Healthy Land & Water

Maintaining vegetated stormwater assets

Draft version 1.1, February 2026

Delivering an environment for future generations to thrive

Healthy Land & Water

Version history

#	Date	Title	Contributors
1.0	February 2012	Maintaining Vegetated Stormwater Assets	Version 1 of this document was authored by Shaun Leinster, Eleanor McKeogh, Jason Sonneman, and Robin Allison of Designflow, and Mia Dalby of Dragonfly Environmental. Input and review was provided by Adam Morris of Barry Bros., Geoff Sainty of Sainty and Associates, and Damien McCann of Australian Wetlands. Version 1 was produced by Sarah Jones and Alan Hoban of the Water by Design program. A number of councils contributed to the development of this document. This includes Brisbane City Council, Gold Coast City Council, Ipswich City Council, Logan City Council, Moreton Bay Regional Council, Redland City Council, and Sunshine Coast Council. No endorsement by these organisations is implied.
1.1	March 2026	Maintaining Vegetated Stormwater Assets	Additional content for Version 1.1 was provided by Jack Mullaly of Water by Design. Version 1.1 was produced by Jack Mullaly of Water by Design. Funding for Version 1.1 was provided by the Queensland Government Department of the Environment, Tourism, Science and Innovation.

Acknowledgements

A number of councils contributed to the development of this document. This includes Brisbane City Council, Gold Coast City Council, Ipswich City Council, Logan City Council, Moreton Bay Regional Council, Redland City Council, and Sunshine Coast Council. No endorsement by these organisations is implied.

Citation

Water by Design (2026) *Maintaining vegetated stormwater assets*, Healthy Land & Water, Brisbane.

Disclaimer

The material contained in this publication is produced for general information only. It is not intended as professional advice on specific applications. It is the responsibility of the user to determine the suitability and appropriateness of the material contained in this publication to specific applications. No person should act or fail to act on the basis of any material contained in this publication without first obtaining specific independent professional advice. Healthy Land & Water and the participants of our network expressly disclaim any and all liability to any person in respect of anything done by any such person in reliance, whether in whole or in part, on this publication. The information contained in this publication does not necessarily represent the views of Healthy Land & Water or the participants of our network.

About Water by Design

Healthy Land & Water's Water by Design initiative works with individuals and organisations to identify and fill knowledge gaps and facilitate the uptake of improved practices in sustainable water management. For more information, visit www.waterbydesign.com.au.

About Healthy Land & Water

Healthy Land & Water is the peak environmental group for South East Queensland. For over 20 years it has been dedicated to investing in and leading initiatives to build the prosperity, liveability, and sustainability of our 'future region'. A healthy environment also supports a vibrant economy, strong livelihoods, great lifestyles and the happiness and well-being of the community. Healthy Land & Water is focused on **delivering an environment for future generations to thrive**.

Our success and strength stems from our extensive knowledge, science and evidence which informs investment in our environment. We are experts in research, monitoring, evaluation and project management. Our team has led many thousands of projects to restore waterways and landscapes, improve native habitats, manage weeds, protect native species, inform policy and educate communities on the best ways to improve and protect the environment.

Working in partnership with Traditional Owners, government, private industry, utilities and the community, Healthy Land & Water delivers innovative and science-based solutions to challenges affecting the environment. Through a combination of scientific expertise and on-ground management works, Healthy Land & Water **leads and connects through science, big data and actions that will preserve and enhance our natural assets and support resilient regions long into the future**.

Traditional Owner acknowledgement

We acknowledge that the place we now live in has been nurtured by Australia's First Peoples for tens of thousands of years. We believe the spiritual, cultural and physical consciousness gained through this custodianship is vital to maintaining the future of our region.

Funding acknowledgement

The preparation of this document was funded by the Queensland Government's Water Quality Investment Program, delivered by the Department of the Environment, Tourism, Science and Innovation.

Contact details

For further information about Healthy Land & Water www.hlw.org.au, please email info@hlw.org.au or telephone (07) 3177 9100.

Contents

Glossary of terms

Batter (also known as embankment)	Sloped or graded areas immediately surrounding vegetated stormwater assets. Batters provide a transition between the treatment zone and the surrounding ground level.
Biodiversity	The number and variety of living organisms, including genetic diversity, species diversity, and ecological diversity. Also referred to as 'biological diversity'.
Biofilm	A gelatinous sheath or matrix of algae and polysaccharides (sugars) that adsorbs colloids and nutrients. Biofilms often contain diverse and abundant microflora and microfauna. Biofilms form on aquatic vegetation in wetlands and play a critical role in trapping and processing pollutants and nutrients from the water column.
Bioretention system	Vegetated depressions designed to collect, detain and treat stormwater. Stormwater infiltrates into a prescribed filter media that is densely planted. Pollutants are primarily removed by adsorption and biological transformation within the filter media. Bioretention systems are also called biofilters, biopods, biofiltration basins, raingardens, and bioretention swales.
Coarse sediment forebay	Installed at the inlet of bioretention systems to accept stormwater from the drainage inlet, typically a pipe. Removes coarse sediment (> 1 mm) from stormwater to minimise the risk of vegetation in the bioretention system being smothered. Designed to be easily maintained.
Constructed wetland	Constructed wetlands usually consist of a sediment basin followed by a macrophyte zone. A high-flow bypass transports above design flows around the macrophyte zone. The macrophyte zone is a constructed shallow body of water that supports a range of aquatic vegetation. Constructed wetlands remove pollutants from stormwater through enhanced sedimentation, fine filtration, and biological uptake. In this document, a 'constructed wetland' refers to the macrophyte zone.
Debris	Large items of waste created by human activity (e.g. construction waste).
Prohibited and restricted weeds	Plant species that have, or could have serious economic, environmental or social impacts as identified under the Queensland *Biosecurity Act 2014* or equivalent in other jurisdictions. The Act imposes legal responsibilities for all landowners to report and control prohibited and restricted weeds on land under their management.
Ecosystem	A system formed by the interaction between organisms and their environment.
Ephemeral	When used to describe wetlands, 'ephemeral' refers to habitats that are intermittently inundated and go through periods of wetting and drying.
Erosion	The mechanical process of wearing down or translocating the earth's surface by weathering, abrasion, or transportation.
Extended detention	An area above a vegetated stormwater asset that temporarily stores water and then slowly releases the water. Extended detention is particularly useful for maximising the volume of water that is treated.
Failed asset	An asset that has stopped functioning or is not meeting a range of performance indicators and therefore no longer providing the intended stormwater management function.
Filter media	A prescribed soil media used in a bioretention system to filter stormwater and support plant growth.
High-flow bypass	A structure or device (typically a weir, pit, or channel) that bypasses high flows around a vegetated stormwater asset to avoid erosion within the asset.
Infiltration	The process by which surface water enters the soil.

Inlet	Inlets deliver stormwater to the treatment asset and can include stormwater pipes, surcharge pits, flush kerbs (e.g. in swales), and structures that divert flows from a stream or existing pipe system.
Inlet pond	See 'Sediment basin'.
Litter	Small items of waste created by human activity (e.g. cigarette butts, food wrappers, plastic bottles, paper, glass, etc.).
Macrophyte	A plant adapted to living in water or periodically inundated (ephemeral) habitats.
Macrophyte zone (of wetland)	See 'Constructed wetland'.
Normal water level	The water level in a wetland or sediment basin equal to the level of the lowest free-draining outlet. After rainfall, water will pond up within the wetland or sediment basin in the extended detention zone, and then after three or four days the water level will return to its normal level.
Noxious weed	A noxious weed is an invasive species of a plant that has been designated by government as injurious to agricultural or horticultural crops, natural habitats, ecosystems, humans, or livestock. Most noxious weeds are species introduced (non-native) into an ecosystem by ignorance, mismanagement, or accident. They are controlled or managed under state or territory legislation.
Nutrients	Substances such as compounds of nitrogen and phosphorus that promote the growth of plants and algae. Excessive nutrients in waterways and other receiving water environments contribute to algal blooms and degrade waterways.
Outlet	Structures that regulate flows through stormwater assets and can include, amongst other things, pipes, pits, weirs, and submerged pipes with riser arrangements in constructed wetlands.
Overflow	Hydraulic structures, weirs, or spillways that safely convey high flows from a stormwater asset to a downstream waterway or drainage asset.
Performance indicator	A measure that maintenance crews can visually assess to determine if vegetated stormwater assets are likely to be functioning properly.
Plant litter	Organic material such as leaves or twigs, usually dropped from plants in or surrounding the asset and sometimes entering via stormwater. In new bioretention systems, plant litter can include mulch deliberately placed in the asset to support plant establishment.
Pollutants	Substances that may naturally occur but are present at harmful levels (e.g. sediment or nutrients in a water body) or that may be unnatural in the environment and capable of producing environmental harm (e.g. chlorinated pesticides).
Private asset	Vegetated stormwater asset owned by a body corporate, property owner, or other private party.
Public asset	Vegetated stormwater asset owned by a local authority or state government.
Rectification	The works involved in restoring a failed or under-performing vegetated stormwater asset back to a functional state.
Terrestrial	Related to the land, as opposed to air or water.
Sediment basin	A basin designed to slow the flow rate of stormwater, allowing sediments within the stormwater to sink into the storage zone of the basin.
Swale	A turfed or otherwise vegetated shallow channel that conveys stormwater and removes pollutants.
Under-performing asset	An asset where one or two performance indicators are not being met and the asset is only partially providing the stormwater management function for which it was intended.

Water quality	Physical, chemical, and biological characteristics of the water column.
Weed	A plant that is growing where it is not wanted.

1 Introduction

1.1 Background of the guidelines

Waterways are an integral part of our lifestyle and economy. However, as our cities continue to grow and expand, our waterways are under increasing pressure from urban stormwater runoff.

Typically, stormwater is conveyed from urban areas to receiving waterways via a system of pits and pipes. Without intervention, this stormwater is discharged more frequently and in greater volumes than what would occur naturally and carries with it large amounts of pollutants such as nutrients, sediment, and litter. Vegetated stormwater assets such as bioretention systems and wetlands can help reduce these impacts by slowing and treating stormwater before it reaches the receiving environment.

A range of legislative, financial, environmental, and social imperatives is driving the need for vegetated stormwater assets. For example, in Queensland, the *State Planning Policy* requires development to be planned, designed, constructed, and operated to manage stormwater in a way that protects waterways.

Vegetated stormwater assets require maintenance to function effectively.

The implications of not maintaining vegetated stormwater assets include:

- Assets fail to manage stormwater quality, which can result in negative ecological impacts in downstream water bodies and pose liability issues for the asset owner.
- Poor amenity.
- Health and safety problems, such as mosquitoes or offensive odours.
- Rectification costs (the cost of returning a failed asset to a functional state) far exceeding the cost of routine maintenance.
- Reduced asset value.

A comprehensive suite of tools and guidelines is available to support the planning, design and implementation of water sensitive urban design (WSUD) in Queensland and beyond. Figure 1 illustrates these tools and how they can be used over the lifecycle of a typical vegetated stormwater asset.

Planning	Concept design	Detailed design	Construction	Establishment	Operation & maintenance
Strategic waterways Water by Design (2019)					
Living waterways Water by Design (2019)					
Concept design guidelines for water sensitive urban design Water by Design (2009)					
	MUSIC modelling guidelines Water by Design (2018)				
	Bioretention technical design guidelines Water by Design (2014)				
	Wetland technical design guidelines Water by Design (2017)				
	Deemed to comply solutions Water by Design (2010)				
	Drainage and water quality standard drawings Institute of Public Works Engineering Australasia (IPWEA) (2017)				
	Stormwater harvesting guidelines Water by Design (2009)				
			Best practice erosion and sediment control International Erosion Control Association (IECA) (2008)		
			Erosion and sediment control fact sheets Water by Design (2021)		
			Guidelines for improving the biology of bioretention systems Water by Design (2022)		
			Guidelines for the construction and establishment of bioretention systems and wetlands Water by Design (2022)		
				Transferring ownership of vegetated stormwater assets Water by Design (2012)	
					Maintaining vegetated stormwater assets Water by Design (2012)
			Rectifying vegetated stormwater assets Water by Design (2012)		

Figure 1 *WSUD tools and guidelines.*

1.2 Purpose of this document

This document is intended to help asset managers and maintenance staff by providing practical and standardised advice for maintaining swales, bioretention systems, constructed wetlands, and sediment basins. It provides information on planning and undertaking maintenance and checklists for recording the results of inspections and maintenance activities undertaken.

Practitioners who design and approve vegetated stormwater assets can also use this document as a reference to help deliver more maintenance-friendly assets.

1.3 Structure of the guidelines

These guidelines provide a single point of reference for those involved in the maintenance of vegetated stormwater assets in Queensland. Table 1 describes the content of each section.

***Table 1** Structure of the guidelines.*

Planning for maintenance	Provides guidance on planning for maintenance, including scheduling inspections and maintenance.
Undertaking maintenance activities	Provides guidance on how to undertake maintenance activities and associated costs.
Recording inspections and maintenance	Provides inspection and maintenance checklists to record the condition of the asset (against performance indicators) and the maintenance undertaken or action needed.
Appendices	Provides details of common maintenance activities and additional information to assist in identifying and managing contaminated sediment and common weeds.

Users of this document should have a good understanding of the purpose, function, and operation of vegetated stormwater assets.

The inspection and maintenance tasks described in this document are applicable to both private and public assets.

The checklists and information in this document can be inserted into maintenance plans. In many cases, they can replace the need for individual maintenance plans as part of development approvals.

Where there is a problem with the function of an asset that maintenance cannot address, refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

2 Planning for maintenance

Effective planning for the maintenance of vegetated stormwater assets requires an understanding of:

- The number and location of assets.
- The functions and components of the asset (see Section 2.1).
- The difference between maintenance and rectification, and how the two activities are related (see Section 2.2).
- Local, state, and national procedures, guidelines, and legislation that affect how maintenance is undertaken (Section 2.3).
- The skills required (Section 2.4).
- When to schedule inspections and maintenance (Section 2.5).
- How to manage a non-functioning asset (Section 2.6).
- Asset management and maintenance roles and responsibilities (Section 2.7).
- How to ensure privately owned assets are maintained (Section 2.8).

Managers should also understand the current condition and history of each asset, as recurring problems may indicate the need to alter the maintenance regime or conduct a rectification investigation (see *Rectifying Vegetated Stormwater Assets* (Water by Design)).

2.1 Functions and components of vegetated stormwater assets

2.1.1 Swales

The primary functions of a swale are to:

- Slow the flow of stormwater and promote infiltration.
- Convey stormwater within a defined channel.
- Reduce stormwater pollutants through velocity reduction (settlement) and contact with dense vegetation or turf (adhesion).
- Provide visual amenity.

Swales located on grades of less than 1% generally have underdrains to prevent waterlogging. Swales can be designed to allow some infiltration to groundwater in areas with suitable soils. The *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Water by Design) contains a comprehensive description of swales.

Figure 2 shows examples of swales that are functioning properly. Use the performance indicators in the checklists in Section 4.2 to determine if a swale is likely to be functioning properly. If the asset is meeting all of the performance indicators, it can be assumed that it is functioning properly.

Photo: Alan Hoban

Photo: Shaun Leinster

Figure 2 *Examples of properly functioning swales.*

2.1.2 Bioretention systems

The primary functions of a bioretention system are to:

- Capture and filter stormwater through dense vegetation.
- Percolate stormwater through prescribed filter media and infiltrate it into surrounding soils and/or discharge it to downstream drainage.
- Allow high flow to bypass or pass over the bioretention area in a controlled manner.
- Provide visual amenity and promote urban ecology.

Figure 3 shows the typical components of a bioretention system.

The vegetation is critical for both removing nutrients and maintaining the hydraulic conductivity (or infiltration rate) of the filter media. Bioretention systems have three layers beneath the vegetation: the filter media, a transition layer, and a drainage layer. A perforated pipe collection system (known as underdrainage) usually sits in the drainage layer, which discharges the infiltrated water to the downstream waterway or to storage for later reuse. Together these layers and pipework are known as the drainage profile.

There are five different types of drainage profile (Figure 4):

- **Type 1 saturated zone** – A sealed system containing a permanent water storage (known as a saturated zone) within the drainage and transition layers. The saturated zone supports plant health during dry periods.

- **Type 2A traditional sealed** – A sealed system without a saturated zone. Most used where infiltrating water from the bioretention system into the surrounding soils is inappropriate (e.g. where acid sulphate or dispersive soils are present).
- **Type 2B traditional unsealed** – A simple unsealed system used when there is not a specific requirement for one of the other drainage profile types.
- **Type 3 infiltration – with pipe** – An unsealed system used where infiltrating water into the surrounding soil is a priority, but soil porosity is lower than the filter media hydraulic conductivity. Underdrainage pipes allow for drainage when the infiltration capacity of the soil is exceeded.
- **Type 4 infiltration – pipeless** – An unsealed system used where infiltrating water into the surrounding soil is a priority and soil porosity is sufficiently high to negate the need for underdrainage pipes.

