Infiltration Measures

Chapter 7

7.1 Introduction

Stormwater infiltration systems capture stormwater runoff and encourage infiltration into surrounding in-situ soils and underlying groundwater. This has the benefit of reducing stormwater runoff peak flows and volumes, reducing downstream flooding, managing the hydrologic regime entering downstream aquatic ecosystems and improving groundwater recharge.

The purpose of infiltration systems in a stormwater management strategy is as a conveyance measure (to capture and infiltrate flows), NOT as a stormwater treatment system. Appropriate pretreatment of stormwater entering infiltration systems is required to avoid clogging and to protect groundwater quality.

Infiltration systems generally consist of a 'detention volume' and an 'infiltration area' (or infiltration surface):

- The 'detention volume' can be located above or below ground and is designed to detain a certain volume of runoff and make it available for infiltration. When the 'detention volume' is exceeded, the system is designed to overflow to the downstream drainage systems and the receiving environment.
- The 'infiltration area' is the surface or interface between the detention volume and the in-situ soils through which the collected water is infiltrated.

The application of infiltration systems is best suited to moderately to highly permeable in-situ soils (i.e. sandy loam to sandy soils); however, infiltration systems can still be applied in locations with less permeable soils by providing larger detention volumes and infiltration areas.

As outlined in *Australian Runoff Quality* (Engineers Australia 2006) and *Practice Note 5: Infiltration Devices* (LHCCREMS 2002) there are four basic types of infiltration systems:

Leaky Well

A leaky well is typically used in small scale residential applications and consists of a vertical perforated pipe (concrete or PVC) and an open base (Figure 7-1). Pretreated stormwater enters via an inlet pipe at the top of the well and when the detention volume is full, an overflow pipe delivers excess waters to the downstream drainage system. The perforations in the open pipe and the base are covered with a geotextile (non-woven) and the pipe is surrounded by a ring of clean gravel (5 - 10 mm particle size diameter).

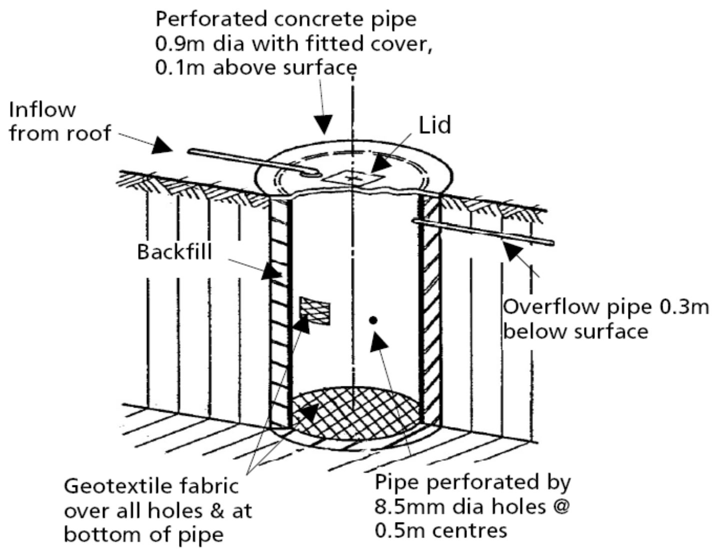


Figure 7-1: 'Leaky Well' Infiltration System (Engineers Australia 2006 and LHCCREMS 2002)

Infiltration Trench

Infiltration trenches can be applied across a range of scales and consist of a trench, typically 0.5 - 1.5 m deep, filled with gravel or modular plastic cells lined with geotextile (non-woven) and placed under 300 mm of backfill (topsoil or sandy loam). Pretreated runoff enters the trench (detention volume) either directly or via an inlet control pit, with excess waters delivered downstream via an overflow pipe. If the trench contains gravel fill then a perforated distribution pipe is incorporated into the system to ensure effective distribution of stormwater into the detention volume. A typical configuration of an infiltration trench is shown in Figure 7-2.

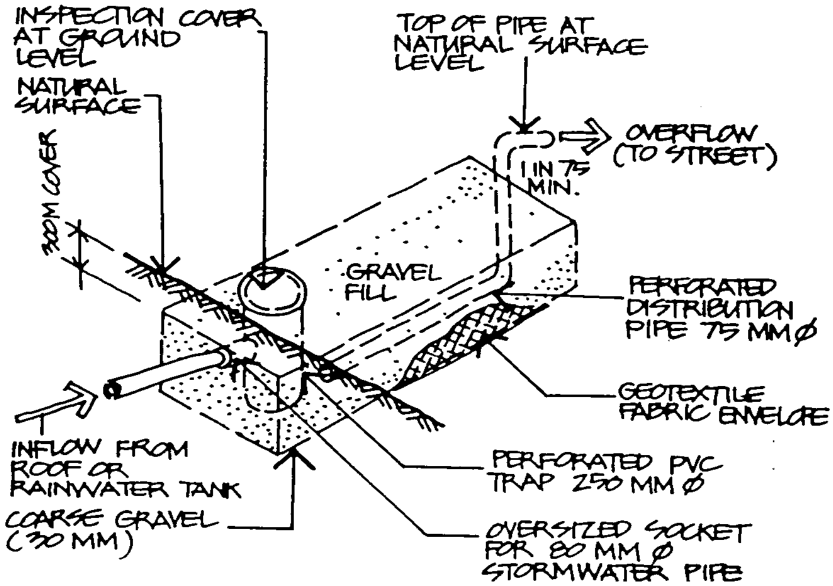


Figure 7-2: Infiltration Trench (Engineers Australia 2006)

Infiltration 'Soak-away'

Soak-aways are similar to trenches in operation but have a larger plan area, being typically rectangular, and of shallower depth (Figure 7-3). Infiltration soak-aways can be applied across a range of scales from residential allotments through to open space or parklands.

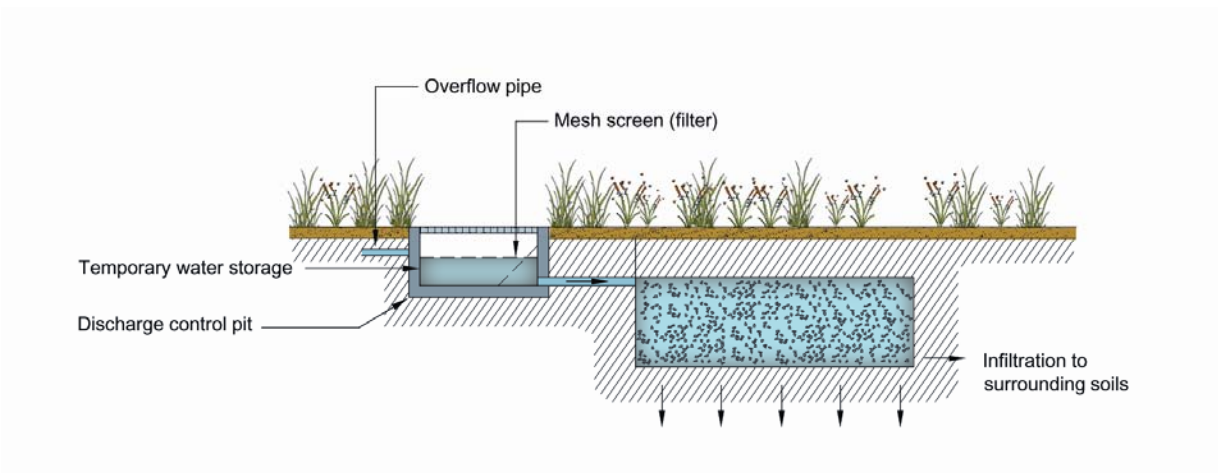


Figure 7-3: Operation of a Gravel Filled 'Trench' or Soak-away' Type Infiltration System

Infiltration Basin

Infiltration basins are typically used in larger scale applications where space is not a constraint (e.g. parklands). They consist of natural or constructed depressions designed to capture and store stormwater runoff on the surface (i.e. detention volume located above ground) prior to infiltration into the in-situ soils. A typical section through an infiltration basin is provided in Figure 7-4. Infiltration basins are best suited to sand or sandy-clay in-situ soils and can be planted out with a range of vegetation to blend into the local landscape. Pretreatment of stormwater entering infiltration basins is required with the level of pretreatment varying depending on in-situ soil type and basin vegetation. Further guidance in this regard is provided in Section 7.2.4.

Plate 7-1: Infiltration Basin

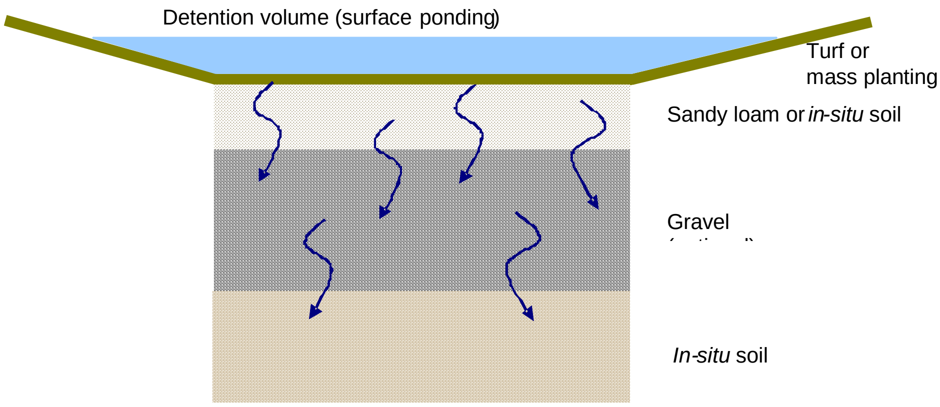


Figure 7-4: Infiltration Basin Typical Section

7.2 Design Considerations

7.2.1 Design Objectives

Infiltration systems can be designed to achieve a range of objectives including:

- Minimising the volume of stormwater runoff from a development
- Preserving predevelopment hydrology
- Capturing and infiltrating flows up to a particular design flow
- Enhancing groundwater recharge or preserving predevelopment groundwater recharge.

The design objective will vary from one location to another and will depend on site characteristics, development form and the requirements of the receiving ecosystems. It is essential that these objectives are established as part of the conceptual design process and approved by the local authority prior to commencing the engineering design.

7.2.2 Selecting the Type of Infiltration System

Selection of the type of infiltration system for a particular application must occur as part of the conceptual design process (i.e. Site Based Stormwater Management Plan) by assessing the site conditions against the relative merits of the four basic types of infiltration systems described in Section 7.1. There is a range of resources available to assist with this selection process, including *Australian Runoff Quality* (Engineers Australia 2006), *Water Sensitive Urban Design: Basic Procedures for 'Source Control' of Stormwater* (Argue 2004) and *Water Sensitive Urban Design: Technical Guidelines for Western Sydney* (UPRCT 2004).

In general, selection of the type of infiltration system is determined by the size of the contributing catchment. Table 7-1 provides guidance on selection by listing the type of infiltration systems against typical scales of application.

