Policy 11: Land Development Guidelines

Section 13 Water Sensitive Urban Design (WSUD) Guidelines

13.6 Bioretention Basins


Established bioretention basin in Brisbane (left) and bioretention basin under establishment in Gold Coast (right)

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13.6.1 Introduction

Bioretention basins are vegetated areas where runoff is filtered through a filter media layer (eg. sandy loam) as it percolates downwards. It is then collected via perforated under-drains and flows to downstream waterways or to storages for reuse. Bioretention basins often use temporary ponding above the filter media surface to increase the volume of runoff treated through the filter media. They treat stormwater in the same way as bioretention swales; however, ‘above design’ flows are conveyed through overflow pits or bypass paths rather than over the filter media. This has the advantage of protecting the filter media surface from high velocities that can dislodge collected pollutants or scour vegetation.

Plate 13.6-A: Example of an established bioretention basin bordering natural vegetation area

Bioretention basins operate by filtering stormwater runoff through densely planted surface vegetation and then percolating runoff through a prescribed filter media. During percolation, pollutants are retained through fine filtration, adsorption and some biological uptake.

The vegetation in a bioretention system is a vital functional element of the system providing a substrate for biofilm growth within the upper layer of the filter media. Vegetation facilitates the transport of oxygen to the soil and enhances soil microbial communities which enhance biological transformation of pollutants.

Bioretention basins are generally not intended to be ‘infiltration’ systems that discharge from the filter media to surrounding *in-situ* soils. Rather, the typical design intent is to recover stormwater at the base of the filter media in perforated under-drains and discharge to receiving waterways or to storages for potential reuse. In some circumstances however, where the *in-situ* soils allow and there is a particular design intention to recharge local groundwater, it may be desirable to allow stormwater to infiltrate from the base of a filter media to underlying *in-situ* soils.

Bioretention basins can be installed at various scales, for example, as landscape planter boxes, in streetscapes integrated with traffic calming measures, in suburban parks and in retarding basins. In larger applications, it is considered good practice to have pretreatment measures (eg. swales) upstream of the basin to reduce the maintenance frequency of the bioretention basin. **Figure 13.6-A** shows examples of a basin integrated into a local streetscape and into a car park. **Figure 13.6-A** also illustrates the key elements of bioretention basins, namely surface vegetation, extended detention, filter media, drainage layer and overflow pit.

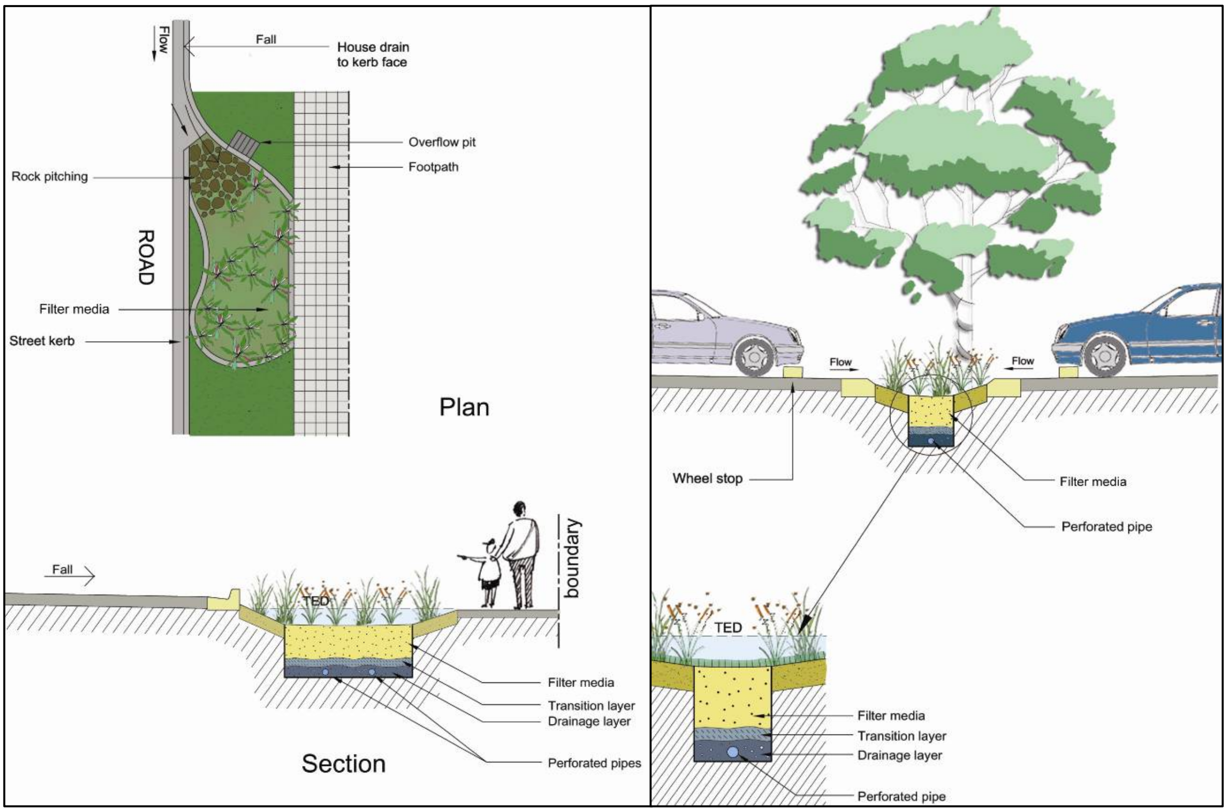

Figure 13.6-A: Bioretention Basin Integrated Into a Local Streetscape (left) and a Car Park (right). (TED = top of extended detention)

13.6.2 Design Considerations

This section outlines some of the key design considerations for bioretention basins that the detailed designer should be familiar with before applying the design procedure presented later in this chapter.

13.6.2.1 Landscape Design

Bioretention basins are predominantly located within public areas, such as open space or within streets, that provide a primary setting for people to experience their local community and environment. It is therefore necessary for bioretention basins to be given an appropriate level of landscape design consideration to compliment the surrounding landscape character. The landscape design of bioretention basins must address stormwater quality objectives whilst also being sensitive to other important landscape objectives such as road visibility, public safety and community character and habitat.

Plate 13.6-B: Raised overflow pit surrounded by bioretention vegetation

13.6.2.2 Hydraulic Design

The correct hydraulic design of bioretention basins is essential to ensure effective stormwater treatment performance, minimize damage by storm flows, and to protect the hydraulic integrity and function of associated minor and major drainage systems. The following aspects are of key importance:

- the finished surface of the bioretention filter media must be horizontal (ie. flat) to ensure full engagement of the filter media by stormwater flows and to prevent concentration of stormwater flows within depressions and ruts resulting in potential scour and damage to the filter media;
- temporary ponding (ie. extended detention) of up to 0.3m depth over the surface of the bioretention filter media created through the use of raised field inlet pits (overflow pits) can assist in managing flow velocities over the surface of the filter media as well as increase the overall volume of stormwater runoff that can be treated by the bioretention filter media;
- where possible, the overflow pit or bypass channel should be located near the inflow zone (refer to **Figure 13.6-A** (left)) to prevent high flows passing over the surface of the filter media. If this is not possible, then velocities during the minor (2-10 year ARI) and major (50-100 year ARI) floods should be maintained sufficiently low (preferably below values of 0.5 m/s and not more than 1.5 m/s for major flood) to avoid scouring of the filter media and vegetation;
- where the field inlets in a bioretention system is required to convey the minor storm flow (ie. is part of the minor drainage system), the inlet must be designed to avoid blockage, flow conveyance and public safety issues;
- for streetscape applications, the design of the inflow to the bioretention basin must ensure the kerb and channel flow requirements are preserved as specified in the **Section 3.5**. These guidelines provide general criteria for stormwater drainage design based on principles contained in the **Queensland Urban Drainage Manual (QUDM) (DPI, IMEA & BCC 1992)**.

13.6.2.3 Ex-filtration to *In-Situ* Soils

Bioretention basins can be designed to either preclude or promote ex-filtration of treated stormwater to the surrounding *in-situ* soils depending on the overall stormwater management objectives established for the given project. When considering ex-filtration to surrounding soils, the designer must consider site terrain, hydraulic conductivity of the *in-situ* soil, soil salinity, groundwater and building setback. Further guidance in this regard is provided in **Section 13.8 – Infiltration Measures**.

Where the concept design specifically aims to preclude ex-filtration of treated stormwater runoff it is necessary to consider if the bioretention basin needs to be provided with an impermeable liner. The amount of water lost from bioretention basins to surrounding *in-situ* soils is largely dependant on the characteristics of the local soils and the saturated hydraulic conductivity of the bioretention filter media (see **Section 13.6.2.5**). Typically, if the selected saturated hydraulic conductivity of the filter media is one to two orders of magnitude (ie. 10 to 100 times) greater than that of the native surrounding soil profile, then the preferred flow path for stormwater runoff will be vertically through the bioretention filter media and into the perforated under-drains at the base of the filter media. As such, there will be little if any ex-filtration to the native surrounding soils. However, if the selected saturated hydraulic conductivity of the bioretention filter media is less than 10 times that of the native surrounding soils, it may be necessary to provide an impermeable liner. Flexible membranes or a concrete casting are commonly used to prevent excessive ex-filtration. This is particularly applicable for surrounding soils that are very sensitive to any ex-filtration (eg. sodic soils, shallow groundwater or close proximity to significant structures such as roads).

The greatest pathway of ex-filtration is through the base of a bioretention basin, as gravity and the difference in hydraulic conductivity between the filter media and the surrounding native soil would typically act to minimise ex-filtration through the walls of the trench. If lining is required, it is likely that only the base and the sides of the drainage layer (refer **Section 13.6.2.5**) will need to be lined.

Where ex-filtration of treated stormwater to the surrounding *in-situ* soils is promoted by the bioretention basin concept design it is necessary to ensure the saturated hydraulic conductivity of the *in-situ* soils is at least equivalent to that of the bioretention filter media, thus ensuring no impedance of the desired rate of flow through the bioretention filter media. Depending on the saturated hydraulic conductivity of the *in-situ* soils it may be necessary to provide an impermeable liner to the sides of the bioretention filter media to prevent horizontal ex-filtration and subsequent short-circuiting of the treatment provided by the filter media. Bioretention basins promoting ex-filtration do not require perforated under-drains at the base of the filter media or a drainage layer (refer to **Section 13.6.2.5**).

13.6.2.4 Vegetation Types

Vegetation is required to cover the whole bioretention filter media surface, be capable of withstanding minor and major design flows, and be of sufficient density to prevent preferred flow paths, scour and re-suspension of deposited sediments. Additionally, vegetation that grows in the bioretention filter media functions to continuously break up the surface of the filter media through root growth and wind induced agitation, which prevents surface clogging. The vegetation also provides a substrate for biofilm growth within the upper layer of the filter media, which facilitates biological transformation of pollutants (particularly nitrogen).

Plate 13.6-C: Established vegetation

Ground cover vegetation (eg. sedges and tufted grasses) is an essential component of bioretention basin function. Generally, the greater the density and height of vegetation planted in bioretention filter media, the better the treatment provided especially when extended detention is provided for in the design. This occurs when stormwater is temporarily stored and the contact between stormwater and vegetation results in enhanced sedimentation of suspended sediments and adsorption of associated pollutants.

Section 13.13 provides more specific guidance on the selection of appropriate vegetation for bioretention basins. It should be noted that turf is not considered to be suitable vegetation for bioretention basins. The stem and root structure of turf is not suitably robust and rapid growing to ensure the surface of the bioretention filter media is continuously broken up to prevent clogging.

13.6.2.5 Bioretention Filter Media

Selection of an appropriate bioretention filter media is a key design step that involves consideration of the following three inter-related factors:

- saturated hydraulic conductivity required to optimise the treatment performance of the bioretention basin given site constraints and available filter media area;
- depth of extended detention provided above the filter media;
- suitability as a growing media to support vegetation (ie. retains sufficient soil moisture and organic content).

The high rainfall intensities experienced on the Gold Coast and in SEQ relative to the southern capital cities means bioretention treatment areas tend to be larger to achieve the same level of stormwater treatment. However, the area available for providing bioretention basins within the urban layout will often be constrained by the same factors defining available treatment area as apply in the southern capital cities. Consequently, bioretention filter media used on the Gold Coast is often required to have higher saturated hydraulic conductivity and extended detention depths. However, it is important to ensure the saturated hydraulic conductivity does not become too high so it can no longer retain enough moisture to sustain vegetation growth. The maximum saturated hydraulic conductivity should not exceed 500 mm/hr (and preferably be less than 200 mm/hr).

The concept design stage will have established the optimal combination of filter media saturated hydraulic conductivity and extended detention depth using a continuous simulation modelling approach (eg. MUSIC). Any adjustment of either of these two design parameters during the detailed design stage will require the continuous simulation modelling to be re-run to assess the impact on the overall treatment performance of the bioretention basin.

As shown in **Figure 13.6-B**, a bioretention media can consist of three layers. In addition to the filter media required for stormwater treatment, a drainage layer is also required to convey treated water from the base of the filter media into the perforated under-drains. The drainage layer surrounds the perforated under-drains and can be either coarse sand (1 mm) or fine gravel (2-5 mm). If fine gravel is used, a transition layer of sand must also be installed to prevent migration of the filter media into the drainage layer and subsequently into the perforated under-drains.

