous nature of the emergent species to be used in revegetation, there is potential for these species to spread into the central portion of the wetland. For these reasons, it may be necessary to undertake routine harvesting of dead plant material to remove this potential source of nutrients.

Wetland design has aimed to limit aquatic vegetation to small stands, preferably located in deeper water (>60cm). The stands of vegetation will be planted approximately parallel to prevailing breezes to maximise the effect of wind action.

Water Circulation

It is generally preferred to have hard vertical edges to wetlands to maximise the effects of wave action which can disrupt midge and mosquito survival. It is considered that this edge type will not be necessary due to the relatively low retention time for water in the constructed wetland. High water turnover resulting from continuous input from groundwater sources upstream will result in a well circulated system that is less likely to support algal blooms.

A backup mitigation strategy is to install a series of small aerators distributed throughout the wetland for water circulation to prevent stratification and stagnation. Smaller aerators are cheaper to run and can allow a greater area of wetland to be aerated. It should be noted that aerators might initially discourage use of the wetland by Black Swans. However, birds (including Black Swans) generally habituate to disturbance well. At other wetlands (such as Hyde Park), Black Swans have become accustomed to the presence of aerators.

Water Quality

The freshwater flowing into the wetland is of good quality which will help minimise the risk of algal blooms. The wetland located upstream of the constructed wetland will provide some treatment function and the dense planting of sedges and rushes at the discharge zone of the proposed wetland (near Clontarf Bay) will further help remove possible pollutants such as sediments and nutrients prior to discharge to the Canning River.

The water management system for Cygnia Cove is consistent with water sensitive urban design practices as prescribed by the DEC and Department of Water (DoW). The stormwater drainage system has been designed using a major/minor approach to convey and detain stormwater. The major system is defined as the arrangement of roads and detention areas planned to convey the stormwater runoff from extreme events that exceed the capacity of the minor system. The minor system consists of a series of underground pipes, swales, kerbs and gutters designed to carry and/or infiltrate runoff generated by low frequency Annual Recurrence Interval (ARI) storm events. Stormwater runoff generated by the impervious areas of the road reserve will be collected in gully or side entry pits. These areas can potentially support mosquito breeding unless minimisation strategies are incorporated.

The development at Cygnia Cove Estate will utilise non-structural controls for the management of stormwater and nutrients. In particular, the use of turf in landscaped areas within the Estate will be kept to a minimum, thereby reducing the requirements for application of fertilisers. When required, fertilisers used will be slow-release, low phosphorous fertilisers. Information relating to efficient fertiliser application practices and waterwise gardening practices will be provided to prospective purchasers at the sales office during the sales period. Brochures are available from the Swan River Trust.

Water samples will be taken upstream and downstream of the constructed wetland. Monitoring water quality will allow early identification of changes in water quality.

Monitoring

Mosquitoes are considered a nuisance when the number of mosquitoes caught at a single location in a single carbon dioxide baited insect trap exceeds 50 over a normal sampling period (12 to 18 hours) (EPA, 2000). If the species caught are ones that are known, or suspected to be vectors of mosquito-borne disease, and the mosquito population is close to heavily populated areas, then the mosquitoes may present a health risk (EPA, 2000).

A monitoring program will be established for the Cygnia Cove Estate that will involve:

- A 12 month baseline sampling period has commenced to determine the species of mosquitoes and midges present; and
- On-going monitoring of mosquito and midge population numbers by the proponent with ultimate responsibility for management to be adopted by the City of South Perth.

Mosquitoes become an increasing pest during summer months. At the same time, humans engage in more outdoor activities during the hotter months and therefore become exposed to mosquitoes in greater frequency. For this reason, the intensity of the monitoring program will be increased during the warmer months (October to March) and will be reduced during cooler months. During the October to March period, monitoring of mosquito and midge populations will be taken on a fortnightly basis and during cooler months on a monthly basis. Depending on the results, the requirement for further monitoring will be assessed and if appropriate, the monitoring program will be revised.

Table 9 outlines relevant mosquito and midge management actions.

TABLE 9

MOSQUITO AND MIDGE MANAGEMENT OBJECTIVE AND ACTIONS

Objective	**Function**	**Management Activity**
Minimise occurrence of nuisance insect events	• Outlet/inlet structures allow water level control for pest control	• *Baseline Monitoring* – conduct fortnightly monitoring of mosquito larvae population during peak nuisance period for a 12 month period by the Proponent to determine speciation and population size; • *Draining* – to reduce mosquitoes and pest control; • *Aeration* – install and run aeration units to encourage water movement if required.

Contingency Measures

Early identification of large mosquito or midge populations will allow control methods to be developed. Control strategies could involve physical, chemical, biological or cultural methods. These might include:

- Physical – Physical modification or removal of source to prevent breeding through techniques such as runnelling;

- Chemical – Application of larvicides and adulticides, including fogging and residual surface adulticides;
- Biological – Introduction of appropriate mosquito predators; and
- Cultural – Encouragement of public to implement personal preventative measures through the provision of signage in POS areas advising people about the risk posed by mosquitoes.

To be effective, a mosquito and midge control programme must utilise an integrated approach to management employing a combination of physical, biological, chemical and cultural control methods and targeting both larvae and adult mosquitoes and midges.

5.6 Water Supply

The proposed wetland design relies on the continued inflow of water from the up-stream wetland. A constant flow of approximately 20L/sec was previously (in 2002) measured, although in February 2007 this flow rate was measured as 10L/sec. It is hypothesised that this decline in flow rate is due to declining rainfall with 2006 recording the lowest rainfall since the keeping of records. However, more recent flow rate monitoring by Coffey Environments has recorded a flow rate in April and May 2008 of 22.46L/sec and 24.23L/sec respectively.

