Chapter 8 Constructed Wetlands

Definition:

A constructed wetland is a man-made copy of a natural wetland system used for the treatment of stormwater runoff.

Purpose:

- Removal of fine and coarse sediments.
- Efficient removal of hydrocarbons and other soluble or fine particulate contaminants from biological uptake.
- To provide extended detention.
- Provide flow retardation for frequent (low ARI) rainfall events.

Implementation considerations:

- In addition to playing an important role in stormwater treatment, wetlands can also have significant community benefits. They provide habitat for wildlife and a focus for recreation, such as walking paths and resting areas. They can also improve the Aesthetics of a development and be a central feature in a landscape.
- Wetlands can be constructed on many scales, from house block scale to large regional systems. In highly urban areas they can have a hard edge form and be part of a streetscape or forecourts of buildings. In regional settings they can be over 10 hectares in size and provide significant habitat for wildlife.




8.1 Introduction

Constructed wetland systems are shallow extensively vegetated water bodies that use enhanced sedimentation, fine filtration and pollutant uptake processes to remove pollutants from stormwater. Water levels rise during rainfall events and outlets are configured to slowly release flows, typically over three days, back to dry weather water levels.

Wetlands generally consist of an inlet zone (sediment basin to remove coarse sediments), a macrophyte zone (a shallow heavily vegetated area to remove fine particulates and uptake of soluble pollutants) and a high flow bypass channel (to protect the macrophyte zone). They are designed to remove stormwater pollutants associated with fine to colloidal particulates and dissolved contaminants. Figure 8.1 shows an example layout of a wetland system.

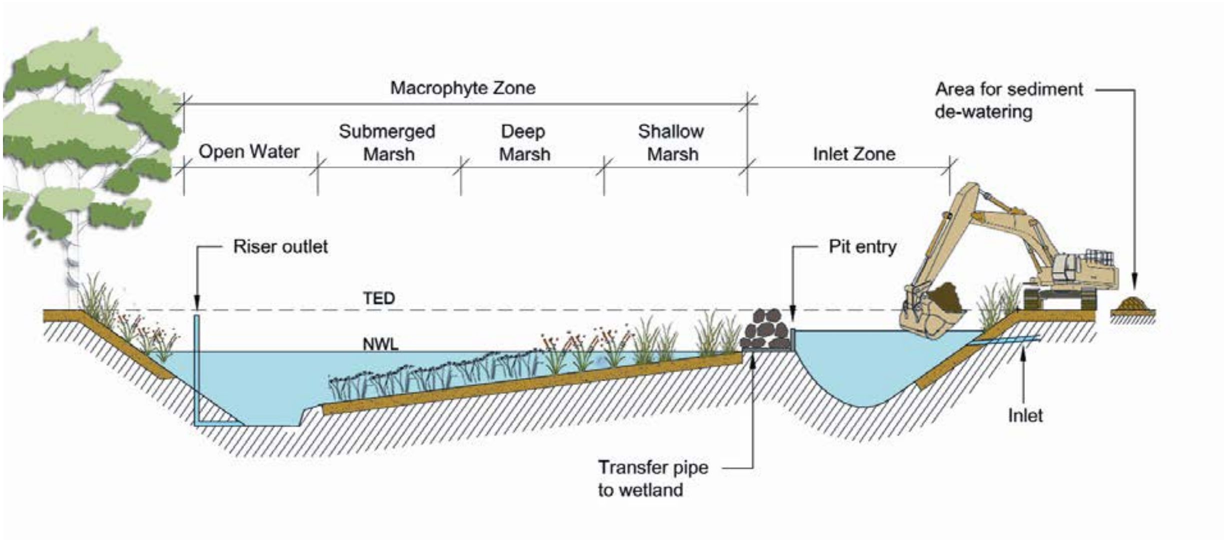


Figure 8.1. Layout of a constructed wetland system

Simulations using computer models are often undertaken to optimise the relationship between detention time, wetland volume and the hydrologic effectiveness of the constructed wetland to maximise treatment. The relationship between detention time and pollutant removal efficiency is influenced by the settling velocity of the target particle size. Standard equations for settling velocities often do not apply for very fine particulates owing to the influence of external factors such as wind and water turbulence. It is recommended that detention periods should notionally be about 72 hours.

The key operational design criteria for constructed wetlands may be summarised as follows:

- Promote sedimentation of particles larger than 125 µm within the inlet zone.
- Discharge water from the inlet zone into the macrophyte zone for removal of fine particulates and dissolved contaminants through the processes of enhanced sedimentation, filtration, adhesion and biological uptake.
- Ensure that the required detention period is achieved for all flow though the wetland system through the incorporation of a riser outlet system.

- Ensure adequate flood protection of the macrophyte zone from scouring during "above-design" conditions by designing for by-pass operation when inundation in the macrophyte zone reaches the design maximum extended detention depth.

Poor design of constructed wetlands has led to many urban wetlands and ponds becoming a long term liability to the community. Common problems encountered include:

- accumulation of litter in some sections of the wetland;
- accumulation of oil and scum at "dead zones" in the wetland;
- infestation of weeds or dominance of certain species of vegetation;
- mosquito problems;
- algal blooms;
- scouring of sediment and banks, especially during high flows.

Many of the above problems can be minimised or avoided by good engineering design principles. Poor wetland hydrodynamics and lack of appreciation of the stormwater treatment chain are often identified as major contributors to wetland management problems. A summary of desired hydrodynamic characteristics and design elements is presented below.

Table 8-1. Desired Wetland Hydrodynamic Characteristics and Design Elements

Hydrodynamic Characteristics	Design Issues	Remarks
Uniform distribution of flow velocity	Wetland shape, inlet and outlet placement and morphological design of wetland to eliminate short-circuit flow paths and "dead zones".	Poor flow pattern within a wetland will lead to zones of stagnant pools which promote the accumulation of litter, oil and scum as well as potentially supporting mosquito breeding. Short circuit flow paths of high velocity will lead to the wetland being ineffective in water quality improvement.
Inundation depth, wetness gradient, base flow and hydrologic regime	Selection of wetland size and design of outlet control to ensure compatibility with the hydrology and size of the catchment.	Regular flow throughput in the wetland promotes flushing of the system and maintains a dynamic system, avoiding problems associated with stagnant water e.g. algal blooms, mosquito breeding, oil and scum accumulation

Hydrodynamic Characteristics	Design Issues	Remarks
	Morphological and outlet control design to match botanical layout design and the hydrology of the wetland.	etc. Inadequate attention to the inundation depth, wetness gradient of the wetland and the frequency of inundation at various depth range would lead to dominance of certain plant species, especially weed species which, over time, results in a deviation from the intended botanical layout of the wetland. Recent research findings indicate that regular wetting and drying of the substrata of the wetland can prevent releases of phosphorus from the sediment deposited in the wetland.
Uniform vertical velocity profile	Selection of plant species and location of inlet and outlet structures to promote uniform velocity profile	Preliminary research findings have indicated that certain plant species have a tendency to promote stratification of flow conditions within a wetland leading to ineffective water pollution control and increase the potential for algal bloom.
Scour protection	Design of inlet structures and erosion protection of banks	Owing to the highly dynamic nature of stormwater inflow, measures are to be taken to “protect” the wetland from erosion during periods of high inflow rates.

In many urban applications, wetlands can be constructed in the base of retarding basins, thus reducing the land required for stormwater treatment. In these situations, the wetland systems will occasionally become inundated to greater depths than the extended detention depth. However, the inundation is relatively short (hours) and is unlikely to affect the vegetation provided there is a safe pathway to drain following flood events that does not scour vegetation or banks.

Key design issues to be considered are:

1. verifying size and configuration for treatment
2. determining design flows
3. design of Inlet Zone (see Design Procedure for Sedimentation Basin, Chapter 4)
4. Macrophyte Zone Layout
    - zonation
    - longitudinal and cross sections
5. hydraulic Structures:
    - Macrophyte Zone outlet structures
    - connection to Inlet Zone
    - bypass weir and channel
6. Recommended plant species and planting densities
7. Provision for maintenance

8.2 Verifying size for treatment

The curves are based on the performance of the system at the reference site with varying extended detention depths and were derived using the MUSIC (eWater, 2009). To estimate an equivalent performance at other locations in Tasmania, the hydrologic design region relationships should be used to convert the treatment area into an equivalent treatment area, refer to Chapter 2. In preference to using the curves, local data should be used to model the specific treatment performance of the system.

The curves were derived assuming the systems receive direct runoff (ie. no pretreatment) and have the following characteristics:

- the Inlet Zone forms part of the wetland system sized to retain 125 μm sediment for flows up to the 1 year ARI peak discharge and with provision for high flow bypass
- notional detention period of 72 hours.

The curves in Figure 8.2 to 8.4 can be used to check the expected performance of the wetland system for removal of TSS, TP and TN. The x-axis on the curves is a measure of the size of the surface of the wetland (measured as the permanent pool area), expressed as a percentage of the contributing *impervious* catchment.