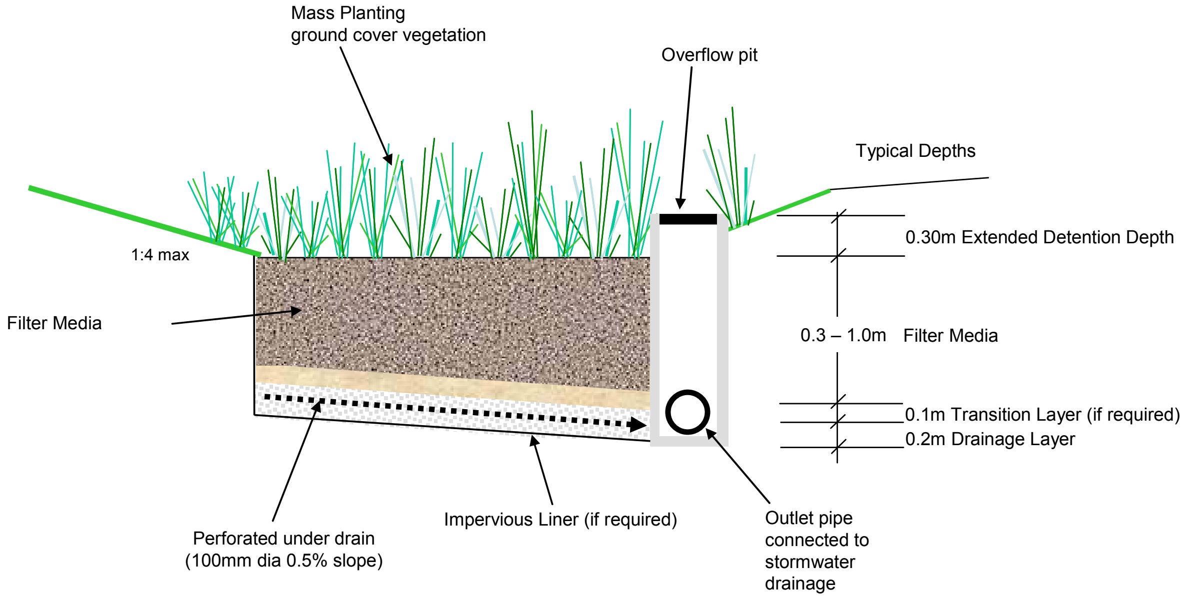

Figure 13.6-B: Typical Cross Section of a Bioretention Basin

13.6.2.6 Traffic Controls

Another design consideration is keeping traffic and building material deliveries off bioretention basins (particularly during the construction phase of a development). If bioretention basins are driven over or used for parking, the filter media will become compacted and the vegetation damaged. As they can cause filter media blockages, building materials and wash down wastes should also be kept out of the bioretention basin. To prevent vehicles driving on bioretention basins, and inadvertent placement of building materials, it is necessary to consider appropriate traffic control solutions as part of the design. These can include dense vegetation planting that will discourage the movement of vehicles onto the bioretention basin or providing physical barriers such as bollards and/or tree planting.

Streetscape bioretention systems must be designed to satisfy GCCC requirements with respect to traffic calming devices within particular street or road reserve widths. Where bioretention is incorporated into traffic calming or control devices, or directly adjacent to mountable kerbs, consideration should be given to protection of the area immediately behind the kerb where vehicles are likely to mount the kerb.

13.6.2.7 Services

Bioretention basins or cells located within road verges or within footpaths must consider the standard location for services within the verge and ensure access for maintenance of services without regular disruption or damage to the bioretention system.

Designers should consult Council's Standard Drawings and ensure:

- for new bioretention basins in new development, the location of the basin does not impinge on requirements for service allocation in the road verge;
- for bioretention in existing development that maintenance access is maintained to all existing services.

The designer should demonstrate that the basin (during construction and operation) will not affect the performance of other services or restrict access to them for maintenance.

Where bioretention basins are located in the street, service conduits should be provided beneath or through the filter media.

A minimum setback distance of 250 mm must be maintained between the bioretention basin and the closest service. This allows room for maintenance to services to be undertaken with no damage to the basin.

13.6.2.8 Standard Drawings

Council's **Standard Drawing N° 05-02-610** provides further guidance on typical bioretention basin details. These should be used alongside this section in designing a bioretention basin.

13.6.3 Design Process

The following sections detail the design steps required for bioretention basins. Key design steps are:

1. Confirm concept design
a. Check Service locations

2. Determine design flows

3. Design inflow systems
a. Inlet Scour Protection
b. Coarse Sediment Forebay
c. Streetscape Bioretention Application
d. High flow bypass

4. Specify the bioretention filter media characteristics
a. Filter media
b. Drainage layer
c. Transition layer

5. Design under-drains and do capacity checks

6. Check requirement for impermeable lining

7. Size overflow pit

8. Specify vegetation

9. Verify Design
a. Vegetation scour velocity check
b. Confirm treatment performance

13.6.3.1 Step 1: Confirm Concept Design

Prior to progressing with detailed design, the designer should review the concept design developed for the site. The concept design should be reviewed to ensure:

- the bioretention system(s) provide an appropriate level of water quality treatment demonstrated through MUSIC modelling;
- bioretention systems are still appropriate for use at the site and are appropriately located within a treatment train;
- there are no additional constraints to the location and/or sizing of the bioretention systems.

A MUSIC model of the surrounding catchment and 'treatment train' should be developed to provide an initial estimate of the bioretention dimensions required to achieve GCCC load based WQOs as part of the concept design. Should the detailed design result in significant changes to any elements of the bioretention system, the water quality treatment performance of the system should be reassessed.

It is noted that although bioretention systems may meet WQO without the aid of other best management practices, appropriate pre-treatment measures (such as a course sediment forebay, vegetated swale or buffer zone) should be implemented upstream of the bioretention system to facilitate the removal of course sediment. GPTs may also be required as part of the treatment train to meet GCCC litter reduction targets.

a) Check Service Locations

As part of the confirmation of objectives and review of the conceptual design, the designer must check that there are no services (existing or proposed) located in the bioretention site. These include telecommunications, power, water and sewerage.

The designer should liaise with civil designers and GCCC officers to ensure:

- bioretention will no result in water damage to existing services or structures;
- access for maintenance to existing services is maintained;
- no conflicts arise between the location of services and WSUD devices.

13.6.3.2 Step 2: Determine Design Flows

a) Design Flows

The hydraulic design of the bioretention basin should be based on the following design flows:

Minor Storm Event	for sizing the inflow system and the overflow pit as well as undertaking the minor storm flow velocity check. The minor storm in Gold Coast City Council is typically the 2, 5 or 10 yr ARI event (refer to **Section 3.5**).
Major Storm Event	for undertaking the major storm flow velocity check where the bioretention basin accepts the major storm event. The major storm is the 100 yr ARI event.

b) Design Flow Estimation

A range of hydrologic methods can be applied to estimate design flows. If the typical catchment areas are relatively small, the Rational Method design procedure is considered to be a suitable method for estimating design flows. However, if the bioretention system is to form part of a retention basin or if the catchment area to the bioretention system is large, then a full flood routing computation method needs to be used to estimate design flows.

13.6.3.3 Step 3: Design Inflow Systems

The design of the inflow systems to bioretention basins needs to consider a number of functions:

1. Scour protection – In most bioretention applications stormwater flows will enter the bioretention basin as concentrated flow (piped, channel or open channel) and as such is it important to slow and spread flows using appropriate scour (rock) protection.
2. Coarse sediment forebay – Where stormwater runoff from the catchment is delivered directly to the bioretention basin without any coarse sediment management (through vegetated swale or buffer treatment) a coarse sediment forebay is to be included in the design. The forebay is to remove coarse sediment (1mm +) from stormwater to minimise the risk of vegetation in the bioretention basin being smothered.
3. Street hydraulics (streetscape applications only) – In streetscape applications, where stormwater is delivered directly from the kerb and channel to the bioretention basin, it is important to ensure the location and width of the kerb opening is designed such that flows enter the bioretention basin without adversely affecting trafficability of the road (**QUDM**, **Table 5.09.01**).

Each of these functions and the appropriate design responses are described in the following sections.

a) Inlet Scour Protection

Erosion protection should be provided for concentrated inflows to a bioretention basin. Typically, flows will enter the bioretention basin from either a surface flow system (ie. roadside kerb, open channel) or a piped drainage system. Rock beaching is a simple method for dissipating the energy of concentrated inflow. Where the bioretention basin is receiving stormwater flows from a piped system (ie. from larger catchments), the use of impact type energy dissipation may be required to prevent scour of the filter media. In most cases this can be achieved with rock protection and by placing several large rocks in the flow path to reduce velocities and spread flows as depicted in **Figure 13.6-C** (with the 'D' representing the pipe diameter dimension). The rocks can form part of the landscape design of the bioretention component.

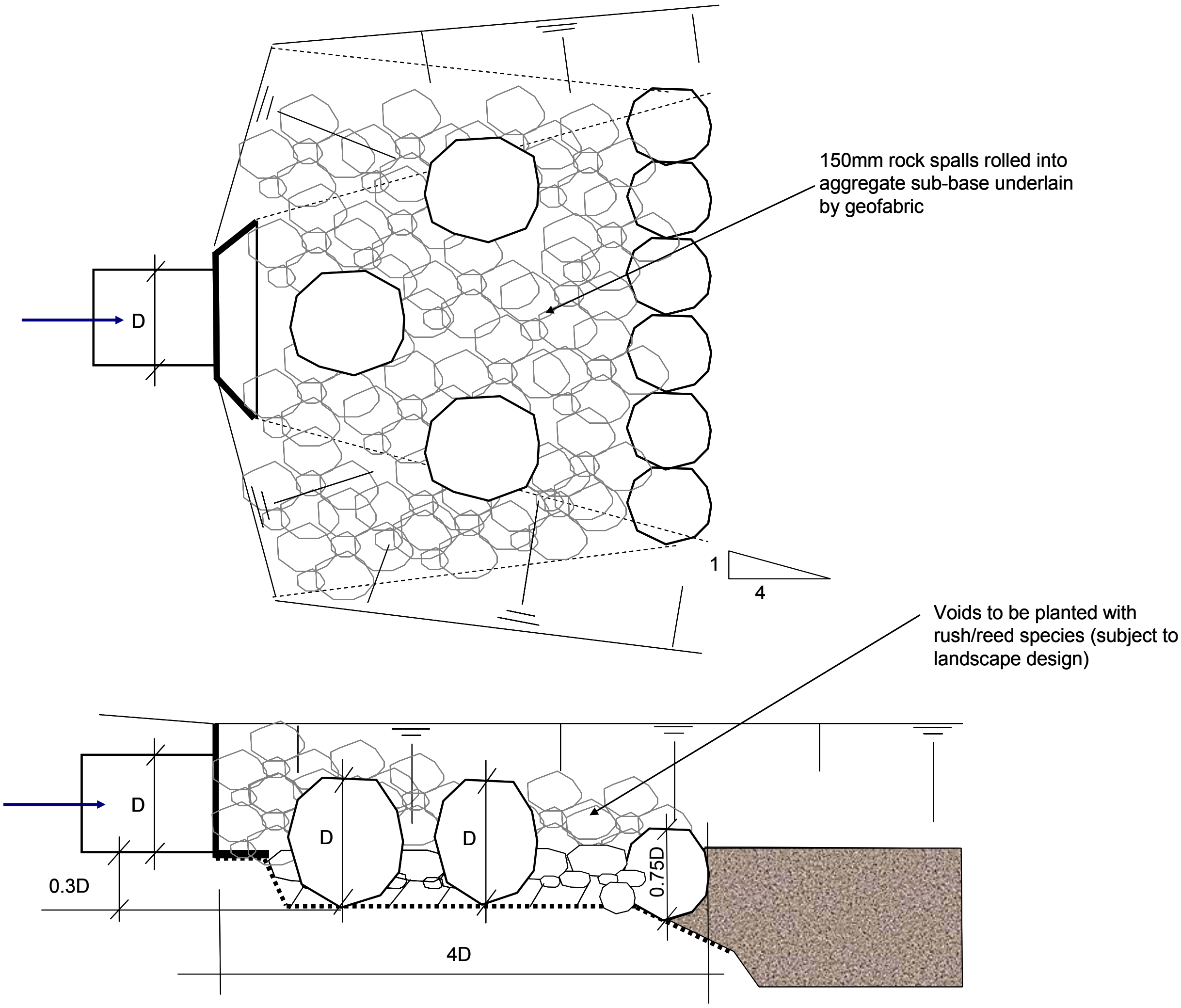

Figure 13.6-C: Typical Inlet Scour Protection Detail for Bioretention Basins Receiving Piped Flows

b) Coarse Sediment Forebay

Where stormwater runoff from the catchment is delivered directly to the bioretention basin without pre-treatment (through vegetated swale or buffer treatment), coarse sediment may accumulate near the basin inflow. This sediment may smother vegetation and reduce infiltration to the filter media. To mitigate these effects, either a sedimentation basin (see **Section 13.5**) must be located upstream or the bioretention basin inflow system should incorporate a coarse sediment forebay. The forebay should be designed to:

- remove particles that are 1mm or greater in diameter from the 3 month ARI storm event;
- provide appropriate storage for coarse sediment to ensure desilting is required once every year.