Table 7-1: Infiltration Types and Associated Application Scales

Infiltration Type	Allotment Scale (< 0.1 ha)*	Medium Scale (0.1 - 10 ha)*	Large Scale (> 10 ha)*
Leaky Wells	✓		
Infiltration Trenches	✓	✓	
Infiltration Soak-aways		✓	
Infiltration Basins		✓	✓

* Catchment area directing flow to the infiltration system

7.2.3 Design (Sizing) Methods

Establishing the size of an infiltration system requires consideration of the volume and frequency of runoff discharged into the infiltration system, the available 'detention volume' and the infiltration rate (product of 'infiltration area' and hydraulic conductivity of in-situ soils). The approach for establishing these design elements depends on the design objectives as outlined in Section 7.2.1. For the purposes of these guidelines, the infiltration system design objectives can be addressed by two design methods: the hydrologic effectiveness method and the design storm method. These methods are summarised in Table 7-2 and discussed in the following sections.

Table 7-2: Design (Sizing) Methods to Deliver Infiltration System Design Objectives

Infiltration Design objective	*Hydrologic Effectiveness Method	*Design Storm Method
Minimise the volume of stormwater runoff from a development	✓	
Preserve pre-development hydrology	✓	
Capture and infiltrate flows up to a particular design flow		✓
Enhance groundwater recharge or preserve pre-development groundwater recharge	✓	

*Unless otherwise approved by the Local Authority, the hydrologic effectiveness method must be used when designing infiltration systems.

7.2.3.1 Hydrologic Effectiveness Method

The hydrologic effectiveness of an infiltration system defines the proportion of the mean annual runoff volume that infiltrates. For a given catchment area and meteorological conditions, the hydrologic effectiveness of an infiltration system is determined by the combined effect of the nature/ quantity of runoff, the 'detention volume', in-situ soil hydraulic conductivity and 'infiltration area'.

The hydrologic effectiveness of an infiltration system requires long term continuous simulation which can be undertaken using the *Model for Urban Stormwater Improvement Conceptualisation* (MUSIC) (CRCCH 2005). However, in most situations, where a number of the design considerations can be fixed (i.e. frequency of runoff, depth of detention storage, saturated hydraulic conductivity), hydrologic effectiveness curves can be generated and used as the design tool for establishing the infiltration system size.

7.2.3.2 Design Storm Method

Where the design objective for a particular infiltration system is peak discharge attenuation or the capture and infiltration of a particular design storm event (e.g. 3 month ARI event), then the design storm approach can be adopted for sizing the infiltration system.

This method involves defining the required 'detention volume' by relating the volume of inflow and outflow for a particular design storm, and then deriving the 'infiltration area' to ensure the system empties prior to the commencement of the next storm event. Details of the approach for defining the detention volume and infiltration area are presented in Section 7.3.6.2. However, unless otherwise approved by Townsville City Council, the Hydrologic Effectiveness Method described in Section 7.3.2.1 must be used.

7.2.4 Pretreatment of Stormwater

Pretreatment of stormwater entering an infiltration system is primarily required to minimise the potential for clogging of the infiltration media and to protect groundwater quality. In line with these requirements, there are two levels of stormwater pretreatment required:

- Level 1 Pretreatment - Stormwater should be treated to remove coarse and medium sized sediments and litter to prevent blockage of the infiltration system. Level 1 Treatment applies to all four types of infiltration system.
- Level 2 Pretreatment - To protect groundwater quality, pretreatment is required to remove fine particulates and associated pollutants, such as nutrients and metals. This second level of treatment is the most stringent as any stormwater infiltrated must be of equal, or preferably superior, quality to that of the receiving groundwater to ensure the groundwater quality and values are protected. To determine an appropriate level of pretreatment, assessment of the groundwater aquifer quality, values, possible uses and suitability for recharge is required to the satisfaction of Townsville City Council.

Level 2 pretreatment applies to leaky wells, infiltration trenches and infiltration soak-aways. It also applies to most infiltration basin applications, however, there are situations where pretreatment is not required. For example, where basins are located on sandy clay to clay soils (hydraulic conductivity <180 mm/hr) and the depth to groundwater is greater than 1.0 m, the system can be planted out with rush and reed species and allowed to function in a similar manner to a bioretention system prior to waters entering the underlying groundwater. A summary of pretreatment requirements for each of the infiltration system types is presented in Table 7-3.

Table 7-3: Pretreatment Requirements for Each Type of Infiltration System

Infiltration Type	Level 1 Pretreatment	Level 2 Pretreatment
Leaky Well	✓	✓
Infiltration Trench	✓	✓
Infiltration Soak-away	✓	✓
Infiltration Basin		
- Sandy clay to clay soils (K_{sat} < 180 mm/hr) + dense ground cover	✓	
- Sandy clay to clay soils (K_{sat} < 180 mm/hr) + turf ground cover	✓	✓
- Sandy soils (K_{sat} > 180 mm/hr)	✓	✓

Note: K_{sat} = saturated hydraulic conductivity (mm/hr) of in-situ soil (see Section 7.2.5.1)

7.2.5 Site Terrain

Infiltration into steep terrain can result in stormwater re-emerging onto the surface at some point downslope. The likelihood of this pathway for infiltrated water is dependent on the soil structure. Duplex soils and shallow soil over rock create situations where re-emergence of infiltrated water to the surface is most likely to occur. These soil conditions do not necessarily preclude infiltrating stormwater, unless leaching of soil salt is associated with this process. The provision for managing this pathway will need to be taken into consideration at the design stage to ensure hazards or nuisance to downstream sites are avoided.

Additionally, the introduction of infiltration systems on steep terrain can increase the risk of slope instability. Installation of infiltration systems on slopes greater than 10 % will not be approved by Townsville City Council unless a detailed engineering assessment has been undertaken.

7.2.6 In-Situ Soils

7.2.6.1 Hydraulic Conductivity

Hydraulic conductivity of the in-situ soil, being the rate at which water passes through a water-soil interface, influences both the suitability of infiltration systems and the size of the infiltration area. Therefore, it is essential that field measurement of hydraulic conductivity be undertaken to confirm assumptions of soil hydraulic conductivity adopted during the concept design stage (i.e. site based Stormwater Management Plan). The determination of hydraulic conductivity must be undertaken in accordance with procedures outlined in Appendix 4.1F of AS/NZS 1547:2000, which provides an estimate of saturated hydraulic conductivity (K_{sat})(i.e. the hydraulic conductivity of a soil when it is fully saturated with water). The typical ranges of saturated hydraulic conductivities for homogeneous soils are provided in Table 7-4.

Table 7-4: Typical Soil Types and Associated Saturate Hydraulic Conductivity (Engineers Australia 2006)

Soil Type	Saturated Hydraulic Conductivity	
	m/s	mm/hr
Coarse Sand	$>1 \times 10^{-4}$	>360
Sand	5×10^{-5} to 1×10^{-4}	180 – 360
Sandy Loam	1×10^{-5} to 5×10^{-5}	36 to 180
Sandy Clay	1×10^{-6} to 1×10^{-5}	3.6 to 36
Medium clay	1×10^{-7} to 1×10^{-6}	0.36 – 3.6
Heavy Clay	1×10^{-7}	0.0 to 0.36

When assessing the appropriateness of infiltration systems and the type of in-situ soils, the following issues must be considered:

Soils with a saturated hydraulic conductivity of 3.6 mm/hr to 360 mm/hr are preferred for infiltration application.

Infiltration systems will not be accepted by Townsville City Council where the in-situ soils are very heavy clays (i.e. < 0.36 mm/hr).

Soils with a low hydraulic conductivity (0.36 - 3.6 mm/hr) do not necessarily preclude the use of infiltration systems even though the required infiltration/ storage area may become prohibitively large. However, soils with lower hydraulic conductivities will be more susceptible to clogging and will therefore require enhanced pretreatment.

7.2.6.2 Soil Salinity

Infiltration systems must be avoided in areas with poor soil conditions, in particular sodic/ saline and dispersive soils, and shallow saline groundwater. If the 'Site and Soil Evaluation' (refer to Section 7.3.1) identifies poor soil conditions, then Townsville City Council will not approve the use of infiltration systems.

7.2.6.3 Impermeable Subsoil, Rock and Shale

Infiltration systems must not be placed in locations where soils are underlain by rock or a soil layer with little or no permeability (i.e. $K_{sat} < 0.36$ mm/hr). In locations where fractured or weathered rock prevail, the use of infiltration systems may be approved by Townsville City Council provided detailed engineering testing has been carried out to ensure the rock will accept infiltration.

7.2.7 Groundwater

7.2.7.1 Groundwater Quality

As outlined in Section 7.2.4, the suitability of infiltrating stormwater and the necessary pretreatment requires assessment of the groundwater quality. The principle legislation governing the management of groundwater quality is the *Environmental Protection (Water) Policy 1997* and the overriding consideration is that there should be no deterioration in groundwater quality. This means the stormwater being infiltrated must be of equal or preferably superior quality to that of the receiving groundwater in order to ensure the groundwater quality and values are protected. To determine an appropriate level of pretreatment for stormwater, assessment of the groundwater aquifer quality, values, possible uses and suitability for recharge is required and must be approved by the local authority.

7.2.7.2 Groundwater Table

A second groundwater related design consideration is to ensure that the base of an infiltration system is always above the groundwater table. It is generally recommended that the base of the infiltration system be a minimum of 1.0 m above the seasonal high water table.

If a shallow groundwater table is likely to be encountered, investigation of the seasonal variation of groundwater levels is essential. This should include an assessment of potential groundwater mounding (i.e. localised raising of the water table in the immediate vicinity of the infiltration system) that in shallow groundwater areas could cause problems with nearby structures.

7.2.8 Building Setbacks (Clearances)

Infiltration systems should not be placed near building footings to avoid the influence of continually wet sub-surface or greatly varying soil moisture content on the structural integrity. *Australian Runoff Quality* (Engineers Australia 2006) recommends minimum distances from structures and property boundaries (to protect possible future buildings in neighbouring properties) for different soil types. These values are shown in Table 7-5.

