Water Sensitive Urban Design (WSUD)

Bio-retention Systems — Information sheet No.4

Purpose of this fact sheet

This fact sheet provides an overview of Bio-retention systems.

Overview

Bio-retention systems are one of the most commonly used Water Sensitive Urban Design (WSUD) technologies in Australia. Bio-retention systems are a type of stormwater treatment measure designed to treat stormwater runoff and are often part of a 'treatment train' with other WSUD technology. Typically as water enters the bio-retention garden bed it filters through a vegetated soil media layer. This filtered stormwater is then collected in perforated pipes below the garden bed and flows to the stormwater system, natural waterway or a detention basin. In certain situations the stormwater may be treated to a sufficient standard for collection and reuse. All bio-retention systems utilise a filter medium to trap and remove pollutants through gravity-induced infiltration. Vegetation that grows in the filter media enhances its function by preventing erosion of the filter medium, continuously breaking up the soil through plant growth to prevent clogging of the system, and providing biofilms on plant roots to metabolise pollutants. Sandfilters are an alternate treatment system using filtration, but without plants. Such systems are not covered here.

Benefits

- Fine and soluble pollutants removal
- Cost - often lower capital and maintenance costs than alternative proprietary treatment systems
- Reduces impervious areas and disconnects runoff from receiving water bodies to better replicate natural drainage systems.
- Versatility - they work in a variety of climate, soil and groundwater conditions. Simple to integrate into the treatment train.
- Performance - bioretention systems provide effective removal of sediment and heavy metals.
- Ecosystem health - living plants provide habitat for wildlife
- Aesthetics - they provide green spaces in urbanised environments.
- Applicability - they may often require less space than other treatment systems
- Detention - storage and reduction of flash flooding

Target Pollutants
- Fine to medium sediment
- Heavy metals
- Nutrients (Phosphorus, Nitrogen)
- Bacteria

Functions

Bio-retention systems are utilised as secondary and tertiary treatment of stormwater aimed to remove nutrients, bacteria, fine sediments and heavy metals.

Each component of a bioretention system area is designed to perform a specific function. The generic structure of a bioretention system includes an extended detention ponding area, a filter media, transition layer and a drainage layer.

Stormwater conveyed to a bioretention system is treated by filtering the stormwater through a vegetated layer and biologically active filter media layer. The vegetation provides a substrate for biofilm growth and facilitates the biological transformation of pollutants (particularly nitrogen). The vegetation also prevents the filter media clogging through root growth. The filter media layer helps to remove pollutants and provide a growing media for planting. The transition layer prevents filter media from washing into the drainage layer and the drainage layer helps to drain the water. The extended detention ponding area assists to temporarily hold stormwater runoff.

Refer to the Planning and Design section of this factsheet for a typical profile of a bioretention system.

Types of bio-retention systems

Examples of bio-retention systems;

Bio-retention systems typically include:

a) Street tree bio-retention system

Street tree bio-retention pits - street tree bio-retention pit systems are small systems that are incorporated with street tree landscaping. They receive overland flow from adjacent impervious street areas. The filter media should be at least 0.8 metres deep to allow for root growth of the tree, therefore substantial depth is required between the inlet and outlet.

Figure 1: Cross-section of a tree pit showing key elements

b) Bio-retention swale

Bio-retention swales - bio-retention swales provide for both stormwater treatment and conveyance functions. Bio-retention swales are a street scale application of bioretention basins. The swale component provides stormwater pre-treatment to remove coarse to medium sediments while the bio-retention system (installed in the base of a swale) removes finer particulates and dissolved contaminants.

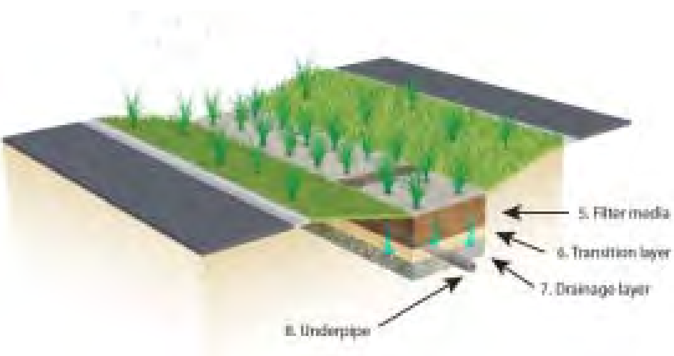


Figure 2: Cross-section of a bio-swale showing key elements

c) Small bio-retention basin / raingarden

d) Bio-retention basin / raingarden

Bio-retention basin / raingarden - bio-retention basins operate with the same treatment processes as bio-retention swales except they do not have a conveyance function. A bio-retention basin is an end-of-pipe bio-retention system, designed to allow water to pool temporarily before percolating through the vegetation and filter media in treating the stormwater.

