BELLAMACK ELRUNDIE AVENUE WETLAND
Functional Design Report

Prepared for the Northern Territory Department of Planning and Infrastructure
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1 INTRODUCTION

Ecological Engineering, now Ecological Engineering Practice Area of EDAW, was engaged by the Northern Territory Government Department of Planning and Infrastructure (DPI) to develop functional design for treatment systems to reduce pollutant loads for a residential sub-division at Bellamack in Palmerston. The overall WSUD strategy for Bellamack is identified in the Bellamack WSUD Strategy report (Ecological Engineering, 2007).

Wetland systems have been proposed as one treatment measure. Specifically the proposed wetland discussed in this report is located:

(i) Immediately upstream of Elrundie Avenue

The detailed designs are a key step in the implementation of the integrated approach to managing stormwater within Bellamack. The integrated approach to management has been formalised in the Bellamack WSUD Strategy a program was undertaken to develop a plan for urban water management within the development. The strategy for Bellamack is based on a series of multi-disciplinary and multiple stakeholder planning workshops. The stormwater management strategy is shown in Figure 1.

The current detailed design is based on concepts broadly described in the Bellamack WSUD Strategy (Ecological Engineering, 2007a) and Stormwater Treatment Options for Darwin (Ecological Engineering, 2007c). The wider goal of the strategy is to provide integrated urban water management to best management practice standards and to meet the WSUD objectives for Darwin such as those outlined in WSUD Design Objectives (Ecological Engineering, 2007b).

The objective of this report is to document the detailed design for the treatment systems in sufficient detail to inform key stakeholders, including Department of Planning and Infrastructure and Palmerston Council and to provide a basis for detailed design drawings.

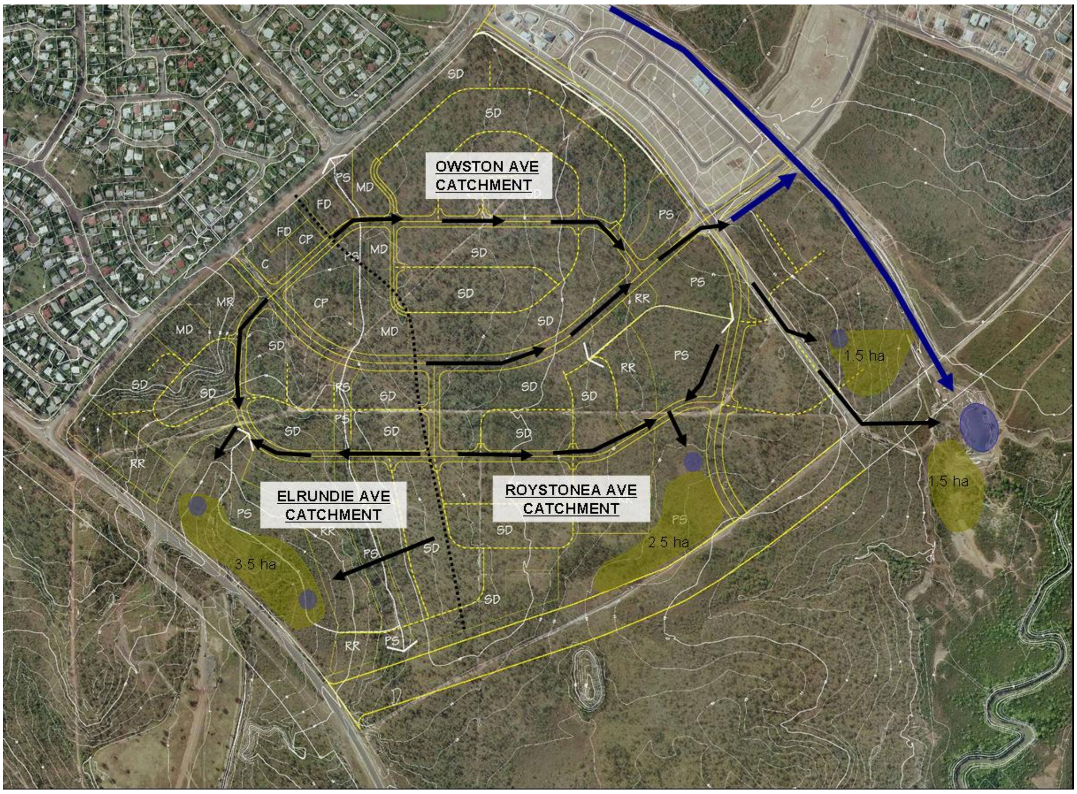

Figure 1 Bellamack WSUD Strategy

2 ELRUNDIE CATCHMENT STORMWATER MANAGEMENT STRATEGY

The strategy to manage stormwater within Elrundie Avenue Catchment are outlined in the WSUD Strategy for Bellamack (December 2007). The strategies include:

- Promote stormwater treatments within landscape features
- Create a wetland area within the development immediately upstream of Elrundie Avenue
- Provide a flexible design that is capable of retrofitting for aquifer recharge if required
- Meet the WSUD objectives in regard to stormwater quality for the development.

2.1 Stormwater treatments within landscape features

The stormwater collection and treatment systems within the Elrundie catchment development are designed for multiple benefits of providing stormwater conveyance and treatment as well as increasing habitat values, landscape amenity and recreation opportunities.

To achieve these objectives, the drainage system is designed to facilitate the creation of landscape features, by using wetlands within public open spaces for stormwater treatment. The wetland and drainage lines are to be based around the natural topography of the area.

The wetland and natural drainage paths will act to disconnect impervious areas from waterways thus slowing flow rates from the impervious urban areas and providing a more natural streamflow response following rainfall compared to conventional drainage design.

Linear corridors of open space can become recreation assets

Provisions in the design have been made to safely convey large flood events to comply with current engineering standards.

The proposed wetland system has been designed for stormwater treatment as well as to enhance wildlife habitat and landscape amenity within the development.

2.2 Wetland treatment system

The wetland system proposed for the Elrundie Catchment is intended to provide treatment of stormwater to best practice standards through sedimentation and filtration through vegetation and nutrient uptake. In addition, this system will *potentially* provide temporary storage of treated water for injection into an aquifer. The design has incorporated flexible designs so that future injection is possible.

The wetland will have three major components

- a sedimentation basin to remove coarse sediment
- an area of permanent deep open water, that retains water throughout the year, and draws down considerably during the dry season
- a seasonally inundated zone that will dry out during the dry season, but will retain a permanent pool water during the wet season.

3 ELRUNDIE CATCHMENT

The Elrundie Catchment is bounded by Chung Wah Terrace to the north and Elrundie Avenue to the West and by a north south ridge line running through the development to the East as shown in Figure 2.

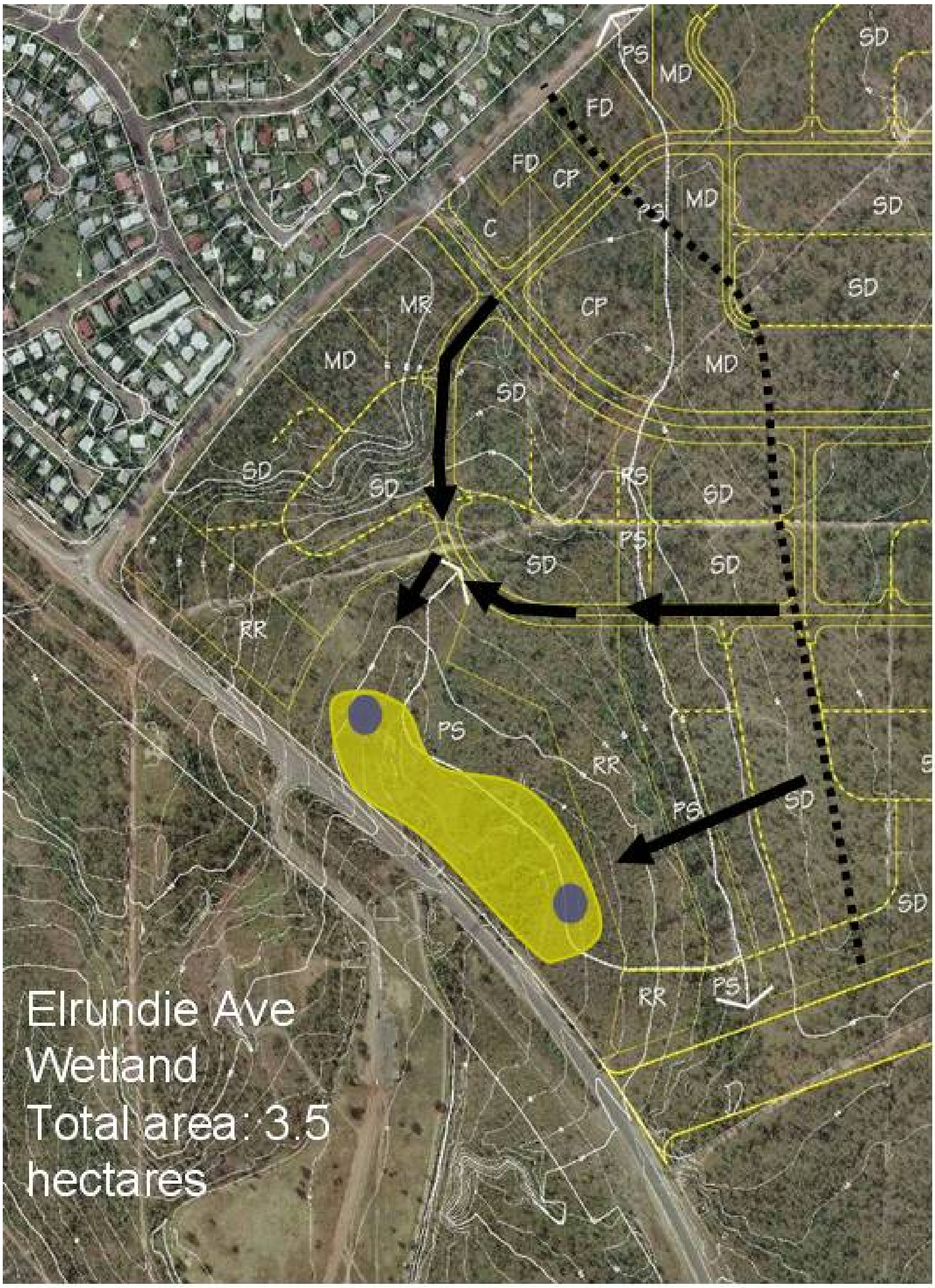

Figure 2 Elrundie Avenue Catchment and Location of Wetland

The majority of the catchment, 80% including Subcatchments E1, E2, E3 and E4, will drain low flows to the northern end of the wetland. The remaining 20% of the catchment, E5 and E6, will drain directly to the permanent pool in the southern end of the wetland. This is shown in Figure 3

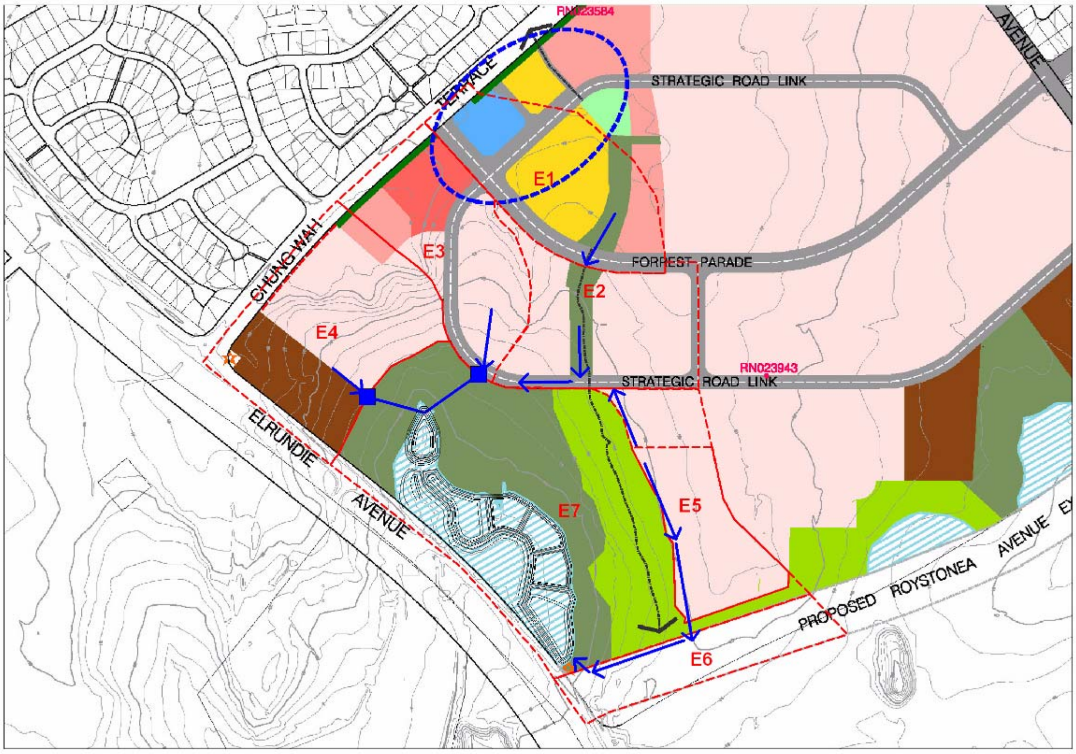

Figure 3 Elrundie Avenue Subcatchments and Delivery to Wetland

The wetland is designed to treat stormwater runoff that drains a 52 hectare residential catchment before it is discharged into the existing drainage corridor on the western side of Elrundie Avenue.

The catchment area of the Owston Avenue system is approximately 52 hectares, consisting of approximately 21 hectares of residential and 10 hectares of road and footpath, 3 hectares of commercial and multi- purpose and 18 hectares of open space. The percentage imperviousness of the catchment is estimated to be approximately 40% for the total catchment.

The details of the catchment areas are summarised in Table 1.

Table 1 Summary of Catchment Details

Land Use	Road Catchment (ha)	Estimated % Impervious
Roads and footpath	9.85	100
Open Space	18.29	5
Multi-Purpose	2.21	30
Commercial	0.72	80
Multi-dwelling	1.44	50
Medium Density	1.21	70
Single Dwelling	16.26	40
Low Density	2.26	30
TOTAL	55.2	40

4 ELRUNDIE FLOOD DESIGN FLOWS

This section summarises a hydrological analysis for the proposed wetland required in the Bellamack Residential subdivision area adjacent to Elrundie Ave. This analysis was undertaken to determine the peak flood design flows for the system.

Two methods were undertaken to determine flows and these were compared to the design peak flows of the existing culverts. These methods included:

- A RORB model
- Rational Method (based on AR&R)

4.1 RORB Model Parameters

The parameter set described for Darwin in AR&R was used to undertake the RORB modelling. Details of the key parameters are as follows:

- $k_c=1.8(A/\sqrt{s})^{0.55}$ = 0.55 (Area = 0.52 km^2; slope = 20 m/km)
- m = 0.8
- Initial loss = 0 mm
- Runoff coefficient = 0.86 (100 year ARI), 0.72 (10 year ARI) and 0.58 (1 year ARI)

4.2 Rational Method

Discharges from the catchment have been estimated, based on the Probabilistic Rational Method described in Australian Rainfall and Runoff (ARR) (1997). The details of this are shown below:

Q = CIA/360 (from ARR, Vol 1, 1997)

Area = 52 hectares

The catchment area is estimated to be 40% impervious.

4.3 Elrundie design flows

The design flows used to size elements of the wetland system and downstream waterway are presented in Table 2.

Table 2 Results of the Design Flow Analysis

ARI	RORB (m^3/s)	Rational Method (m^3/s)	Existing Culvert (m^3/s)
1 year ARI	7.9	6.3	Not Known
10 Year ARI*	15.1	12.8	Not Known
100 year ARI	24.0	22.4	10.5 (northern culvert) +6.8 (southern culvert)

These flow rates were used to size the various elements of the wetland including the bypass channels, inlets to the wetland, the overflow structures of the wetland system as well as the downstream channel characteristics including the channel section and crossings.

5 ELRUNDIE CONSTRUCTED WETLAND SYSTEM

The intention of the wetland system is to protect downstream waterways from increases in pollutant loads generated as a consequence of urbanisation of the upstream catchment. In addition, the system has an important temporary storage function for treated flows that can be potentially injected into an aquifer for storage and subsequent recovery for irrigation (should aquifer recharge be required due to insufficient natural recharge and changes to the catchment).

The nature of the land use change from natural vegetation to residential areas is likely to contribute contaminants including sediments, nutrients, heavy metals, hydrocarbons and litter. Pollutant loads will be reduced from stormwater flows by filtering through shallow vegetation and providing sufficient detention to allow for extended sedimentation and other physical, chemical and biological processes to occur.

In addition to providing water quality improvement, the system is designed to enhance habitat for aquatic and bird species and become an attractive component of the public open space network.

A proposed layout of the system is shown in Figure 4 that shows flow directions and the main components of the wetland system.

