Chapter 10 **Ponds and Lakes**

10.1 Introduction

Ponds and lakes are artificial bodies of open water usually formed by a simple dam wall with a **weir** outlet structure or created by excavating below natural surface levels. The depth of water in these waterbodies is typically greater than 1.5 m and there is usually a small range of water level fluctuation although newer systems may have riser style outlets allowing for **extended detention** and longer temporary storage of inflows. Aquatic vegetation has an important function for water quality management in ponds and lakes. Emergent **macrophytes** are normally restricted to the margins because of water depth, although submerged plants may occur in the open water zone. Submerged plants are important to the maintenance of both biological processes and water quality. They provide a surface for the absorption of dissolved nutrients and provide food and shelter for zooplankton which may graze on algal species. The oxygen released during photosynthesis is important in maintaining oxygen saturation in the water column which is depleted by animal respiration and decomposing organic matter. Vegetation can also help stabilise sediments and reduce the release of sediment-bound nutrients arising from resuspension processes. Ponds are seldom used as 'stand-alone' stormwater treatment measures and are often combined with **constructed wetlands** as a treatment forebay to the open waterbody. In many cases, these ponds ultimately become the ornamental waterbody that require water quality protection.

Ponds and lakes often form part of a flood-retarding system and design requirements are generally associated with hydraulic structures for flow conveyance and flood attenuation. These are not covered in this document and only design elements associated with the water quality function of the system is presented.

There have been cases where water quality problems in ornamental ponds and lakes have been caused by poor inflow water quality, especially high organic load, infrequent waterbody 'turnover' and inadequate mixing. Detailed modelling may be necessary to track the fate of nutrients and consequential algal growth in the waterbody during periods of low inflow (and thus long detention period). As a general rule, it is recommended that the turnover period for

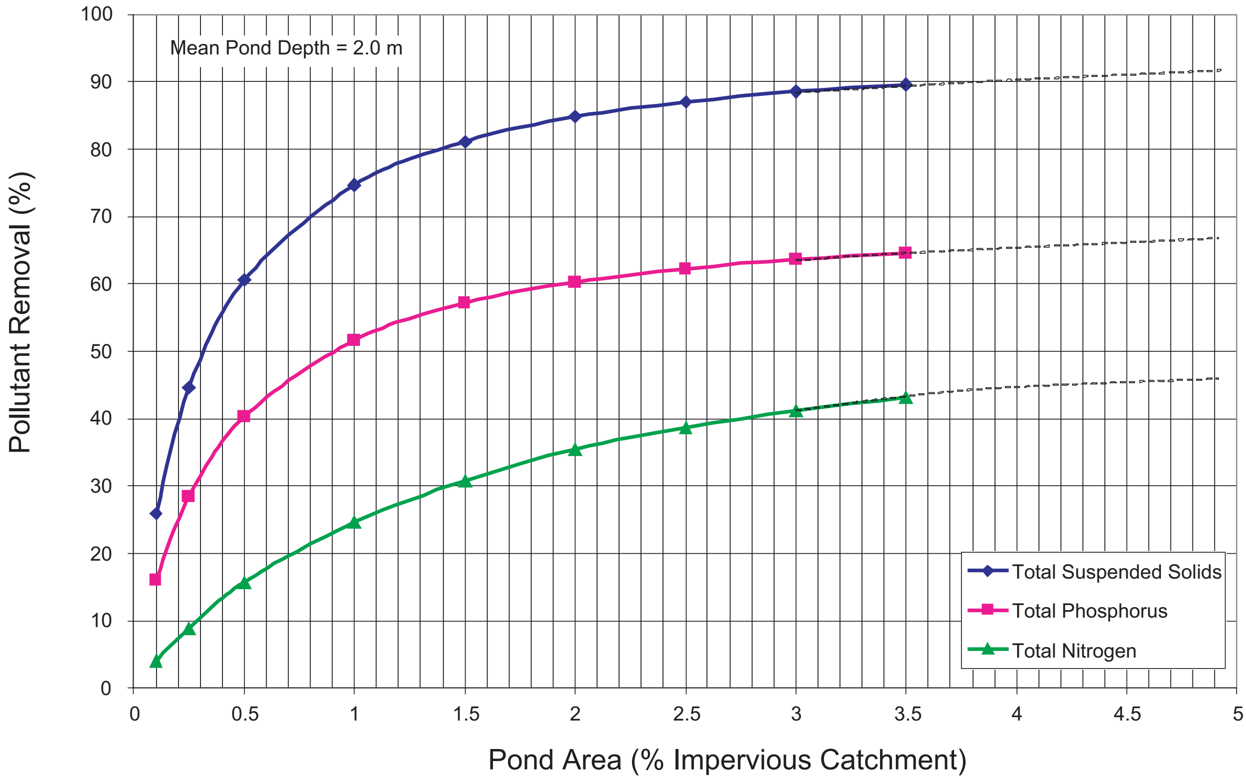

Figure 10.1 Performance of ponds and lakes in removing Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) in Melbourne.

lakes is between 20 and 50 days (depending on water temperatures) at least 80% of the time (see Appendix D). If these turnover times can not be met, it may be necessary to introduce a lake management plan to reduce the risk of algal blooms during the dry season. This design procedure outlines design elements for large waterbodies associated with the design of a constructed lake, an associated **wetland** forebay (or **inlet zone**) and water recirculation scheme (if required) to maintain water quality in the pond. Further investigations need to be undertaken to finalise the design from that presented in the worked example to address issues such as the embankment stability and detailed design. These are discussed in the worked example.

The design procedure is primarily concerned with the risk of cyanobacterial blooms and therefore the health risk of these systems. Nuisance green algal blooms may occur more frequently than cyanobacterial blooms and possibly affect the amenity of the system, particularly in residential areas. Acknowledgement of these issues is essential to any waterbody design, construction and handover process. A number of additional steps can be taken in the planning and design of open waterbodies to minimise algal growth:

- Ensure that pre-treatment of stormwater is adequate to prevent large nutrient 'spikes' entering the system.
- Submerged macrophytes should include a minimum of 50% area cover and 50% volumetric coverage of the lake. A greater cover is highly recommended.
- The lake should be oriented to the dominant winds to facilitate mixing, particularly for summer and autumn; edge treatments should be designed to minimise wave damage.

Residents and managing authorities must be aware that as the lake system ages, it has a greater chance of problem algal growth and algal blooms. It is possible that a lake system may require desilting and a total 'reset' if algal blooms become a recurrent and persistent problem.

10.2 Verifying size for treatment

The curves shown in Figure 10.1 describe the pollutant removal performance expected for constructed pond and lake systems in Melbourne (reference site) for Total Suspended Solids

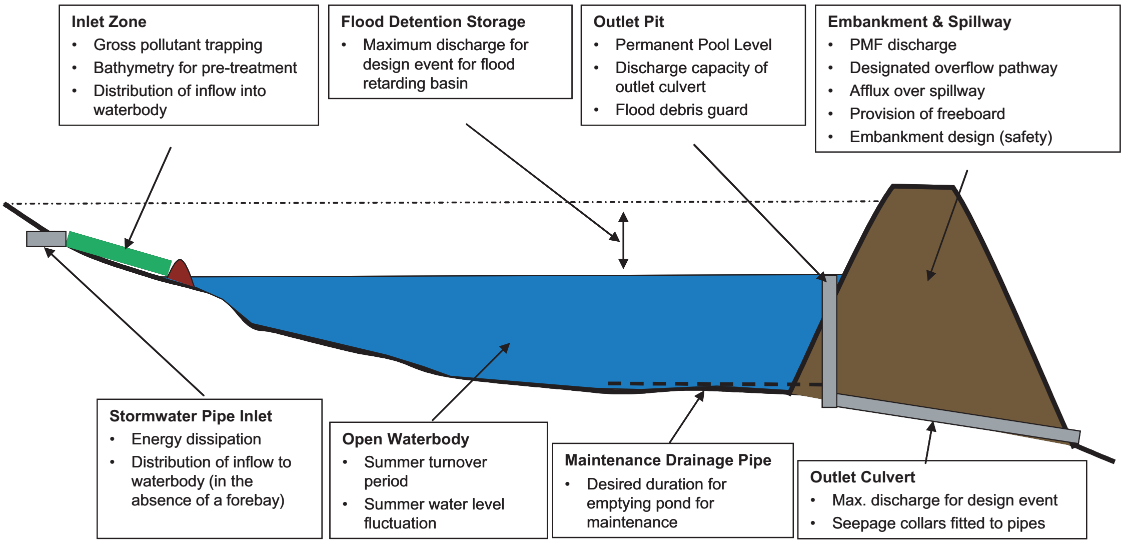

Figure 10.2 Pond or lake design elements and design considerations.

(TSS), Total Phosphorus (TP) and Total Nitrogen (TN). The curves were derived assuming the systems receive direct runoff (i.e. no other Water Sensitive Urban Design, WSUD, elements upstream) and have the following characteristics:

- mean depth of 2.0 m
- outflow from the system is via an overflow weir.

These curves can be used, together with the **adjustment factors** derived from the hydrologic regionalisation procedure discussed in Chapter 2, to check the expected performance of the wetland system for removal of TSS, TP and TN.

10.3 Design procedure: ponds and lakes

Design considerations include the following:

1. computations to ensure that the pond volume is not excessively large or too small in comparison to the hydrology of the **catchment**
2. configuration of the layout of the pond and inlet zone such that the system's hydraulic efficiency can be optimised, including a transition structure between the inlet zone and the open waterbody
3. design of hydraulic structures, including
   - inlet structure to provide for energy dissipation of inflows up to the 100-year Average Recurrence Interval (ARI) peak **discharge**
   - design of the pond outlet structure for the pond
4. landscape design, including
   - edge treatment
   - recommended plant species and planting density
5. maintenance provisions.

Figure 10.2 summarises the pond/lake design elements. The following sections describe the design steps required for ponds and lakes.

10.3.1 Hydrology

The hydrologic operation of a pond or lake is to safely convey stormwater inflows up to the peak 100-year ARIdischarge into the pond or lake system with discharge from the pond or lake being via a combination of pipe (low flow) culvert and overflow spillway.

10.3.1.1 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

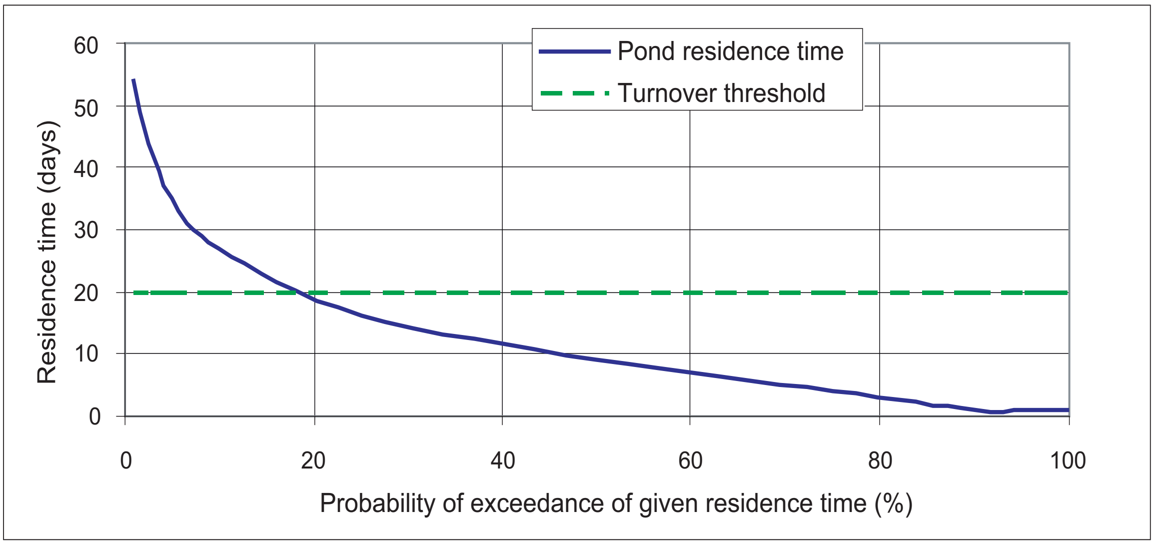

Figure 10.3 Results of residence time analysis for a waterbody in Melbourne.

method for estimating design flows. However, the use of the Rational Method Design Procedure should strictly be used only to size inlet hydraulic structures A full flood routing computation method should be used in sizing the outlet hydraulic structures (e.g. outlet pipe, spillway and embankment height).