If the surface water flow entering the constructed wetland ceased, then the wetland would change from a permanent system to an ephemeral system. This has a number of implications for the management of the wetland. For example, falling water levels may result in plant deaths, further encroachment of emergent plant species into the central portions of the wetland, declining water quality in the wetland or discouragement of Black Swans due to the absence of freshwater. Mitigation strategies will be needed to protect the health of the wetland and to maintain key habitat values. For example, aeration may be necessary to prevent stagnant ponds of water or water from other sources may need to be pumped into the wetland to maintain a constant water level while maintaining through flow, or harvesting of excess plant material as required. The proposed compacted limestone base will also help minimise water loss through the base of the wetland.

5.7 Monitoring, Completion Criteria and Reporting

The implementation of management strategies detailed in this Plan will be an on-going process, which should be flexible in responding to changes in the natural environment, the recreational use of the environment and community values. Monitoring procedures will assist in the adaptive management of the wetlands, as well as informing the progress of management.

The Proponent will implement monitoring procedures to assess the operation of the wetland, Black Swan usage of the wetland and the success of management strategies such as revegetation and weed control activities during the post-construction two year management period. This will allow the identification of areas requiring augmentation or remedial works to be identified early and appropriately planned. In addition, the monitoring will ensure that an adequate representation of plant species is achieved to maximise opportunity for usage of the wetland by Black Swans.

The program of monitoring the success of the strategies is essential for the purposes of reviewing and updating the Plan by the City of South Perth following handover. This will ensure that the objectives of the Plan are achieved and that any changes or new developments in management techniques can be incorporated.

5.7.1 Black Swan Monitoring

Up to 60 Black Swans regularly utilise Clontarf Bay. Although Black Swans may visit the wetland after it has been constructed, it is not expected that they will breed there in the short term. Black Swans will need to feel secure from threats (such as dogs) and feel comfortable with the wetland before they breed there.

In the short term, monitoring of Black Swan usage will aim to gauge the swans acceptance and habitat utilisation (3 to 5 year period). In the longer term (5 years or more), it may be possible to determine the usage of the site by Black Swans for breeding, by monitoring the wetland during breeding season and following hatching.

Monitoring during Black Swan breeding season consisting of monthly site visits will be conducted to identify breeding patterns and usage of the wetland area by Black Swans. As the peak number of nests occur in late winter (ATA Environmental *et. al.*, 2000), monthly monitoring will commence in early winter through to the end of spring. Monthly site visits during the breeding season will record:

- The number of swans using the wetland area and the adjacent Clontarf Bay;
- The activities such as feeding, preening or roosting being undertaken;
- Any evidence of nesting or breeding; and
- Occurrences of deaths or injured swans and the likely cause of injuries.

5.7.2 Water Quality and Quantity Monitoring

Ministerial Statement No. 692 requires that the water quality discharged into Clontarf Bay/Canning River be of no worse or better quality than pre-development conditions. Relative performance of the wetland with respect to its water quality treatment function can be adequately assessed by monitoring concentrations of selected parameters at inflows and outflows from the wetland. Quarterly monitoring of surface water discharged to Clontarf Bay will be undertaken pre-development and during the construction period to establish baseline water quality against which future sampling results can be compared. Surface samples will be collected from the northern side of the culvert upstream of the proposed wetland site in order to minimise potential tidal impacts on data (refer to Figure 5 for indicative location).

To assess the performance of the wetland with respect to water quality, sampling downstream of the wetland (i.e. from the discharge zone) following construction on a quarterly basis during the two year maintenance period will allow comparison of upstream and downstream water quality. It is anticipated that the wetland will receive additional nutrient inputs through increased bird usage and decaying plant biomass.

Samples collected during the pre-development and post-development water quality monitoring program will be analysed for:

- Nutrients (Ammonia-N, NO_x-N, Total Kjeldahl Nitrogen, Total Nitrogen, and Total Phosphorus); and
- Inorganic parameters (pH, conductivity, dissolved oxygen, total suspended solids (TSS) and acidity).

Significant exceedances (greater than 10% of pre-development surface water quality) in seasonal data and where values are greater than Guidelines for Aquatic Ecosystems (for

Fresh Waters including Lowland Rivers) values (where available) will be further investigated with a view to establishing the cause of the exceedance with appropriate remedial works to be undertaken.

In addition to quality, an assessment of flow rate at the upstream culvert and at the discharge point of the wetland at the time of water quality sampling will be undertaken to ensure that post-development flow-rate is comparable to pre-development conditions.

Results from the monitoring will be reported to the City of South Perth and Department of Water on an annual basis. The report will outline criteria where pre-development or guideline values have been exceeded with details of remedial actions taken.

In order to control sediment input into the wetland, a number of structural (e.g. Gross Pollutant Traps) and non-structural control measures (e.g. street sweeping) will be put in place upstream of the wetland. These measures are dealt with in detail in the Drainage and Nutrient, Irrigation and Water Quality Management Plan.

5.7.3 Vegetation Establishment Monitoring

The Proponent will monitor plant establishment once initially during spring then monthly during summer months (i.e. December, January and February) following completion of the revegetation program to ensure plants are well established for water stress. A subjective assessment will be made of:

- General plant health or vigour;
- Species composition (including presence of introduced species); and
- Plant density.

Thereafter, monitoring will be conducted biannually during the two year maintenance period by the Proponent.

Records of plant health will be documented and site photographs taken. Watering of plants will be provided if plants are exhibiting signs of water stress. If required, supplementary plantings will be undertaken to increase plant densities where necessary.

5.7.4 Weed Monitoring

Regular monitoring (bimonthly) of the wetland area in general will occur throughout the year during the two year maintenance period by the Proponent. Visual inspection is a more efficient method of monitoring weeds rather than permanent sampling locations. The appropriate weed management techniques (such as manual removal) will be used to control areas of weeds that are considered to pose a threat to the environmental values of the site. It should be noted that there is some risk that *Typha orientalis* will become established in the proposed constructed wetland due to the upstream prevalence of this species and the off-site stormwater inputs to the Cygnia Cove Estate site. The proponent has committed to undertaking a *Typha orientalis* control program for the upstream retained wetland as documented in the *Wetland Management Plan – Proponent Commitment No. 3, Retained Wetland* (Coffey Environments, 2008a). The regular monitoring of weeds will need to ensure early identification of any establishment of *Typha orientalis* to enable early eradication.