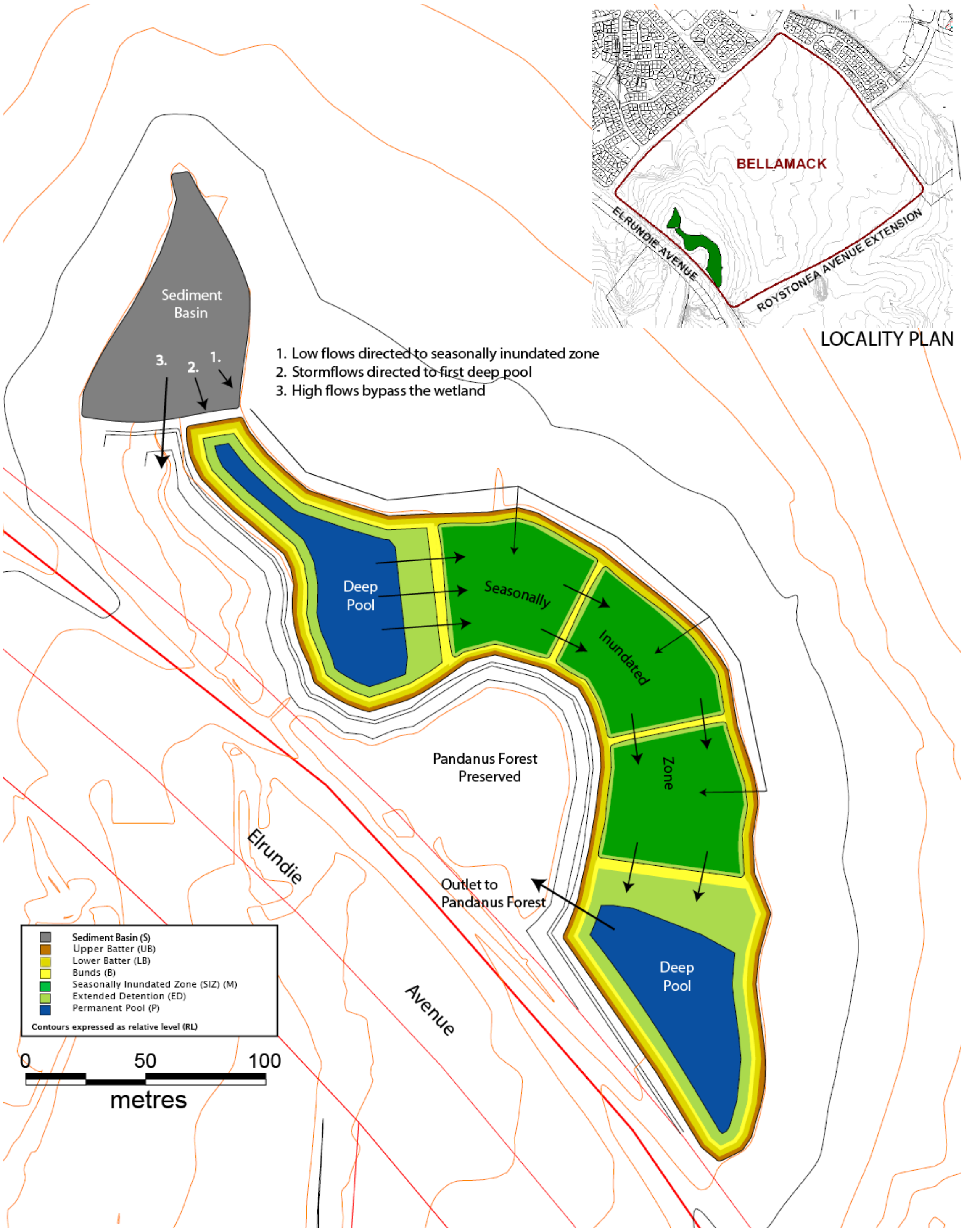

Figure 4 Layout of Elrundie Wetland

5.1 Stormwater Quality objectives

Proposed stormwater treatment objectives for Darwin are outlined in the WSUD Design Objectives for the Darwin Region (Ecological Engineering, 2007b). These objectives relate to reductions in pollutant loads compared to conventional urban areas with no treatment measures. Specifically the stormwater treatment objectives adopted are:

- 80% reduction in total suspended solids loads
- 60% reduction of total phosphorous loads
- 45% reduction in total nitrogen loads
- 70% reduction in litter loads.

A wider range of stormwater pollutants are carried in stormwater than those listed above, however, by meeting these objectives it is considered that most of the other contaminants will also be captured in a similar proportion.

5.2 Overview of operation

The wetland comprises three main zones:

- An inlet zone, for removal of coarse sediment
- Two separated permanent pool zones planted with submerged aquatic vegetation, to provide storage for aquifer recharge, a refugia for predators of mosquito larvae during the dry season and an area of open water for increased aesthetics and landscaping
- A seasonally inundated zone planted with emergent macrophytes, to provide good contact time and pollutant removal. The seasonally inundated zone is separated into three cells to ensure good hydraulic performance of the system and even flow across the wetland.

In general stormwater is delivered to the inlet zone where it overflows into the first permanent pool zone, and flows into the three seasonally inundated cells before entering the second permanent pool zone. Excess flows which are not contained within the wetland are discharged via a riser and overflow weir into the protected pandanus zone. A detailed description of the operation is outlined below.

Stormwater will be conveyed from the development by conventional stormwater drainage systems to a sedimentation basin which forms the inlet zone of the wetland system. This zone is relatively deep (2.0 to 2.5 m) where velocities will slow and coarse sediments settle.

From the inlet zone, the first 1750kL and low flows (up to 30 L/s) are transferred into a seasonally inundated macrophyte (emergent marsh) zone (SIZ). In this area flows pass through a series of shallow vegetated 'bands' of emergent vegetation (0.6m deep). Vegetation will be densely planted and arranged such that 'short circuiting' of flows is minimised. This area of the wetland (approximately 1 hectare of emergent macrophytes) will be configured so that water levels will rise by up to an extra 0.5 m (1.1 m in total and up to RL 8.5m) during storm events and take approximately three days to drain back to the normal water level. Outflows from the SIZ will be controlled by a riser outlet with multiple discharge points up to 500 mm above the normal water level (RL 7.9m).

Once the first 1750 kL of the inlet zone is full, water level will rise in the sediment basin up to the top of extended detention (10.0m). Flows will rise up to an additional 0.5m and pass flows up to 4 m^3/s into the first deep pool zone via an overflow pit and a submerged pipe.

Stormwater will then pass into the three cells of the SIZ, and into the second and final permanent deep pool. This second pool zone contains 'open water' (up to 2 m deep) and submerged macrophyte (900 mm deep) with emergent macrophytes on the edges. This area will further remove nutrients, provide for UV disinfection and act as temporary store of water before possible injection into an aquifer.

Stormwater flows out of the wetland via two methods:

- A riser outlet from the emergent macrophyte zone will be used to control flows out of the extended detention system of the main wetland system .
- Excess overflows from the wetland occur when water levels within the SIZ and the deep pool zone reaches its maximum extended detention level. Once the SIZ zone is full (ie. 500mm deeper than normal water levels, RL 8.50) water will overflow from the weir in the SIZ and exit the main wetland zone.

Flows leaving the wetland will discharge into the protected pandanus zone and exit the development site via the two series of existing culverts underneath Elrundie Avenue.

The main wetland system will be protected from high flows (greater than 4 m^3/s) by an overflow weir from the inlet zone into a bypass channel. The bypass system has been designed to discharge the overflows into a channel to the south-east via a weir, where it will ultimately discharge via an existing culvert underneath Elrundie Avenue. In this way the vegetation and deposited fine particulates in the

macrophyte zone are protected from high flows and detention times are maintained near to three days.

Edge details of the system are proposed to be soft (planted) edges that will compliment the landscape of the area, and in particular the area of native vegetation that is to be retained on the development site.

5.3 Wetland components

The following sections describe the approach taken to design the wetland system for Elrundie Avenue.

5.3.1 Design flows

Design flows are outlined in section 4 which. Key flow rates for the wetland design are the inflow rates, as estimated using RORB, are:

$Q_{1\text{-year}}$ = 7.9 m^3/s

$Q_{10\text{-year}}$ = 15.1 m^3/s

$Q_{100\text{-year}}$ =24.0 m^3/s

To determine what flows were diverted through the wetland for treatment MUSIC was also used to determine the cumulative frequency distribution of peak flows into the system. The results of this analysis are shown in Figure 5. This analysis showed that by diverting up to 4.0m^3/s into the macrophyte zone of the wetland more than 95% of the flows would be diverted into the wetland.

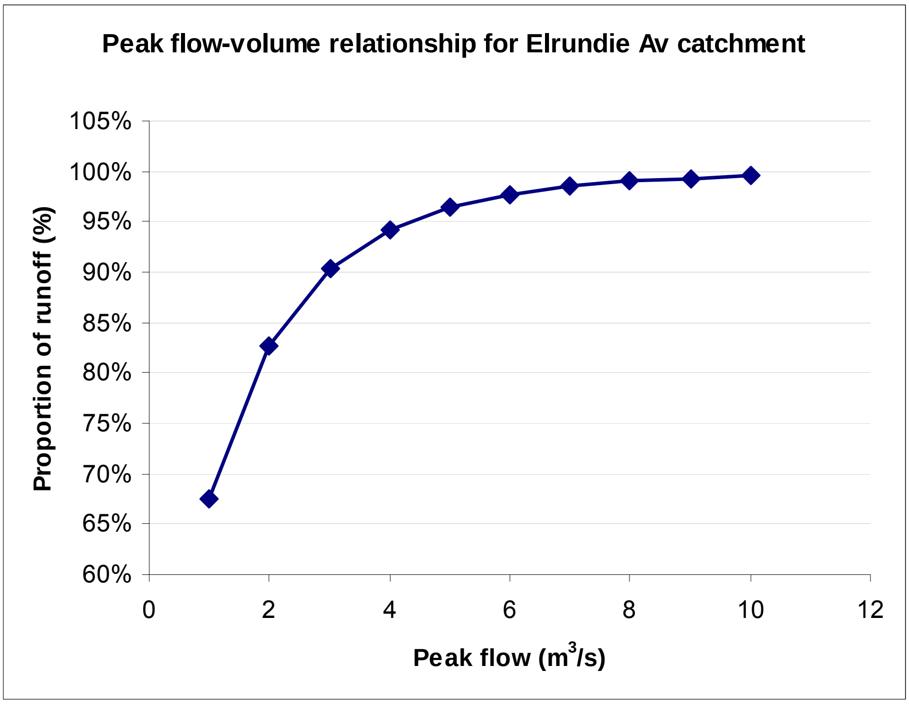

Figure 5 Cumulative Frequency Distribution of Flows into Elrundie Wetland.

5.4 Inlet zone

The inlet zone is sized to promote settling to capture 90% of 125 micron particles for the design flow event (4.0m^3/s) , yet not to be too large to effectively retain finer material.

To size the inlet pond, a settling velocity of 0.011m/s is adopted for a 125 micron particle (Engineers Australia, 2003). A required area (assuming ideal settling conditions) for a 1-year flow rate is was calculated using the following equation:

$A = Q_{design}/V_{settling}$

Thus, the area required is 365m^2. Turbulence within the inlet zone is likely to impact on the settling characteristics of particles in the flow.

To estimate the effect of turbulence on the removal efficiency of 125 micron particles, an expression by Fair and Geyer (1954) is applied.

$$R = 1 - \left(1 + \frac{1}{n}\frac{v_s}{Q/A}\right)^{-n}$$

where R is the fraction of solids removed

v_s is the settling velocity of particles

Q/A is the hydraulic loading

n is the turbulence parameter

This equation is applied with ‘n’ being a turbulence parameter. Chapter 11 in ARQ (Engineers Australia, 2003) provides guidance on selecting an appropriate ‘n’ value (according to the configuration of the basin). ‘n’ is selected using the following relationship

$$\lambda = 1 - 1/n$$

λ is a measure of the hydraulic efficiency of a pond depending on it’s configuration. Figure 4.2, from Chapter 11 of ARQ (Engineers Australia, 2003), presents a range of λ value for different configurations of ponds.

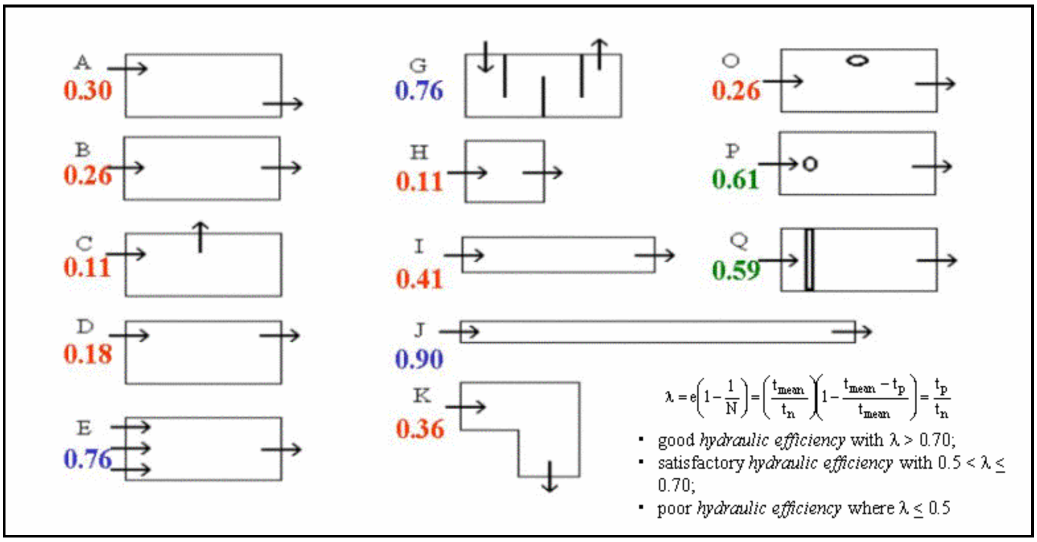

Figure 4.2 Hydraulic efficiency value for λ (IE Aust, 2003)

From Figure 4.2 a value for λ of 0.5 was adopted, reflecting a configuration that is in between to shape E and I. Therefore, the value of 2 is adopted for n.

Hence the removal efficiency for the inlet basin is estimated to be:

$$R = 1 - \left(1 + \frac{1}{3}\frac{0.011}{4.0/365}\right)^{-2} = 0.55$$

This removal efficiency is considered to be too low.

Therefore the inlet basin size was increased to 1200m², which yielded a removal efficiency of 90%.

A two metre depth for the inlet zone was initially adopted to provide for sediment accumulation and also to prevent unwanted vegetation growth. Using this volume, an estimation of the required cleaning frequency was undertaken adopting a theoretical sediment generation rate of 1.6m^3/year/hectare (Willing and Partners, 1992) and two estimates of TSS loads, 1920 kg/ha/yr (MUSIC) and 775 (Karama and Moil)

The annual sediment load was calculated based on an urban contributing area of 42 hectares and a capture rate of 90% which gives an annual sediment load of 45m3 (MUSIC) or 18 m^3 (Karama and Moil). Thus the sediment basin has more than sufficient capacity to be cleaned out at a frequency every 5 years.

While it is possible to clean out the sediment basin less frequently an annual clean out of the sediment basin is recommended at the end of the dry season. The sediment basin should be emptied annually and cleaned especially during the first 5 years of operation, during the construction phase and first few years of the development.

An additional velocity check is performed to ensure that when the sediment basin is full (i.e. 1.5 m of accumulation) and flows are transferred into the macrophyte zone (i.e. 1-year flows) sediments do not scour and are carried into the macrophyte zone. Keeping velocities below 0.5 m/s is considered reasonable.

Therefore with 0.5m depth and a width of approximately 20m, using the 1-year flow of 4m^3/s, a velocity of 0.4m/s is estimated, which is considered adequate.

The normal water level in the inlet zone is set 1.5 m higher than the normal water level in the macrophyte zone (i.e. it is set at RL 9.5 m), to create a deeper pool to help aid sedimentation. The extended detention depth in the inlet zone is to be 0.5 m (RL 10.0 m) so that the top of extended detention in the inlet zone is 1.5 m above that in the main wetland zone (RL 8.5 m), to provide enough head to ensure flows pass out of the inlet zone and into the wetland.

An inlet zone of 1200m^2, 2m depth and an aspect ratio of 4:1 is adopted with a permanent water level of RL 9.5 m and top of extended detention of RL 10.0 m.

The entrance to the inlet zone will require some energy dissipation to help reduce and spread velocities across the pond (eg. large rocks placed in the flow path).

5.4.1 High Flow Transfer from inlet zone to macrophyte zone

The hydraulic connection between the inlet zone and macrophyte zone is via a grated pit and culvert. The crest of the grated pit sets the permanent pool in the

inlet zone at RL 9.5m and is designed to have the capacity to discharge the design flow (4 m^3/s) when the inlet zone is at the top of its extended detentin (RL 10 m). As the water level in the inlet zone rises above the top of extended detention (RL 10 m) the grated pit will eventually be submerged and ultimately bypass of the inlet zone occurs.

To size a pit such that the design flows can be delivered with 0.5 m head two scenarios are checked for, free overfall conditions (weir equation) and drowned conditions (orifice equation).

For free overfall conditions (weir equation):

$Q = B.C.L.H^{3/2}$ (with C = 1.7 and H = available head above weir crest, B = blockage factor and L = length of weir)

$4.0 = 0.5 \times 1.7 \times L \times (0.5)^{3/2}$

Therefore L = 13.6m (adopt a 3.4m by 3.4m pit or similar)

Now check for drowned outlet conditions (orifice equation):

$Q = BxCxAx \sqrt{2gh}$ with C = 0.6 and H = available head above weir crest

$4.0 = 0.6xA \sqrt{2x9.8x0.5}$

Therefore A = 4.3 m^2 (eg. pit 2.25m by 2.25m)

From these calculations it is expected that free overfall conditions dominate and a pit size of 3.4m by 3.4 is adopted.