10.3.1.2 Waterbody residence time

A combination of inflow water quality, organic load and water circulation characteristics influence the water quality in the pond. Water quality problems for large lakes exhibiting relatively small upstream catchments typically arise because the water body receives insufficient water inflows to circulate and/or displace the water stored in the lake. Under long residence times blooms of cyanobacteria (blue-green algae) can occur.

Experience with management of many open waterbodies suggests that a large number of these incidences of algal blooms are preceded by extended periods of no or minimal inflows. Waterbody residence time (or turnover frequency) analysis can often be a very useful indicator as to whether the waterbody is at significant risk of water quality problems (especially associated with algal growth) (see Appendix D).

Turnover analysis can be undertaken using probabilistic monthly evaporation and rainfall data or daily historical rainfall data, with the latter providing a more rigorous analysis. Average residence times are calculated by modelling continuous simulation of flows into and out of a lake. Estimates of daily outflows are then summed (in arrears) to give an estimate of the average residence time of the lake for each day of the simulation.

Seasonal distribution of rainfall and the relative volume of the waterbody to the mean annual runoff will determine the range of residence periods for the waterbody. For example, a small waterbody with a large catchment will have small residence times because the volume of the waterbody is a small fraction of the mean annual runoff volume of the catchment. However, the residence times of a larger waterbody will be more sensitive to seasonality of rainfall and thus be at a higher risk of long periods of water detention and associated water quality problems.

A cumulative probability distribution of exceedance versus waterbody residence time can be derived using the modelled outflows from a lake (e.g. Figure 10.3).

Algal growth can occur rapidly under favourable conditions. Growths (blooms) of cyanobacteria (blue-green algae) can occur in both natural and constructed water bodies. In constructed water bodies it is important to ensure that designs include measures to restrict cyanobacterial growth. Cyanobacterial blooms can have adverse effects on aquatic ecosystem function, aesthetics and public amenity. Some species of cyanobacteria are of particular concern because of their potential to produce toxins.

Many factors influence cyanobacterial growth including (Sherman et al. 1998; Mitrovic et al. 2001; Tarczynska et al. 2002; Reynolds 2003):

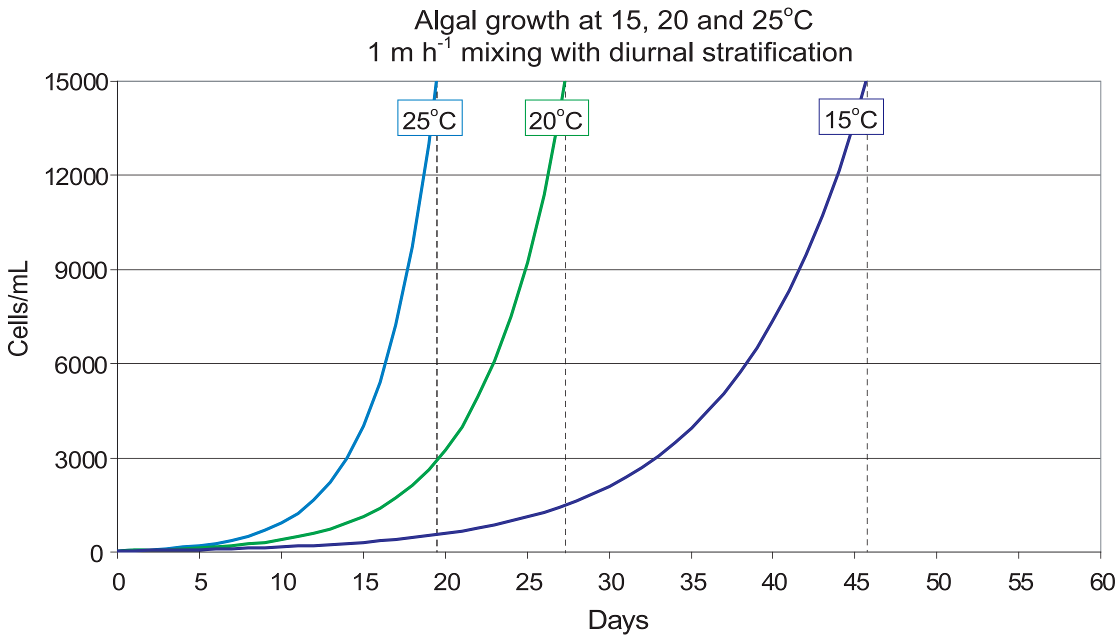

Figure 10.4 Growth curves illustrating modelled times for cyanobacterial populations to reach bloom proportions under different temperature conditions and 1 m/h mixing conditions with diurnal stratification. Based on growth rates of *Anabaena. circinalis* measured *in situ* (Westwood and Ganf 2004) adjusted for temperature, a Q_{10} 2.9, and assuming starting concentrations of 50 cells/mL.

- light intensity
- water temperature
- nutrient concentration
- hydrodynamics
- stratification
- catchment hydrology
- zooplankton grazing
- parasitism.

Excessive growth of cyanobacterial species is considered an 'Alert Level 1 Algal Bloom' when concentrations reach 15 000 cells/mL (Government of Victoria 1995) (see Appendix D).

Assuming adequate light and nutrient availability, a model of algal growth can be developed using a simple relationship between time and growth rate at various temperatures (see Appendix D). This simple model can be used to determine how long it will take for an algal population to reach bloom proportions (15 000 cells/mL) and hence inform the development of guidelines on water body hydraulic **detention time**.

Modelling conducted and based on reasonable assumptions suggests the following times (Figures 10.4 and 10.5) under ideal conditions for blooms to occur depending on mixing conditions (Appendix D). Figures 10.4 and Figure 10.5 were derived assuming a 'best practice' design of a pond. This includes a pond having a shallow depth, a flat bottom and being well mixed. A reasonable assumption is that the hydrodynamic conditions in a best-management practice design varies somewhere between fully mixed and diurnally, partially mixed.

The curves represent three temperature zones in Victoria relating to summer water temperature as follows:

- 15°C Use for upland sites in the Eastern and Western Ranges
- 20°C Use for lowland sites south of the Great Dividing Range
- 25°C Use for lowland sites north of the Great Dividing Range.

The modelling approach taken is considered to be reasonably conservative. For example, it adopts:

- non-limiting conditions for nutrient and light availability
- growth rates for a known nuisance species (*Anabaena circinalis*)

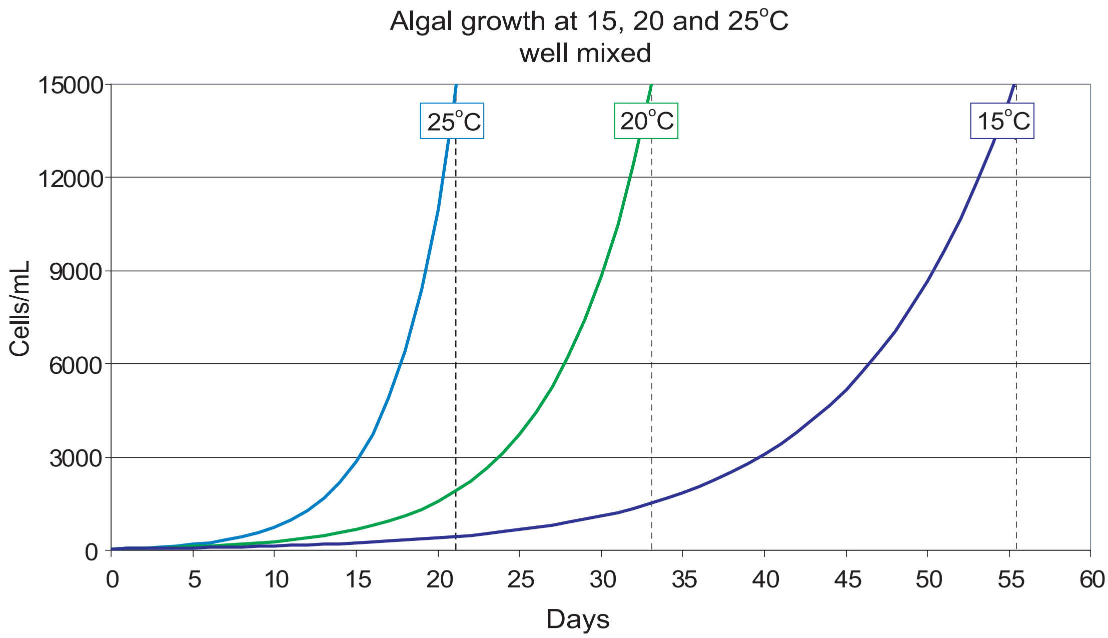

Figure 10.5 Growth curves illustrating modelled times for cyanobacterial populations to reach bloom proportions under different temperature conditions and well mixed conditions. Based on growth rates of *Anabaena circinalis* measured *in situ* (Westwood and Ganf 2004) adjusted for temperature, Q_{10} 2.9, and assuming starting concentrations of 50 cells/mL.

- summer temperature values (the main risk period)
- high starting population concentrations (50 cells/mL).

As a result, a probabilistic approach to the use of detention time criteria is recommended. A 20% exceedance is suggested as an acceptable risk to compensate for the occurrence of all other risk factors being favourable for algal growth. The 20% exceedance of a specific detention time objective does not indicate that a bloom will occur; just that detention time (for a given temperature range) is long enough for exponential growth to achieve a bloom alert level of 15 000 cells/mL if all other risk factors were favourable. The 20% exceedance value is an interim value chosen as a relatively conservative estimate of the general variation in ecological factors in the Australian environment.

10.3.1.3 Turnover design criteria

The following guidelines for detention times are recommended. For water bodies with summer water temperatures in the following ranges, the 20th percentile detention times should not exceed:

- 50 days (15°C)
- 30 days (20°C)
- 20 days (25°C).

These values are broadly consistent with detention time values published in the literature that are considered to be protective against the risk of cyanobacterial blooms (Reynolds 2003, Wagner-Lotkowska et al. 2004) and consistent with current industry experience.

10.3.1.4 Lake water level fluctuation analysis

Analysis of the fluctuation in water levels is another important analysis that needs to be undertaken as these levels may have a significant influence on the landscape design of the lake's edge. As in the waterbody turnover analysis, lake water level analysis can be undertaken using probabilistic monthly evaporation and rainfall data or daily historical rainfall data, with the latter providing a more rigorous analysis. A variety of models can be used to predict water levels from continuous simulations (e.g. Model for Urban Stormwater Improvement Conceptualisation, **MUSIC**) (Cooperative Research Centre for Catchment Hydrology 2003). A typical analysis may be to determine the 10th percentile, 50th percentile and 90th percentile water depths in a lake during summer (e.g. Figure 10.6).