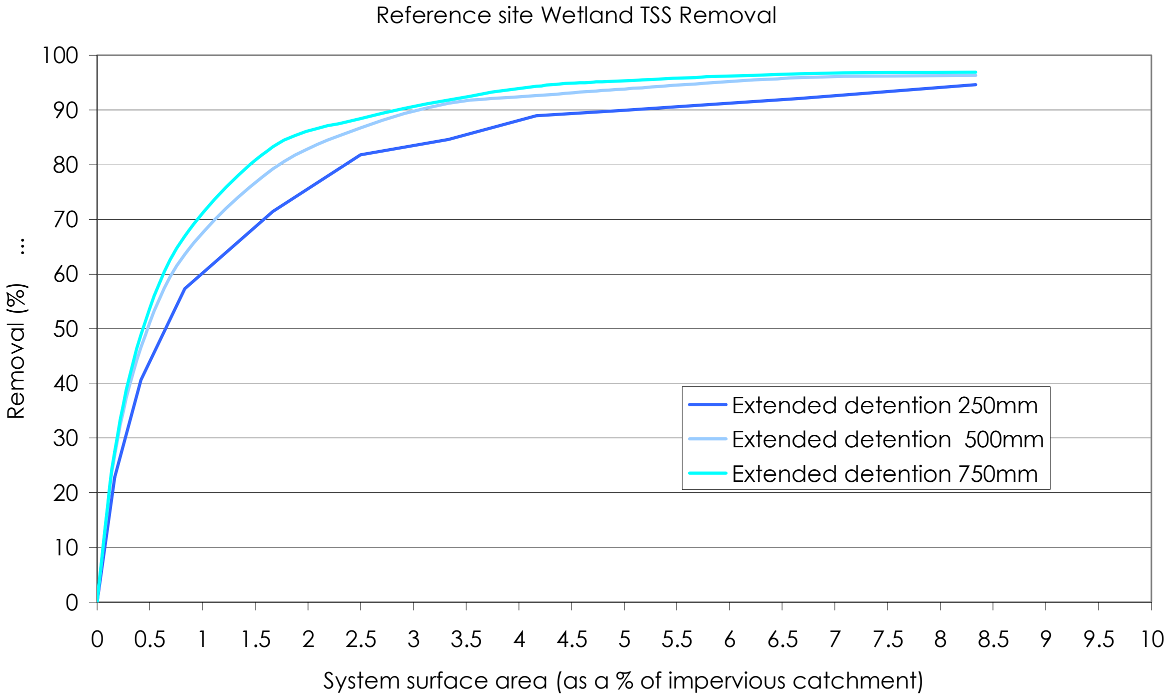


Figure 8.2. TSS removal in wetland systems with varying extended detention

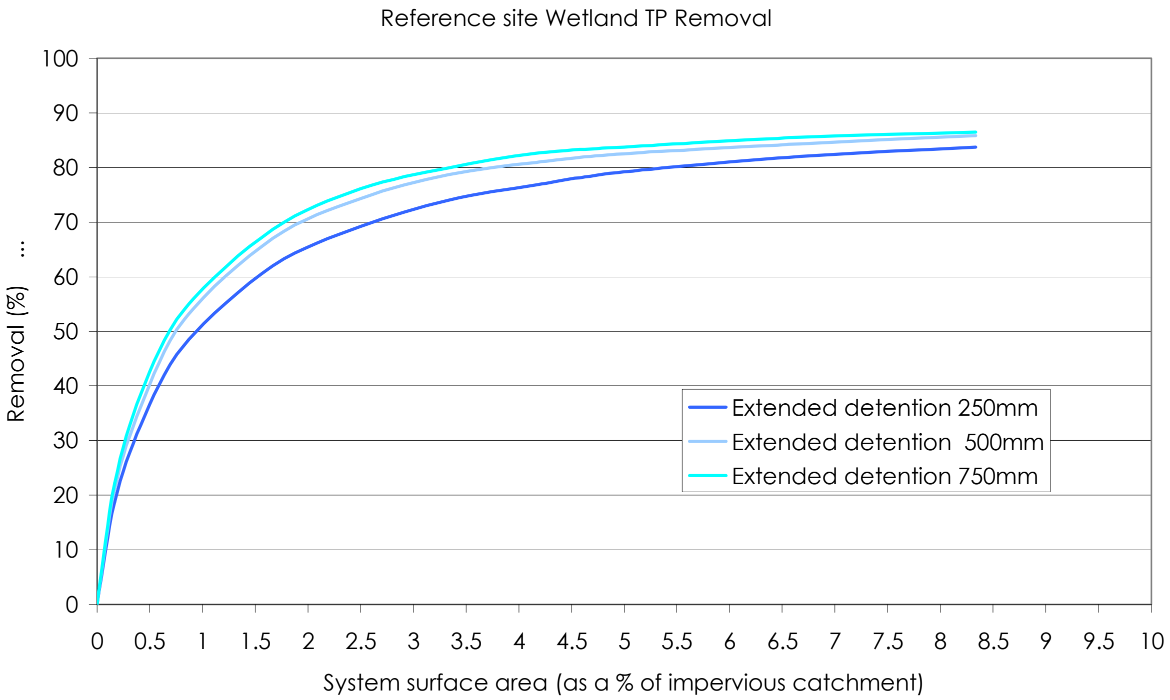


Figure 8.3 TP removal in wetland systems with varying extended detention

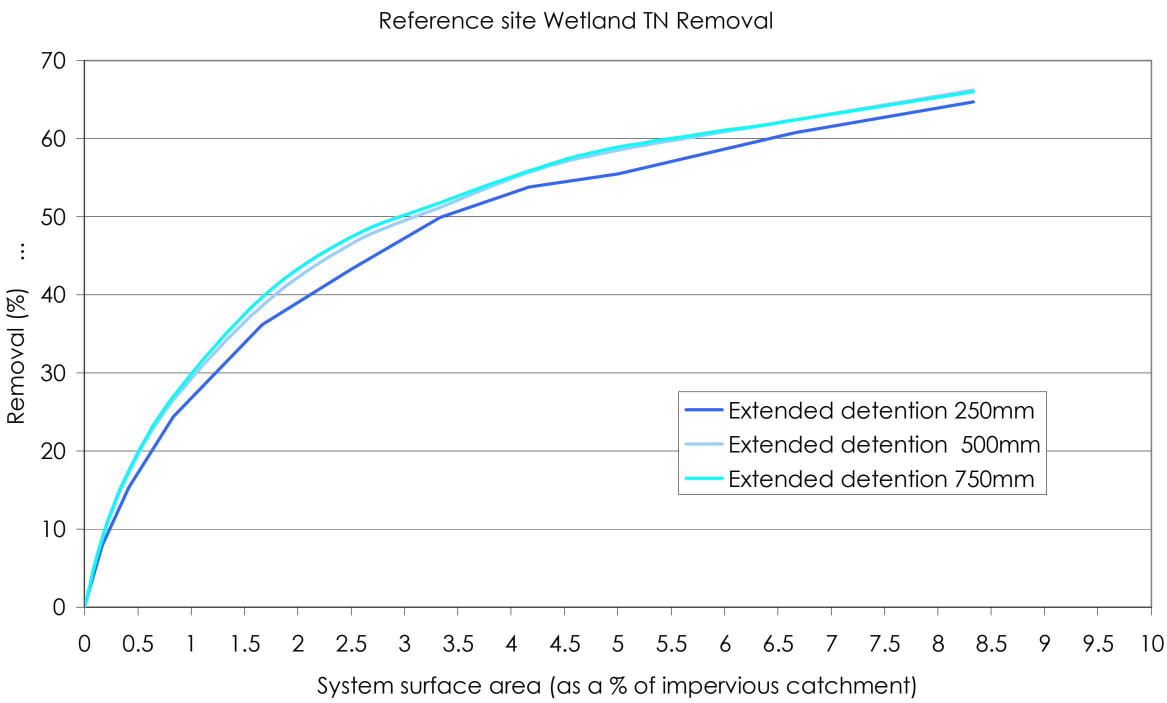


Figure 8.4. TN removal in wetland systems with varying extended detention

8.3 Design procedure: constructed wetlands

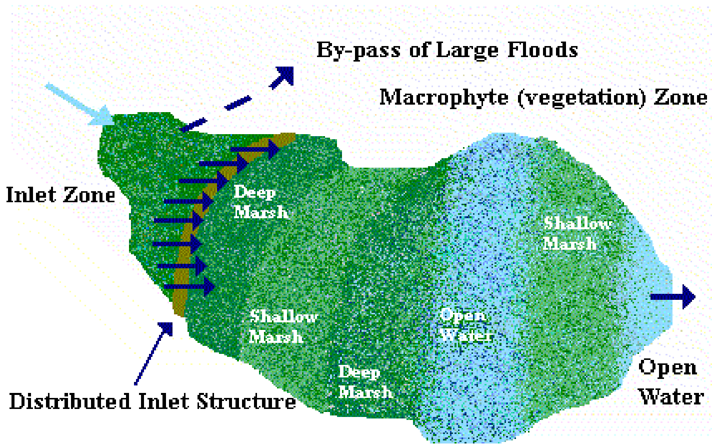


Figure 8.5. Elements of a constructed wetland system

Analyses to be undertaken during the detailed design phase of the inlet zone and the macrophyte zone of a constructed wetland system include the following:

- Design of the inlet zone as a sedimentation basin to target sediment of 125 µm or larger. Design considerations include:
  - Inlet zone to operate as a flow regulator into the macrophyte zone during normal operation

    - Inlet zone to operate for by-pass of the macrophyte zone during above-design conditions
    - Design the connection between the inlet zone and the macrophyte zone with appropriate design of inlet conditions to provide for energy dissipation and distribution of inflow into the macrophyte zone
    - Provision for sediment and debris removal.

- Configure the layout of the macrophyte zone to provide an extended detention volume in a manner such that the system's hydraulic efficiency can be optimised. Design considerations include:-
    - Suitable extended detention depths are between 0.25 m and 0.75 m, depending on the desired operation of the wetland and target pollutant.
    - Bathymetric design the of the macrophyte zone to promote a sequence of ephemeral, shallow marsh, marsh and submerged marsh systems in addition to a small open water system in the vicinity of the outlet structure.
    - Particular attention to the placement of the inlet and outlet structures, the aspect ratio of the macrophyte zone and flow control features to promote a high hydraulic efficiency within the macrophyte zone.
    - A key design consideration is the location and depth of permanent pools within the macrophyte zone.
    - Provision to drain the macrophyte zone if necessary should also be considered.
    - Design of the macrophyte zone outlet structure to provide for a 72 hour notional detention time for a wide range of flow depth. The outlet structure should include measures to trap debris to prevent clogging.
- Landscape design will be required including:-
    - Macrophyte zone vegetation (including littoral zone)
    - Terrestrial vegetation

The following sections detail the design steps required for constructed stormwater wetland systems.

8.3.1 Estimating design flows

The hydrologic design objectives for the inlet zone are as follows:

i. Capacity to convey stormwater inflows up to the peak 1 year ARI discharge into the macrophyte zone

ii. Capacity to convey above-design stormwater inflows to the by-pass system. Design discharge capacity for the by-pass system corresponds to the following, e.g.:

a. the minor system capacity (2 or 5 year ARI) if overland flow path does not direct overland flow into the wetland

b. 100 year ARI peak discharge if the wetland system forms part of the major drainage system.

8.3.2 Minor and major flood estimation

A range of hydrologic methods can be applied to estimate design flows. If the typical catchment areas are relatively small, the Rational Method Design Procedure is considered to be a suitable method for estimating design flows. However, the use of the Rational Design Procedure should strictly be used to size inlet hydraulic structures only and that a full flood routing computation method should be used in sizing the outlet hydraulic structures (e.g. outlet pipe, spillway and embankment height, etc.).

8.3.3 Inlet Zone

The Inlet Zone of a constructed stormwater wetland serves two basic functions, i.e. (i) the pre-treatment of inflow to remove gross pollutants and coarse to medium sized sediment; and (ii) the hydrologic control of inflows into the macrophyte zone and bypass of floods during “above-design” operating conditions. The Inlet Zone typically comprise a relatively deep open water body (> 1.5 m) that operates primarily as a sedimentation basin. It may often be necessary that a Gross Pollutant Trap (GPT) be installed at the inlet to this zone such that litter and large debris can be captured at the interface between the incoming waterway (or pipe) and the open water of the Inlet Zone.

For more information and guidance on the design of the Inlet Zone, the reader is referred to Chapter 3 Sediment Basins.

8.3.4 Macrophyte Zone Layout

8.3.4.1 Size and Dimensions

To optimise hydraulic efficiency, i.e. reduce short circuits and dead zones, it is desirable to adopt a high length to width ratio. The ratio of length to width varies depending on the size of the system and the site characteristics. To simplify the design and earthworks smaller systems tend to have length to width ratios at the lower end of the range. This can often lead to poor hydrodynamic conditions within the macrophyte zone. Persson *et al* (1999) used the term hydraulic efficiency to define the expected hydrodynamic characteristics for a range of configurations of stormwater detention systems.