5.4.2 Inlet to macrophyte zone pipe

The pipe system conveying flows from the inlet zone to the macrophyte zone is sized for the design flow of the 1-year ARI peak flow when the water level in the macrophyte zone is at the top of extended detention (RL 8.5 m) while the inlet zone is at the top of extended detention (RL 10m).

A drowned pipe is assumed and therefore the orifice equation is adopted to estimate the pipe area required. The available head is 1.5m (inlet zone at RL 10 and macrophyte zone at RL 8.5:

$Q = CA \sqrt{2gh}$ with C = 0.6 and H = available head above weir crest

$3.0 = 0.6.A \sqrt{2g.1.5}$

Therefore A = 2.5 m^2

Adopt 1250mm diameter pipe to connect inlet zone to macrophyte zone.

5.4.3 Low flow outlet to Seasonally Inundated Zone

The inlet zone is also designed to transfer low flows from into the SIZ. Low flows will be preferentially diverted to the seasonally inundated zone to ensure that the macrophyte vegetation in the SIZ survives the long dry season and to ensure that it has preferential wetting over the permanent pool.

Vegetation in the SIZ is capable of withstanding an initial 200mm rise in water level and is capable of withstanding subsequent water level rises of 2 to 7 cm a day. This results in:

- the initial volume of water that can be diverted to the SIZ is approximately 2000 m^3 and
- a subsequent flow rate of 10 L/s into the SIZ

Thus the sediment basin has been configured to contain a low flow volume of approximately 2000 m^3 below the normal water level (RL 9.5m) and the low flow outlet (RL 8.5 m). The low flow outlet is sized to deliver 10 L/s based on a submerged orifice equation and no assumed blockage (discussed in more detail below)

$Q = CA\sqrt{2gh}$ with C = 0.6 and H = available head above weir crest

$0.01 = 0.6.A\sqrt{2g.1}$

Therefore A = 0.0038 m^2

Therefore adopt a 35mm diameter orifice to connect the inlet zone to the SIZ. This orifice is very small and is thus prone to blocking. To ensure that the orifice does not become blocked it is proposed to place the orifice inside a separate 600 mm by 600 mm outlet pit with a lid level at 9.5m – the top of the normal water level to provide access. Within the pit will be contained a 150 mm diameter upstanding riser with a 35mm diameter orifice drilled into the side of the riser at RL 8.5m. The pit will have 4 openings cut out of the side, 300 mm by 300 mm which will be screened with a fine mesh of 50mm. This will provide a total surface area of 0.36 m^2 or approximately 100 times the required area of opening for the orifice. Thus this screened inlet can be 99% blocked before the capacity of the orifice is protected and will provide a sufficient screening function for the orifice.

5.4.4 Low flow transfer pipes to Seasonally Inundated Zone

From the low flow outlet pit from the inlet zone a 150mm diameter pipe at 0.3% slope will convey low flows to the three SIZ cells. The flows will then be split evenly through a series of flow splitting pits. The flow splitting pits will split a third of the flow, 3.3 L/s, into the SIZ cell.

The pit will be configured with a weir plate and a 90mm outlet to the SIZ cell. The weir flow plate will be 150mm high. Using a drowned orifice equation assuming no blockage:

$Q = CA\sqrt{2gh}$ with C = 0.6 and H = available head above weir crest

$0.0033 = 0.6.A\sqrt{2g0.1}$

Therefore $A = 0.004\ m^2$

Adopt an orifice plate with diameter circular opening of 35mm to connect inlet zone to macrophyte zone. The orifice plate will be constructed over a 90mm outlet pipe.

To pass water over the weir a minimum width of 0.35m is required with a minimal head of 0.05m. Thus use a flow diverter pit size of 450mm by 450mm.

5.4.5 Inlet Zone Bypass system

A bypass system is designed to transfer high flows, up to the Q_{100} year event (10.5 m^3/s) from the inlet zone into a bypass channel to avoid scouring vegetation within the macrophyte zone. The bypass channel will convey flows to the existing culvert outlet along an existing incised channel heading south eastwards.

When the inlet zone is at the top of extended detention (RL 10 m) flows will pass over a weir from the inlet zone into the existing incised channel. The weir will have a crest level of RL10 m and have a length of 18m.

During a 100 year ARI event water levels within the inlet pond will surcharge up to RL10.5m and therefore bank heights around the sediment pond are to be at least RL10.5m. It is assumed that the weir is able to pass the full flow, assuming in the worst case scenario the outlet to the wetland zone is blocked.

The culvert transferring flow to the submerged marsh zone to the north have been sized to convey up to a 1-year flow rate before the overflow weir engages. The required area is estimated using a weir equation (i.e. to estimate their capacity before they become submerged:

$Q = C.L.H^{3/2}$ with C = 1.7 and H = available head above weir crest

$4 = 1.7.L.(0.5)^{3/2}$

therefore L = 18m.

Adopt a 18m long weir with crest at RL 10 m and set the bank height around the inlet pond at RL 10.5 m.

5.4.6 Edge treatments

A combination of edge treatments are to be used to compliment the landscape of the area. Soft (i.e. planted) edges are proposed for the inlet zone.

Figure 7 shows a diagram of the proposed planted edge details and batter slopes. These edges include ledges for safety, as well as recommended batter slopes of 1 in 5 to ensure that safe exit can be made from the wetland during rising water levels.

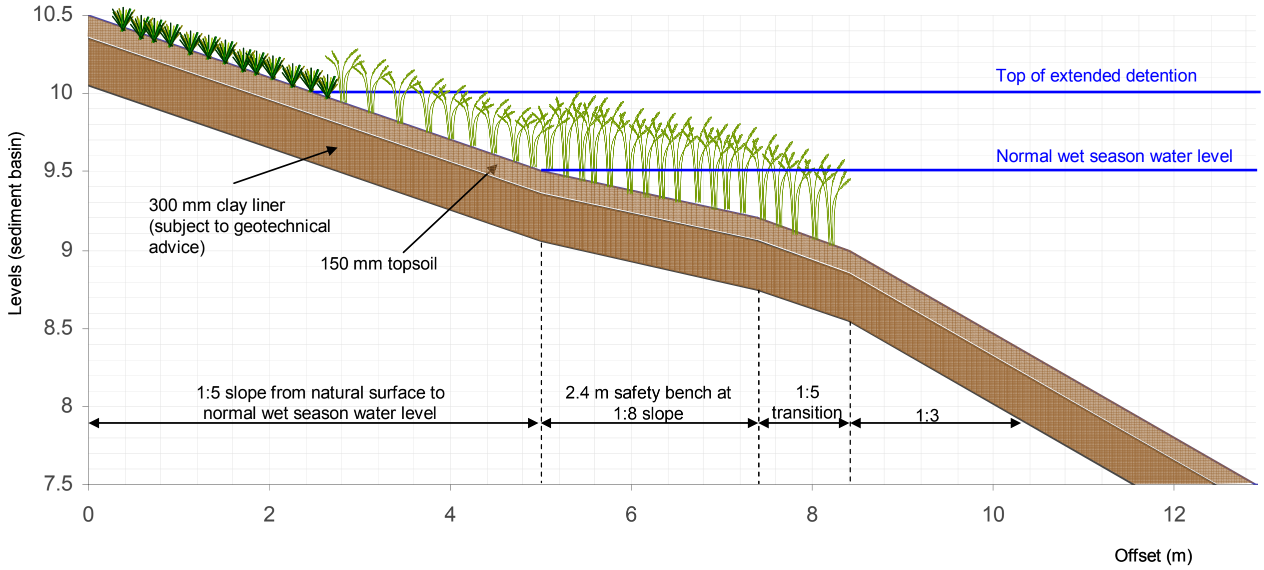

Figure 6 Soft Edge Details

5.5 Litter control

Litter control is preferred as part of the inlet zone of the wetland. It is proposed to locate one Humeceptor or equivalent gross pollutant trap at the outlet of E1, E2 and E3 subcatchments. This subcatchment has the highest density of development as well as mixed use including community and commercial uses. The remaining catchments E4 and E5 are not expected to require gross pollutant removal. These catchments are low density single dwelling catchments which do not have expected large litter loads. If litter control is considered necessary for these

subcatchments it can be undertaken at source and potentially retrofitted at a later date if required.

5.6 Seasonally Inundated Zone

The seasonally inundated zone is the main treatment area in the wetland, and it has been designed to provide maximum contact between stormwater and vegetation. By further slowing the flow of water the vegetation promotes enhanced sedimentation. The emergent macrophytes growing in the seasonally inundated zone provide the surface area for colonisation by algal and microbial biofilms. These biofilms provide much of the pollutant processing and removal in stormwater treatment wetlands. The vegetation also oxygenates and stabilises the sediment.

Bunds in the seasonally inundated zone will ensure the uniform horizontal and vertical distribution of flow through this part of the wetland. The bunds will prevent the creation of preferential flow paths and disperse flows evenly as they pass through this treatment zone. The bunds will also help to retain water within the seasonally inundated zone at the end of the wet season, thus shortening the length of the dry period in each dry season. To further reduce the exposure of the vegetation to drought, the first flows of the wet season will be directed to the seasonally inundated zone. This will give the vegetation the chance to begin growing before the intensity of rainfall builds up.

The seasonally inundated zone of the wetland system is designed to be a relatively shallow vegetated area with a high length to width ratio. The permanent water level during the wet season is RL 8.0 m with a 0.6 m wet season water depth and an extended detention depth of 0.5m (RL 8.5 m). The SIZ is designed to have water level variation in the extended detention depths with a nominal detention time of 72 hours.

The SIZ is split into three cells to ensure even distribution of flow throughout the SIZ and to create conditions close to plug flow conditions. This ensures that short circuiting of the SIZ is minimised as the bunds provide a physical control forcing flows through the width of the SIZ.

Generally the bathymetry in the three cells of the SIZ is a flat basin which rises to the existing contours on the northern side and an embankment on the southern side, intersected by bunds which separate the SIZ from submerged marsh and deep open water areas at either end of the macrohpyte zone. The SIZ will have a

densely vegetated area using plant species suited to the water level variation in the SIZ. The surrounding banks of the macrophyte zone will rise to at least RL 8.8m.

The SIZ will incorporate three key components:

- A main SIZ with a normal water depth of 0.6m during the wet season, which will slowly dry out and drawdown at the end of the wet season
- Three shallower bunded zone to ensure even flow distribution throughout the SIZ. The bunded zones will have a normal wet season water level of 0.1m and pond up to 0.6m during storm events.
- Edge zones battering at 1 in 5 from the existing surface (RL 8.8 m) to the base of the wetland at RL 7.4 m. The edge zones incorporate benches (2.4 m wide at 1 in 8 slope) as recommended by Melbourne Water (2005) for safety requirements and will be heavily vegetated to prevent access.

Stormwater will enter the SIZ in three main ways:

- Rising water levels overtopping the most westerly bund from the deep pool located at the western end of the SIZ
- The low flow outlet from the inlet zone of the wetland.
- Overland sheet flow into the wetland for events that exceed the capacity of the minor drainage system. These flows will occur when the SIZ is at its maximum capacity and will pass

5.6.1 SIZ Inlet Low Flow Inlet

Low flows will be delivered to the SIZ from the inlet zone via a low flow outlet and series of flow splitting pits. From the flow splitting pits a 90mm pipe will be connected to a 225mm ‘half pipe’ laid across the width of the SIZ and filled with 2mm to 5mm gravel. The half pipe will be used to distribute the low flows evenly along the SIZ cell. The ‘obvert of the half pipe’ will be laid flush with the surface at RL 7.4 m and with an invert of RL 7.2875 m. The pipe will be capped at the end of the pipe forcing the low flows to pond to exit the distribution pipe flow out along an effective long weir into the SIZ.

5.6.2 SIZ Vegetation

Plant species have been selected that suit the area as well as the functionality of the different zones in the SIZ. Figure 4 shows an indicative layout of the bathymetry of the macrophyte zone and the different zones suitable for a range of

vegetation types. The vegetation layout has also been designed to avoid short circuiting of the wetland.

The vegetation in the flat basins or macrophyte cells of the SIZ is planted with emergent macrophytes. These species were chosen for the following properties:

- Ability to survive periodic dry spells of up to 2 months duration
- Tolerance of regular inundation of up to 1.1m
- Growth habit – thin, tall, firm stems to provide a large surface area for colonisation by microbial and algal biofilms
- Aesthetic appeal

The vegetation in the bunds of the SIZ was chosen for the following properties:

- Tolerance of seasonal dry spells
- Tolerance of seasonal inundation of 0.1m for extended periods and up to 0.6m for short periods
- Provision of a tree canopy and landscape aesthetic of the wetland (especially due to the provision of deeper soils in the bunds)

The batters between the SIZ and the submerged marsh zone are areas of relatively variable water level. The batters can be planted with annual species that grow either in shallow water during the wet season or that establish on the drying batters during the dry season. Vegetation in the batters was chosen for the following properties:

- Tolerance of seasonal dry spells

Tolerance of seasonal inundation of 0.1m for extended periods and up to 0.6m for short periods

Table 3 Table 3 presents a list of recommended plant species for the different zones within the SIZ. The final selection of species will be undertaken in detailed design depending on availability and in consultation with the NT Government, Council and local suppliers.

Table 3 Recommended plant species for zones in the SIZ

Scientific Name	Common Name (m)	Type of Plant	Max Height (m)	Exposure Tolerance (months)	Inundation Tolerance - Depth	Inundation Tolerance - Duration
Seasonally Inundated Zone - Macrophyte cells						
Pseudoraphis spinescens	Spiny Mudgrass	Emergent Grass	1-2	High	1	10
Eleocharis sphacelata	Tall Spikerush	Emergent Macrophyte	2	Low	2	12
Phragmites australis	Common reed	Emergent Grass	5	High	1.5	9.5
Seasonally Inundated Zone - Bunds – understorey						
Fimbristylis dichotoma	Sedge	Amphibious Sedge	1	High	0.5	6
Cyperus scariosis		Amphibious Sedge	0.8	High	0.5	6
Ischaemum australe		Amphibious Grass	1.5	High	0.5	6
Oryza australiensis	Native Rice	Emergent Grass	2.5	High	1	9 ?
Paspalum distichum	Water Couch	Amphibious Grass	0.6	High	0.5	6
Isoetes coromandelina	Quillwort	Amphibious Fern	0.8	High	0.5	6
Seasonally Inundated Zone - Bunds - trees						
Melaleuca dealbata	Paperbark	Amphibious Tree	12	High	1	6
Melaleuca viridiflora	Paperbark	Amphibious Tree	2-16	High	1	6
Pandanus spiralis	Screw Palm	Amphibious Tree	10	High	1	6
Lower Batter (seasonally wet) - wet season						
Cyperus scariosis		Amphibious Sedge	0.8	High	0.5	6
Fimbristylis dichotoma		Amphibious Sedge	1	High	0.5	6
Schoenoplectus praelongatus		Amphibious Sedge	0.5	High	0.3	6
Lower Batter (seasonally wet) - dry season						
Coldenia procumbens		Herb		High	0.1	6
Phyla nodiflora		Herb	0.2	High	0.1	6
Sporobolus virginicus	Salt Couch	Grass	0.6	High	0.1	6
Cynodon dactylon	Couch	Prostrate grass	0.2	High	0.1	6
Glinus oppositifolius		Herb	0.5	High	0.1	6
Upper Batter (terrestrial vegetation)						
Sorghum plumosum						
Sorghum stipodeum						
Themeda australis	Kangaroo grass	Grass	0.75	High		
Eucalyptus papuana	Ghost Gum	Tree	8-15	High		
Eucalyptus polycarpa			10-15	High		

5.6.3 SIZ Velocity Check

A velocity check is performed when the SIZ is at the top of extended detention (i.e 0.6m depth above the bund) and carrying design flows through the wetland (4 m^3/s). The velocity check is to ensure that high velocities do not scour the wetland, resuspend settled fine sediments and do not disturb vegetation in the zone. Keeping velocities below 0.5 m/s is considered reasonable.

Therefore with 0.6m depth and a minimum width of 50m, using the design flow of $4m^3/s$, a velocity of less than 0.2 m/s is estimated, which is considered adequate.

5.7 Submerged marsh/permanent pool zone

The role of the deep pools is to control, slow and disperse flows across the wetland. The first deep pool also facilitates sedimentation, while the second provides an opportunity for UV disinfection. The deep pools create habitat for the growth of submerged aquatic macrophytes and act as refugia for aquatic fauna.

Flows from the inlet zone are directed into the first submerged marsh zone via a submerged orifice for further treatment and for temporary storage prior to dispersal through the via a bund into the SIZ.

Flows from the SIZ are directed into the second submerged marsh zone via a bund for further treatment and for temporary storage prior to either discharge from the system or to aquifer injection (if aquifer recharge is required).

The submerged marsh zone (SMZ) is designed to be completely vegetated with submerged plants that will enhance the treatment of the flows and prevent ingress of weed species. It has been sized to provide for adequate treatment of flows and also to have sufficient turn over times to prevent long residence times that could lead to excessive algal growth.

The SMZ has a key functionality to provide a refugia for mosquito predators such as fish and macroinvertebrates during the dry season. The permanent pool will contain water levels within the system during the entire year to ensure that mosquito predators can survive the dry season. As water levels recede during the dry season due to evaporation and little or no top up flows from rainfall, the water SIZ will dry out but the SMZ will retain water throughout the year.