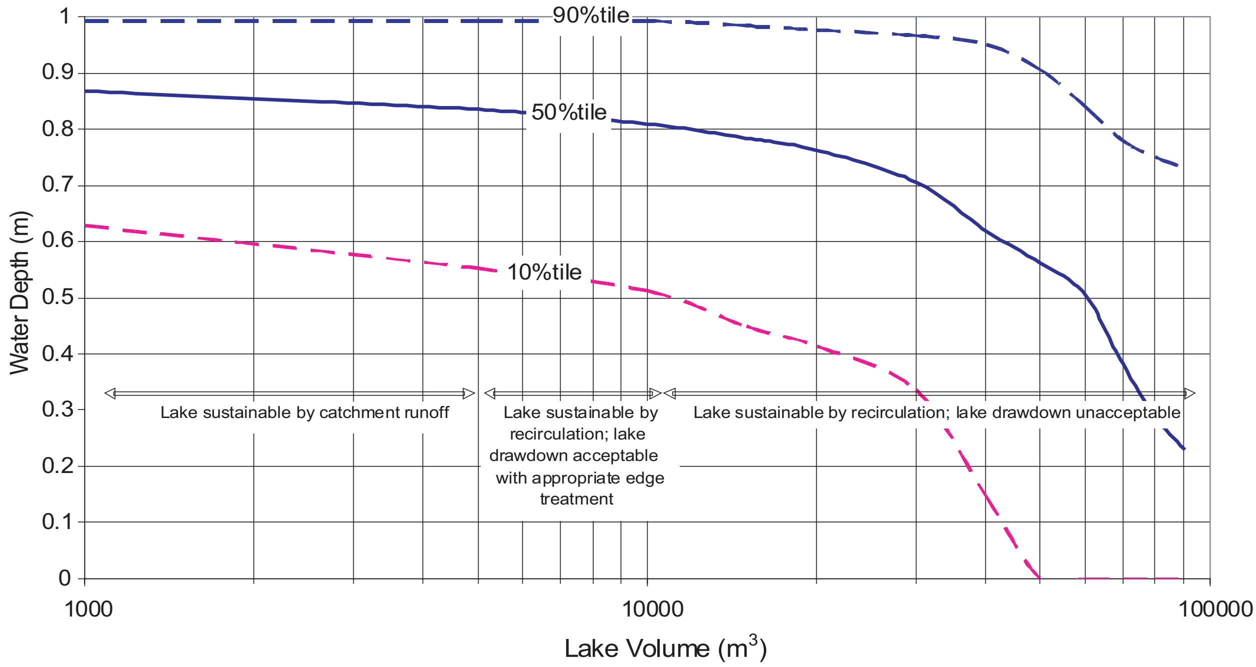

Figure 10.6 Analysis of probabilistic summer water depth with different lake volume for a proposed lake in Shepparton, Victoria.

10.3.1.5 Option for a larger waterbody

Often much larger open waterbodies are proposed by landscape and urban designers to be converted to ornamental lakes. This can mean further design and operation considerations necessary to maintain a healthy waterbody, to provide an acceptable low level of risk of algal growth.

If an analysis indicates that a waterbody is at significant risk of algal blooms (i.e. the turnover design criteria are not met) a lake turnover strategy will need to be developed. In addition, a lake management plan may be required and involve more detailed modelling using such models as the Cooperative Research Centre for Freshwater Ecology's Pond Model.

10.3.2 Pond layout

10.3.2.1 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 and to avoid zones of water stagnation. The ratio of length to width varies depending on the size of the system and the site characteristics wheras inlet and outlet conditions as well as the general shape of the pond can influence the presence and extent of water stagnation zones. 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.

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 (2003) 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 the λ value for such systems should not be less than 0.5 and should be designed to promote hydraulic efficiencies greater than 0.7 (see Figure 10.7). The value for λ is estimated from the configuration of the basin according to Figure 10.7.

The numbers in Figure 10.7 represent the values of λ that are used to estimate the turbulence parameter ***n*** for Equation 4.2 (see Chapter 4) or Equation 10.2 (see Section 10.3.2.2). In Figure 9.6, '○' in diagrams O and P represent islands in a waterbody and the double line in diagram Q represents a structure to distribute flows evenly.

There can often be multiple inlets into the waterbody and the locations of these inlets to the outlet structure can influence the hydraulic efficiency of the system. A design for inlet structures that reduces localised water eddies and promotes good mixing of water within the immediate

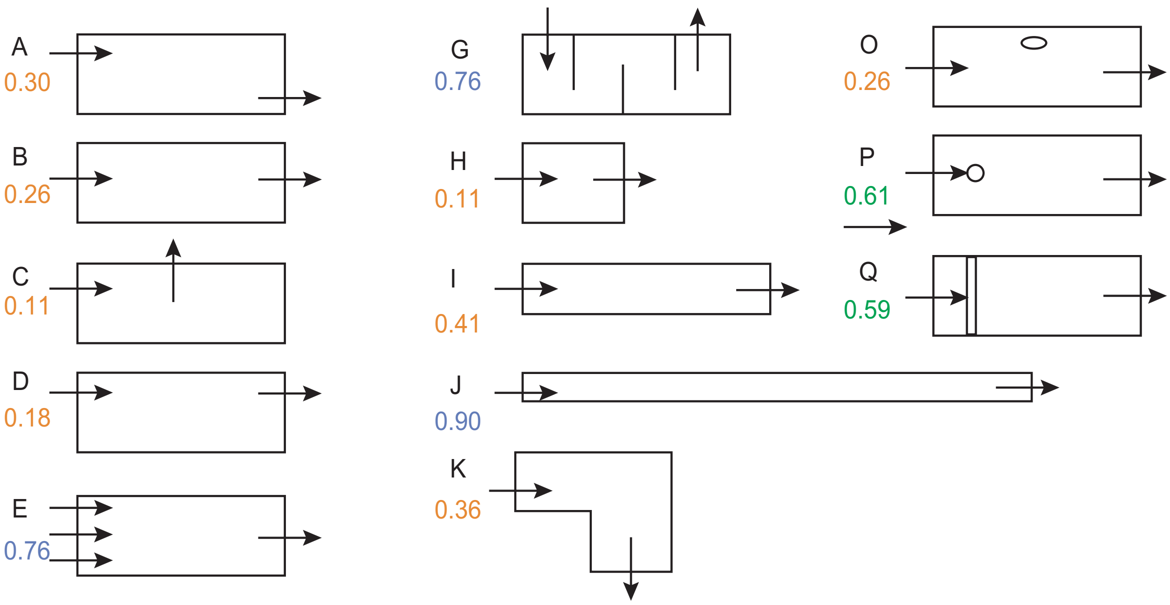

Figure 10.7 Hydraulic efficiency – λ – a measure of flow hydrodynamic conditions in constructed wetlands and ponds; range is from 0 to 1, with 1 representing the best hydrodynamic conditions for stormwater treatment (Persson et al. 1999).

vicinity of the inlet may be necessary and the use of an inlet zone is a common approach to inlet design.

10.3.2.2 Inlet zone

It is good design practice to provide pretreatment of stormwater to ponds and lakes for removal of sediment, organic matter and nutrients. The inlet zone can take many forms, ranging from systems that function as a **sedimentation basin** to that of a shallow **ephemeral** wetland. They are a transitional zone into the deeper waters of a pond. Some inlet zones are constructed with a porous embankment at its transition with the deeper water zone to promote a wider distribution of inflow water across the open water body.

The **bathymetry** across the inlet zone is to vary gradually from 0.2 m above the permanent pool level to 0.3 m below the permanent pool level over a distance of between 10 m and 20 m.

There is generally little need for any hydraulic structures to separate an inlet zone of a pond to the open water section, although a designer may consider the use of a porous embankment to promote better flow distribution into the open water zone. A low flow vegetated **swale** should be provided to convey dry weather flow and low flows to the open waterbody.

The notional required inlet zone area can be computed by the use of **sedimentation** theory (see Chapter 4), targeting the 125 μm sediment (settling velocity of 11 mm/s) operating at the one-year ARI peak discharge.

The specification of the required area (A) of a sedimentation basin may be based on the expression by Fair and Geyer (1954), formulated for wastewater sedimentation basin design:

$$R = 1 - \left(1 + \frac{1}{n}\frac{v_s}{Q/A}\right)^{-n} \qquad \text{(Equation 10.1)}$$

where R = fraction of target sediment removed
v_s = settling velocity of target sediment
Q/A = rate of applied flow divided by basin surface area
n = turbulence or short-circuiting parameter.

The above expression for sedimentation is applied with n being a turbulence parameter. Figure 10.7 provides guidance on selecting an appropriate n value (according to the configuration of the basin). A value of n is selected using the following relationship:

$$\lambda = 1 - 1/n;\ n = \frac{1}{1-\lambda} \qquad \text{(Equation 10.2)}$$

Figure 10.8 Open water with edge vegetation.

Equation 10.1 is strictly applicable for systems with no permanent pool, and will generally overestimate the required area of a sedimentation basin. This equation is thus often considered to provide an upper limit estimate of the required size for sedimentation basins.

Good practice in the design of inlet zone will include a permanent pool to reduce flow velocities and provide storage of settled sediment. The presence of a permanent pool reduces flow velocities in the sedimentation basin and thus increases detention times. Owing to the outlet structure being located some distance above the bed of a sedimentation basin, it is also not necessary for sediment particles to settle to the bed of the basin to effectively retain the sediments. It is envisaged that sediments need only settle to an effective depth which is less than the depth to the bed of the sediment. This depth is considered to be about 1 m below the permanent pool level. Equation 10.1 can thus be re-derived to account for the effect of the permanent pool storage as follows:

$$R = 1 - \left[1 + \frac{1}{n} \times \frac{v_s}{Q/A} \times \frac{(d_e + d_p)}{(d_e + d^*)}\right]^{-n} \qquad \text{(Equation 10.3)}$$

where d_e is the extended detention depth (m) above the permanent pool level
d_p is the depth (m) of the permanent pool

Table 10.1 list the typical settling velocities of sediments. d^* is the depth below the permanent pool level that is sufficient to retain the target sediment (m) – adopt 1.0 or d_p whichever is lower.

10.3.2.3 Cross sections

Batter slopes on approaches and immediately under the water line have to be configured with consideration of public safety. Both hard and soft edge treatments can be applied to complement the landscape of the surrounding area of a pond or lake. Soft edge treatments involve using gentle slopes to the water's edge and extending below the water line for a distance before the batter slopes steepen into deeper areas (Figure 10.9).

An alternative to the adoption of a flat batter slope beneath the water line is to provide a 3 m 'safety bench' around the waterbody that is less than 0.2 m deep below the permanent pool level.

Figure 10.10 shows an option for a hard edge detail using a vertical wall, and has an associated handrail for public safety. This proposal uses rock to line the bottom of the pond to prevent vegetation (particularly weed) growth.