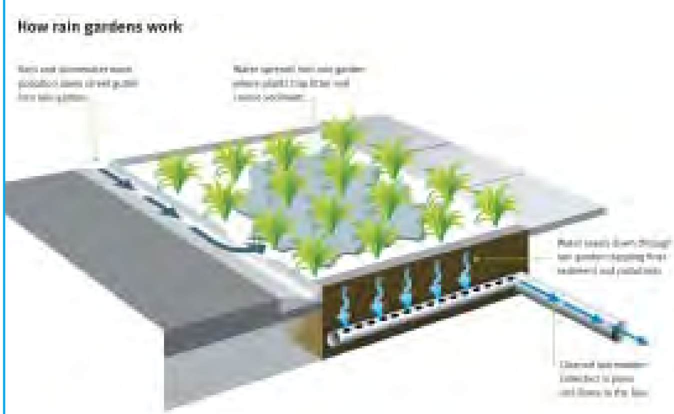


Figure 3: Cross-section of a bio-retention raingarden showing key elements

Planning and Design

Location: where to use them in the treatment train

Catchment area and site suitability

Bio-retention systems can be sized for different catchments and integrated at various scales, from tree pits to large bio-retention basins. Bio-retention systems are designed to carry out secondary and tertiary treatment biological processes to 'treat' stormwater whilst facilitating conveyance, infiltration and retention. A bio-retention system can be used at source or end of pipe and can be integrated into a treatment train system to treat runoff prior to discharging to receiving waters.

Bio-retention systems are typically designed to treat up to the three month average recurrence interval (3 month ARI) rainfall event with flows in excess of this bypassed to the drainage network. Land slope and available space should be considered when contemplating a bio-retention system. Bio-retention swales systems are best used in relatively flat areas. Steep slopes (gradients greater than four per cent) make it difficult to construct functional bioretention swale systems, however this may be overcome with check dams. Systems can be integrated into streetscapes at various scales but will need at least the same space required for a standard Council tree pit.

Pollution Type and Load

The selection of measures must also consider the nature of the pollutants and whether they are organic or inorganic. Anthropogenic litter such as newspapers and plastic bags for example behave differently in their potential to decay. Likewise silt or clay can fill up bioretention swales, whereas most fine particulate organics can decay away and have minimal impact. High loads of fine particulates however can smother and coat the system.

Like larger bioretention basins, rain gardens rely on biofiltration processes to reduce stormwater pollutants. They are suitable for installation in greenfield developments as well as for retrofitting in existing urban areas.

Bioretention System Design Considerations

- **Site suitability**
  - o Land slope and space
  - o Existing services
  - o Surrounding landscape
- **Pollutant type and loads**
  - o Appropriate device selection
  - o Treatment train system
  - o Landuse
- **Filter media**
  - o Filter depth
  - o Permeability
  - o Composition
- **Landscaping**
  - o Water quality function
  - o Aesthetics

Protection of Bioretention systems

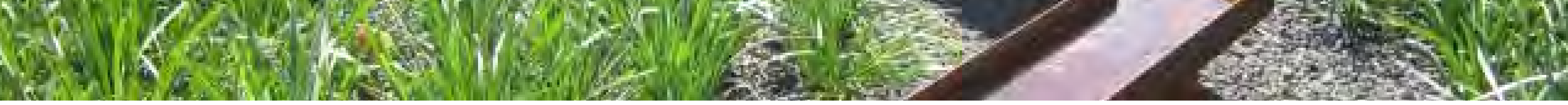
Bioretention systems must be protected from clogging by pre-treating stormwater to remove course to medium sediments. As noted above, clay and silt can smother and clog filter areas making them ineffective. Smaller systems require the installation of silt traps in the nearest upstream pit or sediment forebays to protect the filter. Larger systems require proprietary gross pollutant traps. If the filter media clogs, it will need to be replaced.