The size of the sediment forebay is established using the following:

$$V_s = A_c \cdot R \cdot L_o \cdot F_c$$

Where:

V_s	=	volume of forebay sediment storage required (m^3)
A_c	=	contributing catchment area (ha)
R	=	capture efficiency (assume 80%)
L_o	=	sediment loading rate (m^3/ha/year)
F_c	=	desired cleanout frequency (years)

Equation 13.6.1

A catchment loading rate (L_o) of 1.6 m^3/ha/year for developed catchments can be used to estimate the sediment loads entering the basin. The area of the forebay is established by dividing the volume by the depth. The depth of the forebay should not be greater than 0.3m below the surface of the filter media.

$$A_s = V_s / D_s$$

Where:

D	=	depth of sediment forebay (max 0.3 m below filter media surface)

Equation 13.6.2

The sediment forebay area should be checked to ensure it captures the 1mm and greater particles using the following expression (modified version of **Fair and Geyer** (**1954**):

$$R = 1 - \left[1 + \frac{1}{n} \cdot \frac{v_s}{Q/A}\right]^{-n}$$

Where:

R	=	fraction of target sediment removed (80%)
v_s	=	settling velocity of target sediment (100mm/s or 0.1m/s for 1mm particle)
Q/A	=	applied flow rate divided by basin surface area ($m^3/s/m^2$)
n	=	turbulence or short-circuiting parameter (adopt 0.5)

Equation 13.6.3

The coarse sediment forebays will contain large rocks for energy dissipation and be underlain by filter material to promote drainage following storm events.

c) Kerb Opening Configuration

In streetscape applications where stormwater is delivered directly from a kerb and channel to a bioretention basin, the following design issues must be considered:

- the location of the kerb opening must be designed to ensure flows in the channel do not exceed the maximum allowance widths as defined in **QUDM Table 5.0901 (DPI, IMEA & BCC 1992)** and **Section 3.5**;
- the width of the kerb opening is designed to allow the design flow to enter the bioretention basin.

Channel Flow Width at Kerb Opening

The width of flow at the entry from the road during a minor storm event (2-10 year ARI) needs to be checked. This can be undertaken by applying Manning's equation and ensuring that flow widths do not exceed the maximum allowable widths as defined in **Section 3.5** of this guideline and **QUDM Tables 5.08.1** and **5.09.01 (DPI, IMEA & BCC 1992)**.

Design Kerb Opening Width (where Kerb and Channel is used)

To determine the width of the opening in the kerb to allow flows to enter the bioretention basin, Manning's equation or Izzard's equation (**QUDM Section 5.09.2**) can be used with the kerb, gutter and road profile to estimate the flow depth in the kerb and channel at the entry point. Once the flow depth for the minor storm (eg. 2-10 year ARI) is known, this can then be used to calculate the required width of the opening in the kerb by applying a broad crested weir equation. The opening width is estimated by applying the flow depth in the gutter (as h) and solving for L (opening width).

$$Q = C_w \cdot L \cdot h^{3/2}$$

Where:

Q	=	flow (m^3/s)
C_w	=	weir coefficient (= 1.7)
L	=	length of opening (m)
h	=	depth of flow (m)

Equation 13.6.4

This method ensures the kerb opening does not result in an increase in the upstream gutter flow depth, which in turn ensures the bioretention basin does not impact on the trafficability of the adjoining road pavement as required by the **QUDM**.

d) High Flow Bypass

For bioretention systems, particularly larger ones in open space areas, all flows in excess of the design operation flow and up to the above design flow are to bypass the bioretention filter media to avoid damaging the system.

This is facilitated by a high flow bypass weir as part of the sediment forebay designed to convey the above design flow with the weir crest level at the top of the extended detention depth of the bioretention system.

The weir length is calculation using the weir flow equation:

$$L = \frac{Q_{des}}{C_w \cdot H^{3/2}}$$

Where:

Q_{des} = flow rate over weir (m^3/s)

C_w = weir coefficient (~1.7)

H = depth of water above the weir (m)

Equation 13.6.5

13.6.3.4 Step 4: Specify the Bioretention Filter Media Characteristics

At least two (and possibly three) types of media are required in bioretention basins (refer **Figure 13.6-B**).

a) Filter Media

The filter media layer provides the majority of the pollutant treatment function, through fine filtration and also by supporting vegetation. The vegetation enhances filtration, keeps the filter media porous, provides substrate for biofilm formation and provides some uptake of nutrients and other stormwater pollutants. As a minimum, the filter media is required to have sufficient depth to support vegetation. Typical depths are usually between 400-1000 mm with a minimum depth of 400 mm for grasses and shrubs and a minimum depth of 800 mm for tree species to avoid roots interfering with the perforated under-drain system.

The saturated hydraulic conductivity of the filter media is established by optimising the treatment performance of the bioretention system given site constraints of the particular site (using a continuous simulation model such as MUSIC). Saturated hydraulic conductivity should remain between 50-200 mm/hr (saturated hydraulic conductivity should be 180 mm/hr for most cases and under no circumstances will values of greater than 500 mm/hr be accepted by Gold Coast City Council). Once the saturated hydraulic conductivity of the filter media has been determined for a particular bioretention basin, the following process can then be applied to derive a suitable filter media soil to match the design saturated hydraulic conductivity using the existing *in-situ* soil (from **FAWB 2006**):

1. Identify if local top soil is capable of supporting vegetation growth and if there is enough top soil (some top soils are very shallow) be used as a base for the filter media (may require active collection of top soil during the construction process). Any topsoil found to contain high levels of salt, extremely low levels of organic carbon (<<5%), or any other extremes which may be considered retardant to plant growth should be rejected. If the top soil is not suitable, a sandy loam soil can be purchased from a supplier for use as a base soil.
2. Conduct laboratory tests to establish hydraulic conductivity, water holding capacity, particle size distribution, and **AS4419-2003** parameters.
3. If the soil needs to be amended to achieve the desired design saturated hydraulic conductivity and particle size distribution either mix in a loose non-angular sand (to increase saturated hydraulic conductivity) or a loose soft clay (to reduce saturated hydraulic conductivity).
4. The required content of sand or clay (by weight) to be mixed to the base soil will need to be established in the laboratory by incrementally increasing the content of sand or clay until the desired saturated hydraulic conductivity is achieved (within reasonable bounds). The sand or clay content (by weight) that achieves the desired hydraulic conductivity should then be adopted on-site.
5. The base soil should have sufficient organic content to establish vegetation on the surface of the bio-retention system. If the proportion of base soil in the final mix is less than 50% then it may be necessary to add in additional organic material. This will be limited to 10% organic content (measured in accordance with **AS1289 4.1.1**).
6. The pH of the soil mixture for the filtration layer is to be amended to between 5.5 and 7.5. f the filter media mix is being prepared off-site, this amendment should be undertaken before delivery to the site. before delivery to the site.
7. Ensure soil meets the following specifications (refer to **Guideline Specifications for Soil Media in Bioretention Systems (FAWB 2006)**):
   - hydraulic conductivity;
   - water holding capacity;
   - particle size distribution;
   - **AS4419-2003** parameters.
8. The salt content of the final filter media (as measured by EC1:5) must be less than 0.63 dS/m for low clay content soils like sandy loam. (EC1:5 is the electrical conductivity of a 1:5 soil/ water suspension).
9. Once the drainage layer is in place, the hydraulic conductivity can be tested in accordance with **AS1547:2000** as a final check.

Imported soils must not contain Fire Ants. Visual assessment is required and any machinery should be free of clumped dirt. Soils must not be brought in from Fire Ant restricted areas. For further information on Fire Ant restrictions, contact the Department of Primary Industries and Fisheries.

b) Drainage Layer (if required)

The drainage layer is used to convey treated flows from the base of the filter media layer into the perforated under-drainage system. The composition of the drainage layer is to be considered in conjunction with the selection and design of the perforated under-drainage system (refer to **Section 13.6.3.5**) as the slot sizes in the perforated pipes may determine the minimum drainage layer particle size to avoid washout of the drainage layer into the perforated pipe system. Coarser material (eg. fine gravel) is to be used for the drainage layer if the slot sizes in the perforated pipes are too large for use of a sand based drainage layer. Otherwise, sand is the preferred drainage layer media as it is likely to avoid having to provide a transition layer between the filter media and the drainage layer. The drainage layer is to be a minimum of 150mm thick, and preferably 200 mm.

Ensure drainage media is washed prior to placement in bioretention system to remove any fines. Drainage media must also be free from Fire Ants and visually checked to confirm this. Drainage media must not be imported from a Fire Ant restricted area.

c) Transition Layer (if required)

The particle size difference between the filter media and the underlying drainage layer should be not more than one order of magnitude to avoid the filter media being washed through the voids of the drainage layer. Therefore, if fine gravels are used for the drainage layer (which will be at least two orders of magnitude coarser than the likely average particle size of the filter media), then a transition layer is recommended to prevent the filter media from washing into the perforated pipes. If a transition layer is required then the material must be sand/ coarse sand material. An example particle size distribution (% passing) is provided below (based on a Unimin specification):

- 1.4 mm 100 %
- 1.0 mm 80 %
- 0.7 mm 44 %
- 0.5 mm 8.4 %

The transition layer is recommended to be 150 mm thick. The addition of a transition layer increases the overall depth of the bioretention system and may be an important consideration for some sites where total depth of the bioretention system may be constrained. In such cases, the use of a sand drainage layer and/or perforated pipes with smaller slot sized may need to be considered (**Section 13.6.3.5**).

13.6.3.5 Step 5: Design Under-Drain and Undertake Capacity Checks (if required)

The maximum spacing of the perforated under-drains in bioretention basins located in streetscape zones and small public zones (ie. bioretention < 100 m^2) is 1.5 m (centre to centre). This ensures that the distance water needs to travel horizontally toward the perforated pipes through the drainage layer does not hinder drainage of the filter media. The maximum spacing of the perforated pipes in bioretention basins located in local parks and large open space areas (ie. bioretention > 100 m^2) can be increased to 2.5 – 3 m.

Where possible the perforated pipes are to grade at a minimum of 0.5% towards the overflow pit to ensure effective drainage. This is best achieved by grading the base of the bioretention system towards the pit and placing the perforated pipes (and the drainage layer) on this grade. Perforated pipes should not use a geofabric wrapping, as this is a potential location for blockage and would require a complete resetting of the bioretention system. Where perforated pipes are supplied with geofabric wrapping, it is to be removed before installation.

Installing parallel pipes is a means to increase the capacity of the perforated pipe system. 100 mm diameter is recommended as the maximum size for the perforated pipes to minimise the thickness of the drainage layer. Either slotted PVC pipes or flexible perforated pipes (eg. ag pipe) can be used; however, care needs to be taken when selecting the type of pipe to consider the following:

- ensure the slots in the pipes are not so large that sediment will freely flow into the pipes from the drainage layer. This is also a consideration when specifying drainage layer media;
- minimise the potential for tree root intrusion into underdrainage. This is a concern when the filter media has a low water holding capacity, or the filter media depth is too shallow. Trees are not to be planted if the filter media depth is less than 800 mm. Flexible 'ribbed' pipes are more likely, than PVC pipes, to retain 'beads' of moisture due to the small corrugations on the inside of the pipe. Therefore, a smooth surface perforated pipe system is recommended for use in bioretention basins with a low water holding capacity. No trees should be considered for bioretention less than 800mm deep, and tree/ plant selection should demonstrate that root intrusion into the underdrainage will not occur.

To ensure slotted pipes are of adequate size, several checks are required:

- ensure the perforations are adequate to pass the maximum filtration rate;
- ensure the pipe itself has sufficient capacity;
- ensure that the material in the drainage layer will not be washed into the perforated pipes (consider a transition layer).

The maximum filtration rate represents the maximum rate of flow through the bioretention filter media and is calculated by applying Darcy's equation as follows:

$$Q_{max} = K_{sat} \cdot L \cdot W_{base} \cdot \frac{h_{max} + d}{d}$$

Where:

Q_{max}	=	maximum filtration rate (m^3/s)
K_{sat}	=	saturated hydraulic conductivity of the soil filter (m/s)
W_{base}	=	base width of the ponded cross section above the soil filter (m)
L	=	length of the bioretention zone (m)
h_{max}	=	depth of pondage above the soil filter (m)
d	=	depth of filter media (m)

Equation 13.6.6

The capacity of the perforated under-drains need to be greater than the maximum filtration rate to ensure the filter media drains freely and does not become the hydraulic 'control' in the bioretention system (ie. to ensure the filter media sets the travel time for flows percolating through the bioretention system rather than the perforated under-drainage system).

To ensure the perforated under-drainage system has sufficient capacity to collect and convey the maximum filtration rate, it is necessary to determine the capacity for flows to enter the under-drainage system via the perforations in the pipes. To do this, orifice flow can be assumed and the sharp edged orifice equation used. Firstly, the number and size of perforations needs to be determined (typically from manufacturer's specifications) and used to estimate the flow rate into the pipes, with the maximum driving head being the depth of the filter media if no extended detention is provided. If extended detention is provided in the design, then the maximum driving head is to the top of extended detention depth. It is conservative, but reasonable to use a blockage factor to account for partial blockage of the perforations by the drainage layer media. A 50% blockage of the perforations should be used.

The flow capacity of the perforations is thus:

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

Where:

Q_{perf}	=	flow through perforations (m^3/s)
C_d	=	orifice discharge coefficient (0.6)
A	=	total area of the orifice (m^2)
g	=	gravity (9.81 m/s^2)
h	=	maximum depth of water above the pipe (m)
B	=	blockage factor (0.5)

Equation 13.6.7

If the capacity of the drainage system is unable to collect the maximum filtration rate additional under-drains will be required.