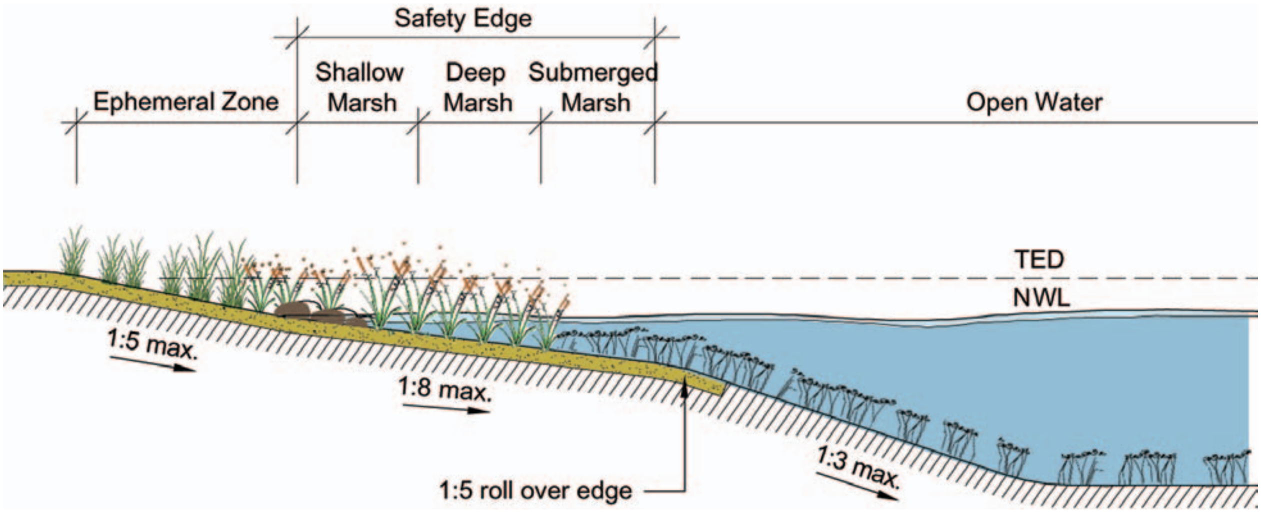

Figure 10.9 Illustration of a soft edge treatment for ponds and lakes (Graeme Bentley Landscape Architects 2004).

Table 10.1 Settling velocities under ideal conditions

Classification of particle size	Particle diameter (μm)	Settling velocities (mm/s)
Very coarse sand	2000	200
Coarse sand	1000	100
Medium sand	500	53
Fine sand	250	26
Very fine sand	125	11
Coarse silt	62	2.3
Medium silt	31	0.66
Fine silt	16	0.18
Very fine silt	8	0.04
Clay	4	0.011

The safety requirements for individual ponds and lakes may vary between sites, and it is recommended that an independent safety audit be conducted of each design.

10.3.3 Hydraulic structures

Hydraulic structures are required at the inlet and outlet of a pond or lake. Their function is essentially one of conveyance of flow with provisions for (i) energy dissipation at the inlet structure(s) and (ii) extended detention (if appropriate) at the outlet.

10.3.3.1 Inlet structure

Discharge of stormwater into the open waterbody of a pond or lake may be via an inlet zone or direct input. In both cases it will be necessary to ensure that inflow energy is adequately dissipated so as not to cause localised scour near the pipe outfall. Design of stormwater pipe outfall structures are common hydraulic engineering practice (see e.g. Chow 1959; Henderson 1966).

Litter control is normally required at the inlet structure and it is generally recommended that some form of **gross pollutant trap, GTP** be installed as part of the inlet structure. Several proprietary products are available for capture of gross pollutants (see Engineers Australia 2003, Chapter 7). The storage capacity of GPTs should be sized to ensure that maintenance (clean-out) frequency is not greater than once every three months.

10.3.3.2 Outlet structure

The outlet structure of a pond or lake can be configured in many ways and depends on the specified operation of the system during periods of high inflows. Many ponds form part of a **flood retarding basin** in which case the outlet structure consists of two components: an outlet pit and an outlet culvert. The computation of the required outlet culvert is an essential element

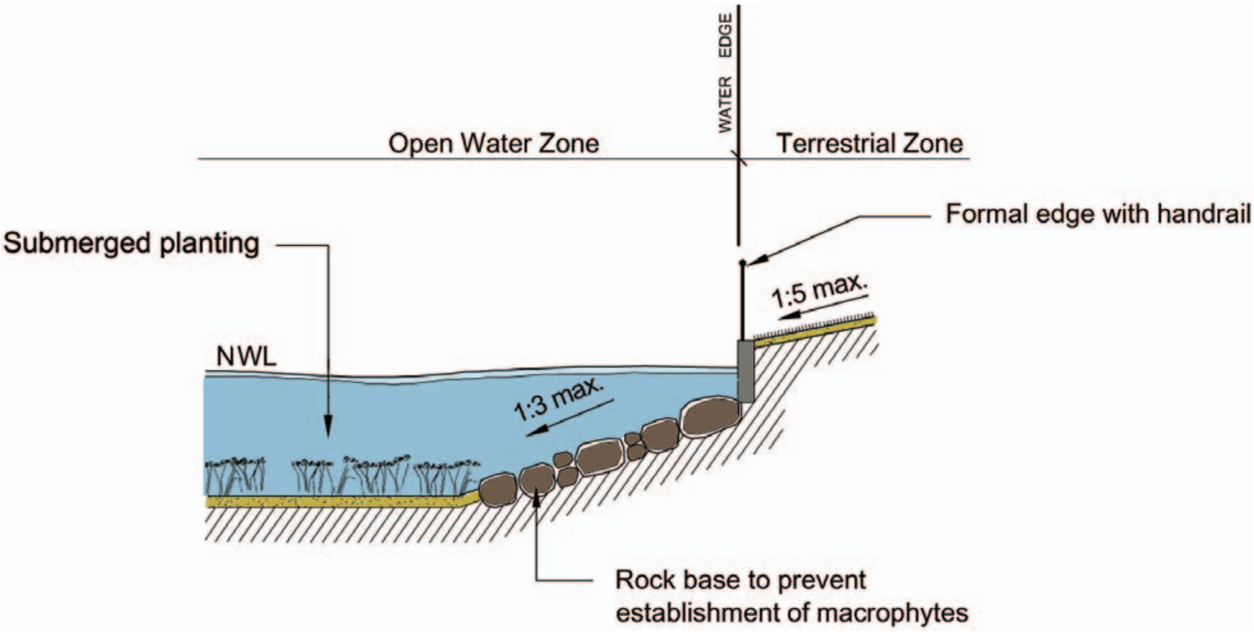

Figure 10.10 Illustration of hard edge treatment for open waterbodies (Graeme Bentley Landscape Architects 2004).

of the retarding basin design and will be based on flood routing computation as outlined in ARR (Institution of Engineers 2001). The main function of the inlet pit is to maintain the desired permanent pool level and to provide a means of connecting the maintenance pipe to the outlet culvert. Design considerations of the outlet pit include:

- ensuring that the crest of the pit is set at the permanent pool level of the lake or pond
- ensuring that the dimension of the pit provides discharge capacity that is greater than the discharge capacity of the outlet culvert or pipe
- protection against clogging by flood debris.

The dimension of an outlet pit is determined by considering two flow conditions: weir and orifice flow (Equations 10.4 and 10.5).

A blockage factor (*B*) is also used to account for any debris blockage; a value of 50% blockage is recommended. Generally, the discharge pipe from the inlet zone (and downstream water levels) controls the maximum flow rate from the area. It is therefore less critical if the outlet pit is oversized to allow for blockage.

1. Weir flow condition – usually when the extended detention storage of the retarding basin is not fully engaged:

$$P = \frac{Q_{des}}{B \times C_w \times H^{1.5}} \qquad \text{(Equation 10.4)}$$

P = Perimeter of the outlet pit (m)
B = Blockage factor (0.5)
H = Depth of water above the crest of the outlet pit (m)
Q_{des} = Design discharge (m^3/s)
C_w = weir coefficient (1.7).

2. Orifice flow conditions – this equation is applied when the inlet pit is completely submerged (corresponding to conditions associated with larger flood events):

$$A_o = \frac{Q_{des}}{B \times C_d \sqrt{2gH}} \qquad \text{(Equation 10.5)}$$

C_d = Orifice Discharge Coefficient (0.6)
B = Blockage factor (0.5)
H = Depth of water above the centroid of the orifice (m)
A_o = Orifice area (m^2)
Q_{des} = Design discharge (m^3/s)

Use of whichever equation that results in the larger size of required pipe should be adopted. It is important that an outlet pit is prevented from blockage by debris. Design consideration needs to include means of preventing blockage of the outlet structure.

Outlet culvert of pipe capacity is estimated using the orifice discharge equation (Equation 10.5) without a blockage factor.

10.3.3.3 Maintenance drain

The waterbody should be able to be drained for maintenance with manual operation. A suitable design flow rate is one which can draw down the permanent pool within seven days although, depending on the volume of the waterbody, this may not be realistic.

The orifice discharge equation (Equation 10.5) is considered suitable for sizing the maintenance drain (without a blockage factor) on the assumption that the system will operate under inlet control.

10.3.4 High-flow route design

The provision of a high flow route is standard design practice to ensure that overflow from the dam embankment can be safely conveyed either by the use of a spillway or ensuring that the embankment is designed to withstand overtopping. This issue requires specialised design inputs and is not discussed in this document.

10.3.5 Vegetation specification

Vegetation planted along the **littoral zone** of a pond or lake serves the primary function of inhibiting public access to the open waterbody. Terrestrial planting beyond the littoral zone may also be recommended to screen areas and provide an access barrier to uncontrolled areas of the stormwater treatment system.

Plant species for the inlet zone area will be predominantly those of ephemeral wetlands (see Appendix A).

10.3.6 Design calculation summary

A *Ponds and Lakes Calculation Summary* is included to aid the design process of key design elements of a pond or lake.

10.4 Checking tools

Checking aids are included for designers and referral authorities. In addition, advice on construction techniques and lessons learnt from building lake systems are provided.

Checklists are provided for:

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

10.4.1 Design assessment checklist

The *Pond and Lake Design Assessment Checklist* presents the key design features that should be reviewed when assessing a design of a lake. 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, the design procedure should be assessed to determine the effect of the omission or error.

Ponds and Lakes CALCULATION CHECKLIST

CALCULATION TASK	OUTCOME		CHECK
1 Identify design criteria			☐
Design ARI flow for inlet hydraulic structures		year	
Design ARI flow for outlet hydraulic structures			
Design ARI for emergency hydraulic structures		year	
80%tile turnover period		days	
Probabilistic summer water level – 10%tile		m	
Probabilistic summer water level – 90%tile		m	
Flood detention storage volume (from flood routing analysis)		m^3	
Outlet pipe dimension (from flood routing analysis)		mm	
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:			
Design rainfall intensity for inlet structure(s)		mm/hr	☐
Design runoff coefficient			
Inlet structure(s)			☐
Peak design flows			☐
Inlet structure(s)		m^3/s	
Outlet structure(s)		m^3/s	
4 Forebay zone layout			☐
Area of forebay zone			
Aspect ratio			
Hydraulic efficiency			
5 Lake residence time			☐
6 Pond layout			☐
Area of open water		m^2	
Aspect ratio		L:W	
Hydraulic efficiency			
Length		m	
Width		m	
Cross section batter slope		V:H	
		m	
7 Hydrualic structures		m	
Inlet structure			☐
Provision of energy dissipation			
Outlet structure			☐
Pit dimension		L x B	
		mm diam	
Discharge capacity of outlet pit		m^2/s	
Provision of debris trap			
Maintenance drain			☐
Diameter of maintenance valve		mm	
Drainage time		days	
Discharge pipe			☐
Discharge capacity of discharge pipe		m^3/s	
8 Emergency spillway			☐
Discharge capacity of emergency spillway		m^3/s	

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 Handover Checklist* (see Section 10.4.4).

