Sediment Basins

Chapter 4

4.1 Introduction

Reducing sediment loads is an important component of improving stormwater quality. Sedimentation basins can form an integral component of a stormwater treatment train and are specifically employed to remove coarse to medium sized sediments by settling them from the water column. Sedimentation basins can take various forms and can be used as permanent systems integrated into an urban design, or temporary measures to control sediment discharge during construction. This chapter describes the design and construction of permanent sedimentation basins ('wet' basins) that form part of a treatment train (e.g. an inlet zone/ pond to a constructed wetland) for operation in the post construction/building phase. For the design and application of temporary sedimentation ('dry') basins to control sediment discharge during the construction/ building phase, refer to *Sediment Basin Design, Construction and Maintenance Guidelines* (BCC 2001).

Sedimentation basins are stormwater detention systems that promote settling of sediments through the reduction of flow velocities and temporary detention. Key elements include purpose designed inlet and outlet structures, settling pond, and high flow, overflow structures. The storage volume consists of two components: the permanent pool settling zone and the sediment storage zone. Access for maintenance must also be provided. These elements are shown below in Figure 4-1 and Figure 4-2. Key design parameters are selecting a target sediment size, design discharge, basin area and shape, sediment storage volume and outlet structures.

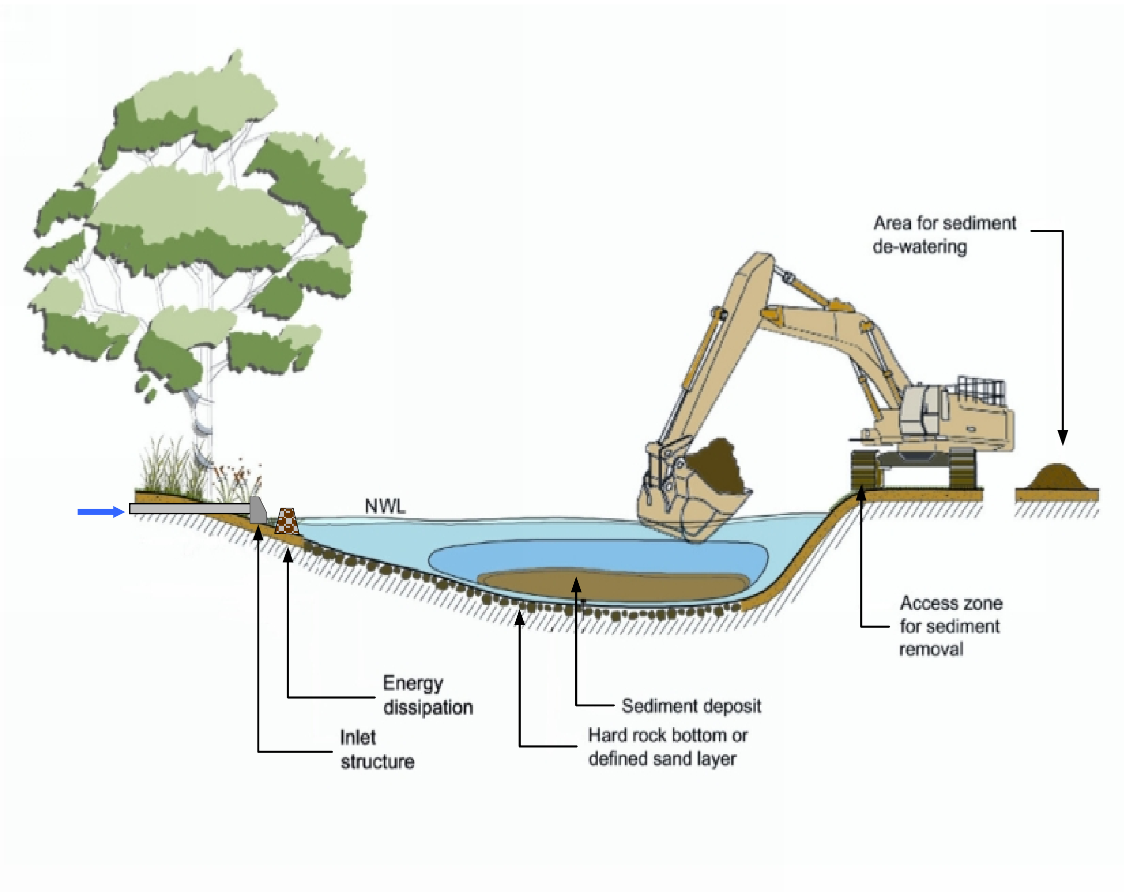


Figure 4-1: Sedimentation Basin Conceptual Layout

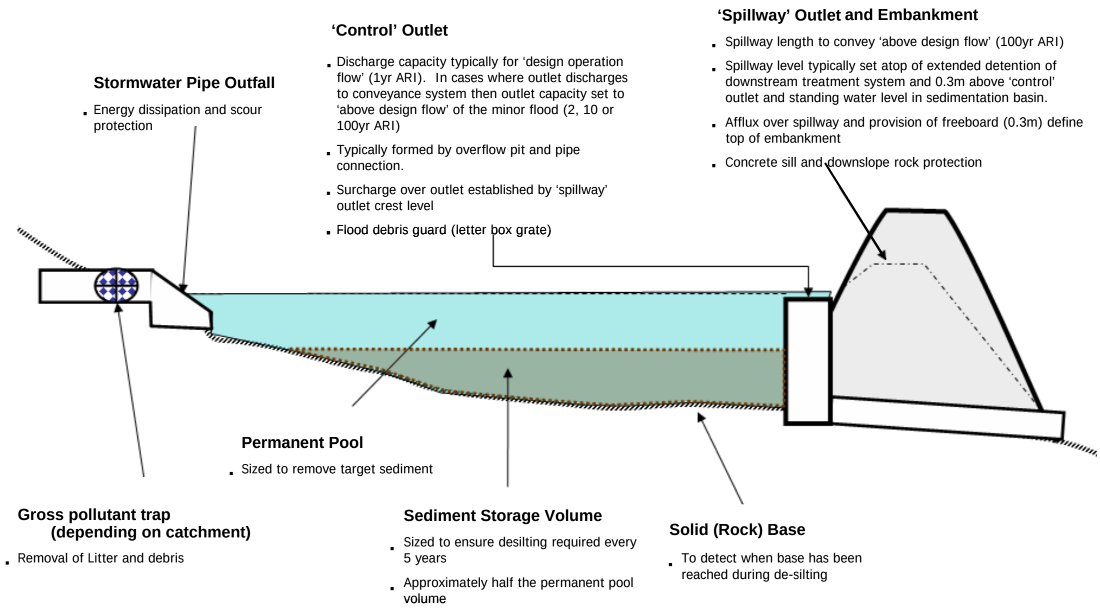


Figure 4-2: Sedimentation Basin Key Elements

4.2 Design Considerations

4.2.1 Role in the Treatment Train

Sedimentation basins have two key roles when designed as part of a stormwater treatment train. The primary function is as a sedimentation basin to target coarse to medium sized sediment (i.e. 125 μm or larger) prior to waters entering the downstream treatment systems (e.g. macrophyte zone of a constructed wetland or a bioretention basin). This ensures the vegetation in the downstream treatment system is not smothered by coarse sediment and allows downstream treatment systems to target finer particulates, nutrients and other pollutants.

The second function is the control or regulation of flows entering the downstream treatment system during 'design operation' and 'above design' conditions. The outlet structures from the sedimentation basin are designed such that flows up to the 'design operation flow' (typically the 1 year ARI) enter the downstream treatment system, whereas 'above design flows' are bypassed around the downstream treatment system. In providing this function, the sedimentation basin protects the vegetation in the downstream treatment system against scour during high flows. The configuration of outlet structures within sedimentation basins depends on the design flows entering the basin and the type of treatment systems located downstream as described in Section 4.2.4.

Where the sedimentation basin forms part of a treatment train and when available space is constrained, it is important to ensure that the size of the sedimentation basin (i.e. inlet zone of a constructed wetland) is not reduced. This ensures the larger sediments are effectively trapped and prevented from smothering the downstream treatment system. If the site constrains the total area available for the treatment train, the downstream treatment system should be reduced accordingly.

4.2.2 Sizing a Sedimentation Basin

The required size of a sedimentation basin is calculated to match the settling velocity of a target sediment size with a design flow (typically 1 year ARI). Selecting a target sediment size is an important design consideration. As a pretreatment facility, it is recommended that particles of 125 μm or larger be the selected target sediment size because analysis of typical catchment sediment loads suggest that between 50 - 80 % of suspended solids conveyed in urban stormwater are 125 μm or larger. Almost all sediment bed loads are larger than this target sediment size.

Analysis of the characteristics of particulate nutrients and metals indicates that coarse to medium sized sediments (i.e. $> 125\ \mu m$) have low concentrations of attached pollutants (e.g. nutrients, heavy metals) when compared to finer sediment and colloidal particles. Basins sized to target coarse to medium sized sediment are therefore expected to capture sediment that has low levels of contamination and is unlikely to require special handling and disposal. Removal of particles $< 125\ \mu m$ is best undertaken by treatment measures other than sedimentation basins (e.g. constructed wetlands and bioretention systems). Therefore, while a basin must have adequate size for capturing the target sediment size, they should not be grossly oversized. Conversely, a sedimentation basin that is too small could have limited effectiveness, resulting in sediment smothering of downstream treatment measures.

4.2.3 Sediment Storage

A further consideration in the design of a sedimentation basin is the provision of adequate storage for settled sediment to prevent the need for frequent desilting. A desirable frequency of basin desilting is once every five years (generally triggered when sediment accumulates to half the basin depth). The volume of accumulated sediment can be estimated from regular monitoring of sediment levels with a measuring post and reference against the top water level.

4.2.4 Outlet Design

An outlet structure of a sedimentation basin can be configured in many ways and is generally dependant on the design flow entering the basin and the type of stormwater treatment system or conveyance system downstream of its outlet. For example, a sedimentation basin forming the inlet zone of a constructed wetland (refer Chapter 6 – Constructed Wetlands), would typically include an overflow pit located within the sedimentation basin with one or more pipes connecting the sedimentation basin to an open water zone at the head of the wetland macrophyte zone. A sedimentation basin pretreating stormwater runoff entering a bioretention basin (refer Chapter 5 – Bioretention Basins) would typically use a weir outlet to keep stormwater flows at surface, to enable the flow to discharge onto the surface of the bioretention filter media. Where the sedimentation basin is formed by constructing an embankment across a drainage gully (such as shown on Figure 4-1), it may also be possible to use an overflow pit and pipe outlet and still be able to discharge to the bioretention surface.

In most cases, the outlet design of a sedimentation basin will consist of a 'control' outlet structure and a 'spillway' outlet structure:

- The 'control' outlet can be either an overflow pit/ pipe or weir which delivers flows up to the 'design operation flow' (Section 4.3.1) to the downstream treatment system(s).
- The 'spillway' outlet structure ensures that flows above the 'design operation flow' (Section 4.3.1) are discharged to a bypass channel or conveyance system. The 'spillway' bypass weir level is set above the 'control' outlet structure and typically at the top of the extended detention depth of the downstream treatment system.

Where the sedimentation basin discharges to a conveyance system (e.g. swale or piped system), a 'control' outlet may not be required and one outlet can be designed to allow discharge of all flows including flood flows.

4.2.5 Landscape Design

Sedimentation basins are often located within open space zones areas and can be landscaped to create a focal point for passive recreation (Figure 4-3). Landscape design treatments to sedimentation basins generally focus on dense littoral vegetation planting to restrict access to the open water zone, and therefore increase public safety, but can also include pathways and information signs. Plant species selection and placement should aim at creating a barrier to restrict public access to the open water zone and integrate with the surrounding landscape (i.e. constructed wetland landscape) and community character as discussed below, as well as providing or enhancing local habitat. Landscape design must also consider access to the sedimentation basin for maintenance (e.g. excavator).

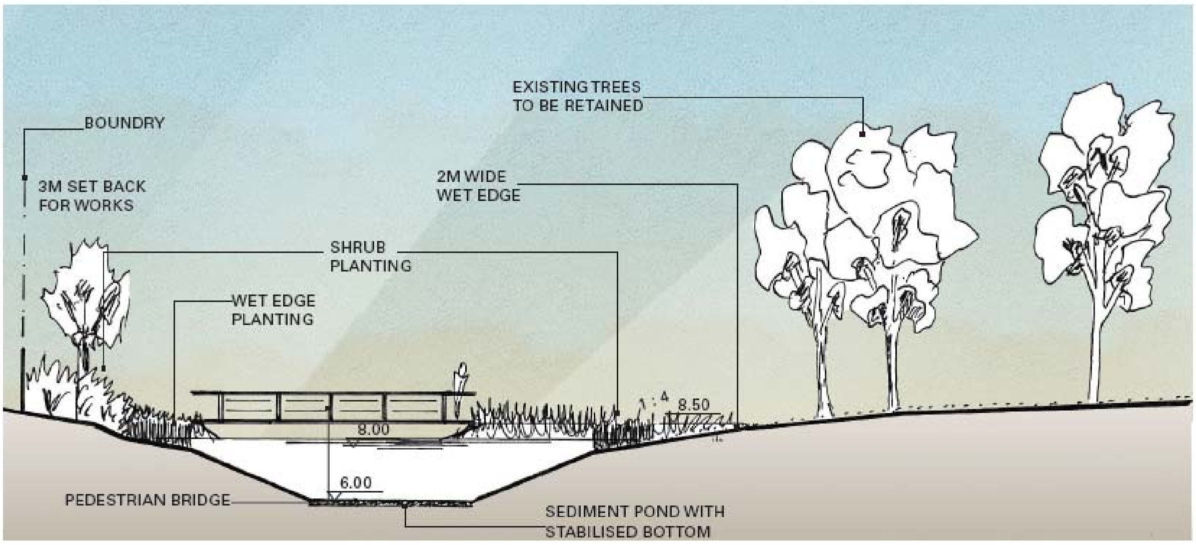


Figure 4-3: Cross section through a sediment basin.

4.2.6 Vegetation Specification

The role of vegetation in sedimentation basin design is to provide scour and erosion protection to the basin batters. In addition, dense planting of the littoral zones will restrict public access to the open water, reducing the potential safety risks posed by water bodies. Terrestrial planting may also be recommended to screen areas and provide a barrier to steeper batters.

Planting of the shallow marsh zone (to a depth of 0.5 m) and littoral zone around the perimeter of a sedimentation basin is recommended to bind the bank and reduce erosion at the waters edge. Plant species should be selected based on the water level regime, soil types of the region, and the life histories, physiological and structural characteristics, natural distribution, and community groups of the plants. Appendix A (Plant Selection for WSUD Systems) provides a list of suggested plant species suitable for sedimentation basins. The planting densities recommended in the list should ensure that 70 – 80 % cover is achieved after two growing seasons (2 years).

