resources available to assist with this selection process, including Australian Runoff Quality (Engineers Australia 2003), 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

<table>
<thead>
<tr>
<th>Infiltration Type</th>
<th>Allotment Scale (&lt; 0.1 ha)*</th>
<th>Medium Scale (0.1 - 10 ha)*</th>
<th>Large Scale (&gt; 10 ha)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaky Wells</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infiltration Trenches</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Infiltration Soak-aways</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Infiltration Basins</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

* 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

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

*Unless otherwise approved by BCC, 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.
The hydrologic effectiveness curves derived for infiltration systems (with defined parameters) located in Brisbane are presented in Section 7.3.6.1 and represent Step 6 in the design steps required for infiltration measures.

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 BCC, 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 BCC.

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

<table>
<thead>
<tr>
<th>Infiltration Type</th>
<th>Level 1 Pretreatment</th>
<th>Level 2 Pretreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaky Well</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Infiltration Trench</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Infiltration Soak-away</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Infiltration Basin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Sandy clay to clay soils ($K_{sat}$ &lt; 180 mm/hr) + dense ground cover</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>- Sandy clay to clay soils ($K_{sat}$ &lt; 180 mm/hr) + turf ground cover</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>- Sandy soils ($K_{sat}$ &gt; 180 mm/hr)</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

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 BCC 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>
<thead>
<tr>
<th>Soil Type</th>
<th>Saturated Hydraulic Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m/s</td>
</tr>
<tr>
<td>Sand</td>
<td>$&gt;5 \times 10^{-5}$</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>$1 \times 10^{-5}$ to $5 \times 10^{-5}$</td>
</tr>
<tr>
<td>Medium Clay</td>
<td>$1 \times 10^{-6}$ to $1 \times 10^{-5}$</td>
</tr>
<tr>
<td>Heavy Clay</td>
<td>$1 \times 10^{-8}$ to $1 \times 10^{-6}$</td>
</tr>
</tbody>
</table>

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 180 mm/hr are preferred for infiltration application.
- Infiltration systems will not be accepted by BCC where the in-situ soils are very heavy clays (i.e. $< 0.36$ mm/hr) or wind blown sand (i.e. $> 360$ 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 BCC 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 BCC 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 BCC.

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 2003) 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>
<thead>
<tr>
<th>Soil Type</th>
<th>Saturated Hydraulic Conductivity (mm/hr)</th>
<th>Minimum distance from structures and property boundaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>&gt;180</td>
<td>1.0 m</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>36 to 180</td>
<td>2.0 m</td>
</tr>
<tr>
<td>Medium Clay</td>
<td>3.6 to 36</td>
<td>4.0 m</td>
</tr>
<tr>
<td>Heavy Clay</td>
<td>0.0036 to 3.6</td>
<td>5.0 m</td>
</tr>
</tbody>
</table>
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. Pre-treatment design
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. Maintenance plan

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 2003), 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.
• ‘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
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 BCC, the hydrologic effectiveness method must be used when designing infiltration systems.

7.3.6.1 Hydrologic Effectiveness Method

Figures 7.5 to 7.8 below show 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. The curves are based on the performance of an infiltration system in a typical residential suburb of Brisbane (i.e. with an annual volumetric runoff coefficient (AVRC) of 0.38). The curves were derived using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC)(CRCCH 2005).

Where local data are available, or if the configuration of the system varies to that described below, MUSIC should be used in preference to the hydrologic effectiveness curves. MUSIC results will always supersede the curves.

The curves were derived (conservatively) assuming the systems have the following characteristics:

- varying in-situ soil hydraulic conductivity
- ‘infiltration area’ = ‘detention volume’ area
- ‘detention volume’ depth of 1.0 m and porosity of 1.0 (i.e. an open detention volume with no fill media) – Figure 7.5
- ‘detention volume’ depth of 1.0 m and porosity of 0.35 (gravel filled detention volume) – Figure 7.6
- ‘detention volume’ depth of 0.5 m and porosity of 1.0 (see above) – Figure 7.7
- ‘detention volume’ depth of 0.5 m and porosity of 0.35 (gravel filled detention volume) – Figure 7.8.

These curves can be used to establish the size of both the ‘detention volume’ and ‘infiltration area’ of the infiltration systems to achieve a particular hydrologic effectiveness. The designer is required to select the relevant hydrologic effectiveness curve by establishing the likely configuration and form of the infiltration system, namely whether it will be 0.5 m or 1.0 m deep and whether it will be an open void detention volume (porosity = 1.0) or gravel filled (porosity = 0.35).

