Maintaining Vegetated Stormwater Assets

Version 1, February 2012

waterbydesign

Water by Design is a program of Healthy Waterways Ltd

HEALTHY WATERWAYS

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Water by Design

Water by Design is a program of Healthy Waterways Ltd. It helps individuals and organisations to sustainably manage urban water. For more information, visit www.waterbydesign.com.au

Healthy Waterways

Healthy Waterways is a not-for-profit, non-government organisation working to protect and improve waterway health in South East Queensland (SEQ). We facilitate careful planning and coordinated efforts among a network of member organisations from government, industry, research, and the community to achieve our shared vision for healthy waterways. For more information, visit www.healthywaterways.org

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Glossary

This glossary defines words commonly used in relation to vegetated stormwater assets. Definitions given here fit the context of the words as they are used in this document.

Batter (also known as embankment) Sloped or graded areas immediately surrounding vegetated stormwater assets. They 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. Designed to remove coarse sediment (> 1 mm) from stormwater to minimise the risk of vegetation in the bioretention system being smothered.

Constructed wetland Constructed wetlands usually consist of a sediment basin followed by a 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 Organic waste such as leaves or twigs.

Declared weed Plant species that have, or could have, serious economic, environmental, or social impacts as declared under the *Queensland Land Protection (Pest and Stock Route Management) Act 2002* or equivalent in other jurisdications. The Act imposes a legal responsibility for all landowners to control declared 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 is therefore is 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 Waste created by human activity.

Macrophyte A plant adapted to living in water or periodically (emphermal) inundated habitats.

Macrophtye 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 Outlet structures 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 Quantitative measure that maintenance crews can visually assess to determine if vegetated stormwater assets are likely to be functioning properly.

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 Asset usually delivered by a developer and owned by a body corporate, property owner, or other private party.

Public asset Asset owned by a local authority or state government.

Rectification The works involved in repairing a failed or under-performimg 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.

ONE **INTRODUCTION**

1.1 Purpose of this document

This document helps 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.

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

1.2 Why use this document

Waterways are an integral part of our lifestyle and economy, and urban stormwater run-off can significantly affect them. Typically, a system of pits and pipes conveys stormwater from urban areas to receiving waterways more frequently and in greater volumes than what happens naturally. This stormwater carries large volumes of pollutants, such as nutrients, sediment, and litter. Vegetated stormwater assets, such as bioretention systems and wetlands, can reduce the impacts of urban stormwater provided they are well planned, designed, constructed, and maintained.

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 4/10 Healthy Waters 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
- the cost of returning the asset to a functional state (i.e. rectifying the asset) can often be substantially more than the cost of routine maintenance
- the value of the asset is reduced

1.3 How to use this document

Figure 1 illustrates how to use *Maintaining Vegetated Stormwater 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.

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.

Figure 1 How to use Maintaining Vegetated Stormwater Assets

Section 1: Introduction	Read this section to understand the scope and purpose of this document, how to use it, and the relationship with other documents.
Section 2: Planning for maintenance	Read this section for guidance on planning for maintenance, including scheduling inspections and maintenance.
Section 3: Undertaking maintenance activities	Read this section for guidance on how to undertake maintenance activities and when to refer to *Rectifying Vegetated Stormwater Assets.*
Section 4: Recording inspections and maintenance	Use the inspection and maintenance checklists on site to record the condition of the asset (against performance indicators) and the maintenance undertaken or action needed.
Appendix A Appendix B	Additional information to assist in identifying and managing contaminated sediment and common weeds.

Rectifying Vegetated Stormwater Assets

Refer to this guideline when there is a problem with the function of the asset that maintenance cannot address.

