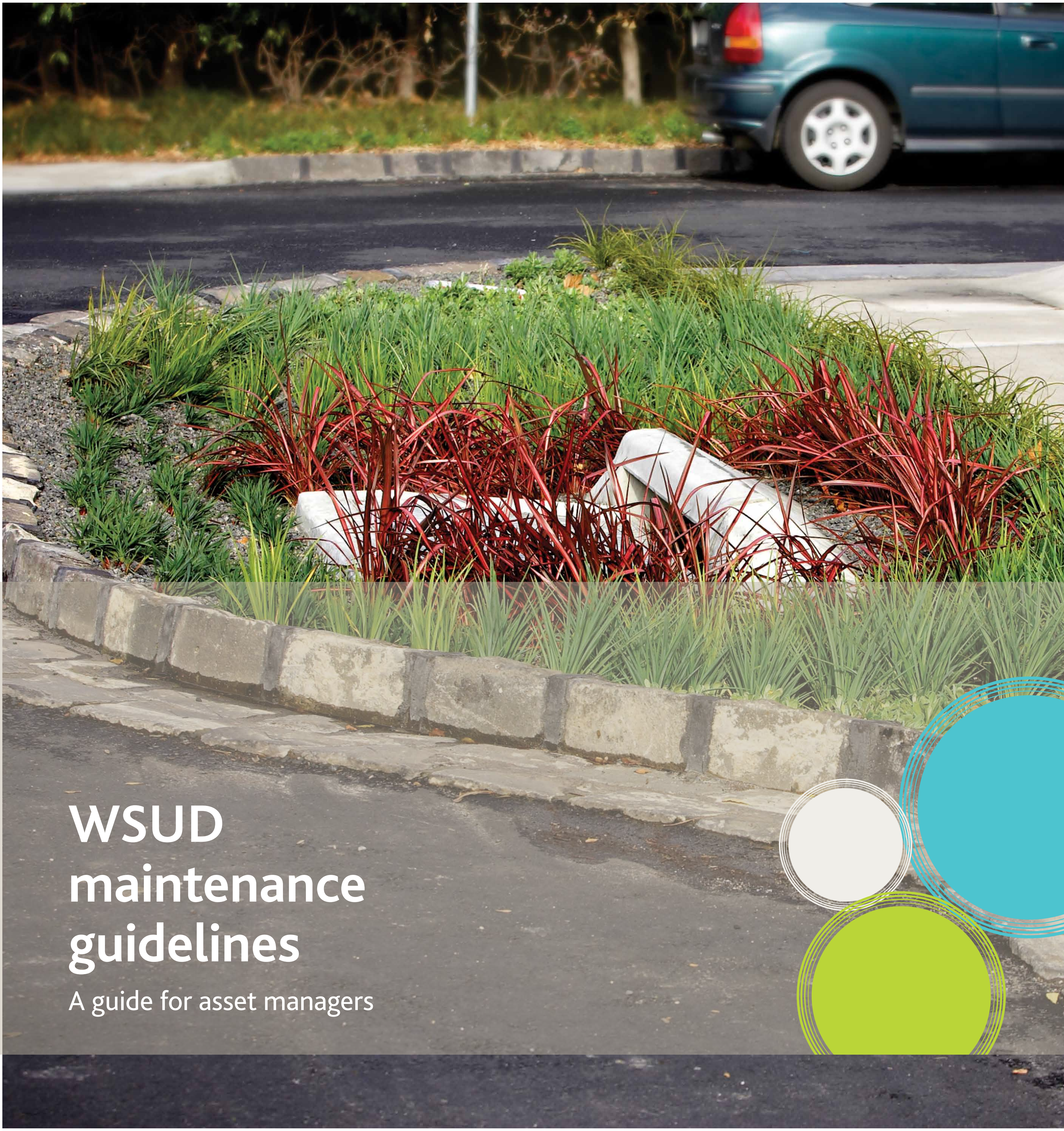

WSUD maintenance guidelines

A guide for asset managers

healthy waterways

Melbourne Water

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Introduction

Assets that provide water quality treatment of stormwater provide an integral component of broader Water Sensitive Urban Design (WSUD) strategies. Systems can be designed and constructed at a range of scales and are intended to provide multiple benefits for the community. Additional benefits can include reduced peak stormwater flows, landscape amenity, biodiversity/habitat, education and passive cooling through vegetation. In considering integrated water management in the urban context, these stormwater treatment assets are often referred to as WSUD assets in recognition of these multiple benefits. For the purposes of these guidelines (which relate more specifically to the water treatment function of assets) these assets are herein referred to as WSUD assets.

WSUD assets require regular scheduled maintenance to ensure that they remain healthy and perform as intended. These guidelines provide simple, standardised guidance for designing and implementing maintenance programmes for WSUD assets.

WSUD assets covered by the guidelines include:

- Raingardens
- Tree pits
- Swales and bio-swales
- Permeable pavements

Guidance for maintaining constructed wetlands can be found in the Melbourne Water publication 'Constructed Wetland Guidelines'[1].

1 The Melbourne water constructed wetland guidelines can be accessed online: http://www.melbournewater.com.au

How to use the guidelines

Maintenance information is provided in the following sections.

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Overview of the different types of maintenance for stormwater treatment assets.

Section 2: Raingardens
Main components and specific actions for maintenance, including an inspection and maintenance schedule and an example inspection and maintenance form.

Section 3: Grated tree pits
Main components and specific actions for maintenance, including an inspection and maintenance schedule and an example inspection and maintenance form.

Section 4: Swales
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Appendix A
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1 Asset management framework

1 Asset management framework

This asset management framework provides guidance on how to effectively manage WSUD assets. This section includes information to help develop an asset management framework including types of maintenance (proactive, reactive and rectification) and options for undertaking maintenance (in-house or outsourced). It also provides some information on record keeping for inspections and activities, as well as condition assessment audits.

1.1 TYPES OF MAINTENANCE

Water Sensitive Urban Design (WSUD) assets require both proactive and reactive maintenance to ensure long term system health and performance.

Proactive maintenance refers to regular scheduled maintenance tasks, whereas reactive maintenance is required to address unscheduled maintenance issues. If an asset is not functioning as intended, then rectification may be required to restore the asset back to its desired function.

This guideline focuses on proactive maintenance.

Note: Maintenance and rectification requirements for vegetated stormwater treatment assets are comprehensively covered in Water by Design (2012) *Maintaining Vegetated Stormwater Assets* and Water by Design (2012) *Rectifying Vegetated Stormwater Assets*[2].

Where applicable, these documents have been referenced to provide more specific information on maintenance and rectification tasks described in these guidelines.

1.1.1 Proactive maintenance

Proactive maintenance is a set of scheduled tasks to ensure that the WSUD asset is operating as designed.

Proactive maintenance involves:

- Regular inspections of the WSUD asset
- Scheduled maintenance tasks for issues that are known to require regular attention (e.g. litter removal, weed control)
- Responsive maintenance tasks following inspections for issues which require irregular attention (e.g. sediment removal, mulching, and scour management).

Proactive maintenance in the first two years after the establishment period (construction and planting phases) are the most intensive and important to the long term success of the treatment asset.

Proactive maintenance is a cost effective means of reducing the long-term costs associated with operating stormwater treatment assets.

Maintenance activities specific to each WSUD asset type are detailed in the inspection and maintenance schedules and checklists provided at the back of each asset section.

The frequency of scheduled maintenance depends on the asset type and the issue being managed. As a general guide, scheduled maintenance should be completed on a three to four month cycle. The checklists provided should be used as a minimum guide to scheduled maintenance tasks, and should be amended to suit different system designs and maintenance requirements.

Treatment assets should also be inspected at least once a year during or immediately after a significant rainfall event. This is important to confirm that the treatment system is functioning correctly under wet conditions.

A higher level of scheduled maintenance may be arranged for some treatment assets. This is often the case for treatment assets which are located in high profile locations (e.g. streetscapes and parklands), and where public amenity is considered to be a high priority. In these cases, a more frequent maintenance regime may be required to remove litter and weeds and to ensure vegetation health and cover is maintained to a high level.

2 The Water by Design documents: 'Maintaining Vegetated Stormwater Assets' and 'Rectifying Vegetated Stormwater Assets' can be accessed online at: http://waterbydesign.com.au

1.1.2 Reactive maintenance

Reactive maintenance is undertaken when a problem or fault is identified that is beyond the scope of proactive maintenance. Reactive maintenance may occur following a complaint about the WSUD asset (e.g. excessive odours or litter). Reactive maintenance often requires a swift response, and may involve specialist equipment or skills.

1.1.3 Rectification

Rectification of a WSUD asset is undertaken when the system is not functioning as intended, and proactive and reactive maintenance activities are unable to return the asset to functional condition.

The lack of functional performance and therefore failure of a stormwater treatment asset may be related to many factors including inappropriate design, poor construction or lack of regular maintenance. In many cases, the design of assets has not included adequate consideration of the maintenance requirements, in terms of the system's ability to cope with catchment pollutant loads (i.e. sediments) and the frequency of maintenance required to maintain the system at a functional level.

Maintenance planning at the design phase is therefore crucial to both the long term operating costs and the expected life cycle of the treatment system. In general, the expected lifecycle of a stormwater treatment asset (e.g. a raingarden) that has been well designed and constructed, and is regularly maintained should be at least 20 years[3].

However, the lifecycle for each treatment system will be different and related to:

– whether the system has been designed, constructed and maintained according to best practice
– catchment characteristics (influences the quality of the stormwater)
– the age and general health of the system
– the type of plants that have been used in the system.

Regular asset condition assessments should be undertaken to monitor the system condition and to inform where an asset is in terms of its expected lifecycle. Renewal of a system refers to replacing the main elements of the system including:

– infrastructure
– removing deposited sediment, removing and replacing the top soil (or filter media in the case of a raingarden) and profiling the top soil level back to the design levels
– re-planting
– pavement and sub-layers (in the case of permeable pavements).

A WSUD specialist may be required to assess whether a treatment system has reached the end of its life cycle and to provide advice on the renewal works.

Asset condition assessments can also identify assets that need to be rectified. The decision to continue with an increased maintenance regime or to rectify an asset, and over what timeframe, can be a difficult one to make. This is because certain maintenance items are more important to overall system function than others. For example, extended ponding on the surface of a raingarden or persistent scouring of a swale should be addressed more rapidly than recurrent weed problems.

3 Note: A detailed review of stormwater treatment asset life cycle costs has been undertaken by Melbourne Water, including the development of a life cycle costing tool for different types of stormwater treatment assets. The life cycle costing tool enables stormwater treatment asset owners to accurately plan future maintenance and asset renewal costs based upon the 'best available' industry data. Please refer to Melbourne Water (2013) life cycle costing tool for further information.

The following scenarios should be considered when deciding whether to increase maintenance frequency or to rectify an asset.

- If one or more of the maintenance items (listed in the schedules in each asset section) has not been met on at least two consecutive inspections, then the maintenance frequency should increase.
- If increased maintenance is still not resolving the problem, then a rectification investigation should be undertaken in accordance with the Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets*.
- Significant functional problems should be immediately rectified. Rectification works should be undertaken as soon as possible, as regular maintenance activities will not be sufficient to return the system to a functional state.