5.7.5 Operational Monitoring

The Proponent will undertake bimonthly visual inspections of the wetland during the two year maintenance period to ensure its effective operation. In particular, the following will be assessed:

- Water level of the wetland;
- Signs of erosion;
- Integrity of infrastructure such as weir structures at inlet/outlet areas; and
- Identification of stagnant water.

Inspections will also take place after high tides and large storm events (or other events such as fire) to ensure that no damage to wetland function has occurred. If damage is identified, the Proponent will be responsible for remedial actions during the two year maintenance period and thereafter the City of South Perth.

5.7.6 Completion Criteria and Reporting

Prior to the City of South Perth accepting responsibility for the management of the wetland area, it will need to be demonstrated that the completion criteria have been achieved.

The completion criteria for the Wetland Management Plan are:

- 80% survival of stated plant numbers within each zone – the final (or actual) planting numbers will be provided to the City of South Perth on completion of the revegetation program. Note that the numbers of each species provided in Tables 3, 4, 5 and 6 are indicative only;
- A maximum of three invasive weeds per m^2 with a maximum of 5% cover;
- Fencing and other infrastructure maintained in good condition; and
- Completion of all other commitments as specified in the Wetland Management Plan.

An annual progress report detailing rehabilitation work undertaken will be submitted to the City of South Perth, the Swan River Trust and the DEC. Assuming construction of the wetland is completed in early 2008, the reporting periods will be February 2008 - January 2009 and February 2009 – January 2010.

5.8 Schedule of Works

Table 10 outlines the proposed timeline for the construction and revegetation program. Earthworks are proposed to commence in summer (February 2009). It is proposed that weed control commences in autumn 2009 to reduce weed density prior to commencement of planting in winter 2009.

TABLE 10

WORKS TIMELINE

Expected Start	Activity	Anticipated Completion
February 2009	Undertake earthworks to construct wetland.	April 2009
June to July 2009	Planting of wetland species in inundated areas and riparian zone.	August 2009
Following adequate winter rains, May to June 2009	Planting of wetland and dryland species.	August 2009 for dryland species October 2009 for wetland species
November 2009	Watering of dryland species on an as needs basis.	February 2010
Following adequate autumn rains, May 2010	Maintenance planting of dryland and wetland species 10%.	To be completed 1 – 2 months after commencement of planting.
November 2010	Watering of dryland species on an as needs basis.	February 2011
Following adequate autumn rains, May 2011	Maintenance planting of dryland species 5%.	To be completed 1 – 2 months after commencement of planting.
October 2011	Maintenance planting of wetland species 5%.	November 2011

5.9 Allocation of Management Responsibilities

The Proponent will be responsible for the implementation of the recommendations in this management plan to the satisfaction of the City of South Perth for a period of two years (refer to Table 11) except where identified. The two year maintenance period will commence following practical completion, following which the transfer of titles for the POS will be vested in the City of South Perth. On completion of all of the Proponent requirements, the City of South Perth will assume responsibility for the on-going management and maintenance of the constructed wetland and its surrounds.

TABLE 11

MANAGEMENT RESPONSIBILITIES

Strategy	Specification	Timing	Responsibility
Access and Education	Construct a 3.5m wide reconstituted limestone DUP (sufficient standard to withstand infrequent vehicle movement) around the wetland as depicted in Figure 6.	Once only post construction of wetland.	Developer
	Install interpretive signage along the DUP (refer to Figure 6 for indicative locations) highlighting the importance of wetland conservation and how residents can assist with protecting their local natural environment.	Once only post construction of wetland.	Developer
	Construct a 1.5m high dog proof fence consisting of post and rail with black cyclone fencing infill around the wetland as depicted in Figure 6.	Once only post construction of wetland.	Developer
	Inspect fences and banks for safety and maintain signage.	Quarterly post-construction.	Developer for an initial two year period, thereafter the City of South Perth
Vegetation Management and Weed Control	Revegetate rehabilitation areas in the wetland POS area with the lowering or raising of water levels to assist with plant establishment.	Once only post construction of wetland.	Developer
	The boundary between the two will be temporarily demarcated with flagging during contruction to ensure that construction activities do not encroach into the foreshore reserve.	During construction	Developer
	Implement weed control using manual or chemical methods.	Post construction prior to revegetation then on an as needs basis.	Developer

Strategy	Specification	Timing	Responsibility
	Undertake harvesting of excess plant material in the wetland as required to reduce plant biomass.	Post construction of wetland on an as needs basis.	Developer for an initial two year period, thereafter the City of South Perth
General Maintenance and Monitoring	Establish a 12 month baseline mosquito and midge monitoring program to determine speciation and population numbers.	Spring 2007 to Spring 2008 followed with a review of need for further monitoring.	Developer
	Record complaints regarding mosquito and midges.	Post construction	City of South Perth
	Undertake quarterly monitoring of flow rates at the upstream culvert and at the wetland outlet.	Post construction	Developer for an initial two year period, thereafter the City of South Perth
	Undertake quarterly water quality monitoring.	On-going post construction of wetland	Developer for an initial two year period, thereafter the City of South Perth
	Monitor Black Swan usage of the wetland during breeding season (start of winter to end of spring) on a monthly basis.	On-going post construction of wetland	Developer for an initial two year period, thereafter the City of South Perth
	Undertake bimonthly visual inspections of the wetland area to identify emergent weeds that may require control.	Bimonthly post construction of wetland	Developer for an initial two year period, thereafter the City of South Perth
	Monitor rehabilitation success once initially during Spring, then monthly during the first summer (i.e. December, January, and February), and biannually during the following years until plants are well established for water stress and individually hand watered if necessary.	On-going post revegetation	Developer for an initial two year period, thereafter the City of South Perth
	Undertake bimonthly visual inspections of the wetland to ensure effective operation.	Post-construction	Developer for an initial two year period, thereafter the City of South Perth
	Inspect the wetland after high tides and large storm events to make sure no storm damage has occurred.	On-going post construction of wetland	Developer for an initial two year period, thereafter the City of South Perth