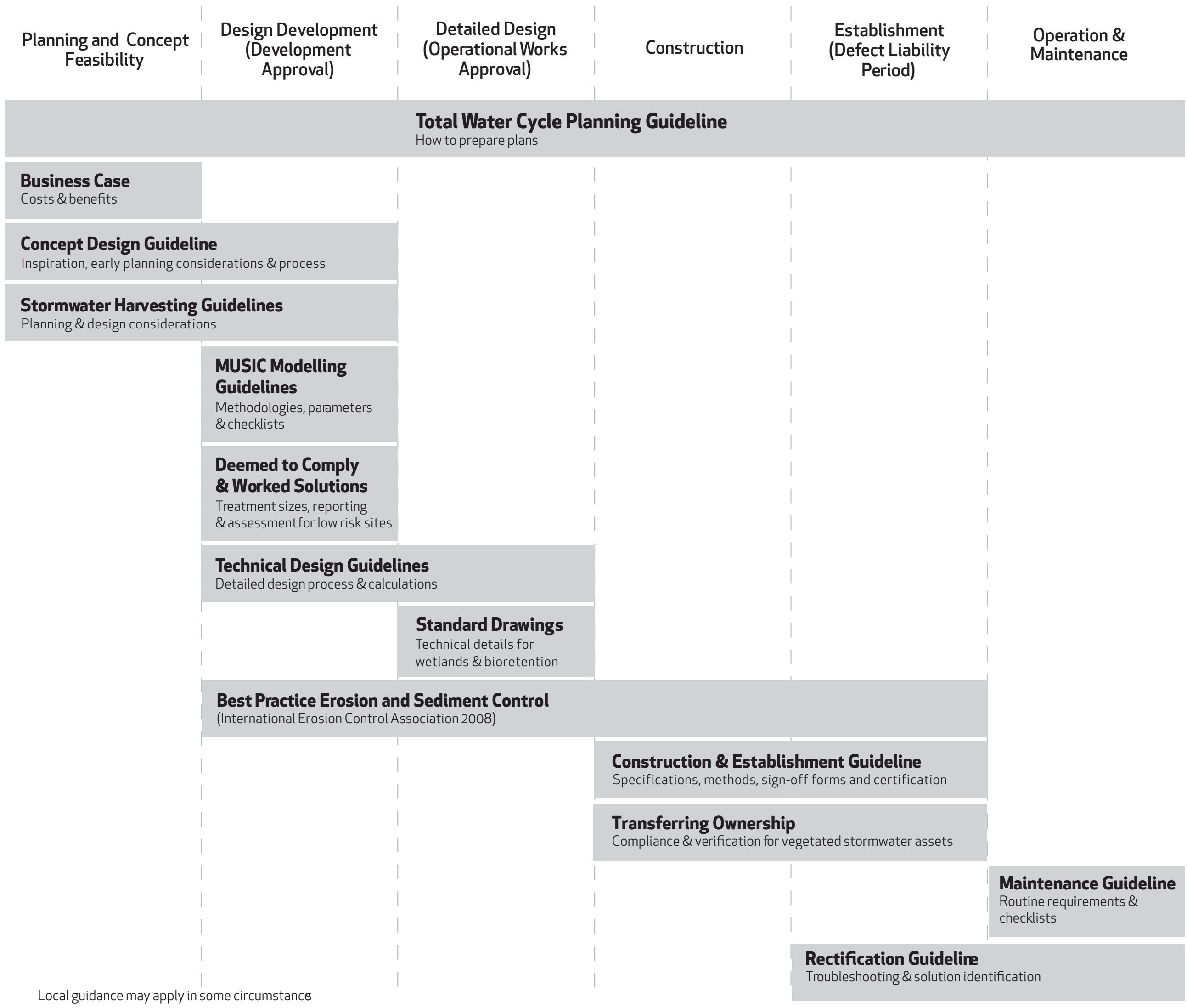
1.4 Links with other Water by Design resources

Figure 2 shows the key resource documents that Water by Design provides to help individuals and organisations sustainably manage urban water. These resources assist stakeholders to plan, design, implement, and manage vegetated stormwater assets.