Coarse sediment forebays are normally installed at the inlet of bioretention systems. Their function is to remove coarse sediment (> 1 mm) from stormwater to minimise the risk of vegetation in the bioretention system being smothered. Coarse sediment forebays are designed to be cleaned out once a year.

Figure 5 illustrates the many different shapes and sizes of bioretention systems. Due to the variability in design, maintenance staff need accurate and specific information on each asset. This should include a diagram showing the location of inlet areas, outlet pipes, and overflows. Onsite handover or training should also be conducted.

The *Bioretention Technical Design Guidelines* (Water by Design) contain a comprehensive description of bioretention systems.

Figure 5 shows examples of bioretention systems that are functioning properly. Use the performance indicators in the checklists in Section 4.3 to determine if a bioretention system is likely to be functioning properly. If the asset is meeting all of the performance indicators, it can be assumed that it is functioning properly.

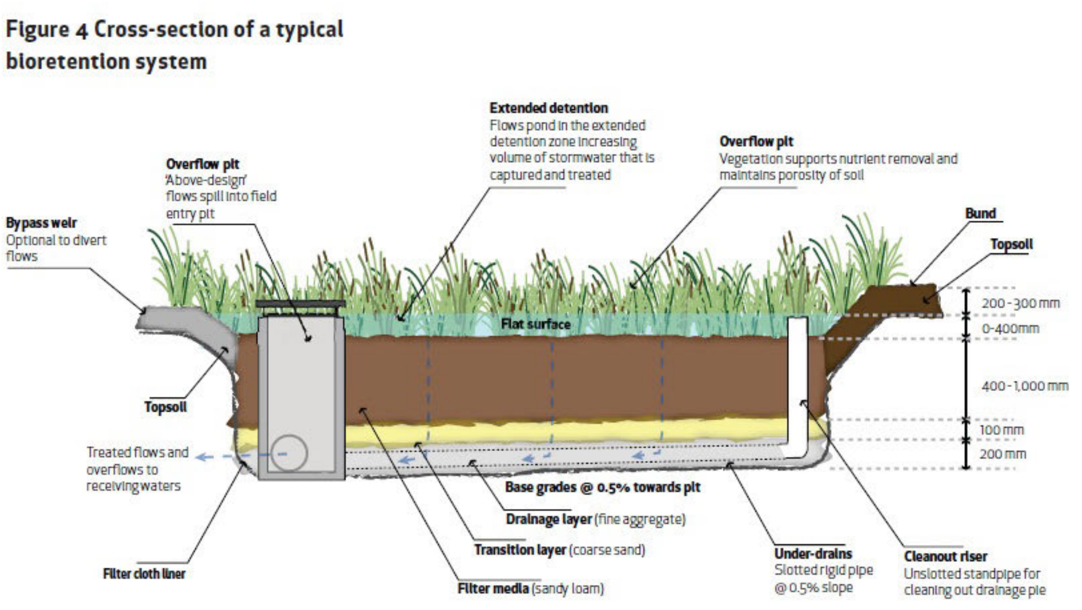


Figure 3 *Cross-section of a typical bioretention system.*

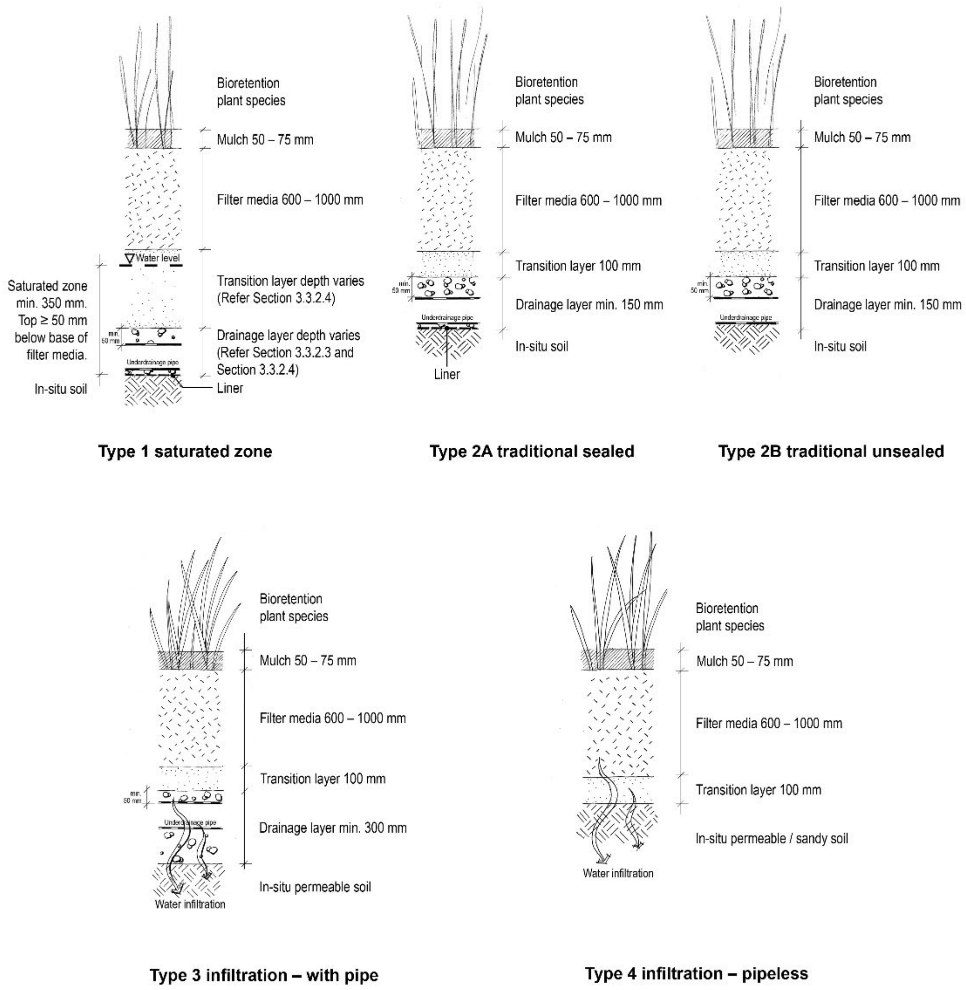


Figure 4 *Cross-section of a typical bioretention system with a saturated zone.*

Photo: Alan Hoban

Photo: Alan Hoban

Photo: Jack Mullaly

Photo: Shaun Leinster

Photo: Alan Hoban

Photo: Jack Mullaly

Photo: Jack Mullaly

Figure 5 *Examples of properly functioning bioretention systems.*

2.1.3 Constructed wetlands

A constructed wetland is a shallow water body dominated by emergent water plants.

The primary functions of a constructed wetland are to:

- Capture and retain sediment through settling within the water column.
- Remove nutrients through chemical and biological transformations by biofilms and macrophytes.
- Regulate flows entering downstream vegetated stormwater assets or channels.
- Provide habitat for aquatic fauna.
- Provide visual amenity.

Constructed wetlands should have a sediment basin as an inlet zone followed by a macrophyte zone. In this document, a 'constructed wetland' refers to the macrophyte zone of the wetland. Use the sediment basins checklist for the inlet zone (Section 4.5) and the wetlands checklist for the macrophyte zone (Section 4.4).

Figure 6 illustrates the components of a typical constructed wetland. The *Wetland Technical Design Guidelines* (Water by Design) contain a comprehensive description of constructed wetlands.

The water level in a constructed wetland during dry weather is referred to as the normal water level. When it rains, inflows enter the wetland via the sediment basin. Design flows are conveyed to the macrophyte zone. This causes the water level in both the macrophyte zone and the sediment basin to rise towards an overflow level. The overflow level sets the maximum water level in the wetland. Most constructed wetlands are designed so that high-velocity inflows bypass the wetland, usually via an overflow weir located in the inlet zone.

The difference between this maximum water level and the normal water level is called the extended detention depth. The extended detention depth is closely related to the amount of water that a constructed wetland can treat and thus its overall treatment performance.

A riser pipe (Figure 7) usually controls treated outflows from a constructed wetland. Weirs can also be used. Some wetlands may use a riser plate (Figure 8) to control outflows, however this is less favourable than a riser pipe as riser plates are more prone to blockage. The outlet releases water over a number of days (usually 3-4) until the water level in the wetland drops down to the normal operating level.

Figure 9 shows examples of constructed wetlands that are functioning properly. Use the performance indicators in the checklists in Section 4.4to determine if a constructed wetland is likely to be functioning properly. If the asset is meeting all of the performance indicators, it can be assumed that it is functioning properly.

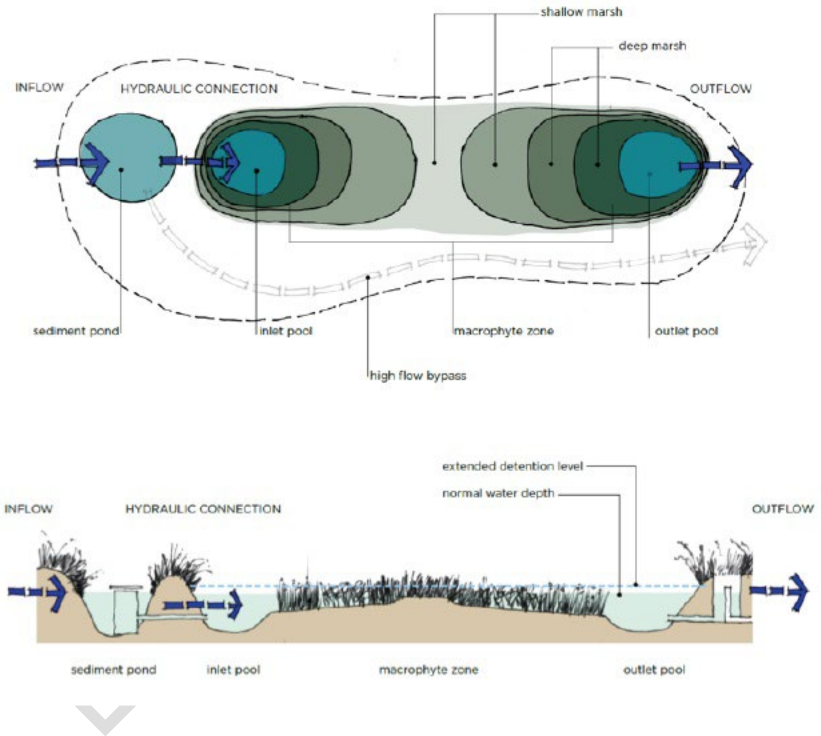


Figure 6 *Typical layout of a constructed wetland.*

Photo: Shaun Leinster

Figure 7 *Riser pipe outlet.*

Photo: Robin Allison

Figure 8 *Riser plate at full water level.*

Photo: Jack Mullaly

Photo: Jack Mullaly

Figure 9 *Examples of properly functioning constructed wetlands with good vegetation cover.*

2.1.4 Sediment basins

This section is about permanent sediment basins, which are typically used upstream of wetlands or large bioretention systems as inlet zones. It does not apply to temporary sediment basins associated with sediment control activities during construction.

The primary functions of a sediment basin are to:

- Capture and retain coarse to medium-sized sediment through settling within the water column.
- Regulate flows entering a downstream vegetated stormwater asset or channel.

Unlike other assets in this document, vegetation does not form a primary functional element of sediment basins. Vegetation is included for amenity, screening, and public safety.

Figure 10 illustrates the components of a typical sediment basin. Many have a high-flow bypass built into them to allow high-velocity flows to be directed away from the downstream asset to protect it from erosion. The *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Water by Design) contains a comprehensive description of sediment basins.

Further information on sediment basins as they relate to bioretention systems and constructed wetlands is contained in the *Bioretention Technical Design Guidelines* and *Wetland Technical Design Guidelines* respectively.

Figure 11 shows examples of sediment basins functioning properly. Use the performance indicators in the checklists in Section 4.5 to determine if a sediment basin is likely to be functioning properly. If the asset is meeting all of the performance indicators, it can be assumed that it is functioning properly.

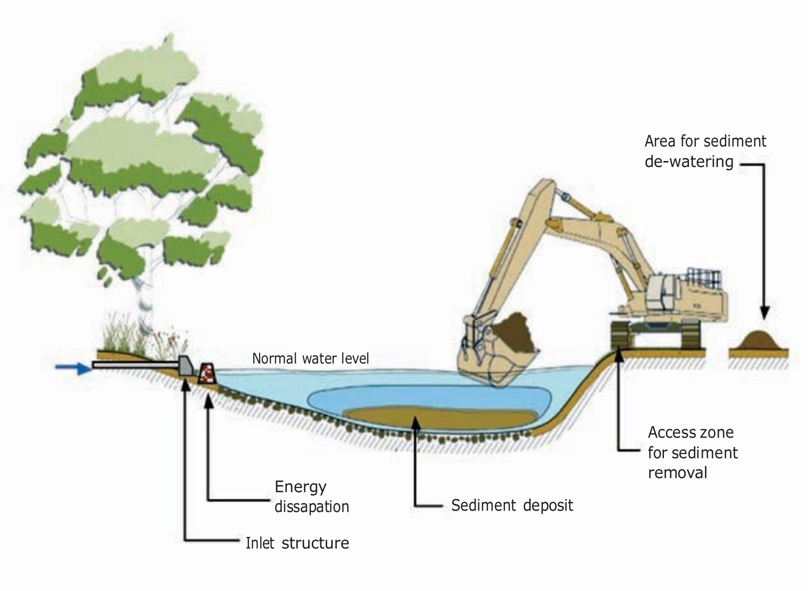


Figure 10 *Cross-section of a typical sediment basin.*

Photo: Shaun Leinster

Photo: Jack Mullaly

Figure 11 *Examples of properly functioning sediment basins.*

2.2 Maintenance versus rectification

Maintenance involves regular or scheduled activities undertaken to keep vegetated stormwater assets functioning properly. Common maintenance activities include weeding, removal of litter and debris, and inspection for defects.

To identify if a vegetated stormwater asset is functioning properly, compare the state of the asset against the performance indicators in the inspection and maintenance checklists in Section 4 of this document. If the asset is meeting all of the performance indicators, it can be assumed that it is functioning properly. However, if the asset is not meeting the performance indicators, decide whether maintenance will be sufficient to resolve the problem or whether rectification is needed.

Rectification is required when there is a problem with a function (e.g. the ability to treat stormwater) that maintenance activities cannot address.

Examples include:

- A design flaw, such as the levels of the hydraulic structures within the asset are not correct.
- Poor construction, such as incorrectly placed soil or filter media.
- The collapse of a hydraulic structure.
- Mass plant failure within a wetland.

Problems will develop over different timeframes. Some problems, if left unchecked, will develop into problems that are more serious and difficult to rectify than the original problem. For example, if an issue with the water levels in a wetland is not picked up early, mass plant failure can result. This is a far more costly and difficult problem to repair than changing the wetland outlet to adjust the water level. Generally, addressing problems at the earliest possible stage is more cost-efficient.

Engineering or horticultural experience may be required to identify whether a problem requires rectification and within what timeframe.

Certain components are more important to the overall functioning of the asset than others and represent different levels of risk to the asset owner. For example, permanent ponding on the surface of a bioretention system indicates no or very poor hydraulic conductivity of the filter media. This is likely to require rectification works, whereas a recurrent patch of weeds or excess litter may be addressed by temporarily increasing the frequency of maintenance. Which of these problems to address first will depend on a number of factors, but in the first instance, a maintenance program should focus on cost-effective actions that keep as many assets functioning as possible before considering costly rectification of individual failed assets (see Section 3.2.3).

The following approach is recommended:

1. If the asset has not met one or more of the performance indicators on at least two consecutive maintenance inspections, increase the maintenance frequency.
2. If increased maintenance is still not resolving the problem, investigate the need to rectify the asset in accordance with *Rectifying Vegetated Stormwater Assets* (Water by Design).

2.3 Procedures, guidelines, and legislation

Due care must be taken when working on or near stormwater treatment assets to minimise risk to workers and the environment. Stormwater can be contaminated with pollutants (such as heavy metals) and can contain waste (such as syringes).

Users of this guideline should refer to their internal processes, including risk assessment procedures, safe work method statements, and standard operating procedures, to undertake maintenance in accordance with local, state, and national legislation and guidelines.