Rectification activities generally involve partial or complete renewal of the WSUD asset, and often incur a notably higher cost compared to proactive and reactive maintenance.

Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Assets* for detailed information on the rectification of vegetated stormwater assets.

1.2 IN-HOUSE AND OUTSOURCED MAINTENANCE OPTIONS

The maintenance of stormwater treatment assets often comprises a combination of engineering, landscape, ecological or horticultural components. To effectively manage and operate treatment assets, a number of skilled people are required.

It is important that asset owners, managers and maintenance personnel understand the intended purpose and function of a stormwater treatment asset, and activities and equipment required for maintaining it.

Maintenance of stormwater treatment systems may be:

- undertaken in-house using works crews
- outsourced to a single contractor
- outsourced to separate civil and landscape contractors.

Maintenance of stormwater treatment assets is usually separated in two components:

Civil
Includes engineering infrastructure and hydraulic components (may include filter media). Skillsets required include an understanding of:

- hydrological and hydraulic processes
- function of hydraulic structures (e.g. pits and headwalls)
- erosion processes.

Landscape
Includes vegetated and litter components. Skillsets required include a good understanding of:

- plant management
- weed identification and eradication methods.

Capacity building

Training
Regular training and up skilling of maintenance personnel is an essential component of an effective maintenance regime.

Communication
Effective communication on the function of stormwater treatment assets between approval authority (at the planning, design, construction, establishment and maintenance phases), asset owner and the local community is a crucial component to the ‘buy in’ (ownership) and long term viability of stormwater treatment assets. ‘Ownership’ of treatment assets by both agencies and the community can lead to a much greater level of care and better maintenance outcomes.

It is increasingly common for Councils (or other stormwater treatment asset owners) to outsource the maintenance of stormwater treatment assets. A number of options exist for undertaking maintenance of stormwater treatment assets depending upon the structure and skill base of an organisation.

It may be cost effective for the asset owner to undertake combined inspection and maintenance of the civil and landscape components. Alternatively, separation of the civil and landscape components may provide access to specialist skills and ensure that a high level of maintenance is achieved.

Some municipalities have dedicated WSUD officers whose role is to oversee the management of stormwater treatment assets. This can be very effective as it enables coordination between the council departments responsible for both civil and landscape maintenance components and/or maintenance contractors.

Where contractors are used to provide maintenance services, it is important that maintenance contracts include all aspects of maintenance including:

- scope of works
- project duration
- performance criteria
- activity specifications.

An example of an outsourced maintenance tender document is provided in Appendix A.

1.3 CONDITION ASSESSMENT AUDITS

It is recommended that audits of treatment systems are undertaken periodically to:

- monitor the condition of assets
- assess the effectiveness of maintenance (especially important when assets are maintained by an external party)
- determine likely timeframes for renewal.

It is recommended that audits are undertaken of:

- each asset at least every 10 years
- all assets covered by a maintenance contract at the start and end of the contract
- a sample of assets covered by a maintenance contract each year.

Note: There are currently no industry guidelines or standard methods for auditing the condition of stormwater treatment assets.

1.4 RECORD KEEPING

All stormwater treatment assets should be included in an asset management database. Records of inspections and maintenance activities should be kept by the asset owner. The database should include links to:

- design drawings and reports
- as constructed survey
- site specific Asset Operation and Access Summary.

The Asset Operation and Access Summary should include:

- a brief description of how the system operates
- plan showing the system layout including:
  - maintenance access routes
  - ownership boundaries/maintenance roles around the treatment asset[4]
- specialist equipment required (e.g. keys, pit lifting equipment).

An example of an Asset Operation and Access Summary has been provided in Appendix B.

1.5 OCCUPATIONAL HEALTH AND SAFETY

It is important that all maintenance activities are undertaken in a manner that minimises the occupational health and safety risk to maintenance personnel and general health and safety of the public.

It is important that maintenance staff:

- Comply with their employer's occupational health and safety policy and risk management processes
- Have a thorough knowledge of the occupational health and safety risks (able to identify and reduce any workplace hazards and risks) associated with maintenance activities (e.g. working in close proximity to traffic)
- Are equipped with adequate personal safety protection equipment
- Are aware of public health and safety risks associated with maintenance activities.

4 In some circumstances, delineation of asset ownership and maintenance responsibility may be important, as the surrounding landscape and treatment assets may be managed or owned by different entities. The most common example of this is where different council departments are responsible for maintaining the civil infrastructure and landscape components of a raingarden, however there may be other situations where different asset owners are involved such as a municipal council and Melbourne Water. Clear delineation of maintenance responsibilities is required (may require formal agreement) to ensure that the treatment asset is adequately maintained.

2 Raingardens

2 Raingardens

Raingardens, also known as bioretention systems, biofilters, bioinfiltration systems and bioremediation systems, are vegetated infiltration systems that improve stormwater quality.

Stormwater ponds on the raingarden surface, slowly infiltrates through the filter media to the base of the system and is then conveyed to the downstream drainage system. Pollutants such as nitrogen, phosphorus and suspended solids are removed as stormwater passes through the filter media.

Raingardens may comprise of up to 14 key functional components (Figures 1–4);

1. **Inlet –** Conveys stormwater into the raingarden (generally a pipe or kerb cut). The inlet may be fitted with a trash rack or screen to trap coarse litter.
2. **Sediment forebay (optional) –** Traps and prevents coarse sediment (>1 mm) from entering the raingarden and accumulating on the surface of the filter media.
3. **Maintenance access ramp (optional) –** Enables access to the sediment forebay for cleaning. Generally only present in large raingarden systems.
4. **Filter vegetation –** Healthy, actively growing plants are integral to pollutant removal processes and the long term sustainability of the raingarden.
5. **Batter vegetation (optional) –** Dense vegetation cover on the batters provides soil stability, traps litter and prevents unauthorised access to the raingarden.
6. **Extended detention zone –** Space above the surface of the raingarden which fills with stormwater during rainfall events.
7. **Mulch (optional) –** Prevents weed growth, helps to insulate and retain moisture within the filter media, particularly during the establishment phase.
8. **Filter media –** Highly permeable sandy-loam mix that enables stormwater to infiltrate the raingarden, facilitates pollutant removal and supports plant growth.
9. **Transition layer –** Coarse sand layer that prevents fine silts and sediments from being washed out of the raingarden.
10. **Drainage layer –** Coarse aggregate that enables treated stormwater to enter the underdrain system.
11. **Underdrain system (optional) –** Network of slotted pipes that convey treated stormwater from the base of the raingarden. Raingardens in sandy soil may not have underdrains as infiltrated flows may discharge directly into the underlying soil.
12. **Inspection opening –** Usually a capped PVC pipe for inspecting and cleaning the underdrain system.
13. **Overflow –** Conveys excess flows away from the raingarden when the capacity of the extended detention zone is full. Generally a grated pit or side entry pit. Underdrain pipes often discharge into an overflow pit.
14. **Submerged zone (optional) –** Raingardens can be designed so that water remains in the base (submerged zone) of the raingarden beneath the filter media (Figure 2). The submerged zone can improve nitrogen removal and be beneficial to raingarden plants in drier summer months. Submerged zone raingardens are maintained in a similar way to conventional raingardens.

Figure 1 Schematic of conventional raingarden in open space (piped inflow) showing key functional elements

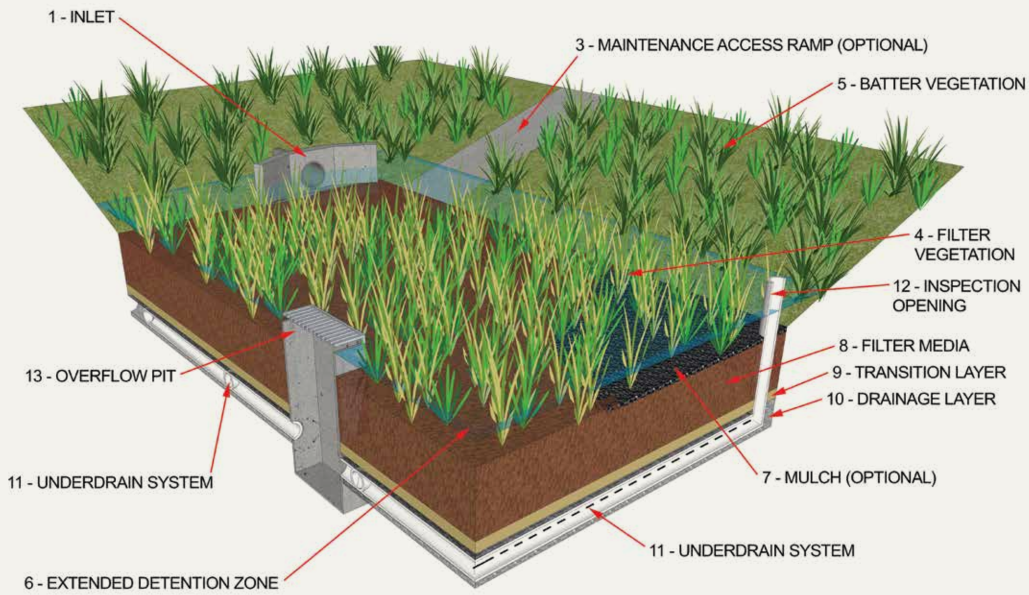


Figure 2 Schematic of conventional raingarden integrated into streetscape connected to standard kerb and channel showing key functional elements