Linear interpolation between the curves may be used to estimate the infiltration area required for systems with hydraulic conductivities not shown on the charts. However, it should be noted that the relationship between the curves is not linear and as a result, these interpolations do not provide an exact representation of the size of infiltration area (as a % of catchment area). Designers must be careful not to under size infiltration areas through this process.
Figure 7.5: Hydrologic Effectiveness of ‘Detention Storage’ for Infiltration Systems in Brisbane (Depth = 1 m and Porosity = 1.0)

Figure 7.6: Hydrologic Effectiveness of ‘Detention Storage’ for Infiltration Systems in Brisbane (Depth = 1 m and Porosity = 0.35)
Infiltration Hydrologic Effectiveness (Depth = 0.5m, Porosity = 1.0)

Figure 7.7: Hydrologic Effectiveness of ‘Detention Storage’ for Infiltration Systems in Brisbane (Depth = 0.5 m and Porosity = 1.0)

Infiltration Hydrologic Effectiveness (Depth = 0.5m, Porosity = 0.35)

Figure 7.8: Hydrologic Effectiveness of ‘Detention Storage’ for Infiltration Systems in Brisbane (Depth = 0.5 m and Porosity = 0.35)
In areas that are unlikely to have an AVRC of 0.38 (i.e. commercial, industrial and completely impervious areas), the adjustments shown in Table 7.6 can be used to modify values from the charts. These adjustments allow the hydrologic effectiveness to be estimated for a range of land use types in the Brisbane area. An example using this method is provided at the end of this section.

### Table 7.6: Performance Adjustment Factors for Commercial, Industrial and Fully Impervious Sites in Brisbane

<table>
<thead>
<tr>
<th>% impervious in MUSIC*</th>
<th>Commercial</th>
<th>Industrial</th>
<th>Roof, Car park etc</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVRC</td>
<td>0.48</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Infiltration Hydrologic Effective Adjustment Factor</td>
<td>– 2.5%</td>
<td>– 4%</td>
<td>– 7%</td>
</tr>
</tbody>
</table>

* Effective impervious area adjusted to achieve annual volumetric coefficients as recorded for these landuses by BCC

Table 7.6 shows that as impervious area increases, the effectiveness of an infiltration system decreases (shown by negative infiltration hydrologic effective adjustment factors).

An example of using the curves:

A residential development (10 ha and 28 % impervious) increases mean annual runoff from 10 ML/yr (predevelopment) to 18 ML/yr (post development) and the design objective for the infiltration system is to capture and infiltrate the excess 8 ML/yr which equates to a 45 % hydrologic effectiveness (i.e. 8 ML/18 ML). Assuming a 1.0 m deep gravel filled (porosity = 0.35) infiltration system is used and the in-situ soil hydraulic conductivity is 36 mm/hr, what is the ‘detention volume’ and ‘infiltration area’.

- From Figure 7.6, the size of the infiltration system to achieve 45 % hydrologic effectiveness is 0.8 % of the catchment area. Therefore, the ‘infiltration area’ = 800 m² and ‘detention volume’ = 800 m³ (gravel filled).
- If the development was an industrial estate (48 % impervious) then the hydrologic effectiveness objective to achieve the same outcome increases to 49 %. Therefore, the size of the infiltration system is 1 % of the catchment area which equates to an ‘infiltration area’ = 1000 m² and ‘detention volume’ = 1000 m³ (gravel filled).

#### 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 BCC for sizing infiltration systems.

**Design Storm Selection (Q_{des})**

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 BCC and will generally relate to 3 month ARI and 1 year ARI design storms.
Detention Volume

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 \( V_i \) is determined, in accordance with Section 6 of QUDEM (DPI et al. 1993), as the product of the design storm flow and the storm duration:

\[
V_i = Q_{des} \cdot D
\]  
**Equation 7.1**

Where:
- \( V_i \) = inflow volume (for storm duration \( D \)) (m³)
- \( Q_{des} \) = design storm flow for sizing as outlined in Section 7.3.5 (Rational Method, \( Q = CIA/360 \) (m³/s))
- \( D \) = storm duration (hrs x 3600 s/hr)

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 2003) suggests that pressure is hydrostatically distributed and thus equal to half the depth of water over the bed of the infiltration system:

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

Where:
- \( V_o \) = outflow volume (for storm duration \( D \)) (m³)
- \( K_{sat} \) = saturated hydraulic conductivity (mm/hr) as provided in Step 1.
- \( A_{inf} \) = infiltration area (m²)
- \( P \) = 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:

\[
V_d = V_i - V_o
\]  
**Equation 7.3**

Where:
- \( V_d \) = required detention volume (m³)
- \( V_i \) = inflow volume (m³)
- \( V_o \) = outflow volume (m³)

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.
Soil Hydraulic Conductivity Moderating Factor

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 2003) recommends that moderation factors for hydraulic conductivities determined from field test be applied as shown in Table 7.7.