A water level analysis was conducted to determine how frequently and to what level the submerged marsh zone permanent pool would dry out during the dry season. The water level analysed 65 years of daily rainfall data and average evaporation data to predict the likely impact on water levels in the submerged marsh zone. A summary of the results of this analysis are:

- Water level receded to less than 0.5m depth (RL 6.5 m) on less than 3 occasions in the 65 year record
- The lowest water depth over this period was 0.2m (RL 6.2 m)

As a risk management measure the wetland will be topped up with water from the aquifer if it falls below the minimum water level depth of 0.5m. This ensures that even during long or extreme dry seasons the water level will maintain the refugia throughout the season and will also ensure that plants in the SMZ have a permanent water body.

5.7.1 Submerged marsh bathymetry

The SMZ system is designed to be approximately 1.1 ha in area, with two distinct SMZ of 0.55 hectares each. Both SMZs will have a normal wet season water depth of 2 metres (RL 8.0 m) and have a maximum water depth of 2.5 at the top of the extended detention (RL 8.5m). Flows from the initial western SMZ will discharge into the first cell of the SIZ over a wide bund on the eastern edge of the SMZ. Flows will discharge from the second SMZ via an orifice and overflow pit into the protected pandanus zone.

Soft edge treatments are intended to compliment the landscape of the area. Soft edge treatments will include planting with vegetation that will reduce erosion potential and minimise access to the water body.

The layout of the submerged marsh system is designed to reduce the risk of stagnant zones, where poor mixing may lead to very long detention times and therefore the possibility of excessive algal growth. Submerged rocks are used along the southern bank to promote even flow across the submerged marsh to avoid stagnant flow areas.

The second SMZ will also receive flows directly from the western part of the catchment (from E5 subcatchment) which will enter the submerged marsh at the north-eastern corner of the zone.

5.7.2 Submerged vegetation

The submerged marsh zone is to be completely planted with vegetation. This will enhance the treatment performance as well as reducing the likelihood of weed species establishing. The vegetation in the SMZ was chosen for their tolerance of deep water and habitat for aquatic fauna including mosquito predators.

Vegetation on the edges of the SMZ is also important for treatment. The edges will have emergent macrophytes which have

- thin, tall, firm stems to provide a large surface area for colonisation by microbial and algal biofilms
- dense clustered growth form with spiky stems to discourage pedestrian access to the SMZ
- aesthetic appeal

Vallisneria nana and *Potamogeton spp* are recommended for the entire submerged marsh and open water areas. A range of additional species for the deep pool may is also included in Table 4. Edge and emergent vegetation is selected to

compliment the macrophyte zone edge vegetation and should be selected from the species listed in Table 4.

Table 4 Recommended plant species for the SMZ

Scientific Name	Common Name	Type of Plant	Max Height (m)	Exposure Tolerance	Inundation Tolerance - Depth (m)	Inundation Tolerance - Duration (months)
Deep Pools - Permanently wet emergent macrophytes						
Actinoscirpus grossus		Tall Rush	3	Nil	1 ?	12
Eleocharis sphacelata	Tall Spikerush	Tall Rush	2	Low	1.5	12
Lepironia articulata		Tall Rush	4	Nil	1.5	12
Schoenoplectus littoralis		Tall Rush	2	Low	1 ?	12
Deep Pools - Permanently wet submerged macrophytes						
Ceratophyllum demersum	Hornwort	Submerged Aquatic Herb	0.6	Low ?	1-2	12
Myriophyllum dicoccum	Water Milfoil	Submerged Aquatic Herb		moderate	1-2	12
Najas tenuifolia	Water Nymph	Submerged Aquatic Herb	0.5	Nil	2	12
Vallisneria nana	Ribbonweed	Submerged Aquatic Herb	0.7	Nil	1	12
Potamogeton javanicus	Pondweed	Submerged Aquatic Herb		Low ?	1-2	12
Potamogeton tricarinatus	Pondweed	Submerged Aquatic Herb		Nil	1-2	12

5.7.3 Edge treatments

A combination of edge treatments are to be used to compliment the landscape of the area. Soft (i.e. planted) edges are proposed for the submerged marsh zone.

Figure 7 shows a diagram of the proposed planted edge details and batter slopes. These edges include ledges for safety, as well as recommended batter slopes of 1 in 5 to ensure that safe exit can be made from the wetland during rising water levels.

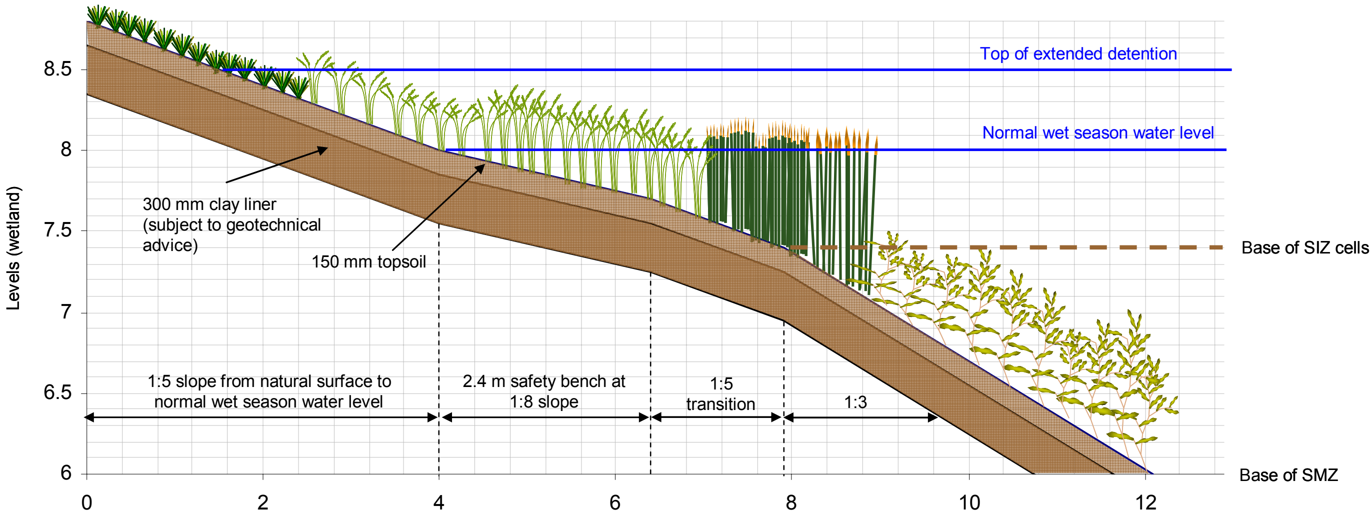

Figure 7 Soft Edge Details

5.7.4 Wetland Outlet structure

A notional detention time of 72 hours is adopted for the extended detention of the SMZ and SIZ. This will be achieved with the use of a riser style outlet that has multiple inlets, set at different levels. The intention is to provide for as consistent detention time as possible regardless of the water depth in the macrophyte zone.

Analysis of different configurations of orifices was conducted, using different heights and number of orifices (for construction simplicity it was decided to use the same size orifices for the whole riser and use multiple orifices at particular levels to increase discharge). The objectives of the analysis was to achieve as consistent detention time as possible for different water levels in the macrophyte zone.

A combination of 75 mm diameter orifices is adopted with heights at 0 mm, 125 mm, 250 mm and 375 mm above the normal wet season top water level (RL 8.0 m). Figure 8 shows the relationship between stage and discharge in the SMZ (and SIZ), indicating a relatively consistent stage-discharge relationship resulting is reasonable consistent detention times.

Table 5 presents the results of the riser analysis and Figure 9 shows a diagram of the riser orifice arrangement.

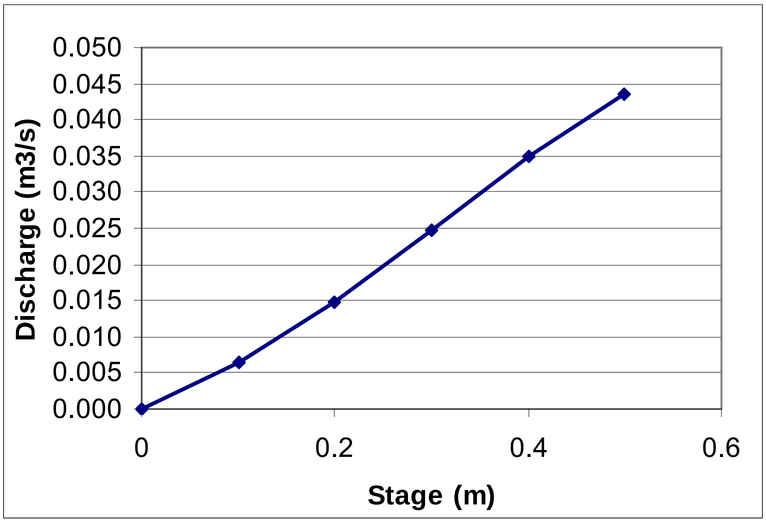

Figure 8 Stage-discharge relationship for the riser outlet

Table 5 SIZ and SMZ zone outlet riser analysis results

	Water Level (above RL45.1)	Wetland volume (m^3)	Layer volume (m3)	Q1	Q2	Q3	Q4	Total flow (m^3/s)	Notional turnover time if maintained at this level (hours)	Layer notional detention time (hours)
Q1	0	0		0.0000				0.0000		
Q2	0.1	2026	2026	0.0066	0.0000			0.0066	85.8	85.8
Q3	0.2	4106	2080	0.0106	0.0041	0.0000		0.0147	77.5	39.3
Q4	0.3	6241	2135	0.0134	0.0093	0.0021	0.0000	0.0248	69.9	23.9
Q5	0.4	8430	2189	0.0158	0.0124	0.0046	0.0021	0.0349	67.0	17.4
Q6	0.5	10674	2243	0.0178	0.0150	0.0062	0.0046	0.0437	67.9	14.3

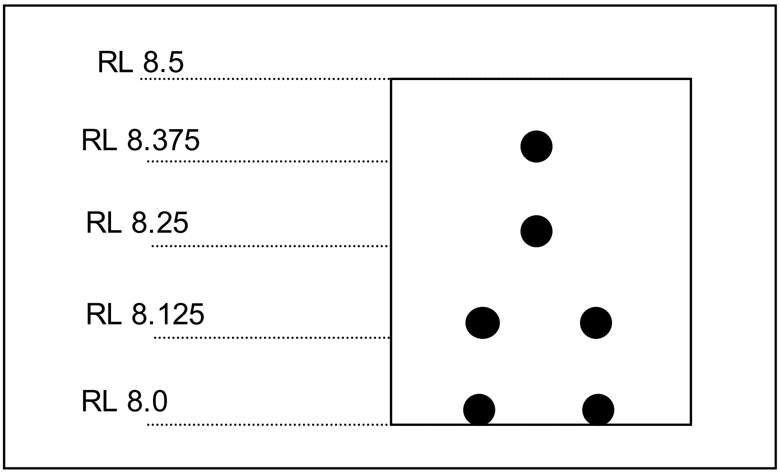

Figure 9 Macrophyte zone outlet riser orifice arrangement

The riser system is to be designed with a maximum discharge rate of 46 L/s when water level is at RL 8.50 m to transfer flows out of the main wetland zone.

The riser is to be housed within an underground pit located in the bank in the second SMZ. This will reduce the visual detraction of the riser outlet in the wetland. The riser is to be constructed out of a galvanized weir plate with the holes drilled through the plate or similar. Flow through the weir plate then

connects to a 225 mm transfer pipe into the protected pandanus zone. The 225 mm pipe enters the pandanus zone on the surface and drains into an existing depression in the zone.

Flow is transferred to the riser pit via a 300 mm diameter pipe that takes water from below the permanent pool level of the SMZ. The submerged intake reduces the likelihood of floating debris from blocking the riser holes.

The weir plate can be removed from the pit to act as a maintenance to draw down water levels in the SMZ and SIZ. Removing the weir plate will drain the macrophyte zone down to the top of the wet season normal water level. This pit will also be configured with a pen stock so the water level in the SMZ can be drained.

5.7.5 Submerged marsh high flow outlet

A spillway outlet is proposed as an outlet from the submerged marsh zone (and SIZ). The design flow for the outlet weir is the 1 in 100 year ARI event for the catchment that drains to the second culvert underneath Elrundie Avenue. The wetland will receive overland flow from the open space and development upstream of the culvert. The culvert has been sized for 6.5 m^3/s and this is used as the design flow from the SMZ via a spillway. The weir has an available head of 0.3m. The spillway is sized using a weir equation and applying a flow rate of the maximum flow rate through the wetland

Using weir equation:

$Q = C.L.H^{3/2}$ with C = 1.7 and H = available head above weir crest

$6.5 = 1.7.L.(0.3)^{3/2}$

L = 23.3m which is the required length of spillway.

Adopt a spillway length of 25 m with a crest level of RL 8.5 m and set the bank around the SIZ and SMZ at RL 8.8m.

The spillway will be constructed as a concrete weir with appropriate rock reinforcement on the downstream side.

5.8 High flow bypass

In major storm events, overland flows need to be managed to protect the wetland from damage. The relevant flows were taken as the design flows for the two sets of culverts under Elrundie Avenue. These were taken from a Department of Transport and Works drawing of 1982 (Drawing #R82-1562, sheet 37 of 38):

- The northern set of culverts have a design flow of 10.5 m^3/s (100 year ARI)

- The southern set of culverts have a design flow of 6.8 m^3/s (100 year ARI)

Figure 10 shows the location of the culverts.

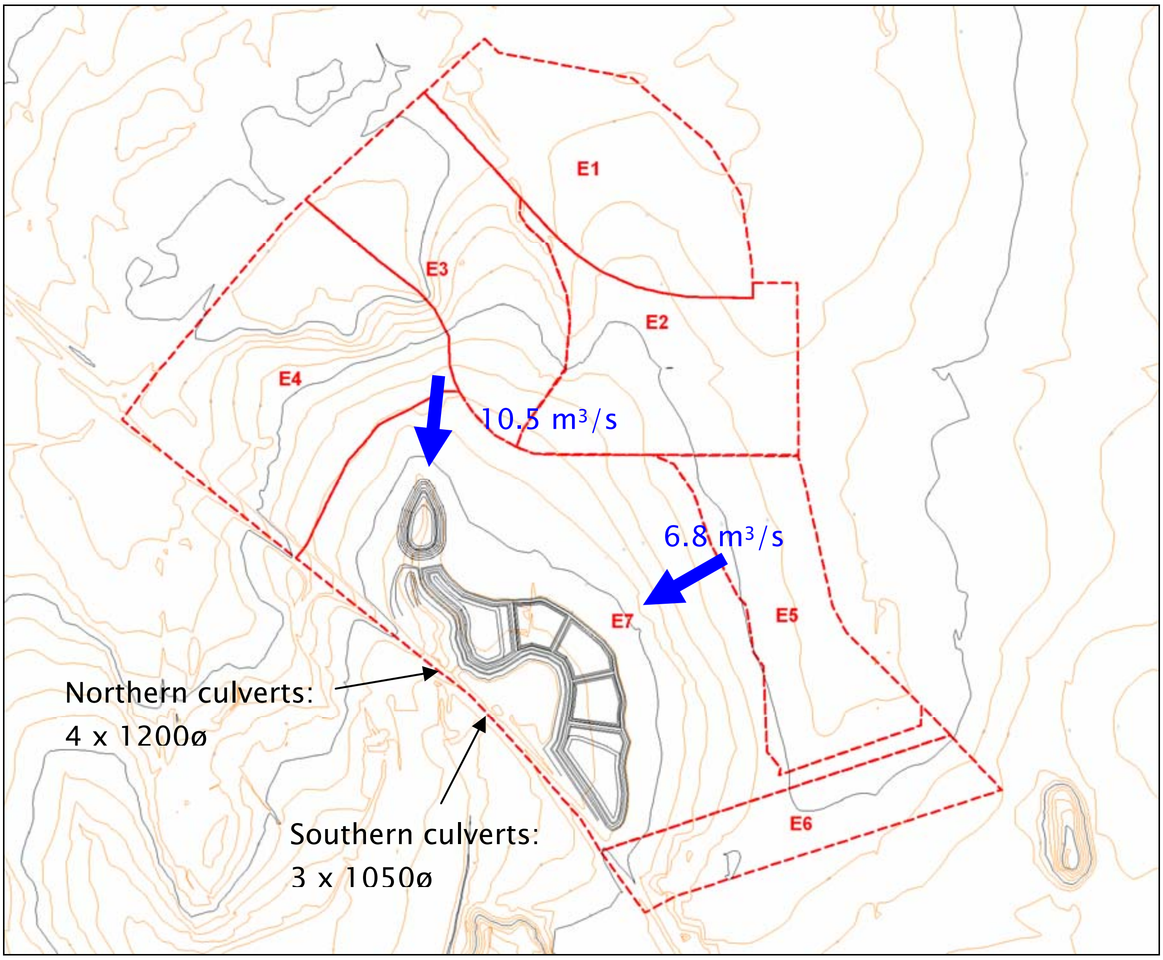

Figure 10: High flows

5.8.1 Northern catchment

A bypass channel is required to convey high flows (up to 100 year ARI) from the inlet pond to the set of 4 x 1200 mm culverts under Elrundie Ave.

The design flow rate is assumed to be 10.5 m^3/s for the channel (the same as the design flow for the existing culverts).