Typical bio-retention system profile

Bio-retention systems such as raingardens, street trees or bio-retention swales, have a generic structure including an extended detention ponding area, a filter media, transition layer and a drainage layer. The extended detention ponding area assists to temporarily hold stormwater runoff. The filter media layer helps to remove pollutants and provide a growing media for planting. The transition layer prevents filter media from washing into the drainage layer and the drainage layer helps to drain the water.

When considering a bio-retention system it is important to consider that;

- There is sufficient depth for bio-retention structures: (the extended detention area, filter media, transition layer and drainage layer)
- The inflow structure on street tree bioretention system preserve the kerb and channel profile in the street for minor and major storm events.
- The surface of the bio-retention basin is flat to ensure stormwater pools evenly across the surface of the basin.



Typical design factors and specification

The below table outlines typical design factors and specification for bioretention systems (bioretention basins/ raingardens).

Requirements	Key values
Vegetation	Vegetation selected to match filter depth. Refer to the section on 'plant species selection'.
Extended detention depth	Maximum of 400mm
Slope (top surface slope of filter media, transition & drainager layer)	The top surface of the drainage layer, transition layer and filter media layer should be flat (to ensure even distribution of stormwater flows).
Filter media depth	400mm to 800mm loamy sand • 400mm for tufted species and small shrubs • 600mm for large shrubs • 800mm for trees
Filter median particle diameter	0.45mm
Transition layer depth	100 mm coarse sand transition layer. Note: Geotextile fabrics are not permitted for use in biofiltration systems due to the risk of clogging.
Drainage layer depth	Typically 150mm to 200 mm of 5 mm gravel
Subsoil lines	• Unsocked slotted PVC pipes are to be provided within the drainage gravel layer of the bioretention basin. Maximum spacing between pipes at any point of 3 m. • Provide a minimum 2 subsoil lines (not 1) along the narrow section of bioretention.
Saturated hydraulic conductivity	• The maximum Saturated Hydraulic Conductivity permitted in Blacktown is 250mm/hr (or 125 mm/hr for MUSIC model) • The minimum hydraulic conductivity as defined by ASTM F1815-06 is to be 200 mm/hr.
Exfiltration and liner	• No exfiltration is permitted in Blacktown • The bio-retention system is to be encased in a HDPE liner or similar
Inflows	The inflows to the smaller bio-retention basins are to include a minimum 400 mm deep silt trap to protect the filter material from clogging. Larger systems require proprietary gross pollutant traps (GPTs).
Submerged zone	Note: Bio-retention systems using submerged zones are not permitted in Blacktown.
Soil filter media	Certification is to be provided that the bioretention filter media has: i. A minimum hydraulic conductivity as defined by ASTM F1815-06 of 200 mm/hr (actual, not predicted). (Where this cannot be certified amended design rates and MUSIC modelling based on half the tested rate will be required and the drainage plans amended.) ii. A maximum hydraulic conductivity as defined by ASTM F1815-06 of 400 mm/hr (actual, not predicted). iii. An Orthophosphate content < 40 mg/kg, and iv. A Total Nitrogen content < 800 mg/kg.
Filter media topsoil	As per the FAWB specification for filter media, prior to planting the top 100 mm of the bio-retention filter medium is to be ameliorated with appropriate organic matter, fertiliser and trace elements to aid plant establishment as per the table below:

Constituent	Quantity (kg/100 m2 of filter area)
Granulated poultry manure fines	50
Superphosphate	2
Magnesium sulphate	3
Potassium sulphate	2
Trace Element Mix	1
Fertilizer NPK (16.4.14)	4
Lime	20

Table 1: Recipe for ameliorating the top 100 mm of bio-retention filter media

Requirements	Key values
Mulch	Organic mulching is not permitted. Non-floatable mulch could include crushed rock, gravel, coarse river sand, scoria or river pebbles. 4-7mm screenings or similar.
Outlets	Scour protection and occasional energy dissipaters using rock aprons, is required on all outlet pipes.
Signage	Interpretative signage is to be provided to highlight the water quality improvement process

Treatment measure	Requirements	Key values
Bio-retention swales	Slopes; vegetation	• Longitudinal slope = 1 to 4% per cent • Side slopes = 1:6, max 1:4 • Vegetation height = 0.1 to 0.25 metres Otherwise as per bio-retention systems and swales.