After confirming the capacity of the under-drainage system to collect the maximum filtration rate, it is necessary to confirm the conveyance capacity of the underdrainage system is sufficient to convey the collected runoff. To do this, Manning's equation can be used (which assumes pipe full flow but not under pressure). The Manning's roughness used will be dependant on the type of pipe used (refer to **QUDM Table 5.21.3** (**DPI, IMEA & BCC 1992**)).

Under-drains should be extended vertically to the surface of the bioretention system to allow inspection and maintenance when required. The vertical section of the under-drain should be unperforated and capped to avoid short-circuiting of flows directly to the drain. A concrete surround for a flush point with a DWV bolted trap screw for access and marker post should be used for this purpose. The marker post should be labelled 'Flush Point'. Reference is made to the drawings following the worked example (**Section 13.6.8**) for further guidance.

13.6.3.6 Step 6: Check Requirement for Impermeable Lining

The saturated hydraulic conductivity of the natural soil profile surrounding the bioretention system should be tested together with depth to groundwater, chemical composition and proximity to structures and other infrastructure. This is to establish if an impermeable liner is required at the base (only for systems designed to preclude ex-filtration to *in-situ* soils) and/or sides of the bioretention basin (refer also to discussion in **Section 13.6.2.3**). If the saturated hydraulic conductivity of the filter media in the bioretention system is more than one order of magnitude (10 times) greater than that of the surrounding *in-situ* soil profile, no impermeable lining is required.

13.6.3.7 Step 7: Size Overflow Pit

In bioretention basins, the overflow pit is designed with the pit crest raised above the level of the bioretention filter media, to establish the design extended detention depth (ie. maximum ponding depth). Typically, grated pits are used. The allowable head for discharges into the pits is the difference in level between the pit crest and the maximum permissible water level to satisfy minimum freeboard requirements as defined in the **QUDM** and **Section 3.5** of this guideline. Depending on the location of the bioretention basin, the design flow to be used to size the overflow pit could be the minor flood flow or the major flood flow. There should be a minimum of 100 mm head over the overflow pit crest to facilitate discharge of the design flow into the overflow pit.

In streetscape bioretention applications, a level of conservatism is built into the design of grated overflow pits by placing their inverts at least 50 mm below the invert of the street gutter (and therefore setting the maximum ponding depth). The head over the overflow pit crest is the sum of the 50 mm and the maximum ponding in the street gutter under the minor storm. The overflow pit can be located near the inflow zone or external to the bioretention basin, potentially in the kerb and gutter immediately downstream of the inlet to the basin in streetscape applications. In this way, the overflow pit can operate in the same way as a conventional side entry pit, with flows entering the pit only when the bioretention basin is at maximum ponding depth.

To size an overflow pit, two checks must 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, IMEA & BCC 1992)**). In addition, a blockage factor that assumes the grate is 50% blocked is to be used.

For free overfall conditions (weir equation):

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

Where:

Q_{weir}	=	flow over weir (pit) (m^3/s)
B	=	blockage factor (0.5)
C_w	=	weir coefficient (1.66)
L	=	Length of weir (m)
h	=	flow depth above the weir (m)

Equation 13.6.8

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):

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

Where:

B	=	blockage factor (0.5)
g	=	gravity (9.81 m/s^2)
h	=	maximum depth of water above the pipe (m)
$Q_{orifice}$	=	flow rate under drowned conditions (m^3/s)
C_d	=	discharge coefficient (drowned conditions = 0.6)
A	=	area of orifice (perforations in inlet grate) (m^2)

Equation 13.6.9

When designing grated field inlet pits, reference is also to be made to the procedure described in **QUDM Section 5.10.4** and **Section 3.5.7.11** of this Guideline.

In terms of the actual grate, dome type grates are preferred for use in bioretention basins. An example of an acceptable solution for a dome top cover is provided in Council's **Standard Drawing N^{os} 05-03-009** and **05-02-610**.

13.6.3.8 Step 8: Vegetation Specification

Refer to **Section 13.6.4** and **Section 13.13** for advice on selecting vegetation for bioretention basins in the Gold Coast City Council area. Consultation with landscape architects is recommended when selecting vegetation to ensure the treatment system also compliments the landscape of the area.

13.6.3.9 Step 9: Verification Checks

a) Vegetation Scour Velocity Check

Scour velocities over the vegetation in the bioretention basin are determined by assuming the system flows at a depth equal to the maximum ponding depth across the full width of the system. By dividing the minor and major storm design flow rates by this cross sectional flow area, an estimate of flow velocity can be made. It is a conservative approach to assume that all flows pass through the bioretention basin (particularly for a major storm), however this will ensure the integrity of the vegetation.

Velocities should be kept below:

- 0.5 m/s for minor flood (2-10 year ARI) discharges;
- 2.0 m/s for major flood (100 year ARI) discharges.

If the inlet to the bioretention basin 'controls' the maximum inflow to the basin then it is appropriate to use this maximum inflow to check velocities. In this case, velocities should be maintained below 0.5 m/s.

b) Confirm Treatment Performance

If, during the course of undertaking detailed design of the bioretention basin, the basic design parameters established by the conceptual design phase have changed (eg. area, filter media depth, etc) then the designer should verify that the current design meets the required water quality improvement performance. This can be done by referring to **Step 1** and simulating the design using MUSIC.

13.6.3.10 Design Calculation Summary

A calculation summary sheet for the key design elements of a bioretention basin is provided below.

	Bioretention Basin		Calculation Summary	
	Calculation Task		Outcome	Check
	Catchment Characteristics			
		Catchment Area	Ha	
		Catchment Land Use (ie. Residential, Commercial, etc)		
		Storm event entering inlet	yr ARI	
	Conceptual Design			
		Bioretention Area	m^2	
		Filter Media Saturated Hydraulic Conductivity	mm/hr	
		Extended Detention Depth	mm	
1	**Confirm Concept Design**			
	Bioretention to Achieve Water Quality Objectives			
		Total Suspended Solids	%	80
		Total Phosphorus	%	60
		Total Nitrogen	%	45
	Bioretention Area		m^2	
		Extended Detention Depth	m	
2	**Determine Design Flows**			
	Time of Concentration – Refer to Section 3.5 and QUDM		minutes	

	Bioretention Basin	Calculation Summary	
	Calculation Task	Outcome	Check
	Identify Rainfall Intensities		
	Minor Storm ($I_{2\text{-}10\ \text{year ARI}}$)	mm/hr	
	Major Storm ($I_{100\ \text{year ARI}}$)	mm/hr	
	Design Runoff Coefficient		
	Minor Storm ($C_{2\text{-}10\ \text{year ARI}}$)		
	Major Storm ($C_{100\ \text{year ARI}}$)		
	Peak Design Flows		
	Minor Storm (2 – 10 year ARI)	m^3/s	
	Major Storm (100 year ARI)	m^3/s	
3	**Design Inflow Systems**		
	Adequate Erosion and Scour Protection?		
	Coarse Sediment Forebay Required?		
	Volume (V_s)	m^3	
	Area (A_s)	m^2	
	Depth (D)	m	
*	**Check Flow Widths in Upstream Gutter**		
	Minor Storm Flow Width	m	
	Check ADEQUATE LANES TRAFFICABLE		
*	**Kerb Opening Width**		
	Kerb Opening Length	m	
4	**Specify Bioretention Media Characteristics**		
	Filter Media Hydraulic Conductivity	mm/hr	
	Filter Media Depth	mm	
	Drainage Layer Media (Sand or Fine Screenings)		
	Drainage Layer Depth	mm	
	Transition Layer (Sand) Required		
	Transition Layer Depth	mm	
5	**Under-Drain Design and Capacity Checks**		
	Flow Capacity of Filter Media	m^3/s	
	Perforations Inflow Check		
	Pipe Diameter	mm	
	Number of Pipes		
	Capacity of Perforations	m^3/s	
	Check PERFORATION CAPACITY > FILTER MEDIA CAPACITY		
	Perforated Pipe Capacity		
	Pipe Capacity	m^3/s	
	Check PIPE CAPACITY > FILTER MEDIA CAPACITY		
6	**Check Requirement for Impermeable Lining**		
	Soil Hydraulic Conductivity	mm/hr	
	Filter Media Hydraulic Conductivity	mm/hr	
	MORE THAN 10 TIMES HIGHER THAN *IN-SITU* SOILS?		
7	**Size Overflow Pit**		
	System to convey minor floods (2yr ARI)	L x W	
8	**Verification Checks**		
	Velocity for Minor Storm (< 0.5 m/s)	m/s	
	Velocity for Major Storm (< 2.0 m/s)	m/s	
	Treatment Performance consistent with **Step 1**		

Note: * ***Relevant to streetscape application only.***

13.6.4 Landscape Design Notes

13.6.4.1 Introduction

Landscaping of bioretention basins will provide nutrient removal and visual amenity to the surrounding landscape. The form and function of these basins can vary widely, ranging between large open space basins to small compact urban/ civic planter boxes.

13.6.4.2 Objectives

Landscape design of bioretention basins require the following key objectives to meet WSUD strategies:

1. Integrated planning and design of bioretention basins within the built and landscape environments.
2. Ensure surface treatments for bioretention basins address the stormwater quality objectives whilst enhancing the overall natural landscape.
3. Allow for GCCC **Crime Prevention Through Environmental Design (CPTED)** principals to be incorporated into bioretention basin design and siting.
4. Create landscape amenity opportunities that enhance the community and environmental needs such as shade, habitat creation, screening, view framing and visual aesthetics.

13.6.4.3 Context and Site Analysis

Bioretention basins are flexible WSUD solutions that can be applied to treat stormwater in most built and natural environments. They can effectively be designed in streetscapes, carparks, open space areas, balconies and as part of the street tree planting strategy. It is important that bioretention basins enhance the overall landscape. Careful planning to allow integration between buildings/ landscape and pavements is crucial. For large open space basins, it is also desirable to provide ease of access for maintenance activities.

Landscape treatments to bioretention basins will largely depend on their context and size. For example, planter box type systems in urban areas will require a different approach than larger systems located in open space areas. Comprehensive site analysis should inform the landscape design as well as road layouts, civil works and maintenance access requirements. Existing site factors such as roads, driveways, buildings, landforms, soils, plants, microclimates, services and views should be considered. Landscape design and treatments must be in accordance with the **Landscape Works Documentation Manual (GCCC 2003)**. Another useful reference is **Water Sensitive Urban Design in the Sydney Region: 'Practice Note 2 – Site Planning'** (**LHCCREMS 2002**) for further guidance.

13.6.4.4 Streetscape and Urban Bioretention Basins

a) Street Tree Bioretention

This bioretention system is based on using filter media contained around street trees in certain locations to capture and treat stormwater from road pavements. Key issues to consider for landscape design include:

- tree species selection and suitability to growing in filter media environment;
- containment of the filter media and plant roots to prevent root intrusion into the drainage system and/or other services and infrastructure;
- maintenance access for trash and heavy pollutant removal;
- selection of inlet planter cover.

Figure 13.6-D gives a general arrangement for street tree bioretention.

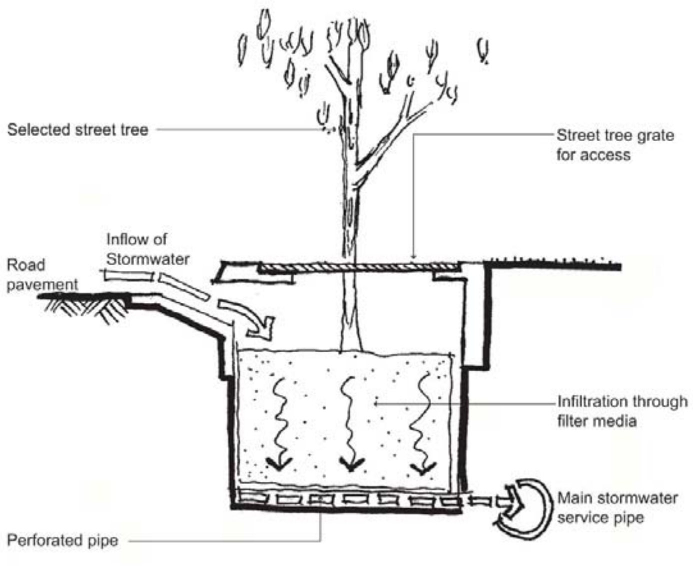

Figure 13.6-D: Typical Street Tree Bioretention System

Note: ***Council does not find this treatment device desirable. Approval is required at the concept stage before adopting these devices in a given Stormwater Management Plan.***

b) Planter Boxes

Specifically designed planter boxes that are part of the treatment train for the WSUD strategy, can be effective in high density urban situations that have minimal outdoor areas for traditional treatments. In well used areas, planter boxes are likely to be highly visible elements that could become local features. The urban landscape design principles of form, colour, texture and massing should apply to both plantings and raised containers. Given the urban context, an irrigation system may be required to provide supplementary watering. Traditional podium style planters can also utilize this technique to allow greater treatment of stormwater and minimize irrigation requirements.

13.6.4.5 Open Space Bioretention Basins

Once the general location has been determined, it will be necessary to investigate how the elements of the bioretention system will be arranged within the open space including an assessment of:

- opportunities and constraints presented by various siting options;
- if the device is to be visually prominent (perhaps for educational value) or merged with the surrounding parkland space using a consistent planting layout in the basin, embankment and parkland;
- if a formal or informal style is required dependent on the setting and surrounding open space and urban design.