Strategy	Specification	Timing	Responsibility
Reporting	Prepare an annual report on implementation and rehabilitation progress.	Annually, February 2008 - January 2009 and February 2009 - January 2010	Developer to submit annual report to the City of South Perth, Swan River Trust and the DEC

6 REFERENCES

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7 DISCLAIMER

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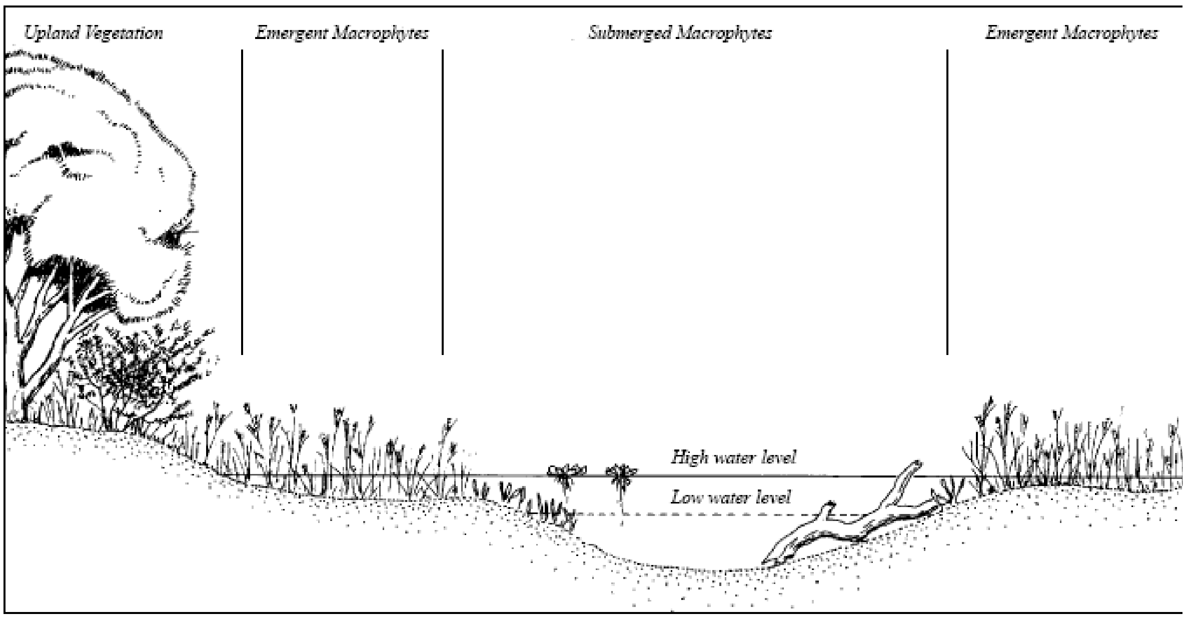
Plates