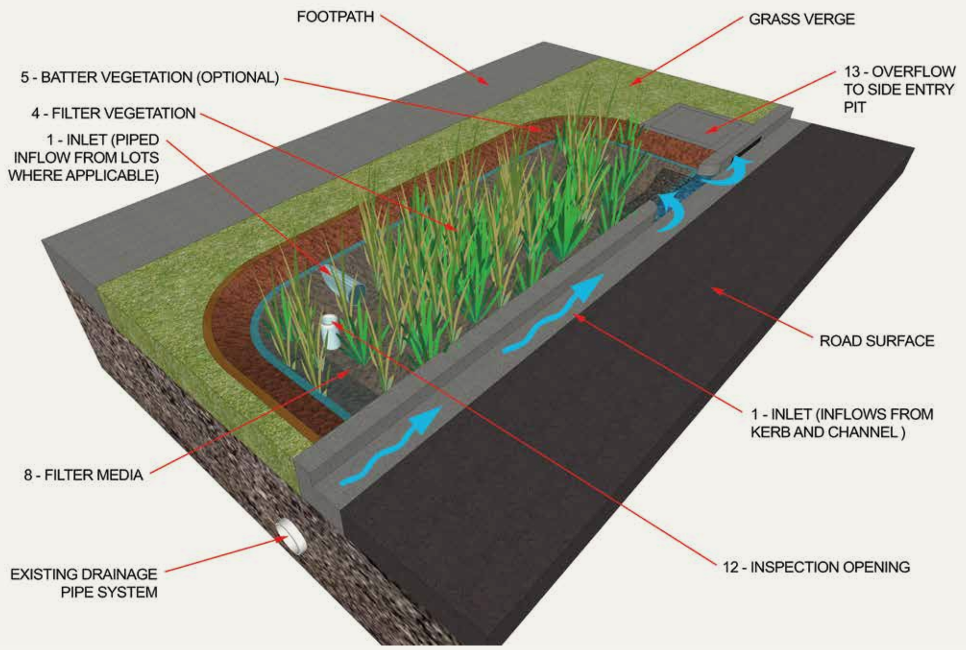


Figure 3 Cross section of conventional raingarden outlet control

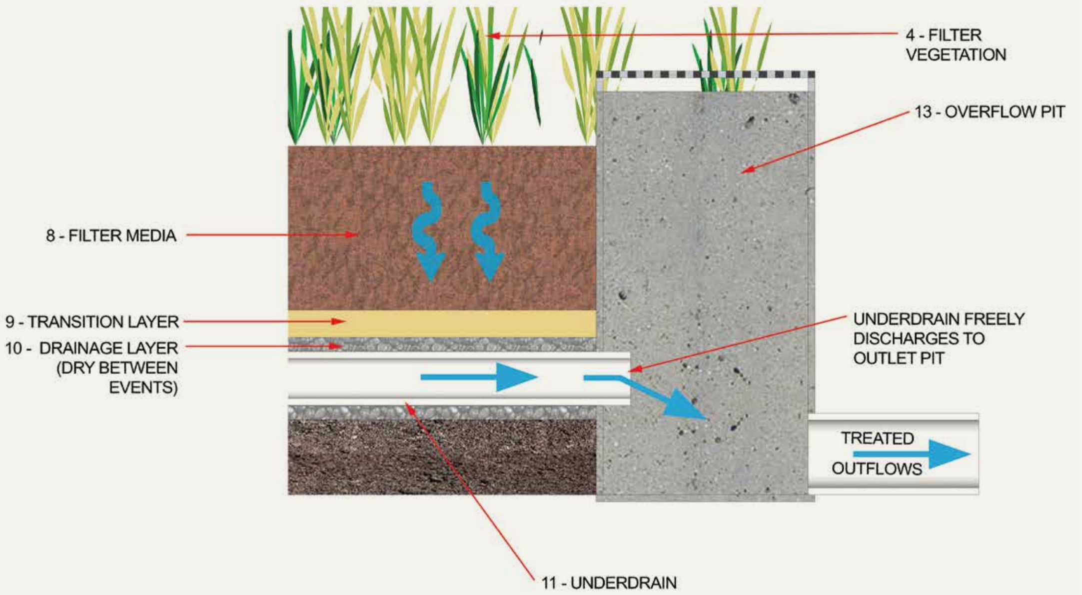
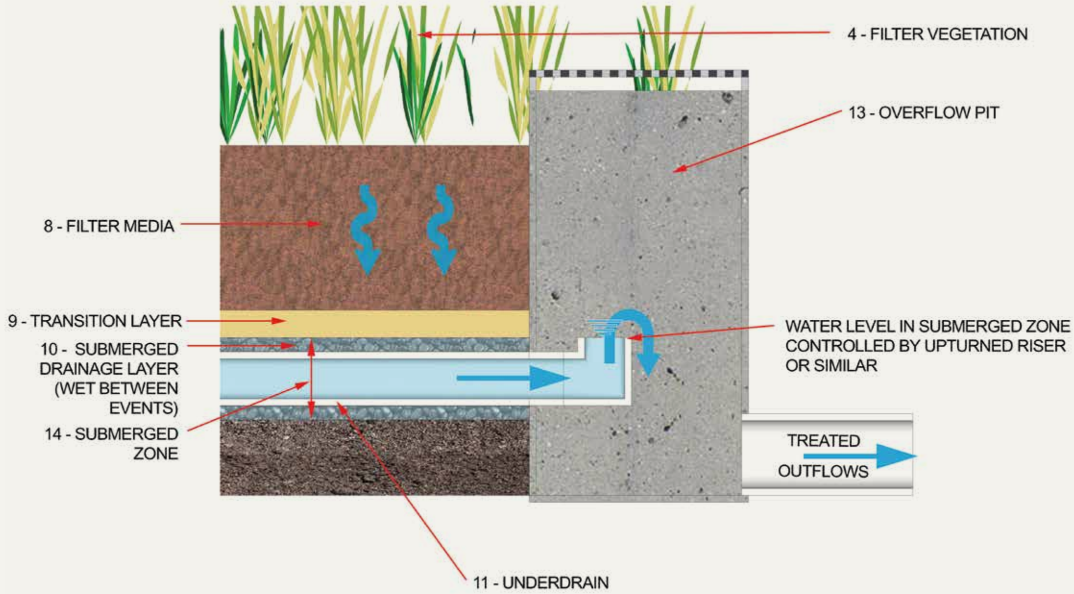


Figure 4 Cross section of submerged zone raingarden outlet control



2.1 RAINGARDEN SURFACE

2.1.1 Filter media

The filter media infiltration rate (speed that water drains through the filter media) is a key functional component of raingardens. Regular inspection of the filter media is required to monitor the infiltration rates.

Raingardens are particularly susceptible to clogging during the establishment period. After the filter media is installed, it may take 12–24 months to reach the designed infiltration rate. The infiltration rate of the filter media increases as the plant roots begin to grow down through the filter media and plant transpiration rates increase.

Maintenance crews need to be aware of potential issues associated with clogging of the upper filter media layer resulting in reduced infiltration rates. Clogging of the filter media surface is often indicated by water pooling on the surface of the raingarden for long periods of time (more than 12 hrs) following rainfall events. Raingardens with accumulated sediment (including clay/fine silt) greater than 15 mm average depth on the surface of the filter media are at risk of clogging.

Poor plant health can be an indicator of problems with clogging of the filter media. Clogging may prevent water entering the filter media and contribute to poor plant health. Plant health indicators may include yellowing of the foliage, wilting or stunted growth.

Sediment accumulation
Maintenance of the filter media may involve removing the accumulated sediment or raking (scarifying) the top ~20–50 mm. Raking the filter media should aim to disturb or remove accumulated silt/sediment (sediment crust) on top of the raingarden surface and allow stormwater to freely drain through the surface of the filter media. Care should be taken not to rake too close to vegetation with developing roots.

Note: If rock mulch is present, it may be necessary to remove the mulch prior to scarifying (physically breaking up) the filter media surface, as fine sediments often accumulate at the base of the rock mulch layer and not at the surface.

If sediment clogging persists within a raingarden, a sediment forebay or upstream sediment sump may need to be retrofitted to remove coarse sediments from the stormwater prior to entering the raingarden.

Organic litter accumulation
Large quantities of leaf litter can also contribute to clogging in raingardens. This commonly occurs in developed catchments which generally have more deciduous trees. It is important that excessive leaf litter (>70% surface area) is removed, particularly during the establishment period. Dense vegetation growth should help to trap leaf litter above the surface and reduce the need for removal after the establishment period.

Incorrect filter media specification
Incorrect initial filter media specification (e.g. high clay or fine sediment content) can also lead to reduced infiltration rates. Clogging due to incorrect filter media cannot be adequately addressed by proactive maintenance, and generally requires resetting of the filter media layer.

Algal biofilms
In some circumstances, algal biofilms may develop on the surface of the filter media leading to clogging issues. The presence of algal biofilms on the surface of the raingarden is generally indicative of other problems such as permanently wet filter media due to constant inflows, clogging or filter media with low hydraulic conductivity.

If inflows are observed for prolonged periods after rain (e.g. 24 hours after rain has stopped) an assessment of the catchment and inlet arrangement should be undertaken by an expert.

Inspection and maintenance activities include:

- Checking for sediment accumulation
- Removing sediment or scarifying filter media surface (when applicable)
- Removing leaf litter
- Checking for biofilms
- Monitoring ponding of water following rainfall events
- Checking for permanently boggy/pooled areas within the raingarden
- Monitoring plant health.

2.1.2 Erosion

Erosion of the raingarden surface can lead to the establishment of preferential flow paths around and through the raingarden. Erosion of the filter media often occurs due to high stormwater flow velocities passing through the raingarden.

High flow velocities may be due to excessive flows being discharged to the raingarden, the lack of infrastructure to dissipate flows, or the lack of vegetation cover. Rock protection around inlets can help to minimise scour and disperse energy.

Eroded filter media or soil (batters) should be replaced and any vegetation that has been damaged or removed restored.

The persistence of erosion problems within a raingarden may require rectification of the raingarden design. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Assets* for further information on rectifying erosion issues within raingardens.

Inspection and maintenance activities include:

- Checking for erosion/scouring
- Checking for evidence of preferential flow paths
- Replacing filter media in eroded areas
- Adding rock protection around inlets
- Replanting dead plants.

2.1.3 Mulch

A mulch layer may be placed on top of the filter media surface to prevent weed growth, retain moisture and to prevent erosion of the raingarden surface.

Inorganic mulches (e.g. gravel) are commonly used in raingardens. Organic mulches are highly susceptible to scour and are easily dislodged or washed from raingardens. Regular inspection is required to ensure that the mulch layer remains intact and that an even depth of mulch is maintained across the raingarden. Note: buoyant mulch should be secured e.g. using pins and course jute netting or mats.

The average depth of the mulch across the raingarden is important to reduce scouring and prevent weeds from growing. Excessive mulch depths can reduce the ability of some plants to spread and establish evenly throughout the raingarden.

The accumulation of mulch around the lower stems of plants may result in plant damage and subsequent growth decline or death of the plant. Care should be taken during inspection and maintenance to ensure that the mulch layer is not touching the stems of the plants.

The level of the mulch layer in relation the inflow point (inlet pipe, kerb and channel) is also very important, as excessive mulch may cause stormwater to bypass the raingarden. The mulch level should ideally be below the inlet height to ensure that water enters and spreads evenly across the raingarden surface.

The surface of the mulch layer should be at least 100mm below the top of the outflow pit. If the mulch layer is too thick, then the raingarden will lose treatment effectiveness due to the reduced storage volume (i.e. the extended detention depth above the filter bed is reduced).

Inspection and maintenance activities include:

- Checking the average depth and distribution of the mulch layer
- Checking that the mulch is not touching the plant stems
- Replacing mulch that has been washed out or displaced
- Checking for evidence of sediment/silt accumulation within the mulch layer (refer to Section 2.1.1)
- Retaining mulch using jute mats or nets.

2.2 VEGETATION

2.2.1 Filter surface

Vegetation plays an important role in reducing the velocity of stormwater entering the raingarden, removing pollutants, maintaining the porous nature of the filter media and providing an attractive landscape feature for the community.

It is very important for ongoing function of the raingarden that healthy, densely planted (6–10 plants per square metre) vegetation is established.

Vegetation should be evenly distributed across the raingarden, so that there are no bare patches for weeds to invade. It is important that at least 90% of the filter area is covered by vegetation. Bare patches (greater than 5% of the filter area) should be replanted using either new plants or by dividing and translocating existing plants.

The condition of the raingarden vegetation needs to be constantly monitored to ensure that the plants are healthy, free from disease and vigorously growing. It is important that vegetation is maintained in healthy condition, as this ensures that vigorous root systems develop throughout the raingarden filter bed. Dead or diseased plants should be removed and replaced.

Monitoring the condition of the vegetation is important, as signs of poor plant health may be indicative of other functional problems in the raingarden such as too low or high infiltration rates.

The growth of weeds within raingardens is inevitable, and some level of weed control is required to maintain the function of the asset. Regular weeding is critical to the successful establishment of vegetation, as competition from weeds may reduce the growth rate and cover of the desirable plants.