Engineers Australia (2006) present expected hydraulic efficiencies of detention systems for a range of notional shapes, aspect ratios and inlet/outlet placements within stormwater detention systems and recommends that constructed wetlands systems should not be less than 0.5 and should be designed to promote hydraulic efficiencies greater than 0.7. (see Figure 8.6)

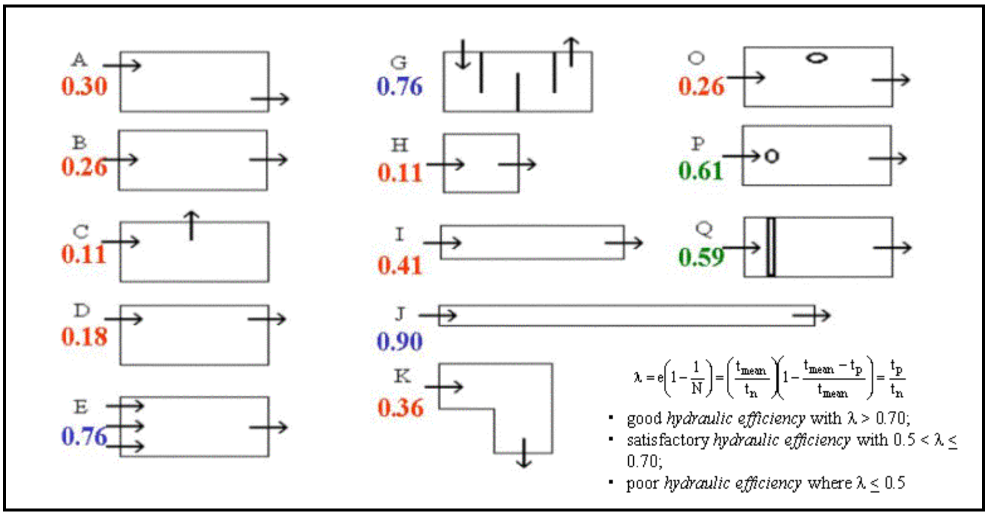


Figure 8.6. Hydraulic Efficiency - λ- A measure of Flow Hydrodynamic Conditions in Constructed Wetlands and Ponds; Range is from 0 to 1, with 1 representing the best hydrodynamic conditions for stormwater treatment (Persson et al, 1999)

Figure 8.6 provides some guidance on what is considered to be good design with the higher values (of λ) representing structures with good sediment retention properties, where a value of λ greater than 0.5 should be a design objective. If the basin configuration yields a lower value, modification to the basin configuration should be explored to increase the λ value (e.g. inclusion of baffles, islands or flow spreaders).

The shape of the structure has a large impact on the effectiveness of the basin to retain sediments and generally a length to width ratio of at least 3:1 should be aimed for. In addition, the location of the inlet and outlet, flow spreaders and internal baffles impact the hydraulic efficiency of the basin for stormwater treatment. These types of elements are noted in Figure 4.3 as the figure "o" in diagrams O and P (which represent islands in a waterbody) and the double line in diagram Q which represents a structure to distribute flows evenly.

> **DESIGN ADVICE –**
>
> Consideration of maintenance access to a structure is also required when developing the shape of a wetland as this can impact the allowable width (if access is from the banks) or the shape if access ramps into a basin are required. An area for sediment de-watering should also be accommodated and it is required to drain back into the basin. This too may impact on the footprint area required for a sedimentation system.

8.3.4.2 Zonation

It is good design practice to provide a range of habitat areas within wetlands to support a variety of plant species and ecological niches. The wetland is broadly divided into four macrophyte zones and an open water zone. The bathymetry across the four macrophyte zones is to vary gradually over the depth range outlined below, ranging from 0.2 m above the permanent pool level to 0.5 m below the permanent pool level (refer to Appendix B for guidance on selection of plant species). The depth of the open water zone in the vicinity of the outlet structure is to be 1.0 m below the permanent pool level.

To ensure optimal hydraulic efficiency of the wetland for the given shape and aspect ratio, the wetland zones are arranged in bands of equal depth running across the flow path. Appropriate bathymetry coupled with uniform plant establishment ensures the cross section has equivalent hydraulic conveyance, thus preventing short-circuiting.

8.3.4.3 Long Section

In defining a long section for the macrophyte zone, it is necessary to provide areas for habitat refuge. For this reason it is desirable to have areas of permanent pools interconnected to prevent fauna being isolated in areas that dry out. This also reduces the piping required to drain the wetland for maintenance purposes.

An example bathymetry of a wetland system is shown in Figure 8.7. It illustrates gradual changes in depth longitudinally to create different vegetation areas as well as consistent zone banding across the wetland.

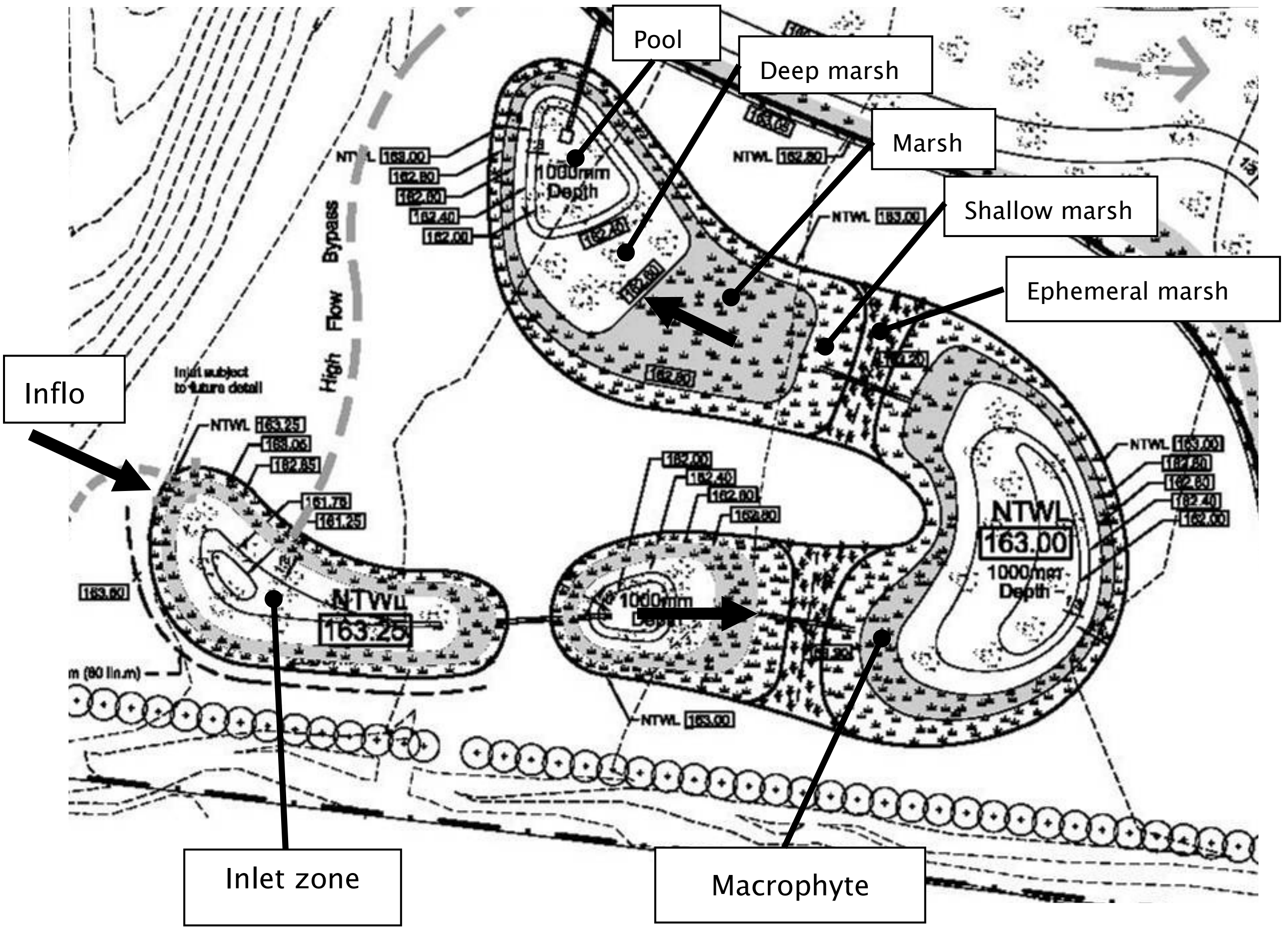


Figure 8.7. Example bathymetry of a constructed wetland system (GbLA, 2004)

8.3.4.4 *Cross Sections*

The batter slopes on approaches and immediately under the permanent water level have to be configured with consideration of public safety (e.g. Figure 8.8).

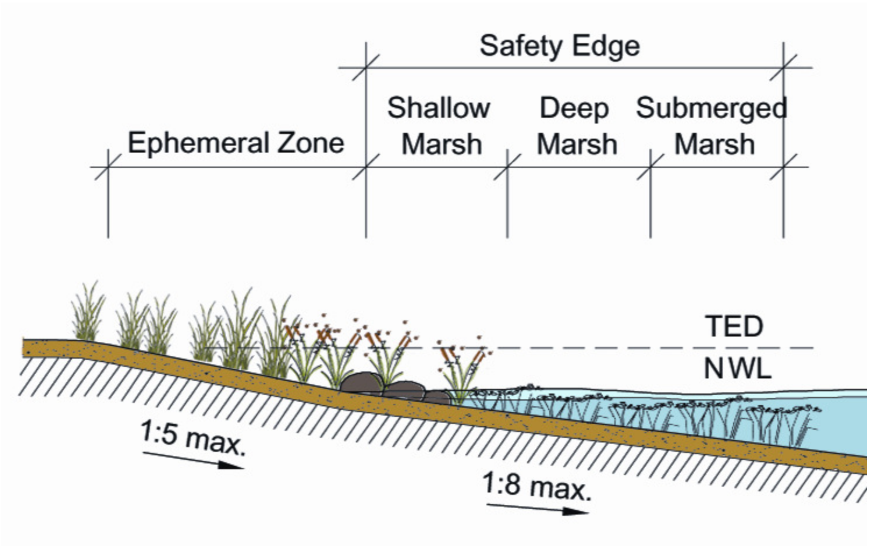


Figure 8.8. Example of edge design to a constructed wetland system

It is recommended that a gentle slope to the water edge and extending below the water line be adopted before the batter slope steepens into deeper areas. An alternative to the adoption of a flat batter slope is to provide a 3 m “safety bench” that is less than 0.2 m deep below the permanent pool level be built around the wetland.

Safety requirements for individual wetlands may vary from site to site, and it is recommended that an independent safety audit be conducted for each design. Safety guidelines are also provided by some local authorities (e.g. Royal Life Saving Society of Australia *Guidelines for Water Safety in Urban Water Developments*) and these should be followed.

8.3.5 Macrophyte Zone Outlet Structure

The macrophyte zone outlet structure forms two purposes. The first is to control discharges from the extended detention storage to ensure the wetland maintains a notional detention time of 72 hours. The outlet structure also needs to include features to allow the permanent pool to be drained for maintenance.

8.3.5.1 Maintenance Drain

The permanent pool of the wetland should be able to be drained with a maintenance drain operated manually. A suitable design flow rate is one which can draw down the permanent pool within 12 hours, i.e. overnight

The orifice discharge equation is considered suitable for sizing the maintenance drain on the assumption that the system will operate under inlet control with its discharge characteristics determined as follows, ie.

$$A_o = \frac{Q}{C_d \sqrt{2gh}}$$

Equation 8.1

C_d = Orifice Discharge Coefficient (0.6)

H = Depth of water above the centroid of the orifice (m)

A_o = Orifice area (m^2)

Q = required flow rate to drain the volume of the permanent pool in 12 hours

8.3.5.2 Riser Outlet – Size and Location of Orifices

The riser is designed to provide a uniform notional detention time over the full range of the extended detention depth[1]. The target maximum discharge may be computed as the ratio of the volume of the extended detention to the notional detention time, ie.

[1] It should be noted that detention time is never a constant and the term notional detention time is used to provide a point of reference in modelling and determining the design criteria for riser outlet structures.

Target Maximum Discharge (m^3/s) = extended storage volume (m^3)/ detention time (s)

The placement of outlet orifices and determination of appropriate diameters is designed iteratively by varying outlet diameters and levels, using the orifice equation (Equation 9.1) applied over discrete depths along the length of a riser up to the maximum detention depth. This can be performed with a spreadsheet as illustrated in the worked example.

As the outlet orifices can be expected to be small, it is important that the orifices are prevented from clogging by debris. Some form of debris guard is recommended as illustrated in the images below.