A channel slope of 1.0% has been estimated for the channel from survey data and the channel is currently earthen lined and incised as it flows towards the culverts. HEC-RAS was used to model the 10.5 m^3/s flows in the existing channel, and results are shown in Figure 11. A typical cross-section is shown in Figure 12. The 10.5 m^3/s flow is generally contained within a width of approximately 20-40 m and maximum depth of approximately 1.0-1.5 m.

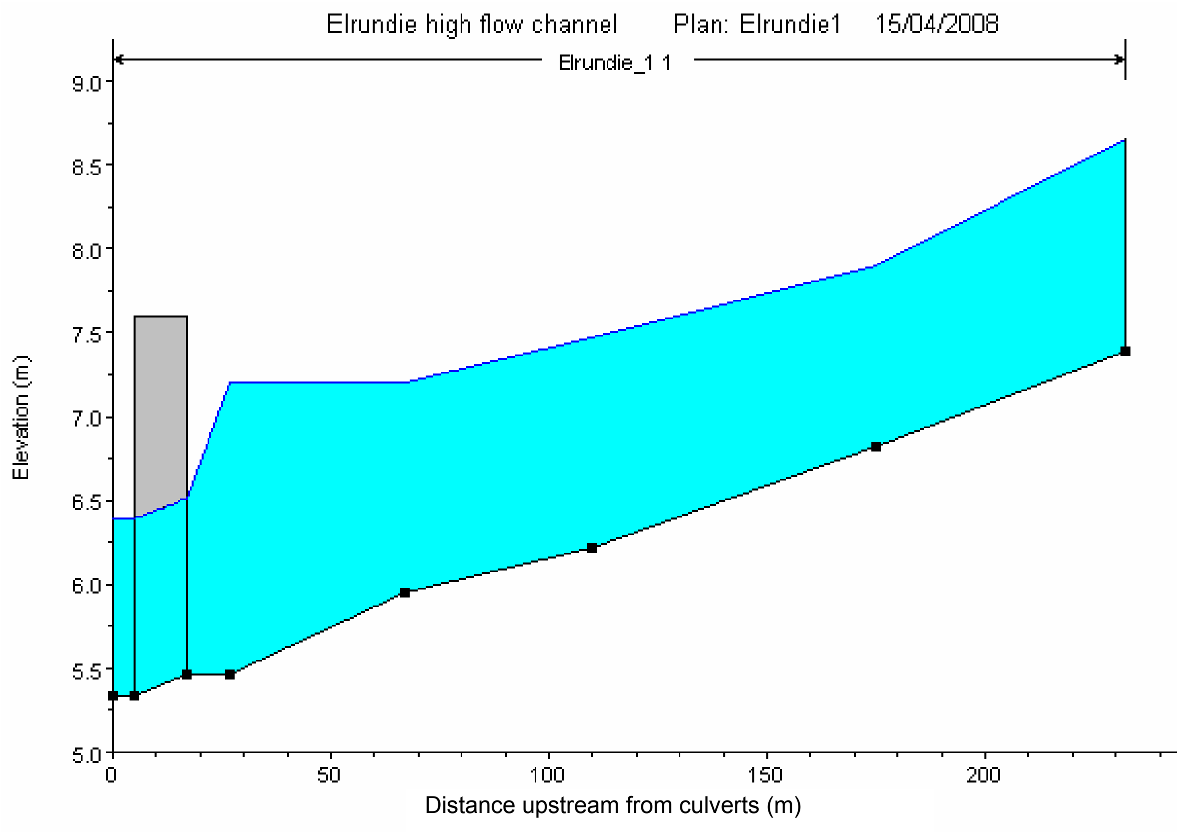

Figure 11 Bypass channel long section

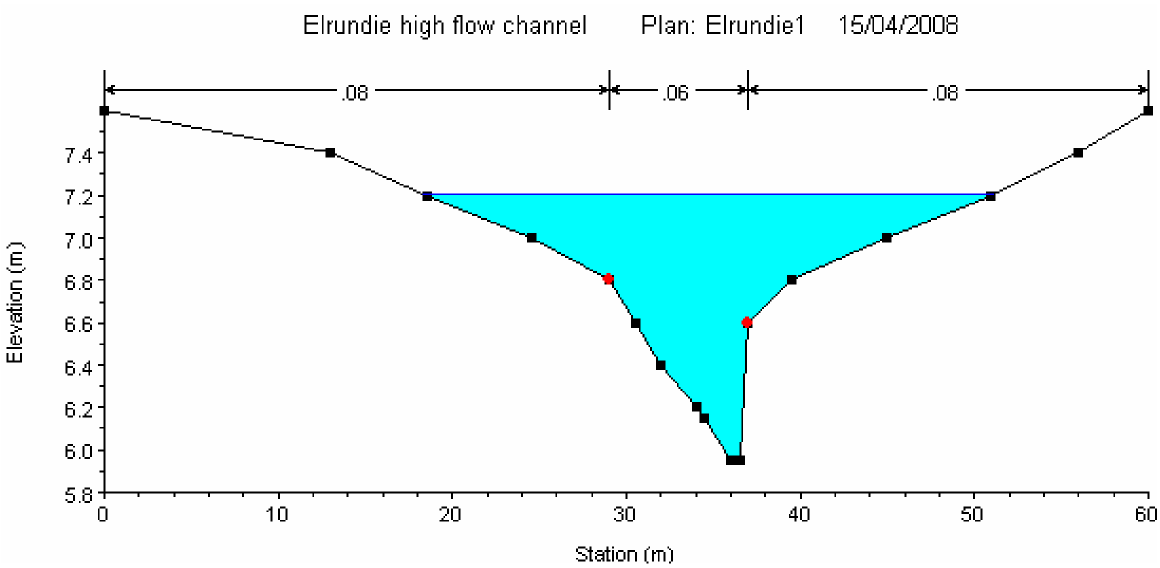

Figure 12 Bypass channel typical cross-section

The upstream end of the bypass channel will need to be modified to transition from the inlet zone spillway (18 m wide at 10.0 m AHD) to the existing channel. The entrance of the bypass channel down the bank of the sediment basin and the inlet of the channel is to be rock lined to protect the bank and channel from erosion.

5.8.2 Southern catchment

It is expected that high flows from the southern catchment will be dispersed and it will not be possible to bypass them around the wetland. It is proposed to allow these flows to pass over the wetland. An overflow weir is required to convey high flows (up to 100 year ARI) to the set of 3 x 1050 mm culverts under Elrundie Ave.

The design flow rate is assumed to be 6.8 m^3/s (the same as the design flow for the existing culverts).

The weir should be 25 m wide to pass 6.8 m^3/s when the water level in the wetland is 8.8 m AHD. The weir should be set at a level of 8.5 m AHD.

5.9 Construction Cost Estimate

Preliminary cost estimates for the Elrundie Avenue wetland have been produced for constructing the treatment system. Cost estimates were developed from determining expected earthworks required for construction and by quantifying key element and structures of the systems. These are detailed in Table 6.

Table 6 Preliminary Construction Cost Estimate

Item	Quantity	Unit	Unit Cost	Cost
Clear Site of vegetation	30960	sqm	$ 0.45	$ 13,932
Inlet to Wetland	3	Unit	$ 3,000	$ 9,000
Humegard HG40A (or similar) GPT	1	Unit	$ 85,500	$ 85,500
Access Track to Sediment Basin	1	Unit	$ 15,000	$ 15,000
Inlet Zone Spillway and channel works	1	Unit	$ 40,000	$ 50,000
Excavation and Earthworks	29000	cum	$ 10	$ 290,000
0.3m Clay Liner	6773	cum	$ 45	$ 304,787
Place growing media (assumed soil from site)	5629	cum	$ 2	$ 11,258
Wetland Planting	28145	cum	$ 12	$ 337,740
Inlet Zone Overflow Pit	1	Unit	$ 3,000	$ 3,000
Inlet Zone Low Flow Pit	1	Unit	$ 3,000	$ 3,000
1250 mm connection from inlet to wetland	45	m	$ 750	$ 33,750
150mm Low Flow Inlet	340	m	$ 35	$ 11,900
Flow Splitter Pits	3	unit	$ 2,000	$ 6,000
90mm Low Flow Distribution Channels	198	m	$ 25	$ 4,950
Riser Pit	1	Unit	$ 5,000	$ 5,000
225 mm Riser Outlet Pipe to Pandanus Zone	40	m	$ 65	$ 2,600
Wetland Spillway	1	Unit	$ 30,000	$ 30,000
Subtotal				*$ 1,217,417*
Contingency			25%	$ 304,354
TOTAL				**$ 1,520,000**

6 REFERENCES

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APPENDIX A –PROGRESS REPORT AND WATER LEVEL ANALYSIS

BELLAMACK STORMWATER TREATMENT WETLANDS
Design Development Report

Prepared for the Northern Territory Department of Planning and Infrastructure
GPO Box 2520
Darwin NT 0801

March 2008
07512593.01

EDAW
Level 1, 2-14 Mountain Street, Ultimo NSW 2007
T 02 9212 3666 F 02 9212 4499 www.edaw.com.au

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Table of Contents

1 Introduction

A Water Sensitive Urban Design (WSUD) Strategy has been prepared for the proposed Bellamack development at Palmerston. The WSUD Strategy was detailed in the following report:

- EDAW (2007) *Water Sensitive Urban Design Strategy for Bellamack (Final)* Prepared for the Northern Territory Department of Planning and Infrastructure, December 2007.

The WSUD Strategy for Bellamack proposes the use of 3-4 stormwater treatment wetlands to manage stormwater quality from the site and reduce suspended solids and nutrient loads entering downstream waterways.

This document reports the development of designs of the stormwater treatment wetlands at Bellamack.

2 Design process

The design process is currently underway for the stormwater treatment wetlands at Bellamack. EDAW is undertaking the design according to the process outlined in our proposal of 19 February 2008, and our progress is detailed in Table 1.

Table 1: Bellamack wetlands design process and progress at 13 March 2008

Tasks	Sub-tasks	Comments	Progress
Task 1: Concept design refinement and data analysis	Refine concept designs	We have revisited the conceptual wetland options presented in the *Stormwater Treatment Options for Darwin – Discussion Paper* (EDAW, 2007) and selected a preferred option	Complete
	Analyse Owston Avenue Diversion	To be completed when the Owston Avenue detailed design is commenced	Ongoing
	Analyse existing data	We have reviewed existing data and identified the need for additional survey at each of the wetland sites. Additional survey is underway (by SKM), and meanwhile the design process is moving forward on the basis of the existing survey	Waiting on survey data
	Internal workshop – concept design completion	We have workshopped a preferred conceptual wetland and tested its application at the Elrundie Avenue site in an internal workshop. Following the workshop, the preferred option has been developed into a concept design	Complete
Task 2: Detailed design	Develop detailed designs for Elrundie Avenue wetland	We have applied the concept design initially to the Elrundie Avenue wetland, in order to develop the details: • We have undertaken detailed modelling of the Elrundie Avenue wetland – results are presented in this progress report • We have completed the design calculations to size inlet and outlet structures and other elements of the Elrundie Avenue wetland	Complete
	Develop detailed designs for Owston Avenue wetland	Detailed designs for Owston Avenue and Roystonea Avenue wetlands will be commenced after the Elrundie Avenue wetland design is complete. The Elrundie design will be used as a template at the Owston and Roystonea sites.	Ongoing
	Develop detailed designs for Roystonea Avenue wetland		Ongoing
	Develop cost plans		Ongoing
	Design development meetings		Ongoing
	Detailed design report		Ongoing

3 Elrundie Avenue wetland

The proposed layout of the Elrundie Avenue wetland is shown in Figure 1.

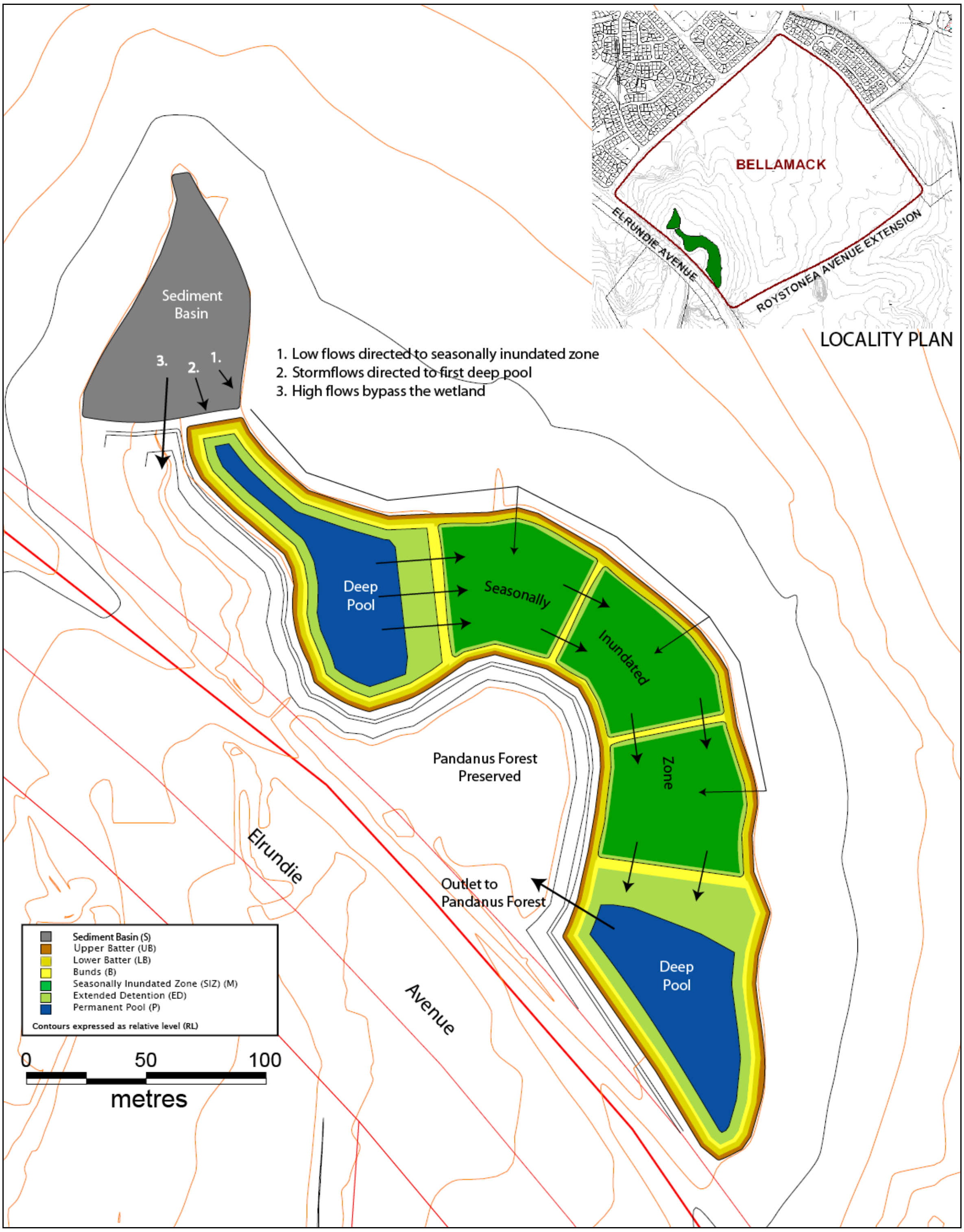


Figure 1: Elrundie Avenue wetland layout

The wetland includes the following components:

- Sediment basin, designed to trap sediment in a permanent open water pool and control flows to the wetland
- The wetland area itself consists of:
  - Two deep open water pools, designed to retain water year-round, with a permanent pool depth of 2m
  - A seasonally inundated zone (including bunds and macrophyte cells), to be densely vegetated with macrophytes and designed to dry out during the dry season and re-fill during the wet season
- Extended detention will be included above the normal wet season water level, designed to detain storm flows temporarily and release them slowly

Each of these components plays a role in one or more key functions, including water treatment and pollutant removal, hydrodynamics, water level control, mosquito risk management, etc. In order to design each of these components, it is important to understand the inflows and water level regime that it will experience, and to ensure that they suit the intended function. Therefore we have modelled inflows and water level fluctuations in the Elrundie Avenue wetland in detail, and refined the design accordingly.

The sections below outline for each component:

- Its functional roles
- Important design considerations
- Water level modelling results and interpretation

Appendix A includes details of the vegetation proposed for each zone of the wetland

3.1 Sediment basin

The sediment basin is located upstream of the wetland and is designed to function as a sediment trap. It also plays a secondary role of controlling stormwater inflows to the wetland. The sediment basin will direct low flows to the seasonally inundated zone, storm flows (up to 4 m^3/s) to the first deep pool and bypass high flows around the wetland to the culverts under Elrundie Avenue. Low flows are directed to the seasonally inundated zone to ensure that it is protected from long dry spells; this is discussed further in Section 3.3.

The sediment basin will release water slowly into the seasonally inundated zone, so that the water level in this zone does not rise too quickly at the start of the wet season. If the seasonally inundated zone fills too quickly, some plants may not survive the sudden and complete inundation. This is important for the growth of *Pseudoraphis* in the seasonally inundated zone. *Pseudoraphis* stems can grow and elongate in response to flooding at a rate of 4 to 7 cm per day (Roberts and Marston 2000). If water levels rise too quickly in the wetland in response to the first rains of the wet season, there is a risk that *Pseudoraphis* will be drowned by being submerged too deeply and thus unable to photosynthesise sufficiently to maintain growth at rates roughly equivalent to the rate of water level rise.