It is important that no more than 10% of the filter media surface area and batters are covered in weeds. Greater cover of weeds may indicate the need for increased maintenance or further planting to increase vegetation cover across the raingarden.

Weeds should be physically removed from the filter media surface and batters. The use of herbicides should be avoided as these may harm the desirable raingarden vegetation and contaminate the filter media.

Refer to Appendix B of Water by Design (2012) *Maintaining Vegetated Stormwater Assets* for a detailed description of weeding techniques that may be used in raingardens.

Inspection and maintenance activities include:

- Inspecting plant health and cover
- Removing weeds (avoid using herbicides)
- Watering plants (establishment phase)
- Replacing dead plants to maintain a consistent vegetation density (6–10 plants per m^2) across the raingarden
- Pruning plants (where applicable).

Figure 5 Healthy, densely planted vegetation is important to the long term performance of the raingarden

2.2.2 Batters

Vegetated batters are sometimes used to transition from the raingarden surface to the surrounding land surface. Low vegetation, or alternative edge treatment, may be used in streetscape raingardens to maintain traffic sight lines. The batter vegetation is often the most prominent vegetation visible within the raingarden and the maintenance of healthy vegetation is important to the overall amenity of the raingarden.

The batter vegetation is important for stabilising the edges of the raingarden, trapping litter that enters the raingarden from the surrounding landscape and preventing unauthorised access to the raingarden. It is important to ensure that continuous vegetation cover is maintained along the lower batter.

Inspection and maintenance activities include:

- Inspecting plant health and cover
- Removing weeds
- Replacing dead plants
- Pruning plants (where applicable)
- Watering plants (establishment phase).

2.3 CIVIL COMPONENTS

2.3.1 Structural damage

The structural integrity of the raingarden infrastructure is important to ensure that stormwater enters, disperses and exits the raingarden as designed. Raingarden infrastructure includes: inlet pipe, kerbing and channel, sediment forebay, overflow pit, underdrain pipes, inspection openings and walls/edges.

Damage to the raingarden infrastructure can cause stormwater to bypass the raingarden, resulting in the loss of performance or further damage to the raingarden such as scouring of the filter media or loss of vegetation.

Raingardens in high-traffic areas are particularly susceptible to vehicular damage if they are not adequately protected by bollards or similar.

Damage to the raingarden infrastructure should be noted during regular inspections and reported to the asset manager. Generally, damage to the raingarden infrastructure will require rectification measures. Advice may need to be sought from a qualified engineer/designer prior to undertaking repairs.

Inspection and maintenance activities include:

- Checking for damage to raingarden infrastructure and repairing as required.

2.3.2 Blockages

All inflow and outflow points must remain free of sediment, litter and debris to ensure that stormwater is able to freely enter and exit the raingarden.

It is particularly important to keep the outflow point (usually an overflow pit) clear of leaf litter and debris so that stormwater can exit the raingarden during and after high rainfall events.

Leaf litter is generally the primary cause of outlet blockage. After the establishment period, leaf litter should be trapped in the dense raingarden vegetation before it reaches the outlet. If litter is consistently blocking the outlet, consider installing a gross pollutant trap (GPT) at the inlet.

Inspection and maintenance activities include:

- Ensuring that all inlet and outlet points are clear of sediment, litter and debris.

2.3.3 Sediment forebay

Sediment forebays are basin-like pre-treatment measures that can be used to protect the raingarden from coarse sediment loads (and some leaf litter accumulation) (Figure 6).

Sediment, leaf debris and coarse litter will need to be periodically removed from the sediment forebay and inlet area of the raingarden. Accumulated sediment should be removed from the sediment forebay when it is more than 75% full.

The sediment forebay should be designed so that a flat shovel (small raingarden) or bobcat (large raingarden) can be used to easily remove accumulated sediment.

Inspection and maintenance activities include:

- Removing course litter from the sediment forebay and inlet areas
- Removing accumulated sediment from the sediment forebay when it is more than 75% full
- Removing accumulated sediment from the inlet area.

Figure 6 Example of a sediment forebay at the inlet zone of a raingarden (note the raingarden surface is covered with turf to protect the filter media from construction phase sediment loads)

2.3.4 Inspection opening

Most raingardens are designed with one or more inspection openings (vertical pipes) which are connected to the underdrain system of the raingarden. The inspection pipe is usually identified by a screw-cap at the surface of the raingarden (Figure 7). Inspection pipes are often covered by vegetation and can be difficult to find. Design drawings should indicate the location of inspection openings.

The inspection openings are designed so that subsurface water levels can be checked and a water jet or pipe snake can be used to flush out the underdrain. When the underdrain is flushed out, a clear stream of water should be visible at the base of the outlet pit.

Note: the underdrain systems in some raingardens are not connected to an outlet pit, and inspection of flushing water may not be possible.

For raingardens with saturated zones, the saturated zone should be drained before flushing out underdrain pipes.

Inspection and maintenance activities include:

- Checking the water level in the base of the raingarden
- Checking for sediment accumulation within the underdrain system
- Flushing the underdrain system.

Figure 7 Example of inspection openings in a raingarden

2.4 INSPECTION AND MAINTENANCE SCHEDULE

This is an example schedule to guide the timing of your inspection and maintenance activities. This schedule outlines the average service the assets require, but you can adjust these timings to suit your assets. This schedule and the "Inspection and Maintenance form" (see over page) have been designed to be copied and used on site.

Responsibility of assets
Example: Regular inspections should be carried out every 3 months. The inspection and maintenance of the raingarden including all civil and landscape components is the responsibility of Council/contractor. The operation and maintenance of adjacent stormwater infrastructure, parklands, garden beds, recreational assets, pathways and road surfaces is the responsibility of Council.

Item	What to check for	Action	Frequency
Civil components – Raingarden			
Inlet	No evidence of erosion, blockage, damage or standing water.	Clear inlet of accumulated sediment or debris.	Storm events
		Eroded areas should be locally re-profiled or reinforced, and re-planted if necessary. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if the erosion is either recurring or severe.	3 months
Outlet	No evidence of erosion, blockage, damage or standing water Outlet freely draining.	Clear outlet of accumulated sediment or debris.	Storm events
		Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if standing (backwatering into the raingarden) is present.	3 months
Other structures	No evidence of erosion and damage to other structures, e.g. pits, pipes, access ramps, walls and rock protection.	Repair minor damage to structures. Eroded areas should be repaired (reinforced). This may involve minor re-profiling or re-planting works. For severe damage, i.e. where flows have scoured down the side of a structure refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets*.	3 months
Batters and bunds	No evidence of erosion.	Eroded areas should be locally re-profiled or reinforced, and re-planted if necessary.	Annually
Hydraulic conductivity	Filter media is draining freely. No water ponded on the surface of the raingarden for more than 12 hours after rainfall.	If water is ponded on the surface of the raingarden for more than 12 hours after rainfall, refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets*. Note: the disposal of raingarden filter material must comply with EPA Victoria guidelines for the disposal of contaminated soil (Appendix C).	Storm events
Sediment accumulation	Sediment forebay less than 75% full. No major sediment accumulation on surface of the raingarden.	Clean out accumulated sediment from the sediment forebay. Accumulated sediment to be removed from the surface of the raingarden and the system replanted as required.	Annually
Filter media surface	No surface scour, depressions.	Filter surface to be repaired. This may involve evening out the surface, importing additional filter media and replanting.	3 months
Fine sediment surface crust	No impermeable or clayey surface on the filter media. No major surface crusting (<3mm depth across less than 10% of the filter area is permissible).	Repair surface layer by scarify filter media surface, re-profiling and re-establishing vegetation, if required. If the problem persists refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets*.	3 months
Mulch layer	Even depth and distribution of the mulch layer. Surface of the mulch layer is at least 100 mm below the top of the outflow pit. Mulch is not touching the plant stems	Re-distribute or replace mulch that has been washed out or displaced. This may involve retaining mulch using jute mats or nets. Remove mulch that is touching plant stems.	3 months
Algal or moss growth	No major algal growth (less than 10% of raingarden area is permissible). No moss growth.	If significant patches of algal growth or moss persist across the surface of the raingarden (i.e. greater than 10% of the surface) then refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets*.	3 months
Inspection opening	Water level is below filter media layer. No sediment accumulation in underdrain system.	Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if standing water is present in the filter media layer. Flush the underdrain system using low pressure water jet to remove accumulated sediment.	Annually

Item	What to check for	Action	Frequency
Landscape components – Raingarden			
Vegetation cover – filter media	Greater than 90% vegetation cover. Plants healthy, free from disease and vigorously growing.	Remove any dead or diseased vegetation. Replant individual bare patches (greater than 5% of the area) using either new plants or by dividing and translocating existing plants. If bare areas represent greater than 30% of the raingarden area, refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets*.	3 months
Vegetation cover – batters	Continuous vegetation cover along the lower batter. Greater than 90% vegetation cover. Plants healthy, free from disease and vigorously growing.		Annually
Weeds – filter media – batters	Less than 10% of the filter media surface area and batters covered in weeds.	Physically remove weeds from filter media surface and batters. Do not use herbicides as these may harm the desirable raingarden vegetation and contaminate the filter media. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if weed ingress is a persistent problem (i.e. weed coverage is persistently greater than 30%).	3 months
Litter	Filter media surface and batters free of litter (i.e. less than 1 piece litter per $4m^2$).	Remove all litter and excessive debris	3 months
Pests	No damage by pest animals and insects.	Seek specialist advice if persistent insect damage is observed. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if there is evidence of pest animal damage.	3 months

2.5 INSPECTION AND MAINTENANCE FORM

This form should be used during inspection and maintenance, as it provides a checklist of the key inspection elements and a permanent record of the maintenance activities undertaken.

This form should be submitted to the asset manager following every inspection and maintenance event, so that any persistent problems or issues requiring further investigation can be identified and responded to.

Raingarden inspection and maintenance form			
Asset ID			
Location			
Inspection officer's name			
Date		**Date of last rainfall**	
Photos of site (explanatory notes) **1.** **2.** **3.** **4.** **5.**			
General comments, sketches, description of maintenance undertaken			

Item	What to check for	Inspected	Maintenance undertaken	Further action required or comment
Civil components – Raingarden				
Inlet	No evidence of erosion, blockage, damage or standing water.			
Outlet	No evidence of erosion, blockage, damage or standing water Outlet freely draining.			
Other structures	No evidence of erosion and damage to other structures, e.g. pits, pipes, access ramps, walls and rock protection.			
Batters and bunds	No evidence of erosion.			
Hydraulic conductivity or permeability	Filter media is draining freely. No water ponded on the surface of the raingarden for more than 12 hours after rainfall.			