Maintaining Vegetated Stormwater Assets does not provide specific guidance on this, except for the following points that are specific to vegetated stormwater assets:

- **Contaminated sediment:** Prior to removing sediment or soil, assess the risk that it is contaminated using either local procedures or the procedure provided in Appendix A. Where sediment or soil is contaminated, transporting and disposing of the sediment is subject to local and state regulations. Where sediment is not contaminated, opportunities for beneficial reuse should be sought.
- **Prohibited and restricted weeds:** Refer to relevant local regulations regarding prohibited and restricted weeds. In Queensland, the *Biosecurity Act 2014* identifies plant species that could cause serious economic, environmental, or social impacts. The Act imposes a legal responsibility for all landowners to control prohibited and restricted weeds on land under their management. Refer to Appendix B for more information.
- **Personal safety:** A Safe Work Method Statement for vegetated stormwater assets should (at a minimum) deal with potential needlestick injuries, working within and around polluted water, working on slopes and confined spaces, and working adjacent to roads.
- **Working adjacent to roads:** Where a swale is located in the centre median of a road, undertake a traffic risk assessment to identify how to manage traffic risks. Options may include undertaking maintenance:
    - during the day with traffic management
    - with signage but without traffic management
    - at night with signage, appropriate lights on equipment and headlamps but without traffic management.

2.4 Skills required for undertaking maintenance

Vegetated stormwater assets have many different components (e.g. inlets, vegetation, and outlet structures), all of which are important for achieving their primary functions, including improving stormwater quality and providing visual amenity. Therefore, a team of people with skills in engineering, landscaping, and ecology or horticulture is often required to effectively maintain vegetated stormwater assets.

The skills that inspection and maintenance teams require to maintain vegetated stormwater assets include:

- For the **civil components** (structural and erosion), an understanding of basic hydrological and hydraulic processes, as well as structural engineering and geomechanics, in order to assess the structural integrity of structures and erosion processes.
- For the **vegetated components**, a good understanding of plants that are suitable for vegetated stormwater assets, terrestrial weeds and eradication methods, aquatic weeds and eradication methods, and the distinction between prohibited, restricted and other weeds.

All personnel need to understand the purpose and function of the assets. This is critical to ensure that maintenance activities undertaken to address one issue within an asset do not inadvertently compromise another component of the asset.

As maintenance programs mature, internal expertise regarding vegetated stormwater assets will develop. In sufficiently large markets (e.g. South East Queensland), specialised vegetated stormwater asset maintenance contractors have emerged.

2.5 Scheduling inspections and maintenance

Inspections and maintenance can be completed in a number of ways. The choice of method is often dependent on the resources and internal structure of the organisation. Figure 12 illustrates the various options. Local governments commonly engage an external contractor to inspect for emerging issues while undertaking regular weed control and litter removal.

OPTION 1	OPTION 2		OPTION 3	
Inspection and regular maintenance of civil and landscape components	Inspection of civil components	Inspection of landscape components	Inspection of civil components	Inspection and regular maintenance of landscape components
Responsive maintenance	Responsive maintenance		Responsive maintenance	

Figure 12 *Options for undertaking inspections and maintenance.*

Regular maintenance is useful for activities that require a small number of resources such as weeding and removing litter and debris. Responsive maintenance is useful for activities that require specific equipment or skills such as cleaning out sediment from a sediment basin, repairing local erosion, or responding to ponding or blinding of bioretention filter media.

Table 2 sets out the recommended frequency for inspections and regular maintenance of standard vegetated stormwater assets. These frequencies will help ensure vegetated stormwater assets function properly (i.e. achieve the performance indicators in Section 4) and allow problems to be addressed in a cost-effective manner.

When undertaking inspections and maintenance, use the checklists in Section 4 to record the condition of assets (i.e. by comparing the state of the asset against the performance indicators), maintenance undertaken, and additional maintenance or rectification that may be required.

Table 2 *Recommended frequency of inspections and regular maintenance.*

ASSET TYPE	SUB-TROPICAL		TROPICAL		TEMPERATE
	Wet season	Dry season	Wet season	Dry season	
Swales	4 months*	4 months*	4 months*	4 months*	4 months*
Bioretention systems	2 months	4 months	2 months**	4 months	3 months
Constructed wetlands	2 months	3 months	1 month**	3 months	3 months
Sediment basins	2 months	3 months	1 month**	3 months	3 months

*Turf swales will require more frequent mowing.

** For tropical climates, monthly inspections are required during the wet season due to the risk of noxious/prohibited/restricted weeds (e.g. Salvania and Para grass). Costs saved addressing weed issues early greatly outweighs the additional costs of monthly inspections.

An asset may need to be maintained more often than the frequencies outlined in Table 2 for the following reasons:

- Activities in the catchment (e.g. poorly managed house building) are producing higher than expected loads of litter, debris, sediment, or weeds.
- A high standard of amenity is a priority.
- Requests from the community.
- Recurring problems.

Ideally the condition of each asset should be inspected at least once a year during, or immediately after, a significant rainfall event (i.e. more than 50 mm/day) to confirm that the asset operates properly in wet conditions. Check assets for erosion, the condition of structures, and the cover and health of the vegetation. Check that swales and bioretention systems are free-draining and that the water level control is operating effectively in constructed wetlands.

2.6 Maintenance of non-functioning assets

2.6.1 Minimum maintenance requirements for a non-functioning asset

Vegetated stormwater assets may fail due to a design error, a construction problem, a lack of regular maintenance, or an external influence (such as vandalism). If this is the case, refer to *Rectifying Vegetated Stormwater Assets* (Water by Design) for advice on how to return the asset to a functional state.

There may be some time between identifying a problem and implementing a solution. While developing a solution, undertake a minimum level of maintenance to ensure the asset is not causing a hazard and that minimum regulatory requirements are met. Consider maintaining public safety, maintaining flood conveyance, and managing environmental issues when planning maintenance of underperforming or failing assets.

Maintaining public safety

Use access controls such as fences and signposts to prevent the public from getting too close to parts of the asset that may cause safety or security concerns. In particular, protect areas that pose trip or fall hazards (e.g. near steep batter slopes and eroded areas).

Ensure appropriate controls are in place to manage other risks, such as needle-stick injuries or excessive algae.

Maintaining flood conveyance

In many cases, vegetated stormwater assets help to convey stormwater. This function is particularly important where the asset is online (i.e. does not take diverted flows or does not have a high-flow bypass). If there is a problem with the asset that is impeding its capacity to handle stormwater (e.g. the asset is full of sediment or choked with weeds), it will need to be cleared or an alternative passage for stormwater will need to be provided.

Managing environmental issues

Consider the control of noxious weeds and waterway impacts, including statutory requirements. Pollutants may be discharging from the failing asset. If a sensitive aquatic environment is downstream of the asset, environmental issues must be addressed as soon as possible.

2.6.2 Maintaining partial performance of failed assets

In some situations, a vegetated stormwater asset may contain substantial flaws requiring rectification but still have the potential to provide partial function for very little maintenance expenditure. In these instances, maintenance should be conducted in such a way as to maintain this partial function until rectification can be completed. There are many situations where this could occur. Two examples are provided below.

Example 1 – Weedy bioretention basin

A large bioretention basin is located out of public sight, adjacent to well-established bushland. Due to a lack of maintenance during the establishment phase, non-prohibited/restricted weeds became established in the system and outcompeted desirable vegetation. The system was then incorrectly handed over to council in this condition.

To restore full function, the bioretention basin will need to be rectified by:

- Removing all weeds.
- Completely replanting with desirable vegetation.
- Receiving regular weed control and watering as the new plants establish.

As the system is large, these will be costly. It may be some time before a budget is obtained and work can commence.

In the interim, the asset must receive some level of maintenance. The presence of weeds within a bioretention basin would typically trigger a maintenance response to control or irradicate the weeds. However, this will leave the system bare and compromise treatment performance. The weeds within the system may not deliver treatment equivalent to that provided by desirable bioretention species, but they will almost certainly deliver greater treatment performance than a system without any vegetation at all.

An alternative, relatively low-cost approach that will retain at least partial treatment performance while preventing the weeds from spreading would be to:

- Inspect and maintain the civil infrastructure of the system as normal.
- Inspect for prohibited/restricted weeds and manage any found.
- Leave any nuisance, non-prohibited/restricted weeds in place.
- Manage the remaining weeds to prevent them from spreading into the adjacent bushland.

Example 2 – Small sinkhole in bioretention filter media

A bioretention system with well-established vegetation and few weeds is observed to have a small sinkhole in the filter media adjacent to the outlet pit. Further inspection reveals that the underdrains were poorly sealed into the outlet pit. Thus, the likely cause of the sinkhole in the filter media is water short-circuiting down the side of the outlet pit and out the hole formed by the badly sealed underdrains, taking filter media, transition sand and drainage gravel with it. This issue compromises system performance because much of the water that enters the system will flow out of the system via this sinkhole without passing through the filter media.

To restore full function, the system will need to be rectified by:

- Excavating around the outlet pit.
- Re-sealing the underdrains into the pit.

- Replacing the drainage layer, transition layer and filter media.
- Replanting the excavated area and re-establishing the vegetation.
- Making good any damage caused in accessing the system (e.g. repairing erosion of the batters and subsequent replanting).

With the system currently short-circuiting, it may seem sensible to stop maintaining the system until the sinkhole can be rectified. However, this overlooks two key points:

- The system is well established with few weeds. It can be kept in this relatively weed-free state with little effort, but if unmaintained weeds will gradually enter the system, requiring much greater expenditure to rectify in the future.
- Even though the system is short-circuiting and much water is bypassing the filter media untreated, some water that enters the system will still be passing through the filter media and receiving treatment. Thus, the system is still partially functioning.

To maintain partial function until rectification (and avoid additional rectification costs), a prudent interim maintenance regime would involve:

- Maintaining the vegetation and civil infrastructure as normal.
- Preventing the sinkhole from becoming worse by stabilising it with geofabric and placed rock.

2.7 Asset management and maintenance responsibilities within local government

Public asset owners such as local governments must assign asset management responsibilities to an internal department.

Local governments often already have asset management departments or teams with a focus on each of the following:

- Stormwater drainage.
- Parks/horticulture.
- Natural areas management.

Ownership is most often assigned to the department that manages stormwater drainage assets, but any of the three are acceptable. Regardless of the department chosen, ownership of any given asset must be assigned to a single department.

Assigning the various components of vegetated stormwater assets to different asset owners (e.g. assigning civil infrastructure to stormwater drainage and vegetation to parks) results in substandard outcomes and should be avoided.

Assigning different types of vegetated stormwater assets to different departments (e.g. assigning swales to stormwater drainage and bioretention systems, constructed wetlands and sediment basins to natural area management or parks) is uncommon but acceptable because each asset retains a single point of truth and thus can be managed as an integrated asset.

In addition to assigning asset management responsibilities, local governments must also decide which department shall be responsible (and receive a budget) for maintenance. As with asset ownership, a single department should be responsible for ensuring that each type of vegetated stormwater asset is maintained. Individual maintenance tasks can be undertaken by different departments or external contractors, but they must occur under the direction of a single department responsible for maintenance outcomes for the entire asset.

For example, one arrangement for asset management and maintenance responsibilities within a local government might be:

- Asset management responsibilities for bioretention systems are assigned to the department that manages all other stormwater assets (pits, pipes, etc).
- Asset maintenance responsibilities and budget are retained within the same department.
- An external contractor is engaged to undertake regular inspections, weed control and litter removal consistent with Table 2.
- Internal stormwater maintenance crews are engaged to clean coarse sediment forebays once per year.
- Tasks are assigned to address other issues on an as-needed basis.

As well as ensuring clear responsibilities for asset management and maintenance, arrangements such as these generally result in the relevant departments gradually acquiring integrated, WSUD-specific skillsets that will support improved ongoing management and maintenance outcomes.

2.8 Ensuring private assets are maintained

Private assets are typically constructed and established by developers with ownership handed over to a body corporate, property owner, or other private party.

To ensure privately owned vegetated stormwater assets are maintained, local governments should establish a private asset compliance framework. For detailed guidance on how to do this, refer to the *Water Sensitive Urban Design Maintenance Compliance Framework* (Ocean Protect, 2025).

Implementing a compliance framework includes tasks such as:

- Creating a **register** of privately owned vegetated stormwater assets.
- **Providing information** to owners so they are aware of the maintenance needs of their assets.
- Establishing a **maintenance agreement** as a planning obligation or as a condition attached to planning approval.
- Attaching a note to the **covenant** of a property. The covenant can specify maintenance requirements and allow authorities to access and inspect assets. If the inspection finds problems with the asset, the authority can issue a formal request to the owner to undertake maintenance.
- Creating a vegetated stormwater **easement** to access assets for inspection. If an inspection finds a problem with the asset, the authority can issue a formal request for the owner to undertake maintenance.
- Requiring **mandatory reporting**, where the owner uses a private contractor to undertake maintenance and submits an annual maintenance report to the authority. The authority should also undertake spot inspections or scheduled inspections to ensure adequate maintenance is undertaken.

In addition to vegetated stormwater assets, a comprehensive compliance framework should also cover the maintenance of privately owned non-vegetated treatment devices such as gross pollutant traps.

3 Undertaking maintenance

3.1 Maintenance activities

When vegetated stormwater assets are well designed, properly constructed and regularly maintained post establishment, maintenance is simple and comprised of a few key tasks (Table 3). Maintenance activities should also include regular inspections to identify emerging defects (see Figure 12).

Table 3 *Common maintenance activities by type of vegetated stormwater asset.*

Swales	Bioretention systems	Constructed wetlands	Sediment basins
Weed control. Litter/debris removal. Mowing (if grassed). Inspection for defects.	Weed control. Litter/debris removal. Inspection for defects.	Weed control. Litter/debris removal. Clearing of macrophyte zone riser. Inspection for defects.	Weed control. Litter/debris removal. Clearing of riser. Inspection for defects.

Periodically, assets may develop additional defects requiring responsive maintenance.

A full list of maintenance activities for swales, bioretention systems, constructed wetlands, and sediment basins includes:

- Repairing erosion.
- Unblocking inlets and outlets.
- Removing sediment.
- Removing litter and debris.
- Managing plant litter.
- Harvesting plants.
- Managing mosquitoes.
- Managing birds.
- Managing high or low water levels in a wetland.
- Responding to a paint or fuel spill.
- Replanting.
- Controlling weeds.
- Managing excessive algae in sediment basins and constructed wetlands.
- Managing algal or moss growth on bioretention systems.

The need for maintenance can be identified by comparing the state of the asset against the performance indicators in the checklists in Section 4.

Refer to Appendix C for further information on each maintenance activity.

3.2 Maintenance budgets

3.2.1 Publicly available maintenance cost data

Historically, several documents have provided estimates of the cost of maintaining vegetated stormwater assets:

- *A Business Case for Best Practice Urban Stormwater Management: Case Studies* (Water by Design, 2010).

- *Water Sensitive Urban Design Life Cycle Costing Data* (Melbourne Water, 2013).
- *The Guide to the Cost of Maintaining Bioretention Systems* (Water by Design, 2015).

These documents can be used when developing a maintenance program to make a preliminary estimate of the budget required for maintenance. However, it should be noted that at the time of publication of this guideline all three documents were over 10 years old and thus likely underestimate current maintenance costs.

3.2.2 Process for obtaining a maintenance budget

The process for developing a budget for maintaining vegetated stormwater assets will vary between local governments. However, most local governments that successfully obtain a budget do so by undertaking some or all of the following steps:

1. Coordinate an internal working group.
2. Identify all publicly owned and soon to be received vegetated stormwater assets in the local government area. Capturing information on privately owned assets is time-effective and will support efforts to ensure that private assets are maintained (see Section 2.8).
3. Assess the condition of all publicly owned vegetated stormwater assets.
4. Use maintenance cost unit rates (see Section 3.2.1) to estimate the required maintenance (and rectification) budget.
5. Determine the internal department most suited to be the asset owner and receive the maintenance (and rectification) budget.
6. Make a budget bid.

3.2.3 Methods to reduce maintenance costs

Individual vegetated stormwater assets are not expensive to maintain. Regular proactive maintenance retains assets in good condition for little cost. However, as asset bases grow, overall maintenance program costs are not insignificant. A well-designed maintenance program implements strategies to reduce long-term costs.

Strategies to reduce maintenance costs for vegetated stormwater assets include:

1. **Prioritising maintenance over rectification:** While costs vary, it is approximately 10 times cheaper to maintain a vegetated stormwater asset for one year than it is to rectify a failed asset. Maintenance programs should focus on proactively maintaining assets that are already in good condition. Only when all good condition assets are being regularly maintained should money be spent rectifying failed assets. The only exception is where there is an overriding need to rehabilitate a particular failed asset. Such needs might relate to public safety, flood conveyance, environmental protection (see Section 2.6), or preventing an identified problem from getting worse, further degrading the asset and increasing rectification costs.
2. **Prioritising simple but regular maintenance:** When vegetated stormwater assets are well designed and constructed, the issues that require maintenance typically arise slowly over time. Prioritising simple, regular maintenance allows issues to be identified early and before they develop into bigger or more complex problems, reducing the cost of rectification.
3. **Prioritising low-maintenance design and planting styles:** Vegetated stormwater asset design and planting style greatly influence maintenance costs. For example, bioretention basins planted with both canopy and understorey species are over 80% cheaper to maintain than similar basins planted with only understorey species (*Guide to the Cost of Maintaining Bioretention Systems* (Water by Design)) (Figure 13). Local governments should ensure that all new vegetated stormwater assets implement low-maintenance design and planting styles, and that opportunities are sought to transition existing assets to these styles. A good example of low-maintenance bioretention design is *Manningham City Council's Zero Additional Maintenance Water Sensitive Urban Design* (ZAM WSUD) program (Manningham City Council, 2017).