The documents of most relevance to maintaining vegetated stormwater assets are:

- *Construction and Establishment Guidelines* (Section 1.4.1)
- *Transferring Ownership of Vegetated Stormwater Assets* (Section 1.4.2)
- *Rectifying Vegetated Stormwater Assets* (Section 1.4.3)

Figure 2 Vegetated stormwater asset timeline and supporting resources



1.4.1 *Construction and Establishment Guidelines*

The *Construction and Establishment Guidelines* outline the methods for constructing and establishing swales, bioretention systems, and wetlands. For each method, step-by-step instructions are included to ensure the assets are constructed properly. The guidelines provide sign-off forms for supervisors and designers to certify the constructed assets before handing them over. For guidance on maintaining vegetated stormwater assets during the construction and establishment phase, see the *Construction and Establishment Guidelines*.

1.4.2 *Transferring Ownership of Vegetated Stormwater Assets*

Transferring Ownership of Vegetated Stormwater Assets provides guidance on how to transfer ownership of vegetated stormwater assets from the constructing party, typically the developer, to the long-term owners and managers of the assets, typically the local authority or a private entity (such as a body corporate). This is so that owners inherit assets that are functioning properly and that are meeting their design intent. It provides information, processes, and checklists to assist with each stage of the handover process. It covers swales, bioretention systems, constructed wetlands, and sediment basins.

The focus of *Transferring Ownership of Vegetated Stormwater Assets* is vegetated stormwater assets constructed as part of subdivisions. However, as many vegetated stormwater assets are created as part of other developments and remain in private ownership, handover options for private assets are included.

1.4.3 *Rectifying Vegetated Stormwater Assets*

Rectifying Vegetated Stormwater Assets recommends how to repair under-performing or failing vegetated stormwater assets to their intended, functioning state. It provides:

- a process to determine whether to rectify an asset
- guidance on how to identify typical problems
- possible solutions for how to rectify problems

1.5 Maintenance versus rectification

Maintenance involves regular or scheduled activities undertaken to keep vegetated stormwater assets functioning properly. Examples are weeding or removing sediment and litter. 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 function (e.g. the asset's 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

Engineering or horticultural experience may be required to identify whether a problem requires rectification and within what timeframe. Problems will develop over different timeframes and some problems, if left unchecked, will develop into problems that are more serious and more 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. In addition, 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, which indicates no or very poor hydraulic conductivity of the filter media, is likely to require rectification works and should be addressed more rapidly than a recurrent patch of weeds or excess litter, which may benefit from temporarily increasing the frequency of maintenance.

If the asset has not met one or more of the performance indicators on at least two consecutive maintenance inspections, increase the maintenance frequency.

If increased maintenance is still not resolving the problem, investigate the need to rectify the asset in accordance with *Rectifying Vegetated Stormwater Assets*.

1.6 Ensuring private assets are maintained

A developer usually constructs and establishes private assets and a body corporate, property owner, or other private party usually owns them.

Authorities can apply a number of methods to ensure owners maintain privately owned vegetated stormwater assets:

- **Encourage** maintenance by providing information to the owner so they are aware of the maintenance needs. For example, Suncorp Stadium maintains their stormwater treatment devices despite the assets not being subject to compliance checks.
- Establish a **maintenance agreement** as a planning obligation or as a condition attached to planning approval.
- Attach 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.
- Create 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.
- Require **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.

TWO **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)
- local, state, and national procedures, guidelines, and legislation that affect how maintenance is undertaken (Section 2.1.3)
- the resources required, including the skills for undertaking maintenance (Section 2.3) and equipment (Section 3)
- when to schedule inspections and maintenance (Section 2.4)
- how to manage a non-functioning asset (Section 2.5)

Managers should also understand the current condition and history of each asset, as recurring problems may indicate the need to alter the maintenance regime (see Section 2.3) or conduct a rectification investigation (see *Rectifying Vegetated Stormwater Assets*).

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 under-drains to prevent water logging. Swales can be designed to allow some infiltration to groundwater in areas with suitable soils. The *Technical Design Guidelines* contain a comprehensive description of swales.

Figure 3 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.

Figure 3 Examples of properly functioning swales

Photo: Alan Hoban, Healthy Waterways

Photo: Shaun Leinster, Designflow

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 ecology within urban zones

Figure 4 shows the typical components of a bioretention system. The vegetation is critical for both removing nutrients and maintaining the hydraulic conductivity, or the rate of infiltration, of the filter media. Bioretention systems have three soil layers beneath the vegetation: the filter media, a transition layer, and a drainage layer. A perforated-pipe collection system usually sits in the drainage layer, which discharges the infiltrated water to the downstream waterway or to storage for later reuse.