Item	What to check for	Inspected	Maintenance undertaken	Further action required or comment
Sediment accumulation	Sediment forebay less than 75% full. No major sediment accumulation on surface of the raingarden.			
Filter media surface	No surface scour, depressions.			
Fine sediment surface crust	No impermeable or clayey surface on the filter media. No major surface crusting (<3mm depth across less than 10% of the filter area is permissible).			
Mulch layer	Even depth and distribution of the mulch layer. Surface of the mulch layer is at least 100 mm below the top of the outflow pit. Mulch is not touching the plant stems.			
Algal or moss growth	No major algal growth (less than 10% of raingarden area is permissible). No moss growth.			
Inspection openings	Water level is below filter media layer. No sediment accumulation in underdrain system.			
Landscape components – Raingarden				
Vegetation cover – filter media	Greater than 90% vegetation cover.			
	Plants healthy, free from disease and vigorously growing.			
Vegetation cover – batters	Continuous vegetation cover along the lower batter. Greater than 90% vegetation cover. Plants healthy, free from disease and vigorously growing.			
	Greater than 90% vegetation cover.			
	Plants healthy, free from disease and vigorously growing.			
Weeds – filter media – batters	Less than 10% of the filter media surface and batters covered in weeds.			
Litter	Filter media surface and batters free of litter (i.e. less than 1 piece litter per $4m^2$).			
Pests	No damage by pest animals and insects.			

3 Tree pits

3 Tree pits

Tree pits are 'mini-raingardens' that comprise of a tree or large shrub planted within an underground planting module (pit).

Stormwater runoff from catchment areas including roads, car parks and pavements is directed to the tree pits, where it is both treated and used to passively irrigate the street trees. Similar to raingardens, tree pits comprise of a combination of media layers that allow stormwater to slowly infiltrate from the surface of the tree pit down to the underdrain system where it is discharged to the stormwater drainage system. In some situations, the tree pit may have a pervious base, and water is infiltrated directly to the surrounding soils.

Tree pits are defined in this Guideline as treatment systems containing trees surrounded by grates. For treatment systems containing trees and other planting, refer to Section 2 – Raingardens of this manual.

Tree pits may comprise of up to 12 key functional components (Figure 8):

1. **Kerb and channel –** Stormwater is normally conveyed to the tree pit from impervious surfaces (such as roads, footpaths, adjacent roof spaces) via a concrete kerb and channel.
2. **Inflow point –** Stormwater enters the tree pit via a dedicated inflow point which may be slot or diversion placed in the kerb and channel.
3. **Vegetation –** Generally a large shrub or small tree that contributes to pollutant removal processes within the filter media whilst providing an attractive landscape feature.
4. **Pit cover –** Grate placed around the tree at the top of the pit to protect the tree roots, prevent litter from entering the tree pit and unauthorised access.
5. **Extended detention zone –** Space above the surface of the filter media which fills with stormwater during rainfall events.
6. **Mulch (optional) –** Prevents weed growth, helps to insulate and retain moisture within the filter media, particularly during the establishment phase.
7. **Filter media –** Highly permeable sandy-loam mix that enables stormwater to infiltrate into the tree pit, facilitates pollutant removal (total suspended solids and nutrients) and supports plant growth.
8. **Transition layer –** Coarse sand layer that prevents fine silts and sediments from being washed out of the tree pit.
9. **Drainage layer –** Coarse aggregate that enables treated stormwater to enter the underdrain.
10. **Underdrain (optional) –** Slotted pipe/s that conveys the treated stormwater from the base of the tree pit.
11. **Overflow route –** Conveys excess flows away from the tree pit when the capacity of the extended detention zone is full. The common outflow route from a tree pit is via the kerb and channel to a downstream side entry pit.
12. **Inspection opening –** Usually a capped PVC pipe which provides access to the underdrain for inspections and cleaning.

Figure 8 Cross-section of a tree pit showing key functional elements

3.1 TREE PIT SURFACE

3.1.1 Filter media

Regular inspection of the filter media is required to monitor sediment, gross pollutant and leaf litter accumulation upon the surface. Accumulation of sediment, gross pollutants and leaf litter upon the surface of the tree pit filter bed can lead to clogging of the filter media, resulting in low infiltration rates and regular bypassing of the tree pit during rainfall events.

Refer to Section 2.1.1 for further details on other issues associated with clogging of the filter media surface.

Inspection and maintenance activities include:

- Checking for sediment, gross pollutant or leaf litter accumulation
- Removing accumulated sediment or scarifying filter media surface (when applicable)
- Removing leaf litter
- Checking for biofilms
- Monitoring the ponding of water following rainfall events
- Monitoring plant health.

Figure 9 Example of a tree pit integrated with kerb and channel.

Figure 10 Leaf litter and sediment accumulation in a tree pit located in a busy commercial precinct

3.1.2 Mulch

A mulch layer may be placed on top of the filter media surface to prevent weed growth within the tree pit, retain moisture in the filter media and to prevent scouring of the tree pit surface.

Common types of mulch used in tree pits include: gravel, stones or coarse organic matter such as wood chips. One of the problems often encountered when using coarse organic matter is that the mulch may float and be removed from the tree pit when the extended detention volume is full (the tree pit is full and overflowing).

If mulch is present in the tree pit, regular monitoring is required to ensure that the mulch is not placed within 50 mm of the tree trunk to avoid collar rot.

Refer to Section 2.1.3 for further details on other issues associated with the use of mulch on the filter media surface.

Inspection and maintenance activities include:

- Checking the depth and distribution of the mulch layer
- Checking that the mulch is not touching the tree trunk
- Replacing mulch that has been washed out or displaced
- Checking for evidence of sediment/silt accumulation within the mulch layer (refer to Section 2.1.1 – Filter Media).

3.2 VEGETATION

The establishment and maintenance of healthy plants within tree pits is important to both the long term capacity of the system to remove pollutants whilst providing an attractive landscape feature for the community.

The tree pit needs to be intensively maintained during the establishment period, including the removal of weeds, regular watering and plant health inspections.

Tree supports are often required during the establishment phase to stabilise plants as the tree is unable to expand lateral roots beyond the extent of the pit, and must develop roots around the edge of the tree pit to be self-supporting.

As with raingardens, the two to three year vegetation establishment period is important to the success of the tree pit, as vigorous root growth will help to maintain porosity of the filter media over the life of the asset.

Maintenance of tree pit vegetation should be undertaken in accordance with the general advice provided in Section 2.2 – Vegetation.

Inspection and maintenance activities include:

- Inspecting plant health (signs of disease, pests, poor growth)
- Checking plant stability (tree supports)
- Removing weeds
- Pruning plants (where applicable)
- Watering plants (establishment phase).

3.3 CIVIL COMPONENTS

3.3.1 Structural damage

The structural integrity of the tree pit infrastructure is important to ensure that stormwater enters and exits the tree pit as designed. Tree pit infrastructure may include: an inlet pipe, kerbing and channel, overflow pit, underdrain pipes, inspection openings and walls/edges.

Damage to the tree pit infrastructure can cause stormwater to bypass the tree pit resulting in the loss of treatment performance.

Tree pits located adjacent to roads and car parks can be damaged by traffic. Maintenance crews should regularly inspect tree pits for damage, concrete cracking and subsidence (sinking). Cracked concrete or subsidence will require rectification of the asset.

Inspection and maintenance activities include:

- Inspecting for physical damage, concrete cracking and subsidence.

3.3.2 Blockages

All inflow and outflow points must remain free of sediment, litter and debris to ensure that stormwater is able to freely enter and exit the tree pit.

Inspection and maintenance activities include:

- Ensuring that all inlet and outlet points are clear of sediment, litter and debris.

3.3.3 Inspection opening

Tree pits are designed with an inspection opening (vertical pipe) that is connected to the underdrain system. The inspection pipe is usually identified by a screw-cap above the surface of the tree pit.

The inspection openings are designed for checking the underdrain and using a water jet or pipe snake for flushing.

Inspection and maintenance activities include:

- Checking the underdrain system for standing water or sediment accumulation
- Flushing the underdrain system.

3.4 INSPECTION AND MAINTENANCE SCHEDULE

This is an example schedule to guide the timing of your inspection and maintenance activities. This schedule outlines the average service the assets require, but you can adjust these timings to suit your assets. This schedule and the "Inspection and Maintenance form" (see over page) have been designed to be copied and used on site.

Responsibility of assets
Example: Regular inspections should be carried out every 3 months. The inspection and maintenance of the tree pit including all civil and landscape components is the responsibility of Council/contractor. The operation and maintenance of adjacent stormwater infrastructure, pathways and road surfaces is the responsibility of Council.

Item	What to check for	Action	Frequency
Civil components – Tree pit			
Inlet	No evidence of erosion, blockage, damage or standing water.	Clear inlet of accumulated sediment or debris.	Storm events 3 months
Other structures	No evidence of erosion and damage to other structures, e.g. pits, pipes, walls.	Repair minor damage to structures.	3 months
Hydraulic conductivity	Filter media is draining freely. No water ponded on the surface of the tree pit for more than 12 hours after rainfall.	If water is ponded on the surface of the tree pit for more than 12 hours after rainfall, refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* – bioretention section. Note: the disposal of tree pit filter material must comply with EPA Victoria guidelines for the disposal of contaminated soil (Appendix C).	Storm events
Sediment accumulation	No major sediment accumulation on surface of the tree pit.	Accumulated sediment to be removed from the surface of the tree pit and the system replanted as required.	Annually
Filter media surface	No localised surface scour, depressions.	Filter surface to be repaired. This may involve evening out the surface, importing additional filter media and replanting.	3 months
Fine sediment surface crust	No impermeable or clayey surface on the filter media. No major surface crusting (<3mm depth across less than 10% of the filter area is permissible).	Repair surface layer by scarifying filter media surface and re-profiling. If the problem persists refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* – bioretention section.	3 months
Mulch layer	Even depth and distribution of the mulch layer. Surface of the mulch layer is at least 100 mm below the top of the outflow pit. Mulch is not touching the plant stem.	Re-distribute or replace mulch that has been washed out or displaced. This may involve retaining mulch using jute mats or nets. Remove mulch that is touching plant stem.	3 months
Inspection opening	Water level is below filter media layer. No sediment accumulation in underdrain system.	Flush the underdrain system using low pressure water jet to remove accumulated sediment. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* – bioretention section if standing water is present in the filter media layer.	Annually
Landscape components – Tree pit			
Plant health	Plant healthy, free from disease and vigorously growing.	Remove any dead or diseased foliage. Consult an arborist if plant health is persistently poor (i.e. the plant is not producing new leaves or shoots, or the foliage is showing signs of stress (pale or blotched leaves)). Note: regular street cleaning activities around the tree pit may also need to be considered, i.e. the use of chemicals to clean nearby pavements.	3 months
Weeds	Less than 10% of the filter media surface area covered by weeds.	Physically remove weeds from filter media surface . Do not use herbicides as these may harm the tree and contaminate the filter media.	3 months
Litter	Filter media surface free of litter (i.e. less than 1 piece litter per $4m^2$).	Remove all litter and excessive debris	3 months
Pests	No damage by pest animals or insects.	Seek specialist advice if persistent damage is observed.	3 months

3.5 INSPECTION AND MAINTENANCE FORM

This form should be used during inspection and maintenance, as it provides a checklist of the key inspection elements and a permanent record of the maintenance activities undertaken.

This form should be submitted to the asset manager following every inspection and maintenance event, so that any persistent problems or issues requiring further investigation can be identified and responded to.