An alternative to using a debris guard is to install the riser within a pit which is connected to the permanent pool of the macrophyte zone via a submerged pipe culvert. This connection should be adequately sized such that there is minimal water level difference between the water within the pit and the water level in the macrophyte zone. With the water entering into the outlet pit being drawn from below the permanent pool level, floating debris are prevented from entering the outlet pit while heavier debris would normally settle onto the bottom of the permanent pool.

8.3.5.3 Riser Outlet – Pipe Dimension

While conservative, it is desirable to size the riser pipe such that it has the capacity to accommodate the 1 year ARI peak discharge operating as a “glory hole” spillway. Under normal operation, this flow would be by-passed around the macrophyte zone when this zone is already operating at design capacity. Nevertheless, it is good practice to provide a level of contingency in discharge capacity for the riser outlet to prevent any overtopping of the embankment of the macrophyte zone. A minimum of 0.3 m freeboard for the embankment (ie. crest level of embankment above top of extended detention) is often required.

Significant attenuation of the peak 1 year ARI inflow can be expected and some routing of the inflow hydrograph through the storage provided by the macrophyte zone is recommended.

The weir equation can be used in defining the required perimeter (and thus dimension) of the riser outlet. A weir coefficient of 1.7 (sharp-crested weir) is recommended, ie.

$$P = \frac{Q_{des}}{C_w \cdot H^{1.5}}$$

Equation 8.2

P = Perimeter of the outlet pit

H = Depth of water above the crest of the outlet pit

Q_{des} = Design discharge (m^3/s)

8.3.5.4 Discharge Pipe

The discharge pipe of the wetland conveys the outflow of the macrophyte zone to the receiving waters (or existing drainage infrastructure). The conveyance capacity of the discharge pipe is to be sized to match the higher of the two discharges, ie. maximum discharge from the riser or the maximum discharge from the maintenance drain.

8.3.6 Connection to Inlet Zone

The pipe that connects the inlet zone to the macrophyte zone must have sufficient capacity to convey a 1 year ARI flow, assuming the macrophyte zone is at the permanent pool level, without resulting in any flow in the bypass system. The configuration of the hydraulic structure connecting the inlet zone to the macrophyte zone would normally consist of an overflow pit connected to one or more pipes through the embankment separating these two zones.


Typical specifications of water and embankment levels are as follows:-

- Bypass spillway level = top of extended detention in the macrophyte zone
- Permanent Pool level in inlet zone = 0.3 m above permanent pool level in macrophyte zone

Velocity checks are to be conducted for when the wetland is full and when it is near empty. Velocities should ideally be less than 0.05 m/s.

8.3.7 High-flow route and by-pass design

To protect the integrity of the macrophyte zone of the wetland, it is necessary to consider the desired above-design operation of the wetland system. This is generally provided for with a high flow route that by-passes the macrophyte zone during flow conditions that may lead to scour and damage to the wetland vegetation. As outlined in **Section 8.3.1**, a function of the inlet zone is to provide hydrologic control of inflow into the macrophyte zone. A by-pass weir is to be included in the design of the inlet zone, together with a by-pass floodway (channel) to direct high flows around the macrophyte zone.

Ideally, the bypass weir level should be set at the top of the extended detention level in the macrophyte zone. This would ensure that a significant proportion of catchment inflow will bypass the Macrophyte Zone once it has reached its maximum operating extended detention level. The width of the spillway is to be sized to safely pass the maximum discharge conveyed into the inlet zone or the 100 year ARI discharge (as defined in **Section 8.3.1**) with the maximum water level above the crest of the weir to be defined by the top of embankment level (plus a suitable freeboard provision).


8.3.8 Vegetation specification

Vegetation planted in the macrophyte zone (ie. marsh and pool areas) is designed to treat stormwater flows, as well as add Aesthetic value. Dense planting of the littoral berm zone will inhibit public access to the macrophyte zone, minimising potential damage to the plants and the safety risks posed by water bodies. Terrestrial planting may also be recommended to screen areas and provide an access barrier to uncontrolled areas of the stormwater treatment system.

Plant species for the wetland area will be selected based on the water regime, microclimate and soil types of the region, and the life histories, physiological and structural characteristics, natural distribution, and community groups of the wetland plants. Refer to the Appendix B for a list of suggested plant species suitable for constructed wetland systems in Tasmania and recommended planting densities. The distribution of species within the wetland will relate to their structure, function, relationship and compatibility with other species. Planting densities should ensure that 70-80 % cover is achieved after two growing seasons (2 years).

8.3.9 Designing to avoid mosquitos

Mosquitos are a natural component of wetland fauna and the construction of any water body will create some mosquito habitat. To reduce the risk of high numbers of mosquitoes designs should function as balanced ecosystems with predators controlling mosquito numbers. Design considerations that should be addressed include:

- providing access for mosquito predators to all parts of the water body (do not have stagnant isolated area of water)
- providing an area of permanent water (even during long dry periods) where mosquito predators can seek refuge
- maintaining natural water level fluctuations that disturb the breeding cycle of some mosquito species
- providing a bathymetry such that regular wetting and drying is achieved and water draws down evenly so isolated pools are avoided
- providing sufficient gross pollutant control at the inlet such that human derived litter does not accumulate and provide breeding habitat
- ensuring maintenance procedures do not result in wheel ruts and other localised depressions that create isolated pools when water levels fall.

Local agency's guidelines should also be consulted with regard to approaches for avoiding excessive mosquito populations.

8.3.10 Design Calculation Summary

Overleaf is a design calculation summary sheet for the key design elements of a construction wetland to aid the design process.

Constructed Wetand — CALCULATION SUMMARY

	CALCULATION TASK	OUTCOME		CHECK
1	**Identify design criteria**			
	Design ARI Flow for Inlet Zone		year	
	Target Sediment Size for Inlet Zone		mm	
	Notional Detention Period for Macrophyte Zone		hrs	
	Design ARI Flow for Bypass Spillway		year	
	Extended Detention Volume		m^3	☐
2	**Catchment characteristics**			
	Residential		Ha	
	Commercial		Ha	
	Fraction impervious			
	Residential			
	Commercial			☐
3	**Estimate design flow rates**			
	Time of concentration			
	estimate from flow path length and velocities		minutes	☐
	Identify rainfall intensities			
	station used for IFD data:			
	100 year ARI		mm/hr	
	1 year ARI		mm/hr	☐
	Design runoff coefficient			
	C_1			
	C_{100}			☐
	Peak design flows			
	Q_1		m^3/s	
	Q_{100}		m^3/s	☐
4	**Inlet zone**			
	refer to sedimentation basin calculation checksheet			☐
5	**Macrophyte Zone Layout**			
	Extend Detention Depth		m	
	Area of Macrophyte Zone		m^2	
	Aspect Ratio		L:W	
	Hydraulic Efficiency			
	Length		m	
	Top width (including extended detention)		m	
	Cross Section Batter Slope		V:H	☐
6	**Macrophyte Zone Outlet Structures**			
	Maintenance Drain			
	Diameter of Maintenance Valve		mm	
	Drainage time		hrs	☐
	Riser			
	Linear Storage-Discharge Relationship for Riser			☐
	Discharge Pipe			
	Discharge Capacity of Discharge Pipe		m^3/s	☐
7	**Connection between Inet Zone and Macrophyte Zone**			
	Discharge Capacity of Connection Culvert		m^3/s	☐
8	**Bypass Weir**			
	Discharge Capacity of Bypass Weir		m^3/s	☐

8.4 Checking tools

This section provides a number of checking aids for designers and referral authorities. In addition, advice on construction techniques and lessons learnt from building wetland systems are provided.

Checklists are provided for:

- design assessments
- construction (during and post)
- operation and maintenance inspections
- asset transfer (following defects period).

8.4.1 Design assessment checklist

The checklist below presents the key design features that should be reviewed when assessing a design of a constructed wetland system. These considerations include configuration, safety, maintenance and operational issues that should be addressed during the design phase.

Where an item results in an “N” when reviewing the design, referral should be made back to the design procedure to determine the impact of the omission or error.

In addition to the checklist, a proposed design should have all necessary permits for its installations. The referral agency should ensure that all relevant permits are in place. These can include permits to clear vegetation, to dredge, create a waterbody, divert flows or disturb fish or platypus habitat.

Land and asset ownership are key considerations prior to construction of a stormwater treatment device. A proposed design should clearly identify the asset owner and who is responsible for its maintenance. The proposed owner should be responsible for performing the asset transfer checklist (see 8.4.4).

Wetland Design Assessment Checklist

Wetland Location:					
Hydraulics	Minor Flood: (m^3/s)		Major Flood: (m^3/s)		
Area	Catchment Area (ha):		Wetland Area (ha)		

Treatment	**Y**	**N**
Treatment performance verified from curves?		

Inlet Zone	**Y**	**N**
Inlet pipe/structure sufficient for maximum design flow (Q_5 or Q_{100})?		
Scour protection provided at inlet?		
Configuration of inlet zone (aspect, depth and flows) allows settling of particles >125µm?		
Bypass weir incorporated into inlet zone?		
Bypass weir and channel sufficient to convey >Q1 <= maximum inlet flows?		
Bypass weir crest at macrophyte permanent pool level + extended detention depth?		
Bypass channel has sufficient scour protection?		
Structure from inlet zone to macrophyte zone enables energy dissipation/flow distribution?		
Structure from inlet zone to macrophyte zone enables isolation of the macrophyte zone for maintenance?		
Inlet zone permanent pool level above macrophyte permanent pool level?		
Maintenance access allowed for into base of inlet zone?		
Public access to inlet zone prevented through vegetation or other means?		
Gross pollutant protection measures provided on inlet structures (both inflows and to macrophyte zone)		

Macrophyte Zone	**Y**	**N**
Extended detention depth >0.25m and <0.75m?		
Vegetation bands perpendicular to flow path?		
Vegetation bands of near uniform depth?		
Sequencing of vegetation bands provides continuous gradient to open water zones?		
Vegetation appropriate to selected band?		
Aspect ratio provides hydraulic efficiency >0.5?		
Velocities from inlet zone <0.05 m/s or scouring protection provided?		
Batter slopes from accessible edges shallow enough to allow egress?		
Maintenance access provided into areas of the macrophyte zone (especially open water zones)?		
Public access to macrophyte zones restricted where appropriate?		
Safety audit of publicly accessible areas undertaken?		
Freeboard provided above extended detention depth?		

Outlet Structures	**Y**	**N**
Riser outlet provided in macrophyte zone?		
Orifice configuration allows for a linear storage-discharge relationship for full range of the extended detention depth?		
Riser diameter sufficient to convey Q_1 flows when operating as a “glory hole” spillway?		
Maintenance drain provided?		
Discharge pipe from has sufficient capacity to convey the maintenance drain flows or Q_1 flows (whichever is higher)?		
Protection against clogging of orifice provided on outlet structure?		

8.4.2 Construction advice

This section provides general advice for the construction of wetlands. It is based on observations from construction projects around Australia.

Protection from existing flows

It is important to have protection from upstream flows during construction of a wetland system. A mechanism to divert flows around a construction site, protect from litter and debris is required. This can be achieved by constructing a high flow bypass channel initially and then diverting all inflows along the channel until the wetland system is complete.

High flow contingencies

Contingencies to manage risks associated with flood events during construction are required. All machinery should be stored above acceptable flood levels and the site stabilised as best as possible at the end of each day as well as plans for dewatering following storms made.