Constructed Wetland Management Plan
Cygnia Cove Estate, Waterford

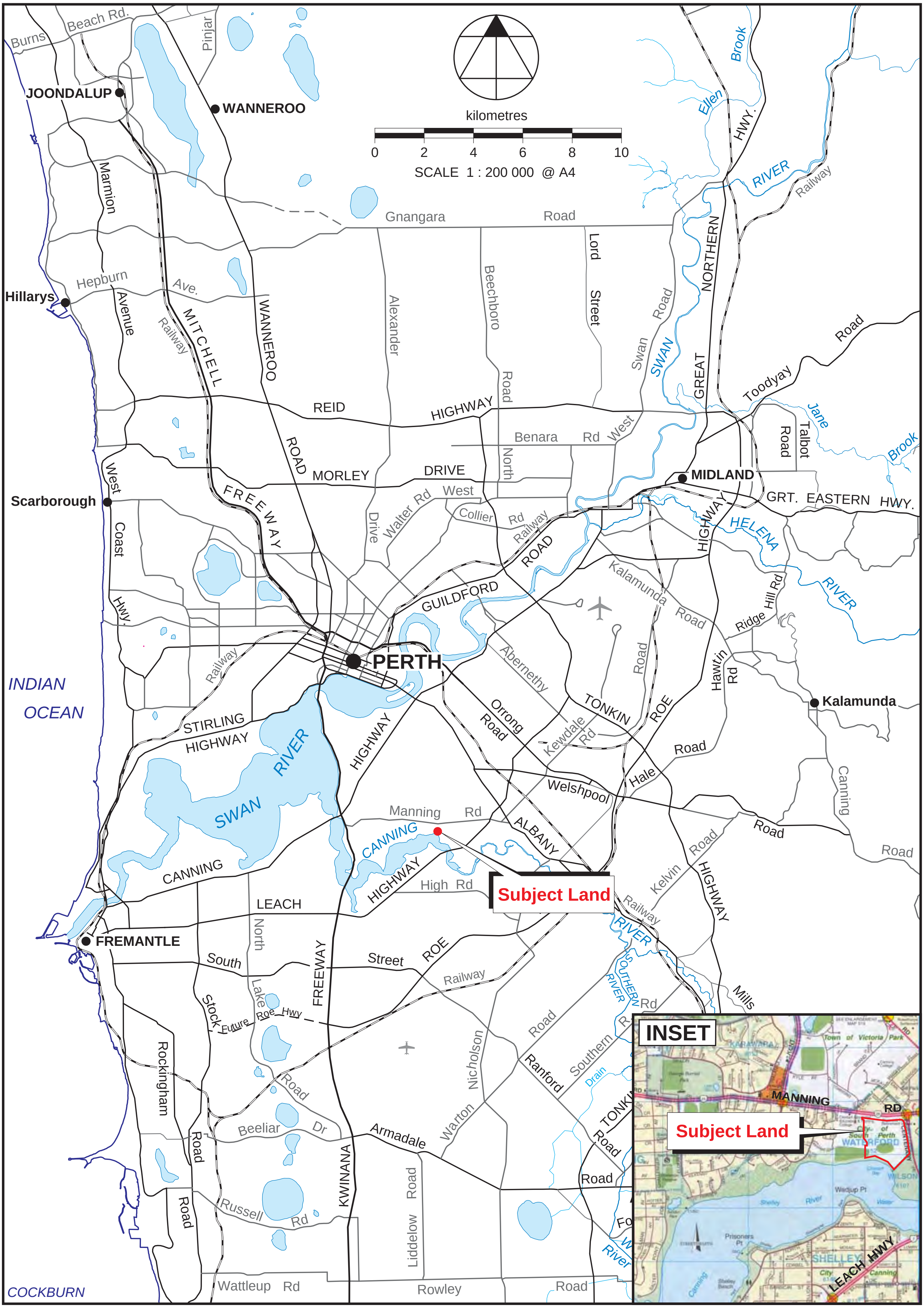


Source: Water and Rivers Commission (2001)

Plate 1: Simplified Profile of Wetland Plant Communities

Figures

Constructed Wetland Management Plan
Cygnia Cove Estate, Waterford



TCB-2007-012/WMPL/27_122f1.dgn DATUM: MGA DRAWN: 08-05-07 CHECKED: PZ 09-05-07 PRINTED: Mon 16 Jul 07

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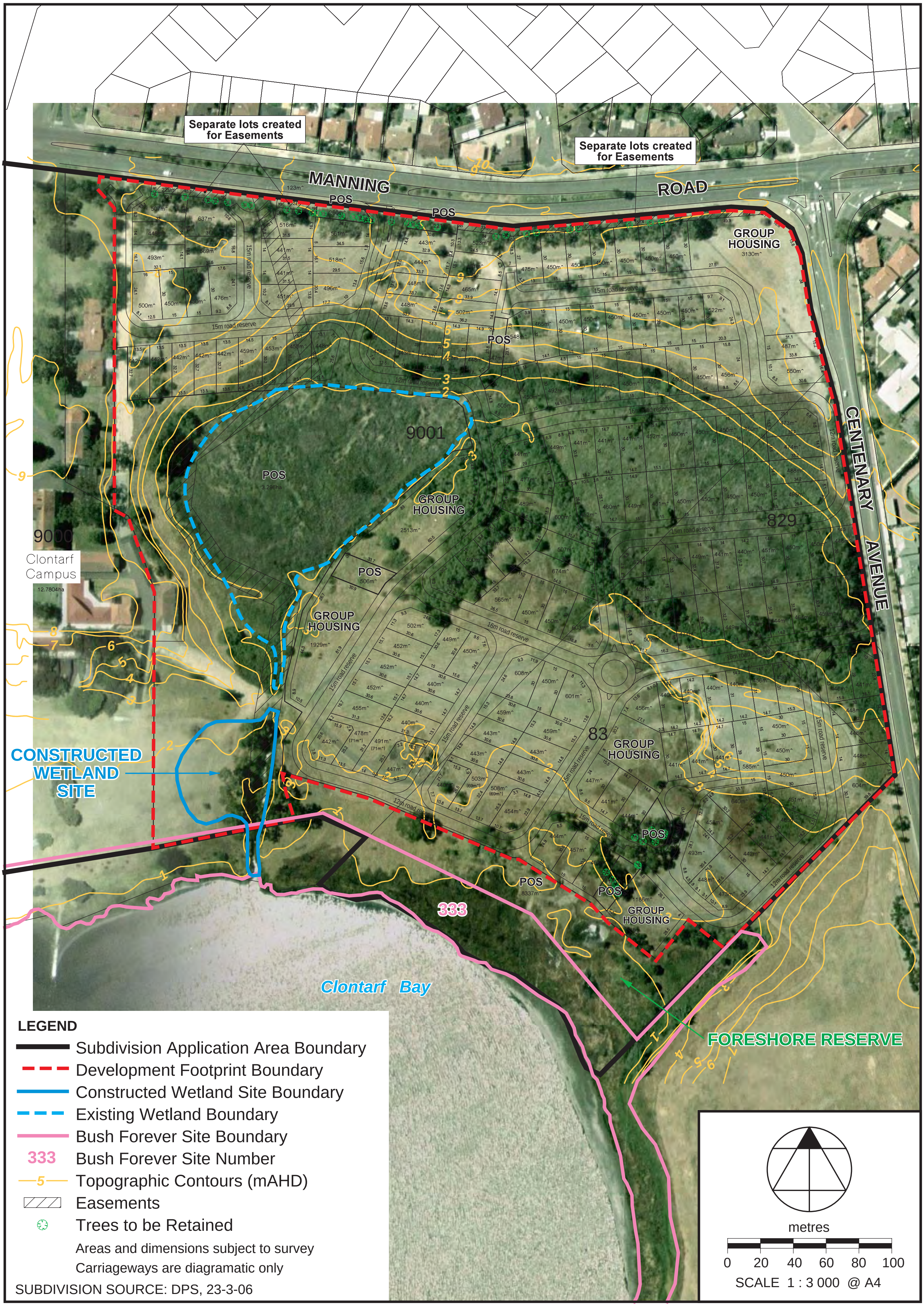
REGIONAL LOCATION

FIGURE 1



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SUBDIVISION PLAN

FIGURE 2

TCB-2007-012/WMPL/27_122f3.dgn DATUM: Not spatially correct DRAWN: 18-07-07 CHECKED: PZ 18-07-07 PRINTED: Wed 18 Jul 07