Only the waters edge and batters of sedimentation basins should be planted and care needs to be taken in species selection to ensure vegetative growth will not spread to cover the deeper water zones. Similarly, floating or submerged macrophytes should be avoided. A sedimentation basin should primarily consist of open water to allow for settling of only the target sediments (e.g. > 125 μm) and to permit periodic sediment removal.

4.2.7 Maintenance

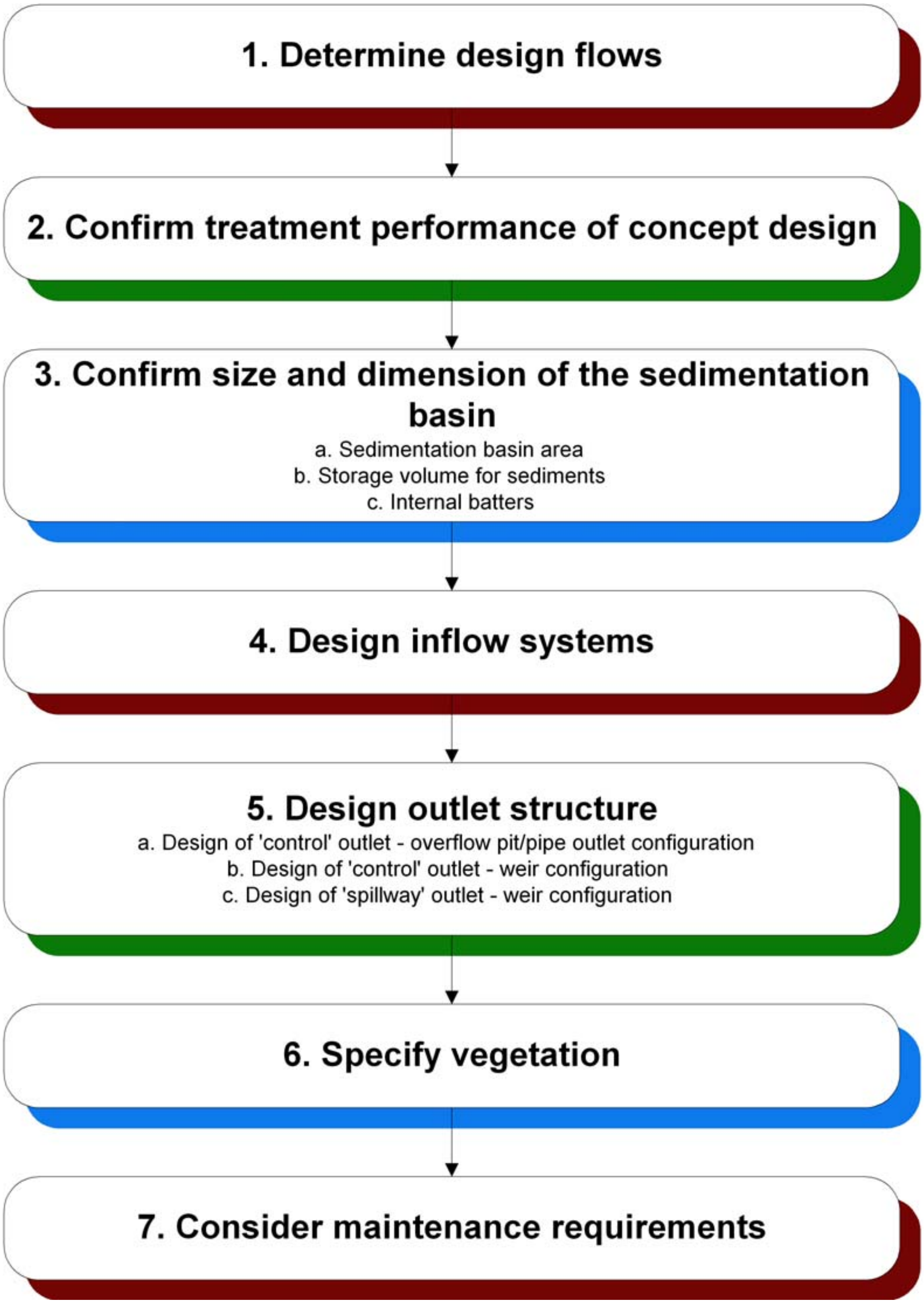
Sedimentation basins are designed with a sediment storage capacity to ensure sediment removal is only required approximately every 5 years (triggered when sediment accumulates to half the basin depth, determined from regular monitoring of sediment depth with a measuring post during maintenance visits). Accessibility for maintenance is an important design consideration. If an excavator is able to reach all parts of the basin from the top of the batter then an access ramp may not be required; however, an access track around the perimeter of the basin will be required and will affect the overall landscape design. If sediment collection requires earthmoving equipment to enter the basin, a stable ramp will be required into the base of the sedimentation basin (maximum slope 1:10).

It is recommended that a sedimentation basin is constructed with a hard (i.e. rock) bottom (with a bearing capacity to support maintenance machinery when access is required within the basin). This serves an important role by allowing excavator operators to detect when they have reached the base of the basin during desilting operations.

Provision to drain the sedimentation basin of water for maintenance must be considered, or alternatively a pump can be used to draw down the basin. Approvals must be obtained to discharge flows downstream or to sewer. Alternatively, a temporary structure (e.g. sand bags) can hold water upstream until maintenance is complete.

4.3 Design Process

The following sections detail the design steps required for sedimentation basins. Key design steps following the site planning and concept development stages are:



4.3.1 Step 1: Determine Design Flows

4.3.1.1 Design Discharges

Two design discharges are required to size sedimentation basins and their structures:

- 'Design Operation Flow' (1 year ARI) for sizing the basin area and to size a 'control' outlet structure when discharging directly into a treatment system (e.g. wetland or bioretention system)
- 'Above Design Flow' for design of the 'spillway' outlet structure to allow for bypass of high flows around a downstream treatment system. Defined by either:
    - Minor design flow (2 year ARI) – required for situations where only the minor drainage system is directed to the sedimentation basin. For commercial and industrial areas the design flow requirement for minor flows is a 5 year ARI event.
    - Major flood flow (50 year ARI) – required for situations where the major drainage system discharges into the sedimentation basin.

Where the sedimentation basin discharges to a conveyance system (e.g. open channel flow or piped drainage system), the 'Design Operation Flow' is only required to size the sedimentation basin, not for outlets from the system.

Sedimentation basins should not be designed to have high flows diverted around them. All flows should be directed through a sedimentation basin such that some level of sedimentation is achieved even during high flow conditions.

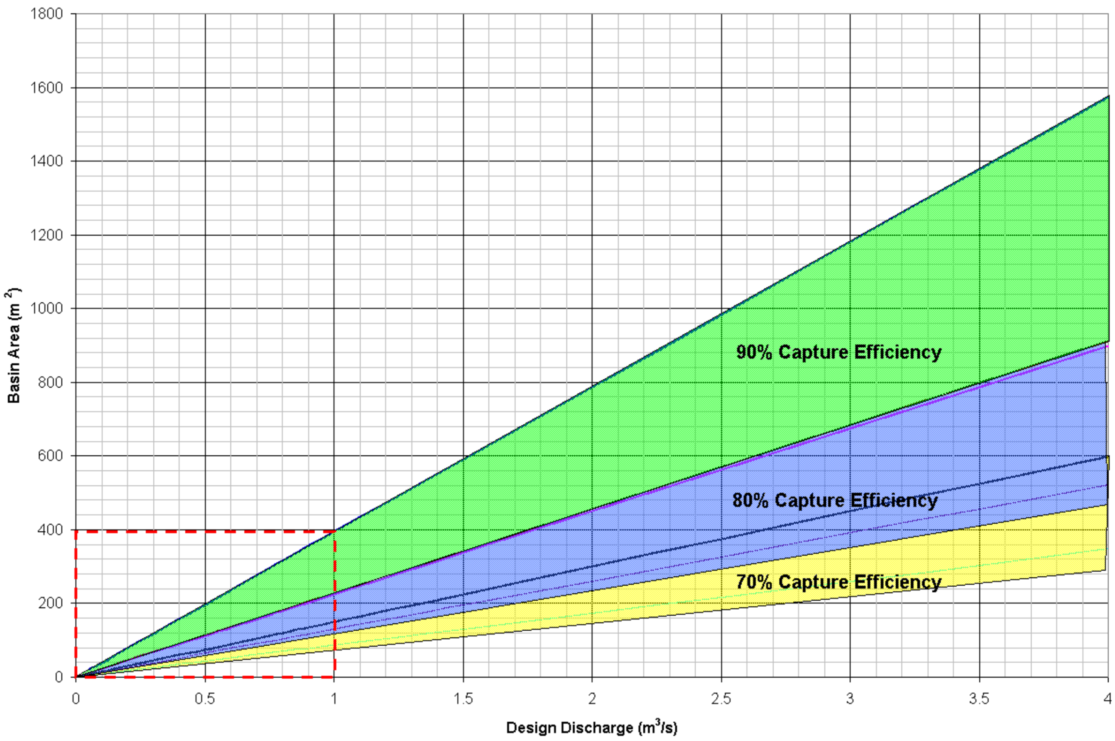
4.3.1.2 Design Flow Estimation

A range of hydrologic methods can be applied to estimate design flows. With typical catchment areas being relatively small, the Rational Method design procedure is considered to be the most suitable method. For sediment basins with large catchments (> 50 ha), a runoff routing model should be used to estimate design flows.

4.3.2 Step 2: Confirm Treatment Performance of Concept Design

Figure 4-4 shows relationships between a required basin area and design discharge for 125 μm sediment capture efficiencies of 70 %, 80 % and 90 % using a typical shape and configuration (□ = 0.5, see Section 4.3.3). The influence of a permanent pool reduces flow velocities in the sedimentation basin and thus increases detention times (and hence removal efficiency). Therefore, a range of values are presented for 70%, 80% and 90% removal (shown as shaded bands), depending on permanent pool depths. A typical 2 m deep permanent pool was used to define the lower limit of the required sedimentation basin thus forming three shaded areas in the figure, with the upper limit being defined using no permanent pool.

The performance of typical designs of sedimentation basins can be expected to fall within the shaded curves shown and they can be used to estimate the size of the proposed sedimentation basin as part of conceptual design and to verify the size derived as part of Step 3. The volume of a permanent pool in a sedimentation basin should have sufficient capacity to ensure that desilting of the basin is not more frequent than once every 5 years. However, sizing of sediment basins should be balanced with practicality and as such, extravagantly large basins should not be designed based primarily on long term storage of sediment. Design guidance for this sediment storage is provided in Section 4.3.3 (Step 3).



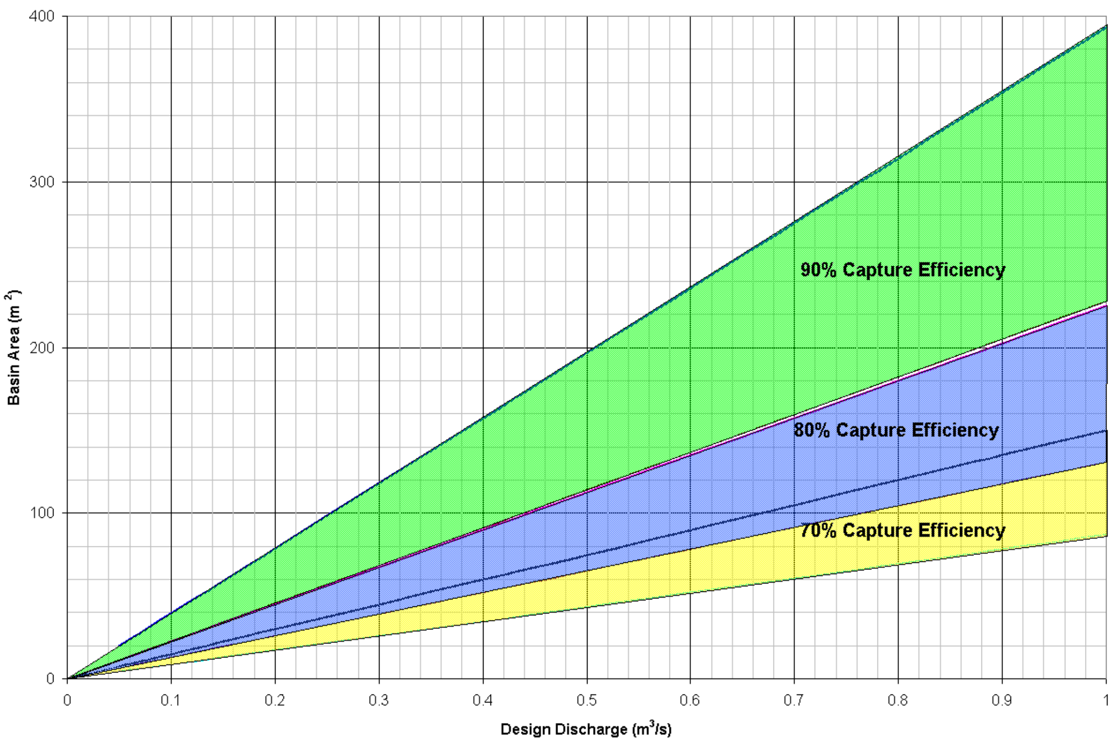


Figure 4-4: Sedimentation Basin Area vs Design Discharges for Varying Capture Efficiencies of 125 μm Sediment

4.3.3 Step 3: Confirm Size and Dimension of the Sedimentation Basin

4.3.3.1 Sedimentation Basin Area

The required area (*A*) of a sedimentation basin should be defined through the use of the following expression (modified version of Fair and Geyer (1954)):

$$R = 1 - \left[1 + \frac{1}{n} \cdot \frac{v_s}{Q/A} \cdot \frac{(d_e + d_p)}{(d_e + d^*)}\right]^{-n} \qquad \text{Equation 4.1}$$

Where R = fraction of target sediment removed

v_s = settling velocity of target sediment (see Table 4.1)

Q/A = applied flow rate divided by basin surface area ($m^3/s/m^2$)

n = turbulence or short-circuiting parameter

d_e = extended detention depth (m) above permanent pool level

d_p = depth (m) of the permanent pool

d^* = depth below the permanent pool level that is sufficient to retain the target sediment (m) – adopt 1.0 m or d_p whichever is lower.

The concept design stage will generally guide the selection of the fraction of target sediment removed (*R*) and permanent pool depth (d_p) depending on water quality objectives and the nature of local soils/ sediments. Table 4.1 lists the typical settling velocities (v_s) of sediments under 'ideal conditions' (velocity in standing water).