Photo: Jack Mullaly

***Figure 13** A good condition bioretention system requiring little maintenance.*

3.3 Maintenance case studies

Four case studies are provided to demonstrate typical maintenance of vegetated stormwater assets:

- **Case study 1** – Bioretention basin vegetated with understorey species.
- **Case study 2** – Bioretention basin vegetated with canopy and understorey species.
- **Case study 3** – Streetscape bioretention.
- **Case study 4** – Constructed wetland.

All are real sites drawn from a local government area in South East Queensland.

3.3.1 Case study 1 – Bioretention basin vegetated with understorey species

This bioretention basin is typical of many throughout Australia. Constructed in 2018 and planted in 2021, it has a filter media area of 1200 m^2 and is located within the base of a larger 6,700m^2 detention basin. The basin:

- is mostly densely vegetated with understorey plants, primarily *Lomandra* sp. and *Imperata cyclindrica* (Figure 14). Some bare patches exist where weeds have been removed.
- contains a coarse sediment forebay, often observed to be full of sediment.
- was planted prior to house building being completed and has more sediment than average on the filter media surface.
- has subsidence in one portion of the filter media.
- receives a base flow for at least a few days after rain.

The asset is in moderate condition and considered to function moderately.

Regular maintenance consists mainly of weeding, litter picking and vegetation management/ trimming if required. This occurs eight times per year. The coarse sediment forebay is cleaned twice per year, separately from other maintenance. These maintenance activities and frequencies are typical of bioretention basins vegetated with understorey plants, regardless of the presence of further defects.

To date no major rectifications have occurred. To restore full functionality of the system, rectification is likely to include:

- Repairing the subsidence in the filter media.
- Installation of a simple low flow diversion to bypass base flows around the filter media.
- Replanting of the bare patches if the *Imperata cyclindrica* does not colonise them naturally.

The sediment accumulation on the system surface should be monitored to determine if any action is required.

Photo: Jack Mullaly

Figure 14 *Bioretention basin with understorey species.*

3.3.2 Case study 2 – Bioretention basin vegetated with canopy and understorey species

This bioretention basin is an example of a resilient, low-maintenance asset (refer to Section 3.2.3). It has a filter media area of approximately 335 m^2 and is vegetated with both canopy (*Casuarina* sp.) and understorey (*Lomandra* sp.) plants. It was constructed in 2011 (Figure 15) and planted in 2014. It contains a coarse sediment forebay.

The original plant list was not available at the time of writing, but aerial photographs suggest that the system was planted with both canopy and understorey species, presumably the Casuarina sp. and Lomandra sp. now present in the system.

The coarse sediment forebay is cleaned twice per year. The only other maintenance that the system receives is sporadic litter removal. No vegetation management has been required since the system was established. The established canopy and understorey, along with dense plant litter coverage across the filter media surface suppresses weed growth to such an extent that weed management is not required (Figure 16). Due to its self-sustaining nature, this system costs very little to maintain.

Photo: Jack Mullaly

__Figure 15__ The basin shortly after construction in 2011.

Photo: Jack Mullaly

__Figure 16__ The current condition of the bioretention basin in 2026.

3.3.3 Case study 3 – Streetscape bioretention

This residential subdivision includes more than two dozen streetscape bioretention systems. The size varies, but filter media areas of between 7 m^2 and 25 m^2 are typical. They were constructed in 2018 and planted in either late 2020 or early 2021. Filter media vegetation is generally monocultures of *Lomandra* sp. with typical landscape planting of the batters (Figure 17). Each system contains a small coarse sediment forebay (Figure 18).

Each system receives eight maintenance visits per year, consisting of weeding, litter picking and vegetation management/trimming if required. The coarse sediment forebay is cleaned on each visit. Owing to the size of each forebay, this is likely done by hand with a shovel. Because these systems are located in the streetscape, aesthetics is a greater focus of maintenance activities than for other, less visible systems. Some of these systems have previously been damaged by cars and required rectification.

Photo: Jack Mullaly

***Figure 17** Dense vegetation on the batters and filter media.*

Photo: Jack Mullaly

***Figure 18** Coarse sediment forebay within a streetscape system.*

3.3.4 Case study 4 – Constructed wetland

This system is a large, constructed wetland located in a park within a residential subdivision. It was planted in 2018 and became a Council asset in 2022. The macrophyte zone is approximately 13,200 m^2. Figure 19 shows the asset shortly before handover to the local council.

Maintenance occurs eight times per year and consists of weed management and litter removal on the batters. Occasionally weeds and litter are removed manually from the macrophyte zone by crews entering the waterbody in waders. The system remains well vegetated and is considered highly functional (Figure 20), although minor vegetation loss may have occurred from the macrophyte zone gradually over time.

Photo: Nic Smith

Figure 19 *Dense vegetation cover in 2021 (shortly before handover to council).*

Photo: Nic Smith

Figure 20 *Continued good condition in 2025 (shortly after Ex-Tropical Cyclone Alfred).*

4 Recording inspections and maintenance

4.1 Overview

Use the checklists in this section when undertaking inspections and maintenance to record the condition of assets (by comparing the state of the asset against the performance indicators), the maintenance undertaken, and any additional maintenance or rectification that may be required.

The checklists are structured in the order that the inspection is likely to be undertaken, starting with an inspection of the surroundings and then moving on to specific elements of the asset (e.g. inlet, forebay, batters, etc).

Identify the need for maintenance by comparing the state of the asset against the performance indicators. The performance indicators are quantitative measures that inspectors and maintenance crews can visually assess to determine if vegetated stormwater assets are likely to be functioning properly. Maintenance is required when one or more performance indicators are not met. Refer to Section 3 for guidance on how to undertake maintenance activities and when to refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

Determining vegetation cover can be difficult in large bioretention systems and wetlands, particularly where it is difficult to see the inner areas of the asset due to dense vegetation along the margins. In these cases, it may be necessary to survey the asset from various points.

4.1.1 Water quality monitoring

Water quality monitoring of vegetated stormwater assets can provide useful information on asset performance. However, it is **not recommended** as a part of normal asset management or maintenance activities because it is complex and very costly to perform in a rigorous manner. When it is not performed rigorously (e.g. simple grab sampling), it produces misleading results. This is due to how treatment occurs within vegetated stormwater assets and the natural variability of pollution within stormwater.

If asset owners do want to perform water quality monitoring of their assets, the recommended approach is to select a discrete number of assets in a particular area and seek specialist advice about sampling location, type, and frequency to ensure the results can be extrapolated to other similar assets.

Useful water quality monitoring techniques include:

- **Manual dosing**: Systems are dosed with synthetic stormwater. Inflow and outflow rates, volumes, and pollutant concentrations are recorded to allow treatment performance to be calculated in terms of both pollutant concentration and total loads. This method can only be used on small systems, as the volumes of water required for testing larger systems are prohibitively big. It is also important to note that synthetic stormwater does not perfectly replicate real stormwater, which may influence calculated treatment performance.
- **Continuous monitoring**: Automated monitoring equipment is installed on both the inlet and outlet of the system. Inflow and outflow rates, volumes, and pollutant concentrations are recorded for multiple storm events. Treatment performance can then be calculated in terms of both pollutant concentration and total loads. This approach is the gold standard for monitoring vegetated stormwater asset treatment performance, but it is expensive to set up and operate and not all inlets and outlets are suitably designed to accommodate monitoring equipment.

4.2 Inspection and maintenance checklist for swales

For bioretention swales, use the checklist for bioretention systems (Section 4.3).

ASSET TYPE	Swale	ASSET ID
Location		
Date		
Date of last rainfall		Weather
Officer name		

Swale plan

Insert diagram or plan of the asset showing key features (e.g. locations of inlet, outlet, overflow).

Additional information	
Time taken to complete inspection or maintenance	
Photos of site (explanatory notes)	1. 2. 3. 4. 5. 6.
General comments and sketches	
Officer signature	

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
SURROUNDS				
Damaged or removed structures (e.g. traffic bollards)	No damage that poses a risk to public safety or structural integrity.			
INLET				
Erosion	Inlet is structurally sound and there is no evidence of erosion or subsidence/settlement.			
Damaged or removed structures (e.g. pit lids or grates)	No damage that poses a risk to public safety or structural integrity.			
Sediment, litter, or debris	No blockage.			
BATTER SLOPES AND BASE INVERT				
Erosion	Minor erosion only that does not pose a risk to public safety or structural integrity and would not worsen if left unattended.			
Sediment	Minor amount of sediment accumulated.			
Surface ponding or boggy conditions	No surface ponding or boggy areas.			
Litter	Maximum 1 piece litter per 4 m^2			

Unusual odours, colours, or substances (e.g. oil and grease)	None detected			
Vegetation	Minimum 80% vegetation cover (minimal bare batches); 100% cover if turfed			
	Plants healthy and free from disease			
Weeds	No prohibited/restricted weeds (or they are controlled)			
	Maximum 10% cover of weeds			
Erosion	Outlet is structurally sound and there is no evidence of erosion or subsidence/settlement			
Damaged or removed structures (e.g. pit lids or grates)	No damage that poses a risk to public safety or structural integrity			
Sediment, litter, or debris	No blockage			

* 1 – PI met; 2–PI met after maintenance activity undertaken; 3 – Additional maintenance needed; 4 – Rectification may be needed; NI – not inspected; NA – not applicable.

** Quantify where possible (e.g. amount of sediment or litter removed).

4.3 Inspection and maintenance checklist for bioretention systems

ASSET TYPE	Bioretention	ASSET ID
Location		
Date		
Date of last rainfall		Weather
Officer name		

Bioretention plan

Insert diagram or plan of the asset showing key features (e.g. locations of inlet, outlet, and overflow).

Additional information	
Time taken to complete inspection or maintenance	
Photos of site (explanatory notes)	1. 2. 3. 4. 5. 6.
General comments and sketches	
Officer signature	

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
SURROUNDS				
Damaged or removed structures (e.g. traffic bollards)	No damage that poses a risk to public safety or structural integrity.			
INLET				
Erosion	Inlet is structurally sound and there is no evidence of erosion or subsidence/settlement.			
Damaged or removed structures (e.g. pit lids or grates)	No damage that poses a risk to public safety or structural integrity.			
Sediment, litter, or debris	No blockage.			
COARSE SEDIMENT FOREBAY (IF PRESENT)				
Erosion	Minor erosion only that does not pose a risk to public safety or structural integrity and would not worsen if left unattended.			
Sediment	Coarse sediment forebay <75% full and no litter.			
BATTER SLOPES AND BASE INVERT				

Erosion	Minor erosion only that does not pose a risk to public safety or structural integrity and would not worsen if left unattended.			
Crust of fine sediment	No surface crusting.			
Depressions or mounds	No surface depressions or mounds > 100 mm.			
Hydraulic conductivity or permeability* **	Filter media is draining freely (water is not ponded on the surface for more than 12 hours after rainfall and there is no obvious impermeable or clay-like surface on the filter media).			
Underdrains/cleanout points	Cleanout points not damaged and end caps securely in place.			
Litter	Maximum 1 piece of litter per 4 m^2.			
Unusual odours, colours, or substances (e.g. oil and grease)	None detected.			
Vegetation	Minimum 95% vegetation cover (minimal bare patches).			
	Plants healthy and free from disease.			
	Average plant height > 500 mm.			

Algal or moss growth	Maximum 10% of surface covered in algae.			
	No moss growth.			
OUTLET (OVERFLOW WEIR, PIPE, OR OUTFALL)				
Erosion	Outlet is structurally sound and there is no evidence of erosion or subsidence/settlement, including around edges of rock protection or toe of weir for large systems.			
Damaged or removed structures (e.g. pit lids or grates)	No damage that poses a risk to public safety or structural integrity.			
Sediment, litter or debris	No blockage.			
Outlet freely draining to receiving drainage or waterway	No downstream impediments to the release of water, no erosion or damage to the outfall structure, and no evidence of malfunction (e.g. excessive sediment accumulated).			

* 1 – PI met; 2 – PI met after maintenance activity undertaken; 3 – Additional maintenance needed; 4 – Rectification may be needed; NI – not inspected; NA – not applicable.

** Quantify where possible (e.g. amount of sediment or litter removed).

*** Presence of *Typha sp.* is an indicator of poorly draining filter media.

4.4 Inspection and maintenance checklist for constructed wetlands

Use the sediment basin checklist for inspecting and maintaining the inlet zone of a wetland.

ASSET TYPE	Constructed wetland	ASSET ID
Date		
Date of last rainfall		Weather
Officer name		
Wetland plan *Insert diagram or plan of the asset showing key features (e.g. locations of inlet, outlet, overflow, and normal water level)*		

Additional information	
Time taken to complete inspection or maintenance	
Photos of site (explanatory notes)	1. 2. 3. 4. 5. 6.
General comments and sketches	
Officer signature	

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
SURROUNDS				
Damaged or removed structures (e.g. traffic bollards)	No damage that poses a risk to public safety or structural integrity.			
INLET				
Erosion	Inlet is structurally sound and there is no evidence of erosion or subsidence/settlement.			
Damaged or removed structures (e.g. pit lids or grates)	No damage that poses a risk to public safety or structural integrity.			
Sediment, litter, or debris	No blockage.			
BATTER SLOPES AND BASE INVERT				
Erosion	Minor erosion only that does not pose a risk to public safety or structural integrity and would not worsen if left unattended.			
Depressions or mounds	No surface depressions or mounds > 100mm.			
Isolated pools of water	No isolated pools/depressions that could provide mosquito habitat.			

Litter	Maximum 1 piece of litter per 4 m^2.			
Unusual odours, colours, or substances (e.g. oil and grease)	None detected.			
Accumulated sediment*	No visible coarse sediment accumulated.			
Water levels	During dry conditions, the water level is not more than 0.3 m below the normal level.			
Vegetation	Minimum 80% vegetation cover on batters and in water up to 300 mm deep (higher if the vegetation provides a public exclusion/safety role).			
	Average plant height > 500 mm above normal water level.			
	Plants healthy and free from disease.			
Weeds (emergent, floating, or submerged)	No prohibited/restricted weeds (or they are controlled).			
	Maximum 10% cover of weeds.			
Algal mats	Maximum 10% cover of algal mats on two consecutive inspections.			
OUTLET (RISER OVERFLOW WEIR, PIPE OR OUTFALL)				

Erosion	Outlet is structurally sound and there is no evidence of erosion or subsidence/settlement.			
Damaged or removed structures (e.g. pit lids or grates)	No damage that poses a risk to public safety or structural integrity.			
Sediment, litter, or debris	No blockage.			
Downstream outfall	No downstream impediments to the release of water, no erosion or damage to the outfall structure, and no evidence of malfunction (e.g. excessive sediment accumulated).			

* 1 – PI met; 2 – PI met after maintenance activity undertaken; 3 – Additional maintenance needed; 4 – Rectification may be needed; NI – not inspected; NA – not applicable.

** Quantify where possible (e.g. amount of sediment or litter removed).

*** Monitor the rate of accumulation by checking sediment levels at least once per year. This may involve establishing one or more reference points within different zones of the wetland. Where sediment depths are greater than 150 mm, a bathymetric survey of the wetland may be required to determine the full extent of accumulation.

4.5 Inspection and maintenance checklist for sediment basins

This checklist is for permanent sediment basins, which are typically used upstream of wetlands or large bioretention systems as inlet ponds. It does not apply to temporary sediment basins associated with sediment control activities during construction activities.

ASSET TYPE	Sediment basin	ASSET ID
Date		
Date of last rainfall		Weather
Officer name		

Wetland plan

Insert diagram or plan of the asset showing key features (e.g. locations of inlet, outlet and overflow and normal water level)

Additional information	
Time taken to complete inspection or maintenance	
Photos of site (explanatory notes)	1. 2. 3. 4. 5. 6.
General comments and sketches	
Officer signature	

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
SURROUNDS				
Damaged or removed structures (e.g. fences)	No damage that poses a risk to public safety.			
INLET				
Erosion	Inlet is structurally sound and there is no evidence of erosion or settlement.			
Damaged or removed structures (e.g. pit lids or grates)	No damage that poses a risk to public safety or structural integrity.			
Sediment, litter, or debris	No blockage.			
BATTER SLOPES				
Erosion	Minor erosion only that does not pose a risk to public safety or structural integrity and would not worsen if left unattended.			
Depressions or mounds	No surface depressions or mounds > 100mm.			
Isolated pools of water	No isolated pools/depressions that could provide mosquito habitat.			
Litter	No litter.			