As stormwater infrastructure, bioretention basins will generally not be considered ‘creditable land’ under Planning Scheme **Policy 16 – Recreation Facilities Network Developer Contributions**. The requirements of **Policy 16** with respect to open space contributions must also be followed with respect to flood immunity.

Open space bioretention basins typically are larger in surface area and have a deeper profile to allow for extended detention periods. This basically means the basin will periodically hold stormwater prior to discharging through the filter system. The landscape design needs to be able to respond to these engineering requirements and can include:

- specific planting strategies that reflect the ephemeral edges of natural wetland/ creek systems. This will ensure that planting will thrive under all conditions of dry and wet;
- use of shrub and tree plantings to visually screen areas of low amenity (eg. scour protection areas and inlet/ outlet pipes and pits);
- facilitate changes to batter and overall basin profiles to provide a more organic and natural layout. This will ensure the basin visually integrates with the other open space requirements more effectively.

13.6.4.6 Appropriate Plant Selection

Planting for bioretention basin systems may consist of up to four vegetation types:

1. Groundcovers for sediment removal and erosion protection (required element).
2. Shrubbery for screening, glare reduction, character, and other values.
3. Trees for shading, character and other landscape values.
4. Existing vegetation.

For specific guidance on plant species the designer is initially directed to **Section 13.13 – Plant Selection for WSUD Systems**, which outlines plant species suitable for the Gold Coast region and the plant selection guidelines in Council's **Landscape Strategy Part 2 – Landscape Works Documentation Manual (GCCC 2003)**. Ideally species selection should include locally endemic species.

The following sections describe the functional requirements of the different types of vegetation that can be applied to bioretention basins.

a) Trees

Trees for bioretention basin systems to streets and planter boxes should conform to the plant selection guidelines in Council's **Landscape Strategy Part 2 – Landscape Works Documentation Manual (GCCC 2003)** and respond to the surrounding built environment.

Trees planted into bioretention basins in open space areas should take into account existing vegetation species, soil types, be able to grow under conditions associated with periodic inundation and allow for open canopies to promote groundcover growth. While **Section 13.13** provides guidance on plant species selection, it is not intended as an exhaustive list and designers should ensure that the proposed planting schedule is suitable for the specific site.

b) Shrubs

Shrubs and trees are not a functional requirement for bioretention basins but can be designed into the systems to ensure integration within the wider landscape (streetscape or parkscape) and to provide amenity and character. Shrubs provide an important role in allowing for visual screening, providing interest and should compliment the design and siting of the bioretention basin. Some species are outlined in **Section 13.13** that are useful in urban and residential landscapes, however it should be noted that these lists are guides only. Other species and cultivars may be appropriate given the surrounding natural and/or built environment.

When incorporating trees and shrubs into bioretention systems appropriate space should be allowed between the systems to promote an open canopy that allows sunlight to penetrate to groundcover plants. Additionally, trees and shrubs must be accompanied by shade tolerant groundcover species.

In general, trees and shrubs planted into bioretention basins should have the following features:

- able to tolerate short periods of inundation (and water logged soils) punctuated by longer dry periods;
- have relatively sparse canopies to allow light penetration to support dense groundcover vegetation;
- root systems that are relatively shallow and are not known to be adventurous 'water seekers' to reduce the risk of root intrusion into under-drainage pipes;
- preferably native to the Gold Coast region and not exotic or deciduous.

c) Groundcovers

Groundcover vegetation (eg. sedges and tufted grasses) is an essential functional component of bioretention basins. Generally, the greater the density and height of vegetation planted in bioretention filter media, the better the treatment provided especially when extended detention is provided for in the design. This occurs when stormwater is temporarily stored and the contact between stormwater and vegetation results in enhanced sedimentation of suspended sediments and adsorption of associated pollutants.

Additionally, groundcover vegetation plays the primary role of continuously breaking up the surface of the bioretention filter media through root growth and wind induced agitation, which prevents surface clogging. The vegetation also provides a substrate for biofilm growth within the upper layer of the filter media, which facilitates biological transformation of pollutants (particularly nitrogen).

In general, ground cover vegetation should:

- cover the whole bioretention filter media surface;
- possess high leaf density within the design extended detention depth to aid efficient stormwater treatment;
- a dense and uniform distribution to prevent preferred flow paths, to prevent scour/ resuspension and to create a uniform root zone within the bioretention filter media;
- where appropriate, be endemic to the area and as a minimum be local to SEQ;
- species (including natives) that have the potential to become invasive weeds should be avoided;
- tolerate short periods of inundation (and water logged soils) punctuated by longer dry periods.

It should be noted that turf is not considered to be suitable vegetation for bioretention basins.

13.6.4.7 Safety

Bioretention basins within streetscapes and parks need to be generally consistent with public safety requirements for new developments. These include reasonable batter profiles for edges, providing adequate barriers to medians for vehicle/ pedestrian safety and safe vertical heights from adjacent pavements.

a) Crime Prevention Through Environmental Design (CPTED)

Landscape design of bioretention basins need to accommodate the standard principles of informal surveillance, reducing concealment areas by providing open visible areas as required. Regular clear sight lines between local roads and footpaths/ properties, which can be facilitated by vegetation lower than 1 metre or clear trunked trees above 1.6 metres.

Where planting may create places of concealment or hinder informal surveillance, groundcovers and shrubs should not generally exceed 1 m in height. For specific guidance on **CPTED** requirements the designer should refer to:

- GCCC website <www.goldcoast.qld.gov.au> ;
- the GCCC Community Safety Unit (Tel: 5581 6361) for appropriate and current guidelines and standards.

b) Traffic

Where landscaping for bioretention basins in road verges and medians are located in critical sightline corridors as required for traffic visibility, the standard rules apply to vegetation heights. Planting designs should allow for visibility at pedestrian crossings, intersections, rest areas, medians and roundabouts. Refer to the landscaping, **Landscape Works Documentation Manual (GCCC 2003)** and the **Road Landscape Manual (DMR 1997)** for further guidance.

c) Restricting Access to Open Water

Fences or vegetation barriers to restrict access should be incorporated into bioretention basin areas where:

- there is risk of serious injury in the event of a fall (over 0.5 m high and too steep to comfortably walk up/ down);
- there is a high pedestrian or vehicular exposure (on footpaths, near bikeways, near playing/ sporting fields, near swings and playgrounds, etc);
- water ponds to a depth of greater than 300 mm;
- grassed areas requiring mowing abut the asset.

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

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

Further guidance on designing for safety can be found in **Section 13.5 – Sediment Basins**.

d) GCCC Grating Guidelines

Inlet and outlet has identified that GPT's represent considerable safety risks if grating of pipeline inlets and/or outlets are not adequately addressed. Refer to GCCC report '**Stormwater Inlet/Outlet Screens ER295/249/46/02**'.

Note: Submerged outlet pipelines are not acceptable.

13.6.5 Construction and Establishment

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

It is important to note that bioretention basin systems, like most WSUD elements that employ soil and vegetation based treatment processes, require approximately two growing seasons (ie. two years) before the vegetation in the systems has reached its design condition (ie. height and density). In the context of a large development site and associated construction and building works, delivering bioretention basins and establishing vegetation can be a challenging task. Therefore, bioretention basins require a careful construction and establishment approach to ensure the basin establishes in accordance with its design intent.

The following sections outline a staged construction and establishment methodology for bioretention basins as adopted from **Delivering the Final Product – Establishing Water Sensitive Urban Design Systems (Leinster, 2006)**.

13.6.5.1 Construction and Establishment Challenges

There exist a number of challenges that must be appropriately considered to ensure successful construction and establishment of bioretention basins. 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 13.6-E**).

a) Subdivision Construction Phase

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 smother vegetation and clog bioretention filter media;
- construction traffic and other works can result in damage to the bioretention basins.

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

Plate 13.6-D: Example of Building Phase destruction

b) Building Phase

Once the Subdivision Construction works are complete and the development plans are sealed then the Building Phase can commence (ie. 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 bioretention basins.

13.6.5.2 Staged Construction and Establishment Method

To overcome the challenges associated within delivering bioretention basins a Staged Construction and Establishment Method should be adopted (see **Figure 13.6-E**):

Stage 1:

Functional Installation

Construction of the functional elements of the bioretention basin at the end of Subdivision Construction (ie. during landscape works) and the installation of temporary protective measures. For example, temporary protection of bioretention basins can be achieved by using a temporary arrangement of a suitable geofabric covered with shallow topsoil (eg. 25mm) and instant turf, *in lieu* of the final basin planting.

Stage 2:

Sediment and Erosion Control

During the Building Phase the temporary protective measures preserve the functional infrastructure of the bioretention basins against damage whilst also providing a temporary erosion and sediment control facility throughout the building phase to protect downstream aquatic ecosystems.

Stage 3:

Operational Establishment

At the completion of the Building Phase, the temporary measures protecting the functional elements of the bioretention basins can be removed along with all accumulated sediment and the system planted in accordance with the design planting schedule.

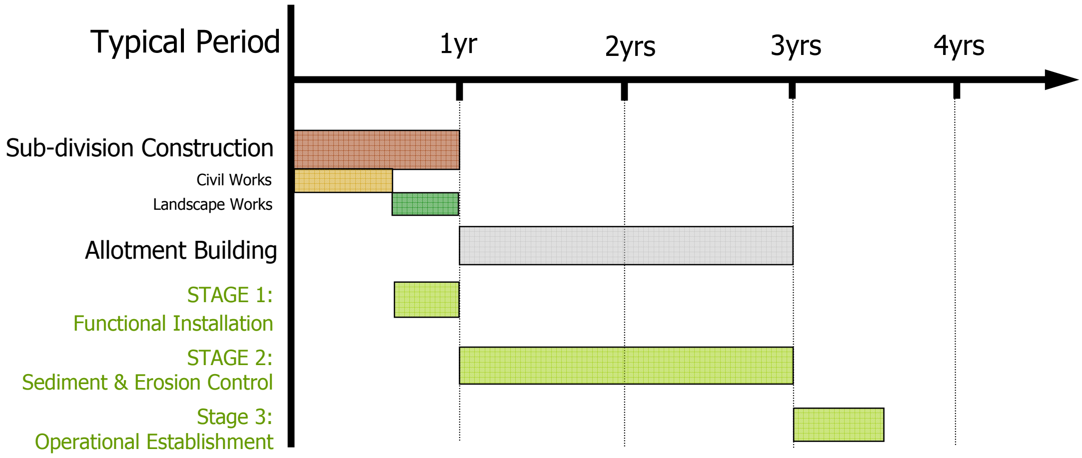

Figure 13.6-E: Staged Construction and Establishment Method

a) Functional Installation

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

- bulking out and trimming;
- installation of the outlet structures;
- placement of liner and installation of drainage layer (ie. under-drains and drainage layer);
- placement of filter media;
- placement of a Temporary Protective Layer – Covering the surface of filtration media with geofabric and placement of 25mm topsoil and turf over geofabric. This temporary geofabric and turf layer will protect the bioretention basin during construction (Subdivision and Building Phases) ensuring sediment/ litter laden waters do not enter the filter media causing clogging;
- place silt fences around the boundary of the bioretention basin to exclude silt and restrict access.

Plate 13.6-E: Bioretention basin functional installation

b) Sediment and Erosion Control

The temporary protective layers are left in place through the Allotment Building Phase to ensure sediment laden waters do not clog the filtration media and allotment building traffic does not enter the bioretention system. Importantly the configuration of the bioretention basin and the turf vegetation allow the system to function effectively as a shallow sedimentation basin reducing the load of coarse sediment discharging to receiving environment. This is positive outcome and indicates how WSUD systems can operate effectively to protect downstream ecosystems immediately after construction.

Plate 13.6-F: Bioretention basin sediment and erosion control

c) Operational Establishment

At the completion of the Allotment Building Phase the temporary measures (ie. geofabric and turf) are removed with all accumulated sediment and the bioretention system re-profiled and planted in accordance with the proposed landscape design. Establishment of the vegetation to design condition can require more than two growing season, depending the vegetation types, during which regular watering and removal of weeds will be required.

13.6.5.3 Construction Tolerances

It is important to stress the significance of tolerances in the construction of bioretention basins (eg. profiling of trench base and surface grades). Ensuring the base of the filtration trench and surface of the bioretention filter media is free from localised depressions resulting from construction is particularly important to achieve even distribution of stormwater flows across the surface and to prevent localised ponding on the surface, which may cause mosquito problems. In addition, to enable the perforated sub-surface drainage pipes to drain freely, the base of the trench should be sloped towards the outlet pit (min 0.5% longitudinal grade). Generally an earthworks tolerance of plus or minus 50 mm is considered acceptable.