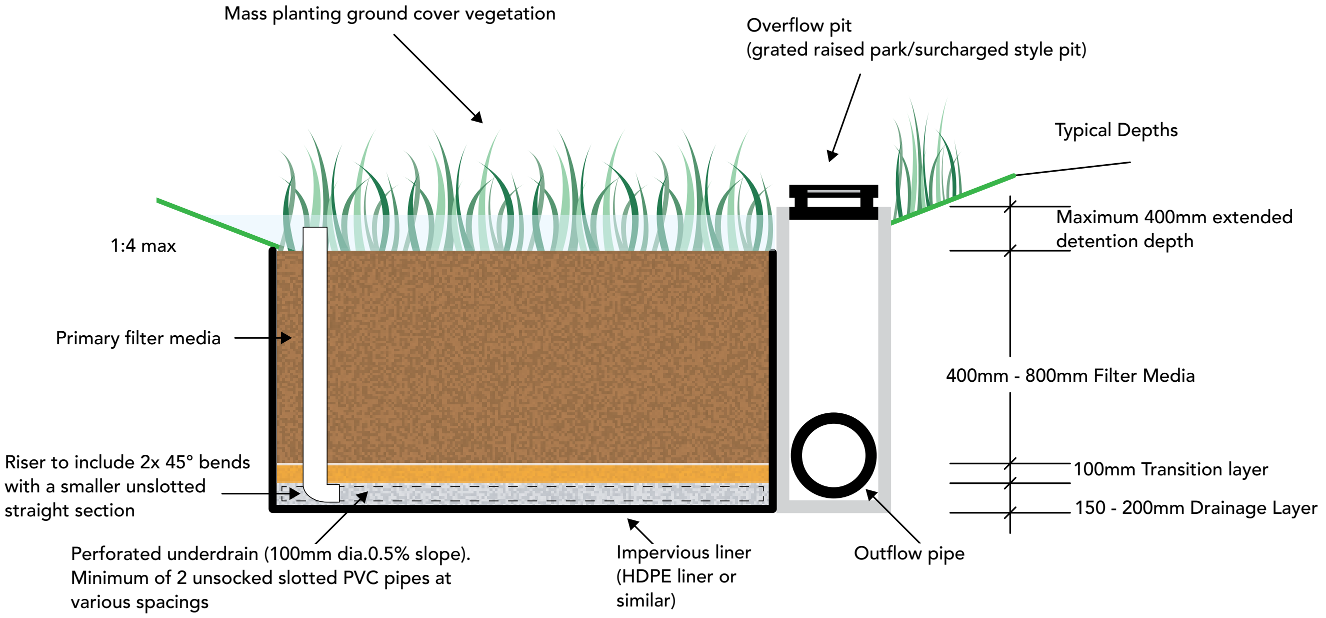


Figure 4: Long cross section of a typical bio-retention system (basin, cell, raingarden)

Planning considerations

- Development applications that have some stormwater treatment measures shall be submitted in accordance with Part R Water Sensitive Urban Design and Integrated Water Cycle Management and Council's Engineering Guide for Development 2005.
- A Positive and/or restrictive covenant may be required over stormwater Treatment Measures in accordance with the requirements of Council's Engineering Guide for Development 2005.
- All Development Application conditions of consent over Stormwater Treatment Measures need to be adhered to. Typical conditions may include the following:

Certification and testing

- A Hydraulic Engineer is to certify that all the requirements of the approved drainage plan have been met at development application stage undertaken.
- Prior to installation, certification is to be provided that the bio-retention filter media satisfies the soil specification.
- Once installed and planted out and prior to occupation, a Geotechnical Engineer is to undertake insitu Saturated Hydraulic Conductivity Testing of each of the bio-retention systems in accordance with Practice Note 1 of the FAWB guidelines.

Maintenance and reporting

- The designer of the stormwater treatment measures must prepare a maintenance schedule for each of the Stormwater Treatment Measures. For bio-retention systems this schedule shall include ultimate system replacement.
- An annual maintenance report outlining the maintenance undertaken on the Stormwater Treatment Measures in accordance with the approved maintenance schedule and covenant requirements, provided to Blacktown Council on the 1st September each year.