Erosion control

Immediately following earthworks it is good practice to revegetate all exposed surfaces with sterile grasses (e.g. hydroseed). These will stabilise soils, prevent weed invasion yet not prevent future plants from establishing. Site runoff may be prevented by establishing the inlet zone as temporary sediment basin in the early stages of construction. Common soil and water management practices for any potential runoff are crucial.

Inlet erosion checks

It is good practice to check the operation of inlet erosion protection measures following the first few rainfall events. It is important to check for these early in the systems life, to avoid continuing problems. Should problems occur in these events the erosion protection should be enhanced.

Tolerances

Tolerances are important in the construction of wetlands (eg base, longitudinal and batters). Levels are particularly important for a well distributed flow path and establishing appropriate vegetation bands. It is also important to ensure that as water levels reduce (e.g. for maintenance) that areas drain back into designated pools and distributed shallow pools across the wetland are avoided. Generally plus or minus 50mm is acceptable.

Transitions

Pay attention to the detail of earthworks to ensure smooth transitions between benches and batter slopes. This will allow for strong edge vegetation to establish and avoid local ponding, which can enhance mosquito breeding habitat.

Inlet zone access

An important component of an inlet zone is accessibility for maintenance. If excavators can reach all parts of the inlet zone an access track may not be required to the base of the inlet zone, however an access track around the perimeter of the inlet zone is required. If sediment collection is performed using earthmoving equipment a stable ramp will be required to the base of the inlet zone (maximum slope 1:10).

Inlet zone base

It is recommended that the inlet zone be constructed with a hard (i.e. rock) bottom. This is important if maintenance invoves driving into the basin. It also serves an important role in determining the levels that excavation should extend to (ie how deep to dig).

Dewatering collected sediments

An area should be constructed that allows for dewatering of removed sediments from an inlet zone. This area should be located such that water from the material drains back into the inlet zone. Material should be allowed to drain for a minimum of overnight before disposal.

Timing for planting

Timing of vegetation planting is influenced by season (and potential irrigation requirements) as well as timing in relation to the phases of development. Temporary sediment controls should always be used prior to planting as lead times from earthworks to planting are often long.

Vegetation establishment

During the establishment phase water levels should be controlled carefully to prevent seedlings from being desiccated or drowned. This is best achieved with the use of maintenance drains. Once established, water levels can be raised to operational levels.

Bird protection

Bird protection (e.g. nets) should be considered for newly planted areas of wetlands, birds can pull out young plants and reduce plant densities.

8.4.3 Construction checklist

CONSTRUCTION INSPECTION CHECKLIST

Wetlands

INSPECTED BY:
DATE:
TIME:
WEATHER:
CONTACT DURING VISIT:

SITE: ______________________

CONSTRUCTED BY: ______________________

DURING CONSTRUCTION									
Items inspected	Checked		Satisfactory	Unsatisfactory		Checked		Satisfactory	Unsatisfactory
Preliminary works	Y	N				Y	N		
1. Erosion and sediment control plan adopted					18. Concrete and reinforcement as designed				
					19. Inlets appropriately installed				
2. Limit public access					20. Inlet energy dissipation installed				
3. Location same as plans					21. No seepage through banks				
4. Site protection from existing flows					22. Ensure spillway is level				
5. All required permits in place					23. Provision of maintenance drain(s)				
Earthworks					24. Collar installed on pipes				
6. Integrity of banks					25. Low flow channel rocks are adequate				
7. Batter slopes as plans					26. Protection of riser from debris				
8. Impermeable (eg. clay) base installed					27. Bypass channel stabilised				
9. Maintenance access to whole wetland					28. Erosion protection at macrophyte outlet				
10. Compaction process as designed					**Vegetation**				
11. Placement of adequate topsoil					29. Vegetation appropriate to zone (depth)				
12. Levels as designed for base, benches, banks and spillway (including freeboard)					30. Weed removal prior to planting				
					31.Provision for water level control during establishment				
13. Check for groundwater intrusion									
14. Stabilisation with sterile grass					32. Vegetation layout and densities as designed				
Structural components									
15. Location and levels of outlet as designed					33. Provision for bird protection				
16. Safety protection provided					34. By-pass channel vegetated				
17. Pipe joints and connections as designed									
FINAL INSPECTION									
1. Confirm levels of inlets and outlets					9. Check for uneven settling of banks				
2. Confirm structural element sizes					10. Evidence of stagnant water, short circuiting or vegetation scouring				
3. Check batter slopes									
4. Vegetation planting as designed					11. Evidence of litter or excessive debris				
5. Erosion protection measures working					12. Provision of removed sediment drainage area				
6. Pre-treatment installed and operational									
7. Maintenance access provided					13. Evidence of debris in high flow bypass				
8. Public safety adequate					14. Macrophyte outlet free of debris				

COMMENTS ON INSPECTION

ACTIONS REQUIRED

1.									
2.									
3.									

8.4.4 Asset transfer checklist

Asset Handover Checklist		
Asset Location:		
Construction by:		
Defects and Liability Period		
Treatment	**Y**	**N**
System appears to be working as designed visually?		
No obvious signs of under-performance?		
Maintenance	**Y**	**N**
Maintenance plans provided for each asset?		
Inspection and maintenance undertaken as per maintenance plan?		
Inspection and maintenance forms provided?		
Asset inspected for defects?		
Asset Information	**Y**	**N**
Design Assessment Checklist provided?		
As constructed plans provided?		
Copies of all required permits (both construction and operational) submitted?		
Proprietary information provided (if applicable)?		
Digital files (eg drawings, survey, models) provided?		
Asset listed on asset register or database?		

8.5 Maintenance requirements

Wetlands treat runoff by filtering it through vegetation and providing extended detention to allow sedimentation. In addition, they have a flow management role that needs to be maintained to ensure adequate flood protection for local properties and protection of the wetland ecosystem.

Maintaining vibrant vegetation and adequate flow conditions in a wetland are important maintenance considerations. Weeding, planting and debris removal are the dominant tasks. In addition the wetland needs to be protected from high loads of sediment and debris and the inlet zone needs to be maintained in the same way as sedimentation basins (see Chapter 3).

The most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required. Requirements of plant establishment are discussed further in Appendix B Plant Lists. It is also the time when large loads of sediments could impact on plant growth particularly in developing catchments with poor building controls.

Other components of the system that will require careful consideration are the inlet points. Inlets can be prone to scour and build up of litter. Occasional litter removal and potential replanting may be required as part of maintaining an inlet zone.

Maintenance is primarily concerned with:

- Maintenance of flow to and through the system
- Maintaining vegetation
- Preventing undesired vegetation from taking over the desirable vegetation
- Removal of accumulated sediments
- Litter and debris removal

Vegetation maintenance will include:

- Removal of noxious plants or weeds
- Re-establishment of plants that die

Similar to other types of stormwater practices, debris removal is an ongoing maintenance function. Debris, if not removed, can block inlets or outlets, and can be unsightly if located in a visible location. Inspection and removal of debris should be done regularly, but debris should be removed whenever it is observed on the site.

Inspections are also recommended following large storm events to check for scour.

8.5.1 Operation & maintenance inspection form

The form below should be used whenever an inspection is conducted and kept as a record on the asset condition and quantity of removed pollutants over time. Inspections should occur every 3-months for the first year and then 6-monthly thereafter. More detailed site specific maintenance schedules should be developed for major wetland systems and include a brief overview of the operation of the system and key aspects to be checked during each inspection. An example is presented as part of the worked example in 8.6.

Wetland Maintenance Checklist			
Inspection Frequency: 3 monthly	Date of Visit:		
Location:			
Description:			
Site Visit by:			
Inspection Items	**Y**	**N**	**Action Required (details)**
Sediment accumulation at inflow points?			
Litter within inlet or macrophyte zones?			
Sediment within inlet zone requires removal (record depth, remove if >50%)?			
Overflow structure integrity satisfactory?			
Evidence of dumping (building waste, oils etc)?			
Terrestrial vegetation condition satisfactory (density, weeds etc)?			
Aquatic vegetation condition satisfactory (density, weeds etc)?			
Replanting required?			
Settling or erosion of bunds/batters present?			
Evidence of isolated shallow ponding?			
Damage/vandalism to structures present?			
Outlet structure free of debris?			
Maintenance drain operational (check)?			
Resetting of system required?			
Comments:			

8.6 Worked example

8.6.1 Worked example introduction

A sedimentation basin and wetland system is proposed to treat runoff from a residential and commercial area located in Hobart. The wetland will consist of an inlet zone designed to treat the larger pollutant sizes. Flow will than pass through into a macrophyte zone where a riser outlet will be used to control the system detention period to settle out finer sediment particles. A by-pass channel will enable large flood events to by-pass the macrophyte zone during periods when the macrophyte zone is already operating at its design level. This worked example focuses only on the macrophyte zone component of the system with the design of the inlet zone (sedimentation basin) and by-pass channel contained in an earlier worked example. An illustration of the site and proposed layout of the wetland is shown below.

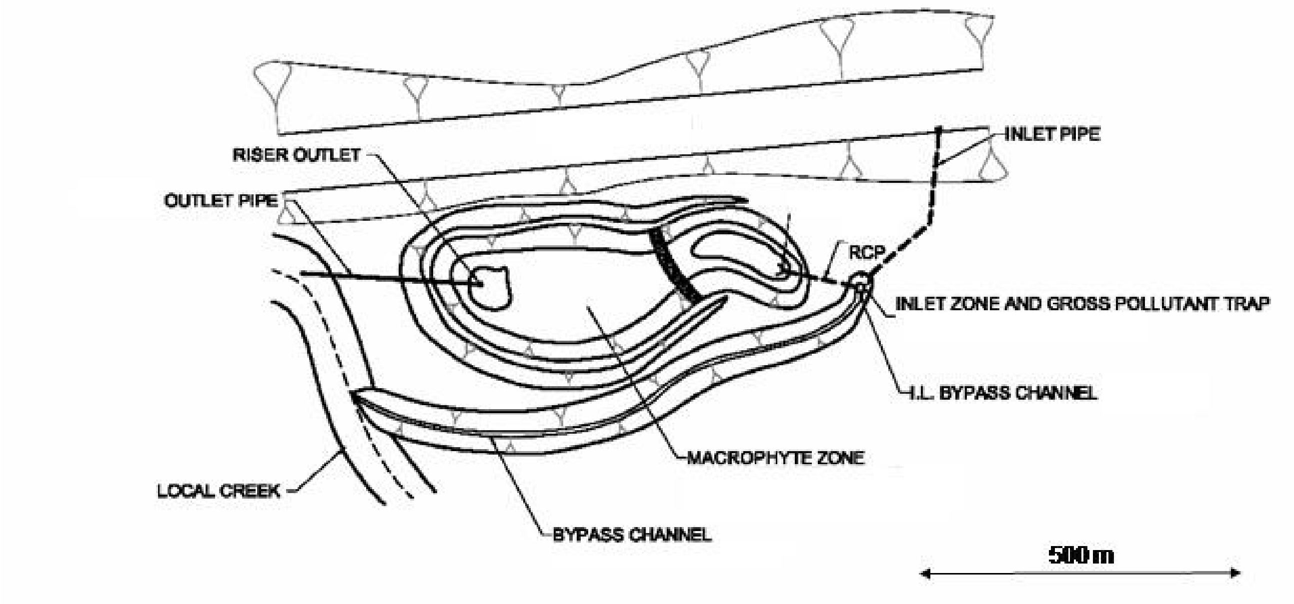


Figure 8.9. Layout of Proposed Wetland System

The contributing catchment area of the proposed wetland is 10 Ha (with percentage imperviousness of 50%). The site is flat with the maximum fall of less than 0.5 m across the site. Stormwater from the catchment is conveyed by conventional stormwater pipes and discharges into the constructed wetland via a single DN1000 diameter pipe. There are no site constrains with regard to the size of the wetland, as construction can extend into an adjacent park if required.