Vegetation	Minimum 80% vegetation cover across full batter slope (minimal bare patches). Average plant height > 500 mm. Plants healthy and free from disease.			
Weeds (emergent, floating or submerged)	No prohibited/restricted weeds (or they are controlled).			
	Maximum 10% cover of weeds.			
OPEN WATER				
Sediment	Minimum 1 m of water above accumulated sediment.			
Litter	No floating litter.			
Unusual odours, colours, or substances (e.g. oil and grease)	None detected.			
Weeds (emergent, floating, or submerged)	Maximum 10% cover of weeds.			
Algal mats	Maximum 10% cover of algal mats on two consecutive inspections.			
OUTLET (OVERFLOW WEIR, PIPE OR OUTFALL)				

Erosion	Outlet is structurally sound and there is no evidence of erosion or settlement.			
Damaged or removed structures (e.g. pit lids or grates)	No damage that poses a risk to public safety risk or structural integrity.			
Sediment, litter, or debris	No blockage.			
Downstream outfall	No downstream impediments to the release of water, no erosion or damage to the outfall structure, and no evidence of malfunction (e.g. excessive sediment accumulated).			

* 1 – PI met; 2 – PI met after maintenance activity undertaken; 3 – Additional maintenance needed; 4 – Rectification may be needed; NI – not inspected; NA – not applicable.

** Quantify where possible (e.g. amount of sediment or litter removed).

5 References

Auld, B.A. and Medd, R.W. (1992) Weeds: An illustrated botanical guide to the weeds of Australia, Inkata Press, Australia.

Department of Environment and Science (2019) *Waste Management and Resource Recovery Strategy*, State of Queensland

Department of Environment, Science and Innovation (2020) *Disposal permit to remove, treat and dispose of contaminated soil guideline*, State of Queensland

Department of Natural Resources (1997) *Weed pocket guide*, State of Queensland.

Department of Primary Industries (2025) *Prohibited invasive plants of Queensland*, State of Queensland

Department of Primary Industries (2025) *Restricted invasive plants of Queensland*, State of Queensland

Lamp, C and Collet, F. (1989) *Field Guide to Weeds in Australia* (third edition), Inkata Press, Australia.

Manningham City Council (2017*) Zero Additional Maintenance Water Sensitive Urban Design Handbook*, https://www.clearwatervic.com.au/user-data/resource-files/zam-wsud-handbook-with-attachments.pdf

Ocean Protect (2025) *Water Sensitive Urban Design Maintenance Compliance Framework*.

Parsons, W.T. and Cuthbertson E.G. (1992) *Noxious Weeds of Australia*, Inkata Press, Australia.

Sainty, G.R. and Jacobs, S.W.L. (2003) *Waterplants in Australia*, Sainty and Associates.

Water by Design (2006) *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland*, Healthy Waterways Ltd, Brisbane.

Water by Design (2012) *Rectifying Vegetated Stormwater Assets*, Healthy Waterways Ltd, Brisbane.

Water by Design (2015) *Guide to the Cost of Maintaining Bioretention Systems*, Healthy Waterways Limited, Brisbane.

Water by Design (2017) *Wetland Technical Design Guidelines*, Healthy Land & Water, Brisbane.

Water by Design (2022) *Guidelines for the construction and establishment of bioretention systems and wetlands*, Healthy Land & Water, Brisbane.

Water by Design (2023) *Improving the Biology of Bioretention Systems*, Healthy Land & Water, Brisbane.

Water by Design (2026) *Bioretention Technical Design Guidelines*, Healthy Land & Water, Brisbane.

APPENDIX A: Assessing sediment contamination and disposal needs

Sediment removed from vegetated stormwater assets may or may not be contaminated depending on the method of capture and activities in the upstream catchment. Where sediment is not contaminated, opportunities for beneficial reuse should be sought.

The Queensland Waste Disposal Levy (commenced in 2019) supports the Queensland Waste Management and Resource Recovery Strategy and aims to:

- Reduce the amount of waste going to landfill.
- Encourage waste avoidance.
- Provide a source of funding to enable better resource recovery practices.
- Provide certainty and security of feedstocks for advanced technology.
- Facilitate industry investment in resource recovery infrastructure.

With the introduction of the waste levy, there is a financial incentive for local governments to divert non-contaminated sediment collected from vegetated stormwater assets away from landfill for beneficial reuse.

While sediment is often classified as waste due to its mixed or uncertain urban origin, it may be reclassified as a resource if it is:

- Proven to be uncontaminated.
- Stored with documented intent for beneficial reuse.
- Used lawfully and in an environmentally safe manner.

Local governments should develop processes and strategies to achieve this goal.

At a minimum, this requires consideration of:

- Potential sources of contamination within the catchment (e.g. sediment from a residential catchment is less likely to be contaminated than that from an industrial catchment).
- The sediment capture method (e.g. the coarse sediment captured within a bioretention coarse sediment forebay is less likely to be contaminated than the coarse and fine sediment captured in a sediment basin or wetland).
- The method of collection (e.g. the potential for contaminated sediment from one asset collected in the same truck as clean sediment from another asset to contaminate the entire load).
- Methods of beneficial reuse.

Where a local government has not developed a strategy for the beneficial reuse of sediment from vegetated stormwater assets, any sediment removed must be disposed of appropriately. Figure 21 shows the steps involved in testing and disposing of sediment from vegetated stormwater assets.

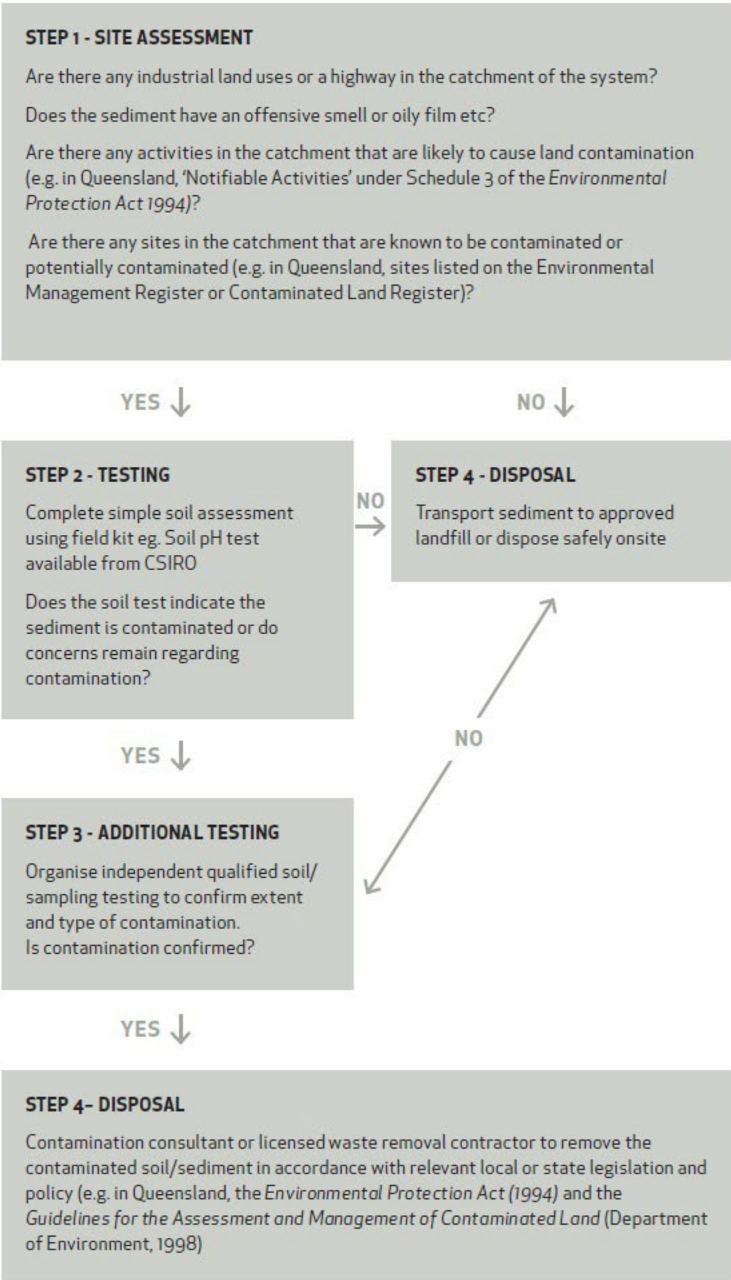


Figure 21 *Testing and disposing of sediment from vegetated stormwater assets.*

For additional information on sediment contamination and disposal, please refer to any locally relevant legislation and guidelines.

APPENDIX B: Identifying and managing weeds

Correctly identifying, controlling, and eradicating weeds can result in considerable time and cost savings. Therefore, it is critical that all inspection and maintenance staff can correctly identify weed species.

RESOURCES

A number of resources can be used for identifying weeds.

Field guides and books

- Field Guide to Weeds in Australia (Lamp and Collet, 1989).
- Noxious Weeds of Australia (Parsons and Cuthbertson, 1992).
- Waterplants in Australia (Sainty and Jacobs, 2003).
- Weeds: An illustrated botanical guide to the weeds of Australia (Auld and Medd, 1992).
- Weed pocket guide (Department of Natural Resources, 1997).

Online resources

- Environmental Weeds of Australia (Lucid Central) keys.lucidcentral.org/search/environmental-weeds-of-australia/
- Weeds to wack (Save Our Waterways now) sown.com.au/weeds-to-whack/
- WeedScan (Weeds Australia) https://weedscan.org.au/
- Weeds of National Significance (Weeds Australia) weeds.org.au/lists/established/
- Weed identification (Brisbane City Council) weeds.brisbane.qld.gov.au

The Australian Government's 'Weeds of National Significance' (WONS) classification includes weed species that have degraded large areas of Australia's landscape and are managed at national level to ensure consistent management across states.

State legislation may also identify weeds.

In Queensland, the *Biosecurity Act 2014* classifies plant species that have or could have serious economic, environmental, or social impacts as either prohibited or restricted weeds, with restricted weeds further divided into four categories. A restricted plant may be assigned more than one category.

Prohibited weeds: A range of invasive plants that have the potential to have significant impacts and are currently not present or known to be present in Queensland. It is an offence to deal with prohibited matter or fail to report its presence. For further information refer to *Prohibited invasive plants of Queensland* (Department of Primary Industries, 2025)

Restricted weeds: A range of invasive plants that are present in Queensland. These invasive plants have significant adverse impacts. It is desirable to manage them and prevent their spread. Everyone is required to take all reasonable and practical measures to minimise the biosecurity risks associated with restricted plants under their control. The *Biosecurity Act 2014* identified 7 classes of restricted material. Of these, the following classes relate to weeds:

- Restricted category 2 – A person must report the invasive plant within 24 hours.
- Restricted category 3 – A person must not distribute the invasive plant either by sale or gift, or release it into the environment.
- Restricted category 4 – A person must not move the invasive plant.
- Restricted category 5 – A person must not keep the invasive plant.

For further information refer to *Restricted invasive plants of Queensland* (Department of Primary Industries, 2025).

Local governments may have additional weed classifications to control or prevent the spread of potentially invasive weed species that pose a threat to local ecosystems.

Common weeds species

Common weed species found in stormwater treatment assets are shown in Table 4

Table 4 *Common weed species found in stormwater treatment assets.*

Weed species	Common name	Life form	Where found*	Status**
Hymenachne amplexicaulis	Olive hymenachne	Emergent	SB, W, SW	Restricted category 3
Limnocharis flava	Limnocharis	Emergent	SB, W	Restricted category 2, 3, 4 and 5
Sagittaria platyphylla	Sagittaria	Emergent	SB, W	Restricted category 3
Alternanthera philoxeroides	Alligator weed	Emergent	SB, W, SW	Restricted category 3
Hygrophila costata	Hygrophila	Emergent	SB, W	Restricted category 3
Gymnocoronis spilanthoides	Senegal tea	Emergent	SB, W	Restricted category 3
Heteranthera reniformis	Kidney leaf	Emergent	SB, W	
Ludwigia peruviana	Peruvian primrose	Emergent	SB, W, B	Prohibited
Typha domingensis/ orientalis	Cumbungi	Emergent	W, SW	
Salvinia molesta	Salvinia	Floating	SB, W	Restricted category 3
Eichhornia crassipes	Water hyacinth	Floating	SB, W	Restricted category 3
Pistia stratoites	Water lettuce	Floating	SB, W	Restricted category 3
Nymphaea mexicana	Yellow waterlily	Floating attached	SB, W	
Nymphaea caerulea	Cape blue waterlily	Floating attached	SB, W	
Urochloa mutica	Para grass	Semi-aquatic	SB, W, SW	
Myriophyllum aquaticum	Parrot's feather	Submerged	SB, W	
Cabomba caroliniana	Cabomba	Submerged	SB, W	Restricted category 3
Egeria densa	Dense water weed	Submerged	SB, W	
Elodea canadensis	Elodea	Submerged	SB, W	
Chloris gayana	Rhodes grass	Terrestrial	SB, W, B, SW	
Desmodium uncinatum	Silverleaf desmodium	Terrestrial	BR, SW, B	
Echinochloa crus-galli	Barnyard grass	Terrestrial	SB, W, B, SW	
Ipomoea cairica	Morning glory	Terrestrial	SB, W, B, SW	

Panicum maximum	Guinea grass	Terrestrial	SB, W, B, SW	
Paspalum mandiocanum	Broad-leaved paspalum	Terrestrial	SB, W, B, SW	
Pennisetum clandestinum	Kikuyu	Terrestrial	B, SW	
Cynodon dactylon	Common couch	Terrestrial	W, B, SW	
Paspalum dilatatum	Paspalum	Terrestrial	W, B, SW	
Setaria sphacelata	Pigeon grass	Terrestrial	B, SW	
Ligustrum lucidum	Broad-leaf privet	Terrestrial	SB, W, B, SW	Restricted category 3
Ligustrum sinense	Chinese privet	Terrestrial	SB, W, B, SW	Restricted category 3
Schinus terebinthifolius	Broad-leaf pepper tree	Terrestrial	SB, W, B, SW	Restricted category 3
Cyperus eragrostis	Umbrella sedge	Emergent	W, SW	
Celtis sinensis	Chinese celtis	Terrestrial	W, B, SW	Restricted category 3
Pennisetum setaceum	African fountain grass	Terrestrial	B, SW	
Conyza sp.	Fleabane	Terrestrial	B, SW	
Setaria sphacelata	Setaria	Terrestrial	SB, W, B, SW	
Sphagneticola trilobata	Singapore daisy	Terrestrial	B, SW	Restricted category 3
Tradescantia fluminensis	Wandering dew	Terrestrial	SB, W, B, SW	

* SB – sediment basin, W – constructed wetland, B – bioretention system, and SW – Swale.

** Under the Queensland *Biosecurity Act 2014.*

Emergent

Emergent aquatic plants are rooted in the substrate and have their stem, leaves, and flowers protruding above the water surface. Emergent plants grow in water depths ranging from +0.1 m to -0.7 m and are generally well adapted to regular drying and wetting phases throughout the year.

Individual or small clumps of emergent plants can be controlled using physical removal methods, such as hand pulling, raking, or grubbing. Many emergent weeds have rhizomatous root systems and care must be taken to ensure that the entire root system is completely removed, as the plant can re-establish from the remaining root fragments.

Mechanical harvesters can also be used for temporary control. However, emergent weeds such as alligator weed reproduce vegetatively from stem fragmentation and disturbance to the floating or emergent foliage may inadvertently help to spread the weed to adjoining areas.

Emergent plants such as *Typha sp*. can be effectively controlled by cutting the stems below the water surface. This removes the oxygen supply to the roots, resulting in anaerobic respiration and ultimately the death of the plant.

The use of appropriate, non-residual herbicides is also an effective control method for emergent plants, particularly where large isolated clumps may have developed within sediment basins or constructed wetlands.

Herbicides may be directly applied to individual plants using rope-wick applicators or hand applied using a sponge and rubber gloves. Foliar application of herbicides is generally more appropriate for controlling large clumps of emergent weeds. Care must be taken to ensure that the herbicide is directed onto the weed foliage and that any adjacent open water areas or non-target plants are avoided.