13.6.5.4 Sourcing Bioretention Vegetation

Notifying nurseries early for contract growing is essential to ensure the specified species are available in the required numbers and of adequate maturity in time for bioretention basin planting. When this is not done and the planting specification is compromised, poor vegetation establishment and increased initial maintenance costs may occur. The species listed in **Section 13.13** are generally available commercially from local native plant nurseries. Availability is, however, dependent upon many factors including demand, season and seed availability. To ensure planting specification can be accommodated, the minimum recommended lead time for ordering is 3-6 months. This usually allows enough time for plants to be grown to the required size. The following pot sizes are recommended as the minimum:

Plate 13.6-G: Plant establishment period in bioretention basin

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

13.6.5.5 Vegetation Establishment

The following weed control measures and watering schedule are recommended to ensure successful plant establishment. Regular general maintenance as outlined in **Section 13.6.6** will also be required.

a) Weed Control

Conventional surface mulching of bioretention basins with organic material like tanbark, should not be undertaken. Most organic mulch floats and runoff typically causes this material to be washed away with the risk of blockage of drains occurring. Adopting high planting densities and if necessary, applying a suitable biodegradable erosion control matting to the basin batters will help to combat weed invasion and reduce labour intensive maintenance requirements for weed removal. A heavy application of seedless hydro-mulch can also provide short term erosion and weed control prior to planting with nursery stock. No matting or hydro-mulch is to be applied to the surface of the bioretention basin following the construction phase (ie. in its final design form, vegetated as per planting schedule), as this will hinder filtration of stormwater through the filter media.

b) Watering

Regular watering of bioretention basin vegetation is essential for successful establishment and healthy growth. The frequency of watering to achieve successful plant establishment is dependent upon rainfall, maturity of planting stock and the water holding capacity of the soil. The following watering program is generally adequate but should be adjusted (increased) to suit the site conditions:

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

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

c) Vegetation Management

Swale treatment relies upon good vegetation establishment and therefore ensuring adequate vegetation growth is the key maintenance objective. In addition, they have a flood conveyance role that needs to be maintained to ensure adequate flood protection for local properties.

Scouring and sediment deposition that occurs throughout the establishment period, which removes or smothers vegetation, needs to be monitored and addressed through replanting and re-construction of the basin. This replanting can be done using harvested on-site groundcovers that are doing well in other parts of the site or stormwater treatment devices.

13.6.6 Maintenance Requirements

Vegetation plays a key role in maintaining the porosity of the filter media of a bioretention basin and a strong healthy growth of vegetation is critical to its performance. Therefore the most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required.

Inflow systems and overflow pits require careful monitoring, as these can be prone to scour and litter build up. Debris can block inlets or outlets and can be unsightly, particularly in high visibility areas. Inspection and removal of debris should be done regularly, and debris should be removed whenever it is observed on a site. Where sediment forebays are adopted, regular inspection of the forebay is required (3 monthly) with remove of accumulated sediment undertaken as required.

For larger bioretention basins, it is essential that a maintenance access point is designed for and maintained in the bioretention basin. The size and complexity of the system will guide its design and may involve provision of a reinforced concrete ramp/ pad for truck or machinery access.

Typical maintenance of bioretention basin elements will involve:

- routine inspection of the bioretention basin profile to identify any areas of obvious increased sediment deposition, scouring from storm flows, rill erosion of the batters from lateral inflows, damage to the profile from vehicles and clogging of the bioretention basin (evident by a 'boggy' filter media surface);
- routine inspection of inflows systems, overflow pits and under-drains to identify and clean any areas of scour, litter build up and blockages;
- removal of sediment where it is smothering the bioretention basin vegetation;
- where a sediment forebay is adopted, removal of accumulated sediment;
- repairing any damage to the profile resulting from scour, rill erosion or vehicle damage by replacement of appropriate fill (to match onsite soils) and revegetating;
- tilling of the bioretention basin surface, or removal of the surface layer, if there is evidence of clogging;
- regular watering/ irrigation of vegetation until plants are established and actively growing;
- removal and management of invasive weeds (herbicides should not be used);
- removal of plants that have died and replacement with plants of equivalent size and species as detailed in the plant schedule;
- pruning to remove dead or diseased vegetation material and to stimulate growth;
- vegetation pest monitoring and control.

Resetting (ie. complete reconstruction) of the bioretention basin will be required if the system fails to drain adequately after tilling of the surface. Maintenance should only occur after a reasonably rain free period when the soil in the bioretention system is dry. Inspections are also recommended following large storm events to check for scour and other damage.

All maintenance activities must be specified in a maintenance plan (and associated maintenance inspection forms) to be documented and submitted to Council as part of the Development Approval process. Maintenance personnel and asset managers will use this plan to ensure the bioretention basins continue to function as designed. An example operation and maintenance inspection form is included in the checking tools provided in **Section 13.6.7**. These forms must be developed on a site specific basis as the nature and configuration of bioretention basins varies significantly.

13.6.7 Checking Tools

This section provides a number of checking aids for designers and Council development assessment officers. In addition, **Section 13.6.5** provides general advice for the construction and establishment of bioretention basins 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 construction)
- Operation and Maintenance Inspection Form
- Asset Transfer Checklist (following 'on-maintenance' period).

Figure 13.6-F below shows the stages of the development approval, construction and establishment, and asset transfer process and which checklists should be used at each stage.

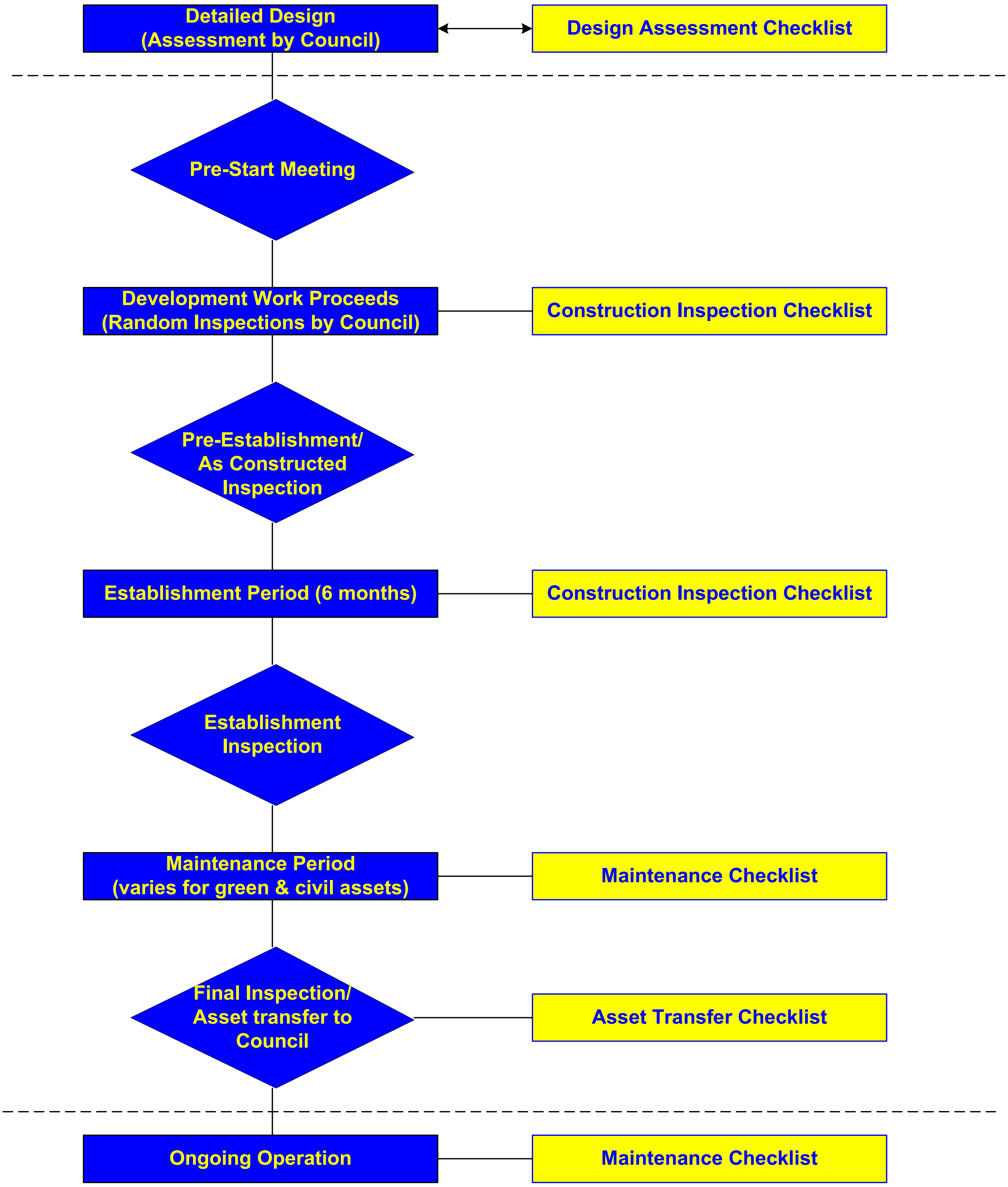

Figure 13.6-F: Development Approval and Handover Stages – Appropriate Checklists

13.6.7.1 Design Assessment Checklist

The design assessment checklist presents the key design features that are to be reviewed when assessing the design of a bioretention basin. 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 made back to the design procedure to determine the impact of the omission or error. A copy of the completed Design Calculation Summary from **Section 13.6.3.10** should be provided as part of the application to assist in the design assessment. In addition to the checklist, a proposed design is to have all necessary permits for its installation. Council development assessment officers will require all relevant permits to be in place prior to accepting a design.

13.6.7.2 Construction Checklist

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

13.6.7.3 Maintenance Checklist

A maintenance checklist using the example provided should be developed and used whenever an inspection is conducted and kept as a record on the asset condition and quantity of removed pollutants over time. Inspections should occur every 1 – 6 months depending on the size and complexity of the system. More detailed site specific maintenance schedules should be developed for major bioretention basins and include a brief overview of the operation of the system and key aspects to be checked during each inspection.

13.6.7.4 Asset Transfer Checklist

Land ownership and asset ownership are key considerations prior to construction of a stormwater treatment device. A proposed design should clearly identify the asset owner and who is responsible for its maintenance. The proposed owner should be responsible for performing the asset transfer checklist. For details on asset transfer to specific to each Council, contact the relevant local authority. The asset transfer checklist provides an indicative asset transfer checklist.

Bioretention Basin Design Assessment Checklist			
Asset I.D.		**DA No.**	
Basin Location:			
Hydraulics:	Minor Flood (m^3/s):	Major Flood (m^3/s):	
Area:	Catchment Area (ha):	Bioretention Area (ha):	

Concept Design	**Y**	**N**
Treatment performance verified from curves?		
Services located and clear of basin (minimum 250mm provided)?		
Bioretention Media and Under-Drainage	**Y**	**N**
Design documents bioretention area and extended detention depth as defined by treatment performance requirements. Area ranges from 1 to 3% of the catchment area. Extended detention depth up to 0.3m. Refer to **Section 13.6.2.2**.		
Overall flow conveyance system sufficient for design flood event(s)? Refer to **Section 13.6.3.7**		
Where required, bypass sufficient for conveyance of design flood event? Refer to **Section 13.6.3.3**		
Where required scour protection provided at inflow point to bioretention? Refer to **Section 13.6.3.3**		
Bioretention media specification includes details of filter media, drainage layer and transition layer (if required)? Refer to **Section 13.6.3.4**. Check filter media and drainage layer included and transition layer (if required).		
Design saturated hydraulic conductivity included in specification? Refer to **Section 13.6.3.4**		
Transition layer provided where drainage layer consists of gravel (rather than coarse sand)?		
Perforated pipe capacity > infiltration capacity of filter media? Refer to **Section 13.6.3.4**		
Selected filter media hydraulic conductivity > 10 x hydraulic conductivity of surrounding soil?		
Liner provided if selected filter media hydraulic conductivity < 10 x hydraulic conductivity of surrounding soil? Refer to **Section 13.6.3.6**		
Maximum spacing of collection pipes <1.5m?		
Collection pipes extended to surface to allow inspection and flushing?		
*Maximum upstream flood conveyance complies with **QUDM**?		
*Overflow pit has set down of at least 50mm below kerb invert? (where conventional gully/ lintel used downstream of bioretention then no overflow pit required)		
Basin	**Y**	**N**
Bioretention area and extended detention depth documented to satisfy treatment requirements?		
Overflow pit crest set at top of extended detention?		
Maximum ponding depth will not impact on public safety?		
Maintenance access provided to surface of bioretention system (for larger systems)?		
Protection from coarse sediments provided (where required) with a sediment forebay? Refer to **Section 13.6.3.3**		
Protection from gross pollutants provided (where required)?		
Landscape	**Y**	**N**
Plant species selected can tolerate extended dry periods, periodic inundation and design velocities?		
Bioretention design and plant species selected integrate with surrounding landscape or built environment design?		
*Planting design conforms with acceptable sight line and safety requirements?		
Comments		

Note: *   ***Streetscape application only.***

Bioretention Basin Construction Inspection Checklist

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

Items Inspected	Checked		Satisfactory		Items Inspected	Checked		Satisfactory	
	Y	N	Y	N		Y	N	Y	N
During Construction and Establishment									
A. Functional Installation					**Structural Components**				
Preliminary Works					15. Location and configuration of inflow systems as designed				
1. Erosion and sediment control plan adopted					16. Location and levels of overflow pits as designed				
2. Temporary traffic/ safety control measures					17. Under-drainage connected to overflow pits as designed				
3. Location same as plans					18. Concrete and reinforcement as designed				
4. Site protection from existing flows					19. Set down to correct level for flush kerbs (streetscape applications only)				
Earthworks and Filter Media					20. Kerb opening width as designed				
5. Bed of basin correct shape and slope									
6. Batter slopes as plans					**B. Sediment and Erosion Control (if required)**				
7. Dimensions of bioretention area as plans					21. Stabilisation immediately following earthworks and planting of terrestrial landscape around basin				
8. Confirm surrounding soil type with design					22. Silt fences and traffic control in place				
9. Confirm filter media specification in accordance with **Step 4**					23. Temporary protection layers in place				
10. Provision of liner (if required)									
11. Under-drainage installed as designed					**C. Operational Establishment**				
12. Drainage layer media as designed					24. Temporary protection layers and associated silt removed				
13. Transition layer media as designed (if required)					**Vegetation**				
14. Extended detention depth as designed					25. Planting as designed (species and densities)				
					26. Weed removal and watering as required				
Final Inspection									
1. Confirm levels of inlets and outlets					6. Check for uneven settling of banks				
2. Confirm structural element sizes					7. Under-drainage working				
3. Check batter slopes					8. Inflow systems working				
4. Vegetation as designed					9. Maintenance access provided				
5. Bioretention filter media surface flat and free of clogging									

Comments on Inspection

Actions Required

Inspection officer signature:

Bioretention Basin Maintenance Checklist			
Inspection Frequency:	1 to 6 monthly	**Date of Visit:**	
Location:			
Description:			
Asset I.D.:			
Site Visit by:			

Inspection Items	Y	N	Action Required (Details)
Sediment accumulation at inflow points?			
Litter within basin?			
Erosion at inlet or other key structures?			
Traffic damage present?			
Evidence of dumping (eg. building waste)?			
Vegetation condition satisfactory (density, weeds, etc)?			
Watering of vegetation required?			
Replanting required?			
Mowing/ slashing required?			
Clogging of drainage points (sediment or debris)?			
Evidence of ponding?			
Damage/ vandalism to structures present?			
Surface clogging visible?			
Drainage system inspected?			
Resetting of system required?			