Table 4-1: Settling Velocities (vs) 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

Source: (Maryland Dept. of Environment 1987 in Engineers Australia 2006)

Equation 4.1 is applied with n being a turbulence parameter that is related to hydraulic efficiency (□). Figure 4-5 provides guidance on estimating a hydraulic efficiency (□) value that is then used to calculate an appropriate n value (according to the configuration of the basin). The shape of a basin has a large impact on the effectiveness of the basin to retain sediments. Generally, a length to width ratio of at least 3 to 1 should be achieved. In addition, the location of the inlet and outlet, flow ‘spreaders’ and internal baffles impact the hydraulic efficiency of the basin for stormwater treatment as the range of values in Figure 4-5 demonstrates. Figure 4-5 provides some guidance on what is considered to be good basin design, with the higher values (of λ) representing basins with good sediment retention properties. Sedimentation basins should be designed to have a λ value of not less than 0.5. 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).

Consideration of maintenance access to a basin is also required when developing the shape, 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 dewatering should also be provided, that drains back to the basin. This may impact on the footprint area required for a sedimentation basin system.

A value of *n* is estimated using the following relationship:

$$\lambda = 1 - 1/n; \text{ so } \quad n = \frac{1}{1-\lambda} \qquad \text{Equation 4.2}$$

λ is estimated from the configuration of the basin according to Figure 4-5.

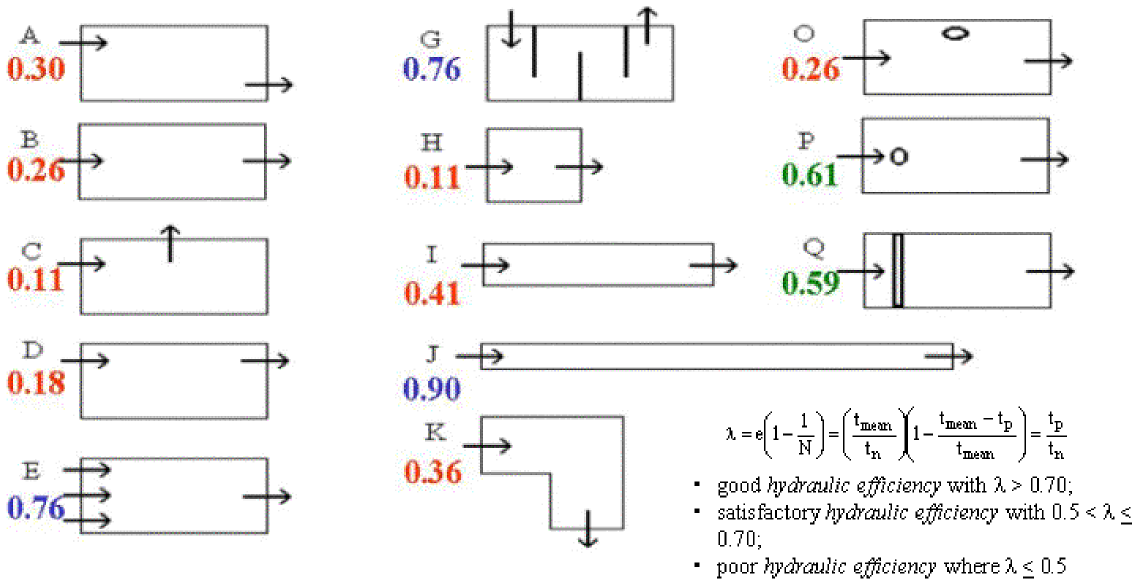


Figure 4-5: Hydraulic Efficiency, λ

Hydraulic efficiency ranges from 0 to 1, with 1 representing the best hydrodynamic conditions for stormwater treatment. The o in diagrams O and P represent islands in the waterbody and the double line in diagram Q represents a weir structure to distribute flows evenly (Persson et al. 1999).

Good practice in the design of sedimentation basins is to 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. With the outlet structure being located some distance above the bed of a sedimentation basin, it is also not necessary for sediment particles to settle all the way to the bed of the basin to be effectively retained. It is envisaged that sediments need only settle to an effective depth (*d**) which is less than the depth to the bed of the sedimentation basin. This depth is considered to be approximately 1.0 m below the permanent pool level.

4.3.3.2 Storage Volume for Sediments

A further consideration in the design of a sedimentation basin is the provision of adequate storage for settled sediment to prevent the need for frequent desilting. A desirable frequency of basin desilting is once every five years (triggered when sediment accumulates to half the basin depth). To ensure this storage zone is appropriate the following must be met:

Sedimentation Basin Storage Volume (V_s) > Volume of accumulated sediment over 5 yrs ($V_{s:5yr}$)

The sedimentation basin storage volume (V_s) is defined as the storage available in the bottom half of the sedimentation basin permanent pool depth. V_s can be calculated using a product of the sedimentation basin area (A_b) and half the permanent pool depth (0.5 x d_p) and appropriate consideration of the internal batters (see Internal Batters below).

The volume of accumulated sediments over 5 years ($V_{s:5yr}$) is established by gaining an understanding of the sediment loads entering the sedimentation basin and applying the fraction of target sediment removed (R):

$$V_s = A_c \cdot R \cdot L_o \cdot F_c \qquad \text{Equation 4.3}$$

Where	V_s	=	volume of sediment storage required (m^3)
	A_c	=	contributing catchment area (ha)
	R	=	capture efficiency (%), estimated from Equation 4.1
	L_o	=	sediment loading rate (m^3/ha/year)
	F_c	=	desired cleanout frequency (years)

A catchment loading rate (L_o) of 1 m^3/ha/year for developed catchments is recommended to be used to estimate the sediment loads entering the basin, based on Figure 8.24, from *Australian Runoff Quality* (Engineers Australia, 2006))

4.3.3.3 Internal Batters

Batter slopes above and immediately below the water line of a basin should be configured with consideration of public safety and landscape integration. Both hard and soft edge treatments can be applied to compliment the landscape of a surrounding area. Soft edge treatments involve using gentle slopes to the waters edge (e.g. 1:8 to 1:10), extending below the water line for a distance (e.g. 2.4 m) before batter slopes steepen into deeper areas. This is illustrated in Figure 4-6.

Plate 4-1: Example of Soft Edge Embankment Planting

Figure 4-7 shows an example of a hard edge treatment with a larger vertical wall and associated handrail for public safety

In both edge treatments, it is recommended to line the bottom of the basin with rock to prevent vegetation (particularly weed) growth and to guide extraction depths during sediment removal (see Section 4.2.7).

The safety requirements for individual basins will vary from site to site, and it is recommended that developers engage an independent safety audit of each design. The *Sediment Basin Design, Construction and Maintenance Guidelines* (BCC 2001) requires the following:

- For water depths > 150 mm and maximum slope of 5:1 (H:V) or less, no fencing is required.
- For water depths > 150 mm and maximum slope > 5:1 (H:V) fencing is required.

Further guidance on landscape and public safety considerations for designing sediment basins is contained in Section 4.4.

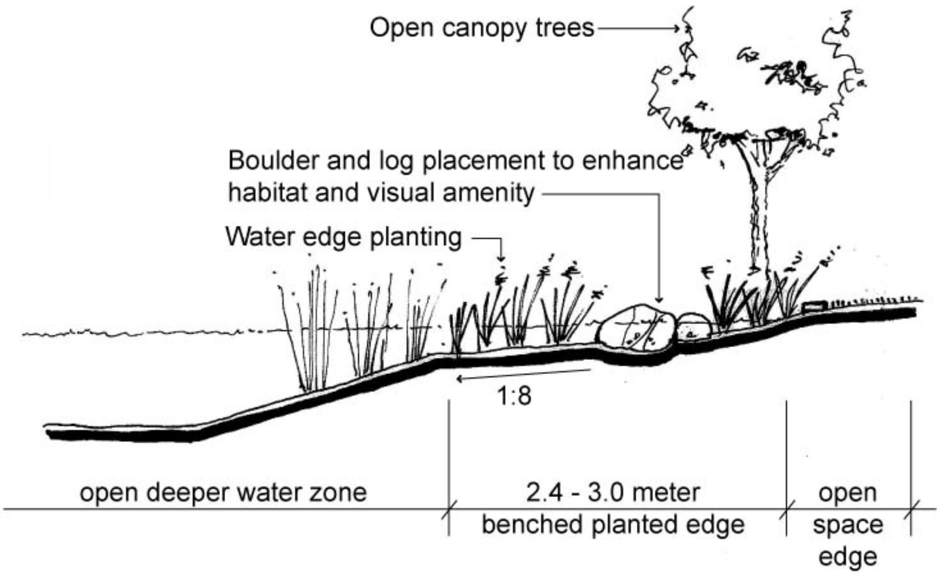


Figure 4-6: Illustration of a Soft Edge Treatment for Open Waterbodies (GBLA 2004)

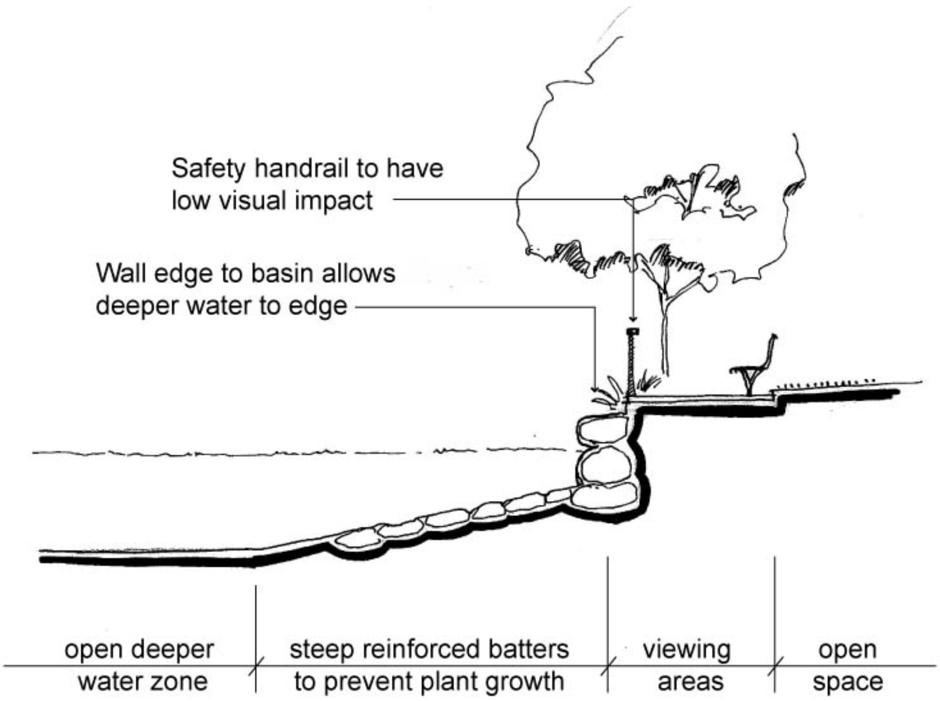


Figure 4-7: Illustration of Hard Edge Treatment for a Sediment Basin

Plate 4-2: Examples of Hard edge Treatment for Open Waterbodies

Additionally, the designs should be verified with the Building Code of Australia for compliance. An alternative to the adoption of a fence is to provide a 2.4 m ‘safety bench’ that is less than 0.2 m deep below the permanent pool level around the waterbody.

4.3.4 Step 4: Design Inflow Systems

Stormwater conveyed by a pipe or open channel would normally discharge directly into a sedimentation basin as this is often the first element of a stormwater treatment train. It will be necessary to ensure that inflow energy is adequately dissipated to prevent localised scour in the vicinity of a pipe or channel outlet.

Design of inlet structures for adequate scour protection is common hydraulic engineering practice and the reader is referred to standard hydraulic design handbooks for further guidance on design of scour prevention methods and appropriate sizing of energy dissipation structures (e.g. Henderson 1966; Chow 1959).

If conceptual design of the stormwater system identified the need to remove anthropogenic litter (i.e. industrial or commercial situations) then some form of gross pollutant trap (GPT) may be required as part of an inlet structure. The provision of a GPT will depend on catchment activities as well as any upstream measures in place. There are a number of proprietary products available for removing gross pollutants and these are discussed in Chapter 7 of *Australian Runoff Quality* (Engineers Australia 2006). The storage capacity of gross pollutant traps should be sized to ensure that maintenance (cleanout) frequency is not greater than once every 3 months.

4.3.5 Step 5: Design Outlet Structure

As outlined in Section 4.2.4, the outlet of a sedimentation basin can be configured in many ways and is generally dependant on the design flow entering the basin and the type of stormwater treatment system or conveyance system downstream of its outlet. In most cases, the outlet design of a sedimentation basin will consist of a ‘control’ outlet structure and a ‘spillway’ outlet structure:

- The ‘control’ outlet can be an overflow pit/ pipe or weir which delivers flows up to the ‘design operation flow’ (Section 4.3.1) to the downstream treatment systems.
- The ‘spillway’ outlet structure ensures that flows above the ‘design operation flow’ (Section 4.3.1) are discharged to a bypass channel or conveyance system.

Where the sedimentation basin discharges to a conveyance system (e.g. bioretention basin or piped system), a ‘control’ outlet may not be required and hence one outlet (‘spillway’ outlet) can be designed to allow discharge of all flows including flood flows.

Where the sedimentation basin is formed by constructing an embankment across a drainage gully (such as shown on Figure 4-1) it may also be possible to use an overflow pit and pipe outlet and still be able to discharge to a bioretention surface or wetland macrophyte zone.

4.3.5.1 Design of 'Control' Outlet - Overflow Pit and Pipe Outlet Configuration

For sedimentation basins that discharge directly to a treatment system (i.e. constructed wetland or bioretention basin) and the 'control' outlet structure discharging to the treatment system is an overflow pit and pipe, the following criteria apply:

- Ensure that the crest of the overflow pit is set at the permanent pool level of the sedimentation basin (which is typically a minimum of 0.3 m above the permanent water level of the downstream treatment system).
- The overflow pit is sized to convey the design operational flow (e.g. 1 year ARI). The dimension of an outlet pit is determined by considering two flow conditions: weir and orifice flow (Equations 4.4 and 4.5 below). Generally, the discharge pipe from the sedimentation basin (and downstream water levels) will control the maximum flow rate from the basin; it is therefore less critical if the outlet pit is oversized to allow for blockage.
- Provide protection against blockage by flood debris.

Plate 4-3: Debris screens in Coorparoo, Mill Park (Victoria) and Herston

The following equations apply to the design of 'control' outlet devices:

1 Weir flow condition – when free overfall conditions occur over the pit:

$$P = \frac{Q_{des}}{B \cdot C_w \cdot h^{3/2}} \qquad \text{Equation 4.4}$$

Where	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 (1.66)

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

$$A_o = \frac{Q_{des}}{B \cdot C_d \cdot \sqrt{2 \cdot g \cdot h}}$$ Equation 4.5

Where	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)

It is important that an outlet pit is prevented from blockage by debris. Design consideration needs to include a means of minimising potential blockage of the outlet structure.