 Photo: Geoff Sainty	**Alligator weed** (*Alternanthera philoxeroides*) Perennial rhizomatous herb that may grow as a terrestrial, emergent, or free-floating aquatic plant. Large mats of interwoven stems often form along the margins of constructed wetlands and may extend over the water surface. Distinguished by hollow stems with opposite leaves. Has ball-shaped white flower heads on stalks to about 9 cm long, originating from the leaf-stem nodes. Note: *Alternanthera philoxeroides* can easily be confused with *Ludwigia* sp. (water primrose) and *Persicaria* sp. (smartweeds). **Flowering:** December-April but will vary with location in Queensland. **Reproduction:** Viable seed not recorded in Australia. Reproduces vegetatively via stem fragmentation, which can occur: • Naturally at the end of the growing season from the feeding habit and in reaction to the feeding habit of the flea beetle *Agasicles hygrophila*. • Due to wave action or physical damage by boats and mowers. Stem fragmentation can be increased by herbicide use. **Control:** Physical removal, chemical control, biological control.
 Photo: Geoff Sainty	**Glush weed** (*Hygrophila costata*) Semi-aquatic perennial herb that grows to 1 m high. May also scramble up through taller vegetation. Distinguished by 4-angled stems, leaves in opposite pairs, and white flowers to 1 cm long that grow in clusters at the leaf-stem junction. **Flowering:** All year. **Reproduction:** Spreads by seeds and vegetatively by rooting at the nodes and fragments. Can produce roots from severed leaves. **Control:** Physical removal, chemical control.

 Photo: Jason Sonneman	**Para grass** (*Urochloa mutica*) Perennial grass that can form extensive floating mats over wetlands. Stolons (runners) to 4 m and growth to 2 m high. Leaves to 2 cm wide, leaf sheath with dense thick hairs. Seed head terminal with 5-20 spikelets, each 2-8 cm long. Distinguished by leafy spreading habit, branching at right angles to the stem, and hairy leaf sheaths and nodes. **Flowering:** Most of the year, depending on location. **Reproduction:** Spreads by seeds and vegetatively by widely creeping stolons and fragments. Also spread by use as a pasture species. **Control:** Physical removal, chemical control.
 Photo: Geoff Sainty	**Cumbungi** (*Typha orientalis, T. domingensis*) Erect native perennial herb with flat or slightly rounded leaves (sometimes spongy) to 3 cm wide and growing to 3 m tall. Flower head is a dense spike above a larger spike of female flowers. *T. domingensis* (narrow-leaf cumbungi) is generally shorter than *T. orientalis* (broad-leaf cumbungi) and has a smaller, narrower seed spike. *T. domingensis* is also more salt tolerant than *T. orientalis*. *Typha* can grow in water depths to 1.5 m and often forms dense stands that outcompete and reduce species diversity within wetland vegetation. **Flowering:** Mostly during summer. **Reproduction:** Spreads by seeds and vegetatively from branching rhizomes (runners). **Control:** Mechanical removal, slashing, chemical control. Effective control of small *Typha* infestations can be achieved by cutting the plants 15 cm below the water surface in autumn.

Floating weeds

Floating weeds are unattached, free-floating plants that grow on the surface of a water body. They are generally characterised by extensive, fibrous root systems that bind together, enabling the plant to develop a dense mat.

Under suitable conditions, floating aquatic weeds rapidly form dense mats over the water surface, reducing light penetration and oxygen exchange. The decomposing plant material removes oxygen from the water, which can result in poor water quality and severe impacts to aquatic fauna.

Small infestations of floating aquatic weeds can be physically removed by hand using rakes and floating booms. Larger infestations may need to be removed using mechanical harvesters or excavators. Physical removal is often expensive but also has the advantage of removing a nutrient load from the water body, provided it is regularly carried out. All removed plant material should be relocated away from the water body and buried, composted, or disposed to landfill.

Herbicides are a cost-effective control method when dealing with large infestations. However, sinking and decomposing vegetation is likely to contribute to water quality problems.

A number of biological control methods have been successfully introduced to control floating aquatic weeds, including salvinia, water hyacinth, and water lettuce. Refer to the plant descriptions for further information on specific biological controls.

Eradication of floating aquatic weeds is difficult. All initial control treatments must be followed with vigilant monitoring and repeated treatments where necessary.

 Photo: Jason Sonneman	**Salvinia** (*Salvinia molesta*) Free-floating perennial fern with 'leaves' (fronds) in groups of three, consisting of two floating leaves and a submerged modified leaf that functions as a root. Salvinia actively grows throughout the year and is difficult to eradicate once established in a water body. **Flowering:** *Salvinia molesta* is a fern, so it does not flower. Fruiting bodies containing sterile spores that hang from the divided leaf. **Reproduction:** Does not produce fertile spores. Spreads vegetatively by fragmentation. **Control:** Physical removal, chemical control, and biological control. Integrated control strategies that combine both physical removal and chemical control techniques have proven to be effective at eradicating small salvinia infestations. Salvinia weevil (*Cyrtobagous salviniae*) has proved to be extremely effective in controlling large salvinia infestations.
 Photo: Jason Sonneman	**Water hyacinth** (*Eichhornia crassipes*) Free-floating perennial aquatic plant with dark green, erect leaves, including stalk, to 60 cm long and fibrous, feathery roots to 1 m. Plants are distinguished by blue-purple flowers produced on spikes to 15 cm. Some leaves are also characterised by a spongy, swollen base that enables the plant to float. **Flowering:** October-July. **Reproduction:** Spreads by seeds. Daughter plants are produced vegetatively at the ends of the stolons and remain attached to the parent plant until they are broken off by wind or damage. **Control:** Physical removal, chemical control, and biological control. *Eichhornia crassipes* is very difficult to eradicate as the seed may remain viable in sediments for up to 15 years. Physical removal should be undertaken before the plants flower and set seed. Integrated control strategies that combine both physical removal and chemical control techniques have proven to be effective at controlling *Eichhornia crassipes* infestations. The integrated use of two introduced weevil species (*Neochetina eichhorniae* and *Neochetina bruchi*) has proven to be effective in the control of large water hyacinth infestations.

	Two moth species (*Niphograpta albiguttalis* and *Xubida infusella*) have also been introduced, however they have not been as successful as the weevils at controlling water hyacinth populations.
 Photo: Jason Sonneman	**Water lettuce** (*Pistia stratiotes*) Free-floating perennial aquatic plant with ribbed, spongy, velvety leaves that overlap to form a rosette that resembles a small lettuce. The plant extends to 20 cm above the water level and has feathery roots up to 80 cm. The leaves are strongly water repellent due to hairs on the surface. **Flowering:** January-March but will vary with location. **Reproduction:** Spreads by seeds and by vegetative daughter plants on the end of stolons. **Control:** Physical removal, chemical control, and biological control. Two introduced weevil species (*Neohydromonus pulchellus* and *Orchetina bruchi*) have been used successfully to control large infestations. However, effective control by these weevils may take years to achieve.

Submerged weeds

Submerged weeds are aquatic plants that are rooted in the substrate and fully (or almost completely) submerged. These plants are characterised by leaves that are located either below or at the water surface. The leaves and stems have specialised thin-walled cells with large air spaces that provide buoyancy and support. The lack of a waxy cuticle on the plant surface allows for the rapid exchange of water, nutrients, and gas, but also makes the plants highly susceptible to drying if removed from the water for any length of time.

Dense infestations of submerged aquatic plants can be physically removed using hand pulling, raking, or mechanical equipment, but the major submerged weeds quickly regrow unless their roots are removed.

Most submerged plants spread easily from fragments. All stems and roots should be completely removed from the water body, as any residual fragments will result in re-establishment and the potential spread of the weed to downstream water bodies.

Care must also be taken to ensure that rigorous hygiene protocols are followed, so that the weeds are not spread to other water bodies. All removed plant material should be relocated well away from the water body and buried, or dried and burnt.

Most submerged aquatic plants are highly sensitive to drying out. Drawing down the water level in a water body and allowing the substrate to completely dry out can provide effective control.

Herbicides can be used for controlling submerged aquatic plants. The application of herbicides is difficult due to the problems associated with applying chemicals in water and the potential impacts on non-target plant species. Seek advice from the relevant authority if chemical control of submerged plants is being considered.

Small areas of submerged aquatic plants may also be treated by increasing shade. This can be achieved by covering the surface of the water body with a lightproof cover, (such as black plastic sheeting) for a month or more. However, this method is usually impractical.

<table>
<tr>
<td>
Photo: Geoff Sainty</td>
<td>Cabomba (Cabomba caroliniana)

Submerged perennial aquatic plant with slender elongated stems up to 5 m long, surrounded by a dense group of leaves and a well-developed fibrous root system.

Plants may be distinguished by the submerged leaves, which are arranged in opposite groups (whorls) and finely divided into linear segments, forming a fan-shape.

White to pale yellow daisy-like flowers are elevated above the water surface on stalks. Small diamond-shaped floating leaves are also borne on the flowering stalks.

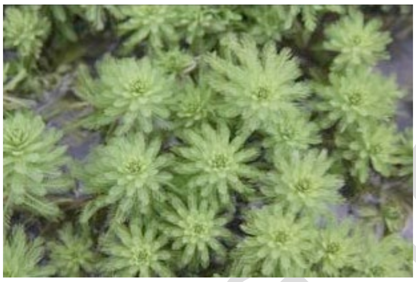
Note: Can easily be confused with Ceratophyllum demersum (a native submerged plant species) and some Myriophyllum species.

Flowering: November-March but will vary with location.

Reproduction: Viable seeds have not been verified. Reproduces vegetatively via dislodged stem fragments.

Control: Physical removal, water level management, and chemical control.

Cabomba caroliniana is extremely difficult to control when introduced to large water bodies.

Drawing down the water level and allowing a water body to completely dry out can provide effective control, but only if the root system is killed.</td>
</tr>
<tr>
<td>
Photo: Jason Sonneman</td>
<td>Parrot’s feather (Myriophyllum aquaticum)

Submerged and emergent perennial plant with spreading stems to 5 m and feathery leaves.

Distinguished by blue-green coloured emergent leaves that form distinctive groups of 4-6 leaves. The emergent leaves have a feathery appearance and are divided into 10-14 linear segments.

Flowering: September-December but will vary with location.

Reproduction: Not known to produce seed. Reproduces vegetatively via stem fragmentation due to wave action or physical damage.

Control: Physical removal, water level management, chemical control.

Physical removal by hand pulling and subsurface cutting can be used to provide temporary control of small infestations.

Integrated strategies, including water level management and chemical control, can be effective in treating large infestations.</td>
</tr>
</table>

Floating attached weeds

Floating attached aquatic plants are rooted to the substrate and have mature leaves floating on the water surface (e.g. waterlilies). Floating attached plants have extensive rhizome systems, from which long stems of up to 5 m and leaves emerge each year. Floating attached plants often form dense stands, and the leaves are often pushed up above the surface of the water.

Floating attached plants can only be eradicated by killing or removing the root system. The roots are strongly bound to the sediments and are not easily dislodged.

Short-term control of floating attached plants can be achieved by cutting the stems below the surface, however the leaves will regrow. Mechanical harvesters can also be used for temporary control.

Rhizomes may be removed from the sediments by hand raking and using dredging equipment. The removal of rhizomes is best undertaken during the summer period when the location of the rhizomes can be detected by the presence of the floating leaves.

The use of herbicides is also an effective method of controlling floating attached plants, particularly where the surface of the water is completely covered with leaves. Care must be taken that the herbicide is directed onto the floating leaves and that any adjacent open water areas or non-target plants are avoided.

 Photo: Jason Sonneman	**African Cape waterlily** (*Nymphaea caerulea*) Distinguished by generally large round leaf blades to 50 cm wide with irregularly spaced teeth around a wavy margin. Showy blue to purple flowers with pointed petal tips. Flowers are located on robust erect stalks above the water. Can be misidentified as *Nymphaea gigantea*, which is an endangered species. **Flowering:** December-April **Reproduction:** Germinates from seed but predominantly reproduces vegetatively from the stolons. **Control:** Physical removal, chemical control.
 Photo: Jason Sonneman	**Yellow waterlily** (*Nymphaea mexicana*) Distinguished by broad elliptic leaves to 25 cm wide with smooth and wavy leaf margins. Produces yellow flowers with pointed petal tips and vertical, knobbly rhizomes. *Nymphaea mexicana* has the potential to cover the water surface and limit the growth of other plants, which in turn reduces the habitat for microorganisms, invertebrates and fish. **Flowering:** October-March but will vary with location. **Reproduction:** Germinates from seed but predominantly reproduces vegetatively from the stolons. **Control:** Physical removal, chemical control.

Terrestrial weeds

Terrestrial plants grow on land and include the majority of living plants. Most terrestrial plants have well-developed root systems and reproduce via flowering. Flowering terrestrial plants are characterised by a range of life forms including herbs (grasses, sedges, rushes, and forbs), shrubs, and trees.

Bioretention systems, swales, and the exposed batter slopes of sediment basins and constructed wetlands are particularly vulnerable to the establishment and ingress of terrestrial weeds.

Terrestrial plants can be either annual or perennial. Annual plants undergo a complete life cycle (germination, flowering, and death) within a year and rely solely upon the annual production of seeds or soil seed stores to persist. Alternately, perennial plants live for more than one year and generally rely on their root systems to sustain the growth of the plant foliage.

Annual weeds are particularly susceptible to control methods that prevent the plants from successfully flowering, as this reduces the seedbank required to re-establish the plants the following year. Strategies that can be used to prevent flowering include physical removal (hand pulling, grubbing, slashing) and chemical control.

Similar control methods may also be used for perennial weeds, which do not rely solely upon the availability of seed to persist. If perennial weeds are physically removed, care must be taken to ensure that the entire root system is removed, as it is possible for the plant to re-establish from the remaining root fragments. This particularly applies to perennial grass species, which are characterised by rhizomatous root systems that enable the plants to rapidly spread and establish daughter plants.

Physical removal methods are generally suitable for isolated plants or small infestations; however, chemical control methods may be necessary for large weed infestations or when woody weeds such as shrubs and trees are present.

Foliar spray and rope-wick application of herbicides are generally suitable for the control of herbs and small shrubs, whereas cut stump and stem injection are effective techniques for applying herbicides to large shrubs and trees. Consideration should also be given to the strategic use of selective herbicides for the removal of weeds. For example, grass-specific herbicides can be used to remove Kikuyu from among native grasses, with minimal damage to the native vegetation.

 Photo: Jason Sonneman	**Broad-leaved paspalum** (*Paspalum mandiocanum*, Syn. *Paspalum wettsteinii*) Perennial grass that is weakly clumped, grows to 1 m tall with spreading leaf blades to 3 cm wide. Seedhead to 12 cm long and with 3-10 branches (racemes). *Paspalum mandiocanum* is a highly invasive plant that prefers moist soils and is shade tolerant. **Flowering:** Mostly during summer. **Reproduction:** Spreads by seed and vegetatively via rhizomes (runners). **Control:** Physical removal, chemical control. Seedlings and small plants are most effectively removed by hand, large infestations will require the use of herbicides.

 Photo: Geoff Sainty	**Guinea grass** (*Panicum maximum*) Tufted perennial grass that grows to 2.5 m tall, with elongated leaf blades to 3.5 cm wide tapering to a long fine point and a rhizomatous root system. Leaves are hairy or hairless. Open seedhead (panicle) to 60 cm long, with numerous branches. Distinguished by short stout rhizome with hairy scale-like leaves and the whorled (group from the same point on the stem) panicle branches. Three varieties are naturalised in Queensland and are now widespread and common on roadsides, stream banks, and cleared land. **Flowering:** Most of the year. **Reproduction:** Spreads by seed and slowly from rhizomes and plants rooting from the nodes. **Control:** Physical removal, chemical control.
 Photo: Jason Sonneman	**Kikuyu** (*Pennisetum clandestinum*) Spreading perennial grass to 50 cm with an extensive rhizome and stolon system. The leaves are bright green, 5-20 cm long and 1 cm wide, with a prominent mid-rib. Flowers are inconspicuous, concealed in the apices of some stolons. *Pennisetum clandestinum* readily invades bare areas of soil or sites subject to frequent disturbance. **Flowering:** Summer. **Reproduction:** Rarely produces seeds. Usually spreads vegetatively from rhizomes, rooting from the nodes or from broken fragments. **Control:** Physical removal, chemical control. Very difficult to eradicate. Small infestations may be removed by hand pulling, however, all rhizomes must be removed for this method to be effective.

 Photo: Geoff Sainty	**Common couch** (*Cynodon dactylon*) Prostrate, mat forming, native perennial grass to 30 cm high, with erect culms and rooting at the nodes. Seedhead comprising a cluster of 2-7 spikelets, each 2-6 cm long. Stems are often flattened with a purple tinge. Readily invades bare areas of soil or sites subject to frequent disturbance. Highly tolerant of extended dry periods due to a deep root system. **Flowering:** Summer. **Reproduction:** Spreads rapidly by seed. Also grows vegetatively via rhizomes and small fragments. **Control:** Physical removal, chemical control. Seedlings and small plants can be removed by hand, however, all rhizomes must be removed for this method to be effective. Difficult to eradicate without the use of herbicides.