Tree pits inspection and maintenance form			
Asset ID			
Location			
Inspection officer's name			
Date		**Date of last rainfall**	
Photos of site (explanatory notes) **1.** **2.** **3.** **4.** **5.**			
General comments, sketches, description of maintenance undertaken			

Item	What to check for	Inspected	Maintenance undertaken	Further action required or comment
Civil components – Tree pit				
Inlet	No evidence of erosion, blockage, damage or standing water.			
Other structures	No evidence of erosion and damage to other structures, e.g. pits, pipes, walls.			
Hydraulic conductivity or permeability	Filter media is draining freely. No water ponded on the surface of the tree pit for more than 12 hours after rainfall.			
Sediment accumulation	No major sediment accumulation on surface of the tree pit.			
Filter media surface	No localised surface scour, depressions.			
Fine sediment surface crust	No impermeable or clay-like surface on the filter media. No major surface crusting (<3mm depth across less than 10% of the filter area is permissible).			
Mulch layer	Even depth and distribution of the mulch layer. Surface of the mulch layer is at least 100 mm below the top of the outflow pit. Mulch is not touching the plant stem.			
Inspection openings	Water level is below filter media layer. No sediment accumulation in underdrain system.			
Landscape components – Tree pit				
Plant health	Plants healthy, free from disease and vigorously growing.			
Weeds	Less than 10% of the filter media surface covered by weeds.			
Litter	Filter media surface free of litter (i.e. less than 1 piece litter per $4m^2$).			
Pests	No damage by pest animals and insects.			

4 Swales

4 Swales

This section covers the maintenance of two swale types: conventional and bioretention swales.

Conventional swales are simple vegetated channels that convey stormwater and provide stormwater treatment through physical filtration and infiltration.

Bioretention swales (bio-swales) comprise of a channel with vegetation, layers of filter media and slotted drainage pipes (underdrain) arranged in a similar layout to a raingarden. Bio-swales facilitate more infiltration than conventional swales and therefore provide a higher level of treatment.

This section covers both types of swales because they both channel water, are commonly used as part of a stormwater treatment train and have similar maintenance requirements.

Refer to Section 2 – Raingardens of this guideline for advice on maintaining subsurface components of bio-swales.

Swales and bio-swales may comprise of up to eight key functional components (Figures 11 & 12):

1. **Channel base –** A vegetated earthen channel which conveys low flows along the swale.
2. **Batter –** Designed to contain high flows within the swale. Normally vegetated and with a low slope to assist with mowing and erosion control.
3. **Vegetation –** Vegetation is important for reducing stormwater flow velocities, removal of suspended solids and sediments, and stabilisation of the channel base and batters. In bio-swales, the vegetation is also integral to pollutant removal processes within the filter media and the long term sustainability of the bio-swale.
4. **Soil –** The use of topsoils along the channel base and batters of the swale facilitates enhanced infiltration of stormwater and maintenance of healthy plant growth.

Bio-swales also contain the following additional components:

5. **Filter media –** Highly permeable sandy-loam mix that enables stormwater to infiltrate into the base of the swale, facilitates pollutant removal (total suspended solids and nutrients) and supports plant growth.
6. **Transition layer –** Coarse sand layer that prevents fine silts and sediments from being washed out of the filter media.
7. **Drainage layer –** Coarse aggregate that enables treated stormwater to enter the underdrain.
8. **Underdrain –** Slotted pipes that convey the treated stormwater from the base of the bio-swale.

Figure 11 Cross-section of a conventional swale showing the main elements for maintenance

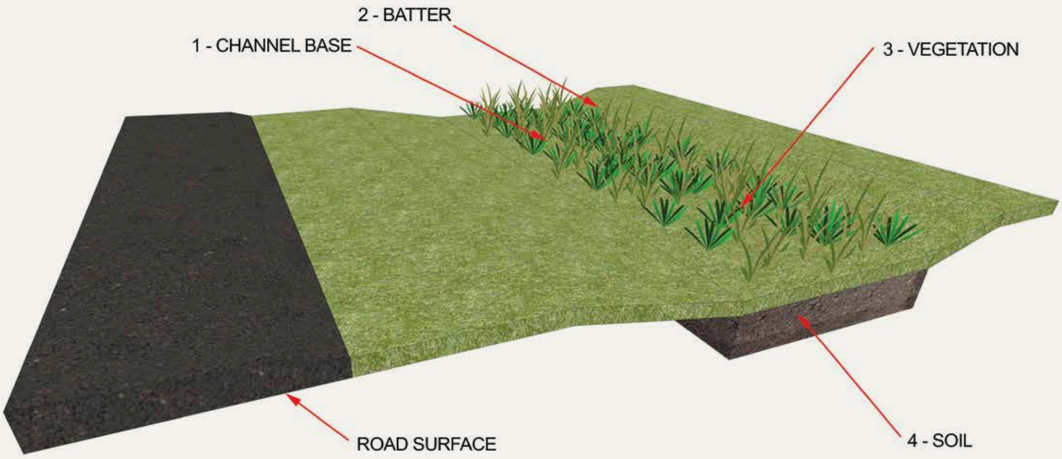


Figure 12 Cross-section of a bio-swale showing the main elements for maintenance

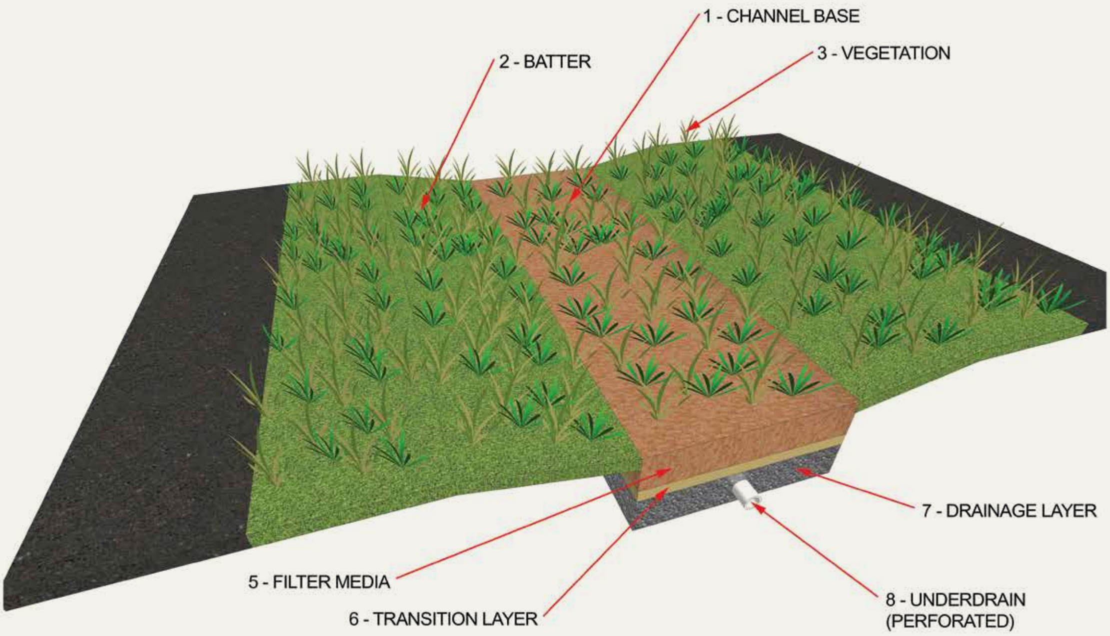


Figure 13 Example swale (photo source: wsud.org.au)

4.1 CHANNEL

4.1.1 Erosion

Erosion of the swale channel base can lead to preferential flow paths, scouring of the swale batters, sediment deposition along the swale and overall loss of vegetation cover.

High stormwater flow velocities within bio-swales may result in scouring of the filter media, leading to the development of scour holes, loss of vegetation cover and areas where stormwater may shortcut the preferred route.

Swales and bio-swales should be regularly inspected for evidence of erosion. Persistent erosion problems within swales may indicate excessive flow velocities, incorrect vegetation cover, excessive batter slopes or the development of preferential flow paths, and may require further investigation and potentially rectification.

Inspection and maintenance activities include:

- Checking for evidence of erosion/scouring
- Checking for evidence of preferential flow paths
- Replacing soil/filter media in eroded areas
- Replanting eroded areas.

4.1.2 Sediment accumulation

The presence of dense vegetation within swales results in the interception of stormwater flows and the gradual accumulation of sediment within the channel base.

Whilst sediment accumulation is a key functional component of swales, the build-up of sediment can impede the movement of stormwater along the base of the swale, resulting in the development of preferential flow paths and potential scouring of the swale batters (as the flow path attempts to meander).

In extreme situations, excessive accumulation of sediment may ultimately reduce the swale's capacity to convey water, leading to the unintended discharge of stormwater from the swale. The installation of upstream sediment traps may need to be considered if excessive sedimentation persists.

Accumulated sediments promote the growth of both the desirable plants and weeds within the swale, by providing an additional source of nutrients and ideal conditions for seeds to germinate.

The swale channel base should be periodically checked for excessive sediment accumulation.

Areas of ponded water or boggy conditions are generally indicative of accumulated sediment; however this may not be obvious where dense vegetation is present. The presence of permanently wet or shallow pooled water can also encourage mosquito breeding.

The deposition of sediments along the upper edges of the swale batters (at the interface of the swale and hard surfaces, e.g. pavements), can be indicative of incorrect surface levels (i.e. the hard surface may be set lower than the edge of the swale), and will require further investigation.

Swales are designed to accumulate sediment throughout their life cycle, and most swales will not require regular maintenance of accumulated sediment.

Accumulated sediments should only be removed from a swale if the function of the swale is being impeded. The rate at which sediments accumulate within a swale will be a function of the upstream catchment characteristics (e.g. landuses), upstream stormwater treatment systems, swale configuration (slope, capacity) and vegetation structure.

The removal of sediments from swales can be difficult due to the presence of established vegetation, and sediment removal may need to be accompanied by vegetation re-establishment.

Inspection and maintenance activities include:

- Checking for sediment accumulation
- Removing sediment (when necessary)
- Monitoring ponding of water following rainfall events
- Checking for preferential flows and scouring
- Checking for permanently boggy/pooled areas within the swale
- Monitoring weed growth within the swale base channel.

4.2 VEGETATION

The vegetation within swales is maintained in a similar way to raingarden vegetation.

It is important that the vegetation design for a swale (or bio-swale) is understood prior to maintenance activities, so that the vegetation can be managed appropriately in order to maintain the swales intended conveyance or stormwater treatment function.

The vegetation structure (size and shape) influences the flow of stormwater through the swale. High profile vegetation (e.g. tall grasses and sedges, shrubs and trees) may inhibit stormwater flow, leading to retardation of flows and the unintentional discharge of stormwater from the edges of the swale.

The design intent of the swale vegetation will therefore influence maintenance activities such as pruning or mowing.

Note: Occupational health and safety (OHS) risks should be carefully considered when mowing swales. Brush cutters may be suitable in constrained spaces and/or on steep slopes. Traffic should be managed during maintenance of roadside swales.

Generally, the presence of weeds within swales does not constitute a major issue concerning the overall function of the system.

Swale vegetation should be maintained in accordance with the general advice provided in Section 2.2 – Vegetation.

Inspection and maintenance activities include:

- Inspecting plant health and cover
- Pruning plants (where applicable)
- Mowing
- Removing weeds
- Replacing dead plants to maintain a consistent vegetation density (6–10 plants per square metre) across the raingarden
- Watering plants (establishment phase).