The low-flow outlet from the sediment basin will release water to the seasonally inundated zone at approximately 10 L/s so that this zone cannot fill in less than one week.

3.2 Deep pools

The role of the deep pools is to control, slow and disperse flows across the wetland. The first deep pool also facilitates sedimentation, while the second provides an opportunity for UV disinfection. The deep pools create habitat for the growth of submerged aquatic macrophytes and act as refugia for aquatic fauna. The aquatic fauna includes predators of mosquito larvae and they play an important role in wetlands as mosquito control.

If the deep pools dry out, aquatic plants and animals will die leading to reduced treatment performance of the wetland. Upon rewetting mosquitoes may be able to breed without the biological control exerted by mosquito predators that normally live in the deep pools. Therefore water level modelling has been undertaken to ensure that the deep pools are deep enough that they will always retain water. Figure 2 shows a plot of modelled water levels in the deep pools over 65 years (based on actual rainfall data from 1941-2006).

A depth of 2.0 m (from 6-8 m AHD) was chosen for the wetland design because at this depth water remained in the deep pools for all of the years modelled. The lowest water level was just over 6.2 m AHD in 1946. In most years, the water level would not drop below 6.5-7.0 m AHD, retaining a substantial pool.

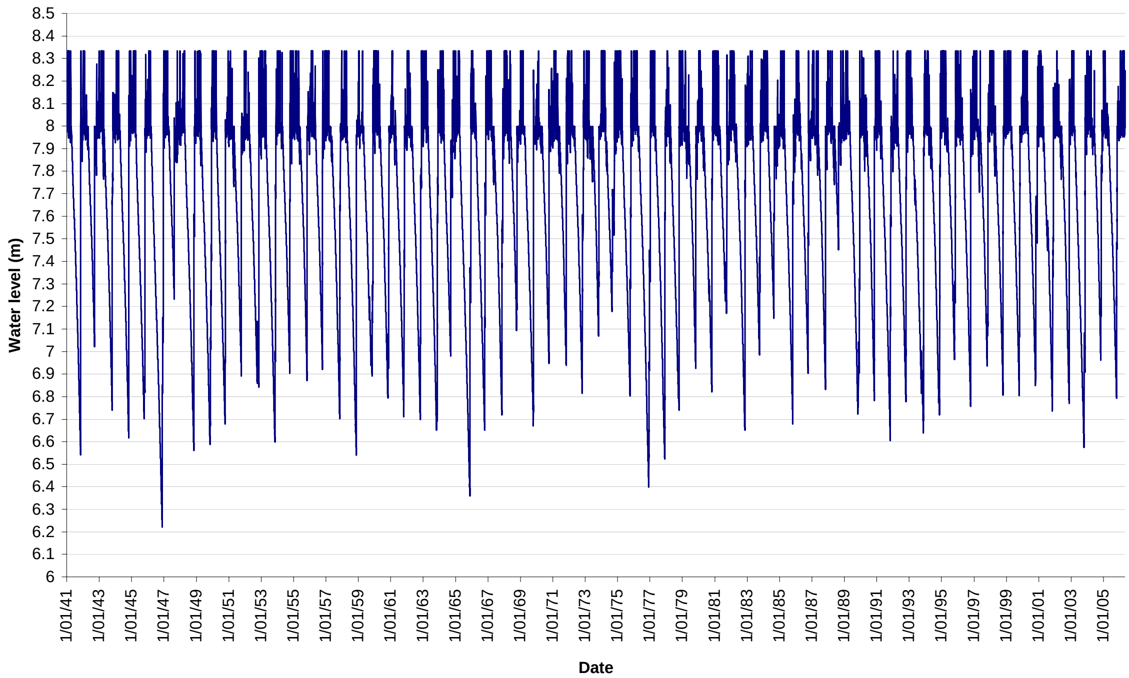


Figure 2: Water levels in the deep pools, modelled over 65 years

3.3 Seasonally inundated zone

The seasonally inundated zone is the main treatment area in the wetland, and it has been designed to provide maximum contact between stormwater and vegetation. By further slowing the flow of water the vegetation promotes enhanced sedimentation. The emergent macrophytes growing in the seasonally inundated zone provide the surface area for colonisation by algal and microbial biofilms. These biofilms provide much of the pollutant processing and removal in stormwater treatment wetlands. The vegetation also oxygenates and stabilises the sediment.

Bunds in the seasonally inundated zone will ensure the uniform horizontal and vertical distribution of flow through this part of the wetland. The bunds will prevent the creation of preferential flow paths and disperse flows evenly as they pass through this treatment zone. The bunds will also help to retain water within the seasonally inundated zone at the end of the wet season, thus shortening the length of the dry period in each dry season. To further reduce the exposure of the vegetation to

drought, the first flows of the wet season will be directed to the seasonally inundated zone. This will give the vegetation the chance to begin growing before the intensity of rainfall builds up.

The seasonally inundated zone has been designed as a seasonal ephemeral zone (i.e. it will dry out in the dry season and retain water in the wet season), however If the dry period is too long, some of the macrophytes may die and the wetland function will be substantially reduced. Plant death also creates opportunities for weeds to become established. We consider that *Eleocharis* could tolerate up to two months of exposure (without inundation by water) without substantially compromising plant growth. The survival of *Pseudoraphis* was not such a concern as it is expected that *Pseudoraphis* will survive the dry season by adopting its xeromorphic or drought tolerant form.

Several design depths were modelled for the seasonally inundated zone to ensure that *Eleocharis* plants growing in this zone would not be subjected to prolonged drought too often. A depth of 0.6 m was found to be the best compromise between minimising the length of the dry period, while not subjecting the plants to inundation that was too deep. In years where the dry spell is prolonged beyond the capacity of plants to survive drought, some *Eleocharis* die-off may be tolerated, or the seasonally inundated zone may be irrigated to keep the plants alive.

Figure 3 and Figure 4 show that for 65 years of dry seasons, the length of the dry spell in the seasonally inundated zone in days. Figure 4 shows that the dry spell only exceeds two months in 38% of dry seasons, and rarely exceeds 90 days (less than one year in ten). At this frequency, we consider the duration of drying a manageable risk.

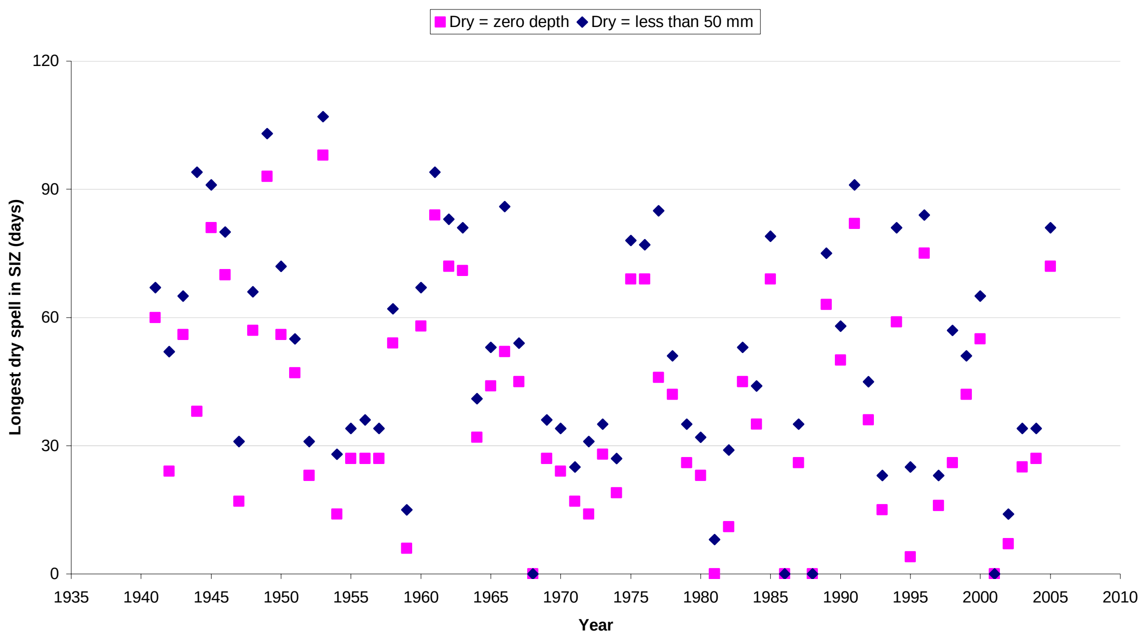


Figure 3: Annual dry spell duration in seasonally inundated zone

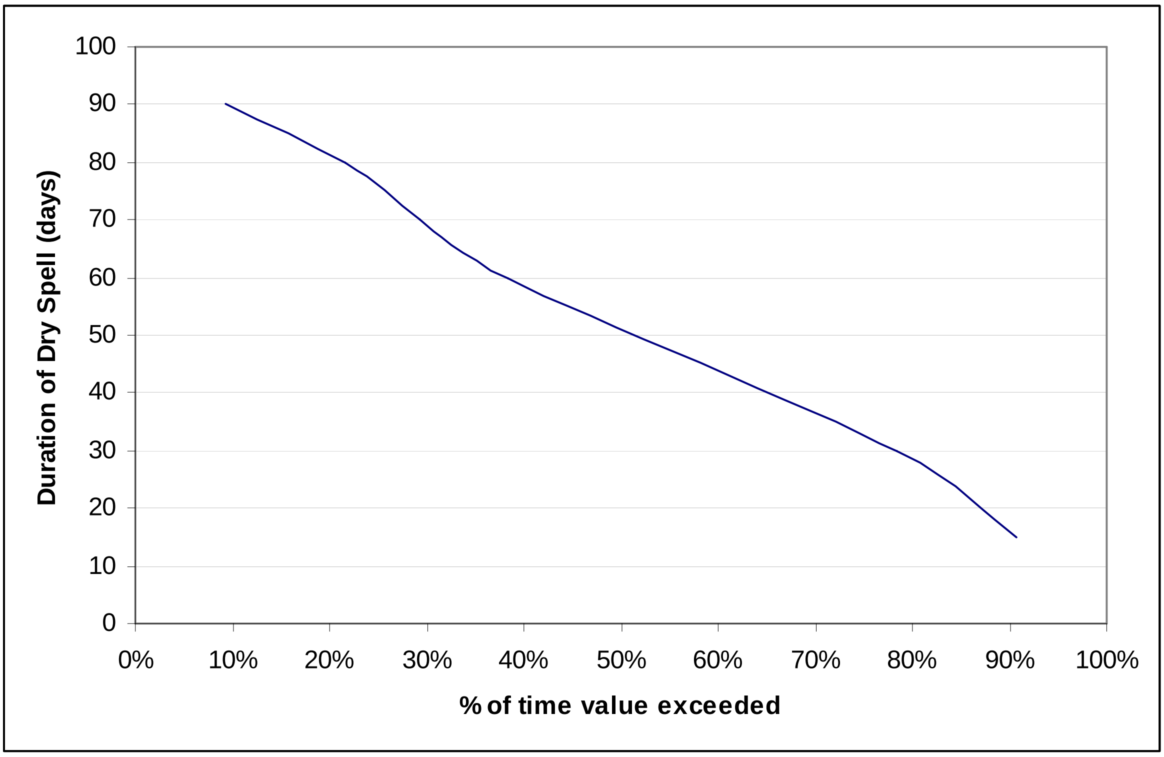


Figure 4: Length of the dry spell in the seasonally inundated zone, modelled over 65 years

3.4 Extended detention

The extended detention detains storm flows in a zone above the normal wet season water level. Water is detained for approximately 72 hours. This detention period allows sediments to fall from the water column, and gives the biological components of the wetland time to process and remove pollutants.

The proposed extended detention depth is 0.5 m (8.0-8.5 m AHD). A greater extended detention depth allows the treatment of a larger proportion of stormwater runoff, however the extended detention should not take water levels higher than the vegetation in the treatment area. If the extended detention is frequently fully engaged or engaged for a long period, the vegetation will be more often submerged under a greater depth of water than desired. This may result in reduced plant vigour or even drowning of emergent macrophytes.

To determine the pattern of water levels in the extended detention, the water levels in the extended detention were modelled over a 10-year period (using historical pluviograph data from 1987-1996) and a statistical analysis was performed to understand the duration and frequency of inundation. Three charts have been produced to summarise the modelling results:

- Figure 5 shows the frequency of inundation to various depths in the extended detention zone, on a seasonal basis
- Figure 6 shows the frequency (number of times per year) that a high water level spell of a given depth and duration occurs in the extended detention zone
- Figure 7 shows the longest high water level spells modelled in the extended detention over the 10-year period.

It was found that the extended detention draws down rapidly and frequently enough to provide the vegetation with sufficient relief from inundation. It is not anticipated that the duration of extended detention will threaten the survival of the wetland vegetation.