Table 7.7 Moderation Factors to Convert Point to Areal Conductivities (after Engineers Australia 2003)

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Moderation Factor ($U$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy soil</td>
<td>0.5</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>1.0</td>
</tr>
<tr>
<td>Medium and Heavy Clay</td>
<td>2.0</td>
</tr>
</tbody>
</table>

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 2003) 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):

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

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.

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.

7.3.10 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 7.8 summarises the typical hydraulic control requirements for the different types of infiltration system.

<table>
<thead>
<tr>
<th>Infiltration Type</th>
<th>Inflow</th>
<th>Discharge control pit</th>
<th>Overflow pipe/ pit</th>
<th>Discharge control pit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaky Wells</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Infiltration Trenches</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Infiltration Soak-aways</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Infiltration Basins</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

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 7.8 are designed using the following techniques.
Pipe flows are to be calculated in accordance with the *Subdivision and Development Guidelines* (BCC 2000a) and QUDM (DPI et al. 1993) 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 ($\Delta H$) 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 (DPI et al. 1993):

$$\Delta H = h_f + h_s$$  \hspace{1cm} \text{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 bioretention system to allow inspection and maintenance when required. The base of the infiltration system must remain flat. Reference is made to the drawings in the worked example for further guidance.

**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.

**Perforate 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.

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

Where
- \( Q_{\text{perf}} \) = flow through perforations (m³/s)
- \( B \) = blockage factor (0.5)
- \( C_d \) = orifice discharge coefficient (assume 0.61 for sharp edge orifice)
- \( A \) = total area of the orifice (m²)
- \( g \) = gravity (9.79 m/s²)
- \( h \) = head above 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 5.10 QUDM (DPI et al. 1993)). In addition, a blockage factor is to be used that assumes the grate is 50% blocked.

For free overfall conditions (weir equation):

\[ \frac{2}{3} \cdot h \cdot L \cdot C_w \cdot B \cdot h^{3/2} \]  
Equation 7.7

Where
- \( Q_{\text{weir}} \) = flow into pit (weir) under free overfall conditions (m³/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):

\[ B \cdot C_d \cdot A \sqrt{2 \cdot g \cdot h} \]  
Equation 7.8

Where
- \( B \), \( g \) and \( h \) have the same meaning as above
- \( Q_{\text{orifice}} \) = flow rate into pit under drowned conditions (m³/s)
- \( C_d \) = discharge coefficient (drowned conditions = 0.6)
- \( A \) = area of orifice (perforations in inlet grate) (m²)
When designing grated field inlet pits, reference is to be made to the procedure described in QUDEM Section 5.10.4 (DPI et al. 1993) and Section 6 of the Subdivision and Development Guidelines (BCC 2000a). Standard Drawings UMS 157 and UMS 337 provide guidance on acceptable solutions for overflow pits (field inlet pits).

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: Maintenance Plan

Refer to Section 7.4 for discussion on maintenance requirements for infiltration measures.

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

<table>
<thead>
<tr>
<th>Calculation Task</th>
<th>Outcome</th>
<th>Check</th>
</tr>
</thead>
</table>

#### Calculation Summary

<table>
<thead>
<tr>
<th>Calculation Task</th>
<th>Outcome</th>
<th>Check</th>
</tr>
</thead>
</table>

#### 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
- **Groundwater quality**
- **Groundwater uses**

#### Confirm Design Objectives

Confirm design objective as defined by conceptual design

#### Select Infiltration System Type

- Leaky Well
- Infiltration Trench
- Infiltration 'Soak-away'
- Infiltration Basin

#### Pre-treatment Design

- Level 1 Pre-treatment (avoid clogging)
- Level 2 Pre-treatment (groundwater protection)

#### Determine Design Flows

- **Design operation flow** (1 year ARI) year ARI
- **Above design flow** (either 2 or 50 year ARI) year ARI