Comments

Bioretention Basin Asset Transfer Checklist		
Asset I.D.:		
Asset Location:		
Construction by:		
'On-Maintenance' Period:		
Treatment	**Y**	**N**
System appears to be working as designed visually?		
No obvious signs of under-performance?		
Maintenance	**Y**	**N**
Maintenance plans and indicative maintenance costs provided for each asset?		
Vegetation establishment period completed (2 years)?		
Inspection and maintenance undertaken as per maintenance plan?		
Inspection and maintenance forms provided?		
Asset Inspected for Defects and/or Maintenance Issues at Time of Asset Transfer	**Y**	**N**
Sediment accumulation at inflow points?		
Litter within basin?		
Erosion at inlet or other key structures?		
Traffic damage present?		
Evidence of dumping (eg. building waste)?		
Vegetation condition satisfactory (density, weeds, etc)?		
Watering of vegetation required?		
Replanting required?		
Mowing/ slashing required?		
Clogging of drainage points (sediment or debris)?		
Evidence of ponding?		
Damage/ vandalism to structures present?		
Surface clogging visible?		
Drainage system inspected?		
Comments/ Actions Required for Asset Transfer		
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?		

13.6.8 Bioretention Basin Worked Example

A series of bioretention basins, designed as landscaped ‘out-stands’, are to be retrofitted into an urban road in a residential development in Pimpama on the Gold Coast to treat local catchment runoff. The street has a longitudinal grade of 1% and the adjacent allotments have an average slope of 2%. The development constitutes high density residential development (>20 dwellings/ha), as defined by **Section 3.5**. A proposed layout for the bioretention basins is shown in **Figure 13.6-G** with an image of a similar system to that proposed shown in **Plate 13.6-H**.

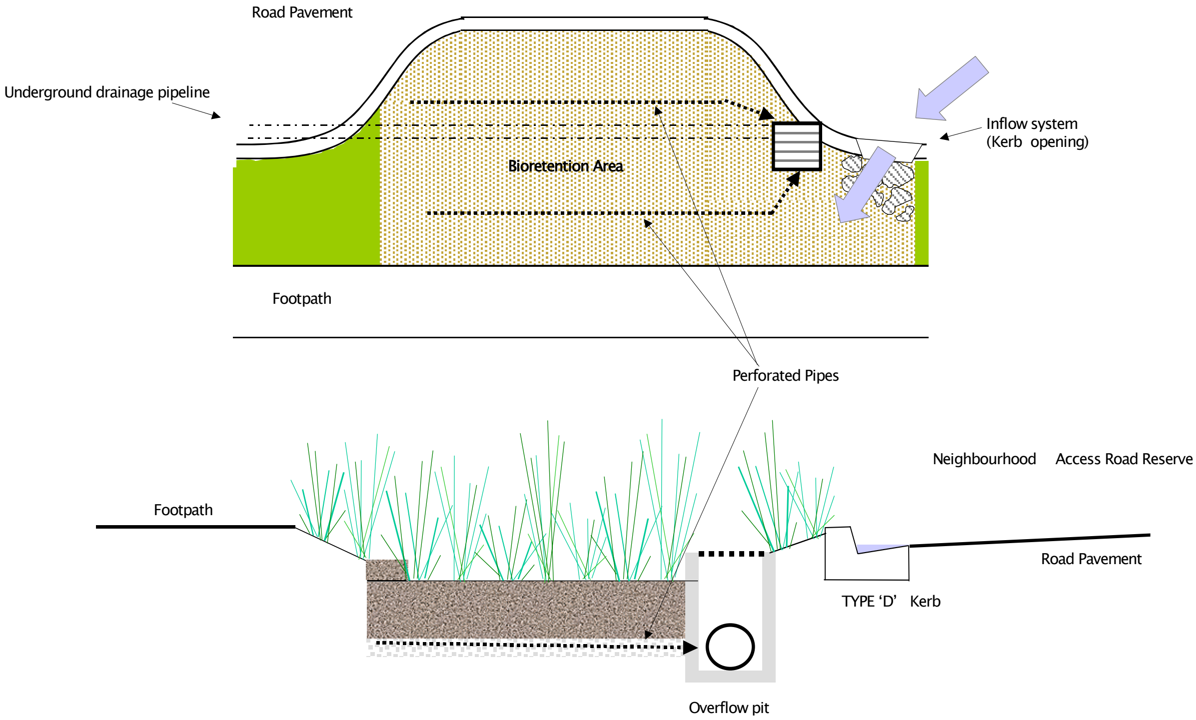

Figure 13.6-G: General Layout and Cross Section of Proposed Bioretention System

Plate 13.6-H: Retrofitted bioretention system in a street

The contributing catchment areas to each of the individual bioretention basins consist of 200 m^2 of road and footpath pavement and 400 m^2 of adjoining properties. Runoff from adjoining properties (approximately 60% impervious) is discharged into the road gutter and, together with road runoff, is conveyed along a conventional roadside gutter for a maximum length of approximately 20 m until it reaches the bioretention basin. The adjacent allotment overland flow path length to the gutter is approximately 15 m.

The aim of the design is to facilitate effective treatment of stormwater runoff while maintaining a 2 year ARI level of flood protection for the local street. Conceptual design of the bioretention basins has been undertaken, with MUSIC used to ensure the stormwater discharges comply with the GGCC Load Reduction Targets (80% TSS, 60% TP and 45% TN reductions). The bioretention basins have an area of 18 m^2 to meet stormwater treatment objectives with an extended detention depth of 300 mm and consisting of a modified sandy loam soil filtration medium (saturated hydraulic conductivity = 180 mm/hr). The width (measured perpendicular to the alignment of the road) of the bioretention basins is 2 m.

The key design elements to ensure effective operation of the bioretention basins are listed below:

- road and gutter details to convey water into the basins;
- detailing inlet conditions to provide for erosion protection;
- configuring and designing a system for 'above design' operation that will provide the required 10 year ARI flood protection for the local street;
- detailing of the bioretention under-drainage system;
- specification of the soil filter medium;
- landscape layout and details of vegetation.

Design Objectives

Stormwater treatment to deliver the GCCC WQOs, which, in this case, equates to at least an 80% reduction in mean annual TSS load, 60% reduction in mean annual TP load and 45% reduction in mean annual TN load, whilst maintaining the minor event (ie. 10 year ARI) level of flood protection for the local street.

Constraints and Concept Design Criteria

Analyses undertaken during a concept design established the following criteria:

1. Bioretention basin area of 18 m^2 required to achieve GCCC Best Practice Load Reduction Guidelines.
2. Maximum width of each bioretention basin is to be 2 m.
3. Extended detention depth is 300 mm.
4. Filter media to have a saturated hydraulic conductivity of 180 mm/hr.

13.6.8.1 Step 1: Confirm Treatment Performance of Concept Design

It is assumed that earlier conceptual design of the stormwater treatment system required of this project will have undertaken appropriate modelling using MUSIC or alternative techniques to ensure that stormwater discharges from the site comply with GCCC WQOs, a prerequisite of development approval. It is noted that these objectives will change dependent on their specific location on the Gold Coast.

13.6.8.2 Step 2: Determine Design Flows

With a small catchment (in this case 600 m^2), the Rational Method is considered an appropriate approach to estimate the design storm peak flow rates. The steps in this calculation follow below.

Time of Concentration (t_c)

Approach:

The time of concentration is estimated assuming overland flow across the allotments. As the use of standard inlet times shall not apply in the Gold Coast City Council area, the methods outlined in **Section 5.05.5** of **QUDM (DPI, IMEA & BCC 1992)** are referred to.

From procedures documented in **QUDM (DPI, IMEA & BCC 1992)** and **Section 3.5** of these guidelines, the overland sheet flow component should be limited to 50m in length and determined using the Kinematic Wave Equation:

$$t = 6.94\ (L.n^*)^{0.6}/I^{0.4}\ S^{0.3}$$

Where:

t	=	overland sheet flow travel time (mins)
L	=	overland sheet flow path length (m)
*n**	=	surface roughness/ retardance coefficient
I	=	rainfall intensity (mm/hr)
S	=	slope of surface (m/m)

When calculating remaining overland flow travel times and kerb and gutter travel times, it is recommended that stream velocities in **Table 5.05.4** of **QUDM** be used.

Assuming:

Predominant catchment slope = 2%

Road longitudinal slope = 1%

Overland sheet flow component = 15 m

Kerb and channel flow component = 20 m

Overland flow path is predominately lawn, with a typical n* = 0.25 (**QUDM**)

10 year ARI:

$t_{\text{sheet flow}} = 6.94\ (15 \times 0.25)^{0.6}/(200.7^{0.4} \times 0.02^{0.3})$

$= 6\ \text{mins}$

Iterations will need to be repeated until $t_{\text{sheet flow}}$ matches 10 year ARI rainfall intensity on the IFD chart for that duration, as shown in the above calculation.

Note: ***IFD data will need to be determined in line with Section 3.5.7.6 of these Guidelines.***

$t_{\text{channel flow}} = (20\ \text{m} / 0.3\text{m/s}) / 60\text{s/min}$

$= 1\ \text{min}$

$t_c = t_{\text{sheet flow}} + t_{\text{channel flow}}$

$= 7\ \text{mins}$

100 year ARI:

$t_{\text{sheet flow}} = 6.94\ (15 \times 0.25)^{0.6}/(292.4^{0.4} \times 0.02^{0.3})$

$= 5\ \text{mins}$

Iterations will need to be repeated until $t_{\text{sheet flow}}$ matches the 100 year ARI rainfall intensity on the IFD chart for that duration, as shown in the above calculation.

Note: ***IFD data will need to be determined in line with Section 3.5.7.6 of these Guidelines.***

$t_{\text{channel flow}} = (20\ \text{m} / 0.3\text{m/s}) / 60\text{s/min}$

$= 1\ \text{min}$

$t_c = t_{\text{sheet flow}} + t_{\text{channel flow}}$

$= 6\ \text{mins}$

Design Rainfall Intensities

Table 13.6-A: Design Event Rainfall Intensities

Design Event	Time of Concentration t_c	Rainfall Intensity
Minor (10 year ARI)	7 mins	189.4 mm/hr
Major (100 year ARI)	6 mins	274.6 mm/hr

Note: ***Rainfall intensities adopted from Pimpama IFD table, determined using the*** **Land Development Guidelines (GCCC 2005)*.***

Design Runoff Coefficient

Apply the rational formula method outlined in **QUDM** using Runoff coefficients outlined in **Table 3.5A** of these Guidelines:

Assuming the Development Category is High Density Res B, with a slope of 2%, C10 = 0.85

Hence, using **QUDM Table 5.04.3**

$C_{10} = 1.00 \times 0.85 = 0.85$

$C_{100} = 1.20 \times 0.85 = 1.02 = 1.00$

Rational Method

$$Q = CIA/360$$

$Q_{10yr\ ARI}$ = 0.027 m^3/s

$Q_{100yr\ ARI}$ = 0.046 m^3/s

13.6.8.3 Step 3: Design Inflow Systems

a) Inlet Scour Protection

Rock beaching is to be provided in the bioretention basins to manage flow velocities entering from the kerb opening.

b) Coarse Sediment Forebay

A bioretention system such as the one proposed here should incorporate a coarse sediment forebay to remove coarse sediment from stormwater prior to flowing across the surface of the filter media. The forebay should be designed to:

- remove particles that are 1mm or greater in diameter from the 3mth ARI storm event;
- provide appropriate storage for coarse sediment to ensure desilting is required once every year.