8.6.2 Design Considerations

The design criteria for the wetland system are to:

- Promote sedimentation of particles larger than 125 μm within the inlet zone.
- Optimise the relationship between detention time, wetland volume and the hydrologic effectiveness of the system to maximise treatment given the wetland volume site constraints. This is equivalent to a hydrologic effectiveness of 85% for a notional detention period of 72 hours.
- Ensure that the required detention period is achieved for all flow though the wetland system through the incorporation of a riser outlet system.
- Provide for by-pass operation when the inundation of the macrophyte zone reaches the design maximum extended detention depth.

This worked example focuses on the design of the macrophyte zone of the wetland system. Analyses to be undertaken during the detailed design phase of the macrophyte zone of the wetland system include the following:

- Configure the layout of the macrophyte zone to provide an extended detention depth of 0.5m in a manner such that the system *hydraulic efficiency* can be optimised. This includes particular attention to the placement of the inlet and outlet structures, the aspect ratio of the macrophyte zone and the need to use bathymetry and other flow control features to promote a high hydraulic efficiency within the macrophyte zone. A key design consideration is the extended detention depth for the macrophyte zone.
- Design the provision to drain the macrophyte zone if necessary.
- Design the connection between the inlet zone and the macrophyte zone with appropriate design of inlet conditions to provide for energy dissipation and distribution of inflow into the macrophyte zone.
- Design the bathymetry of the macrophyte zone to promote a sequence of ephemeral, shallow marsh and marsh system in addition to a small open water system in the vicinity of the outlet structure.
- Design of the macrophyte zone outlet structure to provide for a 72 hour notional detention time, including debris trap.

In addition, a landscape design will be required and they include:

- Macrophyte zone vegetation (including edge vegetation)
- Terrestrial vegetation.

8.6.2.1 Confirming Macrophyte Zone Area

As a basic check of the adequacy of the size of the wetland, reference is made to the performance curves presented in 8.2 Verifying size for treatment. According to Figures 8.2 – 8.4, the required wetland size to satisfy stormwater quality best practice environment management objectives (based on 0.5 m extended detention depth) at the reference site is the larger of 2.1% (for 80% reduction in TSS); 1.1% (for 45% reduction of TP) and 3.0% (for 45% reduction of TN) of the impervious area, (ie. 3.0 % of the impervious area is the critical size).

The required wetland area is as follows:

Catchment area = 10Ha (50% impervious)

Therefore Impervious Area = 5 Ha

Required Wetland Area (0.5 m extended detention) is:

Impervious Area (m^2) x treatment area required (%) = 50000 x 0.03

= 1500 m^2

An adjustment factor is then applied to that size to determine the size wetland required in the area of interest. The wetland adjustment factor equation should be applied (see Section 2.4).

In this worked example the wetland has been sized to require an extended detention volume of 885m^3*. An extended detention depth of 0.5m has been adopted requiring a surface area of 1710m^2*.

* These figures are for the worked example only. The appropriate region and corresponding adjustment factor must be identified then calculated for each individual project (see Section 2.4).

DESIGN NOTE – The values derived from the Figures 8.2 to 8.4 will only be valid if the design criteria for the proposed installation are similar to those used to create the Figures. Site specific modelling using programs such as MUSIC (eWater, 2009) may yield a more accurate result.

8.6.3 <u>Design calculations</u>

8.6.3.1 Estimating Design Flows

See Appendix E Design Flows – tc for a discussion on methodology for calculation of time of concentration.

Step 1 – Calculate the time of concentration.

With the catchment area being relatively small, the Rational Method Design procedure is considered to be an appropriate method for computing the design flows.

Catchment area = 10 Ha

t_c ~ 10 min (ARR 1998 methods)

Using a time of concentration of 10 minutes, the design rainfall intensities from the IFD chart relevant to the catchment location are –

I_1 = 38.2 mm/hr *

I_{100} = 130 mm/hr *

* These figures are for the worked example only. The appropriate region and corresponding rainfall intensities must be selected for each individual project.

Step 2 – Calculate design run-off coefficients (using the method outlined in Australian Rainfall and Runoff Book VIII (Engineers Australia, 2003)).

Where – Fraction impervious (f) = 0.5

Rainfall intensity ($^{10}I_{1}$) = 38.2mm/hr (from the relevant IFD chart)

Calculate C^1_{10} (pervious run-off coefficient)

$C^1_{10} = 0.1 + 0.0133\ (^{10}I_1 - 25) = 0.275$

Calculate C_{10} (10 year ARI run-off coefficient)

$C_{10} = 0.9f + C^1_{10}\ (1-f)$

$C_{10} = 0.587$

Step 3 – Convert C_{10} to values for C_1 and C_{100}

Where – $C_y = F_y \times C_{10}$

From Table 1.6 in Australian Rainfall and Runoff – Book VII;

$C_1 = 0.8 \times C_{10} = 0.47$

$C_{100} = 1.2 \times C_{10} = 0.70$

Step 4 – Calculate peak design flow (calculated using the Rational Method).

$$Q = \frac{CIA}{360}$$

Where – C is the runoff coefficient (C_1 and C_{100})

I is the design rainfall intensity mm/hr (I_1 and I_{100})

A is the catchment area (Ha)

Q_1 = 0.47 m^3/s (466 L/s)

Q_{100} = 2.52 m^3/s (2528 L/s)

8.6.3.2 Inlet Zone

The procedure for the design of the inlet zone follows that presented in Procedure 1 for sediment basin. In this worked example, design computation for the by-pass weir and the connection to the macrophyte zone will be presented.

8.6.3.3 Macrophyte Zone Layout

Size and Dimensions

The wetland has been sized to require an extended detention volume of 885m^3. An extended detention depth of 0.5m has been adopted requiring a surface area of 1710m^2.

In this case it has been chosen to adopt a length (L) to width (W) ratio of 6 to 1. This aspect ratio represents a shape configuration in between Case G and Case I in **Figure 8.6** and the expected hydraulic efficiency is 0.6. This is lower than ideal for a wetland, however the space constraints of the site limit the available area for the macrophyte zone.

*Aspect Ratio is **6(L) to 1(W)**; Hydraulic Efficiency **~ 0.6***

To calculate the dimensions

L = 6W

Wetland Area = 6W x W = 1710

*Notional Macrophyte Zone dimension is ~**102 m (L) x 17 m (W)***

Zonation

The wetland is broadly divided into four macrophyte zones and a open water zone. The bathymetry across the four macrophyte zones is to vary gradually over the depth range outlined below, ranging from 0.2 m above the permanent pool level to 0.5 m below the permanent pool level. The depth of the open water zone in the vicinity of the outlet structure is to be 1.0 m below the permanent pool level.

Zone	**Depth Range (m)**	**Proportion of Macrophyte Zone Surface Area (m)**
Open Water	>1.0 ***below*** permanent pool	10%
Submerged Marsh	0.5 – 1.0 ***below*** permanent pool	10%
Deep Marsh	0.35 – 0.5 ***below*** permanent pool	25%
Marsh	0.2 – 0.35 ***below*** permanent pool	25%
Shallow Marsh	0.0 – 0.2 ***below*** permanent pool	25%
Littoral (edges)	+0.5 – 0.0 ***above*** permanent pool	5%

To ensure optimal hydraulic efficiency of the wetland for the given shape and aspect ratio, the wetland zones are arranged in bands of equal depth running across the flow path. The appropriate bathymetry coupled with uniform plant establishment ensures the cross section has equivalent hydraulic conveyance, thus preventing short-circuiting.

Wetland consist of four macrophyte zones arranged in bands of equal depth running across the flow path

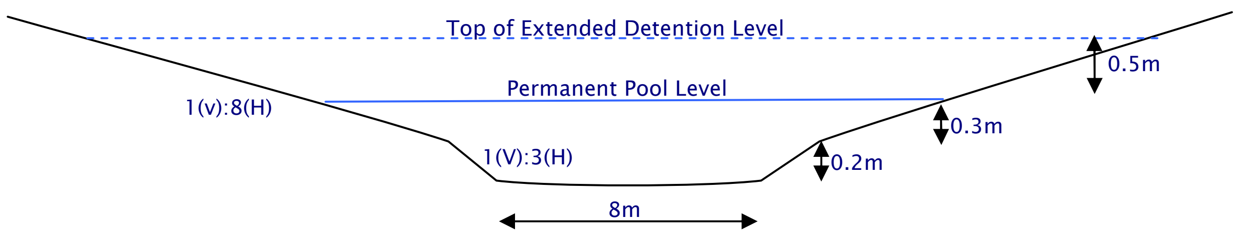
Long Section

Hobart has a relatively low mean annual rainfall, with much of the rainfall falling in winter and spring. The region also has high summer evaporation. It is therefore likely that water losses during summer will be high and it will be necessary to provide areas of habitat refuge. For this reason it is desirable to have areas of permanent pool interconnected to prevent fauna being isolated in areas that dry out. The proposed long section is for the bed of the wetland to gradually deepen over the four macrophyte zones (i.e. excluding edges). This profile also facilitates draining of the wetland.

Long section of the macrophyte zone is to be gradually deepening over the four macrophyte zones ranging from the permanent pool level (shallow marsh) to 1.0 m below the permanent pool (submerged marsh zone).

Cross Sections

The batter slopes on approaches and immediately under the permanent water level have to be configured with consideration of public safety. A batter slope of 1(V):8(H) from the top of the extended detention depth to 0.3 m beneath the water line before steepening into a 1(V):3(H) slope is recommended as a possible design solution (see illustration below). The safety requirements for individual wetlands may vary from site to site, and it is recommended that an independent safety audit be conducted of each design.



Typical Cross Section of Macrophyte Zone

Cross section of macrophyte zone is trapezoidal in shape with a ***base width of 8 m*** *and a* ***top width of 22.0 m.***

8.6.3.4 Macrophyte Zone Outlet Structure

Maintenance Drain

A maintenance drain will be provided to allow drainage of the system. Valves will be operated manually to drain the inlet zone and macrophyte zone independently.

The mean flow rate for the maintenance drain is selected to drawdown the permanent pool over a notional 12 hour period and is computed as follows:

Permanent Pool Volume ~ 500 m^3 (assuming approximate 0.25 nominal depth)

Q = Volume/Time to drain

Q = 500/(12 x 3600) = 0.012 m^3/s

It is assumes the valve orifice will operate under inlet control with its discharge characteristics determined by the orifice equation (Equation 9.1), i.e.

$$A_o = \frac{Q}{C_d \sqrt{2gh}}$$

Q = 500/(12 x 3600) = 0.012 m^3/s

C_d = 0.6

H = 0.33 m (one third of permanent pool depth)

Giving A_o = 0.0079 m^2 corresponding to an orifice diameter of 100mm – adopt **100mm**

> *Pipe valve to allow draining of the permanent pool for maintenance to be* ***at least 100 mm diameter.***

Riser Outlet – Size and Location of Orifices

The riser is designed to provide a uniform notional detention time over the full range of the extended detention depth[2].