Pond and Lake Design Assessment Checklist			
Lake location:			
Hydraulics	Minor flood: (m^3/s):	Major flood: (m^3/s):	
Inlet zone		**Y**	**N**
Inlet pipe/structure sufficient for maximum design flow (Q_5 or Q_{100})?			
Scour protection provided at inlet structures?			
Configuration of forebay zone (aspect, depth and flows) allows even distribution of inflow into open water zone?			
Maintenance access provided?			
Public access to forebay zone managed through designated pathways?			
Gross pollutant protection measures provided on inlet structures?			
Open water zone		**Y**	**N**
Depth of open water > 1.5 m?			
Aspect ratio provides hydraulic efficiency >0.5?			
Depth of permanent water >1.5 m?			
20% probability of exceedance in accordance with guidelines (i.e. 20, 30 or 50 days)			
Edge treatment – batter slopes from accessible edges shallow enough to allow egress?			
Edge treatment – provision of littoral zone planting with 1:8 batter slopes to 0.2 m below the waterline ?			
Edge treatment – vertical fall to shallow bench?			
Maintenance access provided?			
Public access to open zones restricted to designated pathways with appropriate safety considerations?			
Embankment height > flood detention depth?			
Lake turnover management plan developed (if turnover is inadequate)?			
Probabilistic summer water level fluctuation within desired range and edge treatment developed to suit?			
Outlet structures		**Y**	**N**
Outlet pit set at permanent water level?			
Discharge capacity of outlet pit > computed discharge capacity of outlet pipe? (checked against weir flow and orifice flow operating conditions)			
Maintenance drain provided?			
Protection against clogging of outlet pit provided?			

10.4.2 Construction advice

General advice is provided for the construction of lakes. It is based on observations from construction projects around Australia.

Protection from existing flows

It is important to protect lakes and ponds from upstream flows during construction. 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 pond 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 well as possible at the end of each day. Plans for dewatering following storms should also be 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 planting from establishing.

Inlet erosion checks

It is good practice to check the operation of inlet erosion protection measures following the first few rainfall events. These need to be checked early in the system's life, to avoid continuing problems. If problems occur in these events, then erosion protection should be enhanced.

Inlet zone access

An important component of an inlet zone (or forebay) is accessibility for maintenance. Should excavators be capable of reaching 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 by using earthmoving equipment, then a stable ramp will be required into the base of the inlet zone (maximum slope 1:10).

Inlet zone base

To aid maintenance it is recommended that the inlet zone is constructed either with a hard (i.e. rock or concrete) bottom or a distinct sand layer. The base is important for determining the levels that excavation should extend to during sediment removal (i.e. how deep to dig) for either systems cleaned from the banks or directly accessed. Hard bases are also important if maintenance is by driving into the basin.

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 planting vegetation depends on a suitable time of year (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 plants are established, water levels can be raised to operational levels (see Appendix A).

Bird protection

Protection against birds (e.g. using nets) should be considered for newly planted area of wetlands as birds can pull out young plants and reduce plant densities.

Trees on embankments

The size of trees planted on embankments needs to be considered as root systems of larger trees can threaten the structural integrity of embankments.

10.4.3 Construction checklist

CONSTRUCTION INSPECTION CHECKLIST

Ponds and Lakes

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

SITE: ____________________

CONSTRUCTED BY: ____________________

DURING CONSTRUCTION									
Items inspected	Checked		Satisfactory	Unsatisfactory	**Structural components**	Checked		Satisfactory	Unsatisfactory
Preliminary works	Y	N			15. Location and levels of outlet as designed	Y	N		
1. Erosion and sediment control plan adopted					16. Safety protection provided				
					17. Pipe joints and connections as designed				
2. Limit public access					18. Concrete and reinforcement as designed				
3. Location same as plans					19. Inlets appropriately installed				
4. Site protection from existing flows					20. Inlet energy dissipation installed				
5. All required permits in place					21. No seepage through banks				
Earthworks					22. Ensure spillway is level				
6. Integrity of banks					23. Provision of maintenance drain(s)				
7. Batter slopes as plans					24. Collar installed on pipes				
8. Impermeable (eg. clay) base installed					26. Protection of riser from debris				
9. Maintenance access for inlet zone					**Vegetation**				
10. Compaction process as designed					29. Vegetation appropriate to zone (depth)				
11. Placement of adequate topsoil (edges)					30. Weed removal prior to planting				
12. Levels as designed for base, benches, banks and spillway (including freeboard)					31.Provision for water level control during establishment				
13. Check for groundwater intrusion					32. Vegetation layout and densities as designed				
14. Stabilisation with sterile grass									
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 or short circuiting				
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. Outlet free of debris				
8. Public safety adequate									

COMMENTS ON INSPECTION

ACTIONS REQUIRED

1.									
2.									
3.									
4.									
5.									

10.4.4 Asset handover 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 (e.g. drawings, survey, models) provided?		
Asset listed on asset register or database?		

10.5 Maintenance requirements

Pond and lakes treat runoff by providing extended detention and allowing sedimentation to occur. In addition, they are used for flow management and need to be maintained to ensure adequate flood protection for local properties.

Most lake maintenance is associated with the inlet zone (and GPT if installed). Weeding, planting and debris removal are the dominant tasks. In addition, if artificial turnover of the lake is required (because of long residence times) a mechanical system will need to be employed and will require specific maintenance.

Edge vegetation will also require maintenance, including weed removal and replanting. Other components of the system that 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.

Maintenance is primarily concerned with:

- flow to and through the system
- maintaining vegetation
- removal of accumulated sediments
- litter and debris removal.

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. 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.

10.5.1 Operation and maintenance inspection form

The *Pond Maintenance Checklist* should be used whenever an inspection is conducted and kept as a record on the asset condition and quantity of removed pollutants over time.

Pond Maintenance Checklist			
Inspection frequency: 3 monthly	Date of visit:		
Location:			
Description:			
Site visit by:			
Inspection items	Y	N	Action required (details)
Litter within inlet or open water 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.)?			
Replanting required?			
Submerged/floating vegetation requires removal/harvesting ?			
Settling or erosion of bunds/batters present?			
Damage/vandalism to structures present?			
Outlet structure free of debris?			
Maintenance drain operational (check)?			
Comments:			

10.6 Worked example

10.6.1 Worked example introduction

As part of a residential development in Portland, a permanent waterbody is proposed to treat runoff from a residential area of 110 ha (45% catchment imperviousness) and provide landscape amenity as an integral component of the public open space. The residential development is to have several stormwater quality improvement measures within the streetscape. Modelling using MUSIC has indicated that a pond area of 3000 m^2 of 2 m mean depth is required to provide the final component of the treatment train strategy for the development. The pond is expected to reduce the nitrogen load from the catchment by 10%.

This pond is to be nested within the site of a flood retarding basin. The site for the retarding basin is 4.2 ha and is quadrangle in shape (Figure 10.11). A combination of active and passive open space (e.g. urban forestry andpond) functions are to be incorporated into the site.

Stormwater is conveyed by stormwater pipes (up to the 10-year ARI event) and by designated floodways (including roadways) for events larger than the 10-year ARI event. There are four subcatchments discharging into the retarding basin. During the design 100-year ARI event, the maximum discharge from the retarding basin is 4.1 m^3/s.

10.6.2 Design considerations

Key design issues to be considered include:

1. verifying the size of the pond (depth and area)
2. computation to ensure that the pond volume is not excessively large in comparison to the hydrology of the catchment
3. configuring the layout of the pond such that the system's **hydraulic efficiency** can be optimised, including the transition structure between the inlet zone and the open waterbody
4. design of hydraulic structures, including
   - inlet structure to provide for energy dissipation of inflows up to the 100-year ARI peak discharge
   - design of the outlet structure for the pond and retarding basin.
5. designing the landscape, including
   - edge treatment
   - recommending plant species and planting density
6. providing maintenance.

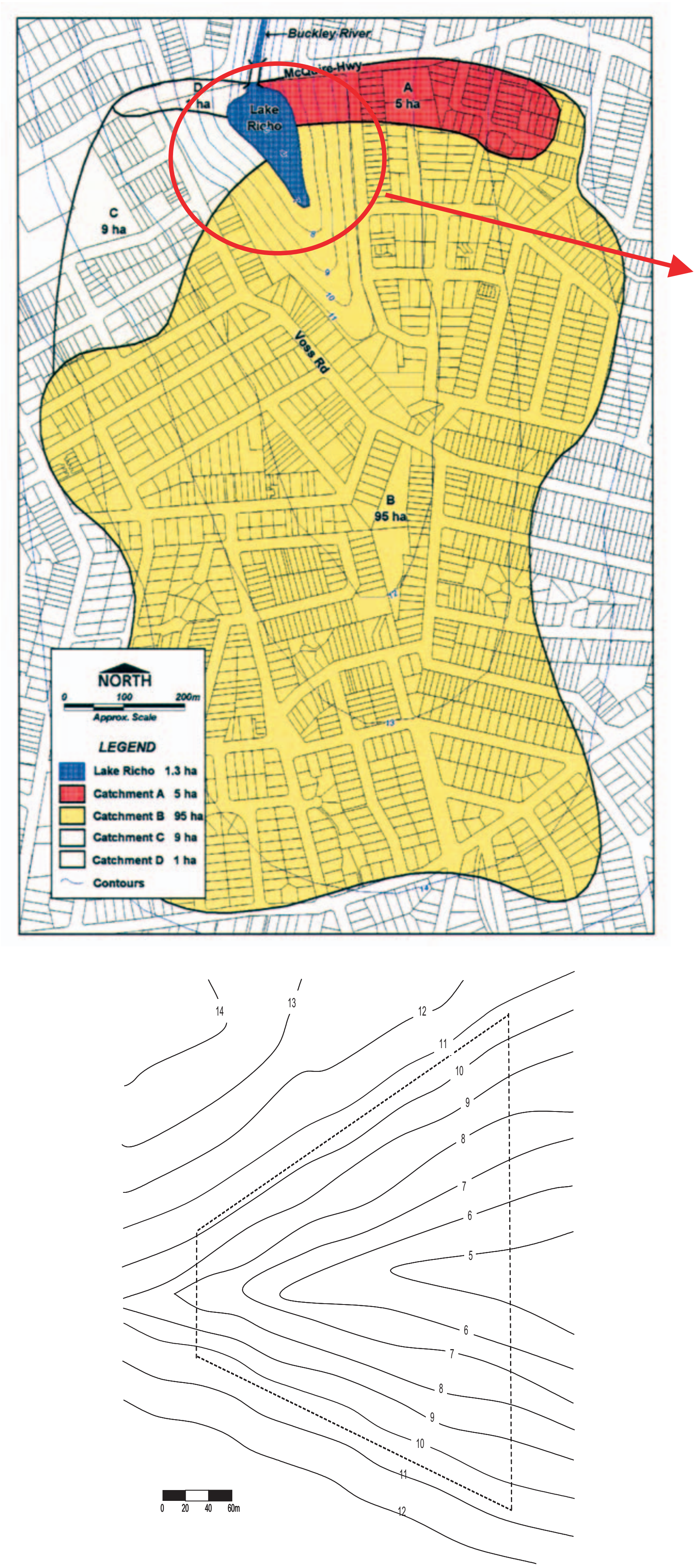

Figure 10.11 Proposed site for retarding basin and pond.