#### Time of Concentration

Refer to BCC Subdivision and Development Guidelines and QUDE

#### Identify Rainfall Intensities

- **Design operation flow** \(- I_1 \) year ARI mm/hr
- **Above design flow** \(- I_2 \) year ARI or \(- I_{50} \) year ARI mm/hr

#### Design Runoff Coefficient

- **Design operation flow** \(- C_1 \) year ARI
- **Above design flow** \(- C_2 \) year ARI or \(- C_{50} \) year ARI

#### Peak Design Flows

- **Design operation flow** - 1 year ARI m³/s
- **Above design flow** - 2 or 50 year ARI m³/s

#### Size Infiltration System

- **Hydrologic effectiveness objective** %
- **Depth** m
- **Porosity** (void = 1.0, gravel filled = 0.35)
- **Size of infiltration area** (from Figure 7.4-7.7) m²
- **Infiltration Area** m²
- **Detention Volume** m³
### Design storm approach

Design storm flow \( \text{m}^3/\text{s} \)
Inflow volume \( \text{m}^3 \)
Outflow volume \( \text{m}^3 \)
Depth \( \text{m} \)
‘Infiltration Area’ \( \text{m}^2 \)
‘Detention Volume’ \( \text{m}^3 \)

### 7 Locate infiltration system

Minimum distance from boundary (Table 7.5) \( \text{m} \)
Width \( \text{m} \)
Length \( \text{m} \)

### 8 Set infiltration depths (sub-surface systems only)

Ground surface level \( \text{m} \) AHD
Groundwater level \( \text{m} \) AHD
Infiltration system depth \( \text{m} \) below surface
Top of infiltration system \( \text{m} \) AHD
Base of infiltration system \( \text{m} \) AHD
Cover \( \text{m} \)
Depth to water table \( \text{m} \)

### 9 Specify infiltration ‘detention volume’ elements

Gravel size \( \text{mm diam.} \)
Modular plastic cells
Geofabric

### 10 Flow management design

**Inflow/Overflow structures**

Direct inflow
Overflow pit/pipe
Discharge control pit

**Discharge pipe**

Pipe capacity \( \text{m}^3/\text{s} \)
Pipe size \( \text{mm diam.} \)

**Inflow pipe**

Pipe capacity \( \text{m}^3/\text{s} \)
Pipe size \( \text{mm diam.} \)

**Overflow pipe**

Pipe capacity \( \text{m}^3/\text{s} \)
Pipe size \( \text{mm diam.} \)

**Overflow pit**

Pit capacity \( \text{m}^3/\text{s} \)
Pit size \( \text{mm x mm} \)

**Perforated inflow pipes**

No. of pipes
Pipe size \( \text{mm} \)

**Discharge control pit**

Pit size \( \text{mm x mm} \)
Weir length \( \text{m} \)
7.4 Maintenance Requirements

Maintenance for infiltration systems 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).

7.5 Checking Tools

This section provides a number of checking aids for designers and Council development assessment officers. In addition, Section 7.5.5 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).
7.5.1 Design Assessment Checklist

The checklist below 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.

<table>
<thead>
<tr>
<th>Infiltration Measure Design Assessment Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infiltration Measure Location:</td>
</tr>
<tr>
<td>Hydraulics:</td>
</tr>
<tr>
<td>Area:</td>
</tr>
<tr>
<td>Site and Soil Evaluation</td>
</tr>
<tr>
<td>Site and Soil Evaluation undertaken in accordance with AS1547-2000</td>
</tr>
<tr>
<td>Soil types appropriate for infiltration (0.36 &lt; Ksat &lt; 360mm/hr, no salinity problems, no rock/shale)?</td>
</tr>
<tr>
<td>Pre-Treatment</td>
</tr>
<tr>
<td>Groundwater conditions assessed and objectives established?</td>
</tr>
<tr>
<td>Level 1 Pre-Treatment provided?</td>
</tr>
<tr>
<td>Level 2 Pre-Treatment provided?</td>
</tr>
<tr>
<td>Infiltration System</td>
</tr>
<tr>
<td>Design objective established?</td>
</tr>
<tr>
<td>Has the appropriate design approach been adopted?</td>
</tr>
<tr>
<td>Infiltration system setbacks appropriate?</td>
</tr>
<tr>
<td>Base of infiltration system &gt;1m above seasonal high groundwater table?</td>
</tr>
<tr>
<td>Has appropriate cover (soil depth above infiltration system) been provided?</td>
</tr>
<tr>
<td>If placed on &gt;10% terrain (ground slope), has engineering assessment been undertaken?</td>
</tr>
<tr>
<td>Flow Management</td>
</tr>
<tr>
<td>Overall flow conveyance system sufficient for design flood event?</td>
</tr>
<tr>
<td>Are the inflow systems designed to convey design flows?</td>
</tr>
<tr>
<td>Bypass/ overflow sufficient for conveyance of design flood event?</td>
</tr>
</tbody>
</table>
## 7.5.2 Construction Checklist