APPENDIX C: Maintenance activities

The sections within this appendix describe the following maintenance activities for swales, bioretention systems, constructed wetlands and sediment basins and the defects that they rectify:

- Repairing erosion.
- Unblocking inlets and outlets.
- Removing sediment.
- Removing litter and debris.
- Managing plant litter.
- Harvesting plants.
- Managing mosquitoes.
- Managing birds.
- Managing high or low water levels in a wetland.
- Responding to a paint or fuel spill.
- Replanting.
- Controlling weeds.
- Managing excessive algae in sediment basins and constructed wetlands.
- Managing algal or moss growth on bioretention systems.

Repairing erosion

ISSUE

Erosion in and around vegetated stormwater assets is generally a result of fast flows, poor soil placement or compaction, inadequate vegetation cover, or dispersive soils.

The most common areas for erosion are:

- At the base of a swale or on the surface of a bioretention system.
- On the batter slopes, usually due to lateral inflows to the asset or poor vegetation cover.
- Around inlet structures, due to high velocities.
- At the interface of concrete and soil surfaces, due to water preferentially flowing along the concrete surface.

Figure 22 and Figure 23 show examples of erosion in vegetated stormwater assets.

If left unaddressed, minor erosion may worsen and lead to larger issues such as undermining of structures and channelling of flows, affecting vegetation health.

Photo: Paul Dubowski

***Figure 22** Erosion at the transition between a swale and bioretention system causing ripping of the jute mat.*

Photos: Jason Sonneman

***Figure 23** Erosion at the transition between wetland cells.*

ACTIONS

If the erosion poses a risk to public safety or the structural integrity of the asset (or is likely to worsen if left unaddressed), undertake repairs immediately.

If the erosion is minor, reprofile using hand tools or light machinery to limit damage to adjacent vegetation. Replant using replacements from other parts of the asset or bring in new stock.

Larger washouts may require large machinery, new fill material and plant stock to be imported. When using large machinery, take care not to compact the filter media of a bioretention system. If imported fill is used, it must meet the design specifications (particularly for bioretention systems). If the design specifications are not known, consult the *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Water by Design), *Bioretention Technical Design Guidelines* (Water by Design) or *Wetland Technical Design Guidelines* (Water by Design). Replant once the earthworks are finished.

If an investigation into the source of the erosion is needed (e.g. the erosion is severe or recurring), refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

Unblocking inlets and outlets

ISSUE

The inlets and outlets are the main hydraulic controls.

If they are blocked or not flowing freely:

- The asset may pose a risk to flooding, particularly if there is no alternative high-flow path.
- The vegetation may be at risk of drowning, leading to damage or dieback.
- The volume of water that can be treated will be restricted as inflow will not enter the asset when it is full, causing flows to overflow or pass downstream untreated.

Figure 24 shows examples of blocked outlet pits that are restricting flows.

Photos: Paul Dubowski and Robin Allison

Figure 24 *Litter blocking outlet pits.*

ACTIONS

Remove litter, debris and plant litter by hand or with hand tools such as shovels, forks, and tongs. Special opening tools (e.g. grate/gatic openers) are required for some outlets.

For sediment basins and wetlands, waders or a boat may be required to access the water body.

In extreme cases, machinery may be required.

If blocking persists, refer to *Rectifying Vegetated Stormwater Assets* (Water by Design). An alternative grate may be required or upstream measures may need to be investigated (e.g. checking or installing gross pollutant traps).

Removing sediment

ISSUE

Swales, constructed wetlands and sediment basins

Significant sediment buildup in swales, constructed wetlands, and sediment basins can:

- Smother vegetation.
- Change the surface profile of the asset, influencing flow patterns.

Minor sediment accumulation does not immediately influence asset performance.

Bioretention systems

When managing sediment in bioretention systems, it is useful to distinguish between fine and coarse sediment.

In large quantities, coarse sediment buildup in bioretention systems (Figure 25) can smother vegetation and change the surface profile of the asset, influencing flow patterns. However, provided that bioretention systems are protected from construction phase sediment, most assets will not experience problematic coarse sediment loads during normal operation. Minor coarse sediment buildup in bioretention systems is unlikely to immediately affect asset performance.

Bioretention systems often include coarse sediment forebays to capture coarse sediment in a defined location with maintenance access so that it can be easily removed.

Large loads of fine sediment in bioretention systems can form an impermeable layer on the surface and prevent infiltration. If infiltration in a bioretention system is reduced or not occurring (see Figure 26), stormwater will bypass untreated into the overflow and the media may become boggy. A lack of water will affect the health of the vegetation and boggy conditions can attract mosquitoes and generate unpleasant odours.

Photo: Paul Dubowski

Figure 25 *Sediment accumulated at an inlet.*

Photos: Alan Hoban and Andrew O'Neill

Figure 26 *Bioretention systems with surface blinded by clay-like sediment deposition.*

ACTIONS

If an asset requires cleaning out (see details below) at an unacceptable or unsustainable frequency, refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

Sediment basins

Sediment basins are normally designed to be cleaned out at least once every five years (after construction activity in the catchment has finished). Clean out a sediment basin when there is less than 1 m of water above the accumulated sediment. Complete the works in dry weather, ideally at the end of the dry season.

When removing sediment:

- Complete a sediment contamination and disposal assessment as outlined in Appendix A. In most cases, sediment contamination should not be a concern for disposal. Beneficial reuse options should be sought where possible. If the sediment is contaminated, engage a licensed waste removal contractor, as transporting and disposing of the sediment is subject to local and state regulations.
- Get necessary approvals for the works, including permission to dewater if necessary. Approval to drain the asset may be required for sediment basins and wetlands.
- Lower the water level with a maintenance valve or dewater the asset with a pump in accordance with the procedures of the relevant authority. Divert inflows away from the asset. Where the system receives constant inflows, install a plug in the inlet pipe, pump the water, and clean the asset while holding the water upstream. Dewatering can take 1-2 days depending on the size of the asset and the capacity of the drain or pump. It is important to ensure the dewatering has no adverse environmental effects. A fauna management plan may be required.

- Remove and store plants that will be disturbed so they may be replanted after the sediment is removed.
- Remove the sediment using appropriate machinery.
- Remove sediment from the bottom of the asset. Sediment basins may have a hard base (such as concrete, rocks, or gravel), which indicates the bottom. The design drawings should identify this.
- If a drying (dewatering) area is available, place the sediment in this area to dry (ensuring sediment controls are in place) and leave it until it is dry enough to remove. Clean sediment (free from pollutants, needles, etc.) may be reused in earthworks or landscaping activities, subject to relevant testing. Otherwise, place the sediment in a truck and transport it to an approved recycling or disposal facility.
- If a drying area is not available, place the sediment in a sealed truck for transport to an approved waste disposal facility. It is worth investigating if a drying area can be created nearby to reduce transport and disposal costs.
- Clean the sediment basin and reinstate the dewatering area and basin edges as required, including replanting.

The equipment required to maintain sediment basins includes:

- A pump to dewater the basin if maintenance valves do not completely drain it.
- A method of stopping inflows to the basin (e.g. sandbags) for small inflows.
- An excavator (possibly a long-reach) or a heavy vacuum loader unit with a 6-inch hose (if sediment needs to be collected from the edge of the basin).
- A backhoe or excavator that can enter the asset (if there are reinforced access tracks).
- A drying pad or a sealed truck to transport the saturated sediment.
- A truck (if the dry sediment if it cannot be reused on site).
- Hand tools or small machinery to reinstate the disturbed area.

Constructed wetlands

Removing sediment from wetlands is similar to removing it from sediment basins, with the following additional tasks:

- Ensure the wetland is offline, diverting flows around the wetland if possible. Always have sediment controls in place in case of flows into the wetland.
- Access the wetland from the edge to avoid damaging vegetation.
- Replant all disturbed areas after removing the sediment.

Bioretention systems – coarse sediment forebay

Coarse sediment forebays are placed at the inflow location to bioretention systems to capture very coarse sediment (>1 mm). The forebays will typically be constructed of rock or concrete and should be designed to be cleaned out once a year. Sediment should be removed when the sediment forebay is 75% full or greater.

Removing sediment should be a straightforward task that can be done by hand or mechanically. As the forebay captures coarse sediment only, it should not be contaminated (refer to Appendix A), and as it is shallow and mostly dry, dewatering should not be needed.

Bioretention systems – surface (coarse sediment)

Minor coarse sediment accumulation on the surface of a bioretention system is unlikely to affect performance. Removing the sediment may damage established vegetation. This likely presents a greater risk to the asset than leaving the sediment in place.

In this instance:

- Monitor sediment accumulation over time.
- If a coarse sediment forebay is present, consider increasing the cleanout frequency to reduce future sediment accumulation.

If coarse sediment is accumulated in large quantities, assess how much it is affecting asset performance. Consider whether the sediment is blocking the inlet, reducing the extended detention depth or smothering desirable vegetation. Weigh this against any damage that may occur to the asset in the process of removing the sediment. Consider the risk of damaging desirable vegetation or crushing the underdrains. If the benefits outweigh the risks, remove the sediment.

Bioretention systems – surface (fine sediment)

Minor fine sediment accumulation can reduce the porosity of bioretention filter media. This will reduce treatment performance but is unlikely to result in the media blocking entirely. Vegetation helps to maintain filter media porosity in bioretention systems. Focus on maintaining a dense coverage of healthy vegetation within the system to combat the clogging effects of minor fine sediment accumulation.

Major fine sediment accumulation in bioretention systems will cause the filter media to block. In these instances, the fine sediment should be removed. The top portion of the filter media may also need to be removed and replaced as fine sediment can become trapped within the filter media.

Bioretention systems – surface – removal methods

If sediment must be removed from bioretention systems, it should be removed:

- In dry weather and ideally at the end of the dry season.
- By hand (if possible) using flat shovels to maintain the integrity of the vegetation and prevent compaction of the filter media.

If machinery is used, it is critical to avoid excessively compacting the filter media or crushing the underdrainage pipes. Ideally, remove sediment via an excavator located on the edge of the bioretention system. If this cannot be achieved, use of a pozitrack bobcat may be acceptable. Watch for compaction of the filter media or signs that the underdrains may be damaged. Once sediment removal is complete, reprofile and replant the area as required.

The equipment required for cleaning the coarse sediment forebay and the surface of the bioretention system includes:

- Shovel and wheelbarrow for small assets.
- Bobcat or small excavator for large assets.
- Tipper truck if sediment disposal cannot occur locally.

Removing litter and debris

ISSUE

In small to moderate quantities, litter and debris in vegetated stormwater assets are primarily an aesthetic issue. However, they can cause environmental harm if able to enter downstream waterways. Excess quantities of litter and debris can smother vegetation, provide habitat for mosquito breeding, be a source of pollutants, block inlet and outlet structures, and pose a risk to public safety.

ACTIONS

Remove litter and excessive debris by hand or with hand tools such as shovels, forks, and tongs. For sediment basins and wetlands, waders or a boat may be required to access the water body. In extreme cases, small machinery such as bobcats may be required.

Managing plant litter

ISSUE

The effect of plant litter on vegetated stormwater assets varies depending on the type and component of the asset.

For the macrophyte zone of constructed wetlands and the waterbody in sediment basins, plant litter is only a problem in excess quantities where it can smother vegetation, be a source of nutrients and block inlet and outlet structures. In small to moderate quantities, it has a neutral effect.

For bioretention basins, swales vegetated with species other than turf, and the batters surrounding sediment basins and constructed wetlands, a moderate quantity of plant litter dropped by the plants in the system is highly beneficial to asset performance. In these situations, leaf litter helps to suppress weeds and makes the system more hospitable to the growth of desirable species by cooling and retaining moisture in the soil and providing a source of carbon. In excess quantities, plant litter can smother vegetation, be a source of nutrients and block inlet and outlet structures.

ACTIONS

If plant litter needs to be removed, do so by hand or with hand tools such as shovels, forks, and tongs. For sediment basins and wetlands, waders or a boat may be required to access the water body. In extreme cases, small machinery such as bobcats may be required.

For related information, see the following section on harvesting plants.

Constructed wetland macrophyte zone and sediment basin waterbody

Remove plant litter only where it threatens asset performance (e.g. by smothering vegetation, being a source of nutrients or blocking inlet and outlet structures).

Bioretention systems, swales vegetated with species other than grass, and batters surrounding sediment basins and constructed wetlands

In these situations, maintaining a layer of plant litter is highly desirable. Only remove plant litter when present in excess quantities where it threatens to smother vegetation, be a source of nutrients or block inlet and outlet structures. Remove only enough plant litter to resolve the problem. Do not remove all plant litter.

Harvesting plants

ISSUE

Vegetated stormwater assets are effective at removing pollution from stormwater without harvesting plants. Nonetheless, harvesting is common practice in other related fields (e.g. phytoremediation) and may prove to be beneficial for some or all vegetated stormwater asset types in the future.

ACTIONS

With the exception of mowing grass swales and turfed bioretention systems, harvesting plants within vegetated stormwater assets is not currently recommended. Nonetheless, it presents a promising opportunity for future investigation that may enhance long-term treatment performance.

If considering harvesting plants from a vegetated stormwater asset, keep in mind that the most important factors influencing vegetated stormwater asset performance are the ability of water to enter the treatment system and the presence of healthy vegetation to facilitate treatment. Under no circumstances should harvesting vegetation from vegetated stormwater assets result in reduced plant coverage or plant health as this will likely result in a net decrease in treatment performance, along with additional maintenance expenditure to reinstate vegetation and control weeds.

Managing mosquitoes

ISSUE

Shallow, isolated pools of water that exist for several days in constructed wetlands, sediment basins, or waterlogged areas of swales and bioretention systems can provide habitat for mosquitoes. Permanent water bodies are less likely to cause mosquito issues because they support predator species that can keep mosquito populations under control.

ACTIONS

Fill and reprofile isolated pools of water and replant if necessary.

If there are excessive numbers of mosquitoes or the problem is recurring, refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

Managing birds

ISSUE

While fauna is generally welcomed in vegetated stormwater assets, large populations of some fauna can be a nuisance and affect how an asset functions. Birds can be a problem in and around constructed wetlands because they may eat or trample vegetation. For example, plant death can result from swamphens trampling vegetation (see Figure 27). Faeces of other birds that gather in high numbers can affect water quality. Common problem species are ibises and ducks.

ACTIONS

Bird populations most often become a problem when there is safe habitat and plentiful food.

Wetlands and sediment basins should not have islands as they encourage birds to nest and roost by providing safety from predators. If an island is already present, this behaviour can be managed by either removing the island or providing a predator bridge. Other options include dropping the water level before and during breeding season to encourage the birds to leave the area (particularly for swamphens). If the wetland does not have an outlet control pit (refer to the Water by Design *Wetland Technical Design Guidelines*), it is recommended that one be installed. If the wetland cannot be drained under gravity, pumping will be required.

To manage food sources, install signs to encourage visitors not to feed the birds and ensure that nearby bins are bird-proof and regularly cleared.

If excessive numbers of birds are causing significant or repeated damage to an asset, refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

Photos: Andrew O'Neill

Figure 27 *Plant dieback caused by swamphens trampling vegetation.*

Managing high or low water levels in a wetland

ISSUE

The water level in a constructed wetland will vary according to climatic conditions. During rainfall, it may rise by up to 0.5 m above the normal water level and during drought conditions, it may fall by up to 0.3 m. Generally, wetland plants will tolerate this variation and most will thrive. In some instances, temporarily lowering water levels will encourage plants to self-propagate. However, persistently high or low water levels (Figure 28) will have a negative impact on the plants and must be addressed.

Photo: Robin Allison

Figure 28 *Example of a wetland with persistently low water levels.*

ACTIONS

If it has not rained for three days and water levels remain high, the outlet may be blocked or there may be high water downstream that is preventing the wetland from drawing down. If an outlet or riser orifice is blocked, see 'Unblocking inlets and outlets'. If there are no blockages, consult *Rectifying Vegetated Stormwater Assets* (Water by Design).

If the water level is much lower than the normal water level, inflows may have reduced or there may be a leak in the wetland. Consult *Rectifying Vegetated Stormwater Assets* (Water by Design).

Responding to a paint or fuel spill

ISSUE

Pollutants from paint or fuel spills can get into stormwater and into a vegetated stormwater asset. Action is required to reduce the impacts, particularly on wetlands.

ACTIONS

Ensure designated staff and equipment are available in the case of a pollution-related incident.

Stop polluted material from moving through a wetland and reaching downstream environments using floating booms and by shutting off the outlet area (if possible).

Record all incidents on the inspection and maintenance checklist.