Target Q_{max} = extended storage volume/detention time

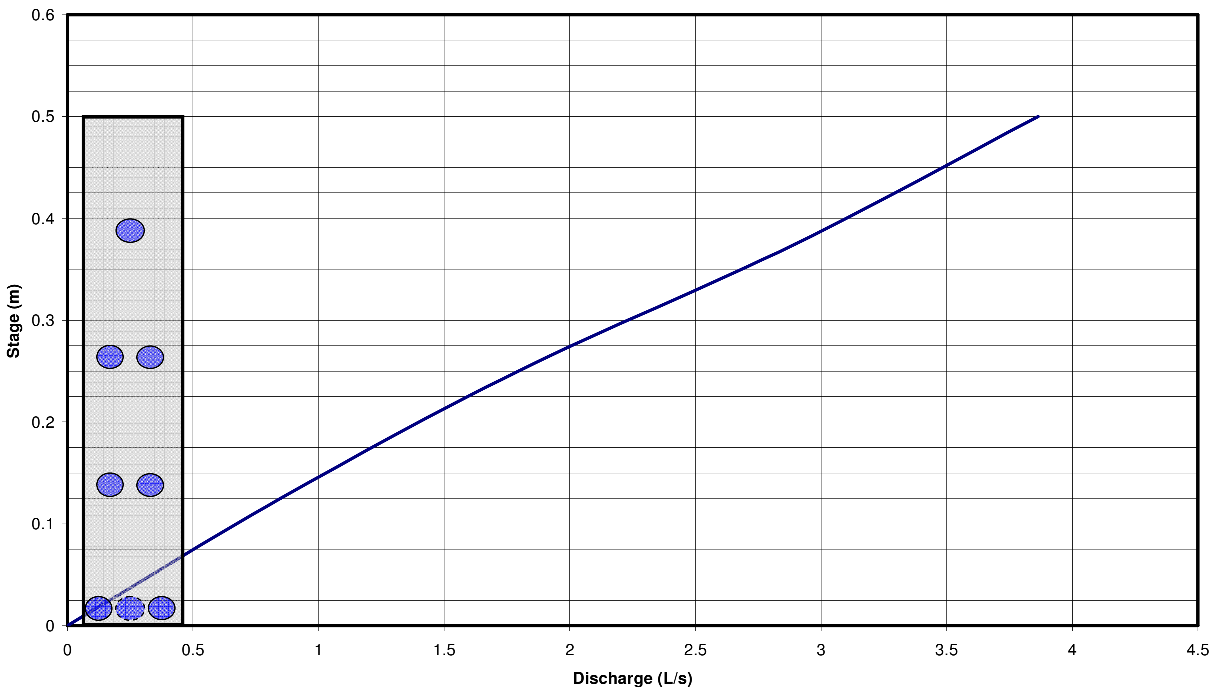
= 750/(72 x 3600) = 0.0029 L/s

Outlet orifices along the riser is located at 0.125 m intervals along the length of riser, ie. at 0 m, 0.125 m, 0.250 m and 0.375 m above the permanent pool level. A standard orifice diameter of 20 mm was selected and the numbers required at each level were determined

[2] It should be noted that detention time is never a constant and the term notional detention time is used to provide a point of reference in modelling and determining the design criteria for riser outlet structures.

iteratively using a spreadsheet (as shown below) and applying the orifice equation (Equation 8.1) applied over discrete depths along the length of the riser up to the maximum detention depth. The results of the design are summarised in the table below. The stage-discharge relationship of the riser is plotted in the chart and shows that the riser maintains a linear stage discharge relationship.

			Q1	Q2	Q3	Q4	total	Notional
Orifice Positions (invert level)			0	0.125	0.25	0.375	Flow	Detention Time
Orifice Diameter (mm)			20	20	20	20	(L/s)	(hrs)
Number			3	2	2	1		
	Water Depth	Volume						
Q1	0	0	0				0	
Q2	0.125	220	0.850				0.850	71.92
Q3	0.25	468	1.228	0.567			1.794	72.38
Q4	0.375	743	1.514	0.818	0.567		2.899	71.15
	0.5	1045	1.754	1.009	0.818	0.283	3.865	75.10



As the wetland is relatively small and the required orifices are small, it is necessary to include measures to prevent blocking of the orifices.

The riser is to be installed within an outlet pit with a culvert connection to the permanent pool of the macrophyte zone. The connection is via a 300 mm diameter pipe. The pit is accessed via a locked screen on top of the pit.

The riser pipe should not be smaller than the pipe conveying the outflow from the wetland to the receiving waters (see next section).

*Outlet Riser consist of 4 rows of orifices of **20 mm diameter** located as follows:-*		
	Depth above permanent pool	*Number of 20 mm diameter orifice*
	0.000 m	*3*
	0.125 m	*2*
	0.250 m	*2*
	0.375 m	*1*

Riser Outlet – Pipe Dimension

As designed, high flows would by-pass around the macrophyte zone when this zone is already operating at design capacity (ie. when water level in the macrophyte zone reaches the top of its extended detention. A notional riser pipe diameter of 150 mm is thus sufficient.

*Riser pipe to be **150 mm diameter***

Discharge Pipe

The discharge pipe of the wetland conveys the outflow of the macrophyte zone to the receiving waters (or existing drainage infrastructure). Under normal operating conditions, this pipe will need to have sufficient capacity to convey larger of the discharges from the riser or the maintenance drain.

- The maximum discharge from the riser = 2.9 L/s
- The maximum discharge through the maintenance pipe occurs for depth of 1.0 m (ie. depth of open water zone). From, the maximum discharge through the 90 mm diameter valve is computed to be 17 L/s.

The required pipe diameter for the outlet should be thus larger than 90 mm. Since the diameter of the riser has been selected to be 150 mm, it is appropriate to also use this dimension for the outlet pipe connecting the wetland to the adjoining creek.

*Outlet pipe for wetland for discharge to receiving waters (or existing drainage infrastructure) is to be **150 mm** diameter.*

8.6.3.5 Connection to Inlet Zone

The configuration of the hydraulic structure connecting the inlet zone to the macrophyte zone consist of an overflow pit (in the inlet zone) and a pipe with the capacity to convey the 1 year ARI peak discharge of 0.47 m^3/s.

Design specifications:

Bypass spillway level = top of extended detention in the macrophyte zone

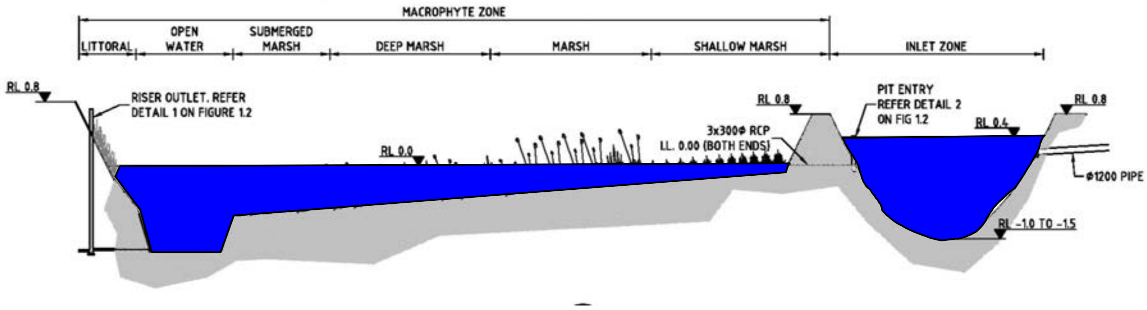
Permanent Pool level in inlet zone = 0.3 m above permanent pool level in macrophyte zone

In designing the culvert connecting the inlet zone to the macrophyte zone, the following conditions apply:

Headwater Level = 0.5 m above macrophyte permanent pool level

Tail water level = permanent pool level

Design Flow = 0.47 m^3/s



Assume culvert under outlet control; $K_e = 0.5$, $K_{out} = 1$, $n = 0.015$

Try 1 by 450 mm dia Capacity = 0.41 m^3/s ....Too small

Try 3 Nos 300 mm dia Capacity = 0.55 m^3/s ....OK

Culverts connecting inlet zone to macrophyte zone is to be **3 Nos. 300 mm diameter**.

Velocity checks are to be conducted for when the wetland is full and when it is at permanent pool level. For the velocity checks the maximum inflow corresponding to the 1 year ARI peak discharge is used, i.e. 0.47 m^3/s.

Flow check V = Q/A

When full

A = 15 x 0.5 = 7.5m^2, V = 0.06 m/s… no risk of scour

When at permanent pool level

A = 15 x 0.1 = 1.5m^2, V = 0.3 m/s…no risk of scour

8.6.3.6 High-flow route and by-pass design

The bypass weir level at the inlet zone is set to match the top of the extended detention level in the macrophyte zone. The width of the spillway is to be sized to safely pass the 100 year ARI discharge with a water level over the weir of 0.3 m (ie. top of wetland embankment).

The 100 year ARI peak discharge = 2.52 m^3/s.

Crest Level = 0.5 m above macrophyte permanent pool

Freeboard (top of wetland embankment) = 0.3 m

k_w = 1.7 (Sharp Crested Weir)

Therefore $L = Q/k_w.H^{1.5}$

Q = 2.52 m^3/s (100 year ARI flow from contributing catchment)

H = 0.30 m

L = 8.6 m

> The spillway length is to be 9.0 m set at a crest level 0.5 m above the permanent pool level of the macrophyte zone.

8.6.3.7 Vegetation Specifications

The vegetation specification and recommended planting density for the macrophyte zone are summarised in the table below.

Zone	**Plant Species**	**Planting Density (plants/m^2)**
Littoral berm	*Persicaria decipens*	3
Ephemeral marsh	*Blechnum minus*	6
Shallow March	*Cyperus lucidus*	6
Marsh	*Bolboschoenus caldwellii*	4
Deep Marsh	*Juncus ingens*	8

The reader is referred to Appendix B Plant Lists for further discussion and guidance on vegetation establishment and maintenance.