Table 7-5: Minimum Setback Distances (adapted from Engineers Australia 2006)

Soil Type	Saturated Hydraulic Conductivity (mm/hr)	Minimum distance from structures and property boundaries
Sands	>180	1.0 m
Sandy Loam	36 to 180	2.0 m
Sandy Clay	3.6 to 36	4.0 m
Medium to Heavy Clay	0.0 to 3.6	5.0 m

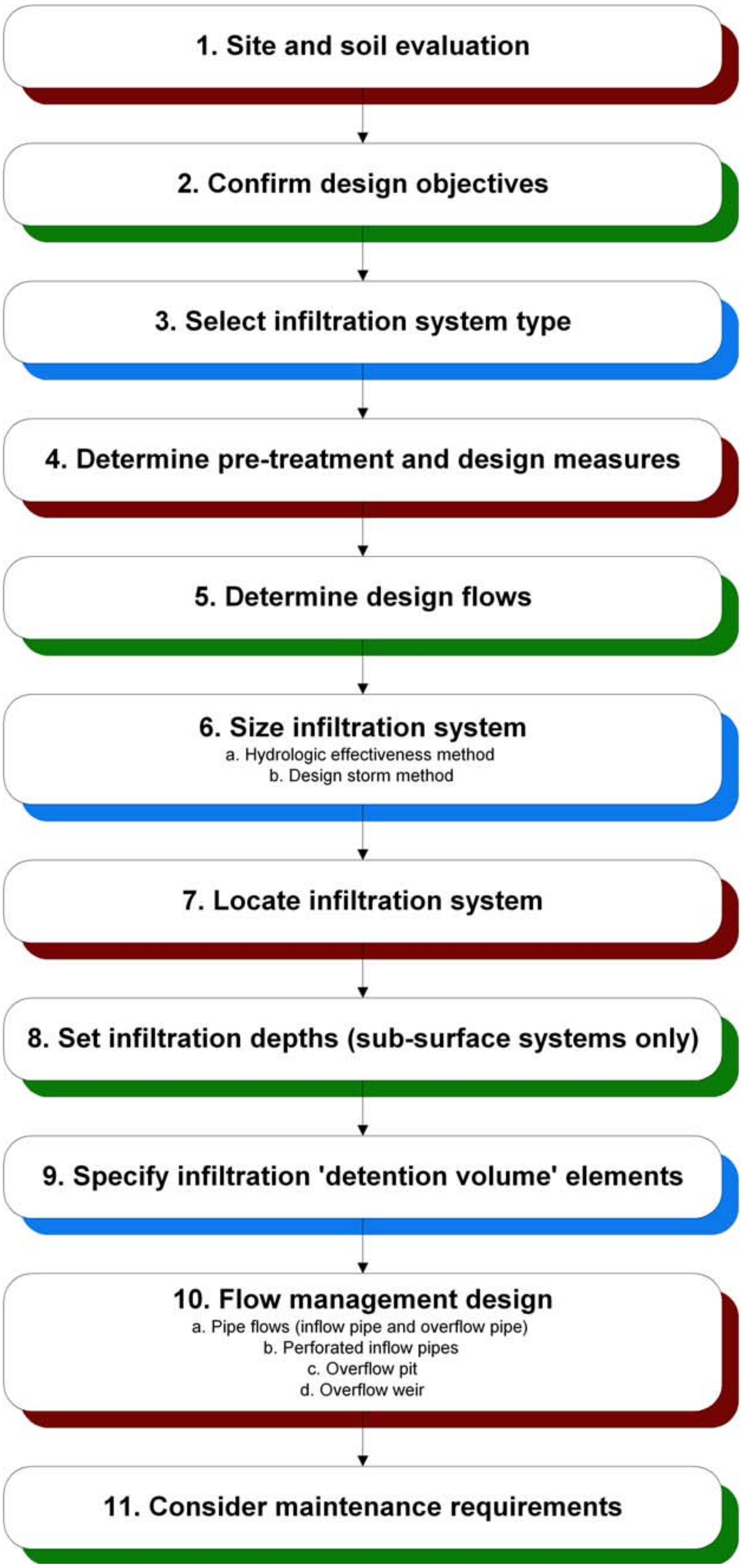
7.2.9 Flow Management

The following issues should be considered when designing the flow control structures within infiltration systems:

- For large scale systems (i.e. infiltration basins), the surface of the ‘infiltration area’ must be flat or as close to this as possible to ensure uniform distribution of flow and to prevent hydraulic overloading on a small portion of the ‘infiltration area’.
- For gravel filled infiltration systems, flow should be delivered to the ‘detention volume’ via a perforated pipe(s) network that is located and sized to convey the design flow into the infiltration systems and allow distribution of flows across the entire infiltration area.
- Where possible, ‘above design’ flows will bypass the infiltration systems. This can be achieved in a number of ways. For smaller applications, an overflow pipe or pit, which is connected to the downstream drainage system, can be used. For larger applications, a discharge control pit can be located upstream of the infiltration system. This will function much like the inlet zone of a constructed wetland to regulate flows (1 year ARI) into the infiltration systems and bypass above design flows (> 1 year ARI).

7.3 Design Process

The following sections detail the design steps required for infiltration measures. Key design steps are:


1. Site and soil evaluation
2. Confirm design objectives
3. Select infiltration system type
4. Determine pre-treatment and design measures
5. Determine design flows
6. Size infiltration system
a. Hydrologic effectiveness method
b. Design storm method
7. Locate infiltration system
8. Set infiltration depths (sub-surface systems only)
9. Specify infiltration 'detention volume' elements
10. Flow management design
a. Pipe flows (inflow pipe and overflow pipe)
b. Perforated inflow pipes
c. Overflow pit
d. Overflow weir
11. Consider maintenance requirements

7.3.1 Step 1: Site and Soil Evaluation

As outlined in Section 7.2, there are a range of site and soil conditions which influence infiltration system design. To define the site's capability to infiltrate stormwater, a 'Site and Soil Evaluation' must be undertaken in accordance with AS/NZS 1547:2000 Clause 4.1.3. The evaluation should provide the following:

- Soil type
- Hydraulic conductivity (must be measured in accordance with AS/NZS 1547:2000 Appendix 4.1F)
- Presence of soil salinity (where applicable)
- Presence of rock shale
- Slope of terrain (%)
- Groundwater details (depth, quality and values).

7.3.2 Step 2: Confirm Design Objectives

This step involves confirming the design objectives, defined as part of the conceptual design, to ensure the correct infiltration system design method is selected (refer to Table 7-2).

7.3.3 Step 3: Select Infiltration System Type

This step involves selecting the type of infiltration system by assessing the site conditions against the relative merits of the four infiltration systems described in Section 7.1. In general, the scale of application dictates selection of the infiltration system. Table 7-1 provides guidance in this regard.

For further guidance in selecting infiltration systems, designer should refer to *Australian Runoff Quality* (Engineers Australia 2006), *Water Sensitive Urban Design: Basic Procedures for 'Source Control' of Stormwater* (Argue 2004) and the *Water Sensitive Urban Design: Technical Guidelines for Western Sydney* (UPRCT 2004).

7.3.4 Step 4: Pretreatment Design

As outlined in Section 7.2.4 and Table 7-3, both Level 1 Pretreatment (minimising risk of clogging) and Level 2 Pretreatment (groundwater protection) are required for all infiltration systems except for specific infiltration basin applications. To determine Level 2 requirements, an assessment of the groundwater must be undertaken to define existing water quality, potential uses (current and future) and suitability for recharge.

Pretreatment measures include the provision of leaf and roof litter guards along the roof gutter, sediment basins, vegetated swales, bioretention systems or constructed wetland as outlined in the other chapters of this guideline.

7.3.5 Step 5: Determine Design Flows

7.3.5.1 Design Flows

To configure the inflow system and high flow bypass elements of the infiltration system the following design flows generally apply:

- 'Design operation flow' for sizing the inlet to the infiltration system. This may vary depending on the particular situation but will typically correspond to one of the following:
  - 1 year ARI – for situations where a discharge control pit is used to regulate flows into the infiltration system and bypass larger flows.
  - 2 year ARI (minor design flow) – for situations where the minor drainage system is directed to the infiltration system. For commercial and industrial areas the design flow requirement for minor flows is a 5 year ARI event.
- 'Above design flow' for design of the high flow bypass around the infiltration system. The discharge capacity for the bypass system may vary depending on the particular situation but will typically correspond to one of the following:

- 2 year ARI (minor design flow) – for situations where only the minor drainage system is directed to the infiltration system. For commercial and industrial areas the design flow requirement for minor flows is a 5 year ARI event.
- 50 year ARI (major design flow) – for situations where both the minor and major drainage system discharge to the infiltration system.

7.3.5.2 Design Flow Estimation

A range of hydrologic methods can be applied to estimate design flows. If typical catchment areas are relatively small, the Rational Method design procedure is considered suitable. However, if the infiltration system is to form part of a detention basin or if the catchment area to the system is large (> 50 ha) then a full flood routing computation method should be used to estimate design flows.

7.3.6 Step 6: Size Infiltration System

As outlined in Section 7.2.3, there are two design methods available for establishing the size of the detention volume and infiltration area of infiltration systems: the hydrologic effectiveness method and the design storm method. Unless otherwise approved by Townsville City Council, the hydrologic effectiveness method must be used when designing infiltration systems.

7.3.6.1 Hydrologic Effectiveness Method

The hydrologic effectiveness of concept design systems can be assessed by using an appropriate quantitative modelling program, such as the *Model for Urban Stormwater Improvement Conceptualisation* (MUSIC) (CRCCH 2005). These programs can reveal the relationship between the hydrologic effectiveness, infiltration area and detention storage for a range of soil hydraulic conductivities, detention storage depths and detention storage porosities. Where possible this assessment should be based on local rainfall data, local stormwater quality information and the proposed characteristics of the system.

7.3.6.2 Design Storm Approach

Where the design objective for a particular infiltration system is peak discharge attenuation or the capture and infiltration of a particular design storm event, then the design storm approach may be adopted for sizing the infiltration system. Use of the design storm approach must be approved by the local authority for sizing infiltration systems.

<u>Design Storm Selection (Q_{des})</u>

The first step in the design storm approach to sizing the infiltration system is selecting the design storm for capture and infiltration. This must occur in consultation with the local authority and will generally relate to 3 month ARI and 1 year ARI design storms.

<u>Detention Volume</u>

The required 'detention volume' of an infiltration system is defined by the difference in inflow and outflow (or infiltrated) volumes for the duration of a storm.

The inflow volume (Vi) is determined, in accordance with Section 5 (Detention/retention systems) of QUDM, as the product of the design storm flow and the storm duration:

$$V_i = Q_{des} \cdot D \qquad \text{Equation 7.1}$$

Where V_i = inflow volume (for storm duration D) (m^3)

Q_{des} = design storm flow for sizing as outlined in Section 7.3.5

(Rational Method, $Q = CIA/360$ (m^3/s)

D = storm duration (hrs x 3600 s/hr)

As outlined in Section 7.3.5.2, if the infiltration system is to form part of a detention basin or if the catchment area to the system is large (> 50 ha) then a full flood routing computation method should be used to estimate design flows.

Outflow from the infiltration system is via the base and sides of the infiltration media and is dependent on the area and depth of the structure. In computing the infiltration from the walls of an infiltration system, *Australian Runoff Quality* (Engineers Australia 2006) suggests that pressure is hydrostatically distributed and thus equal to half the depth of water over the bed of the infiltration system:

$$V_o = \left[A_{inf} + \left(P \cdot \frac{d}{2}\right)\right] \cdot \frac{U \cdot K_{sat} \cdot D}{1000} \qquad \text{Equation 7.2}$$

Where V_o = outflow volume (for storm duration D) (m^3)

K_{sat} = saturated hydraulic conductivity (mm/hr) as provided in Step 1.