4.3 INSPECTION AND MAINTENANCE SCHEDULE

This is an example schedule to guide the timing of your inspection and maintenance activities. This schedule outlines the average service the assets require, but you can adjust these timings to suit your assets. This schedule and the "Inspection and Maintenance form" (see over page) have been designed to be copied and used on site.

Responsibility of assets			
Example: Regular inspections should be carried out every 3 months. The inspection and maintenance of the swale including all civil and landscape components is the responsibility of Council/contractor.		The operation and maintenance of adjacent parklands, garden beds, recreational assets and pathways is the responsibility of Council.	
Item	**What to check for**	**Action**	**Frequency**
Civil components – Swale			
Inlet	No evidence of erosion, blockage, damage or standing water. No excessive sediment build-up (i.e. more than 20% of pipe opening blocked with sediment). If a 'bubble-up inlet pit/pipe' is present – check that it is not holding water.	Clear inlet of accumulated sediment or debris. Eroded areas should be locally re-profiled or reinforced, and re-planted if necessary. Flush bubble-up pit/pipe and clear to allow free flow and draining between rainfall events. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if the erosion is either recurring or severe.	Storm events 3 months
Outlet	No evidence of erosion, blockage, damage or standing water Outlet freely draining. No excessive sediment build-up (e.g. more than 20% of pipe opening blocked with sediment).	Clear outlet of accumulated sediment or debris. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if standing (backwatering into the raingarden) is present.	Storm events 3 months
Erosion and scour	No evidence of erosion.	Eroded areas should be locally re-profiled or reinforced, and re-planted if necessary. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if the erosion is either recurring or severe.	3 months
Sediment accumulation	No sediment accumulated in the base of the swale	Sediment should be removed from the base of the swale if it is impeding the free drainage of stormwater. The removal of accumulated sediment may involve removal and re-establishment of vegetation. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if excessive sediment deposition is a recurring issue. Note: the disposal of sediment material from a swale must comply with EPA Victoria guidelines for the disposal of contaminated soil (Appendix C).	Annually
Surface ponding and boggy conditions	No surface ponding or permanently saturated soils in the base of the swale 24 hours after rainfall. Note: the presence of mosquito larvae in isolated pools of water may indicate ponding problems.	The surface of the swale may need to be re-profiled to allow free drainage of stormwater. This may involve filling minor surface depressions with additional soil material and revegetating. If the swale has sub-surface drainage, check to see if it is blocked. Clear blockages. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if surface ponding or permanently saturated soils are present in the base of the swale 24 hours after rainfall.	3 months
Physical damage	No evidence of trampling, bike riding, vandalism or other types of physical damage.	Undertake minor re-profiling or re-planting works if the damage is small and localised. For severe damage refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets*.	3 months
Item	**What to check for**	**Action**	**Frequency**
Landscape components – Swale			
Vegetation	Turf or vegetation covers at least 90% of the swale's surface. Plants healthy, free from disease and vigorously growing.	Remove any dead or diseased vegetation. Replant individual bare patches (greater than 5% of the area) using either new plants or by dividing and translocating existing plants. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if vegetation loss is widespread or recurring.	3 months
Weeds	Less than 10% of the swale surface area and batters covered in weeds.	Remove weeds. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if weed ingress is a persistent problem (i.e. weed coverage is persistently greater than 30%).	3 months
Litter	Swale surface and batters free of litter (i.e. less than 1 piece litter per $4m^2$).	Remove all litter and excessive debris.	3 months
Pests	No damage by pest animals and insects.	Seek specialist advice if persistent damage is observed. Refer to Water by Design (2012) *Rectifying Vegetated Stormwater Treatment Assets* if there is evidence of pest animal damage.	3 months

4.4 INSPECTION AND MAINTENANCE FORM

This form should be used during inspection and maintenance, as it provides a checklist of the key inspection elements and a permanent record of the maintenance activities undertaken.

This form should be submitted to the asset manager following every inspection and maintenance event, so that any persistent problems or issues requiring further investigation can be identified and responded to.

Swales inspection and maintenance form			
Asset ID			
Location			
Inspection officer's name			
Date		**Date of last rainfall**	
Photos of site (explanatory notes) **1.** **2.** **3.** **4.** **5.**			
General comments, sketches, description of maintenance undertaken			

Item	What to check for	Inspected	Maintenance undertaken	Further action required or comment
Civil components – Swale				
Inlet	No evidence of erosion, blockage, damage or standing water. No evidence of excessive sediment build-up (i.e. more than 20% of pipe opening blocked with sediment). If a 'bubble-up inlet pit/pipe' is present – check that it is not holding water.			
Outlet	No evidence of erosion, blockage, damage or standing water. Outlet freely draining. No evidence of excessive sediment build-up (e.g. more than 20% of pipe opening blocked with sediment).			
Erosion and scour	No evidence of erosion.			
Sediment accumulation	No evidence of sediment accumulated in the base of the swale.			
Surface ponding and boggy conditions	No evidence of surface ponding or permanently saturated soils in the base of the swale 24 hours after rainfall. Note: the presence of mosquito larvae in isolated pools of water may indicate ponding problems.			
Physical damage	No evidence of trampling, bike riding, vandalism or other types of physical damage.			
Landscape components – Swale				
Vegetation	Turf or vegetation covers at least 90% of the swale's surface. Plants healthy, free from disease and vigorously growing.			
Weeds	Less than 10% of the swale surface area and batters covered in weeds.			
Litter	Swale surface and batters free of litter (i.e. less than 1 piece litter per $4m^2$).			
Pests	No damage by pest animals and insects.			

5 Permeable pavements

5 Permeable pavements

Permeable pavements allow stormwater runoff to infiltrate to underlying soils rather than running off hard surfaces and into the stormwater drainage system. Permeable pavements are used for a wide range of purposes including:

- Reducing stormwater runoff volumes
- Reducing sediment and pollutant loads discharged to local waterways
- Enhancing groundwater recharge
- Retarding stormwater runoff (where underdrains are present)
- Water harvesting and re-use.

Two types of permeable pavement are commonly used to infiltrate stormwater runoff (refer Figure 14).

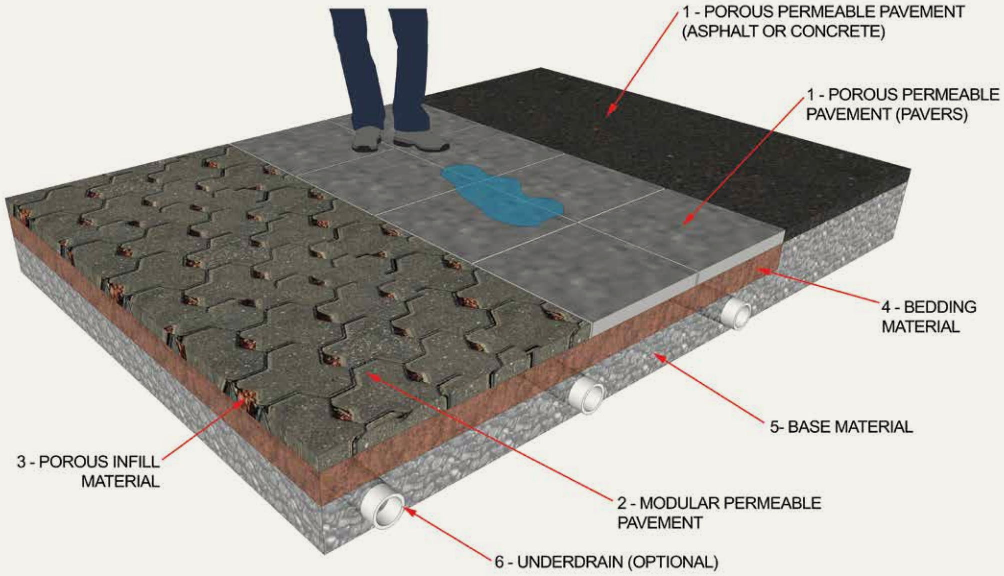
1. **Porous permeable pavement –** comprises permeable asphalt or concrete surfaces, or pervious modular pavers that allow water to pass through the paving surface into the subsurface layers.
2. **Modular permeable pavement –** comprises of non-permeable interlocking pavers with gaps present between each paver that allow water to infiltrate into subsurface layers.

The other key elements of permeable pavement systems include:

3. **Porous infill material –** comprises of permeable material (usually fine sand or gravel) that facilitates infiltration of stormwater between the pavers.
4. **Bedding material –** permeable sand or fine aggregate layer used to bed the paving material and facilitate primary infiltration.
5. **Base material –** aggregate layer that functions both as a support base, filter layer and water storage (by acting as a temporary detention volume).
6. **Underdrain (optional) –** present under some permeable pavements, usually consists of a porous drainage pipe surrounded by coarse aggregate. Functions to convey infiltrated stormwater away from the site.

Note: The variation in design of permeable pavement systems makes it challenging to provide standard maintenance guidelines. It is recommended that manufacturer maintenance guidelines are adhered to.

Figure 14 Cross-section of porous permeable pavement and modular permeable pavement showing the main elements for maintenance



5.1 PERMEABLE PAVING SURFACE

The most important maintenance issue concerning permeable pavements is clogging of the surface due to sediment build-up. Clogging of permeable pavements can reduce infiltration rates and results in increased stormwater runoff.

Whilst permeable pavements can trap up to 90% of total suspended solids (particulates), particulates gradually accumulate over time in the pavement (or between the pavers), and consequently, the permeable pavement slowly clogs.

Porous permeable pavements are particularly susceptible to blockage, as fine sediment fills pore spaces and reduces the ability for water to travel through the pavers.

Porous permeable pavements need to be periodically swept (manually or with a wet vacuum) or pressure hosed to prevent clogging.

Modular paving systems generally use a porous infill material between the pavers to facilitate infiltration. The infill material may be prone to clogging, particularly where fine sediment/clay material is present in the stormwater runoff. Severe clogging of the infill material may require it to be replaced.

Inspection and maintenance activities include:

- Checking for sediment accumulation
- Removing sediment
- Monitoring ponding of water following rainfall events
- Sweeping, wet vacuuming or pressure hosing of the surface of the pavers to remove clogging material
- Checking that the infill material is present between pavers.

5.2 BEDDING MATERIAL LEVELS

The sub-grade materials used largely determine whether pavers remain level. Uneven pavement surfaces may result in variable infiltration rates across the permeable pavement surface, and potential diversion of stormwater flows away from the pavement surface. If the pavement surface is uneven, the sub-grade material may need to be re-graded and the pavers re-laid (rectification).

Inspection and maintenance activities include:

- Checking level of the pavement surface.

5.3 UNDERDRAIN

Some permeable pavements may be designed with underdrains. Underdrains are slotted pipes that run underneath the permeable pavements and convey infiltrated stormwater from the site.

The underdrain (where fitted) can be flushed in a similar way to the inspection opening on a raingarden. This will remove any sediment or debris which may cause the system to clog.

Inspection and maintenance activities include:

- Checking for sediment accumulation (via inspection openings – where provided)
- Flushing of the underdrain to remove sediment.

5.4 INSPECTION AND MAINTENANCE SCHEDULE

This is an example schedule to guide the timing of your inspection and maintenance activities. This schedule outlines the average service the assets require, but you can adjust these timings to suit your assets. This schedule and the "Inspection and Maintenance form" (see over page) have been designed to be copied and used on site.