Signage

- Interpretative signage shall be provided to highlight the Stormwater Treatment Measures

Sizing Bio-retention Systems

Bioretention systems are typically sized to have a filter area of approximately 1.5% to 2% of the catchment draining to the treatment element. This size will vary based on elements of the bioretention system such as extended detention depth, filter depth and the imperviousness of the development.

The size of the stormwater treatment measures including bio-retention systems is determined using MUSIC modelling software or Council's Deemed to Comply solutions in meeting Council's water quality targets.

Plant species selection

Plant species selection for Bio-retention Swales and Basins

The plants used in bio-retention systems should be suited to sandy, free-draining soils and tolerant of drought. Species deemed appropriate for bio-retention systems (street tree pits, bio-retention swales and bio-retention basins / raingardens) in the Blacktown LGA are listed in the following sections. Plants marked with *** have been tested and shown to be particularly effective in removing nutrients according to FAWB. Note: Groundcover species should not be used in the filter area.

Tufted Species	
The following grasses / tufted species require a minimum 400 mm deep filter media	
Aristida vagans	Threeawn speargrass
Austrostipa setacea	Corkscrew grass
*Carex appressa****	Tall Sedge
Cymbopogon refractus	Barbed Wire grass
Cyperus trinervis	Sedge
Danthonia tenuior	Wallaby grass
Dichelachne micrantha	Short-hair Plume-grass
Echinopogon ovatus	Forest Hedgehog grass
Entolasia stricta	Wiry Panic grass
Eragrostis leptostachya	Paddock Love-Grass
*Ficinia nodosa****	Knobby Club Rush
*Juncus usitatus****	Common Rush
Poa Labillardieri	Grass
Themedia australis	kangaroo grass

Shrubs	
Daviesia ulicifolia	Bitter Pea
Dodonaea viscosa	Hop Bush
Goodenia hederacea subsp. Hederacea	Forest Goodenia
*Goodenia ovata****	Hop Goodenia
Leptospermum continentale	Prickly Tea-tree
Melaleuca erubescens	Pink Honey Myrtle, Rosy Paperbark
Phyllanthus similis	
Pimelea curviflora var. subglabrata	Riceflower, endangered species
Pratia purpurascens	Whiteroot
Pultenaea villifera	Bush Pea

Shrubs/Trees	
The following shrubs/trees require a minimum 600 to 700 mm deep filter media	
Bursaria spinosa	Blackthorn
Leptospermum trinervium	Paperbark Tea-tree
Melaleuca bracteata 'Revolution Green'	

Shrubs/Trees	
The following shrubs/trees require a minimum 800 mm deep filter media and preferably as deep as possible	
Melaleuca decora	White Feather Honey Myrtle
*Melaleuca ericifolia****	Swamp Paperbark
Melaleuca linariifolia	Flax-leaved paperbark or Snow-in-Summer
Melaleuca nodosa	Prickly Leafed Paperbark
Melaleuca styphelioides	Prickly Leafed Paperbark

Note: *The following species have low nutrient removal and are unsuitable for direct planting into the bio-retention filter media, however they can be located on the battered banks outside the filter area that is subject to periodic inundation.*

Grasses	
Dianella longifolia	Flax lily
Lomandra filiformis subsp. Filiformis	Matrush
Lomandra longifolia	Spiny Matrush
Lomandra multiflora subsp. Multiflora	Matrush
Melaleuca styphelioides	Weeping grass

Healthy, densely planted vegetation is important to the long-term performance of the raingarden.

Plant Density and Diversity

- *Plant density* - Bio-retention systems should be planted densely to maximise the biological processing of nutrients and to ensure plant roots occupy all parts of the media.

Plant type	Plant Density (per m^2)
Grasses / tufted species	8 to 10 plants p/ m^2
Small shrubs	Varies
Large shrubs	1 plant per 2 to 4m^2
Trees	1 tree per 4 to 8 m^2

- *Plant diversity* - Planting should incorporate several growth forms, including shrubs and tufted plants. A minimum of 4 different species is required for small areas (< 20m^2), typically 6 or more for medium areas (50m^2) and 10 or more for very large areas (>500m^2).

Note: Shrubs or trees are not to be used exclusively without tufted species as this can significantly reduce the effectiveness of the bioretention system.