### Infiltration Measures Construction Inspection Checklist

<table>
<thead>
<tr>
<th>Items inspected</th>
<th>Checked</th>
<th>Satisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INSPECTED BY:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DATE:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TIME:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CONSTRUCTED BY:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WEATHER:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CONTACT DURING VISIT:</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Items inspected</th>
<th>Checked</th>
<th>Satisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DURING CONSTRUCTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Preliminary Works</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Erosion and sediment control plan adopted</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>2. Traffic control measures</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3. Location same as plans</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>4. Site protection from existing flows</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>B. Earthworks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Excavation as designed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Side slopes are stable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Pre-treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Maintenance access provided</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Invert levels as designed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Ability to freely drain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Structural components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Location and levels of infiltration system and overflow points as designed</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>11. Pipe joints and connections as designed</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>12. Concrete and reinforcement as designed</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>13. Inlets appropriately installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Correct fill media/modular system used</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Items inspected</th>
<th>Checked</th>
<th>Satisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FINAL INSPECTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Confirm levels of inlets and outlets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Traffic control in place</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Confirm structural element sizes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Gravel as specified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Confirm pre-treatment is working</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Check for uneven settling of surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. No surface clogging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Maintenance access provided</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Construction generated sediment and debris removed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### COMMENTS ON INSPECTION


### ACTIONS REQUIRED

1. 
2.  
3.  
4.  
5.  

Inspection officer signature:
7.5.3 Operation and Maintenance Inspection Form

In addition to checking and maintaining the function of pretreatment elements, the form below 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.

### Infiltration Measure Maintenance Checklist

<table>
<thead>
<tr>
<th>Inspecton Frequency:</th>
<th>1 to 6 monthly</th>
<th>Date of Visit:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Visit by:</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inspection Items</strong></td>
<td><strong>Y</strong></td>
<td><strong>N</strong></td>
</tr>
<tr>
<td>Sediment accumulation in pre-treatment zone?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion at inlet or other key structures?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence of dumping (eg building waste)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence of extended ponding times (eg. algal growth)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence of silt and clogging within ‘detention volume’?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clogging of flow management systems (sediment or debris)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage/vandalism to structures present?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage system inspected?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resetting of system required?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.5.4 Asset Transfer Checklist

Land ownership and asset ownership are key considerations prior to construction of a stormwater treatment device. A proposed design is to clearly identify the ultimate asset owner and who is responsible for its maintenance. BCC will use the asset transfer checklist below when the asset is to be transferred to BCC.

### Asset Transfer Checklist

<table>
<thead>
<tr>
<th>Asset Location:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction by:</td>
<td></td>
</tr>
<tr>
<td>‘On-maintenance’ Period:</td>
<td></td>
</tr>
<tr>
<td><strong>Treatment</strong></td>
<td><strong>Y</strong></td>
</tr>
<tr>
<td>System appears to be working as designed visually?</td>
<td></td>
</tr>
<tr>
<td>No obvious signs of under-performance?</td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td><strong>Y</strong></td>
</tr>
<tr>
<td>Maintenance plans provided for each asset?</td>
<td></td>
</tr>
<tr>
<td>Inspection and maintenance undertaken as per maintenance plan?</td>
<td></td>
</tr>
<tr>
<td>Inspection and maintenance forms provided?</td>
<td></td>
</tr>
<tr>
<td>Asset inspected for defects?</td>
<td></td>
</tr>
<tr>
<td><strong>Asset Information</strong></td>
<td><strong>Y</strong></td>
</tr>
<tr>
<td>Design Assessment Checklist provided?</td>
<td></td>
</tr>
<tr>
<td>As constructed plans provided?</td>
<td></td>
</tr>
<tr>
<td>Copies of all required permits (both construction and operational) submitted?</td>
<td></td>
</tr>
<tr>
<td>Proprietary information provided (if applicable)?</td>
<td></td>
</tr>
<tr>
<td>Digital files (eg drawings, survey, models) provided?</td>
<td></td>
</tr>
<tr>
<td>Asset listed on asset register or database?</td>
<td></td>
</tr>
</tbody>
</table>