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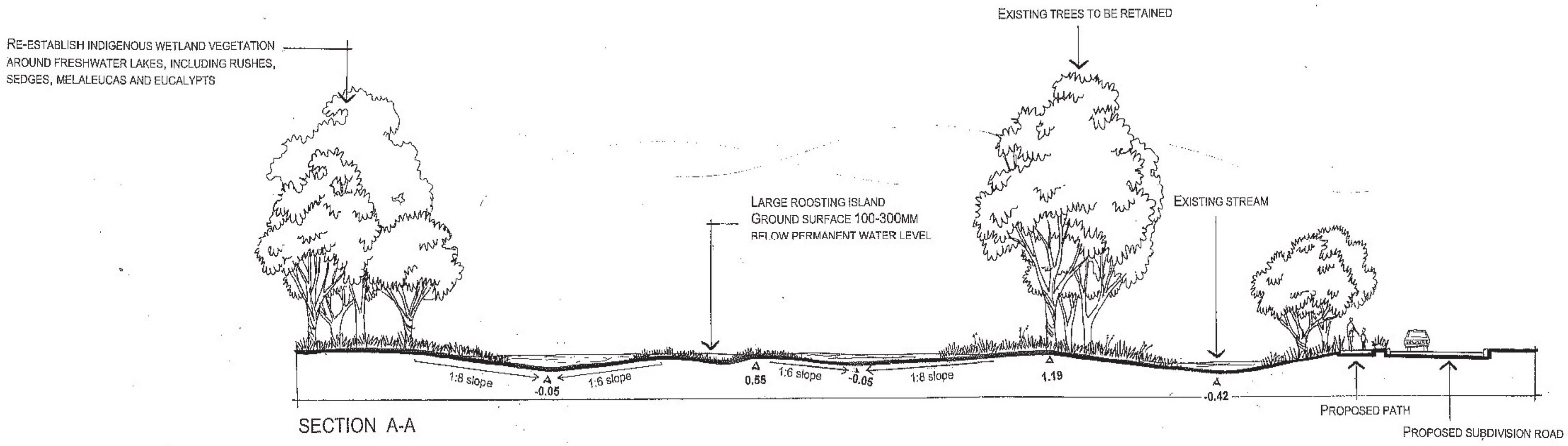
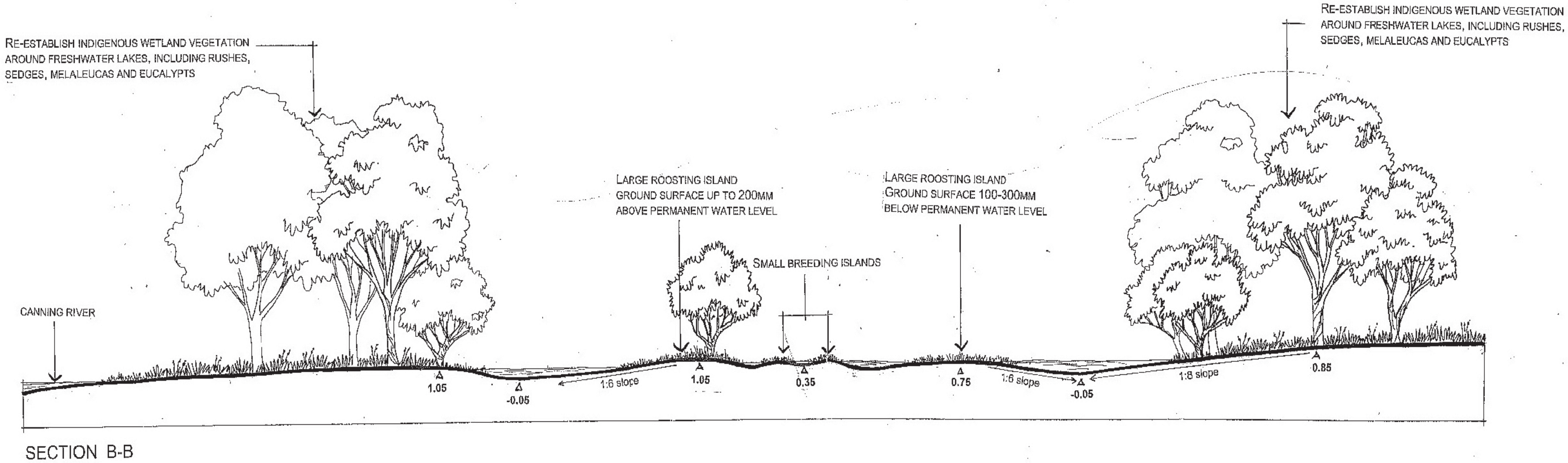
SWAN BREEDING WETLAND CONCEPT PLAN