Responsibility of assets			
Example: Regular inspections should be carried out every 3 months. The inspection and maintenance of the permeable pavement including all civil and landscape components is the responsibility of Council/contractor.		The operation and maintenance of adjacent stormwater infrastructure, pathways and road surfaces is the responsibility of Council.	

Item	What to check for	Action	Frequency
Civil components – Permeable pavement			
Permeability	Pavement area is free draining (i.e. no clogging of the pavement surface). Clogging is generally evident by water ponding on the surface of the permeable paving more than 2 hours after rainfall.	Sweep or wet vacuum the surface of the pavement to remove clogging material. **Modular permeable pavements:** Note: check that infill material between pavers is intact following wet vacuuming. Replace infill material as required. If water ponding persists – remove pavers and check that the sub-layers (base material and bedding material) and underdrain are free draining. If necessary, replace the sub-layer material or flush the underdrain system using low pressure water jet to remove accumulated sediment. **Permanent permeable pavements:** If water ponding persists – the pavement surface or sub-layers (base material and bedding material) may need to be replaced.	Storm events 3 months
Pavement surface	No uneven paver surface (i.e. pavement surface lifting and rutting). No physical damage to the pavement surface – look for cracks and holes.	The surface of pavement may need to reset. **Modular permeable pavements:** May require removing the pavers and re-grading the sub-layers (base material and bedding material). **Permanent permeable pavements:** The pavement surface or sub-layers (base material and bedding material) may need to be replaced. Rutting or vehicular damage to pavement surface may require management of vehicles accessing the site.	Annually
Infill material (modular permeable pavements)	Infill material is present between pavers. No scour occurring.	Replace infill material. Re-sow turf if required.	3 months
Landscape components – Permeable pavement			
Weeds (modular permeable pavements)	Less than 10% of infill surface area (where present) covered by weeds.	Remove weeds from infill surface area.	3 months

5.5 INSPECTION AND MAINTENANCE FORM

This form should be used during inspection and maintenance, as it provides a checklist of the key inspection elements and a permanent record of the maintenance activities undertaken.

This form should be submitted to the asset manager following every inspection and maintenance event, so that any persistent problems or issues requiring further investigation can be identified and responded to.

Permeable pavements inspection and maintenance form			
Asset ID			
Location			
Inspection officer's name			
Date		**Date of last rainfall**	
Photos of site (explanatory notes) **1.** **2.** **3.** **4.** **5.**			
General comments, sketches, description of maintenance undertaken			

Item	What to check for	Inspected	Maintenance undertaken	Further action required or comment
Civil components – Permeable pavement				
Permeability	Pavement area is free draining (i.e. no clogging of the pavement surface). Clogging is generally evident by water ponding on the surface of the permeable paving more than 2 hours after rainfall.			
Pavement surface	No uneven paver surface (i.e. pavement surface lifting and rutting). No physical damage to the pavement surface – look for cracks and holes.			
Infill material	Infill material is present between pavers. No scour occurring.			
Landscape components – Permeable pavement				
Weeds	Less than 10% of infill surface area (where present) covered by weeds.			

Appendices

Appendices

APPENDIX A – SAMPLE TENDER DOCUMENTATION FOR MAINTENANCE CONTRACT

Scope of works

The scope of works includes the regular inspections and maintenance of all stormwater treatment assets located within the municipality as detailed in <<insert reference to asset list>>.

Project duration

Inspection and maintenance services: <<insert duration (typically over a number of years, e.g. December 2011 to June 2015)>>.

Performance criteria

The operator must ensure that the stormwater treatment assets function as designed and are fully operational at all times.

Activity specification

1. The contractor will verify and countersign the asset condition assessment/s undertaken immediately prior to the commencement of this contract.
2. The contractor will attend each site and undertake regular inspection and maintenance activities on a three monthly cycle in accordance with the tasks outlined in the relevant asset section of the WSUD Maintenance Guidelines, Melbourne Water (2013).
3. The contractor will maintain assets in accordance with Melbourne Water (2013) WSUD Maintenance Guidelines unless written approval for a variation is granted by the asset owner prior to commencing inspection and maintenance services.
4. The contractor will record any actions undertaken or required using the inspection and maintenance forms provided in the relevant asset section of the WSUD Maintenance Guidelines, Melbourne Water (2013). Forms will be submitted to the asset owner within one month of inspection and maintenance activities.
5. Periods of heavy rain can increase the frequency of inspections and cleaning required. The contractor will undertake the following additional maintenance activities in response to notification from the asset owner:

Intervention level	Response time
Capacity of inlets and outlets reduced to 30% design capacity	14 days
Capacity of inlets and outlets reduced below 30% and flooding of adjoining properties could result	24 hours

Schedule of rates

The following schedule may be used in conjunction with above tender documentation to enable asset owners to compare tender submissions for maintenance works:

Works item	Rate	Cost
Asset assessment	Per visit	
Regular site inspection	Per visit	
Maintenance		
– sediment removal	$/tonne	
– litter removal	$/hr	
– weed removal	$/hr	
– filter media replacement	$/m^3	
– plant replacement	$/plant	
– minor works (e.g. surface reprofiling)	$/hr	
– mulch replacement	$/m^3	
– reporting	Per visit	

APPENDIX B – EXAMPLE ASSET OPERATION AND ACCESS SUMMARY

Asset operation and access summary plan	
Asset ID	RG00014
Location	Harding Reserve, Black Beach, Melways 43 C5

Stormwater runoff will enter the raingarden at the inlet, where it will flow across the surface and infiltrate into the filter media.

Stormwater pollutant loads will be reduced in the raingarden by fine filtration through the filter media, biological uptake by plants and other more complex biogeochemical processes in the subsurface media.

The treated stormwater is collected via the underdrain system (network of slotted pipes) which conveys the water to the outlet pit.

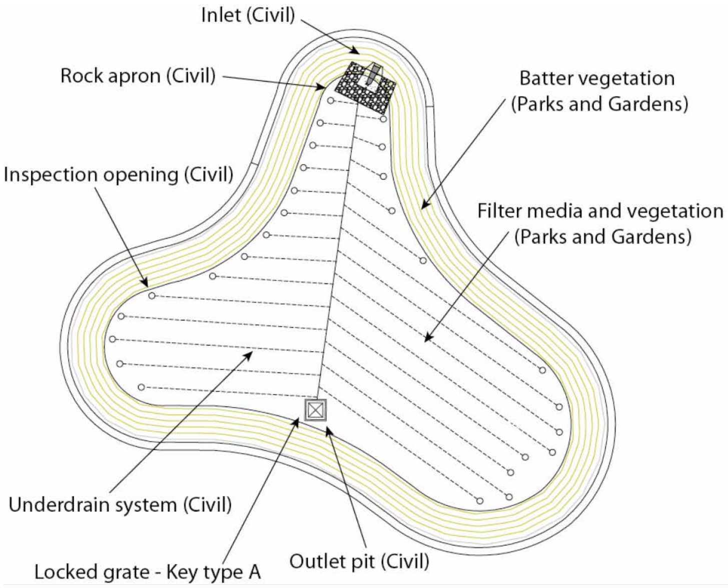
When the raingarden is full or when incoming flow rates exceed the infiltration capacity of the media, further inflows will be discharged into the outlet pit and conveyed to the downstream drainage system.

The underdrain system is provided with inspection openings which will allow for water levels within the filter layers to be monitored and accumulated sediment to be flushed from the underdrains.

Maintenance access to the site is via Glennoy Road along the eastern side of the football ground.

The delineation of asset maintenance responsibilities between the Civil and Parks and Gardens Departments is shown on the asset plan below.

Harding Reserve raingarden



Additional requirements:			
Plants should be lightly pruned annually (early spring) to remove dead flowering material and foliage.			
Planting schedule:			
Filter bed	Percentage cover	Batters	Percentage cover
– Lomandra longifolia	20%	– Imperata cylindrica	25%
– Carex appressa	20%	– Poa labillardierii	25%
– Gahnia sieberiana	10%	– Amphibromus nervosus	5%
– Ficinia nodosa	20%	– Atriplex semibaccata	5%
– Lepidosperma laterale	10%	– Myoporum parviflorum	5%
– Juncus usitatus	20%	– Dianella longifolia	10%
		– Carex appressa	25%

APPENDIX C – DISPOSAL OF CONTAMINATED SOIL

The disposal of contaminated soil in Victoria is regulated by the Environment Protection Authority (EPA) under the *Environment Protection Act* (1970) and Industrial Waste Management Policy.

Classification of contaminated soils

EPA Publication 448 – Classification of Wastes (EPA, 2007) provides guidance for the classification of contaminated soils (including clay, silt and/or sand).

Contaminated soils are classified into one of four categories: Category A, B, C and clean fill according to their level of hazard – based on maximum contaminant concentrations and leachable concentrations (refer to Tables 2–4, Victorian EPA Publication 448).

The level of hazard accorded to each category can be generally summarised as:

Category A – soils which require a very high level of control to protect human health and the environment. These wastes require hazard reduction before they can be sent to landfill.

Category B – soils which require a high level of control and on-going management.

Category C – soils which pose a low hazard or only exhibit offensive aesthetic properties.

Clean fill – soils with low contaminant concentrations (below the contaminant threshold for Category C) that may be suitable for site filling or levelling depending upon the assessment of contaminant levels.

Soil testing

All prescribed contaminated soils must be classified by hazard category prior to being accepted at landfills. Victorian EPA Publication 1178 – Soils sampling guideline (off-site management and acceptance to landfill) (EPA 2007) provides a methodology for sampling and testing of soil for waste classification.

All soil material to be removed and disposed of from stormwater treatment systems should be assessed for contaminants prior to removal. This will involve getting a sample of the soil analysed by an accredited soil testing laboratory. The maximum contaminant concentrations allowed in soil to be disposed of as fill material is summarised in Table 2 below.

Disposal

The transport and disposal of contaminated soil is subject to stringent EPA requirements. For example, the transport of Category C (low hazard soil) requires that the EPA transport certificate system is used and vehicles must hold an EPA permit. There are no EPA requirements for the transport and disposal of clean fill.

Based on the current landfill options in Victoria:

– Category A contaminated soils must be treated, immobilised or stored pending treatment since it is not permitted to be disposed at landfill unless first treated

– Category B contaminated soils can be disposed at only one landfill – Lyndhurst Landfill located in the south-east of Melbourne

– Category C contaminated soil waste can be disposed licensed landfills.

Table 2 Maximum contaminant concentrations allowed in soil to be disposed of as clean fill material.

Contaminant	Concentration (total) mg/kg weight
Arsenic	20
Cadmium	3
Chromium (VI)	1
Copper	100
Lead	300
Mercury	1
Molybdenum	40
Nickel	60
Tin	50
Selenium	10
Silver	10
Zinc	200
Cyanide	50
Fluoride	450
Phenols (halogenated)	1
Phenols (un-halogenated)	60
Monocyclic aromatic hydrocarbons	7
Benzene	1
Polycyclic aromatic hydrocarbons	20
Benzo(a)pyrene	1
Total petroleum hydrocarbons c_6 to c_9	100
Total petroleum hydrocarbons c_{10} to c_{36}	1000
Polychlorinated biphenyls	2
Chlorinated hydrocarbons	1
Organochlorine pesticides	1

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