A_{inf} = infiltration area (m^2)

P = perimeter length of the infiltration area (m)

d = depth of the infiltration system (m)

U = soil hydraulic conductivity moderating factor (see Table 7.5)

D = storm duration (hrs)

Thus, the required detention volume (V_d) of an infiltration system can be computed as follows:

$$V_d = \frac{V_i - V_o}{p} \qquad \text{Equation 7.3}$$

Where V_d = required detention volume (m^3)

V_i = inflow volume (m^3)

V_o = outflow volume (m^3)

p = porosity (void = 1, gravel = 0.35)

Computation of the required storage will need to be carried out for the full range of probabilistic storm durations, ranging from 6 minutes to 72 hours. The critical storm event is that which results in the highest required storage. A spreadsheet application (using equations 7.1 to 7.3) is the most convenient way of doing this. It is important to note that some storm events result in double peaks in the hyetograph for the particular storm and these may affect the size of detention storage required.

<u>Soil Hydraulic Conductivity Moderating Factor</u>

Soil is inherently non-homogeneous and field tests can often misrepresent the areal hydraulic conductivity of a soil into which stormwater is to be infiltrated. Field experience suggests that field tests of 'point' soil hydraulic conductivity (as defined by Step 1) can often under estimate the areal hydraulic conductivity of clay soils and over estimate in sandy soils. As a result, Australian Runoff Quality (Engineers Australia 2005) recommends that moderation factors for hydraulic conductivities determined from field test be applied as shown in Table 7-6.

Table 7-6: Moderation Factors to Convert Point to Areal Conductivities (after Engineers Australia 2005)

Soil Type	Moderation Factor (*U*) (to convert "point" K_{sat} to areal K_{sat})
Sandy soil	0.5
Sandy clay	1.0
Medium and Heavy Clay	2.0

Emptying Time

Emptying time is defined as the time taken to fully empty a detention volume associated with an infiltration system following the cessation of rainfall. This is an important design consideration as the computation procedure associated with Equation 7.3 assumes that the storage is empty prior to the commencement of the design storm event. *Australian Runoff Quality* (Engineers Australia 2006) suggests an emptying time of the detention storage of infiltration systems to vary from 12 hours to 84 hours. For detention basins (surface systems) the emptying time must be limited to 72 hours to reduce the risk of mosquito breeding.

Emptying time is computed simply as the ratio of the volume of water in temporary storage (dimension of storage x porosity) to the infiltration rate (hydraulic conductivity x infiltration area):

$$t_e = \frac{1000 \cdot V_d \cdot P \cdot p}{A_{inf} \cdot K_{sat}}$$ Equation 7.4

Where t_e = emptying time (hours)

V_d = detention volume (m^3)

P = perimeter length of the infiltration area (m)

A_{inf} = infiltration area (m^2)

K_{sat} = saturated hydraulic conductivity (mm/hr) as provided in Step 1

p = porosity (void = 1, gravel = 0.35)

7.3.7 Step 7: Locate Infiltration System

This step involves locating the infiltration system in accordance with the requirement set out in Section 7.2.8 and Table 7-5 to minimise the risk of damage to structures from wetting and drying of soils (i.e. swelling and shrinking of soils and slope stability).

7.3.8 Step 8: Set Infiltration Depths (sub-surface systems only)

For sub-surface infiltration systems, selection of the optimum depth requires consideration of the seasonal high water table and the appropriate cover to the surface.

- Seasonal groundwater table - As outlined in Section 7.2.6.2, it is generally recommended that the base of the infiltration system be a minimum of 1 m above the seasonal high water table.
- Cover (i.e. depth of soil above top of infiltration system) – Minimum cover of 0.3 m. For systems created using modular plastic cell storage units, an engineering assessment is required.

7.3.9 Step 9: Specify Infiltration 'Detention Volume' Elements

The following design and specification requirements must be documented as part of the design process for 'leaky wells', infiltration trenches and 'soak-aways'.

7.3.9.1 Gravel

Where the infiltration 'detention volume' is created through the use of a gravel-filled trench then the gravel must be clean (free of fines) stone/ gravel with a uniform size of between 25 - 100 mm diameter.

7.3.9.2 Modular Plastic Cells

Where the infiltration detention volume is created through the use of modular plastic cells (similar to a milk crate), the design must be accompanied by an engineering assessment of the plastic cells and their appropriateness considering the loading above the infiltration system. A minimum 150 mm thick layer of coarse sand or fine gravel must underlie the base of the plastic cells.

7.3.9.3 Geofabric

Geofabric must be installed along the side walls and through the base of the infiltration detention volume to prevent the migration of in-situ soils into the system. For infiltration system application, Council will only accept the use of non-woven geofabric with a minimum perforation or mesh of 0.25 mm.

7.3.9.4 Inspection Wells

It is good design practice to install inspection wells at numerous locations in an infiltration system. This allows water levels to be monitored during and after storm events and for infiltration rates to be confirmed over time.

7.3.10 Step 10: Flow Management Design

The design of the hydraulic control for infiltration systems varies for the different types of systems. For smaller applications, all pretreated flows will directly enter the infiltration system and an overflow pipe or pit will be used to convey excess flow to the downstream drainage system. For larger applications, a discharge control pit will be located upstream of the infiltration systems to function similar to the inlet zone of a constructed wetland to regulate flows (1 year ARI) into the infiltration systems and bypass above design flows (> 1 year ARI). Table 7-7 summarises the typical hydraulic control requirements for the different types of infiltration system.

Table 7-7: Typical Hydraulic Control Requirements for Infiltration Systems

Infiltration Type	Inflow		Overflow/ Bypass	
	Direct inflow	Discharge control pit	Overflow pipe/ pit	Discharge control pit
Leaky Wells	✓		✓	
Infiltration Trenches	✓		✓	
Infiltration Soak-aways		✓		✓
Infiltration Basins	✓	✓	✓	✓

Note: For gravel filled infiltration systems, flow should be delivered to the 'detention volume' via a perforated pipe network.

The hydraulic control measures described in Table 7-7 are designed using the following techniques.

7.3.10.1 Pipe Flows (Inflow Pipe and Overflow Pipe)

Pipe flows are to be calculated in accordance with the QUDM and the relevant local authority guidelines which use standard pipe equations that account for energy losses associated with inlet and outlet conditions and friction losses within the pipe. For most applications, the pipe or culvert will operate under outlet control with the inlet and outlet of the pipe/ culvert being fully submerged. With relatively short pipe connections, friction losses are typically small and can be computed using Manning's equation. The total energy (head) loss (ΔH) of the connection is largely determined by the inlet and outlet conditions and the total losses can be computed using the expression as provided in QUDM:

$$\Delta H = h_f + h_s$$ Equation 7.5

where

h_f = $S_f \cdot L$ = head loss in pipe due to friction (m)

h_s = $(K_{in} + K_{out}) \cdot V^2/2g$ = head loss at entry and exit (m)

S_f = friction slope which is computed from Manning's Equation (m/m)

L = is the length pipe (m)

$K_{in} + K_{out}$ = the head loss coefficients for the inlet and outlet conditions (typically, and conservatively, assumed to be 0.5 and 1.0 respectively)

V = velocity on flow in pipe (m/s)

g = gravity (9.79 m/s^2)

7.3.10.2 Perforated Inflow Pipes

To ensure the perforated inflow pipes to gravel filled infiltration systems have sufficient capacity to convey the 'design operation flow' (Section 7.3.4.1) and distribute this flow into the infiltration system, there are two design checks required:

- Ensure the pipe itself has capacity to convey the 'design operation flow'
- Ensure the perforations are adequate to pass the 'design operation flow'.

It is recommended that the maximum spacing of the perforated pipes is 3 m (centres) and that the minimum grade is 0.5 % from the inflow point. The inflow pipes should be extended to the surface of the infiltration system to allow inspection and maintenance when required. The base of the infiltration system must remain flat.

Perforated Pipe Conveyance

To confirm the capacity of the perforated pipes to convey the 'design operation flow', Manning's equation can be used (which assumes pipe full flow but not under pressure). When completing this calculation it should be noted that installing multiple perforated pipes in parallel is a means of increasing the capacity of the perforated pipe system.

Perforated Pipe Slot Conveyance

The capacity of the slots in the perforated pipe needs to be greater than the maximum infiltration rate to ensure the slots does not become the hydraulic 'control' in the infiltration system (i.e. to ensure the in-situ soils and 'detention volume' set the hydraulic behaviour rather than the slots in the perforated pipe). To do this, orifice flow can be assumed to occur through the slots and the sharp edged orifice equation used to calculate the flow through the slots for the full length of perforated pipe. Firstly, the number and size of perforations needs to be determined (typically from manufacturer's specifications) and used to estimate the flow rate out of the pipes, with the driving head being the difference between the overflow level and the invert of the perforated pipe. It is conservative, but reasonable, to use a blockage factor to account for partial blockage of the perforations. A 50 % blockage should be used.

$$Q_{perf} = B \cdot C_d \cdot A \cdot \sqrt{2 \cdot g \cdot h}$$ Equation 7.6

Where Q_{perf} = flow through perforations (m^3/s)

B = blockage factor (0.5)

C_d = orifice discharge coefficient (assume 0.61 for sharp edge orifice)

A = total area of the perforations (m^2)

g = gravity (9.79 m/s^2)

h = head above the centroid of the perforated pipe (m)

If the capacity of the perforated pipe system is unable to convey the 'design operation flow' then additional perforated pipes will be required.

7.3.10.3 Overflow Pit

To size an overflow pit, two checks should be made to test for either drowned or free flowing conditions. A broad crested weir equation can be used to determine the length of weir required (assuming free flowing conditions) and an orifice equation used to estimate the area between openings required in the grate cover (assuming drowned outlet conditions). The larger of the two pit configurations should be adopted (as per Section 7.05 QUDM). In addition, a blockage factor is to be used that assumes the grate is 50 % blocked.

For free overfall conditions (weir equation):

$$Q_{weir} = B \cdot C_w \cdot L \cdot h^{3/2}$$ Equation 7.7

Where Q_{weir} = flow into pit (weir) under free overfall conditions (m^3/s)

B = blockage factor (= 0.5)

C_w = weir coefficient (= 1.66)

L = length of weir (perimeter of pit) (m)

h = flow depth above the weir (pit) (m)

Once the length of weir is calculated, a standard sized pit can be selected with a perimeter at least the same length of the required weir length.

For drowned outlet conditions (orifice equation):

$$Q_{orifice} = B \cdot C_d \cdot A\sqrt{2 \cdot g \cdot h}$$ Equation 7.8

Where *B*, *g* and *h* have the same meaning as above

$Q_{orifice}$ = flow rate into pit under drowned conditions (m^3/s)

C_d = discharge coefficient (drowned conditions = 0.6)

A = area of orifice (perforations in inlet grate) (m^2)

When designing grated field inlet pits, reference is to be made to the procedure described in QUDM Section 7.05.4 and the requirements of the local authority.

7.3.10.4 Overflow Weir

In applications where infiltration systems require a discharge control pit, a 'spillway' outlet weir will form part of the high flow bypass system to convey the 'above design flow'. The 'spillway' outlet weir level will be set at the top of the 'detention storage' to ensure catchment flows bypass the infiltration system once the 'detention volume' is full. The length of the 'spillway' outlet weir is to be sized to safely pass the maximum flow discharged to the discharge control pit (as defined the 'above design flow' in Section 7.3.4).