The pipe that connects the sedimentation basin to the downstream treatment system (e.g. macrophyte zone of a constructed wetland or bioretention system) must have sufficient capacity to convey a 1 year ARI flow, assuming the downstream treatment system is at the permanent pool level of the sedimentation basin and without resulting in any flow in the bypass system. This ensures the majority of flows have the opportunity to enter the downstream treatment system before the bypass system is engaged. An energy dissipater is usually required at the end of the pipes to reduce velocities and distribute flows into the downstream treatment system.

If the outlet of the connection pipe is submerged, an energy loss equation can be used to estimate the pipe velocity using the following:

$$h = \frac{2 \cdot V^2}{2 \cdot g}$$ Equation 4.6

Where: h		=	head level driving flow through the pipe (defined as the 'spillway' outlet level minus the normal water level in the downstream treatment system)
	V	=	pipe velocity (m/s)
	g	=	gravity (9.79 m/s^2)

Note: the coefficient of 2 in the equation is a conservative estimate of the sum of entry and exit loss coefficients ($K_{in} + K_{out}$).

The area of pipe required to convey the 'design operation flow' (1 year ARI) is then calculated by dividing the above 'design operation flow' by the velocity. Alternatively, if the pipe outlet is not fully submerged, the orifice equation should be used (Equation 4.5) to estimate the size of the connection pipe.

An example configuration of a sedimentation basin 'control' overflow pit and pipe outlet to the macrophyte zone of a constructed wetland is provided in Figure 4-8 (over page).

4.3.5.2 Design of 'Control' Outlet – Weir Configuration

The required length of the weir for 'control' outlet operation can be computed using the weir flow equation (Equation 4.4) and the 'design operation flow' (Section 4.3.1), adopting a blockage factor of 1.0 (as weir is unlikely to become blocked by debris).

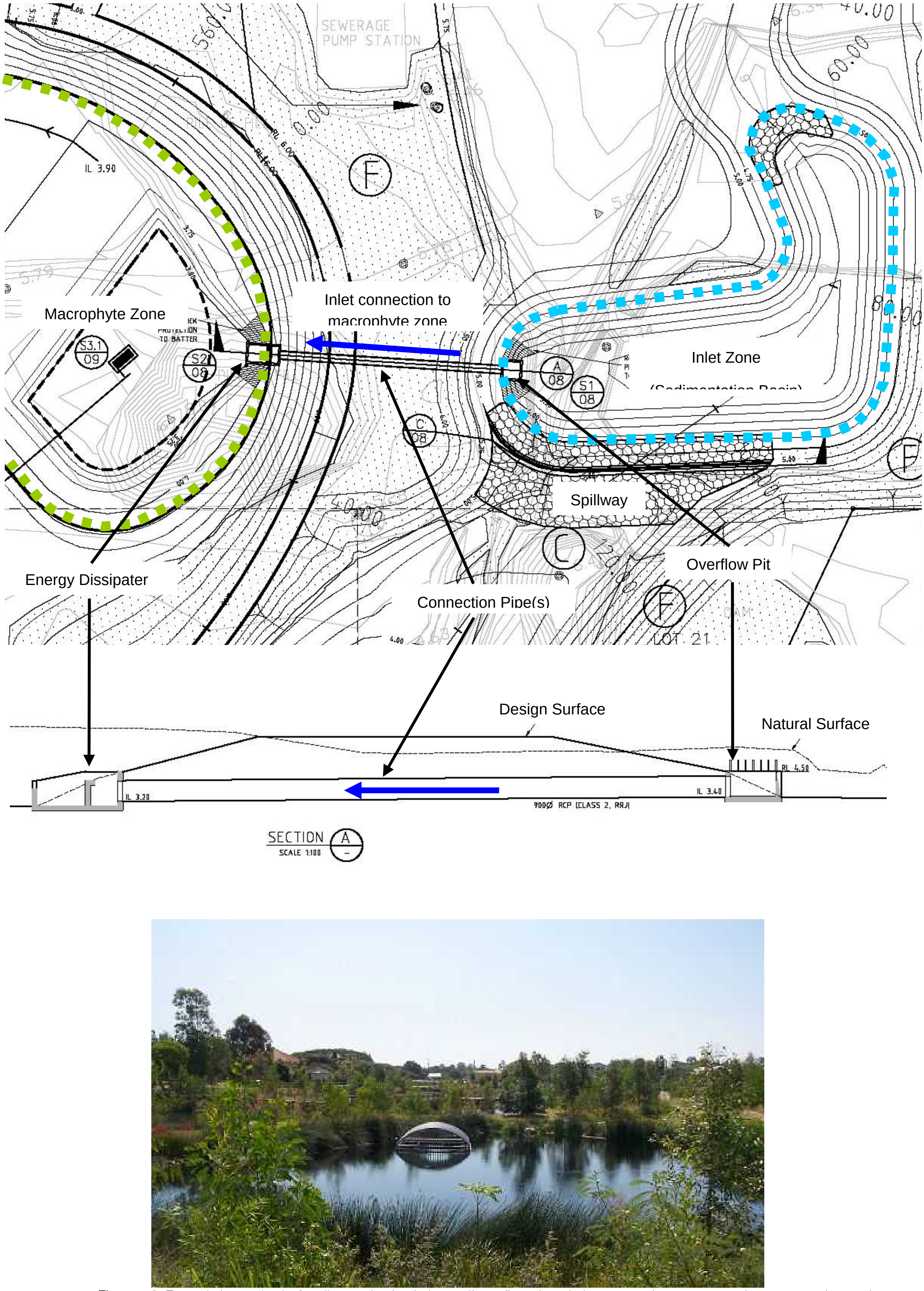


Figure 4-8: Example layout (top) of sedimentation basin 'control' overflow pit and pipe connection to a macrophyte zone and control overflow pit installation (bottom)

4.3.5.3 Design of 'Spillway' Outlet – Weir Configuration

In most applications the 'spillway' outlet weir will form part of the high flow bypass system, which protects the downstream treatment system from scouring during 'above design' storm flows. Ideally, the 'spillway' outlet weir level should be set at the top of the extended detention level of the downstream treatment system. This ensures that a significant proportion of catchment inflow will bypass the downstream treatment system once the extended detention is filled. The length of the 'spillway' outlet weir is to be sized to safely pass the maximum flow discharged into the downstream treatment system (as defined by the 'above design flow' in Section 4.3.1). The water level above the crest of the bypass weir is 0.3 m below the embankment crest separating the sedimentation basin and the downstream treatment system.

The required length of the 'spillway' outlet weir can be computed using the weir flow equation (Equation 4.4 with blockage factor equal to 1.0) and the 'above design flow' (Section 4.3.1). Plate 4-4 shows examples of 'spillway' weir outlets. The 'spillway' outlet weir should be designed using standard methods to avoid scour and erosion. Typically, a concrete sill is required with rock protection on the downslope sides of the sill.

Plate 4-4: Spillway outlet weir structure of sedimentation basins at the Gold Coast and Coorparoo

4.3.6 Step 6: Specify Vegetation

Refer to Section 4.4 and Appendix A for advice on selecting suitable plant species for planting of the littoral zones around sedimentation basins.

4.3.7 Step 7: Consider Maintenance Requirements

Consider how maintenance is to be performed on the sediment basin (e.g. how and where is access available, where is litter likely to collect etc.). A specific maintenance plan and schedule should be developed for the basin, either as part of a maintenance plan for the whole treatment train, or for each individual asset. Guidance on maintenance plans is provided in Section 4.6.

4.3.8 Design Calculation Summary

Below is a design calculation summary sheet for the key design elements of a sedimentation basin to aid the design process.

SEDIMENTATION BASIN DESIGN CALCULATION SUMMARY

	Calculation Task		CALCULATION SUMMARY Outcome	Check
	Catchment Characteristics			
		Residential	Ha	
		Commercial	Ha	
		Roads	Ha	
		Storm event entering inlet pond (minor or major)	yr ARI	
	Conceptual Design			
		Notional permanent pool depth	m	
		Permanent pool level of sedimentation basin	m AHD	
1	**Determine design flows**			
		'Design operation flow' (1 year ARI)	year ARI	
		'Above design flow' (2 to 50 year ARI)	year ARI	
	Time of concentration			
	Refer to *Handbook for Drainage: Design Criteria* (TCC 2004) and QUDM		minutes	
	Identify rainfall intensities			
		'Design operation flow' - $I_{1\ year\ ARI}$	mm/hr	
		'Above design flow'- $I_{2\ year\ ARI}$ to $I_{50\ year\ ARI}$	mm/hr	
	Design runoff coefficient			
		'Design operation flow' - $C_{1\ year\ ARI}$		
		'Above design flow'- $I_{2\ year\ ARI}$ to $I_{50\ year\ ARI}$		
	Peak design flows			
		'Design operation flow' - 1 year ARI	m^3/s	
		'Above design flow' – 2 to 50 year ARI	m^3/s	
2	**Confirm Treatment Performance of Concept Design**			
		Capture efficiency (of 125 μm sediment)	%	
		Area of sedimentation basin	m^2	
3	**Confirm size and dimension of sedimentation basin**			
		Inlet zone size		
		Area of sedimentation basin	m^2	
		Aspect ratio	L:W	
		Hydraulic efficiency		
		Depth of permanent pool	m	
	Storage volume for sediments			
		Sedimentation basin storage Volume V_s	m^3	
		Volume of accumulated sediment over 5 years ($V_{s:5yr}$)	m^3	
		$V_s > V_{s:5yr}$		
		Sediment cleanout frequency	years	

SEDIMENTATION BASIN DESIGN CALCULATION SUMMARY				
	Calculation Task		CALCULATION SUMMARY	
			Outcome	Check
	Internal batters			
		Edge batter slope	V:H	
		Fence required		
4	Design inflow systems			
		Provision of scour protection or energy dissipation		
5	Design outlet structures			
	Design of 'control' outlet - overflow pit and pipe outlet configuration			
		Overflow pit crest level	m AHD	
		Overflow pit dimension	L x W	
		Provision of debris trap		
		Connection pipe dimension	mm diam	
		Connection pipe invert level	m AHD	
	Design of 'control' outlet - weir configuration			
		Weir crest level	m AHD	
		Weir length	m	
	Design of 'spillway' outlet - weir configuration			
		Weir crest level	m AHD	
		Weir length	m	
		Depth above spillway	m	
		Freeboard to top of embankment	m	

4.4 Landscape Design Notes

The successful landscape design and integration of sedimentation basins within open space and parkland areas will ensure that visual amenity, environment, habitat, community safety and stormwater quality are all enhanced.

Within a constructed wetland treatment system, sedimentation basins provide a transition between urbanised streams – possibly piped or channelized – that may have limited access, and natural wetland systems within accessible parkland. They are located at the highest point of a constructed wetland and may provide viewing opportunities across the wetland.

Sedimentation basins are a potential place for community education (through signage and other interpretative elements) as they are large and visible (and perhaps part of a larger constructed wetland). In addition, they may be the first place in an urban water catchment where treatment takes place. They therefore make good locations to tell the story of stormwater treatment processes.

Landscape design has a key role in overcoming negative perceptions that permanent water bodies like sedimentation basins have in some communities. In the past this may have been due to legitimate pest and safety concerns that have arisen from poorly designed and/ or managed systems, particularly remnant swamps and lagoons. Additionally, these older systems may have provided poor amenity values to the community due to lack of access or industrial scale treatment infrastructure.

4.4.1 Objectives

Landscape design for sedimentation basins has five key objectives:

- Addressing stormwater quality objectives by applying adequate edge and littoral zone planting to prevent scour and erosion of batters while ensuring an unvegetated open water pool is retained.
- Addressing public safety issues by ensuring the landscape design and edge treatments restrict public access to the open water zone and allow egress where appropriate.
- Ensuring that the overall landscape design of the sedimentation basin integrates with its host natural and/ or built environment and compliments the landscape design of adjacent treatment measures (e.g. constructed wetlands or bioretention basins).
- Incorporating Crime Prevention through Environmental Design (CPTED) principles.
- Providing other landscape values, such as shade, amenity, habitat, character and place making.

4.4.2 Context and Site Analysis

The sedimentation basin can provide a positive landscape environment and needs to be responsive to the site for this to be maximized. Existing features such as slope, vegetation, waterways and soils need to be considered in planning layouts and locations when designing within constrained sites. Other factors like road layout, buildings, driveways and services can also affect layouts. With appropriate landscape design, sedimentation basins can become interesting features in the local community. Their location and function provide opportunities to view large volumes of flowing water during and just after storm events, and to observe wildlife adapted to lagoon-like environments such as cormorants, kingfishers, turtles and eels. Sedimentation basins provide an interface between fast flowing, shallow, energetic water and deep, slow and serene water. This dynamism can be exploited to provide significant place making opportunities.

Comprehensive site analysis should inform the landscape design as well as road layouts, civil works and maintenance requirements. Existing site factors such as roads, driveways, buildings, landforms, soils, plants, microclimates, services and views should be considered. For further guidance refer to the *South East Queensland WSUD Conceptual Design Guidelines* (Healthy Waterways Partnership, 2008).

4.4.3 Specific Landscape Considerations

Opportunities are available for creative design solutions to specific elements. Close collaboration between the landscape designer, ecologist, hydraulic designer, civil/ structural engineer and maintenance personnel is essential. In parklands and residential areas, a key aim is to ensure elements are sympathetic to their surroundings and are not overly engineered or industrial in style and appearance whilst achieving their desired functions. Additionally, landscape design to specific elements should aim to create places where local residents and visitors will come to enjoy and regard as an asset.

4.4.3.1 Basin Siting and Shapes

Through integrated landscape design, sedimentation basins can become important features within open space areas. Areas of open water provide passive viewing opportunities for plants and wildlife that have adapted to the urban lagoon landscapes. By siting basins such that inlet structures create dramatic "water features" in a highly visible area during high flows, basins can create invigorating large-scale urban environments (see Figure 4-9). Often the sedimentation basins are part of a broader treatment train and generally form the first part of wetlands. This allows the integrated landscape design of habitat renewal and open water vistas with public and recreational areas. This often can be part of broader community education strategy, for the role of sedimentation basins, through appropriate interpretive signage outlining both the natural habitat and water quality benefits.