Infiltration Measures  
August 2005  
7-27
7.5.5 Construction Advice

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

7.5.5.1 Building Phase Damage

Protection of infiltration media and vegetation (if present) is critical during building phase as uncontrolled building site runoff is likely to cause excessive sedimentation and litter build up. This will affect the infiltration capacity of the system and may require replacement of infiltration media. Alternatively, consideration should be given to construction of these devices after building works are complete.

7.5.5.2 Traffic and Deliveries

It is important to ensure traffic does not access infiltration areas during construction. Traffic can compact the filter media, cause preferential flow paths and clogging of infiltration surface. Deliveries and wash-down material can also clog filtration media. Infiltration areas should be fenced off during the building phase and controls implemented to avoid wash-down wastes draining to the infiltration area.

7.5.5.3 Timing for Engagement

It is critical to ensure that the pretreatment system for an infiltration device is fully operational before flows are introduced into the infiltration media. This will prolong the life of the infiltration system and reduce the risk of clogging.

7.5.5.4 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.

7.5.5.5 Clean Drainage Media

Ensure drainage media is washed prior to placement to remove fines and prevent clogging.

7.6 BCC Standard Drawings

Standard Drawings UMS 157 and UMS 337 provide guidance on acceptable solutions for overflow pits (field inlet pits) that may be associated with infiltration systems. Standard drawings are available online at <http://www.brisbane.qld.gov.au/>.
7.7 Infiltration Measure Worked Example

7.7.1 Worked Example Introduction

An infiltration system is to be installed to infiltrate stormwater runoff from an industrial allotment in Brisbane. 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 pretreated 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 7.9.

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 BCC as being hydrologically sensitive to increases in catchment flow. Therefore, BCC require that there 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.

7.7.1.1 Site Characteristics

The site characteristics are summarised as follows:

- Catchment area
  - 2,400 m² (roof)
  - 2,400 m² (ground level paved)
  - 5,200 m² (pervious)
  - 10,000 m² (total)
- Predevelopment mean annual runoff = 2.2 ML/yr
- Post development mean annual runoff = 6.1 ML/yr
- Soil type - sandy clay
- Saturated hydraulic conductivity ($K_{sat}$) = 80 mm/hr
- Topography - flat to moderate grades towards the road (2 - 4 %).

7.7.1.2 Design Objectives

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 BCC as being hydrologically sensitive to increases in catchment flow and BCC require that there be no increase in mean annual runoff as a result of the development. Considering the predevelopment mean annual runoff is 2.2 ML/yr and the post-development mean annual runoff is 6.1 ML/yr, the design objective of the infiltration system is the capture and infiltration of 3.9 ML/yr (equal to 64 % hydrologic effectiveness).
7.7.2 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.
7.7.3 Step 2: Confirm Design Objectives

As outlined in Section 7.6.1.2, 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 64% hydrologic effectiveness. 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. 64% hydrologic effectiveness).

7.7.4 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.

7.7.5 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 (80% reduction in TSS and 45% reduction in TP and TN) was proposed and approved by BCC based on meeting the BCC 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).

7.7.6 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 provided in the Subdivision and Development Guidelines (BCC 2000a), QUDM (DPI et al. 1993) and Supplement to QUDM (BCC 1994). The site has one contributing catchment being 1.0 ha in area, 200 m long and drained by swale bioretention systems and stormwater pipes.

Time of concentration ($t_c$)

- Time of Concentration $t_c = 10$ mins

Design runoff coefficient

Runoff Coefficients

<table>
<thead>
<tr>
<th>$C_{10}$</th>
<th>$C_{2}$</th>
<th>$C_{10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARI</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>QUDM Factor</td>
<td>0.8</td>
<td>0.85</td>
</tr>
<tr>
<td>$C_{ARI}$</td>
<td>0.7</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.88</td>
</tr>
</tbody>
</table>
Catchment Area, \( A = 10,000 \, \text{m}^2 \) (1.0 ha)

Rainfall Intensities (BCC) \( t_c = 10 \) mins

\[
\begin{align*}
I_1 &= 90 \, \text{mm/hr} \\
I_2 &= 116 \, \text{mm/hr}
\end{align*}
\]