The required length of the 'spillway' outlet weir can be computed using the weir flow equation (Equation 7.7) and the 'above design flow' (Section 7.3.4).

7.3.11 Step 11: Consider Maintenance Requirements

Consider how maintenance is to be performed on the infiltration system (e.g. how and where is access available, where sediment likely to collect etc.). A specific maintenance plan and schedule should be developed for the infiltration system, 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 7.5.

7.3.12 Design Calculation Summary

Following is a design calculation summary sheet for the key design elements of an infiltration system to aid the design process.

INFILTRATION SYSTEMS DESIGN CALCULATION SUMMARY

	Calculation Task	CALCULATION SUMMARY Outcome		Check
	Catchment Characteristics			
	Catchment area		ha	
	Catchment landuse (i.e residential, commercial etc.)			
	Storm event entering infiltration system (minor or major)		year ARI	
1	**Site and soil evaluation**			
	Site and Soil Evaluation' undertaken in accordance with AS1547-2000 Clause 4.1.3			
	Soil type			
	Hydraulic conductivity (K_{sat})		mm/hr	
	Presence of soil salinity			
	Presence of rock/shale			
	Infiltration site terrain (% slope)			
	Groundwater level		m AHD	
			m below surface	
	Groundwater quality			
	Groundwater uses			
2	**Confirm design objectives**			
	Confirm design objective as defined by conceptual design			
3	**Select infiltration system type**			
	Leaky Well			
	Infiltration Trench			
	Infiltration 'Soak-away'			
	Infiltration Basin			
4	**Pre-treatment design**			
	Level 1 Pre-treatment (avoid clogging)			
	Level 2 Pre-treatment (groundwater protection)			
5	**Determine design flows**			
	'Design operation flow' (1 year ARI)		year ARI	
	'Above design flow' (2 – 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'- $I_{2-50\ year\ ARI}$		mm/hr	
	Design runoff coefficient			
	'Design operation flow' - $C_{1\ year\ ARI}$			
	'Above design flow'- $C_{2-50\ year\ ARI}$			
	Peak design flows			
	'Design operation flow' - 1 year ARI		m^3/s	
	'Above design flow' (2-50 year ARI)		m^3/s	
6	**Size infiltration system**			
	Hydrologic effectiveness approach			
	Hydrologic effectiveness objective		%	
	Depth		m	
	Porosity (void = 1.0, gravel filled = 0.35)			
	'Infiltration Area'		m^2	
	'Detention Volume'		m^3	

INFILTRATION SYSTEMS DESIGN CALCULATION SUMMARY				
			CALCULATION SUMMARY	
	Calculation Task		Outcome	Check
	Design storm approach			
		Design storm flow	m^3/s	
		Inflow volume	m^3	
		Outflow volume	m^3	
		Depth	m	
		'Infiltration Area'	m^2	
		'Detention Volume'	m^3	
7	Locate infiltration system			
		Minimum distance from boundary (Table 7-5)	m	
		Width	m	
		Length	m	
8	Set infiltration depths (sub-surface systems only)			
		Ground surface level	m AHD	
		Groundwater level	m AHD	
			m below surface	
		Infiltration system depth	m	
		Top of infiltration system	m AHD	
		Base of infiltration system	m AHD	
		Cover	m	
		Depth to water table	m	
9	Specify infiltration 'detention volume' elements			
		Gravel size	mm diam.	
		Modular plastic cells		
		Geofabric		
10	Flow management design			
	Inflow/Overflow structures			
		Direct inflow		
		Overflow pit/pipe		
		Discharge control pit		
	Discharge pipe			
		Pipe capacity	m^3/s	
		Pipe size	mm diam.	
	Inflow pipe			
		Pipe capacity	m^3/s	
		Pipe size	mm diam.	
	Overflow pipe			
		Pipe capacity	m^3/s	
		Pipe size	mm diam.	
	Overflow pit			
		Pit capacity	m^3/s	
		Pit size	mm x mm	
	Perforated inflow pipes			
		No. of pipes		
		Pipe size	mm	
	Discharge control pit			
		Pit size	mm x mm	
		Weir length	m	

7.4 Construction and Establishment

It is important to note in the context of a development site and associated construction/building works, delivering infiltration measures can be a challenging task. A careful construction and establishment approach to ensure the system is delivered in accordance with its design intent. The following sections outline a recommended staged construction and establishment methodology for infiltration measures based on the guidance provided in Leinster (2006).

7.4.1 Construction and Establishment Challenges

There exist a number of challenges that must be appropriately considered to ensure successful construction and establishment of infiltration measures. 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 7-5).

- Subdivision Construction - 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 which can clog infiltration measures
    - Construction traffic and other works can result in damage to the infiltration measures.

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 infiltration measures.

7.4.2 Staged Construction and Establishment Method

To overcome the challenges associated within delivering infiltration measures a Staged Construction and Establishment Method should be adopted (see Figure 7-5):

- Stage 1: Functional Installation - Construction of the functional elements of the infiltration measure at the end of Subdivision Construction (i.e. during landscape works) and the installation of temporary protective measures (i.e. stormwater bypass system).
- Stage 2: Sediment and Erosion Control – During the Building Phase the temporary protective measures preserve the functional infrastructure of the infiltration measure against damage.
- Stage 3: Operational Establishment - At the completion of the Building Phase, the temporary measures protecting the functional elements of the infiltration measure can be removed and the system allowed to operation in accordance with the design intent.

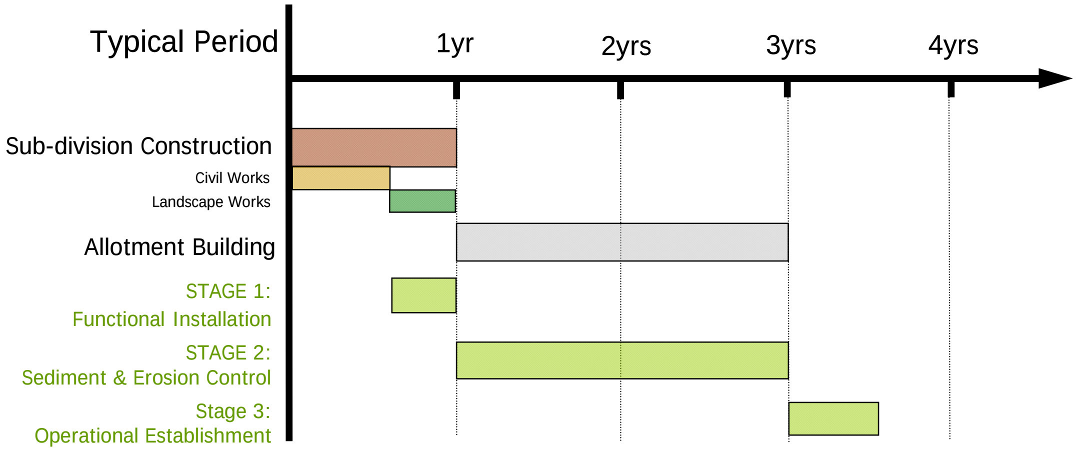


Figure 7-5: Staged Construction and Establishment Method

7.4.2.1 Functional Installation

Functional installation of infiltration measure occurs at the end of Subdivision Construction as part of landscape works and involves:

- Bulking out and trimming
- Installation of the control and pipe structures
- Placement of non-woven geofabric to sides and base
- Placement of gravel (if part of design)
- Where infiltration system is located underground, the inlet should be blocked to ensure sediment laden stormwater flows 'bypass' the system.
- Where the system is an infiltration basin, placement of a temporary protective layer - Covering the surface of filtration media with geofabric and placement of 25 mm topsoil and turf over geofabric. This temporary geofabric and turf layer will protect the infiltration measure during construction (Subdivision and Building Phases) ensuring sediment/litter laden waters do not cause clogging.
- Place silt fences around the boundary of the infiltration measure to exclude silt and restrict access.

7.4.2.2 Sediment and Erosion Control

The temporary protective measures are left in place through the allotment building phase to ensure sediment laden waters do not enter and clog the infiltration measure.

7.4.2.3 Operational Establishment

At the completion of the Allotment Building Phase the temporary measures (i.e. stormwater bypass) can be removed and the infiltration measure allowed to operate. It is critical to ensure that the pretreatment system for an infiltration measure is fully operational before flows are introduced.

7.5 Maintenance Requirements

Maintenance for infiltration measures aims at ensuring the system does not clog with sediments and that an appropriate infiltration rate is maintained. The most important consideration during maintenance is to ensure the pretreatment elements are operating as designed to avoid blockage of the infiltration measure and to prevent groundwater contamination.

To ensure the system is operating as designed, the infiltration zone should be inspected every 1 - 6 months (or after each major rainfall event) depending on the size and complexity of the system. Typical maintenance of infiltration systems will involve:

- Routine inspection to identify any surface ponding after the design infiltration period (refer to Section 7.3.6.2 for appropriate emptying times), which would indicate clogging/ blockage of the underlying aggregate or the base of the trench.
- Routine inspection of inlet points to identify any areas of scour, litter build up, sediment accumulation or blockages.
- Removal of accumulated sediment and clearing of blockages to inlets.
- Tilling of the infiltration surface, or removing the surface layer, if there is evidence of clogging.
- Maintaining the surface vegetation (if present).

7.6 Checking Tools

This section provides a number of checking aids for designers and Council development assessment officers. In addition, Section 7.4 provides general advice on the construction and establishment of infiltration measures and key issues to be considered to ensure their successful establishment and operation based on observations from construction projects around Australia.

The following checking tools are provided:

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

7.6.1 Design Assessment Checklist

The checklist on page 7-24 presents the key design features that are to be reviewed when assessing the design of an infiltration system. These considerations include configuration, safety, maintenance and operational issues that need to be addressed during the design phase. If an item receives an ‘N’ when reviewing the design, referral is to 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. Council development assessment officers will require that all relevant permits are in place prior to accepting a design.

7.6.2 Construction Checklist

The checklist on page 7-25 presents the key items to be reviewed when inspecting the infiltration measure 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 infiltration measure 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.

7.6.3 Operation and Maintenance Inspection Form

In addition to checking and maintaining the function of pretreatment elements, the form on page 7-26 can be used during routine maintenance inspections of the infiltration measure and kept as a record on the asset condition and quantity of removed pollutants over time. Inspections should occur every 1 - 6 months depending on the size and complexity of the system. More detailed site specific maintenance schedules should be developed for major infiltration systems and include a brief overview of the operation of the system and key aspects to be checked during each inspection.

7.6.4 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. For details on asset transfer to Council, contact Townsville City Council. The table on page 7-27 provides an indicative asset transfer checklist.