In some cases, the design of a bioretention system allows treated stormwater to exfiltrate from the base and sides of the filter media into the surrounding soil.

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

Bioretention systems can include a saturated zone. The saturated zone is below the transition layer and contains a permanent pool of water. The purpose of the saturated zone is to support the plants during dry periods. Figure 5 shows a typical cross-section of a bioretention system with a saturated zone.

Figure 6 illustrates the many different shapes and sizes of bioretention systems. Due to the variability in bioretention systems, maintenance staff need accurate and specific information on each asset. Useful information includes a diagram showing the location of inlet areas, outlet pipes, and overflows. On-site handover or training should also be conducted.

The *Technical Design Guidelines* contain a comprehensive description of bioretention systems.

Figure 6 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 4 Cross-section of a typical bioretention system

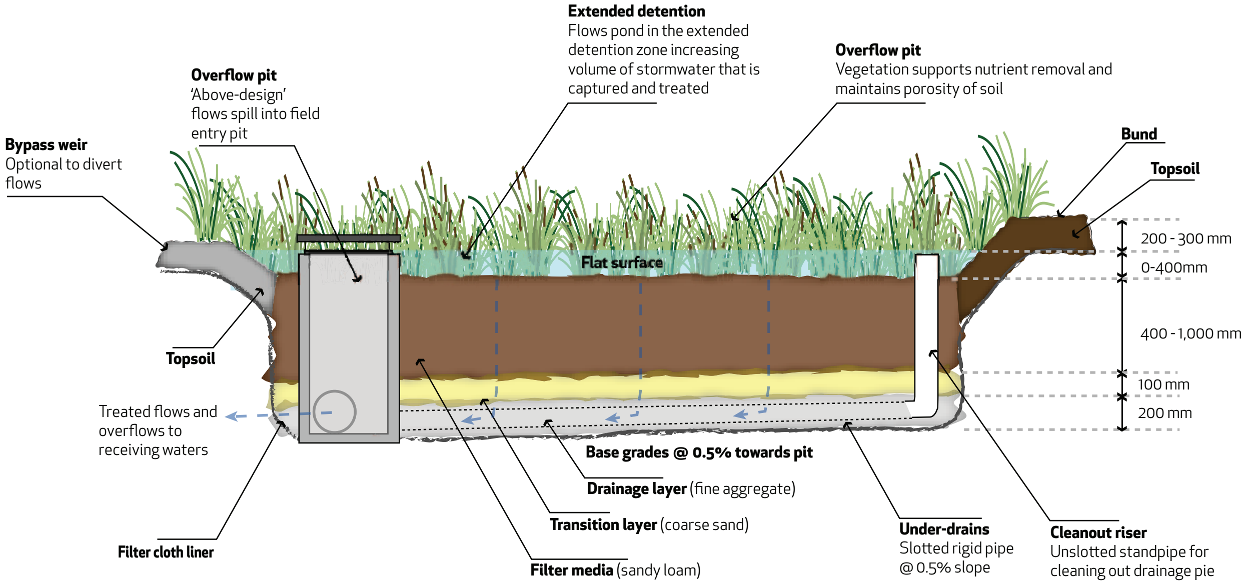


Figure 5 Cross-section of a typical bioretention system with a saturated zone

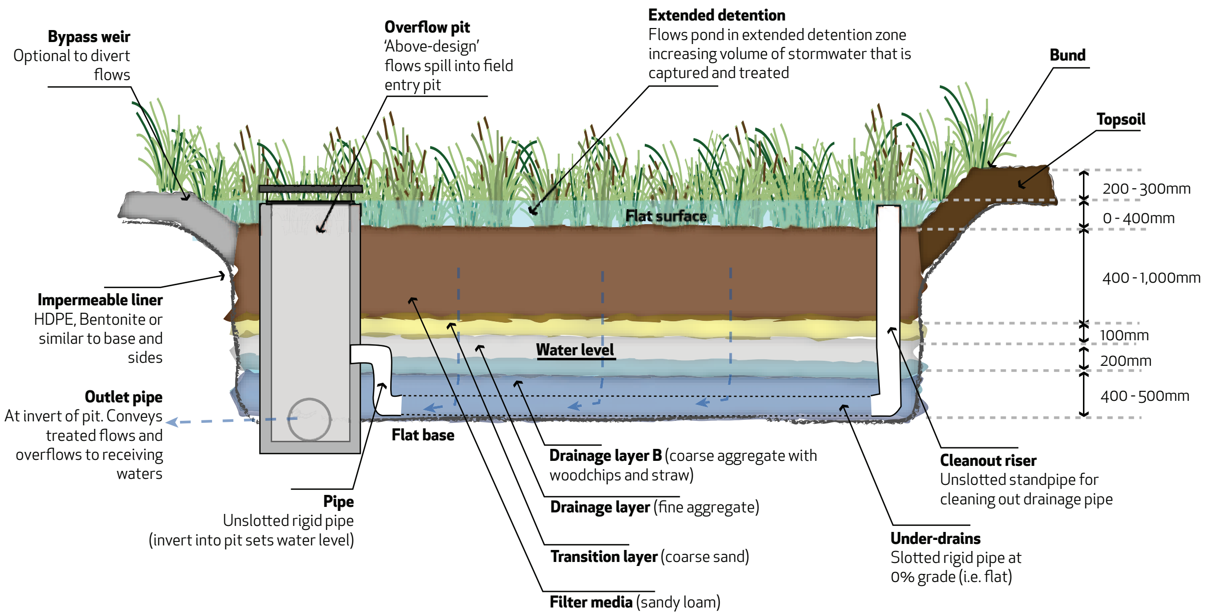


Figure 6 Examples of properly functioning bioretention systems

Photo: Alan Hoban, Healthy Waterways

Photo: Alan Hoban, Healthy Waterways

Photo: Shaun Leinster, DesignFlow

Photo: Alan Hoban, Healthy Waterways

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 7 illustrates the components of a typical constructed wetland. The *Technical Design Guidelines* contain a comprehensive description of constructed wetlands.

Inflows to a wetland can cause water levels to rise to an overflow point or the top of the extended detention. If water rises above the overflow point, it will spill out of the constructed wetland. The volume of the extended detention maximises the amount of stormwater that is treated. Most constructed wetlands are designed so that high-velocity inflows bypass the wetland, usually via an overflow weir located in the inlet zone.

A riser plate or a riser pipe (Figure 8 and Figure 9) usually controls treated outflows from a constructed wetland. Weirs can also be used. 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 10 shows examples of constructed wetlands that are functioning properly. Use the performance indicators in the checklists in Section 4.4 to determine if a 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 7 Cross-section of a constructed wetland