Maintenance

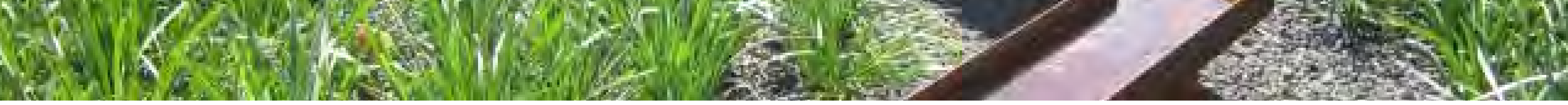
Critical to the performance of a bioretention system is the filter media and vegetation. Maintenance activities should be prompted through routine monitoring of the system. Maintenance is required to ensure that stormwater:

- ponds evenly across the basin surface;
- percolates through the filter media at the desired rate.

Bioretention systems require regular maintenance. Maintenance requirements of bioretention systems include:

- Inspection of bioretention profile to identify areas of sediment deposition or erosion and clogging (evident by a 'boggy' area).
- Inspection of inlet points, look for scour, litter, build up and blockages around pits.
- Removal of sediment if required, re-profiling and re-vegetating.
- Tilling of the bioretention trench surface if there is evidence of clogging.
- Regular watering of plants during establishment phase.
- Removal of invasive weeds.
- Replacement of dead plants.
- Litter and debris removal.

A WSUD specialist may be required to assess whether a treatment system has reached the end of it working life. In general the expected lifespan of a stormwater treatment system should be at least 20 years if well designed, constructed and maintained (Melbourne Water, 2013).



Common issues with Bioretention Planning and Construction'

Common issues that can impact on the effectiveness of a bioretention system include:

- Operating a bioretention system too early in the development process. It will become clogged with sediments during the construction period, and can suffer from erosion if plants have not had enough time to establish cover. It is important that there is plant establishment before the bioretention system is connected to the drainage.
- The surface of the system should be flat, with minimal slope or grade to allow ponding and infiltration.
- It is preferable to use tube-stock size plants because they usually have a higher success rate, are more economical in price and are in a growing medium that is compatible to the bioretention filter media.
- It is important to plant more than one type of plant. This is because a particular plant may not be suited to the local environmental conditions. Planting a greater variety of plants will ensure there is vegetation cover under a range of environmental conditions.
- The inlet pit of a bioretention system must be above the surface level – to allow water to pond on the surface and infiltrate.
- The outlet pit should be below the surface level of the banks of the system to avoid localised flooding in large rainfall events.
- It is important to incorporate scour protection atr the inlet and outlet pits.
- Do not use groundcover vegetation in the bioretention system, refer to our preferred plants list.
- If there is no on-site detention required with the system, the extended detention depth should not exceed 400mm.
- At the base of the Bioretention system it is important that the perforated pipe is not covered by a 'sock'.

Further information

- Blacktown Development Control Plan 2006 Part R: http://goo.gl/WHBGb
- Blacktown City Council's Engineering Guide for Development 2005: http://goo.gl/FWQFg
- Facility for Advancing Water Biofiltration (FAWB) at Monash University: http://www.monash.edu.au/fawb
- Sydney Metropolitan Catchment Management Authority typical drawings for WSUD http://www.wsud.org/resources-examples/tools-resources/typical-drawings/
- Water By Design (2012) Maintaining Vegetated Stormwater Assets.
- Water By Design (2012) Rectifying Vegetated Stormwater Assets.
- Melbourne Water (2013) WSUD maintenance guidelines. A guide for asset managers.

Other WSUD summary sheets

Other Water Sensitive Urban Design Summary Fact Sheets for the Blacktown City Council LGA are available in this series. To download the summary sheets, visit http://www.blacktown.nsw.gov.au/Planning_and_Development

No. 1 Water Sensitive Urban Design

No. 2 Blacktown City Council DCP – Part R and Deemed to Comply Solutions

No. 3 Streetscape Systems

No. 4 Bioretention Systems

No. 5 Vegetated Swales and Buffer Strips

No. 6 Constructed Wetlands

No. 7 Gross Pollutant Traps

Enquiries

For further enquiries contact Blacktown City Council's Asset Design Services on (02) 9839 6000