FIGURE 3

SOURCE: PLAN E, CD-01 REV B, March 2007





SOURCE: PLAN E, CD-01 REV B, March 2007

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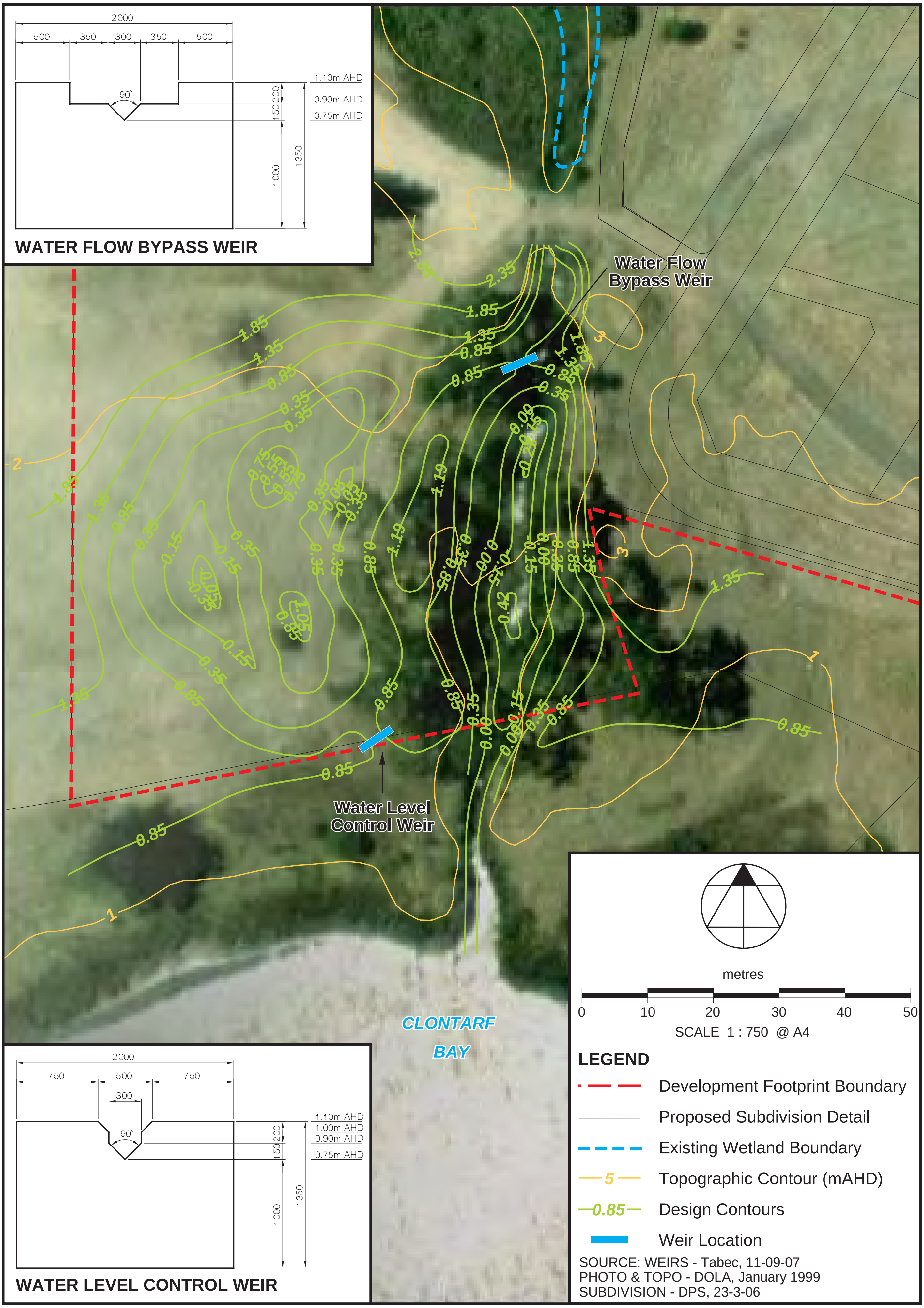
SWAN BREEDING WETLAND CONCEPT SECTIONS

FIGURE 4



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CONSTRUCTED WETLAND LAYOUT

FIGURE 5

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LANDSCAPE CONCEPT MASTER PLAN

FIGURE 6

SOURCE: PLAN E, Job No. 02132-01, May 2007 Rev D

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SOURCE: PLAN E, Job No. 02132-01, October 2007 Rev E

PLANTING ZONES PLAN
FIGURE 7

Appendix A
JDA Water Level Investigation Report

Constructed Wetland Management Plan
Cygnia Cove Estate, Waterford

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Email Transmission

To :	Richard Noble & Company Pty Ltd	**Date :**	6 Mar 07
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Email :	agregg@rnoble.com.au	**Pages :**	4
cc :	Chris Bitmead (TABEC) (cbitmead@tabec.com.au) Paul Zuvela (paul.zuvela@ataenvironmental.com.au)		

CULVERT BLOCKING INVESTIGATION – EAST CLONTARF

Alex,

Please find below JDA's report resulting from the recent culvert blocking investigation conducted at East Clontarf.

1. Background

1.1 Hydrological Investigation 2002/2003

JDA conducted a hydrological investigation of the East Clontarf site in November 2002 and May 2003. This hydrological investigation examined the existing surface and groundwater interaction, seasonal groundwater variation, wetland hydrology, water balance and stormwater drainage. The investigation was reported on in JDA report J3070w (April 2004). The near constant outflow from the wetland through a culvert to Canning River was measured as approximately 20L/s and reported on.

1.2 Swan Breeding Lake

Following advice that a lake was to be constructed for the purposes of encouraging swan breeding, JDA was asked to investigate a suitable top water elevation for the lake design. The results of this investigation were presented in JDA fax report J3812a (December 2006). The results concluded that a lake design top water elevation of 0.4 m AHD would allow sufficient hydraulic grade from the upstream culvert, whilst restricting the occurrence of inflow of saline water from the Swan River to 5% of the time.

1.3 Culvert blocking investigation

JDA was asked to provide advice regarding the impact of raising the upstream culvert from the existing invert elevation of 0.53 m AHD to approximately 0.78 m AHD. JDA identified the following as issues which may potentially result from this proposed increase in culvert elevation:

- Reduction in surface flow to Canning River and associated increase in groundwater flow to Canning River
- Increased area of surface water inundation in wetland
- Increased groundwater levels in wetland
- Changes in wetland hydrology.

To further investigate the impact of raising the culvert on these potential issues it was decided to block the existing culvert temporarily to an approximate elevation of 0.78 m AHD and observe the results.

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2. Fieldwork

2.1 Pre-blocking measurements

2 February 2007: a continuous recording water level recorder was installed upstream of the wetland outlet culvert and flow measurements were conducted at the downstream end of the culvert volumetrically in a 60L vessel.

2.2 Culvert blocking

5 February 2007: data was downloaded from the water level recorder and the flow rate was again measured. The upstream end of culvert was blocked by fixing to it a piece of foam-clad plywood board, the top of which was approximately 0.78 m AHD. The flow through the culvert ceased, the water level upstream rose up to and above the board. Flow measurements were made when it was observed to have reached a steady state (approximately 20 minutes after blocking the culvert). Volumetric flow measurements (as described in 2.1) were repeated once the flow rate was observed to have reached a steady state.

2.3 Culvert unblocking

6 February 2007: the water level was observed to be the same as that observed 20 minutes after the culvert blocking on 5 February. Volumetric flow analysis was repeated to confirm the flow rate recorded on 5 February 2007. The culvert was then unblocked. Monitoring of water level and flow rate not performed after the culvert was unblocked. All equipment was then removed from the area.