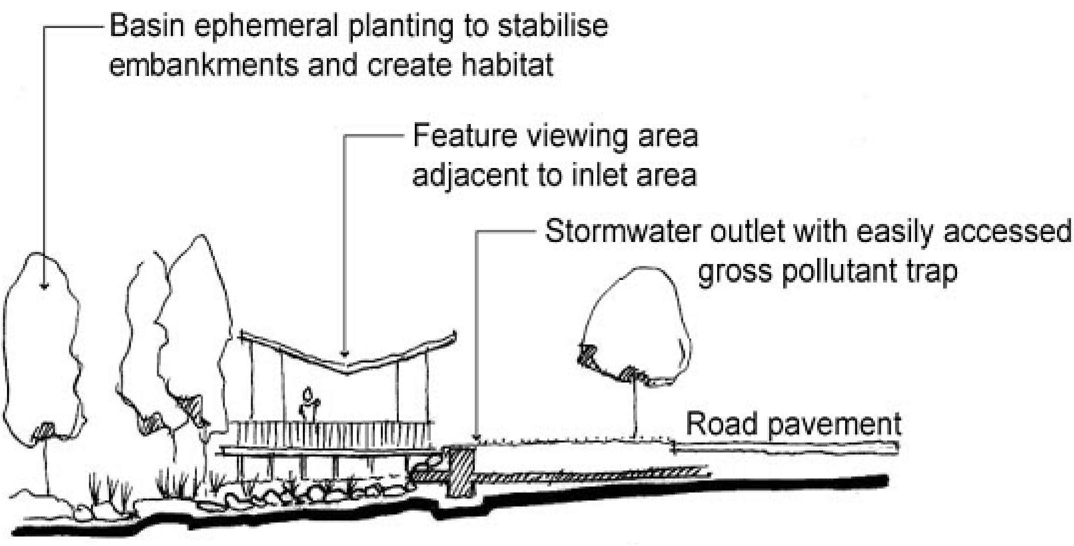


Figure 4-9: Typical Section Through Feature Inlet Structure

Basins shapes can vary widely and need to be primarily responsive to the hydraulic engineers length to width ratio, depths and inlet requirements. The landscape designer has the opportunity to shape the basin to respond to adjacent land uses (i.e. recreational spaces, local landforms and existing features). This often can result in "natural" informal shapes that provide visually aesthetic landscape outcomes. Embankments and batter profiles play an important role in providing an interesting and functional water body.

The length to width ratio of the basin should be determined by the hydraulic designer working within the site constraints (refer to section 4.3.2). Once the overall shape has been determined, one of the first considerations should be if a formal or informal style is required depending on setting. Figure 4-10 illustrates formal and informal options for a given length to width ratio.

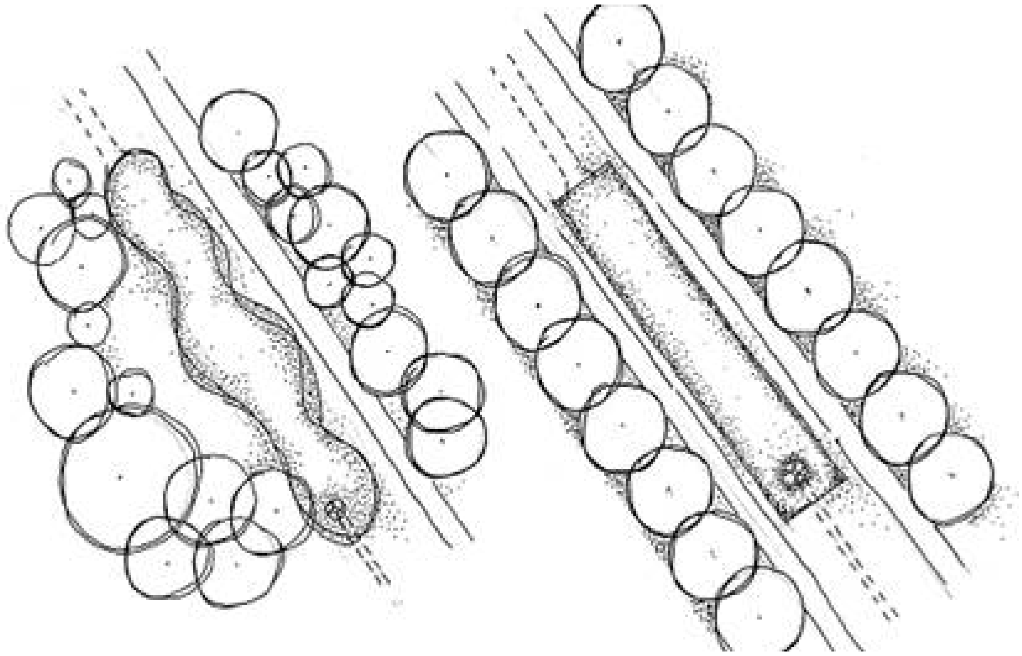


Figure 4-10: Informal and Formal Basin Configuration Given Length to Width Ratio

4.4.3.2 Basin Embankment

Where a natural look is required, the designer should explore opportunities for landform grading to the embankment to create variation in the slope. Geometric planar batters should be avoided. The grading approach also creates a diversity of habitat niches along the slope and can assist in reducing erosion. Figure 4-11 illustrates this technique. It is important that shaping to the slope does not allow areas for mosquitoes to breed such as isolated areas of stagnant water. Designing to avoid mosquitoes is discussed in detail in Chapter 6 (Section 6.2.8) with respect to constructed wetlands.

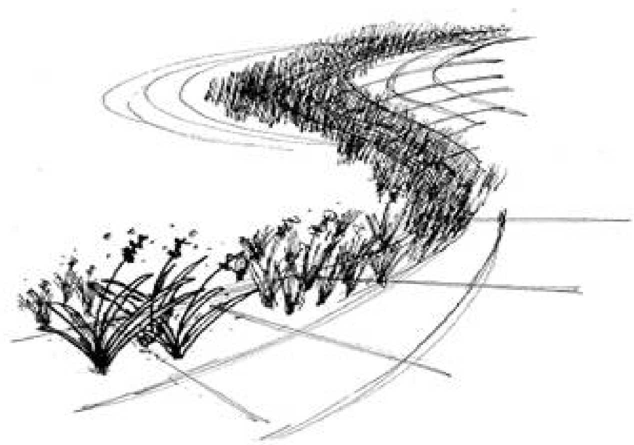


Figure 4-11: Conceptual Landform Grading of Embankment to Waters Edge

4.4.3.3 Edge Treatments and Profiles

In coordination with hydraulic engineers, the landscape design and grading of embankment batters allows a variety of edge treatments and opportunities.

The edge treatments that maximise natural habitats for flora and fauna can be facilitated by slopes flatter than 1:5 and often have benched foreshores with shallow standing water levels. This allows for safe egress from the basin. Rock edges and 'beaches' can also provide interest at key viewing areas and aid in providing further localised habitat and visual interest. This can be seen in Figure 4-6.

For areas where public access is to be restricted, batter slopes can be steeper than 1:5, and require safety fencing to restrict access. This typical treatment can also include a wall to further maximise deep, clear water. This can be seen in Figure 4-7.

Planting of sedimentation basin edges requires analysis of several issues including water depths and variances, soil and basin topsoil types, batter profiles, public access and habitat rehabilitation. For further information refer Section 4.4.4 Appropriate Plant Selection.

4.4.3.4 Basin Inlet

The basin inlet is an important place to experience the confluence of fast flowing water with still water and is a dynamic place within the local landscape. Designers have scope to approach this element in a variety of ways provided the hydraulic design is not compromised. Options to consider include:

- Using salvaged site rocks or patterned and coloured concrete to emphasise the feature and create niche habitats.
- Enhancing the microclimate created by cool running water by adding shade trees.
- Creating places to view running water. Where suitable, this can be achieved with footbridges located above the water. Such structures should be designed appropriately with consideration of life cycle costs (i.e. timber piers should not be used where contact with water occurs). Alternatively, views from the side will provide a different experience. Viewing areas should be located a minimum of 5 m from the open water body to discourage wildlife feeding.

4.4.3.5 Sediment Removal Access

As part of the siting and layout of sedimentation basins, suitable access from an adjacent roadway needs to be provided to periodically remove sediment. The landscape design of these access ramps needs to consider the visual impact created in the landscape and how this can be minimised. Access to the basin floor to remove sediments requires either the installation of a ramp/ ramps, or an access track around the perimeter for smaller basins (refer section 4.2.7). These elements are crucial to the operation of a sedimentation basin, but should be designed sensitively so they do not become visually prominent.

For both ramps and perimeter access tracks, reinforced turfing pavers should be considered as the pavement to create a green surface that blends with the surrounding plantings. Surfaces of concrete or rock should be avoided where possible. Consideration must be given to the size and weight of machinery likely to utilise the access ramp. Reinforced vegetated surfaces should be able to respond to impacts given that desilting of the basin will only be required approximately every 5 years.

Consider incorporating the sediment removal access into other landscape elements. For example, perimeter access tracks could also be used as recreational trails (in this case part of the track width could be paved using reinforced concrete). Investigate if the weir could become part of this access way. Ramps may potentially be integrated with viewing areas.

Trees and shrubs can be employed to screen these elements. The shadow cast by trees also assists in breaking up the form of linear structures so that they blend into formally designed landscapes.

Where gates and fences are required, it is important to use materials and styles that are sensitive to the setting. Products aimed for industrial applications should generally be avoided in parkland spaces, as should products designed for domestic garden situations.

4.4.3.6 Overflow Pit

Grates to overflow pits need to be designed to minimize visual impact on the landscape. The grate above the overflow pit can become an interesting local landmark, particularly if it is sited within the open water surface. Provided that the grate performs its intended function of preventing blockages by debris (refer section 4.3.5) and is structurally sound, there are opportunities for creative design solutions to this component. An important consideration is to prevent local fauna (e.g. ducks) from entering the overflow pit and becoming trapped. Investigate installing 200 mm wide perforated plates (holes to 20 mm) or similar at the base of the grate.

4.4.3.7 Weir Outlets

Weir outlets may be large items that can potentially add character to the design. Grouted rock wall or off-form concrete finishes should be investigated rather than loose dumped rocks, particularly where the weir is visible. Loose rock fill structures create glare, weed and cane toad issues. Alternatives to consider include rock pitched concrete with planting pockets to soften the visual impact of reinforces weirs. Refer to for a typical treatment in Figure 4-12.

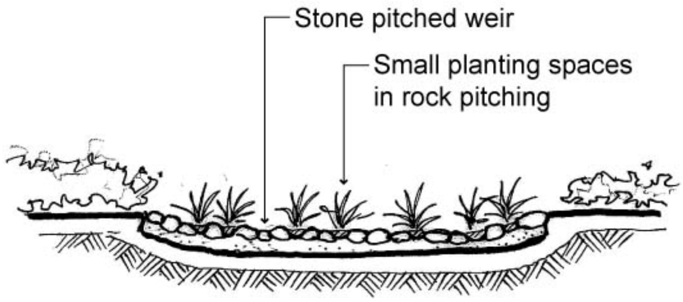


Figure 4-12: Typical weir outlet with Planting Areas

4.4.3.8 Viewing Area

In parkland areas, turfed spaces within barrier fencing offer a simple low maintenance solution. Figure 4-13 provides illustrations. Constructed decks may be appropriate in more urbanised areas. Hardwood timber construction should generally be avoided due to its inherent life-cycle costs.

Viewing areas should be located with a minimum distance of 5 m separating the viewing area from the waterbody, so that wildlife feeding is discouraged.

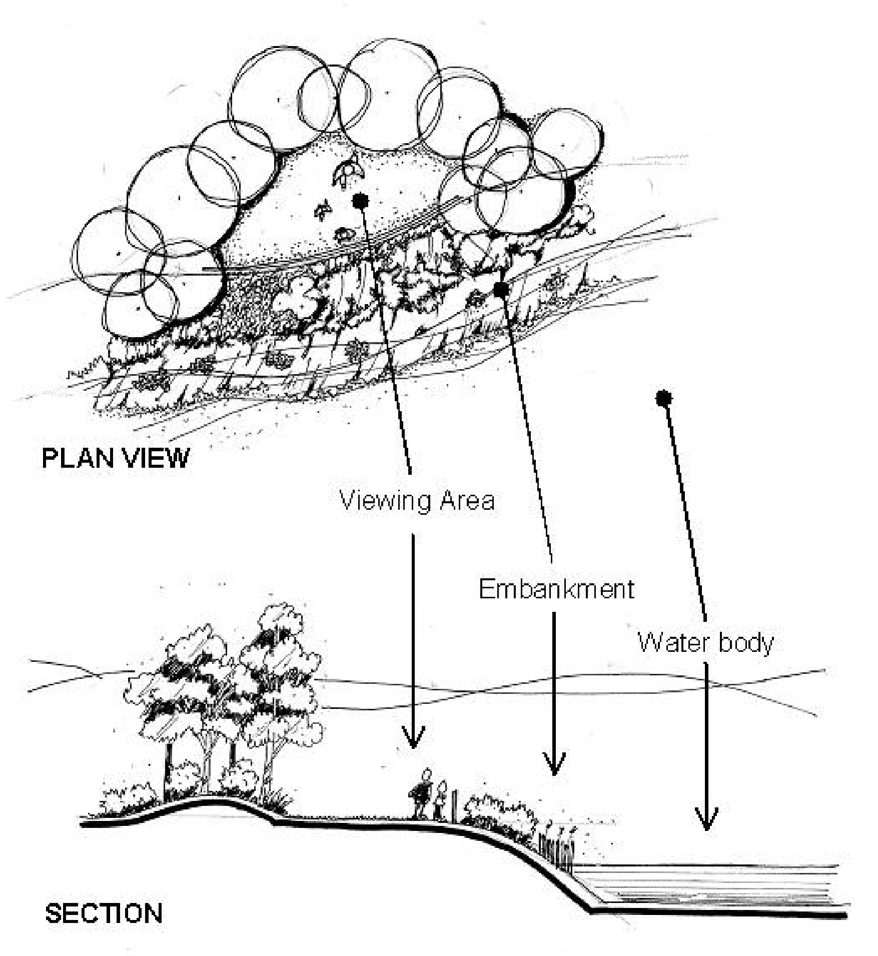


Figure 4-13: Turfed Viewing Areas with Barrier Fencing and Planting

4.4.3.9 Fencing

Where fences are required to sedimentation basin embankment edges, layout and design of fencing is important in creating an overall attractive landscape solution. Fence styles need to respond to functional requirements but also the contextual setting of the sedimentation basin i.e. if it's an urban residential or open space/ parkland area.

If fences are used, consider styles suitable for parkland and urban/ suburban contexts. Products designed for domestic gardens or industrial applications should generally be avoided. Fence types are similar to manufactured pool safety fences to relevant Australian standards. By specifying a black finish, and allowing for a screening garden in front of fences, the visual impact can be greatly reduced. Further safety issues are discussed in Section 5.4).