Replanting

ISSUE

Vegetated stormwater assets should have dense, evenly distributed vegetation across all planted areas.

Maintaining vegetation is crucial to the performance of vegetated stormwater assets because it:

- Assists to spread and slow water, maximising the amount of vegetation in contact with the stormwater.
- Helps to reduce erosion.
- Minimises the establishment of weeds by shading and competing for nutrients.
- Preserves hydraulic conductivity in bioretention systems.
- Traps litter.
- Acts as a deterrent to public access.

A well-vegetated asset is cheaper to maintain than a partially vegetated asset because the desirable plant species impede weed growth.

Some water plant species will dieback (senesce) each winter. This does not equate to dead vegetation.

Figure 29 shows an example of uneven vegetation in a wetland. It is important to quickly re-establish vegetation in bare areas before weeds establish (Figure 30).

Photo: Robin Allison

Figure 29 *Uneven vegetation cover in a wetland and after transplanting.*

Photo: Robin Allison

Figure 30 *Re-established plants in wetlands after transplanting.*

ACTIONS

If the asset does not meet the performance indicators for vegetation, re-establish the vegetation using new stock or (for constructed wetlands) using stock transplanted from elsewhere within the asset. If replanting with new stock, use the plant species that are growing well in other parts of the asset.

Refer to the *Guidelines for the Construction and Establishment of Bioretention Systems and Wetlands* (Water by Design) for detailed advice on planting procedures for vegetated stormwater assets.

If the lack of vegetation cover is severe or recurring or the replanted vegetation fails to establish, consult *Rectifying Vegetated Stormwater Assets* (Water by Design).

Constructed wetlands

For wetlands, look for plants growing in similar depths of water. Otherwise, refer to the *Wetland Technical Design Guidelines* (Water by Design) or consult a person with a good understanding of aquatic vegetation. Plant at a density of between 6-10 plants per m^2 and use a minimum of two species.

In constructed wetlands, dividing and relocating existing vegetation is a simple and cost-effective way of replacing vegetation. Mature water plants from a similar depth zone can be removed and the plant divided by splitting it through the base. Directly plant the new sections into the re-establishment area, taking care to protect the root system. Water plants with rhizomatous root systems (underground stems with multiple shoots off them) are ideal candidates for division and relocation, as each rhizome can be cut into multiple sections.

In wetlands with grazing waterbirds (particularly purple swamphens) or where the water level cannot be maintained at a constant low level (10 cm), replant using larger seedlings or plants. Swamphens tend to pull seedlings out and high water levels often drown seedlings. In areas with few birds and good water level control, use seedlings to revegetate as they are usually more cost-effective.

Use specialist aquatic plant contractors when large areas need replanting. A small boat may be required.

Temporarily lowering the water level in wetlands may encourage existing plants to self-propagate.

Bioretention systems

In bioretention systems, replant with new stock.

Bioretention systems with planting that mixes canopy, midstorey and understorey species are typically most resilient to weed ingress and cheaper to maintain than bioretention systems containing only understorey species. When replanting bioretention systems seek to include a mix of canopy, midstorey and understorey species unless safety, aesthetics or another factor dictates otherwise. Select plant species that are doing well elsewhere within the asset and refer to the *Bioretention Technical Design Guidelines* (Water by Design) for further information on recommended plant species, densities and diversity.

Controlling weeds

A weed is a plant that is growing where it is not wanted.

Plants are considered weeds because they:

- Compete with or displace native plant species.
- Reduce biodiversity.
- Impact ecosystem function.
- Alter natural habitats.
- Restrict natural processes.
- Reduce amenity.
- Cause blockages to hydraulic structures.

While this definition is generally applied to introduced plant species, some native plant species are also classified as weeds when they grow outside of their natural range. Appendix B contains detailed information on common weeds encountered in vegetated stormwater assets.

ISSUE

Identifying and controlling weeds is important to preserve the function of a vegetated stormwater asset.

Assets are particularly vulnerable to weed invasion when the desirable plants are stressed, such as during the dry season or at the end of the wet season.

Swales and bioretention systems

Common terrestrial weeds readily grow within bioretention systems and swales (Table 4). The growth of weeds within bioretention systems can reduce vegetation health, cover, and diversity, and result in excessive organic matter accumulating on the surface of the filter material (noting that some accumulation of organic matter on the surface of bioretention systems is desirable). Dense weeds within swales can reduce the flow capacity of the asset and increase the risk of flooding.

Sediment basins and constructed wetlands

Enriched nutrient conditions and open water provides ideal habitat for aquatic weeds within sediment basins and constructed wetlands. Emergent aquatic plants (e.g. *Typha sp.*) and semi-aquatic weeds (e.g. *Urochloa mutica*) colonise and grow well within the planted marsh zones and ephemeral margins (Table 4). Common terrestrial weeds readily grow on the batters (Table 4).

ACTIONS

Ideally, remove or control all weed species within an asset as part of a regular maintenance program. This is mandatory for prohibited/restricted weeds. A low level of non-prohibited/restricted weed cover may be okay if it does not hinder the functioning of an asset and does not risk the weed outcompeting desirable vegetation. However, early intervention is generally less expensive and more successful for managing weeds than delaying action.

When controlling weeds in vegetated stormwater assets, it is important to:

- Recognise that some weed growth is inevitable because stormwater conveys weed seeds from the catchment.
- Know which weeds cause problems.
- Regularly inspect for weeds.

Persistent weed ingress or excessive weed cover may mean that maintenance activities are not sufficient to manage the weeds. In this case, increase the maintenance frequency for a growing season (6-12 months). If this does not satisfactorily manage weeds, refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

When undertaking weed management, consider the following factors:

- The cause of the weed infestation.
- The biology and ecology of the weed species.
- Methods to remove weeds, including their costs and benefits.

Identifying the source or cause of weeds will help to determine the most appropriate weed control strategy. Weed biology or ecology may influence the timing of the control method. For example, it may be beneficial to control a particular weed before it seeds to prevent further spread.

There is a range of methods commonly used to control weeds within vegetated stormwater assets (see below). An integrated approach (where multiple control methods are used in a coordinated manner) is often the most effective long-term strategy. For example, a weed may initially be removed by hand, with any remaining weeds controlled using chemicals.

Irrespective of the method chosen, take care not to damage desirable vegetation during weed control activities. Well-intentioned but poorly executed weed control has destroyed desirable vegetation in many instances, particularly in bioretention systems. The most common causes of this are herbicide overspray and excessive brush cutting.

Weed control in bioretention systems should generally follow this hierarchy:

1. Prioritise establishing dense vegetation cover. Systems with a mix of canopy, midstorey and understorey are most resilient to weed ingress.
2. Regularly inspect systems and remove weeds early (preferably by hand).
3. Restrict herbicide use and brush cutting to the absolute minimum necessary.

Many aquatic weed species can regrow from small plant fragments and seeds. Take extreme care when physically removing and disposing of the plant material. Thoroughly clean all equipment used with or near aquatic weeds before moving the equipment to another waterway. This includes hand equipment, boats, booms, excavators, harvesters, and transport vehicles.

CONTROL METHODS

Physical removal

Hand pulling: A labour-intensive method that is extremely effective for controlling isolated weed infestations. This method is particularly useful for removing shallow-rooted weed species. Take care to remove all root material, particularly when removing deep-rooted perennial weed species.

Hand raking: A labour-intensive method used to remove small aquatic weed infestations. This method involves using a long-handled rake to remove floating or submerged aquatic weeds from sediment basins and constructed wetlands.

Grubbing: This method uses tools such as shovels and mattocks to remove weeds. Grubbing is a useful method for removing deep-rooted, woody weed species.

Mechanical removal: Use this method to remove large infestations of floating or submerged aquatic weeds from sediment basins and constructed wetlands.

Specialised floating harvesters can remove floating aquatic weeds or cut and remove weed biomass at a fixed depth below the water surface. Floating harvesters can manage weed biomass. Weed harvesting needs to be regularly repeated.

An excavator can remove floating and submerged aquatic weeds from open water areas. This normally involves scooping plants from the water with a bucket. If using excavators, use floating booms to concentrate floating aquatic weeds.

Long-reach draglines, such as chains or nets, can remove floating or submerged aquatic weeds. This involves pulling the chain or net through the water using a tractor. Only use this method when other methods of weed control are unfeasible, as draglines can damage desirable macrophytes.

While using floating harvesters, excavators, or draglines to remove aquatic weeds is unlikely to eradicate them, this may provide an effective strategy for short-term control.

Floating booms: Floating booms are an effective method to control the spread of free-floating aquatic weeds within sediment basins and constructed wetlands. Floating booms are particularly useful for confining small, isolated weed infestations to particular areas of the asset, at which point plants may be physically removed or other control methods used (e.g. herbicides).

Slashing: Slashing can be useful for controlling isolated weed infestations in the short term, but is not an effective method for eradicating weeds. It often worsens weed problems in the long term.

Slashing can directly damage or destroy desirable plants and can also spread weed seed. Problems tend to worsen as weeds colonise newly created space more rapidly than native macrophytes.

Accidental damage to native plants is particularly prevalent in bioretention systems and constructed wetlands due to the dense planting of macrophytes.

Care should be taken if slashing, with use restricted to situations where it is absolutely necessary. Slashing should only be undertaken away from desirable vegetation and before seeds have set. Slashing can be undertaken using either a hand-held brush-cutting machine or a tractor equipped with a slashing implement. Slashed vegetation should generally be removed from the asset.

Biological control

Biological control uses insects or diseases to control the spread of particular weed species. Biological control does not eradicate weeds. Biological control is a long-term strategy that reduces the health of a weed population in order to more easily control it with other methods. Biological control can be a cost-effective and environmentally sensitive method of weed control. A number of aquatic weed species within Australia have been successfully targeted using this method.

Water level management

Lowering the water level in sediment basins and wetlands can help to control floating and submerged aquatic weeds. The drawdown of water levels will dry out the vegetative material. Drying out sediment basins and wetlands is most effective during the dry season when there is little to no stormwater runoff.

Chemical control

There is a growing body of evidence on the ecological impacts of herbicide use, particularly near waterways. Inappropriate use and overuse of herbicides in vegetated stormwater assets kill desirable vegetation and make them prone to further weed ingress. Thus, while chemical weed control is sometimes more cost-effective than mechanical methods in the short term and is particularly effective at controlling large weed infestations, its use within vegetated stormwater assets should be restricted to the absolute minimum necessary.

For further discussion of the risk associated with herbicide use in bioretention systems, refer to *Improving the Biology of Bioretention Systems* (Water by Design).

Major risks associated with using herbicides include the potential impacts on desirable plants and the environmental effects due to chemical residues accumulating within sediments and soils.

When treating aquatic weeds within sediment basins and constructed wetlands, ensure that herbicides are registered or permitted for use around aquatic areas. Use herbicides in accordance with the registered labels and the relevant legislation (e.g. *Chemical Usage (Agricultural and Veterinary) Control Act 1988* in Queensland). Seek advice from the relevant government department if considering uses other than those prescribed on labels. Note that all staff using herbicides should have completed ChemCERT Training or its equivalent. Special licences may be required to use herbicides within a water body.

Herbicides are commonly applied to weeds using either foliar spray or rope-wick applicator methods. Cut stump and stem injection (drill and fill) are suitable methods for applying herbicides to woody weeds.

Foliar spray: Apply foliar herbicides using spot spraying techniques with hand-held sprayers. Spot spraying reduces the amount of herbicide used, which minimises the cost of application and damage to non-target plants. Take care to minimise the amount of herbicide that makes contact with the water. Using booms to confine isolated aquatic weeds may help to minimise non-target application of the herbicide.

Rope-wick applicators: Consists of a handle with a wick or rope attached to the end that is soaked with herbicide. Use the wetted wick or rope to brush herbicide over the surface of the weed. Rope-wick applicators are suitable for herbaceous weeds and young regrowth. This method ensures minimal damage to non-target plants.

Cut stump: This method involves cutting the stump of the weed approximately 15 cm from the ground using a cane knife or secateurs and applying herbicide immediately to the cut surface of the stump using a paintbrush or spray bottle.

Stem injection: This method involves making a 45-degree incision in the bark of the stem of the weed using a small axe or machete and filling the pocket with a herbicide mixture. The incision must penetrate through the sapwood. Incisions are required every 7.5 cm around the circumference of the trunk.

All herbicides are potentially hazardous to humans. Protective clothing is essential when handling or spraying most herbicides.

The minimum personal protective equipment required is:

- Rubber boots.
- Long pants or overalls.
- Rubber or plastic apron or coat covering the tops of the boots.
- Rubber or plastic gloves.
- Face shield.
- Waterproof hat or hood.

Steaming

The direct application of heated steam can be used to control weeds. Applying steam removes the outer, waxy coating of the plant and breaks cellular structures, resulting in discolouration and death within a few days. While steaming is an effective method for controlling annual weeds, regrowth of perennial weeds often occurs unless repeated treatments are undertaken.

Managing excessive algae in sediment basins and constructed wetlands

ISSUE

Algae occurs naturally in sediment basins and constructed wetlands due to the nutrient concentrations in stormwater inflows and the nutrients released from sediment and decomposing organic matter.

Generally, algal growth is either planktonic or filamentous.

Planktonic algae comprise individual free-floating cells that often turn the water green (also known as an 'algal bloom'). Planktonic algae include many blue-green algal species that produce toxins and pose a potential public health risk. Planktonic algae typically grow in open water areas, particularly in sediment basins characterised by highly enriched conditions. Algal blooms will not affect the functional performance of either sediment basins or constructed wetlands.

Filamentous algae comprise single algal cells that form visible chains and often appear as floating or submerged algal mats that are bright green. Filamentous algae feel slimy when handled and individual filaments can often be recognised. Filamentous algae grow in shallow vegetated zones and open water areas. A combination of high nutrient concentrations, light, and warm shallow water often results in excessive filamentous algal biomass.

Excessive filamentous algal biomass may severely affect the functional performance of sediment basins and constructed wetlands. Filamentous algae can block hydraulic structures, resulting in altered water regimes, and can potentially damage vegetation health, cover, and diversity. Filamentous algal biomass in constructed wetlands can smother vegetation and be displaced by stormwater inflow. This can severely reduce plant health and the overall vegetation cover within the wetland. The death and decay of filamentous algal biomass can lead to oxygen depletion and result in poor water quality and fish kills.

ACTIONS

Planktonic algae

If access to sediment basins and constructed wetlands is restricted and there are minimal public health risks, it is not necessary to take any further action regarding planktonic algae.

Where sediment basins or constructed wetlands are accessible to the public or located within prominent public locations, the presence of blue-green algae requires further investigation. Refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

Filamentous algae

If filamentous algal biomass is observed within a sediment basin or wetland, it is generally not necessary to take any further action. However, in high amenity areas, it may be desirable to remove filamentous algal biomass from areas of open water. Filamentous algal biomass can be physically removed using rakes, or through mechanical removal with specialist machinery (e.g. that used for removing wet sediment).

If the filamentous algal mat covers more than 10% of the sediment basin or constructed wetland area on two consecutive inspections, refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

Managing algal or moss growth on bioretention systems

ISSUE

Constant wetting of the filter media surface of a bioretention system may result in the growth of algae or moss. Algae can be identified as a green or brown coloured coating or biofilm on the surface of the filter media (as shown in Figure 31). Filamentous algae may also appear on the surface of the filter media and often appears as a dense mat of fine green filaments. Moss is easy to identify because it looks like a thick green carpet (as shown in Figure 32).

In many circumstances, minor algal and moss growth on the surface of a bioretention system will not be detrimental to infiltration. However, excessive algal or moss growth can clog the filter media surface and prevent infiltration.

Excessive algal or moss growth may indicate that either base flows are entering the asset or there are pre-existing problems with infiltration. If infiltration in a bioretention system is reduced or not occurring (see Figure 26), stormwater will bypass untreated into the overflow, and the media may become boggy. A lack of water will affect the health of the vegetation and boggy conditions can attract mosquitoes as well as generate unpleasant odours.

ACTIONS

If the cover of algal and moss growth is more than 10% of the filter media surface, refer to *Rectifying Vegetated Stormwater Assets* (Water by Design).

For algal or moss growth on bioretention systems caused by baseflows into the system, refer to the *Bioretention Technical Design Guidelines* (Water by Design). It contains details of a simple diversion that can be retrofitted onto existing assets to bypass baseflows around the filter media.

Photo: Leon Rowlands

Figure 31 *Algae growing on the filter media surface.*

Photo: Paul Dubowski

Figure 32 *Moss growing on the filter media surface.*

Healthy Land & Water

Level 11, 240 Queen St, Brisbane QLD 4000 | GPO BOX 735, MEANJIN (BRISBANE) QLD 4001
T. 07 3177 9100 | hlw.org.au