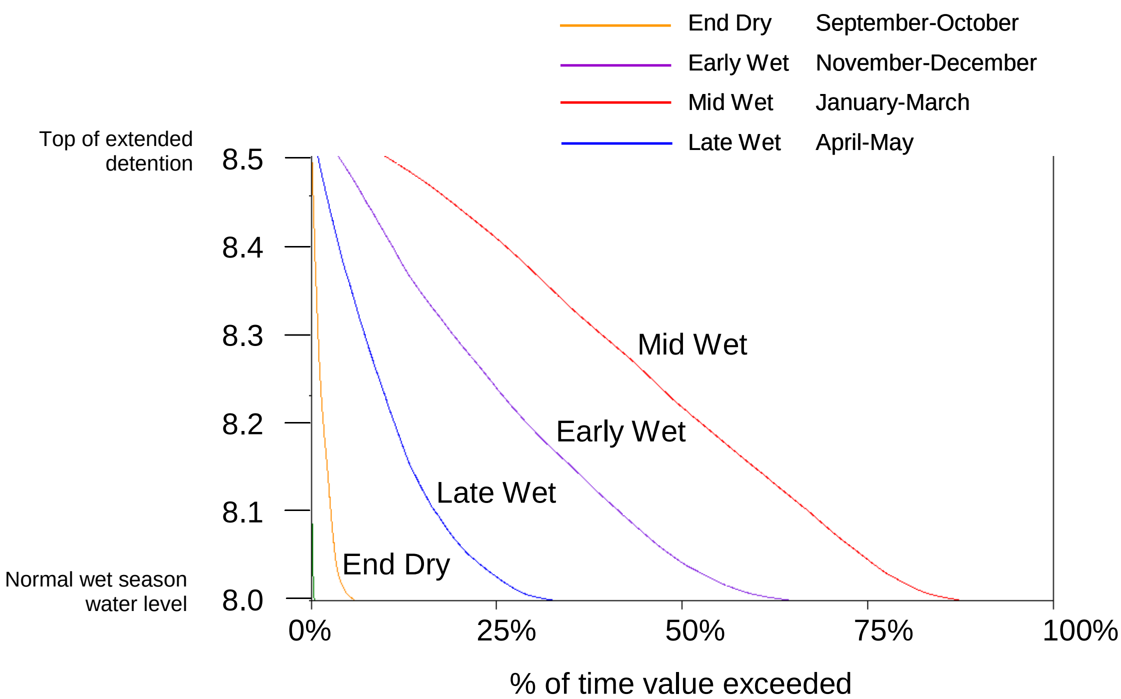


Figure 5: Seasonal water level exceedence curves in the extended detention zone

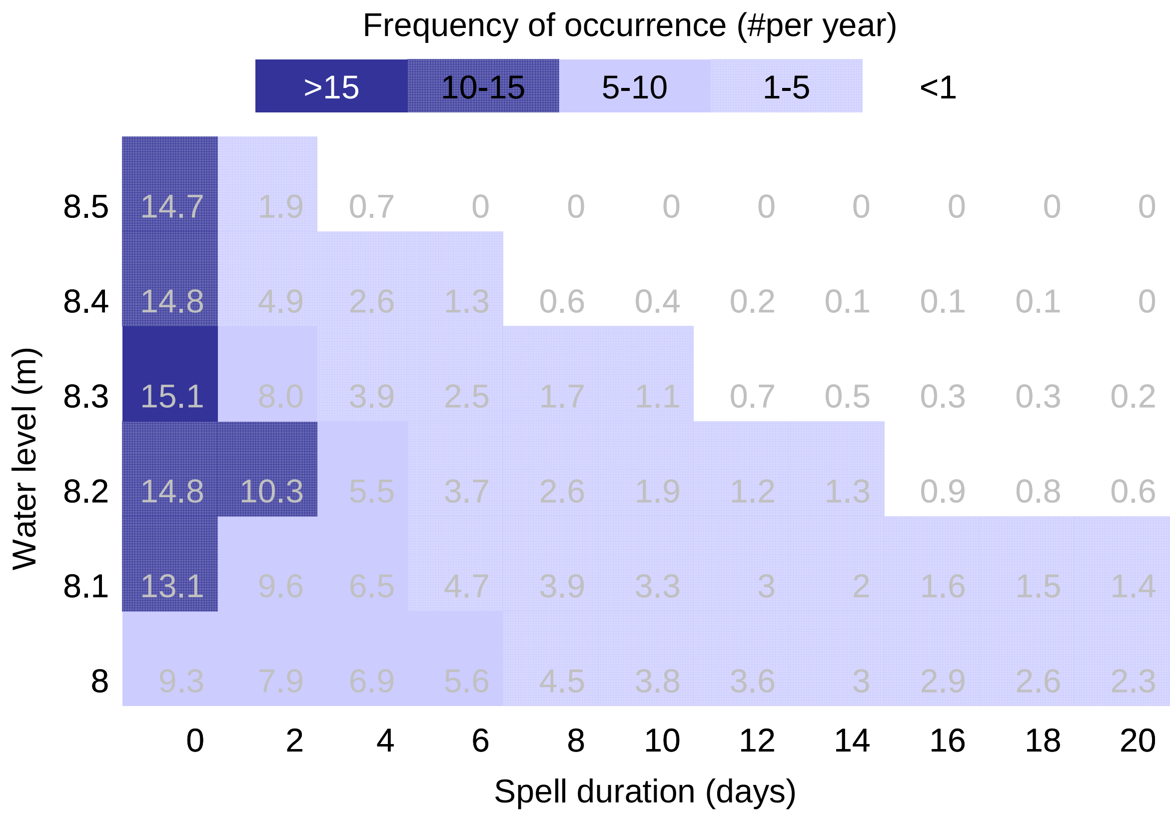


Figure 6: High water level spells in the extended detention zone

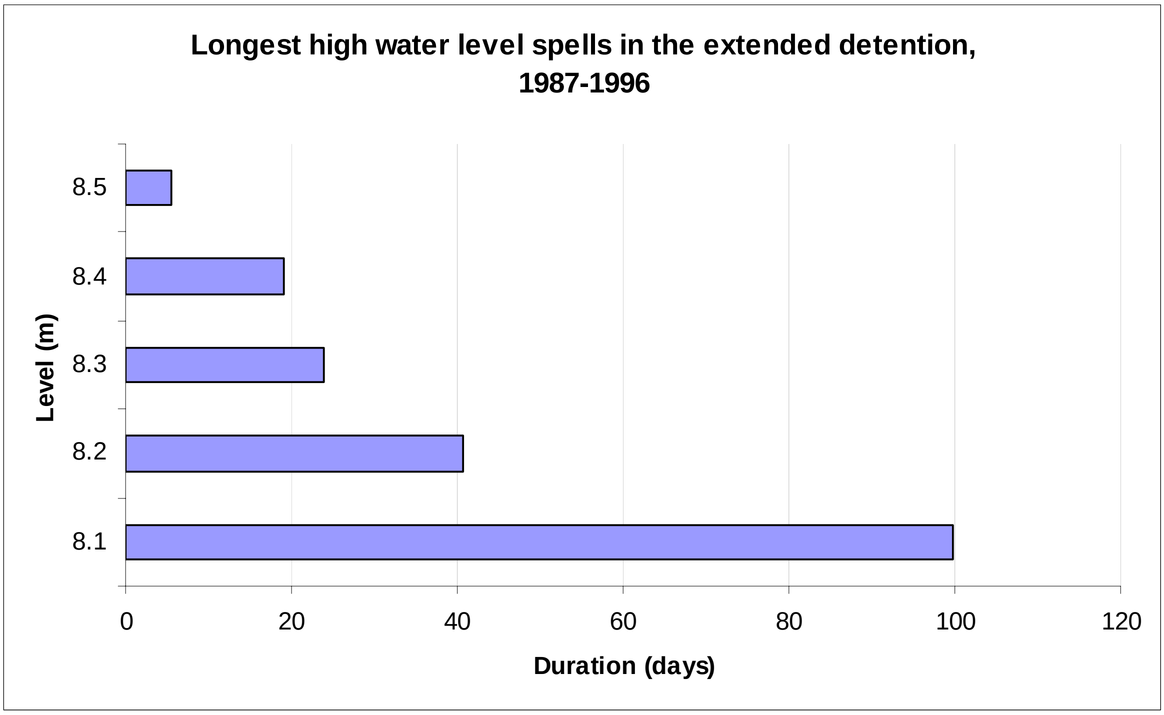


Figure 7: Longest high water level spells in the extended detention zone

4 References

Roberts, J. and F. Marston (2000). Water Regime of Wetland and Floodplain Plants in the Murray-Darling Basin. A Source Book of Ecological Knowledge. Technical Report 30/00 Canberra. CSIRO. 53p.

Appendix A: Selection of Plant Species for Use in Bellamack Wetlands

Vegetation plays an important role in the function of the stormwater treatment wetland. This functional role differs for different zones within the wetland, and the species chosen for each zone perform specific tasks. Table 2 summarises the attributes of species chosen for different zones. Table 3 lists examples of the types of plants proposed for each zone with the attributes upon which their selection was based.

Table 2: Wetland zones and vegetation attributes

Zone	Component	Vegetation
Deep pools	Deep, permanent water	Submerged aquatic plants were chosen for the following properties: o Tolerance of deep water o Habitat for aquatic fauna including mosquito predators
	Edges	Emergent macrophytes were chosen for the following properties: o Growth habit – thin, tall, firm stems to provide a large surface area for colonisation by microbial and algal biofilms o Dense clustered growth form with spiky stems to discourage pedestrian traffic o Aesthetic appeal
Seasonally inundated zone	Macrophyte Cells	Emergent macrophytes were chosen for the following properties: o Ability to survive periodic dry spells of up to 2 months duration o Tolerance of regular inundation of up to 1.1m o Growth habit – thin, tall, firm stems to provide a large surface area for colonisation by microbial and algal biofilms o Aesthetic appeal
	Bunds	Emergent macrophytes were chosen for the following properties: o Tolerance of seasonal dry spells o Tolerance of seasonal inundation of 0.1m for extended periods and up to 0.6m for short periods
	Batters	Emergent macrophytes were chosen for the following properties: o Tolerance of seasonal dry spells o Tolerance of seasonal inundation of 0.1m for extended periods and up to 0.6m for short periods The batters can be planted with annual species that grow either in shallow water during the wet season or that establish on the drying batters during the dry season.

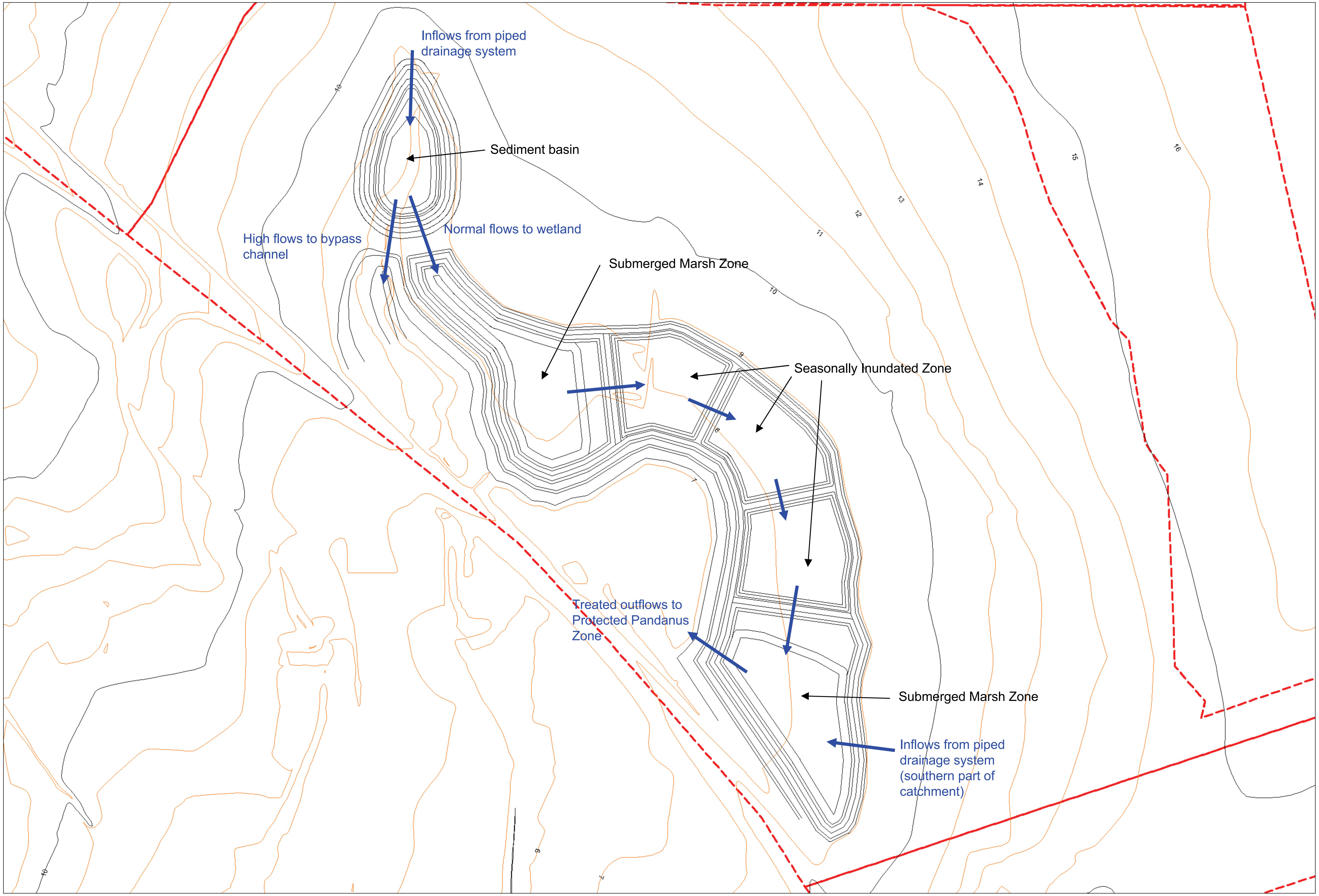
Table 3: Examples of species proposed for different zones in stormwater treatment wetlands in Darwin

Scientific Name	Common Name	Type of Plant	Max Height (m)	Exposure Tolerance	Inundation Tolerance - Depth (m)	Inundation Tolerance - Duration (months)
Deep Pools - Permanently wet emergent macrophytes						
Actinoscirpus grossus		Tall Rush	3	Nil	1 ?	12
Eleocharis sphacelata	Tall Spikerush	Tall Rush	2	Low	1.5	12
Lepironia articulata		Tall Rush	4	Nil	1.5	12
Schoenoplectus littoralis		Tall Rush	2	Low	1 ?	12
Deep Pools - Permanently wet submerged macrophytes						
Ceratophyllum demersum	Hornwort	Submerged Aquatic Herb	0.6	Low ?	1-2	12
Myriophyllum dicoccum	Water Milfoil	Submerged Aquatic Herb		moderate	1-2	12
Najas tenuifolia	Water Nymph	Submerged Aquatic Herb	0.5	Nil	2	12
Vallisneria nana	Ribbonweed	Submerged Aquatic Herb	0.7	Nil	1	12
Potamogeton javanicus	Pondweed	Submerged Aquatic Herb		Low ?	1-2	12
Potamogeton tricarinatus	Pondweed	Submerged Aquatic Herb		Nil	1-2	12
Seasonally Inundated Zone - Macrophyte cells						
Eleocharis sphacelata	Tall Spikerush	Emergent Macrophyte	2	Low	2	12
Pseudoraphis spinescens	Spiny Mudgrass	Emergent Grass	1-2	High	1	10
Phragmites australis	Common reed	Emergent Grass	5	High	1.5	9.5
Seasonally Inundated Zone - Bunds – understorey						
Fimbristylis dichotoma	Sedge	Amphibious Sedge	1	High	0.5	6
Cyperus scariosis		Amphibious Sedge	0.8	High	0.5	6
Ischaemum australe		Amphibious Grass	1.5	High	0.5	6
Oryza australiensis	Native Rice	Emergent Grass	2.5	High	1	9 ?
Paspalum distichum	Water Couch	Amphibious Grass	0.6	High	0.5	6
Isoetes coromandelina	Quillwort	Amphibious Fern	0.8	High	0.5	6
Seasonally Inundated Zone - Bunds - trees						
Melaleuca dealbata	Paperbark	Amphibious Tree	12	High	1	6
Melaleuca viridiflora	Paperbark	Amphibious Tree	2-16	High	1	6
Pandanus spiralis	Screw Palm	Amphibious Tree	10	High	1	6
Lower Batter (seasonally wet) - wet season						
Cyperus scariosis		Amphibious Sedge	0.8	High	0.5	6
Fimbristylis dichotoma		Amphibious Sedge	1	High	0.5	6
Schoenoplectus praelongatus		Amphibious Sedge	0.5	High	0.3	6
Lower Batter (seasonally wet) - dry season						
Coldenia procumbens		Herb		High	0.1	6
Phyla nodiflora		Herb	0.2	High	0.1	6
Sporobolus virginicus	Salt Couch	Grass	0.6	High	0.1	6
Cynodon dactylon	Couch	Prostrate grass	0.2	High	0.1	6
Glinus oppositifolius		Herb	0.5	High	0.1	6
Upper Batter (terrestrial vegetation)						
Sorghum plumosum						
Sorghum stipodeum						
Themeda australis	Kangaroo grass	Grass	0.75	High		
Eucalyptus papuana	Ghost Gum	Tree	8-15	High		
Eucalyptus polycarpa			10-15	High		