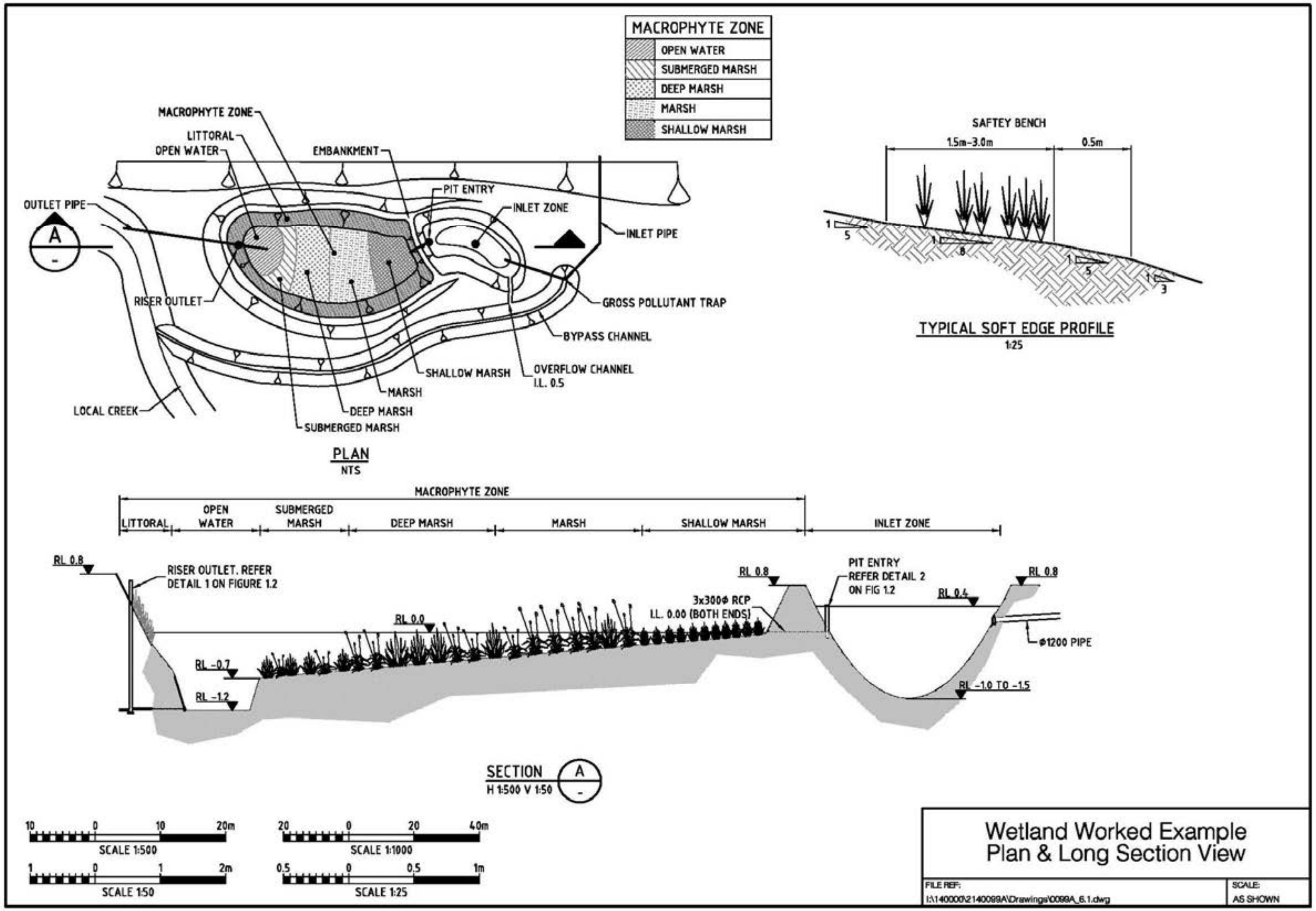
8.6.4 Design Calculation Summary

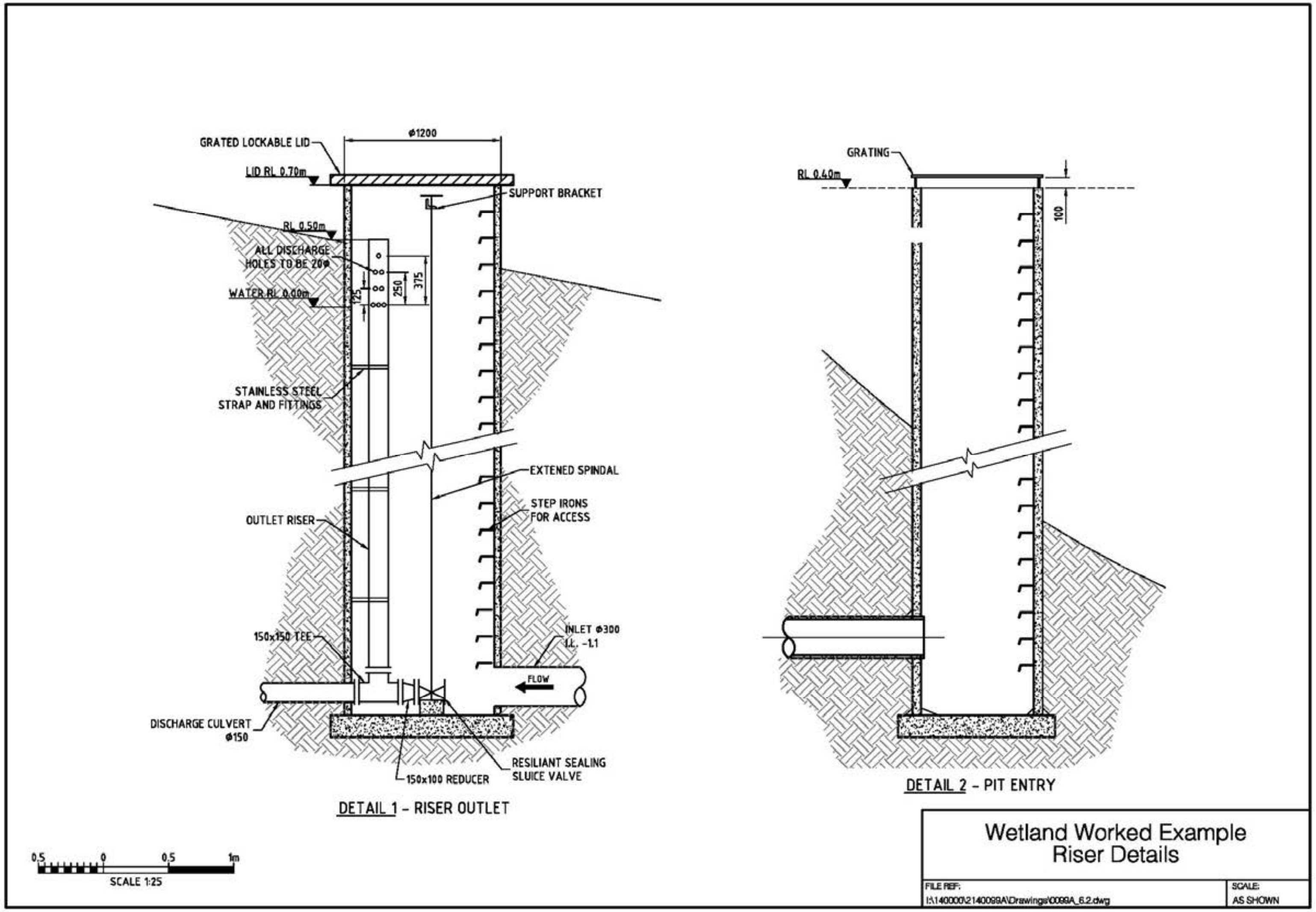
Constructed Wetand

CALCULATION SUMMARY

	CALCULATION TASK	OUTCOME		CHECK
1	**Identify design criteria**			
	Design ARI Flow for Inlet Zone	1	year	
	Target Sediment Size for Inlet Zone	0.125	mm	
	Notional Detention Period for Macrophyte Zone	72	hrs	
	Design ARI Flow for Bypass Spillway	100	year	
	Extended Detention Volume	750	m^3	
2	**Catchment characteristics**			
	Residential	7	Ha	
	Commercial	3	Ha	
	Fraction impervious			
	Residential	0.4		
	Commercial	0.7		
3	**Estimate design flow rates**			
	Time of concentration			
	estimate from flow path length and velocities	10	minutes	
	Identify rainfall intensities			
	station used for IFD data:	Hobart		
	100 year ARI	130	mm/hr	
	1 year ARI	38.2	mm/hr	
	Design runoff coefficient			
	C_1	0.47		
	C_{100}	0.7		
	Peak design flows			
	Q_1	0.47	m^3/s	
	Q_{100}	2.520	m^3/s	
4	**Inlet zone**			
	refer to sedimentation basin calculation checksheet			
5	**Macrophyte Zone Layout**			
	Extend Detention Depth	0.5	m	
	Area of Macrophyte Zone	1710	m^2	
	Aspect Ratio	6(L):1(W)	L:W	
	Hydraulic Efficiency	0.6		
	Length	102	m	
	Top width (including extended detention)	17	m	
	Cross Section Batter Slope	1(V):8(H)	V:H	
6	**Macrophyte Zone Outlet Structures**			
	Maintenance Drain			
	Diameter of Maintenance Valve	90	mm	
	Drainage time	12	hrs	
	Riser			
	Linear Storage-Discharge Relationship for Riser			
	Discharge Pipe			
	Discharge Capacity of Discharge Pipe	0.75	m^3/s	
7	**Connection between Inet Zone and Macrophyte Zone**			
	Discharge Capacity of Connection Culvert	0.55	m^3/s	
8	**Bypass Weir**			

8.6.5 Construction drawings




GRATED LOCKABLE LID
ϕ1200
LID RL 0.70m
SUPPORT BRACKET
RL 0.50m
ALL DISCHARGE
HOLES TO BE 20ϕ
WATER RL 0.00m
125
250
375
STAINLESS STEEL
STRAP AND FITTINGS
EXTENED SPINDAL
STEP IRONS
FOR ACCESS
OUTLET RISER
150x150 TEE
INLET ϕ300
I.L. -1.1
FLOW
DISCHARGE CULVERT
ϕ150
RESILIANT SEALING
SLUICE VALVE
150x100 REDUCER
DETAIL 1 - RISER OUTLET
GRATING
RL 0.40m
100
DETAIL 2 - PIT ENTRY
0.5
0
0.5
1m
SCALE 1:25
Wetland Worked Example
Riser Details
FILE REF:
I:\140000\2140099A\Drawings\0099A_6.2.dwg
SCALE:
AS SHOWN

8.6.6 Example inspection and maintenance schedule

An example inspection and maintenance schedule for a constructed wetland showing local adaptation to incorporate specific features and configuration of each individual wetlands. The following is an inspection sheet developed for the Hobart wetland which was developed from the generic wetland maintenance inspection form.

HOBART WETLANDS – MAINTENANCE FORM		
Location		
Description	Constructed wetland and sediment forebay	
SITE VISIT DETAILS		
Site Visit Date: ______________		
Site Visit By: ______________		
Weather ______________		
Purpose of the Site Visit	Tick Box	Complete Sections
Routine Inspection	☐	Section 1 only
Routine Maintenance	☐	Section 1 and 2
Cleanout of Sediment	☐	Section 1, 2 and 3
Annual Inspection	☐	Section 1, 2, 3 and 4
SECTION 1 INSPECTION		
Depth of Sediment:	______________ m	
Cleanout required if Depth of Sediment ≥ 1.0 m	Yes/No	
Any weeds or litter in wetland (If Yes, complete Section 2 Maintenance)	Yes/No	
Any visible damage to wetland or sediment basin? (If Yes, completed Section 4 – Condition)	Yes/No	
Inspection Comments:		
SECTION 2 MAINTENANCE		
Are there weeds in the wetland?	Yes/No	
Were the weeds removed this site visit?	Yes/No	
Is there litter in the wetland or forebay?	Yes/No	
Was the litter collected this site visit?	Yes/No	

SECTION 3 CLEANOUT OF SEDIMENT		
Have the following been notified of cleanout date?	Yes	No
Coordinator – open space and/or drainage	☐	☐
Local Residents	☐	☐
Other (specify ....)	☐	☐
Method of Cleaning (excavator or eductor)		
Volume of Sediment Removed (approximate estimate)	m^3	
Any visible damage to wetland or sediment forebay? (If yes, complete Section 4 Condition)	Yes/No	

SECTION 4 CONDITION					
Component	Checked?		Condition OK?		Remarks
	Yes	**No**	**Yes**	**No**	
Inlet weir or pipes					
Outlet riser/s and weir/s					
Sediment forebay					
Bypass channel (if constructed)					
Wetland vegetation					
Wetland banks and batter slopes					
Wetland floor					
Wetland diversion bunds (if constructed)					
Retaining walls					
Surrounding landscaping					

Comments:

8.7 References

Engineers Australia, 2006, *Australian Runoff Quality Australian Runoff Quality: A guide to Water Sensitive Urban Design, Editor-in-Chief, Wong, T.H.F.*

eWater, 2009, Model for Urban Stormwater Improvement Conceptualisation (MUSIC) User Manual, Version 4.0, September.

GbLA Landscape Architects, 2004, *Preliminary drawings for Mernda Wetland*, Report for Stockland

Institution of Engineers Australia, 1997, *Australian Rainfall and Runoff – A guide to flood estimation*, Editor in Chief – Pilgram, D.H.

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