Plate 4-5: Typical examples of safety fencing to water edge

4.4.3.10 Signage and Interpretation

All signage and artwork proposed for public information must be approved by Townsville City Council. Signage is an important part of educating the general public on the positive benefits of WSUD strategies. It can be based on stormwater quality information but also educate on waterways, habitat created, local fauna and flora. The following key issues and considerations need to be part of the signage strategy:

- Signage where possible should be kept simple and easy to interpret. Detailed design plans and system flow charts should be avoided, as these are often difficult to understand. Artistic illustrations may be used to explain processes. Text should be kept to a minimum. Annotated photographs or sketches are a more effective way of explaining processes;
- Signage location should take into account pathway networks, designated feature "people places" and locality to key areas requiring interpretive signage;
- Signage materials need to be low maintenance and durable, resistant to UV and graffiti and be easily installed.

Plate 4-6: Annotated sketches/ photographs are an effective way of explaining treatment process to the public

4.4.3.11 Baffles and Flow Spreaders

Within highly visible parkland and urban settings, investigate the use of interesting forms, patterns and colours that still achieve the desired function. For example, off-form concrete patterning, artwork to downstream side, coloured concrete, or organic shapes could be employed.

4.4.4 Sedimentation Basin Vegetation

Planting for sedimentation basins may consist of several vegetation types:

- Fringing vegetation should include Shallow Marsh species planted from design water level to 0.5 m below (refer to Appendix A for suitable plant species).
- Littoral zone planting from design water level to top of batter (refer to Appendix A for suitable plant species).
- Parkland plants, including existing vegetation, adjacent to the sediment basin.

4.4.4.1 Shallow Marsh fringing vegetation (from –0.5 m to 0 m)

Plant selection for sedimentation basin edges need to respond to edge profiles, water depths and functionality. Dense edge planting should occupy habitat to avoid undesirable plant species establishing and provide a public safety barrier to the open water. Appendix A provides guidance on selecting suitable plant species and cultivators that deliver the desired stormwater quality objectives for sedimentation basins. In general, vegetation should provide:

- Densely planted barrier to prevent the spread of weedy species
- Scour and erosion protection to the basin embankment
- A buffer between water body and parkland that inhibits access.

4.4.4.2 Littoral Zone (above 0 m) and Open Space Vegetation

The battered embankment and fringing vegetation to open space or urban areas is important in providing soil stability, screening, habitat, visual amenity and interest. Between the marsh zone and the top of the embankment, trees, shrubs and groundcovers can be selected. Some key consideration when selecting appropriate sedimentation basin embankment planting include:

- Selecting locally endemic groundcovers, particularly for slopes greater than 1 in 3 with erodable soils, with matting or rhizomataceous root systems to assist in binding the soil surface during the establishment phase.
- Preventing marsh zone plants from being shaded out by planting to ensure an open canopy, minimising tree densities at the waters edge and choosing species such as Melaleuca that allow sunlight to penetrate the tree canopy.
- Allowing excavators and other vehicles access to the water body for sediment removal purposes (refer to Section 4.4.3.4 below for further guidance).
- Locating and selecting species that in key view areas are below 1.0m high and form a dense habitat to discourage public access to the water edge.
- Screening planting that provides interest in form and colour, screens fences where applicable and are locally endemic.

Open space vegetation may be of a similar species and layout to visually integrate the sedimentation basin with its surrounds. Alternatively, vegetation of a contrasting species and/ or layout may be selected to highlight the water body as a feature within the landscape. Turf is an ideal consideration for accessible open space.

A wide range of species is at the designer's disposal depending on the desired scheme. Refer to relevant local guidelines and Appendix A.

4.4.5 Safety Issues

4.4.5.1 Crime Prevention Through Environmental Design (CPTED)

The standard principles of informal surveillance, exclusion of places of concealment and open visible areas apply to the landscape design of sedimentation basins. Where planting may create places of concealment or hinder informal surveillance, groundcovers and shrubs should not generally exceed 1 m in height. For specific guidance on CPTED requirements the designer should refer to relevant guidelines from Townsville City Council.

4.4.5.2 Restricting Access to Open Water

Fences or vegetation barriers to restrict access should be incorporated into sediment basin areas, particularly on top of concrete or stone walls where:

- There is risk of serious injury in the event of a fall (over 0.5 m high and too steep to comfortably walk up/ down or the lower surface or has sharp or jagged edges).
- There is a high pedestrian or vehicular exposure (on footpaths, near bikeways, near playing/ sporting fields, near swings and playgrounds etc).
- Water ponds to a depth of greater than 300 mm on a constructed surface of concrete or stone. Natural water features are exempt.
- Water is expected to contain concentrated pollutants.
- Grassed areas requiring mowing abut the asset.

Fences considered appropriate are:

- Pool fences in accordance with Australian Standards (for areas adjacent to playgrounds/ sports fields where a child drowning or infection hazard is present).
- Galvanised tubular handrails (without chain wire) in other areas.
- Dense vegetative hedges.

Dense littoral planting around the sedimentation basin (with the exception of any maintenance access and dewatering areas) will deter public access to the open water and create a barrier to improve public safety. Careful selection of plant species (e.g. tall, dense or spiky species) and planting layouts can improve safety as well as preventing damage to the vegetation by trampling.

Dense vegetation (hedge) at least 2 m wide and 1.2 m high (minimum) may be suitable if vandalism is not a demonstrated concern (this may be shown during the initial 12 month maintenance period). A temporary fence (e.g. 1.2 m high silt fence) will be required until the vegetation has established and becomes a deterrent to pedestrians/ cyclists.

An alternative to the adoption of a barrier/ fence is to provide a 2.4 m ‘safety bench’ that is less than 0.2 m deep below the permanent pool level around the waterbody. This is discussed in Section 4.3.3 with respect to appropriate batter slopes.

4.5 Construction and Establishment Advice

This section provides general advice for the construction and establishment of sedimentation basins and key issues to be considered to ensure their successful establishment and operation. Some of the issues raised have been discussed in other sections of this chapter and are reiterated here to emphasise their importance based on observations from construction projects around Australia.

4.5.1 Staged Construction and Establishment Method

It is important to note that delivering sedimentation basins can be a challenging task in the context of a large development site and associated construction and building works. Therefore, sedimentation basins require a careful construction and establishment approach to ensure the wetland establishes in accordance with its design intent. The following sections outline a recommended staged construction and establishment methodology for sedimentation basins based on the methods presented in Leinster (2006).

4.5.1.1 Construction and Establishment Challenges

There exist a number of challenges that must be appropriately considered to ensure successful construction and establishment of sedimentation basin. These challenges are best described in the context of the typical phases in the development of a Greenfield or Infill development, namely the Subdivision Construction Phase and the Building Phase (see Figure 4-14).

- <u>Subdivision Construction</u> - Involves the civil works required to create the landforms associated with a development and install the related services (roads, water, sewerage, power etc.) followed by the landscape works to create the softscape, streetscape and parkscape features. The risks to successful construction and establishment of the WSUD systems during this phase of work have generally related to the following:

- Construction activities which can generate large sediment loads in runoff
- Construction traffic and other works can result in damage to the sedimentation basins.

Importantly, all works undertaken during Subdivision Construction are normally 'controlled' through the principle contractor and site manager. This means the risks described above can be readily managed through appropriate guidance and supervision.

- Building Phase - Once the Subdivision Construction works are complete and the development plans are sealed then the Building Phase can commence (i.e. construction of the houses or built form). This phase of development is effectively 'uncontrolled' due to the number of building contractors and sub-contractors present on any given allotment. For this reason the Allotment Building Phase represents the greatest risk to the successful establishment of sedimentation basins.

4.5.1.2 Staged Construction and Establishment Method

To overcome the challenges associated within delivering sedimentation basins a Staged Construction and Establishment Method should be adopted (see Figure 4-14):

- Stage 1: Functional Installation - Construction of the functional elements of the sedimentation basin as part of the Subdivision Construction and allowing the basin to form part of the sediment and erosion control strategy.
- Stage 2: Sediment and Erosion Control – During the Building Phase the sedimentation basin will form part of the sediment and erosion control strategy to protect downstream aquatic ecosystems.
- Stage 3: Operational Establishment - At the completion of the Building Phase, the sedimentation basins can be desilted to establish the design bathymetry and landscaped.

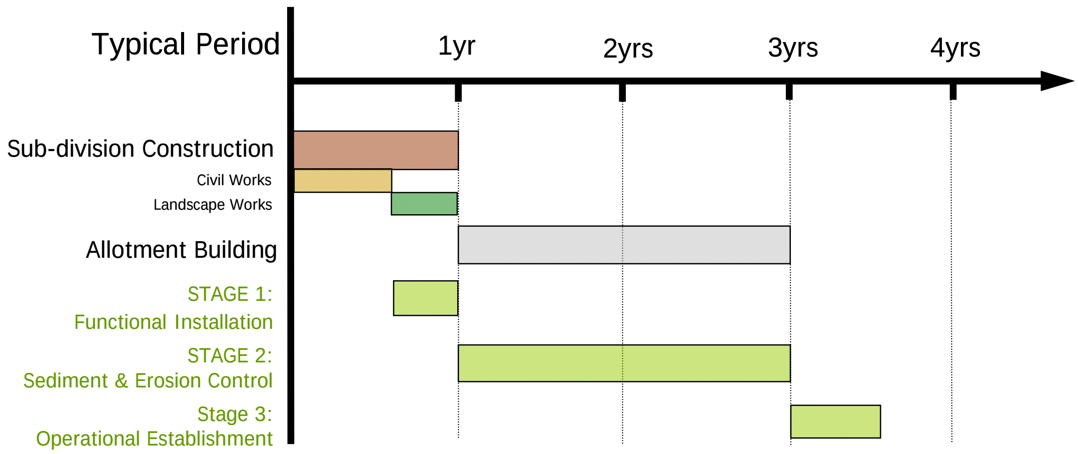


Figure 4-14: Staged Construction and Establishment Method

4.5.2 Construction Tolerances

It is important to emphasise the significance of tolerances in the construction of sedimentation basins. Ensuring the relative levels of the control structures are correct is particularly important to achieve appropriate hydraulic functions. Generally control structure tolerance of plus or minus 5 mm is considered acceptable.

Additionally the bathymetry of the sedimentation basin must ensure appropriate storage is available for accumulated sediment. In this regarding an earthworks tolerance of plus or minus 25 mm is considered acceptable.

4.5.3 Sourcing Sedimentation Basin Vegetation

In the majority of cases, the sedimentation basin will form an inlet pond to a constructed wetland or bioretention basin. In such cases, the landscape and vegetation design of the sedimentation basin will be undertaken in conjunction with the vegetation design of the other treatment measures and hence ordering of plant stock can be combined into one order. The species listed in Table A-2 (Appendix A) are generally available commercially from local native plant nurseries. Availability is, however, dependent upon many factors including demand, season and seed availability. To ensure the planting specification can be accommodated, the minimum recommended lead-time for ordering plants is 3-6 months. This generally allows adequate time for plants to be grown to the required size, so they are completely inundated by water for extended times. The following sizes are recommended as the minimum:

- Viro Tubes — 50 mm wide x 85 mm deep
- 50 mm Tubes — 50 mm wide x 75 mm deep
- Native Tubes — 50 mm wide x 125 mm deep

4.5.4 Topsoil Specification and Preparation

During the sedimentation basin construction process, topsoil is to be stripped and stockpiled for possible reuse as a plant growth medium. It is important to test the quality of the local topsoil, which is likely to have changed from its pre-European native state due to prior land uses such as farming and industry, to determine the soils suitability for reuse as a plant growth medium. Remediation may be necessary to improve the soils capacity to support plant growth and to suit the intended plant species. Soils applied to the littoral zones of sedimentation basins must also be free from significant weed seed banks as labour intensive weeding can incur large costs in the initial plant establishment phase. On some sites, topsoils may be nonexistent and material will need to be imported.

The installation of horticultural soils should follow environmental best practices and include:

- Preparation of soil survey reports including maps and test results at the design phase.
- Stripping and stockpiling of existing site topsoils prior to commencement of civil works.
- Deep ripping of subsoils using a non-inversion plough.
- Reapplication of stockpiled topsoils and, if necessary, remedial works to suit the intended plant species.
- Addition where necessary, of imported topsoils (certified to AS 4419-2003).

The following minimum topsoil depths are required:

- 150 mm for turf species.
- 300 mm for groundcovers and small shrubs.
- 450 mm for large shrubs.
- 600 mm for trees.

4.5.5 Vegetation Establishment

4.5.5.1 Timing for Planting

Timing of vegetation planting is dependent on a suitable time of year (and potential irrigation requirements) as well as timing in relation to the phases of development. October and November are considered ideal times to plant vegetation in treatment elements. This allows for adequate establishment/ root growth before the heavy summer rainfall period but also allows the plants to go through a growth period soon after planting, resulting in quicker establishment. Planting late in the year also avoids the dry winter months, reducing maintenance costs associated with watering. Construction planning and phasing should endeavour to correspond with suitable planting months wherever possible. However, as lead times from earthworks to planting can often be long, temporary erosion controls (e.g. use of matting or sterile grasses to stabilise exposed batters) should always be used prior to planting.

4.5.5.2 Water Level Manipulation

To maximise the chances of successful vegetation establishment, the water level of the sedimentation basin is to be manipulated in the early stages of vegetation growth. When first planted, vegetation in the deep marsh zones may be too small to be able to exist in their prescribed water depths (depending on the maturity of the plant stock provided). Macrophytes intended for the deep marsh sections will need to have half of their form above the water level, which may not be possible if initially planted at their intended depth. Similarly, if planted too deep, the young submerged plants will not be able to access sufficient light in the open water zones. Without adequate competition from submerged plants, phytoplankton (algae) may proliferate.

4.5.5.3 Weed Control

Weed management in sedimentation basins is important to ensure that weeds do not out compete the species planted for the particular design requirements. This may also include some native species like Phragmites that naturally can appear in constructed wetlands and out-compete other more important planted species.

Conventional surface mulching of the wetland littoral berms with organic material like tanbark is not recommended. Most organic mulch floats and water level fluctuations and runoff typically causes this material to be washed into the wetland with a risk of causing blockages to outlet structures. Mulch can also increase the wetland organic load, potentially increasing nutrient concentrations and the risk of algal blooms. Adopting high planting density rates and if necessary applying a suitable biodegradable erosion control matting to the wetland batters (where appropriate), will help to combat weed invasion and will reduce maintenance requirements for weed removal. If the use of mulch on the littoral zones is preferred, it must be secured in place with appropriate mesh or netting (e.g. jute mesh).

4.5.5.4 Watering

Regular watering of the littoral and ephemeral marsh zone vegetation during the plant establishment phase is essential for successful establishment and healthy growth. The frequency of watering to achieve successful plant establishment is dependent upon rainfall, maturity of planting stock and the water level within the wetland. However, the following watering program is generally adequate but should be adjusted (i.e. increased) as required to suit site conditions:

- Week 1-2 3 visits/ week
- Week 3-6 2 visits/ week
- Week 7-12 1 visit/ week

After this initial three month period, watering may still be required, particularly during the first winter (dry period). Watering requirements to sustain healthy vegetation should be determined during ongoing maintenance site visits.