Infiltration Measure Design Assessment Checklist					
Asset I.D.					
Infiltration Measure Location:					
Hydraulics:	Design operational flow (m^3/s):		Above design flow (m^3/s):		
Area:	Catchment Area (ha):	Infiltration Area (m^2):	Detention Volume (m^3):		
SITE AND SOIL EVALUATION				Y	N
Site and Soil Evaluation undertaken in accordance with AS1547-2000					
Soil types appropriate for infiltration (K_{sat} > 0.36mm/hr, no salinity problems, no rock/shale)?					
PRE-TREATMENT					
Groundwater conditions assessed and objectives established?					
Level 1 Pre-Treatment provided?					
Level 2 Pre-Treatment provided?					
INFILTRATION SYSTEM				Y	N
Design objective established?					
Has the appropriate design approach been adopted?					
Infiltration system setbacks appropriate?					
Base of infiltration system >1m above seasonal high groundwater table?					
Has appropriate cover (soil depth above infiltration system) been provided?					
If placed on >10% terrain (ground slope), has engineering assessment been undertaken?					
FLOW MANAGEMENT				Y	N
Overall flow conveyance system sufficient for design flood event?					
Are the inflow systems designed to convey design flows?					
Bypass/ overflow sufficient for conveyance of design flood event?					
COMMENTS					

Infiltration Measures Construction Inspection Checklist

Asset I.D.		Inspected by:	
Site:		Date:	
Constructed by:		Time:	
		Weather:	
		Contact during visit:	

Items inspected	Checked		Satisfactory		Items inspected	Checked		Satisfactory	
	Y	N	Y	N		Y	N	Y	N
DURING CONSTRUCTION									
A. FUNCTIONAL INSTALLATION					Structural components				
Preliminary Works					10. Location and levels of infiltration system and overflow points as designed				
1. Erosion and sediment control plan adopted					11. Pipe joints and connections as designed				
2. Traffic control measures					12. Concrete and reinforcement as designed				
3. Location same as plans					13. Inlets appropriately installed				
4. Site protection from existing flows					14.Provision of geofabric to sides and base				
Earthworks					15. Correct fill media/modular system used				
5. Excavation as designed					B. SEDIMENT & EROSION CONTROL (if required)				
6. Side slopes are stable					16. Stabilisation immediately following earthworks				
Pre-treatment					17. Silt fences and traffic control in place				
7. Maintenance access provided					18. Temporary protection layers in place				
8. Invert levels as designed					C. OPERATIONAL ESTABLISHMENT				
9. Ability to freely drain					19. Temporary protection layers and associated silt removed				

FINAL INSPECTION									
1. Confirm levels of inlets and outlets					6. Check for uneven settling of surface				
2. Traffic control in place					7. No surface clogging				
3. Confirm structural element sizes					8. Maintenance access provided				
4. Gravel as specified					9. Construction generated sediment and debris removed				
5. Confirm pre-treatment is working									

COMMENTS ON INSPECTION

ACTIONS REQUIRED
1.
2.
3.
4.
5.
Inspection officer signature:

Infiltration Measures Maintenance Checklist				
Asset I.D.				
Inspection Frequency:	1 to 6 monthly	Date of Visit:		
Location:				
Description:				
Site Visit by:				
INSPECTION ITEMS		Y	N	ACTION REQUIRED (DETAILS)
Sediment accumulation in pre-treatment zone?				
Erosion at inlet or other key structures?				
Evidence of dumping (eg building waste)?				
Evidence of extended ponding times (eg. algal growth)?				
Evidence of silt and clogging within 'detention volume'?				
Clogging of flow management systems (sediment or debris)?				
Damage/vandalism to structures present?				
Drainage system inspected?				
Resetting of system required?				
COMMENTS				

Infiltration Measure 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?		
Inspection and maintenance undertaken as per maintenance plan?		
Inspection and maintenance forms provided?		
ASSET INSPECTED FOR DEFECTS AND/OR MAINTENANCE ISSUES AT TIME OF ASSET TRANFSFER	Y	N
Sediment accumulation at inflow points?		
Litter present?		
Erosion at inlet or other key structures?		
Traffic damage present?		
Evidence of dumping (e.g. building waste)?		
Evidence of ponding?		
Surface clogging visible?		
Damage/vandalism to structures present?		
COMMENTS		
ASSET INFORMATION	Y	N
Design Assessment Checklist provided?		
As constructed plans provided?		
Copies of all required permits (both construction and operational) submitted?		
Proprietary information provided (if applicable)?		
Digital files (eg drawings, survey, models) provided?		
Asset listed on asset register or database?		

7.7 Infiltration Measure Worked Example

An infiltration system is to be installed to infiltrate stormwater runoff from an industrial allotment in Townsville. The allotment is 1.0 ha in area on a rectangular site (200 m x 50 m) with an overall impervious surface area of 0.48 ha (48 % impervious). All stormwater runoff is to be pre-treated through swale bioretention systems prior to entering the infiltration system to ensure sustainable operation of the infiltration system and protection of groundwater. An illustration of the proposed allotment and associated stormwater management scheme is shown in Figure 7-6.

Treated flows from the swale bioretention systems are to be delivered to the infiltration system via traditional pipe drainage sized to convey the minor storm event (2 year ARI).

The allotment is located within a catchment that drains to a natural wetland that has been defined by the local authority as being hydrologically sensitive to increases in catchment flow. Therefore, there is to be no increase in mean annual runoff as a result of the development.

This worked example focuses on the design of an infiltration 'soak-away' system for the allotment based on the site characteristics and design objectives listed below.

<u>Site Characteristics</u>

The site characteristics are summarised as follows:

- Catchment area: 2,400 m^2 (roof)
2,400 m^2 (ground level paved)
5,200 m^2 (pervious)
10,000 m^2(total)
- Predevelopment mean annual runoff = 2.3 ML/yr
- Post development mean annual runoff = 6.9 ML/yr
- Soil type - sandy clay
- Saturated hydraulic conductivity (K_{sat}) = 80 mm/hr
- Topography - flat to moderate grades towards the road (2 - 4 %).

<u>Design Objectives</u>

As outlined in Section 7.6.1, the allotment is located within a catchment that drains to a natural wetland that has been defined by Townsville City Council as being hydrologically sensitive to increases in catchment flow and Council require that there be no increase in mean annual runoff as a result of the development. Considering the predevelopment mean annual runoff is 2.3 ML/yr and the post-development mean annual runoff is 6.9 ML/yr, the design objective of the infiltration system is the capture and infiltration of 4.6 ML/yr (equal to 67 % hydrologic effectiveness).

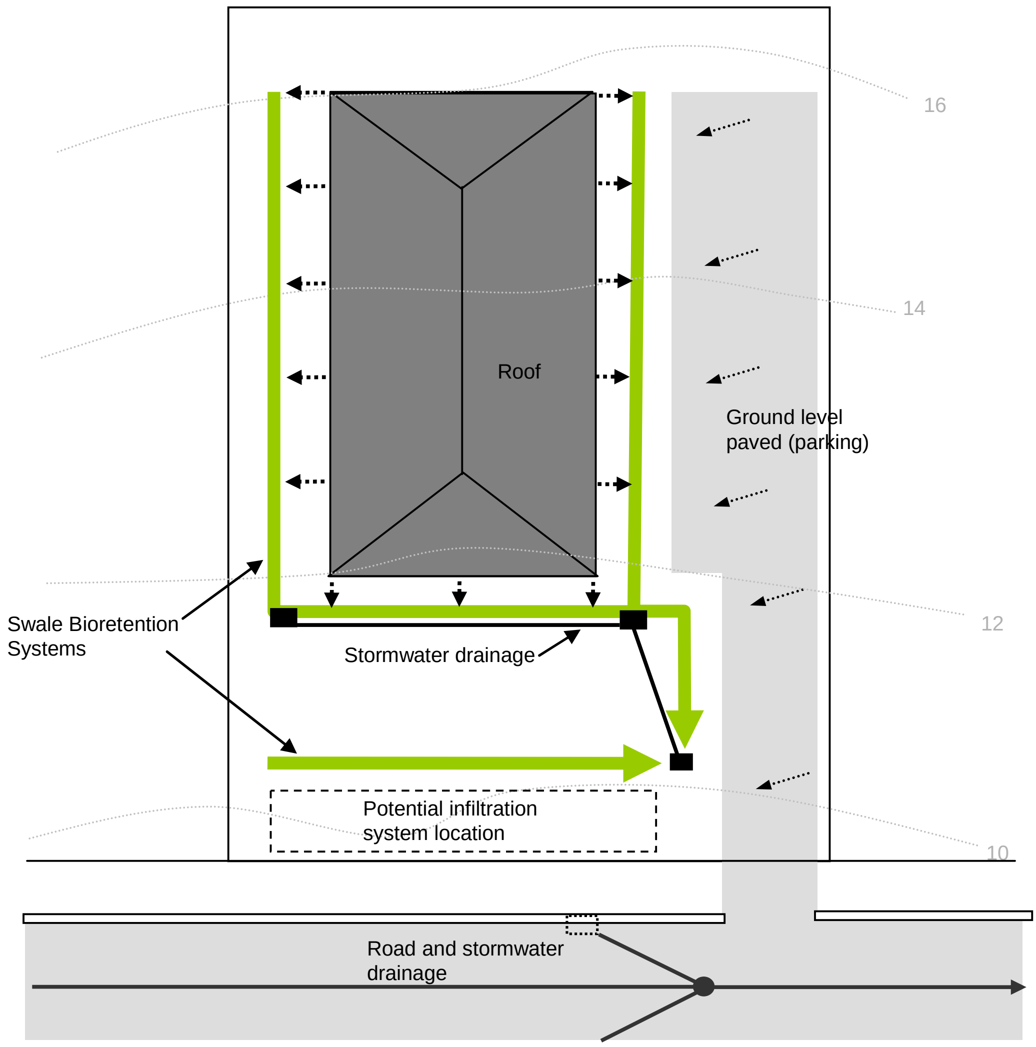


Figure 7-6: Site Layout (see Figure 7.10 for Drainage Detail)

7.7.1 Step 1: Site and Soil Evaluation

To define the site's suitability for infiltration of stormwater a 'Site and Soil Evaluation' was undertaken in accordance with AS1547-2000 Clause 4.1.3. The key information from the evaluation is presented below:

- soil type = sandy clay
- hydraulic conductivity = 80 mm/hr
- presence of soil salinity = no problems discovered
- presence of rock or shale = no rock or shale discovered
- slope/ terrain (%) = 2 – 4 %, ground level 10 m AHD in infiltration location
- groundwater details (depth, quality and values) = water table 5 m below surface (5 m AHD), moderate water quality with local bores used for irrigation.

Field tests found the soil to be suitable for infiltration, consisting of sandy clay with a saturated hydraulic conductivity of 80 mm/hr.

7.7.2 Step 2: Confirm Design Objectives

As outlined in Section 7.7.1.2, the design objective for the infiltration system is no increase in mean annual runoff as a result of the development, which requires the system to achieve 67 % hydrologic effectives. The hydrologic effectiveness approach will be used to establish the size of the infiltration system.

Design objective = no increase in mean annual runoff post- development (i.e. 67 % hydrologic effectiveness).