The size of the sediment forebay is established using the following:

$$V_s = A_c \cdot R \cdot L_o \cdot F_c$$

Where:

V_s	=	volume of forebay sediment storage required (m^3)
A_c	=	contributing catchment area (0.06 ha)
R	=	capture efficiency (assume 80%)
L_o	=	sediment loading rate (1.6 m^3/ha/year)
F_c	=	desired cleanout frequency (2 years)

V_s = 0.06 * 0.8 * 1.6 * 2

= 0.1536m^3

The area of the forebay is established by dividing the volume by the depth. The depth of the forebay should not be greater than 0.3 m below the surface of the filter media.

$$A_s = V_s / D_s$$

Where:

D_s = depth of sediment forebay (0.3 + 0.3)

A_s = 0.1536 / 0.6

= 0.256 m^2

The sediment forebay area should be checked to ensure it captures the 1mm and greater particles using the following expression (modified version of **Fair and Geyer (1954)**):

$$R = 1 - \left[1 + \frac{1}{n} \cdot \frac{v_s}{Q/A}\right]^{-n}$$

Where:

R	=	fraction of target sediment removed (80%)
v_s	=	settling velocity of target sediment (100mm/s or 0.1m/s for 1mm particle)
Q_{3mth} / A	=	applied flow rate divided by basin surface area ($m^3/s/m^2$)
n	=	turbulence or short-circuiting parameter (adopt 0.5)

Q_{3month} = 0.5 * Q_1 (approx)

t_c = t $_{\text{sheet flow}}$ + t $_{\text{channel flow}}$

= 7 mins + 1mins

= 8 mins

I_1 = 110 mm/hr

Q_1 = C*I*A / 360

= 0.85 * 110 * 0.06 / 360

= 0.016 m^3/s

Q_{3month} = 0.5 * 0.016

= 0.008 m^3/s

R = $1 - [1 + 1/0.5 * 0.1 / 0.008 / 0.256]^{-0.5}$

= $1 - [7.4]^{-0.5}$

= 0.632

= 63% of 1mm particles

c) Streetscape Application – Size Kerb Opening

Gutter Flow Width and Kerb Opening

The depth and width of gutter flow at the locality of the kerb opening needs to be determined to establish the hydraulic head at the kerb opening.

The width and depth of gutter flow is estimated using the procedure described in **QUDM Section 5.09** with the '**Road Flow Capacity Chart Tables'** provided in **QUDM Volume 2** (**DPI, IMEA & BCC 1992**) allowing rapid calculation.

$Q_{10\ Year}$ = 0.027 m^3/s gives:

Depth of Flow = 60 mm

Width of Flow = 1.67 m

Velocity = 0.63 m/s

Depth x V = 0.04 m/s

The estimated gutter flow width at the kerb opening during the $Q_{10\ Year}$ storm event is less than half road width during minor storm flow and thus complies with **Section 3.5** of this Guideline.

Kerb Opening Length

The flow depth in the gutter estimated above is used to determine the required length of opening in the kerb to allow for the 2 year ARI flow to pass freely into the bioretention basin.

$Q_{10yr\ ARI}$ = 0.027 m^3/s

Assume broad crested weir flow conditions through the kerb opening and use **Equation 13.6.4** to determine length of opening:

$$Q = C_w \cdot L \cdot h^{3/2}$$

Where:

Q	=	$Q_{10yr\ ARI}$ = 0.027 m^3/s
C_w	=	weir coefficient = 1.7
h	=	depth of (Q_{10}) flow (60mm) = 0.06m
L	=	Length of opening (m)

Solving gives L = 1.08 m, therefore adopt a 1.1 m long opening which ensures there will be no increase in gutter flow depth and width upstream of the kerb opening.

13.6.8.4 Step 4: Specify the Bioretention Media Characteristics

The specification of the filter media and drainage layers requires consideration of the perforated under-drainage system. In this case, a perforated pipe with a slot width of 1.5 mm has been selected, meaning there is a risk that sand (typically 1 mm diameter and less) could wash into the pipe. Therefore, in this case three layers are to be used: an amended sandy loam as the filter media (600 mm), a coarse sand transition layer (100 mm) and a fine gravel drainage layer (200 mm).

a) Filter Media

The filter media is to be a sandy loam and will be formed through the procedure documented in **Section 13.6.3.4**. The filter media will have a saturated hydraulic conductivity of 180 mm/hr and generally meet the following geotechnical requirements:

- particle sizes of between: clay 5 – 15%, silt < 30%, sand 50 – 70%;
- between 5% and 10% organic content, measured in accordance with **AS1289 4.1.1**;
- pH neutral.

b) Drainage Layer

The drainage layer is to be 150 mm of 5 mm screenings graded at 0.5% toward the overflow pit.

c) Transition Layer

Transition layer material shall be coarse sand material such as Unimin 16/30 FG sand grading or equivalent. A typical particle size distribution is provided below:

% passing	1.4 mm	100%
	1.0 mm	80%
	0.7 mm	44%
	0.5 mm	8.4%

13.6.8.5 Step 5: Under-Drain Design and Capacity Checks

Two under-drains are to be installed in the drainage layer approximately 1 m apart. This will ensure the drainage layer does not hinder drainage of the filter media. A standard perforated pipe was selected for the under-drain that has a slot clear opening of 2100 mm^2/m with the slots being 1.5 mm wide. The perforated pipes are to be laid on the base of the bioretention system which grades at 0.5% towards the overflow pit.

The maximum filtration rate reaching the perforated pipe in the drainage layer is estimated by using the saturated hydraulic conductivity of the filter media and head above the pipes and applying Darcy's equation:

$$Q_{max} = K_{sat} \cdot L \cdot W_{base} \cdot \frac{h_{max} + d}{d}$$

Where:

Saturated hydraulic conductivity (K_{sat}) = 180 mm/hr
= 0.18 m/hr

Area of bioretention basin (L x W_{base}) = 18 m^2

Depth of pondage above the soil filter media (hmax) = 0.3 m

Depth of Filter Media (d) = 0.6 m

Maximum filtration rate = ((0.18 m/hr x 18 m^2)/3600 s/hr) x (0.3 + 0.6)/0.6
= 0.00135 m^3/s

Perforations Inflow Check

Estimate the inlet capacity of sub-surface drainage system (perforated pipe) to ensure it is not a choke in the system. To build in conservatism, it is assumed that 50% of the holes are blocked. A standard perforated pipe was selected that is widely available. To estimate the flow rate, an orifice equation is applied using the following parameters:

Head (h) = 0.86 m [0.6 m (filter depth) + 0.3 m (max. pond level) + 0.05 m (half of pipe diameter)]

Assume sub-surface drains with half of all slots blocked (B = 0.5)

Clear Opening = 2100 mm^2/m

Hence,

Blocked Openings = 1050 mm^2/m (50%)

Slot Width = 1.5 mm

Slot Length = 7.5 mm

Pipe diameter = 100 mm

Number of slots per metre = (1050)/(1.5 x 7.5) = 93.3

Assume orifice flow conditions (**Equation 13.6.6**):

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

Where:

C_d = 0.6 (assume slot width acts as a sharp edged orifice)

h = 0.86 m (from above)

A = area of slots (=1.5 mm x 7.5 mm x 93.3 slots = 0.00105 m^2)

g = gravity (9.81 m/s^2)

Note: This already allows for blockage, so B can be ignored in this case.

Inlet capacity per metre length of pipe:

= 0.0026 m^3/s

Inlet capacity per m x total length (two lengths of 5.5 m)

= 0.0026 x (2 x 5.5m)

= 0.029 m^3/s >> 0.00135 (max filtration rate), hence OK.

Perforated Pipe Capacity

Manning's equation is applied to estimate the flow rate in the perforated pipes to confirm the capacity of the pipes is sufficient to convey the maximum filtration rate. Two 100 mm diameter perforated pipes are to be laid in parallel and at a grade of 0.5% towards the overflow pit.

Applying the Manning's Equation assuming a Manning's n of 0.02 gives:

Q (flow per pipe) = 0.0024 m^3/s

Then,

Q_{Total} = 0.0048 m^3/s (for two pipes) > 0.00135 m^3/s, and hence OK.

13.6.8.6 Step 6: Check Requirement for Impermeable Lining

In the catchment, the surrounding soils are clay to silty clays with a saturated hydraulic conductivity of approximately 3.6 mm/hr. The sandy loam media that is proposed as the filter media has a hydraulic conductivity of 180 mm/hr, therefore the conductivity of the filter media is > 10 times (one order of magnitude) the conductivity of the surrounding soils and an impervious liner is not considered to be required.

13.6.8.7 Step 7: Size Overflow Pit

The overflow pit is required to convey 10 year ARI flows safely from above the bioretention system into an underground pipe network. Grated pits are to be used at the upstream end of the bioretention system. The sizes of the pits are established using two calculations for drowned and free overfall conditions. For free overfall conditions, a broad crested weir equation (**Equation 13.6.8**) is used with the maximum headwater depth (h) above the weir being set by the level difference between the crest of the overflow pit and the invert level of the kerb opening (ie. 100 mm for this design):

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

Where:

Q = $Q_{10yr\,ARI}$ = 0.027 m^3/s, B = 0.5, C_w = 1.66 and h = 0.1m

Solving for L:

L = 1.03 m of weir length required (equivalent to 258 x 258 mm pit)

Now, check for drowned conditions using **Equation 13.6.9**:

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

Where:

Q = $Q_{10yr\,ARI}$, B = 0.5, C_d = 0.6 and h = 0.1m

Solving for A:

A = 0.064 m^2 (equivalent to 254 x 254 mm pit)

Hence, free overflow conditions dominate and the pit needs to be greater than 258 x 258 mm.

13.6.8.8 Step 8: Specify Vegetation

With such a small system, it is appropriate to have vegetation of a single species within the bioretention system. For this application, a Tall Sedge (*Carrex appressa*) is proposed with a planting density of 8 plants/m^2. Information on maintenance and establishment is provided in earlier sections of this chapter.

13.6.8.9 Step 9: Verify Design

a) Vegetation Scour Velocity Checks

The location and sizing of the overflow pit precludes flows from minor and major storm events over the bioretention surface. Therefore, no scour velocity checks are required for this worked example.

b) Confirm Treatment Performance

The key functional elements of the bioretention basins developed as part of the conceptual design (ie. area, filter media depth) were not adjusted as part of the detailed design. Therefore, the performance check undertaken in **Step 1** still applies.

13.6.8.10 Design Calculation Summary

The design calculation summary sheet on the following page shows the results of the design process for the worked example.

Drawings 13.6.1 and **13.6.2** demonstrate the principles of the worked example.

Bioretention Basin	Calculation Summary		
Calculation Task	Outcome		Check
Catchment Characteristics			
Catchment Area	0.06	Ha	✓
Catchment Land Use (ie. Residential, Commercial, etc)	Residential		
Storm event entering inlet	10	yr ARI	
Conceptual Design			
Bioretention Area	18	m^2	✓
Filter Media Saturated Hydraulic Conductivity	180	mm/hr	
Extended Detention Depth	0.3	mm	
1 Verify Size for Treatment			
MUSIC Modelling to Achieve Water Quality Objectives			
Total Suspended Solids	90	%	Reduction
Total Phosphorus	75	%	Reduction
Total Nitrogen	45	%	Reduction
Bioretention Area	18	m^2	✓
Extended Detention Depth	0.3	m	
2 Determine Design Flows			
Time of Concentration – Refer to Section 3.5 and QUDM			✓
Minor Storm (10 year ARI)	7	minutes	
Major Storm (100 year ARI)	6	minutes	
Identify Rainfall Intensities			
Minor Storm ($I_{10\ year\ ARI}$)	189.4	mm/hr	✓
Major Storm ($I_{100\ year\ ARI}$)	274.6	mm/hr	
Design Runoff Coefficient			
Minor Storm ($C_{10\ year\ ARI}$)	0.85		✓
Major Storm ($C_{100\ year\ ARI}$)	1.00		
Peak Design Flows			
Minor Storm (10 year ARI)	0.027	m^3/s	✓
Major Storm (100 year ARI)	0.046	m^3/s	
3 Design Inflow Systems			
Adequate Erosion and Scour Protection?	y		✓
Coarse Sediment Forebay Required?	y		
Volume (V_s)	0.15	m^3	
Area (A_s)	0.256	m^2	
Depth (D)	0.6	m	
* **Check Flow Widths in Upstream Gutter**			
Minor Storm Flow Width	1.67	m	✓
Check ADEQUATE LANES TRAFFICABLE			y
* **Kerb Opening Width**			
Kerb Opening Length	1.1	m	✓
4 Specify Bioretention Media Characteristics			
Filter Media Hydraulic Conductivity	100	mm/hr	✓
Filter Media Depth	600	mm	
Drainage Layer Media (Sand or Fine Screenings)			
Drainage Layer Depth	150	mm	✓
Transition Layer (Sand) Required	Y		
Transition Layer Depth	150	mm	

Bioretention Basin	Calculation Summary	
Calculation Task	**Outcome**	**Check**
5 Under-Drain Design and Capacity Checks		
Flow Capacity of Filter Media	0.00135 m^3/s	
Perforations Inflow Check	Y	
Pipe Diameter	100 mm	✓
Number of Pipes	2	
Capacity of Perforations	0.029 m^3/s	
Check PERFORATION CAPACITY > FILTER MEDIA CAPACITY		y
Perforated Pipe Capacity		
Pipe Capacity	0.0048 m^3/s	✓
Check PIPE CAPACITY > FILTER MEDIA CAPACITY		y
6 Check Requirement for Impermeable Lining		
Soil Hydraulic Conductivity	3.6 mm/hr	✓
Filter Media Hydraulic Conductivity	180 mm/hr	
MORE THAN 10 TIMES HIGHER THAN *IN-SITU* SOILS?		y
7 Size Overflow Pit		
System to convey minor floods (2yr ARI)	258 x 258 L x W	✓
8 Verification Checks		
Velocity for Minor Storm (< 0.5 m/s)	N/A m/s	
Velocity for Major Storm (< 2.0 m/s)	N/A m/s	✓
Treatment Performance consistent with **Step 1**	Y	

Note:* * *Relevant to streetscape application only.

13.6.9 References

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