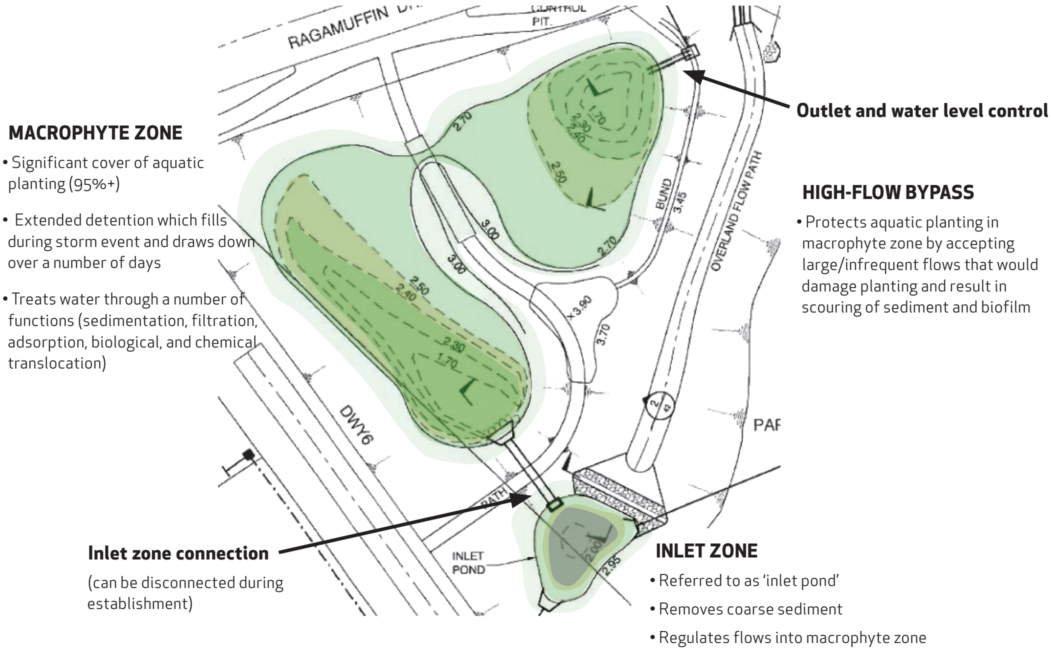


Figure 8 Riser plate at full water level

Photo: Robin Allison, DesignFlow

Figure 9 Riser pipe outlet

Photo: Shaun Leinster, Ecological Engineering

Figure 10 Examples of properly functioning constructed wetlands with good vegetation cover

Photos: Shaun Leinster, DesignFlow

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 11 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, protecting them from erosion. The *Technical Design Guidelines* contain a comprehensive description of sediment basins.

Figure 12 shows an example of a sediment basin 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 11 Cross-section of a typical sediment basin

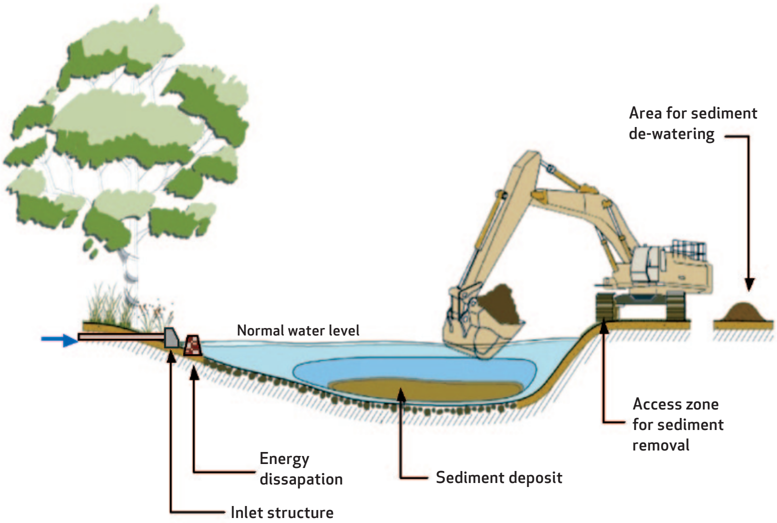


Figure 12 Example of properly functioning sediment basins

Photo: Shaun Leinster, DesignFlow

2.2 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, 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.
- **Declared weeds:** Refer to relevant local regulations regarding declared weeds. In Queensland, the *Land Protection (Pest and Stock Route Management) Act 2002* declares plant species that could cause serious economic, environmental, or social impacts. The Act imposes a legal responsibility for all landowners to control declared weeds on land under their management. Refer to Section 3.10 for more information.
- **Personal safety:** A Safe Work Method Statement for vegetated stormwater assets should, as 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:
  - complete maintenance during the day with traffic management
  - complete maintenance with signage but without traffic management
  - complete maintenance at night with signage and appropriate lights on equipment and headlamps but without traffic management

2.3 Skills required for undertaking maintenance

Vegetated stormwater assets have a number of 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 **vegetation 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 declared and non-declared weeds.

All personnel need to understand the purpose and function of the assets.

2.4 Scheduling inspections and maintenance

Inspections and maintenance can be completed in a number of ways: the choice of method is often dependant on the resources and internal structure of the organisation. Figure 13 illustrates the various options.