7.7.3 Step 3: Select Infiltration System Type

Based on the site attributes, the scale of the infiltration application (i.e. 1.0 ha) and Table 7-1, an infiltration 'soak-away' system is selected for the industrial allotment.

7.7.4 Step 4: Pretreatment Design

As an infiltration 'soak-away' has been selected for the site, reference to Section 7.2.4 and Table 7-3 indicates both Level 1 and 2 Pretreatment is required. Considering the groundwater is of moderate quality and is currently used for irrigation purposes, best practice treatment was proposed and approved by TCC based on meeting the TCC water quality objectives. This is being achieved through the use of swale bioretention systems strategically located through the allotment to capture runoff before it enters the traditional drainage systems (see Figure 7.9).

7.7.5 Step 5: Determine Design Flows

As described in Section 7.3.5, the 'design operation flow' is required to size the inlet to the infiltration system, which may vary depending on the particular situation. In this case, flows into the infiltration system are to be regulated through a discharge control pit, which will deliver flows up to the 1 year ARI into the infiltration system. Flows greater than 1 year ARI, or when the infiltration system is full, will bypass the infiltration system by overtopping the overflow weir in the discharge control pit. Considering only traditional drainage will enter the discharge control pit, the 'above design flow' is the 2 year ARI event. Therefore:

- 'design operation flow' = 1 year ARI
- 'above design flow' = 2 year ARI

Design flows are established using the Rational Method and the procedures in *Stormwater Drainage Design Specification D5* and QUDM (DNRW, IPWEA & BCC 1998). The site has one contributing catchment being 1.0 ha in area, 200 m long and drained by swale bioretention systems and stormwater pipes.

<u>Time of concentration (t_c)</u>

Time of Concentration t_c = 10 mins

Design runoff coefficient

Runoff Coefficients

C_{10} = 0.82

	C Runoff		
ARI	1	2	10
QUDM Factor	0.8	0.85	1.0
C_{ARI}	0.66	0.7	0.82

Catchment Area, A = 10,000 m^2 (1.0 ha)

Rainfall Intensities t_c = 10 mins

I_1 = 91.9 mm/hr

I_2 = 119 mm/hr

Rational Method $Q = CIA/360$

$Q_{1yr\ ARI}$ = 0.168 m^3/s

$Q_{2yr\ ARI}$ = 0.231 m^3/s

'Design operation flow' = 0.168 m^3/s

'Above design flow' = 0.231 m^3/s

7.7.6 Step 6: Size Infiltration System

The design objective for the infiltration basin is to achieve a hydrologic effectiveness of 67 %. This objective is to be delivered through use of an infiltration 'soak-away' created using gravel and being 1.0 m in depth.

Based on quantitative modelling using an appropriate software package the 'infiltration area' was determined to be approximately 1.5 % of the catchment area to achieve a hydrologic effectiveness when the in-situ soil hydraulic conductivity is 80 mm/hr. Therefore, the 'infiltration area' is 150 m^2 and the 'detention volume' is 150 m^3 (gravel filled).

Gravel filled infiltration 'soak-away'

'Infiltration Area' = 150 m^2

'Detention Volume' = 150 m^3

7.7.7 Step 7: Locate Infiltration System

With a sandy clay soil profile, the minimum distance of the infiltration system from structures and property boundary is 2 m (Table 7-5). As the general fall of the site is to the front of the property, it is proposed that the infiltration system be sited near the front.

The infiltration 'soak-away' is to be rectangular in shape, being 30 m long by 5 m wide and located 2 m from the front boundary as shown in Figure 7-7.

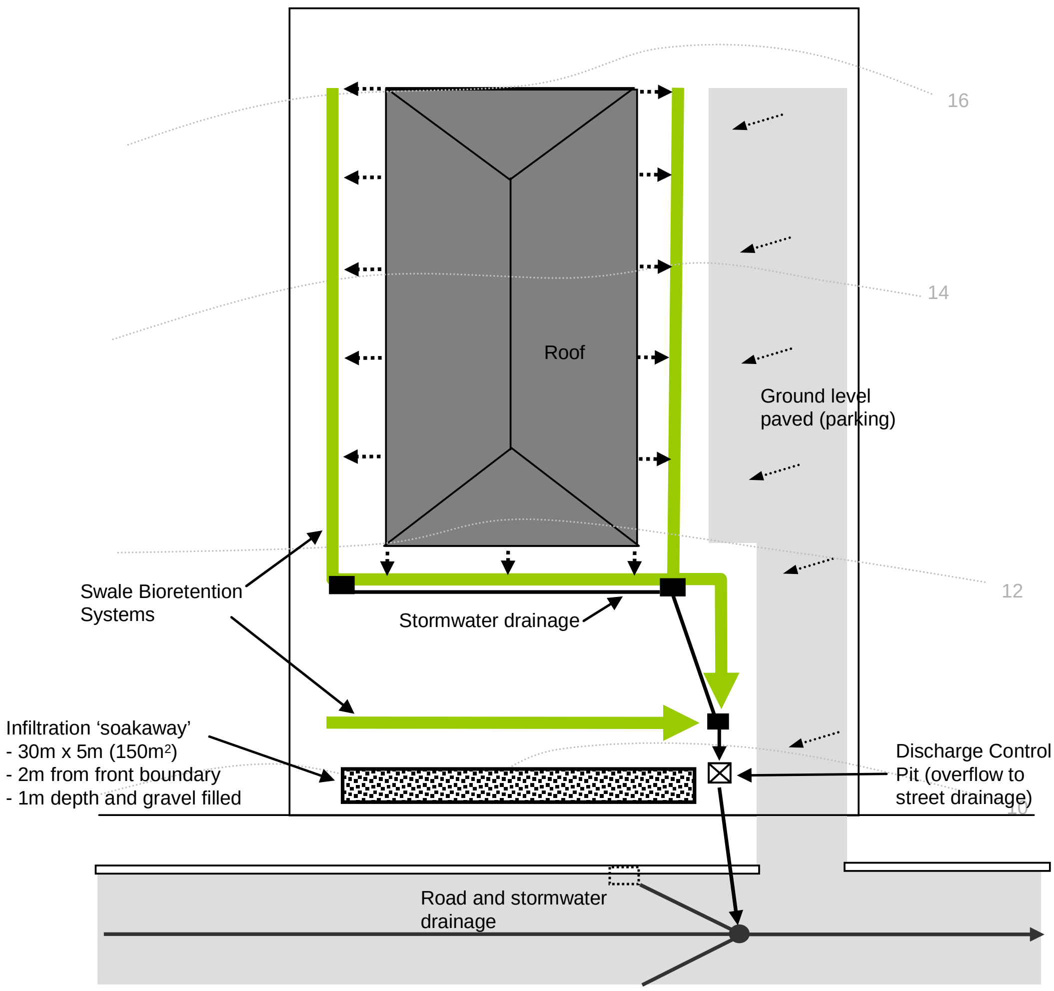


Figure 7-7: Location of Infiltration System

7.7.8 Step 8: Set Infiltration Depths (Sub-surface Systems Only)

The depth of the infiltration systems must be set to ensure the base is a minimum of 1.0 m above the seasonal high water table and there is a minimum of 0.3 m cover. Considering the water table sits 5 m below surface (5 m AHD), an infiltration depth of 1.0 m is adopted with a cover of 0.5 m. This means the base of the infiltration system sits at 8.5 m AHD which is 3.5 m above the water table.

Infiltration depth = 1.0 m

Cover = 0.5 m

Top of infiltration system = 9.5 m AHD

Base of infiltration system = 8.5 m AHD

Depth to water table = 3.5 m

7.7.9 Step 9: Specify Infiltration 'Detention Volume' Elements

The following design specification applies to the infiltration 'soak-away':

- Gravel - clean (fines free) stone/ gravel with a uniform size of 50 mm diameter.
- Geofabric - Geofabric must to be installed along the side walls and through the base of the infiltration detention volume to prevent the migration of in-situ soils into the system. Geofabric must be non-woven type with a minimum perforation or mesh size of 0.25 mm.

7.7.10 Step 10: Hydraulic Control Design

Flow into the infiltration 'soak-away' will be regulated through a discharge control pit with overflow or bypass flows being directed into the piped drainage system located in the road reserve. As depicted in Figure 7-8 (over page), the discharge control pit consists of the following:

- discharge pipe – discharge 'above design flow' (2 year ARI) into the pit
- inflow pipe - connection between the pit and the infiltration basin sized to convey 'design operation flow' (1 year ARI)
- perforated inflow pipes - to distribute ' design operation flow' (1 year ARI) into the gravel filled 'detention volume'
- overflow weir – to bypass 'above design flow' (2 year ARI).

7.7.10.1 Discharge pipe

The discharge pipe into the control pit is sized to convey the 'above design flow' (2 year ARI = 0.231 m^3/s) into the discharge control pit using Equation 7.5 in accordance with QUDM (DNRW, IPWEA & BCC 1998). The resulting pipe size is a 375 mm diameter reinforced concrete pipe (RCP) at 2 % grade (calculation not presented). The pipe will enter the pit at 9.2 m AHD therefore the invert of the discharge control pit is set at 9.0 m AHD.

Discharge Pipe = 375 mm diameter RCP at 2 % grade

Invert Level at Pit = 9.0 m AHD.

7.7.10.2 Inflow Pipe (Connection to Infiltration System)

The size of the inflow pipe connecting the discharge pit to the infiltration system is calculated by estimating the velocity in the connection pipe using a simplified version of Equation 7.5.

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

Where h = head level driving flow through the pipe (defined as the overflow weir crest level minus the invert level of the inflow pipe)

= 9.5 m AHD – 9.0 m AHD = 0.5 m

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 x 0.5) 0.5 = 2.21 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 = 0.168/2.21 = 0.076 m^2

This area is equivalent to ~ 300 mm RCP. The obvert of the pipe is to be set at 9.0 m AHD.