4.6 Maintenance Requirements

- Sediment basins treat runoff by slowing flow velocities and promoting settlement of coarse to medium sized sediments. Maintenance revolves around ensuring inlet erosion protection is operating as designed, monitoring sediment accumulation and ensuring that the outlet is not blocked with debris. The outlets from sedimentation basins are to be designed such that access to the outlet does not require a water vessel. Maintenance of the littoral vegetation including watering and weeding is also required, particularly during the plant establishment period (first two years).
- Inspections of the inlet configuration following storm events should be made soon after construction to check for erosion. In addition, regular checks of sediment build up will be required as sediment loads from developing catchments vary significantly. The basins must be cleaned out if more than half full of accumulated sediment.
- Similar to other types of WSUD elements, debris removal is an ongoing maintenance requirement. Debris, if not removed, can block inlets or outlets, and can be unsightly if deposited in a visible location. Inspection and removal of debris should be done regularly and debris removed whenever it is observed on the site.
- Typical maintenance of sedimentation basins will involve:
- Routine inspection of the sedimentation basin to identify depth of sediment accumulation, damage to vegetation, scouring or litter and debris build up (after first 3 significant storm events and then at least every 3 months).
- Routine inspection of inlet and outlet points to identify any areas of scour, litter build up and blockages.
- Removal of litter and debris.
- Removal and management of invasive weeds (both terrestrial and aquatic).
- Periodic (usually every 5 years) draining and desilting, which will require excavation and dewatering of removed sediment (and disposal to an approved location).
- Regular watering of littoral vegetation during plant establishment (refer section 4.4.6).
- Replacement of plants that have died (from any cause) with plants of equivalent size and species as detailed in the planting schedule.

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

All maintenance activities must be specified in a maintenance plan (and associated maintenance inspection forms) to be developed as part of the design process (Step 7). Maintenance personnel and asset managers will use this plan to ensure the sediment basins continue to function as designed.

The maintenance plans and forms must address the following:

- Inspection Frequency
- Maintenance Frequency
- Data Collection/ Storage Requirements (i.e. during inspections)
- Detailed Clean Out Procedures (main element of the plans) including:
    - equipment needs
    - maintenance techniques
    - occupational health and safety
    - public safety
    - environmental management considerations
    - disposal requirements (of material removed)
    - access issues
    - stakeholder notification requirements

    - data collection requirements (if any)
- Design Details.

An approved maintenance plan is required prior to asset transfer to Council.

An example operation and maintenance inspection form is included in the checking tools provided in Section 4.7. These forms must be developed on a site specific basis as the configuration and nature of sediment basins varies significantly.

4.7 Checking Tools

This section provides a number of checking aids for designers and Council development assessment officers. In addition, Section 4.6.5 provides general advice for the construction and establishment of sedimentation basins and key issues to be considered to ensure their successful establishment and operation based on observations from construction projects around Australia.

Checking tools include:

- Design Assessment Checklist.
- Construction Checklist (during and post).
- Operation and Maintenance Inspection Form.
- Asset Transfer Checklist (following 'on-maintenance' period).
- Construction and Establishment Advice.

4.7.1 Design Assessment Checklist

The checklist on page 4-35 presents the key design features that are to be reviewed when assessing a design of a sedimentation basin. These considerations include (but not limited to) configuration, safety, maintenance and operational issues that should be addressed during the design phase. Where an item receives a 'N' from the review process, 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 installation. Development proponents will need to ensure that all relevant permits are in place. These can include permits to clear vegetation, to dredge, create a waterbody, divert flows or disturb habitat.

4.7.2 Construction Checklist

The checklist on page 4-36 presents the key items to be reviewed when inspecting the sediment basin during and at the completion of construction. The checklist is to be used by Construction Site Supervisors and local authority Compliance Inspectors to ensure all the elements of the basin have been constructed in accordance with the design. If an item receives an 'N' in Satisfactory criteria then appropriate actions must be specified and delivered to rectify the construction issue before final inspection sign-off is given.

4.7.3 Operation and Maintenance Inspection Form

The example form on page 4-37 should be developed and 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 1 to 6 months depending on the size and complexity of the system. More detailed site specific maintenance schedules should be developed for major sedimentation basins and include a brief overview of the operation of the system and key aspects to be checked during each inspection.

4.7.4 Asset Transfer Checklist

Land ownership 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. The table on page 4-38 provides an indicative asset transfer checklist.

Sedimentation Basin Design Assessment Checklist				
Basin Location:				
Hydraulics:	Design operational flow (m^3/s):	Above design flow (m^3/s):		
Area:	Catchment Area (ha):	Basin Area (ha):		
TREATMENT			Y	N
MUSIC modelling performed?				
BASIN CONFIGURATION			Y	N
Discharge pipe/structure to sedimentation basin sufficient for design flow?				
Scour protection provided at inlet?				
Basin located upstream of treatment system (i.e. macrophyte zone of wetland)?				
Configuration of basin (aspect, depth and flows) allows settling of particles >125 μm?				
Basin capacity sufficient for desilting period >=5 years?				
Maintenance access allowed for into base of sediment basin?				
Public access to basin prevented through dense vegetation or other means?				
Gross pollutant protection measures provided on inlet structures where required?				
Freeboard provided to top of embankment?				
Public safety design considerations included in design and safety audit of publicly accessible areas undertaken?				
Overall shape, form, edge treatment and planting integrate well (visually) with host landscape?				
OUTLET STRUCTURES			Y	N
'Control' outlet structure required?				
'Control' outlet structure sized to convey the design operation flow?				
Designed to prevent clogging of outlet structures (i.e. provision of appropriate grate structures)?				
'Spillway' outlet control (weir) sufficient to convey 'above design flow'?				
'Spillway' outlet has sufficient scour protection?				
Visual impact of outlet structures has been considered?				
COMMENTS				

Sedimentation Basin Construction Inspection Checklist

Site:	Inspected by:
	Date:
	Time:
Constructed by:	Weather:
	Contact during site visit:

Items inspected	Checked		Satisfactory		Items inspected	Checked		Satisfactory	
	Y	N	Y	N		Y	N	Y	N
DURING CONSTRUCTION									
A. FUNCTIIONAL INSTALLATION									
Preliminary works					Structural components (continued)				
1. Erosion and sediment control plan adopted					19. No seepage through banks				
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				
B. Earthworks					23. Provision of maintenance drain				
5. Integrity of banks					24. Collar installed on pipes				
6. Batter slopes as plans					Vegetation				
7. Impermeable (eg. clay) base installed					25. Stabilisation immediately following earthworks				
8. Maintenance access (eg. ramp) installed					26. Weed removal prior to planting				
9. Compaction process as designed					27. Planting as designed (species and densities)				
10. Level of base, banks/ spillway as designed					28. Vegetation layout and densities as designed				
11. Check for groundwater intrusion									
12. Stabilization with sterile grass					B. EROSION AND SEDIMENT CONTROL				
Structural components					29. Sediment basins to be used during construction				
13. Location and levels of outlet as designed					30. Stabilisation immediately following earthworks and planting of terrestrial landscape around basin				
14. Safety protection provided					31. Silt fences and traffic control in place				
15. Pipe joints and connections as designed									
16. Concrete and reinforcement as designed					C. OPERATIONAL ESTABLISHMENT				
17. Inlets appropriately installed					32. Sediment basin desilted				
18. Inlet energy dissipation installed									

Items inspected	Checked		Satisfactory		Items inspected	Checked		Satisfactory	
	Y	N	Y	N		Y	N	Y	N
FINAL INSPECTION									
1. Confirm levels of inlets and outlets					8. Check for uneven settling of banks				
2. Confirm structural element sizes					9. Evidence of stagnant water, short circuiting or vegetation scouring				
3. Check batter slopes					10. Evidence of litter or excessive debris				
4. Vegetation plantings as designed					11. Inlet erosion protection working				
5. Erosion protection measures working					12. Maintenance access provided				
6. Maintenance access provided					13. Construction generated sediment removed				
7. Public safety adequate					14. Provision of removed sediment drainage area				

COMMENTS ON INSPECTION

ACTIONS REQUIRED
1.
2.
3.
4.
Inspection officer signature:

Sedimentation Basin Maintenance Checklist			
Inspection Frequency:	1 to 6 monthly	Date of Visit:	
Location:			
Description:			
Site Visit by:			

INSPECTION ITEMS	Y	N	Action Required (details)
Litter accumulation?			
Sediment accumulation at inflow points?			
Sediment requires removal (record depth, remove if >50%)?			
All structures in satisfactory condition (pits, pipes, ramps etc)?			
Evidence of dumping (building waste, oils etc)?			
Littoral vegetation condition satisfactory (density, weeds etc)?			
Replanting required?			
Weeds require removal from within basin?			
Settling or erosion of bunds/batters present?			
Damage/vandalism to structures present?			
Outlet structure free of debris?			
Maintenance drain operational (check)?			
Resetting of system required?			
COMMENTS			

Asset Transfer Checklist		
Asset Description:		
Asset ID:		
Asset Location:		
Construction by:		
'On-maintenance' Period:		
TREATMENT	Y	N
System appears to be working as designed visually?		
No obvious signs of under-performance?		
MAINTENANCE	Y	N
Maintenance plans and indicative maintenance costs provided for each asset?		
Vegetation establishment period completed (2 years?)		
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?		
COMMENTS		

4.8 Sedimentation Basin Worked Example

A constructed wetland system is proposed to treat runoff from a freeway in the Townsville region. A sedimentation basin forms the 'inlet zone' of the wetland system. This worked example focuses on the design of the sedimentation basin component of the system. A photograph of a similar system is shown in Plate 4-7.

Plate 4-7: Example Sedimentation Basin Configuration

The site is triangular in shape with a surface area of approximately 7,000 m2 as shown in Figure 4-15. Road runoff is conveyed by roadside open channels and conventional stormwater pipes (up to the 50 year ARI event) to a single outfall that discharges to the top apex of the sedimentation basin site as shown in Figure 4-15. Approximately 1.0 km of the freeway, with a total contributing area of 8 ha (90 % impervious), discharges to the sedimentation basin. The site of the sedimentation basin has a fall of approximately 2 m (from 5 m AHD to 3 m AHD) towards a watercourse.

The conceptual design process established the following key design elements to ensure effective operation of the constructed wetland and sedimentation basin:

- Notional permanent pool depth of sedimentation basin of 2 m
- Permanent pool 0.3 m (3.8 m AHD)
- Wetland macrophyte zone extended detention depth of 0.5 m (permanent water level of 3.5 m AHD)
- Sedimentation basin permanent pool level ('control' outlet pit level) 0.3 m above the permanent pool level of the wetland (3.8 m AHD)
- 'Spillway' outlet weir set at the top of extended detention for the wetland and 0.3 m above the sediment basin permanent pool level (4.1 m AHD).

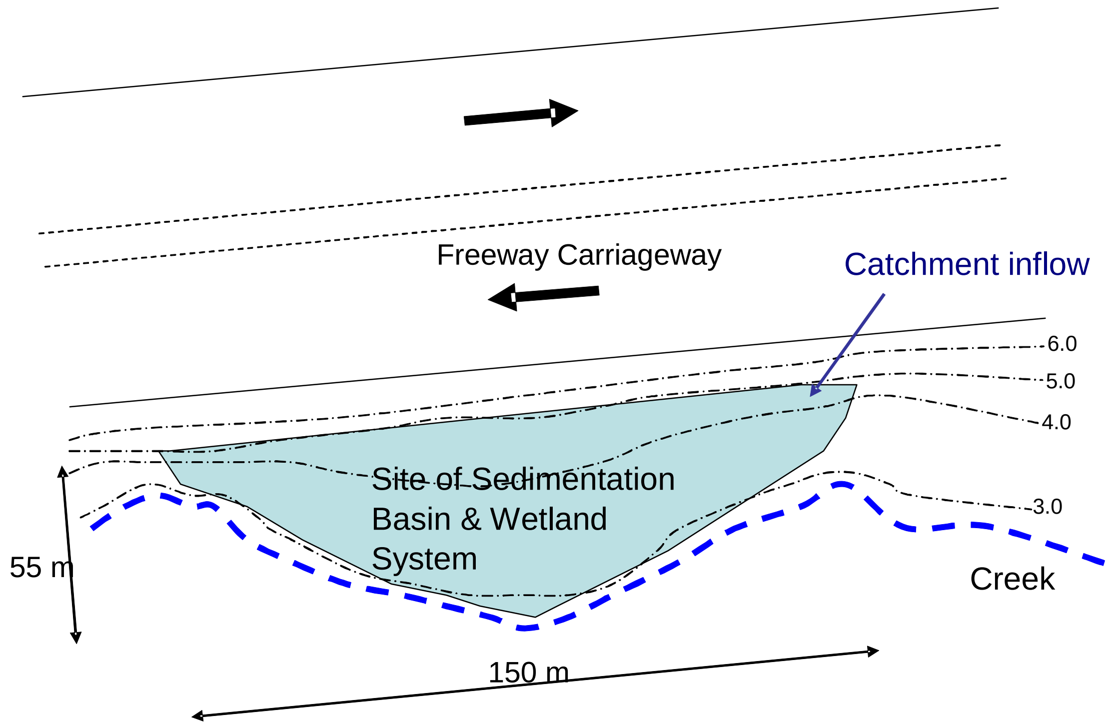


Figure 4-15: Layout of Proposed site for Sedimentation Basin

Design Objectives

As the sedimentation basin forms part of a treatment train (with the wetland macrophyte zone downstream) the design requirements of the sedimentation basin system need to:

- Promote sedimentation of particles larger than 125 μm with 90 % capture efficiency for flows up to the 'design operation flow' (1 year ARI peak discharge).
- Provide for connection to the downstream wetland macrophyte zone with discharge capacity corresponding to the 'design operation flow' (1 year ARI peak discharge).
- Provide for bypass of the 'above design flow' around the wetland macrophyte zone when the inundation of the macrophyte zone reaches the design maximum extended detention depth.

4.8.1 Step 1: Determine Design Flows

4.8.1.1 Design Operation Flow

As described in Section 4.3.1, the 'design operation flow' is defined as the 1 year ARI and provides a basis for sizing the sedimentation basin area and 'control' outlet structure.

Design flows are established using the Rational Method and the procedures provided in QUDM (DNRW, IPWEA & BCC 1998). The site has one contributing catchment being 8 ha in area, 1 km long (along the freeway) and drained by roadside open channels and stormwater pipes.