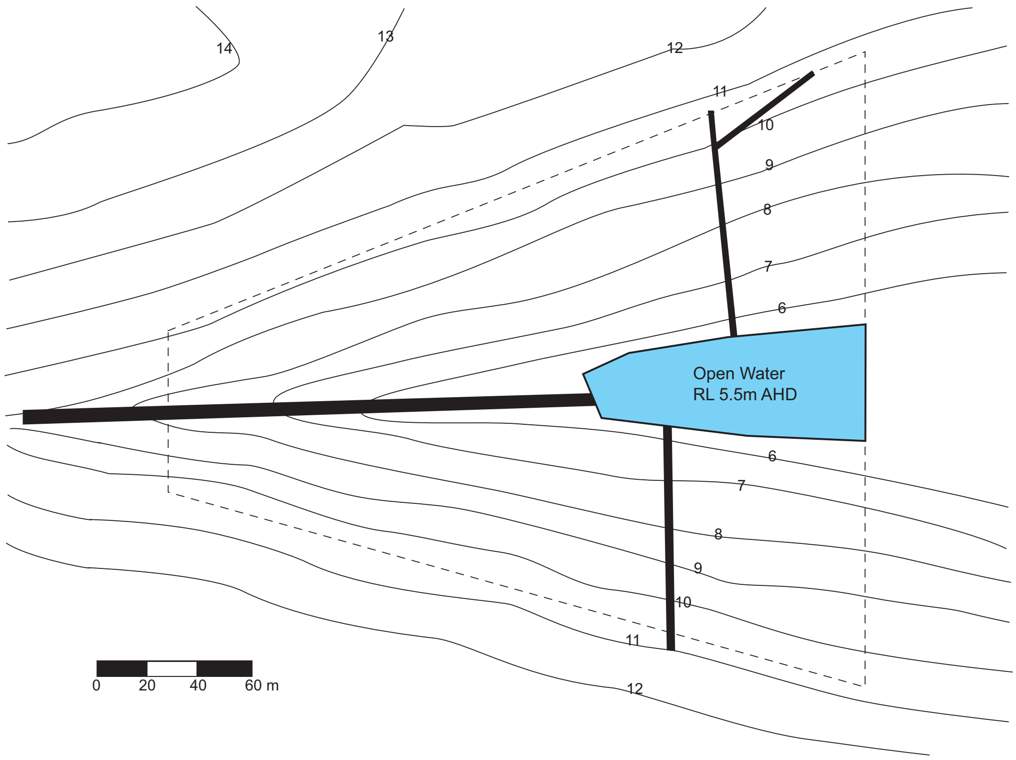

Figure 10.12 Layout of proposed pond.

10.6.3 Confirming pond area

As a basic check of the adequacy of the size of the lake, reference is made to the performance curves presented in Section 10.2. According to Figure 10.1, the required lake area necessary to reduce TN load by 10% is about 0.3% of the impervious area of the catchment.

According to the **hydrologic region** analysis in Chapter 2 (see Section 2.4), the adjustment factor for ponds and lakes in Portland is 1.38.

The required lake area computed from the simple procedure presented in Chapter 2 is as follows:

$$\text{Impervious area} \sim 110 \text{ ha} \times 0.45 \sim 50 \text{ ha}$$

$$\text{Required lake area (mean depth of 2 m)} = 500\,000 \times 0.003 \times 1.38 = 2070 \text{ m}^2.$$

The proposed lake area is 3000 m^2, which is larger than the value determined from the simple procedure contained in Chapter 2, Section 2.4, and is thus acceptable.

The proposed permanent pool level is 5.5 m AHD (Australian Height Datum) with a maximum depth of 2.5 m and a depth range between 1.5 m and 2.5 m. The volume of the proposed lake waterbody is about 6 ML (i.e. 0.3 ha × 2 m depth). The layout of the proposed waterbody is shown in Figure 10.12.

Proposed pond area is 3000 m^2 is confirmed as larger than the expected size required to achieve the 10% reduction in TN proposed
Permanent pool level is set at 5.5 m AHD
Lake volume ~ 6 ML

10.6.4 Design calculations

10.6.4.1 Lake hydrology

Analysis of waterbody residence time

An analysis of waterbody residence time should be undertaken using a continuous simulation approach with the use of historical rainfall data with historical potential evaporation data or estimates of probabilistic monthly potential evaporation (see Section 10.3.1). A 'simplified

Table 10.2 Meteorological data for Portland

	Jan	Feb	Mar	Apr	May	Jun	
Mean Rainfall (mm)	35.2	33.5	43	65.3	88.9	100.1	
Median Rainfall (mm)	25.9	25.8	36.9	61.9	82.1	95.5	
Decile 9 Rainfall (mm)	74.7	72.6	83.6	110.2	145.6	153.7	
Decile 1 Rainfall (mm)	9.4	5.9	12.1	25.6	36	56.4	
Mean no. of Raindays	8.7	8	11.4	14.7	18.4	19.6	
Monthly Area PET (mm)	150	120	100	85	40	30	
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Mean Rainfall (mm)	108.5	107.6	85.1	70.4	53.2	44.7	835.5
Median Rainfall (mm)	102.8	102.6	81.4	67.5	48.9	38.6	834.9
Decile 9 Rainfall (mm)	167.2	165.1	126.6	111.9	93.4	81.8	1001.4
Decile 1 Rainfall (mm)	57	55.5	53.4	29.2	22	13.8	656.6
Mean no. of Raindays	21.1	21.2	18.5	16.2	13	11.3	182.1
Monthly Area PET (mm)	30	45	70	100	125	135	1000

approach' may be undertaken as a preliminary assessment of the adequacy of waterbody turnover in the first instance. This is outlined below.

The statistics of the monthly rainfall and areal potential evapotranspiration data for Portland are summarised (Table 10.2).

From the above meteorological data, a simple assessment of the waterbody residence times for the 10th percentile, 50th percentile and 90th percentile summer meteorological conditions can be done. The ratio of net summer inflow to the lake volume can be computed, and the number of days subsequently divided over the summer period (92 days) with this ratio (Table 10.3).

The 20th percentile residence time can be estimated by interpolating between the 10th percentile value and the 50th percentile value. The interpolation is best undertaken using log-normal probability paper (Figure 10.13).

The analysis undertaken indicated that the proposed pond has a 20th percentile probabilistic residence time of about 28 days. This is just within the guidelines for sustainable ecosystem health of a waterbody of 30 days and it is advisable that a continuous simulation of pond residence time be undertaken to confirm that the pond has a low risk of eutrophication.

Continuous rainfall data was not available for Portland for this case study and the closest available **pluviographic** station is Mortlake. Mortlake, although in the same hydrologic region, is located further inland compared with Portland and its mean annual rainfall is 776 mm compared to 836 mm for Portland. Thus, continuous simulation using Mortlake rainfall data will tend to overestimate the probabilistic residence time of ponds in Portland.

Rainfall data for 1976 to 1990 was used in MUSIC to simulate the hydrology of the proposed pond. For water balance simulation, a daily time step was used. The results of the simulation are plot as a residence time frequency plot (Figure 10.14). The 20% probability of exceedence residence time was estimated to be 26 days and is consistent with the findings of the simplified method.

There is no significant risk of summer blue-green algal bloom with the proposed pond volume.

Table 10.3 Probabilistic residence time

	Summer rainfall (mm)	Net summer inflow (ML)[A]	Net summer inflow/ Lake volume	Summer probabilistic residence time (approx. no. of days)
10%tile	29.1	13.3	2.2	41
50%tile	90.3	43.6	7.3	13
90%tile	229	112	18.7	5

[A]Catchment inflow (~rainfall × impervious area) – net evaporation (~[evaporation – rainfall] × lake area)

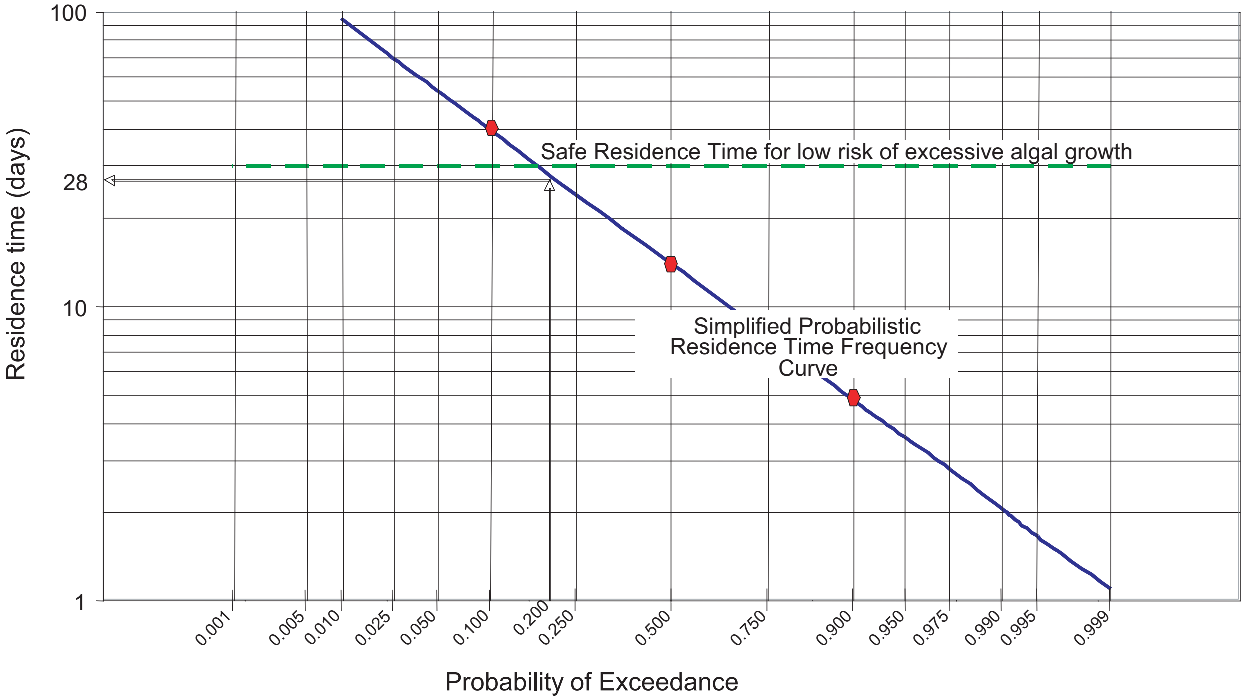

Figure 10.13 Simplified log-normal probability plot of probabilistic residence time of pond water in summer.

Probabilistic summer water levels

Water level fluctuation over the summer is influenced by catchment inflow and evaporation from the lake waterbody. As is the case for the waterbody turnover analysis, a rigorous approach to determination of the probabilistic summer water level fluctuation is through a continuous simulation approach using a daily time step.

A 'simplified approach' to determine if water level fluctuation is excessive within the waterbody can be undertaken by examining the 10th percentile monthly water balance (Figure 10.14). The adoption of the average monthly evaporative losses are not expected to significantly underestimate the evaporative loss corresponding to a 10th percenttile hydrologic scenario.