3. Results

3.1 Impact of blocking culvert on flow from wetland

JDA measured flow rate of 10L/s from the culvert both before (2/2/07) and after (5 and 6 February 2007) culvert blocking. That is the flow was only affected for approximately 20 minutes immediately after blocking while the water level rose up to and above the board.

3.2 Impact of blocking culvert on area of inundation and groundwater level

The dense vegetation of the wetland area upstream of the culvert prevents accurate survey of the ground surface and/or groundwater level. The volume of water built up behind the board is equal to 10L/s over 20 minutes, that is 12 m^3. The rise in water level was 0.03 m corresponding to a surface area of 40m^2.

The water level recorder data was found to be faulty from the time of bore installation and is not referred to.

4. Conclusions

Based on the results presented above, JDA concludes the following with respect to the identified potential impacts resulting from the proposed increase in culvert elevation:

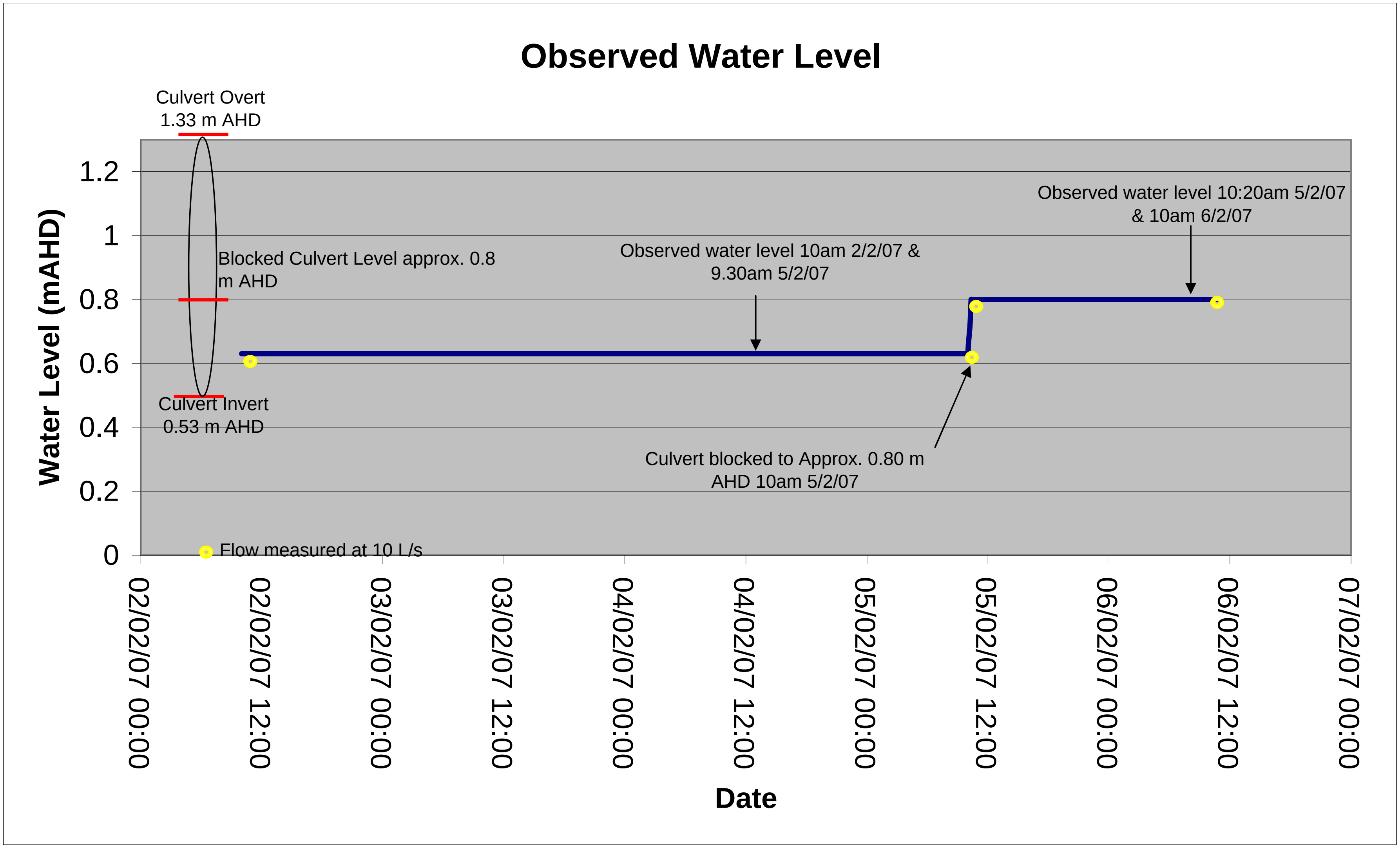
- Reduction in surface flow due to increased groundwater flow – the observed results of flows at approximately 10L/s both before and after the culvert was blocked indicate that the proposed increased culvert elevation will not have a significant impact on flow from the wetland
- Increased area of inundation/Area of increased groundwater elevation – the short duration between the blocking of the culvert and resumption of steady-state water level and flow conditions indicates that the increase in area of inundation upstream of the culvert is 40m^2. The area of increased groundwater elevation is inferred to be similar, 40m^2.
- Significant changes in wetland hydrology – based on the observed lack of impact on flow rate, and time taken for steady water level to be achieved

after culvert blocking , no significant impacts on the wetland hydrology are anticipated to result from the proposed increase in culvert elevation.

Please contact Kieran Coupe or Jim Davies should you have any queries regarding this report.

Regards,

JDA CONSULTANT HYDROLOGISTS



Data Source: JDA field observations 2,5 & 6 February 2007

JDA Consultant Hydrologists	Job No. J3969 	Richard Noble & Company East Clontarf: Culvert Blocking Investigation **Figure 1: Observed Water Level**