Figure 13 Options for undertaking inspections and maintenance

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
Reponsive maintenance	Responsive maintenance		Responsive maintenance	

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

Table 1 sets out the recommended frequency for inspections and regular maintenance of standard vegetated stormwater assets. These frequencies will help vegetated stormwater assets to function properly (i.e. achieve the performance indicators in Section 4) and to cost effectively address problems.

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 1 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/declared weeds (e.g. Salvania and Para grass)

An asset may need to be maintained more often than the frequencies outlined in Table 1 for the following reasons:

- activities in the catchment (e.g. poorly managed house building) are producing higher than expected loads of litter, 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 50mm/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 wetlands.

2.5 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 due to an external influence, such as vandalism. If this is the case, refer to *Rectifying Vegetated Stormwater Assets* 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 minimum regulatory requirements are met. Consider maintaining public safety, maintaining flood conveyance, and managing environmental issues when planning maintenance of under-performing 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. it 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, such as the asset is full of sediment or choked with weeds, it will need to be cleared or an alternative passage for the 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, address environmental issues as soon as possible.

THREE **UNDERTAKING MAINTENANCE**

Maintenance activities for swales, bioretention systems, constructed wetlands, and sediment basins include:

- repairing erosion (Section 3.1)
- unblocking inlets and outlets (Section 3.2)
- removing sediment (Section 3.3)
- removing litter and debris (Section 3.4)
- managing mosquitoes (Section 3.5)
- managing birds (Section 3.6)
- managing high or low water levels in a wetland (Section 3.7)
- responding to a paint or fuel-spill (Section 3.8)
- replanting (Section 3.9)
- controlling weeds (Section 3.10)
- managing excessive algae in sediment basins and constructed wetlands (Section 3.11)
- managing algal or moss growth on bioretention systems (Section 3.12)

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

3.1 Repairing erosion

ISSUE

Erosion in and around vegetated stormwater assets is generally because 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 where there is poor vegetation
- 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 14 and Figure 15 show examples of erosion in vegetated stormwater assets.

Minor erosion can extend and turn into a larger problem, including undermining structures, channelling of flows, and affecting vegetation health.

Figure 14 Erosion at the transition between a swale and bioretention system causing ripping of the jute mat

Photo: Paul Dubowski, Healthy Waterways

Figure 15 Erosion at the transition between wetland cells

Photos: Jason Sonneman, DesignFlow

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

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

Larger washouts may require large machinery and 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 *Technical Design Guidelines*. Re-plant 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*.

3.2 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 will be at risk (the plants may drown eventually)
- 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 to pass downstream untreated

Figure 16 Litter blocking outlet pits

Photos: Paul Dubowski, Healthy Waterways and Robin Allison, DesignFlow

Figure 16 shows examples of blocked outlet pits that are restricting flows.

ACTIONS
Remove litter and debris 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*. An alternative grate may be required or upstream measures may need to be investigated e.g. checking or installing gross pollutant traps.

3.3 Removing sediment

ISSUE

Sediment build-up in swales, bioretention systems (Figure 17), constructed wetlands, and sediment basins can:

- smother vegetation
- change the surface profile of the asset, which influences flow patterns
- form an impermeable layer on the surface of bioretention systems and prevent infiltration

If infiltration in a bioretention system is reduced or not occurring (see Figure 18), 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.

Figure 17 Sediment accumulated at an inlet

Photo: Paul Dubowski, Healthy Waterways

Figure 18 Examples of a bioretention surface that has been blinded with clay-like sediment deposition

Photos: Alan Hoban, Healthy Waterways and Andrew O'Neill, DesignFlow

ACTIONS

If an asset requires cleaning out at an unacceptable or unsustainable frequency, refer to *Rectifying Vegetated Stormwater Assets*.

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[1] . When the sediment forebay is 75% full or greater, remove the sediment.

Removing sediment should be a straightforward task that can be done by hand or mechanically. Because the forebay captures coarse sediment only, it should not be contaminated, and because the forebay is shallow and mostly dry, dewatering should not be needed.

Bioretention systems – surface

Remove sediment in dry weather and ideally at the end of the dry season.