The analysis shows that monthly catchment inflow exceeds evaporative losses in all months indicating that even for the 10th percentile rainfall scenario, the lake level can be expected to be full at least once each month. The maximum fluctuation in water level (corresponding to the

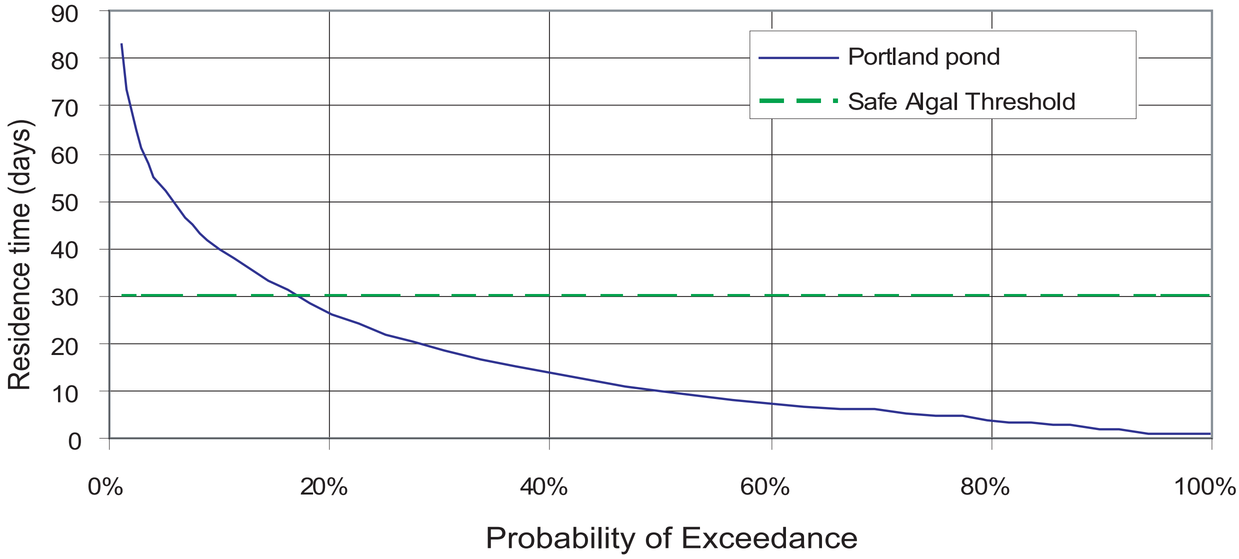

Figure 10.14 Plot of probabilistic residence time determined from continuous simulation using 25 years of rainfall record.

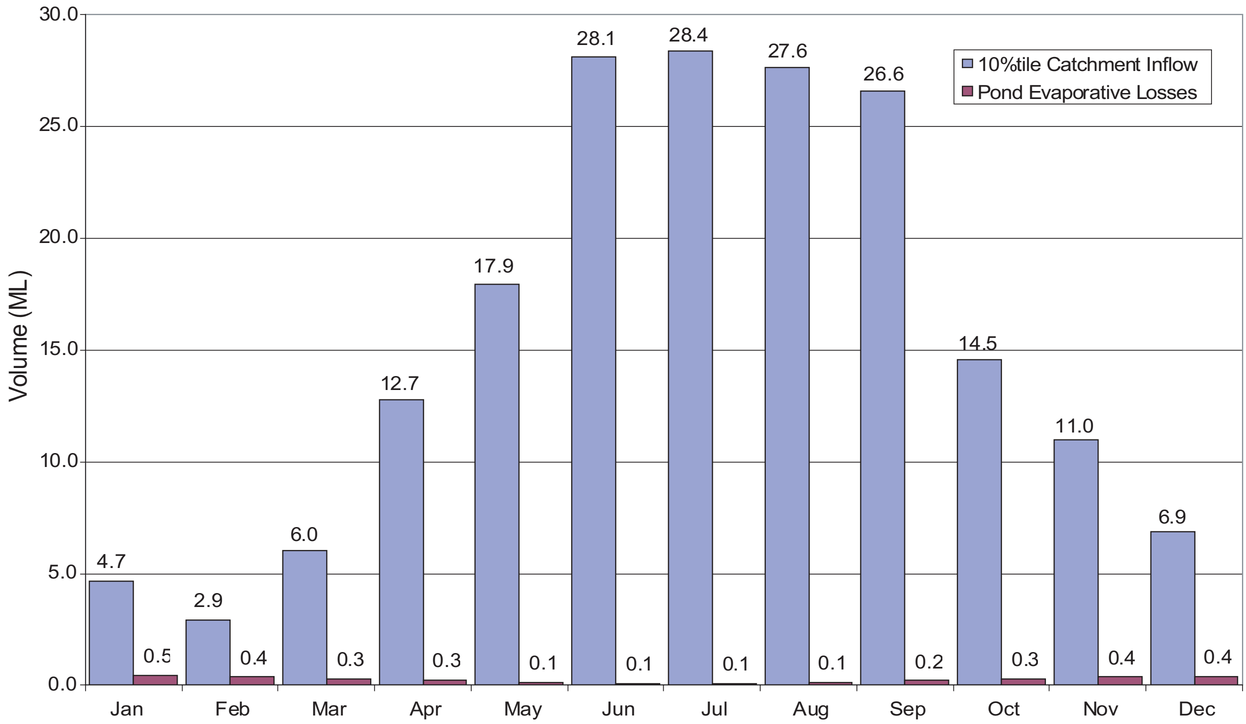

Figure 10.15 Lake water budget showing 10th percentile catchment inflow and pond evaporative losses.).

January/February period) can be conservatively computed to be the sum of the expected evaporation losses of these two months (i.e. about 250 mm).

Lake water level fluctuation is not expected to be a significant aesthetic issue for the proposed lake.

Estimating design flows

Times of concentration (t_c) have been assessed by assuming pipe and overland flow velocities of 1 m/s and estimating flow paths. In smaller catchments, a minimum time of concentration of six minutes has been adopted to allow for lot scale impacts. The characteristics of each catchment are summarised in Table 10.4.

Rainfall intensities were estimated using IFD intensities for Portland and are also summarised in Table 10.4.

10.6.4.2 Open water zone layout

Size and dimensions

The open water zone will be quadrangular in shape to conform to the natural terrain of the site. The general dimension is a mean width of 30 m and 100 m along the long axis, giving an aspect ration of 3(L) to 1(W). With the largest of the catchments discharging into the lake from one end of the longer axis, the expected hydraulic efficiency of the open water body can be of the

Table 10.4 Catchment characteristics (*C*), rainfall intensities (*I*) and design discharges (*Q*)

Subcatchment	Area (ha)	Flow path length (m)	t_c (min)	I_1	C_1	Q_1	I_{10}	C_{10}	Q_{10}	I_{100}	C_{100}	Q_{100}
A	5	220	7	34	0.59	0.28	63	0.74	0.65	144	0.88	1.78
B	95	1400	30	17	0.39	1.73	30	0.49	3.84	64	0.59	9.93
C	9	200	7	34	0.59	0.50	63	0.74	1.17	144	0.88	3.20
D	1	150	7	34	0.59	0.06	63	0.74	0.13	144	0.88	0.36

Note: Runoff coefficients for the one-year, 10-year and 100-year ARI events (each with a 0.45 fraction impervious) were calculated in accordance to the procedure in AR&R 1998 (Book VIII)

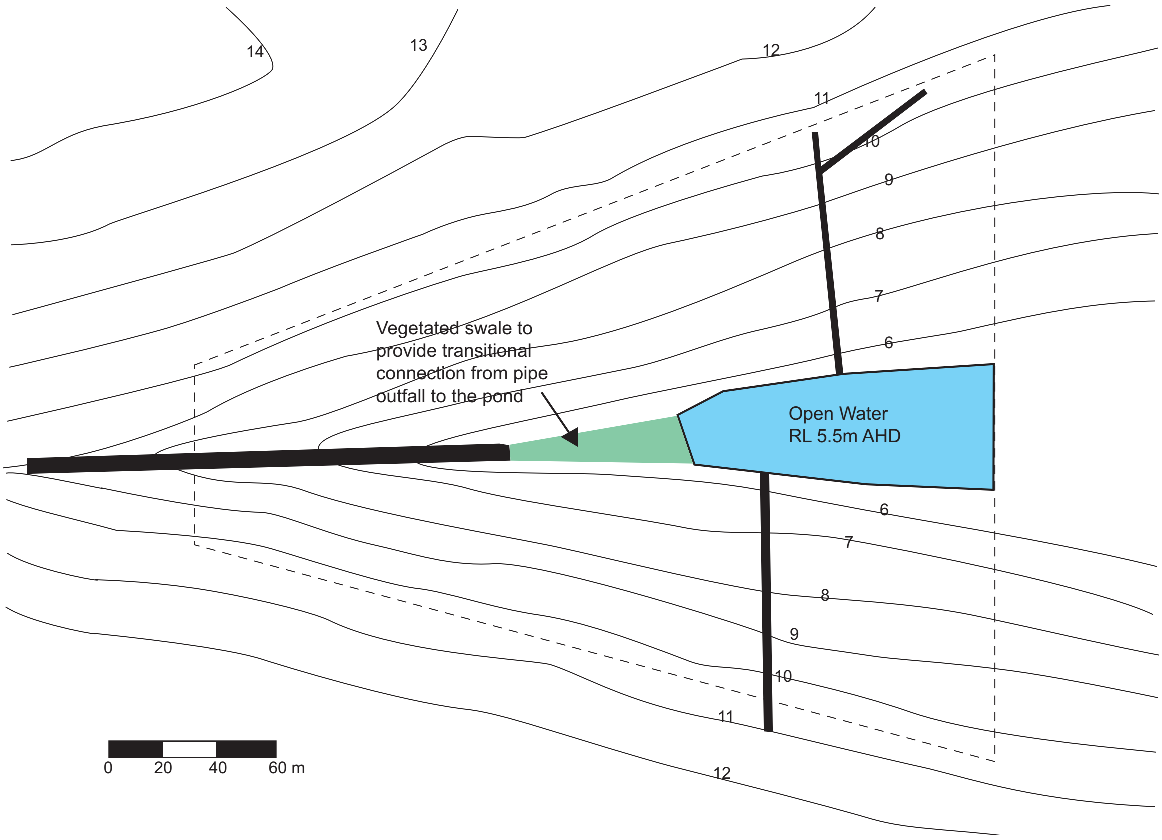

Figure 10.16 Vegetated swale recommended to provide flow transition from pipe outfall to foreshore of pond.

order of 0.34 (Figure 10.7) unless the outlet from subcatchment B can be designed such that outflow is uniformly distributed across the 20 m wide foreshore of the pond. This can be achieved by designing a vegetated swale transition between the pipe outfall and the forebay of the pond (Figure 10.16).

Aspect ratio is **3(L) to 1(W)**;
Hydraulic efficiency ~**0.76** with distributed inflow.

Section

The long and cross sections of the pond will follow the natural terrain with limited requirement for earthworks to form the bathymetry of the pond.

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 littoral zone to 0.3 m beneath the water line before steepening into a 1(V):3(H) slope is recommended as a possible design solution (e.g. Figure 10.17).

Cross section of littoral zone to below the water line consists of a
1:8 batter slope to 0.3 m below the permanent pool level.

10.6.4.3 Pond outlet structure

Maintenance drain

A maintenance drain will be provided to allow drainage of the system. Valves will be operated manually to drain the permanent waterbody. The drawdown period should be about 24 hours if practical.