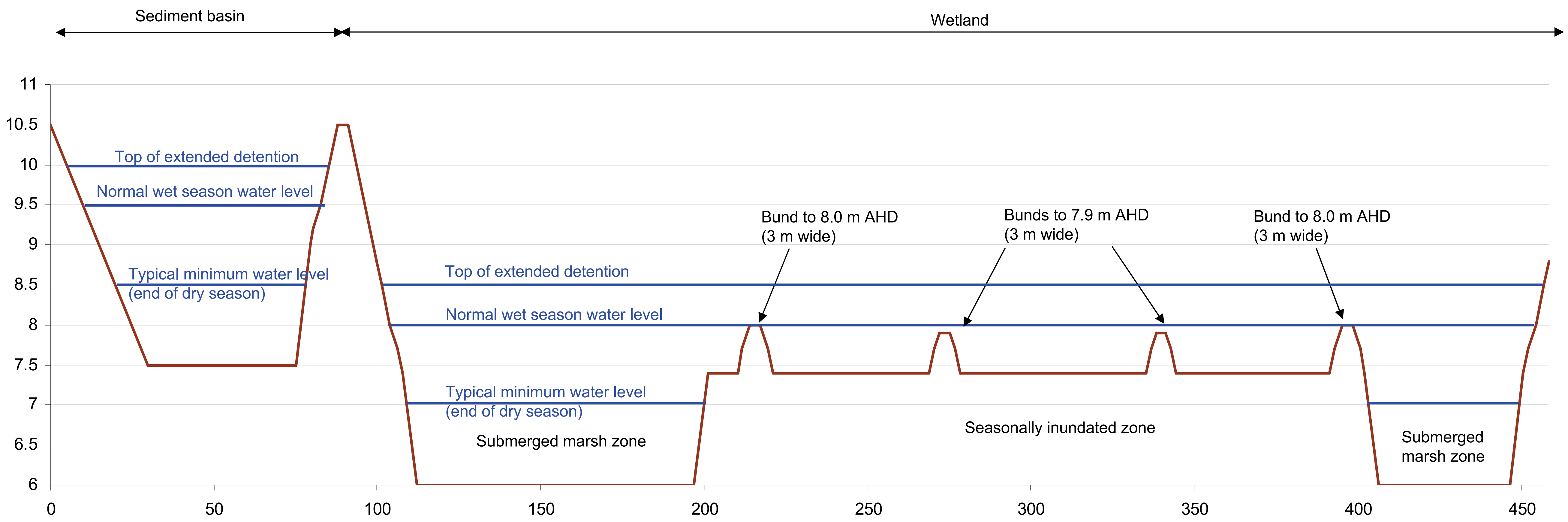
APPENDIX B –FUNCTIONAL DESIGN SKETCHES

Elrundie subcatchment - drainage

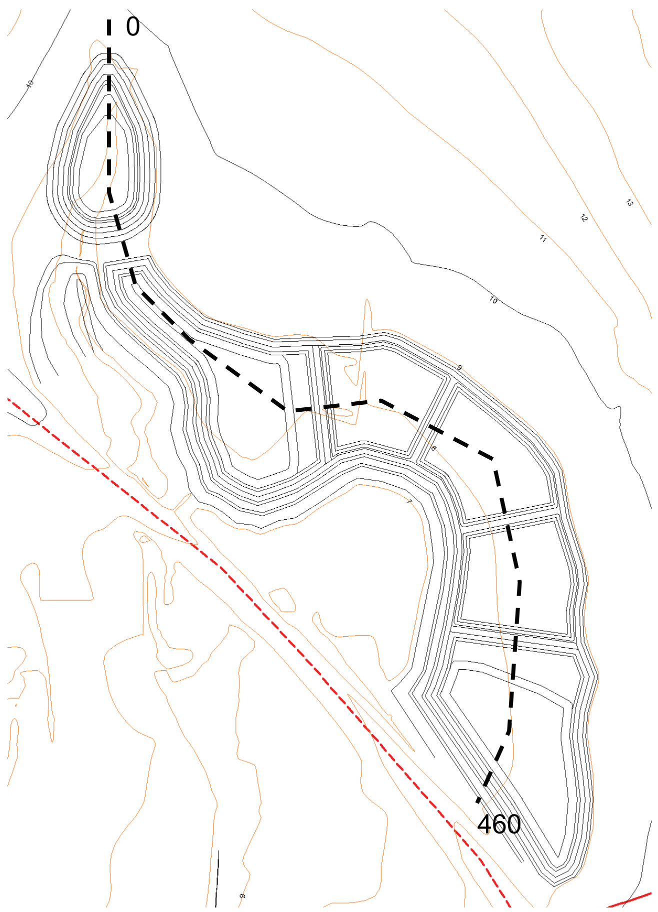
Elrundie wetland – overall plan



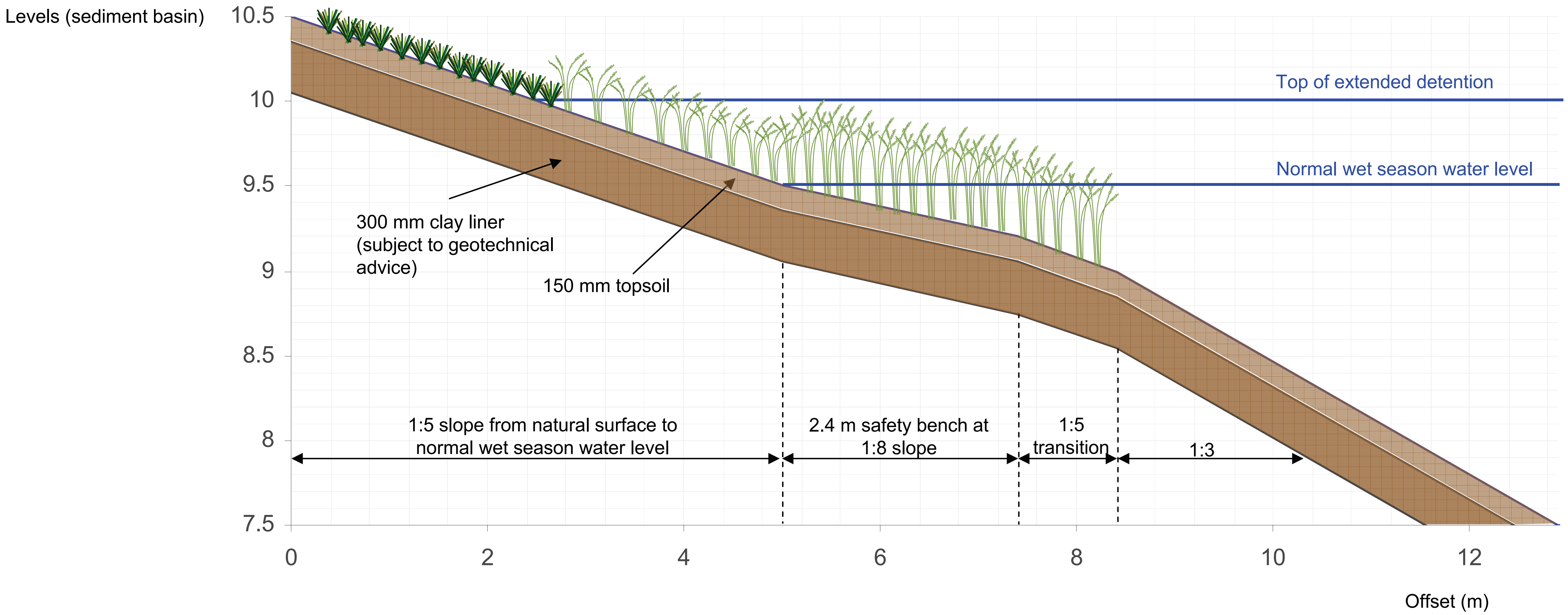
Elrundie wetland – long section

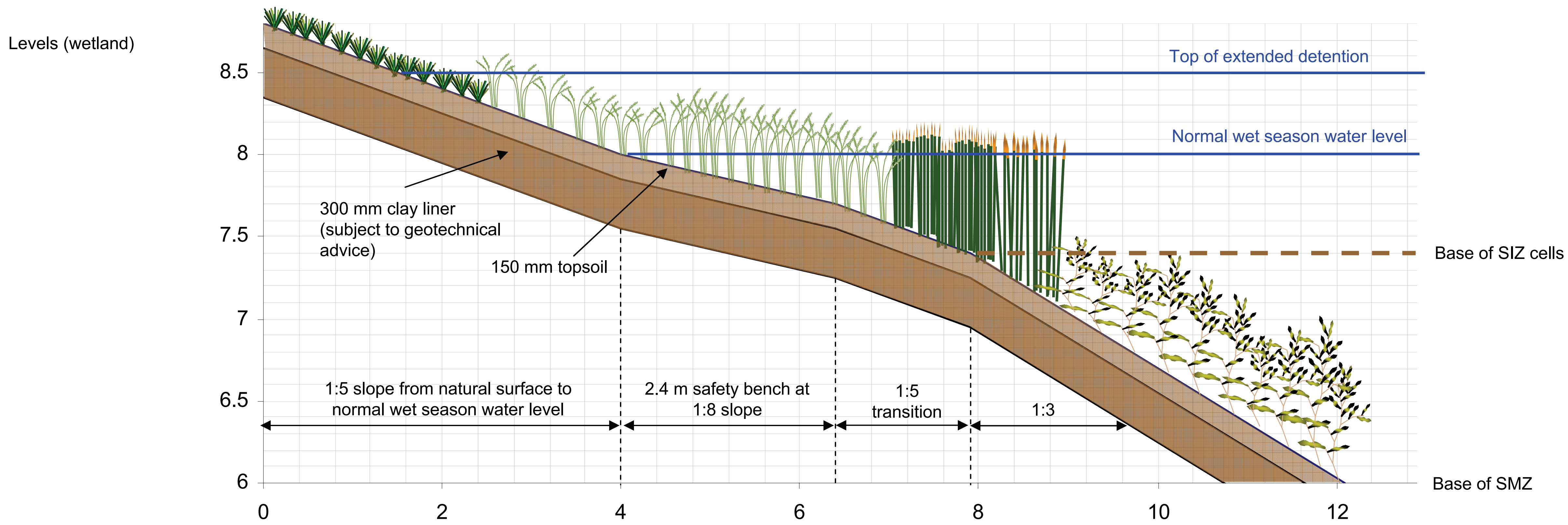


Long section location:

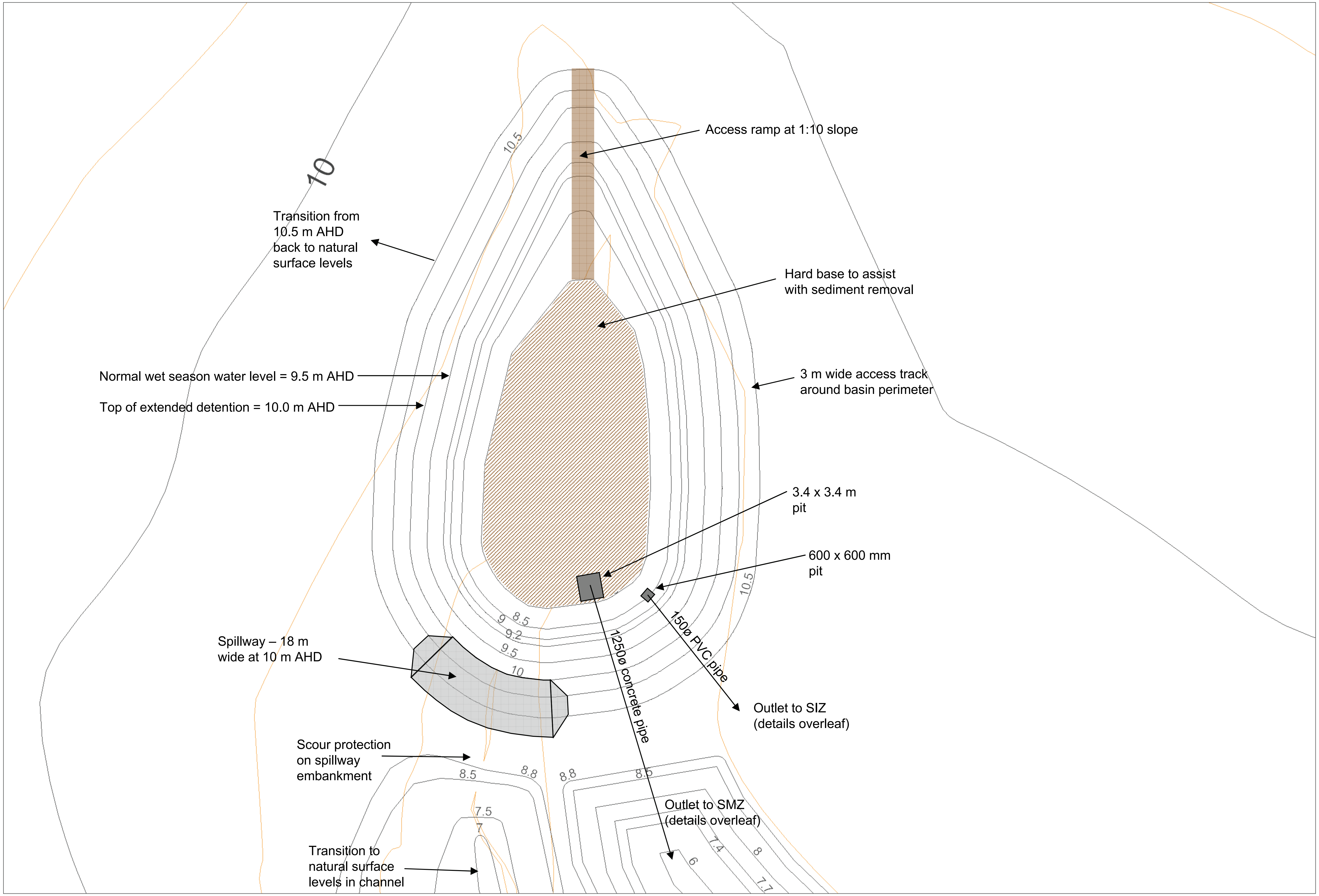


Edge design for safety

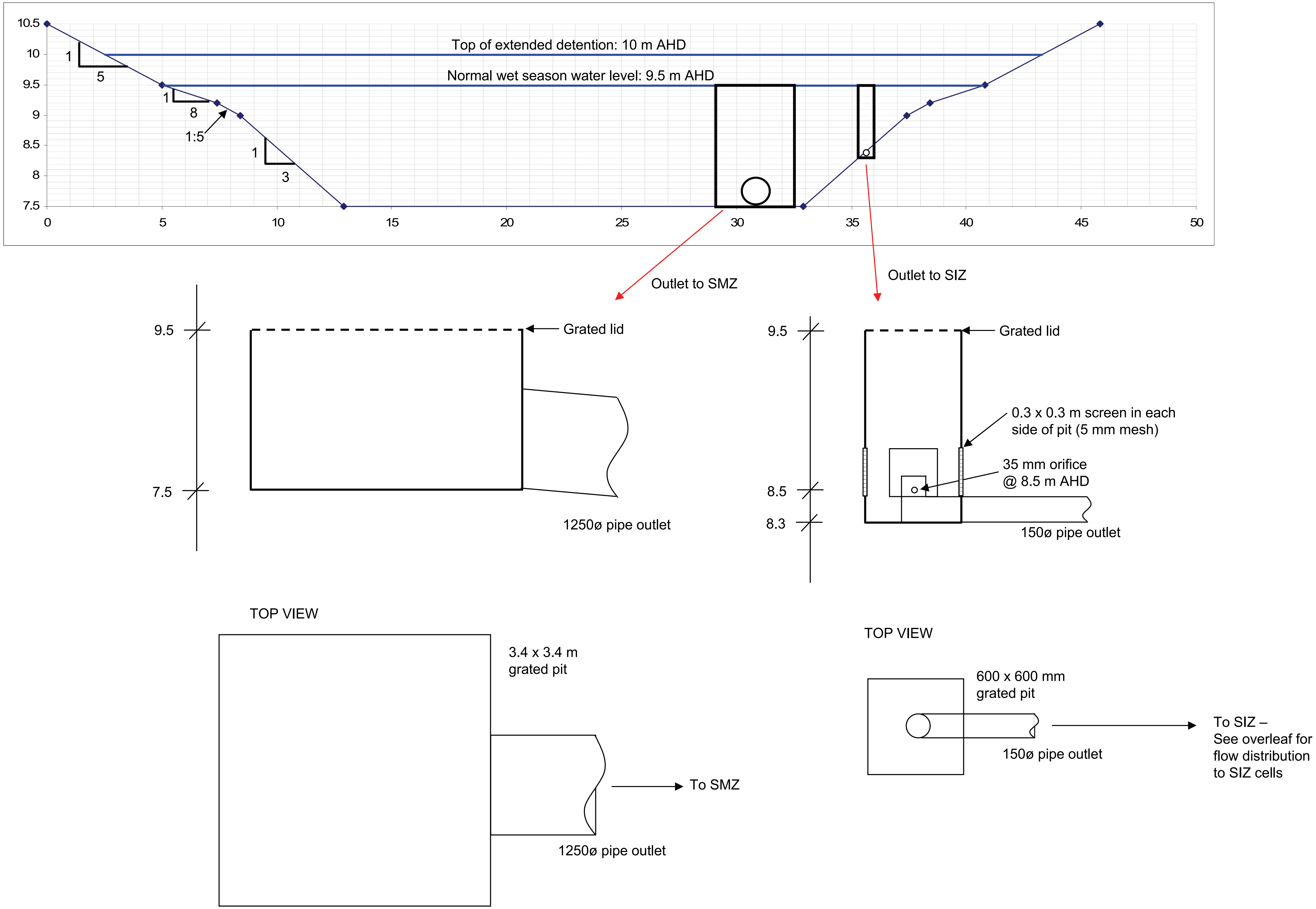




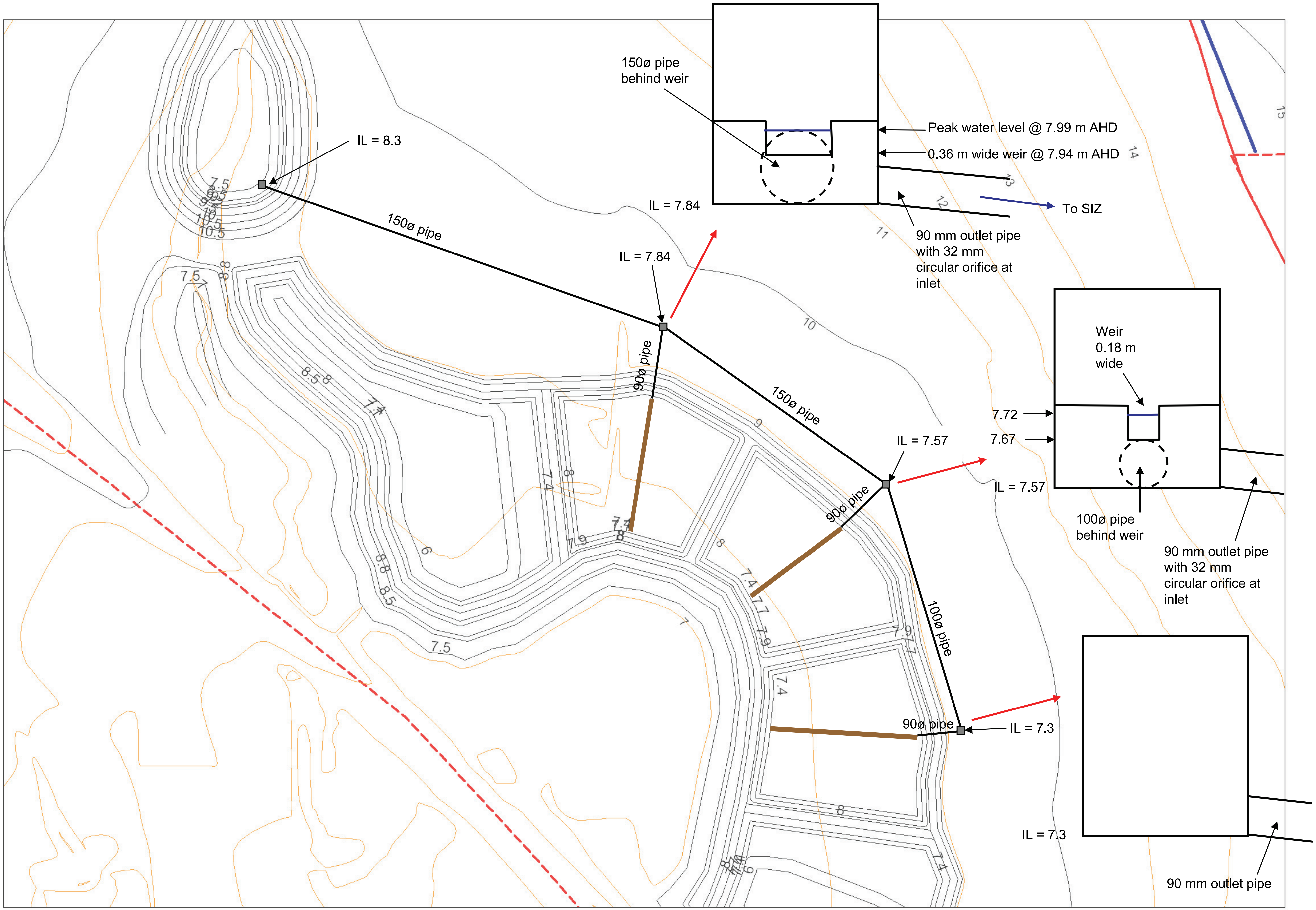
Elrundie Sediment Basin



Elrundie Sediment Basin – cross-section



Elrundie low flow distribution to SIZ



Elrundie macrophyte zone outlets – riser details