For the purposes of establishing the time of concentration, the flow velocity in the roadside channels and underground pipes is estimated at 1 m/s. Therefore:

Time of concentration (t_c) = 1000 m/1 m/s

= 1000s

= 17 minutes

The coefficient of runoffs were calculated using the *Handbook for Drainage: Design Criteria* (TCC, 2004) and Table 4.05.2 of QUDM (DNRW, IPWEA & BCC 1998) as follows:

C_{10} = 0.88 (*QUDM*)

Table 4-2: Runoff Coefficients

	C Runoff		
ARI	1	10	50
QUDM Factor	0.8	1	1.15
C_{ARI}	0.70	0.88	1.01

Rational Method $Q = CIA/360$

Where: C_1 = 0.88

Catchment area = 8 ha

t_c = 17 mins

I_1 = 74.1 mm/hr

I_{50} = 197 mm/hr

Design operation flow ($Q_{1\ year\ ARI}$) = 1.45 m^3/s

4.8.1.2 Above Design Flow

The 'above design flow' is used to design the 'spillway' outlet structure which forms part of the high flow bypass around the wetland. In this case, the major flood flow (50 year ARI) enters the sedimentation basin and thus forms the 'above design flow'.

Rational Method $Q = CIA/360$

Where A = 8 ha

C_{50} = 1.01

I_{50} = 197 mm/hr

'Above design flow' ($Q_{50\ year\ ARI}$) = 4.42 m^3/s

4.8.2 Step 2: Confirm Treatment Performance of Concept Design

An initial estimate of the sedimentation basin area can be established using the curves provided in Figure 4-4. Assuming a notional permanent pool depth of 2 m, a sedimentation basin area of approximately 340 m^2 is required to capture 90 % of the 125 μm particles for flows up to the design operation flow (1 year ARI = 1.45 m^3/s).

4.8.3 Step 3: Confirm Size and Dimensions of the Sedimentation Basin

4.8.3.1 Sedimentation Basin Area

Confirmation of the sedimentation basin area is provided by using Equation 4.1:

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

Based on the description of the sedimentation basin and wetland provided in Section 4.8.1, the following applies:

d_p = 2.0 m

$d*$ = 1.0 m

d_e = 0.3 m

V_s = 0.011 m/s for 125 μm particles

R = 0.9 (90% removal target)

Q = design operation flow rate (1 year ARI) = 1.45 m^3/s

An aspect ratio of approximately 1 (W) to 4 (L) is adopted based on the available space (Figure 4-15). Using Figure 4-5 (configuration I), the hydraulic efficiency (λ) is estimated to be approximately 0.4. This value is less than desirable; however, site constraints prevent any other configuration. The turbulence factor (*n*) is computed from Equation 4.2 to be 1.67. Thus:

$\lambda = 0.4$

$n = 1.67$

Inserting the above parameters into Equation 4.1, the required sedimentation basin area to achieve a target sediment (125 μm) capture efficiency of 90 % is 368m2. With an approximate W to L ratio of 1:4, the notional dimensions of the basin are approximately 9.6 m x 38.3 m.

4.8.3.2 Storage Volume for Sediments

To ensure the storage zone is appropriate the following must be met:

Sedimentation Basin Storage Volume V_s > Volume of accumulated sediment over 5 years ($V_{s:5yr}$)

The sedimentation basin storage volume (V_s) is defined as the storage available in the bottom half of the sedimentation basin permanent pool depth. Assuming the internal batters of the basin (Section 4.3.3.3) are 2:1 (H:V) below the permanent water level, the area of the basin at 1 m depth is determined to be 300 m^2. Therefore, the sedimentation basin storage volume V_s is 300m^3.

The volume of accumulated sediments over 5 years ($V_{s:5yr}$) is established using Equation 4.3 (using a sediment discharge rate (L_o) of 1 m^3/ha/yr):

$$V_{s:5yr} = A_c \cdot R \cdot L_o \cdot F_c$$

Given	A_c	=	8 ha
	R	=	90 %
	L_o	=	1 m^3/ha/year
	F_c	=	5 years

The total sediment accumulation is estimated to be:

= 8 x 0.9 x 1 x 5

= 36 m^3

Therefore, $V_s > V_{s:5yr}$

Rearranging Equation 4.3, the required clean out frequency (Fc) is estimated to be:

$$Fc = \frac{300}{1 \times 8 \times 0.9}$$

$$= 41.8 \text{ years}$$

4.8.3.3 Internal Batters

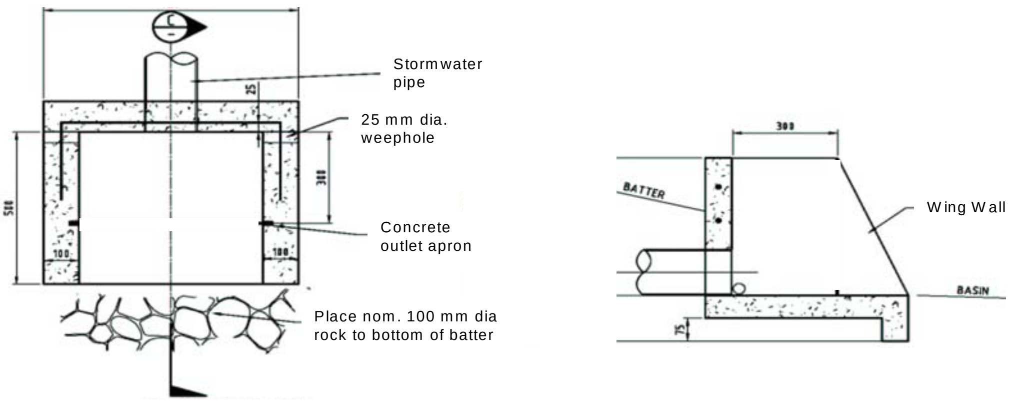
Considering the relatively small size of the sedimentation basin (9.6 m width), it is not possible to achieve the notional permanent pond depth of 2 m using the 5:1 (H:V) required for public safety. Therefore a 4:1 (H:V) batter is to be adopted for the ground above the permanent pool level and to 0.5 m below permanent pool level and a 2:1 (H:V) internal batter slope for 0.5 m to 2 m below the permanent pool level. The sedimentation basin will be fenced around most of its perimeter to ensure public safety.

The base of the sedimentation basin will be lined with rock to prevent vegetation growth and to guide extraction depths during sediment removal. A summary of the sedimentation basin configuration is as follows:

Open Water Area	= 368 m^2
Width	= 9.6 m
Length	= 38.3 m
Depth of Permanent Pool (d_p)	= 2.0 m

4.8.4 Step 4: Design Inflow Systems

To prevent scour of deposited sediments from piped inflows, rock protection and benching is to be placed at the pipe headwall as shown in Figure 4-16.



Plan Inlet Structure **Section Inlet Structure**

Figure 4-16: Conceptual Inlet Structure with Rock Benching

4.8.5 Step 5: Design Outlet Structures

4.8.5.1 Design of 'Control' Outlet - Overflow Pit and Pipe Outlet Configuration

The 'control' outlet structure is to consist of an outlet pit with the crest of the pit set at the permanent pool level of the sedimentation basin (3.8 m AHD) which is 0.3 m above the permanent water level in the wetland. The overflow pit is sized to convey the design operational flow (1 year ARI).

According to Section 4.3.5, two possible flow conditions need to be checked, i.e. weir flow conditions (with extended detention of 0.3 m) and orifice flow conditions.

Weir Flow Conditions

From Equation 4.4, the required perimeter of the outlet pit to pass 1.45 m^3/s with an afflux of 0.3 m can be calculated assuming 50% blockage:`

$$P = \frac{Q_{des}}{B \cdot C_w \cdot h^{3/2}} = \frac{1.45}{0.5 \cdot 1.66 \cdot 0.3^{3/2}} = 10.6 \text{ m}$$

Orifice Flow Conditions

From Equation 4.5, the required area of the outlet pit can be calculated as follows:

$$A_o = \frac{Q_{des}}{B \cdot C_d \cdot \sqrt{2 \cdot g \cdot h}} = \frac{1.45}{0.5 \cdot 0.6 \cdot \sqrt{2(9.81)(0.3)}} = 1.99 \text{ m}^2$$

In this case, the weir flow condition is limiting. Considering the overflow pit is to convey the 'design operation flow' (1 year ARI) or slightly greater, a 3000 x 3000 mm pit is adopted providing a perimeter of 12 m which is greater than the 9.2 m calculated using the weir flow equation above. The top of the pit is to be fitted with a letter box grate. This will ensure large debris does not enter the 'control' structure while avoiding grate blockage by smaller debris.

The size of the connection pipe (i.e. between the sedimentation basin and wetland macrophyte zone) can be calculated by firstly estimating the velocity in the connection pipe (as the outlet is submerged) using the following (Equation 4.5):

$$h = \frac{2 \cdot V^2}{2 \cdot g}$$

Where: *h* = Head level driving flow through the pipe (defined as the 'Spillway' outlet level minus the normal water level in the downstream treatment system)

V = Pipe velocity (m/s)

g = Gravity (9.79 m/s^2)

Note: the coefficient of 2 in the equation is a conservative estimate of the sum of entry and exit loss coefficients ($K_{in} + K_{out}$).

Hence, $V = (9.79 \times 0.6)^{0.5} = 2.43$ m/s

The area of pipe required to convey the 'design operation flow' (1 year ARI) is then calculated by dividing the above 'design operation flow' by the velocity:

$A = 1.45/2.43 = 0.5967$ m^2

This area is equivalent to a 900 mm reinforced concrete pipe (RCP). The obvert of the pipe is to be set just below the permanent water level in the wetland macrophyte zone (3.5 m AHD) meaning the invert is at 2.55 m AHD.

<u>'Control' Outlet Structure:</u>

Overflow pit = 3000 x 3000 mm with letter box grate set at 3.8 m AHD pipe connection (to wetland) = 900mm RCP at 2.55m AHD

Design of 'Spillway' Outlet - Weir Outlet

The 'above design flow' is to bypass the macrophyte zone of the wetland. This will be provided by a 'spillway' outlet weir designed to convey the 'above design flow' (100 year ARI) set at 0.3 m above the permanent pool of the sedimentation basin.

The length of the 'spillway' outlet weir determines the afflux for the 50 year ARI peak discharge and sets the top of embankment of the sedimentation basin. It is common practice to allow for 0.3 m of freeboard above the afflux level when setting the top of embankment elevation. An afflux of 0.3 m has been adopted in defining the length of the spillway weir. This value was adopted as a trade off between the bank height and the width of the weir. A bank height of 0.9 m (0.3 m afflux and 0.3 m freeboard plus 0.3 m extended detention) above the normal water level was deemed acceptable. The weir length is calculated using the weir flow equation (Equation 4.4) substituting outlet perimeter *P* with weir length *L* and blockage factor *B*=1 (no blockage):

$$L = \frac{Q_{des}}{C_w \cdot h^{3/2}} = \frac{4.42}{1.66 \cdot 0.3^{3/2}} = 16.2 \text{ m}$$

The 'spillway' outlet is located adjacent to the inflow culvert to minimise risk of sediment scour.

<u>'Spillway' Outlet Structure:</u>

Spillway length = 16.2 m set at 0.30 m above permanent pool level (4.1 m AHD)

Top of embankment set at 0.9 m above the permanent pool level (4.7 m AHD)

4.8.6 Step 6: Vegetation Specification

The vegetation specification and recommended planting density for the littoral zone around the sedimentation basin have been adapted from Appendix A and are summarised in Table 4-3.

Table 4-3: Vegetation Specification for Worked Example

Zone	Plant Species	Planting Density (plants/m^2)
Littoral Zone (edge)	*Gahnia siberiana*	6
	Lomandra longifolia	6
Shallow Marsh to a depth of 0.5m	*Isolepis inundata*	10
	Juncus usitatus	10

Refer to Appendix A for further discussion and guidance on vegetation establishment and maintenance.

4.8.7 Design Calculation Summary

The sheet below summarises the results of the design calculations.

SEDIMENTATION BASIN DESIGN CALCULATION SUMMARY

	Calculation Task	CALCULATION SUMMARY		
		Outcome		Check
	Catchment Characteristics			
	Residential		Ha	✓
	Commercial		Ha	
	Roads	8	Ha	
	Storm event entering inlet pond (minor or major)	50	yr ARI	
	Conceptual Design			
	Notional permanent pool depth	2	m	✓
	Permanent pool level of sedimentation basin	3.8	m AHD	
1	**Determine design flows**			
	'Design operation flow' (1 year ARI)	1	year ARI	✓
	'Above design flow' (either 2 or 50 year ARI)	50	year ARI	
	Time of concentration			
	Refer to relevant Local Government Guidelines and QUDM	17	minutes	✓
	Identify rainfall intensities			
	'Design operation flow' - $I_{1\ year\ ARI}$	74.1	mm/hr	
	'Above design flow'- $I_{50\ year\ ARI}$	197	mm/hr	
	Design runoff coefficient			
	'Design operation flow' - $C_{1\ year\ ARI}$	0.7		✓
	'Above design flow'- $I_{50\ year\ ARI}$	1.01		
	Peak design flows			
	'Design operation flow' - 1 year ARI	1.45	m^3/s	✓
	'Above design flow' – 2 to 50 year ARI	4.42	m^3/s	
2	**Confirm Treatment Performance of Concept Design**			
	Capture efficiency (of 125 μm sediment)	90	%	✓
	Area of sedimentation basin	340	m^2	
3	**Confirm size and dimension of sedimentation basin**			
	Area of sedimentation basin	368	m^2	
	Aspect ratio	4:1	L:W	✓
	Hydraulic efficiency	0.4		
	Depth of permanent pool	2	m	
	Storage volume for sediments			
	Sedimentation basin storage Volume V_s	300	m^3	
	Volume of accumulated sediment over 5 years ($V_{s:5yr}$)	36	m^3	✓
	$V_s > V_{s:5yr}$	Yes		
	Sediment cleanout frequency		years	

SEDIMENTATION BASIN DESIGN CALCULATION SUMMARY					
	Calculation Task	CALCULATION SUMMARY			
		Outcome		Check	
	Internal batters				
	Edge batter slope	1:2	V:H	✓	
	Fence required	Yes			
4	**Design inflow systems**				
	Provision of scour protection or energy dissipation	Yes		✓	
5	**Design outlet structures**				
	Design of 'control' outlet - overflow pit and pipe outlet configuration				
	Overflow pit crest level	3.8	m AHD		
	Overflow pit dimension	3000 x 3000	L x W	✓	
	Provision of debris trap	Yes			
	Connection pipe dimension	900	mm diam	✓	
	Connection pipe invert level	2.55	m AHD		
	Design of 'control' outlet - weir configuration				
	Weir crest level	N/A	m AHD	✓	
	Weir length	N/A	m		
	Design of 'spillway' outlet - weir configuration				
	Weir crest level	4.1	m AHD		
	Weir length	16.2	m	✓	
	Depth above spillway	0.3	m		
	Freeboard to top of embankment	0.3	m		

4.9 References

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