Rational Method \( Q = CIA/360 \)

\[
\begin{align*}
Q_{1 \text{yr} \ ARI} &= 0.175 \, \text{m}^3/\text{s} \\
Q_{2 \text{yr} \ ARI} &= 0.242 \, \text{m}^3/\text{s}
\end{align*}
\]

‘Design operation flow’ = 0.175 m³/s

‘Above design flow’ = 0.242 m³/s

7.7.7 Step 6: Size Infiltration System

The design objective for the infiltration basin is to achieve a hydrologic effectiveness of 64 %. This objective is to be delivered through use of an infiltration ‘soak-away’ created using gravel and being 1.0 m in depth.

Referring to Figure 7.6 (depth = 1.0 m and porosity = 0.35) and estimating the position of the 80 mm/hr hydraulic conductivity curve (by carrying out a simple interpolation between the 36 mm/hr and the 100 mm/hr curves), the ‘infiltration area’ must 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 m² and the ‘detention volume’ is 150 m³ (gravel filled).

| Note: The relationship between the curves is not linear and as a result, interpolations do not provide an exact representation of the size of infiltration area (as a % of catchment area). Designers must be careful not to undersize infiltration areas through this process. |

Gravel filled infiltration ‘soak-away’

‘Infiltration Area’ = 150 m²

‘Detention Volume’ = 150 m³

7.7.8 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 7.10. 30 x 5 m infiltration system is to be located near the front of the property set back by at least 2 m from the property boundary.
7.7.9 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

7.7.10 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 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.
7.7.11 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 7.11 (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).

7.7.11.1 Discharge pipe

The discharge pipe into the control pit is sized to convey the ‘above design flow’ (2 year ARI = 0.242 m³/s) into the discharge control pit using Equation 7.5 in accordance with QUDM (DPI et al. 1993). 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.

7.7.11.2 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/s²)

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, \( V = (9.79 \times 0.5) \times 0.5 = 2.21 \) 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:

\[ A = \frac{0.175}{2.21} = 0.079 \text{ m}^2 \]

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 7.11: Discharge Control Pit Configuration

Plan View

Infiltration system (continued)

Section View

Infiltration system (continued)
7.7.11.3 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 pipes have a slot clear opening of $3150 \text{ mm}^2/\text{m}$ 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’ ($0.175 \text{ m}^3/\text{s}$).
- 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’ ($0.175 \text{ m}^3/\text{s}$). The four 300 mm diameter perforated pipes are to be laid in parallel at a grade of 0.5%.

Applying Manning’s Equation assuming a Manning’s $n$ of 0.015 finds:

\[
Q \text{ (flow per pipe)} = 0.044 \text{ m}^3/\text{s}
\]

\[
Q_{\text{total}} = 0.176 \text{ m}^3/\text{s} \text{ (for four pipes)} > 0.175 \text{ m}^3/\text{s}, \text{ and hence OK.}
\]

### 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’ ($0.175 \text{ m}^3/\text{s}$). To estimate the flow rate, an orifice equation (Equation 7.6) is applied as follows:

\[
Q_{\text{orifice}} = B \cdot C_d \cdot A \sqrt{2 \cdot g \cdot h}
\]

Where:

- Head ($h$) = 0.5 m
- Blockage ($B$) = 0.5 (50 % blocked)
- Area ($A$) = 2100 $\text{ mm}^2/\text{m}$ clear perforations, hence blocked area = 1050 $\text{ mm}^2/\text{m}$
- 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

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

= 0.002 m$^3$/s

\[
\text{Inlet capacity/m x total length (4 lengths of 30 m) = 0.002 x (4 x 30) = 0.24 m}^3/\text{s} > 0.175, \text{ hence OK.}
\]

Perforated pipes = 4 x 300 mm diameter perforated pipe laid in parallel, 1.0 m apart and at 0.5% grade.
7.7.11.4 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 0.242 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 (0.242 m$^3$/s), $B = 1.0$ (no blockage for internal weir), $C_w = 1.66$ and $h = 0.2$ m we have $L = 1.6$ 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 = 1.6 m length at 9.5 m AHD
Discharge control pit = 1200 x 1200 mm

7.7.12 Design Calculation Summary

The sheet below summarises the results of the design calculations.
**INfiltration Systems**

<table>
<thead>
<tr>
<th>Calculation Task</th>
<th>Outcome</th>
<th>Check</th>
</tr>
</thead>
</table>