The mean flow rate (Q) for the maintenance drain is selected to drawdown the permanent pool over 24 hours and is computed as follows:

$$\text{Permanent pool volume} \sim 6000 \text{ m}^3$$

$$Q = 6000/(1 \times 24 \times 3600) = 0.07 \text{ m}^3/\text{s} = 70 \text{ L/s}. \qquad \text{(Equation 10.6)}$$

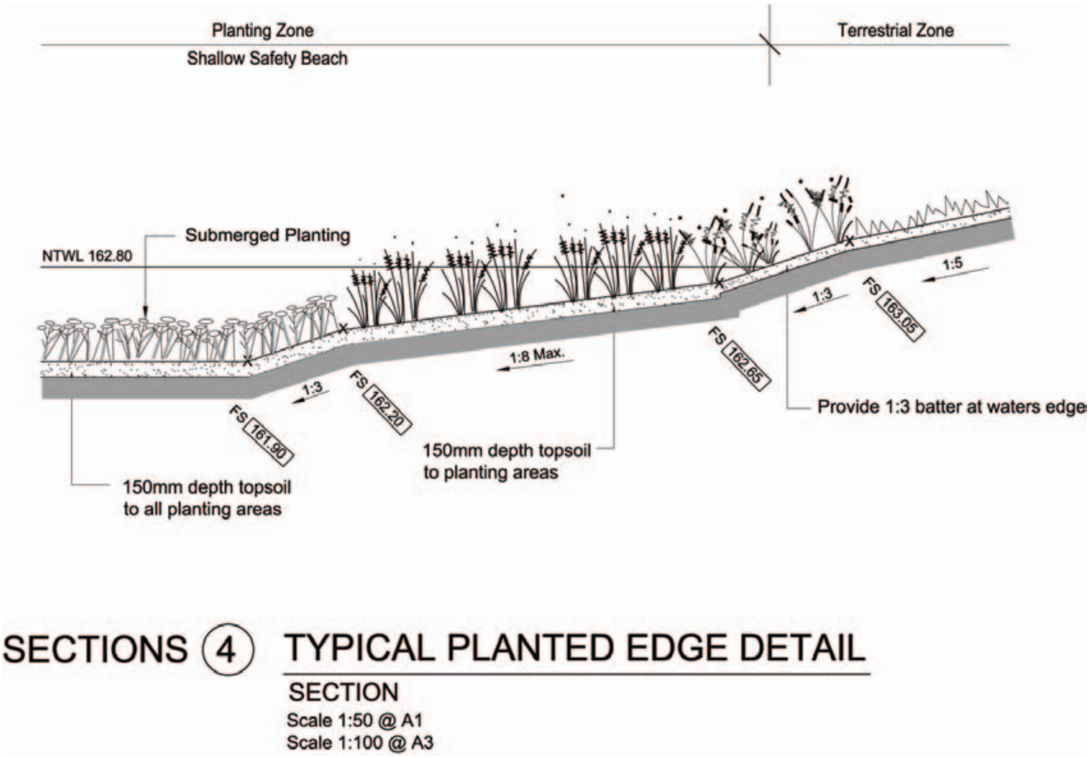

Figure 10.17 Planted edge detail

To determine the area of the orifice for the drain, it assumed that the valve orifice will operate under inlet control with its discharge characteristics determined by the orifice equation (Equation 10.5):

$$A_o = \frac{Q_{des}}{C_d\sqrt{2gH}} \qquad \text{(Equation 10.7)}$$

$Q = 0.07\ m^3/s$
$C_d = 0.6$
$H = 0.67$ m (two-thirds of maximum permanent pool depth)

Giving $A_o = 0.02\ m^2$ corresponding to an orifice diameter of 161 mm – adopt 200 mm maintenance pipe.

Pipe valve to allow draining of the permanent pool for maintenance to be **at least 200 mm diameter.**

Outlet pit

The outlet pit is to be set at a crest level at the nominated permanent pool level of 5.5 m AHD. The discharge capacity of the outlet pit must be at least equal but preferably higher than the design retarding basin outflow.

During the 100-year ARI operation of the retarding basin, the outlet pit will be completely submerged and the required dimension of the outlet pit to discharge 4.1 m^3/s can be computed using the orifice flow equation (Equation 10.5):

$$A_o = \frac{Q_{des}}{C_d\sqrt{2gH}}$$

C_d = Orifice Discharge Coefficient (0.6)
$H = 3.5$ m
A_o = Orifice area (m^2)
$Q_{des} = 4.1\ m^3/s$.

The computed plan area of the overflow pit is 0.825 m^2. The nominal pit dimension to ensure adequate discharge capacity is 1.0 m × 1.0 m although maintenance access may require the pit to be larger.

Outlet pit dimension is 1.0 m × 1.0 m

10.6.4.4 High-flow route and spillway design

The spillway weir level is set at reduced level (RL) 11.0 m AHD and the retarding basin embankment height is about 7 m. The spillway needs to be designed with adequate capacity to safely convey peak discharges up to the probable maximum flood level. This requires specialist hydrological engineering input involving flood estimation and flood routing calculations.

The spillway needs to be designed to safely convey discharges up to the probable maximum flood level.

10.6.4.5 Vegetation specifications

The vegetation specification and recommended planting density for the littoral and open water zone are summarised in Table 10.5 (see Appendix A for further discussion and guidance).

Table 10.5 Vegetation specifications

Zone	Plant species	Planting density (plants/m^2)
Littoral berm	*Persicaria decipens*	3
Open water zone	*Vallisneria spiralis*	4

10.6.4.6 Design calculation summary

The completed *Ponds and Lakes Calculation Summary* shows the results of the design calculations.

Ponds and Lakes — CALCULATION SUMMARY

	CALCULATION TASK	OUTCOME		CHECK
1	**Identify design criteria**			✓
	Design ARI Flow for inlet hydraulic structures	10	year	
	Design ARI Flow for outlet hydraulic structures	100		
	Design ARI for emergency hydraulic structures	PMF	year	
	80%tile turnover period	>>110	days	
	Probabilistic summer water level – 10%tile	7.2	m	
	Probabilistic summer water level – 90%tile	7.5	m	
	Flood detention storage volume (from flood routing analysis)	150000	m^3	
	Outlet pipe dimension (from flood routing analysis)	750	mm	
2	**Catchment characteristics**			✓
	Residential	110	Ha	
	Commercial	0	Ha	
	Fraction impervious			✓
	Residential	0.45		
	Commercial	N/A		
3	**Estimate design flow rates**			
	Time of concentration			
	Estimate from flow path length and velocities	7 to 30	minutes	✓
	Identify rainfall intensities			
	Station used for IFD data:	Portland		
	Design rainfall intensity for inlet structure(s)	30 to 63	mm/hr	✓
	Design runoff coefficient			
	Inlet structure(s)	0.49 to 0.74		✓
	Peak design flows			✓
	Inlet structure(s)	0.13 to 3.84	m^3/s	
	Outlet structure(s)	4.100	m^3/s	
4	**Forebay zone layout**			✓
	Area of forebay zone	15 to 125	m^2	
	Aspect ratio	2(L):1(W)	L:W	
	Hydraulic efficiency	0.4		
5	**Lake residence time**			✓
	Is wetland forebay for recirculation required	Y		
	Area of wetland forebay for water recirculation	10000	m^2	
	Detention time during reciculation of wetland forebay	5	days	
	Lake water recirculation pump rate	17	L/s	
6	**Pond layout**			✓
	Area of open water	22000	m^2	
	Aspect ratio	2(L):1(W)	L:W	
	Hydraulic efficiency	0.76		
	Length	200	m	
	Width	50 to 150	m	
	Cross section batter slope	1(V):8(H)	V:H	
7	**Hydrualic structures**			
	Inlet structure			✓
	Provision of energy dissipation	Y		
	Outlet structure			✓
	Pit dimension	1 x 1	L x B	
			mm diam	
	Discharge capacity of outlet pit	4.1	m^2/s	
	Provision of debris trap	Y		
	Maintenance drain			✓
	Diameter of maintenance valve	200	mm	
	Drainage time	7	days	

10.6.5 Example maintenance schedule

The Portland Lake Maintenance Form is an inspection sheet developed for a lake at Portland showing local adaptation to incorporate specific features and configuration of individual lakes. It was developed from the generic *Pond Maintenance Checklist*.

PORTLAND LAKE – MAINTENANCE FORM	
Location	
Description	Constructed lake 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

Gross pollutant load cleanout required?	Yes/No
Depth of sediment in forebay:	______ 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 forebay and littoral zone?	Yes/No
Were the weeds removed this site visit?	Yes/No
Is there litter in the lake or forebay?	Yes/No
Was the litter collected this site visit?	Yes/No

SECTION 3a – CLEANOUT OF GROSS POLLUTANTS

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 gross pollutant and sediment removed (approximate estimate)	m^3	
Any visible damage to gross pollutant trap? (If yes, complete Section 4 – Condition)	Yes/No	

SECTION 3b – 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 structures					
Outlet structures					
Sediment forebay					
Spillway and spillway channel					
Forebay and littoral zone vegetation					
Banks and batter slopes					
Forebay bunds or porous embankment (if constructed)					
Retarding basin embankment					
Surrounding landscaping					

Comments:

10.7 References

Cooperative Research Centre for Catchment Hydrology (CRCCH) (2003). *Model for Urban Stormwater Improvement Conceptualisation (MUSIC) User Guide*, Version 2.0, CRCCH, Monash University, Victoria.

Engineers Australia (2003). *Australian Runoff Quality Guidelines*, Draft, June.

Fair G.M. and Geyer J.C. (1954). *Water Supply and Waste Disposal*, Vol. 2, John Wiley, New York.

Graeme Bentley Landscape Architects (GbLA) (2004). *Preliminary drawings for Mernda Wetland*, Report for Stockland.

Government of Victoria (1995). *Blue-Green Algae*, *Information Brochure*, Victorian Project Team on Blue-Green Algae, Department of Conservation and Natural Resources, Melbourne.

Institution of Engineers, Australia (2001). *Australian Rainfall and Runoff – A Guide to Flood Estimation*, Revised edn, Pilgram, D.H. (Ed.), Institution of Engineers, Australia, Barton, ACT.

Mitrovic, S.M., Bowling, L.C. and Buckney, R.T. (2001). Vertical disentrainment of *Anabaena circinalis* in the turbid, freshwater Darling River, Australia: quantifying potential benefits from buoyancy, *Journal of Plankton Research*, 23(1), 47–55.

Persson, J., Somes, N.L.G. and Wong T.H.F. (1999). Hydraulic efficiency and constructed wetland and ponds, *Water Science and Technology*, 40(3), 291–289.

Reynolds, C.S. (2003). The development of perceptions of aquatic eutrophication and its control, *Ecohydrology and Hydrobiology*, 3(2), 149–163.

Sherman, B.S., Webster, I.T., Jones, G.J., Oliver, R.L. (1998). Transitions between Aulacoseira and Anabaena dominance in a turbid river weir pool, *Limnology and Oceanography*, 43(8), 1902–1915.

Tarczynska, M., Frankiewicz, P. and Zalewski, M. (2002). The regulation and control of hydrologic and biotic processes within reservoirs for water quality improvement, In *Guidelines for the Integrated Management of the Watershed – Phytotechnology and Ecohydrology*, Freshwater Management Series No. 5, UNEP-IETC and UNESCO-IHP.

Wagner-Lotkowska, I., Izydorczyk, K., Jurczak, T., Tarczynska, M., Frankiewicz, P. and Jorgensen, S.E. (2004). Reservoir and lake management: improvement of water quality, In Zalewski, M. (Ed.), *Integrated Watershed Management – Ecohydrology and Phytotechnology – Manual*, United Nations Publication, United Nations Environment Programme,

Westwood, K.J. and Ganf, G.G. (2004). Effect of cell flotation on growth of *Anabaena circinalis* under diurnally stratified conditions, *Journal of Plankton Research*, JPR Advance Access, June 17, 2004.