Inflow pipe = 300 mm diameter RCP

Invert Level at Pit = 9.0 m AHD

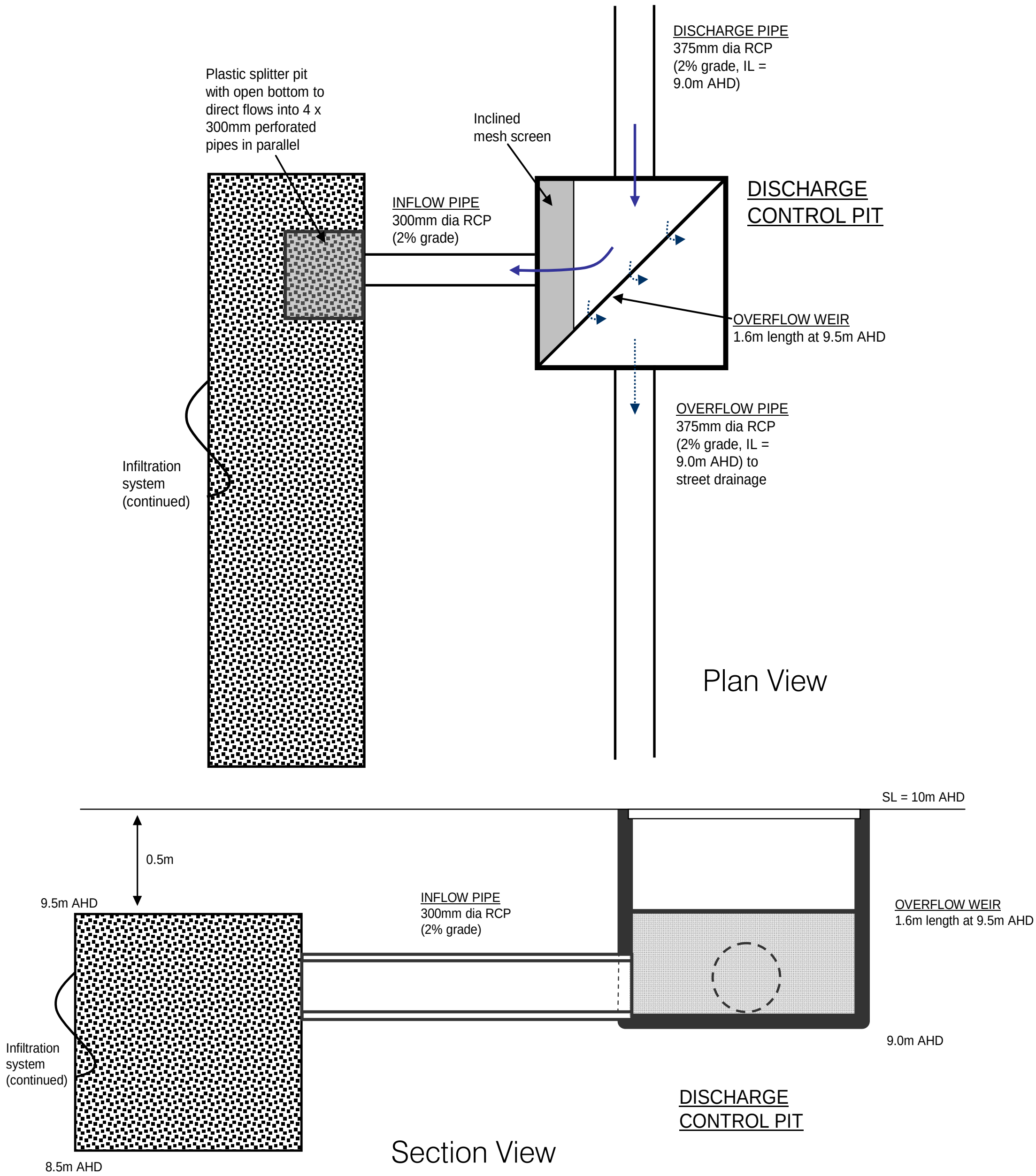


Figure 7-8: Discharge Control Pit Configuration

7.7.10.3 Perforated Inflow Pipes

To ensure appropriate distribution of flows into the gravel filled ‘detention volume’, four 300 mm diameter perforated pipes laid in parallel (1.0 m apart) are to accept flows from the 300 mm diameter RCP. The perforated pipes have a slot clear opening of 3150 mm^2/m with the slots being 1.5 mm wide and are to be placed at 0.5 % grade.

Two design checks are required:

- Ensure the pipe has capacity to convey the ‘design operation flow’ (0.168 m^3/s).
- Ensure the perforations are adequate to pass the ‘design operation flow’.

Perforated Pipe Conveyance

Manning's equation is applied to estimate the flow rate in the perforated pipes and confirm the capacity of the pipes is sufficient to convey the 'design operation flow' (0.168 m^3/s). The four 300 mm diameter perforated pipes are to be laid in parallel at a grade of 0.5 %.

Applying the Manning's Equation assuming a Manning's *n* of 0.015 finds:

Q (flow per pipe) = 0.044 m^3/s

Q_{Total} = 0.176 m^3/s (for four pipes) > 0.168 m^3/s, and hence OK.

Perforated Pipe Slot Conveyance

To ensure the perforated pipe slots are not a hydraulic choke in the system, the flow capacity of perforated pipe slots is estimated and compared with the 'design operation flow' (0.168 m^3/s). To estimate the flow rate, an orifice equation (Equation 7.6) is applied as follows:

$$Q_{orifice} = B \cdot C_d \cdot A\sqrt{2 \cdot g \cdot h}$$

Where	Head *(h)*	= 0.5 m
	Blockage *(B)*	= 0.5 (50 % blocked)
	Area *(A)*	= 2100 mm^2/m clear perforations, hence blocked area
		= 1050 mm^2/m
	Slot Width	= 1.5 mm
	Slot Length	= 7.5 mm
	Pipe diameter	= 300 mm
	Coefficient *(C_d)*	= 0.61 (assume slot width acts as a sharp edged orifice).

Number of slots per metre = (1050)/(1.5x7.5) = 93.3

Note: blockage factor (*B*) already accounted for in 'Area' calculation above

Inlet capacity /m of pipe $= [0.61 \times (0.0015 \times 0.0075) \times \sqrt{2 \times 9.81 \times 0.5}] \times 93.3$

$= 0.002$ m^3/s

Inlet capacity/m x total length (4 lengths of 30 m) = 0.002 x (4 x 30) = 0.24 m^3/s > 0.168, hence OK.

Perforated pipes = 4 x 300 mm diameter perforated pipe laid in parallel, 1.0 m apart and at 0.5 % grade.

7.7.10.4 Overflow Weir

An overflow weir (internal weir) located within the discharge control pit separates the inflow pipe to the infiltration system from the overflow pipe connecting to the street drainage. The overflow weir is to be sized to convey the 'above design flow' of 0.231 m^3/s and surcharge 0.2 m above the weir.

The weir flow equation (Equation 7.7) is used to determine the required weir length:

$$Q_{weir} = B \cdot C_w \cdot L \cdot h^{3/2}$$

So $$L = \frac{Q_{weir}}{B \cdot C \cdot h^{3/2}}$$

Using the 'above design operation' flow (0.231 m^3/s), B = 1.0 (no blockage for internal weir), C_w = 1.66 and h = 0.2 m we have L = 1.56 m.

If the weir is located diagonally across the discharge control pit, a 1200 x 1200 mm pit can be used. The crest of the weir must be set at the top of the 'detention volume' of the infiltration system (i.e. 9.5 m AHD).

Overflow weir = 1.56 m length at 9.5 m AHD

Discharge control pit = 1200 x 1200 mm

7.7.11 Design Calculation Summary

The sheet below summarises the results of the design calculations.

INFILTRATION SYSTEMS DESIGN CALCULATION SUMMARY

	Calculation Task		CALCULATION SUMMARY Outcome		Check
	Catchment Characteristics				
		Catchment area	1.0	ha	✓
		Catchment landuse (i.e residential, commercial etc.)	Industrial		
		Storm event entering infiltration system (minor or major)	2	year ARI	
1	Site and soil evaluation				
	Site and Soil Evaluation' undertaken in accordance with AS1547-2000 Clause 4.1.3				
		Soil type	Sandy Clay		✓
		Hydraulic conductivity (K_{sat})	80	mm/hr	
		Presence of soil salinity	No		
		Presence of rock/shale	No		
		Infiltration site terrain (% slope)	2-4%		
		Groundwater level	5	m AHD	
			5	m below surface	
		Groundwater quality	Moderate		
		Groundwater uses	Irrigation		
2	Confirm design objectives				
		Confirm design objective as defined by conceptual design	No increase in mean annual runoff. 67% hydrologic effectiveness		✓
3	Select infiltration system type				
		Leaky Well			✓
		Infiltration Trench			
		Infiltration 'Soak-away'	✓		
		Infiltration Basin			
4	Pre-treatment design				
		Level 1 Pre-treatment (avoid clogging)	✓		✓
		Level 2 Pre-treatment (groundwater protection)	✓		
5	Determine design flows				
		'Design operation flow' (1 year ARI)	1	year ARI	✓
		'Above design flow' (2 - 50 year ARI)	2	year ARI	
	Time of concentration				
		Refer to GCC *Land Development Guidelines* and *QUDM*	10	minutes	✓
	Identify rainfall intensities				
		'Design operation flow' - $I_{1\ year\ ARI}$	91.9	mm/hr	✓
		'Above design flow'- $I_{2-50\ year\ ARI}$	119	mm/hr	
	Design runoff coefficient				
		'Design operation flow' - $C_{1\ year\ ARI}$	0.66		✓
		'Above design flow'- $C_{2-50\ year\ ARI}$	0.7		
	Peak design flows				
		'Design operation flow' - 1 year ARI	0.168	m^3/s	✓
		'Above design flow' (2 - 50 year ARI)	0.231	m^3/s	
6	Size infiltration system				
	Hydrologic effectiveness approach				
		Hydrologic effectiveness	67	%	✓
		Depth	1	m	
		Porosity (void = 1.0, gravel filled = 0.35)	0.35		
		Size of infiltration area	1.5	% of catchment area	
		'Infiltration Area'	150	m^2	
		'Detention Volume'	150	m^3	

INFILTRATION SYSTEMS DESIGN CALCULATION SUMMARY					
			CALCULATION SUMMARY		
	Calculation Task		Outcome		Check
	Design storm approach				
		Design storm flow	-	m^3/s	✓
		Inflow volume	-	m^3	
		Outflow volume	-	m^3	
		Depth	-	m	
		'Infiltration Area'	-	m^2	
		'Detention Volume'	-	m^3	
7	Locate infiltration system				
		Minimum distance from boundary (Table 7-5)	2	m	✓
		Width	5	m	
		Length	30	m	
8	Set infiltration depths (sub-surface systems only)				
		Ground surface level	10	m AHD	✓
		Groundwater level	5	m AHD	
			5	m below surface	
		Infiltration system depth	1	m	
		Top of infiltration system	9.5	m AHD	
		Base of infiltration system	8.5	m AHD	
		Cover	0.5	m	
		Depth to water table	3.5	m	
9	Specify infiltration 'detention volume' elements				
		Gravel size	50	mm diam.	✓
		Modular plastic cells			
		Geofabric	✓		
10	Flow management design				
	Inflow/Overflow structures				
		Direct inflow			✓
		Overflow pit/pipe			
		Discharge control pit	✓		
	Discharge pipe				
		Pipe capacity	0.231	m^3/s	✓
		Pipe size	375	mm diam.	
	Inflow pipe				
		Pipe capacity	0.168	m^3/s	✓
		Pipe size	300	mm diam.	
	Overflow pipe				
		Pipe capacity	0.231	m^3/s	✓
		Pipe size	375	mm diam.	
	Overflow pit				
		Pit capacity	-	m^3/s	✓
		Pit size	-	mm x mm	
	Perforated inflow pipes				
		No. of pipes	4		✓
		Pipe size	300	mm	
	Discharge control pit				
		Pit size	1200 x 1200	mm x mm	✓
		Weir length	1.5	m	

7.7.12 Worked Example Drawings

The drawing at the end of the chapter details the construction of the infiltration system designed in the worked example.

7.8 References

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