### Catchment Characteristics
- **Catchment area**: 1.0 ha
- **Catchment land use (i.e. residential, commercial etc.)**: Industrial
- **Storm event entering infiltration system**
  - (minor or major) 2 year ARI

### 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

### Confirm design objectives
- **Confirm design objective as defined by conceptual design**: No increase in mean annual runoff. 64% hydrologic effectiveness

### Select infiltration system type
- **Leaky Well**
- **Infiltration Trench**
- **'Soak-away'**
- **Infiltration Basin**

### Pre-treatment design
- **Level 1 Pre-treatment (avoid clogging)**
- **Level 2 Pre-treatment (groundwater protection)**

### Determine design flows
- **'Design operation flow'** (1 year ARI): 1 year ARI
- **'Above design flow'** (either 2 or 50 year ARI): 2 year ARI
- **Time of concentration**: Refer to BCC Subdivision and Development Guidelines and QUDM
  - **10 minutes**
- **Identify rainfall intensities**
  - **'Design operation flow'** - I$_{1}$ year ARI: 90 mm/hr
  - **'Above design flow'** - I$_{I}$ year ARI or I$_{50}$ year ARI: 116 mm/hr
- **Design runoff coefficient**
  - **'Design operation flow'** - C$_{1}$ year ARI: 0.7
  - **'Above design flow'** - C$_{I}$ year ARI or C$_{50}$ year ARI: 0.75
- **Peak design flows**
  - **'Design operation flow'** - 1 year ARI: 0.175 m$^3$/s
  - **'Above design flow'** - 2 or 50 year ARI: 0.242 m$^3$/s

### Size infiltration system
- **Hydrologic effectiveness approach**
  - **Hydrologic effectiveness objective**: 64 %
  - **Depth**: 1 m
  - **Porosity (void = 1.0, gravel filled = 0.35)**: 0.35
  - **Size of infiltration area (from Figure 7.4-7.7)**: 1.5 % catchment area
    - **Infiltration Area**: 150 m$^2$
    - **Detention Volume**: 150 m$^3$

### Design storm approach
### 7. Locate infiltration system

<table>
<thead>
<tr>
<th>Minimum distance from boundary (Table 7.5)</th>
<th>Width</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 m</td>
<td>30 m</td>
</tr>
</tbody>
</table>

### 8. Set infiltration depths (sub-surface systems only)

<table>
<thead>
<tr>
<th>Ground surface level</th>
<th>10 m AHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater level</td>
<td>5 m AHD</td>
</tr>
<tr>
<td>Infiltration system depth</td>
<td>1 m</td>
</tr>
<tr>
<td>Top of infiltration system</td>
<td>9.5 m AHD</td>
</tr>
<tr>
<td>Base of infiltration system</td>
<td>8.5 m AHD</td>
</tr>
<tr>
<td>Cover</td>
<td>0.5 m</td>
</tr>
<tr>
<td>Depth to water table</td>
<td>3.5 m</td>
</tr>
</tbody>
</table>

### 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: 0.242 m³/s
- Pipe size: 375 mm diam.

#### Inflow pipe

- Pipe capacity: 0.175 m³/s
- Pipe size: 300 mm diam.

#### Overflow pipe

- Pipe capacity: 0.242 m³/s
- Pipe size: 375 mm diam.

#### Overflow pit

- Pit capacity: - m³/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

### 7.7.13 Construction Drawings

The drawing below details the construction of the infiltration system designed in the worked example.
**SCHEMATIC ONLY**
*These are not design or construction drawings*

**PLAN**

- **4 x Ø300mm perforated pipes** (0.5% longitudinal grade) (see CH. 7.6.11.3)
- **Gravel filled infiltration “soak-away”** (150m² surface area) (see CH. 7.6.7)
- **750x750 concrete pit (lid not grate) with 25mm holes in base**

**SECTION A**

- **Access opening**
- **Drainage control pit** (1.2m x 1.2m)
- **Overflow pipe** (see CH. 7.6.11.1)

**SECTION B**

- **Access opening**
- **Drainage control pit**
- **Overflow pipe** (see CH. 7.6.11.1)

**NOTES:**

- All levels are to the Australian Height Datum.

**INfiltration Measures**

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**PROJECT**

- **BCC WSUD MANUAL**

**SCALE**

- **1:50**

**DRAWN TO**

- **BCC**

**INFRITRATION MEASURES**

**DATE**

- **2004.04.9.1**
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