To maintain the integrity of the vegetation and prevent compaction of the filter media, remove sediment by hand (if possible) using flat shovels.

If machinery is used, remove sediment via an excavator located on the edge of the bioretention system or via a pozitrack bobcat to avoid compaction of the filter media. Minimise the number of times the bobcat passes over the bioretention surface. 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

Sediment basins
Sediment basins are normally designed to be cleaned out at least once every five years[1]. 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. 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 de-water if necessary. Approval to drain the asset may be required for sediment basins and wetlands.
- Lower the water level with a maintenance valve or de-water the asset with a pump in accordance with the procedures of the relevant authority. Divert inflows away from the asset. In some cases, 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. Ensure the dewatering has no adverse environmental affects.
- Remove and store plants that will be disturbed, in order to replant them after removing the sediment.
- Remove the sediment using appropriate machinery (see below).
- 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 (de-watering) area is available, place the sediment in this area to dry, ensuring it has silt control, and leave it until it is dry enough to remove. Clean sediment (no pollutants, needles etc.) may be re-used in earthworks or landscaping activities subject to relevant testing. Otherwise, place the sediment in a truck and transport 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 sediment pond edges as required, including replanting.

The equipment required to maintain sediment basins includes:

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

1 This clean out frequency is after construction activity in the catchment has finished.

3.4 Removing litter and debris

ISSUE
While litter and debris are mainly an aesthetic issue, they 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. If litter is able to enter downstream waterways it can cause environmental harm.

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.

3.5 Managing mosquitoes

ISSUE
Shallow, isolated pools of water that exist for several days in constructed wetlands, sediment basins, or water-logged 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 re-plant if necessary.

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

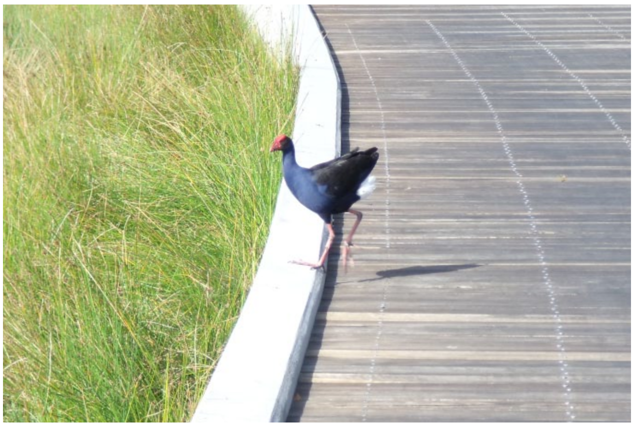
3.6 Managing birds

ISSUE
While fauna is generally welcomed in vegetated stormwater assets, large populations of some fauna can be a nuisance and can affect how an asset functions. In particular, birds can be a problem in and around constructed wetlands because they can eat or trample vegetation. For example, plant death can result from swamp hens trampling vegetation (see Figure 20). Faeces of other birds that gather in high numbers can affect water quality. Common problem species are ibises and ducks.

ACTIONS
Manage the preferred habitat. For example, remove islands or provide a predator bridge. Wetlands should not have islands as these encourage birds to nest and roost safe from predators. Other options are using signs to encourage visitors not to feed the birds or dropping the water level before and during breeding time to encourage the birds to leave the area, particularly for swamp hens. If the wetland does not have an outlet control pit (refer to *Technical Design Guidelines*), it is recommended that one is installed. If the wetland cannot be drained under gravity, pumping will be required.

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

Figure 19 Swamp hen and associated damage



Photos: Andrew O'Neill, DesignFlow

3.7 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 will rise up to 0.5 m above the normal water level and during drought conditions it may lower by up to 0.3 m. The wetland plants will tolerate this variation and most will thrive. However, persistently high or low water levels (Figure 20) will have a negative impact on the plants and will need to be fixed.

Figure 20 Example of a wetland with persistently low water levels

Photo: Robin Allison, DesignFlow

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 Section 3.2. If there are no blockages, consult *Rectifying Vegetated Stormwater Assets*.

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*.

3.8 Responding to paint or fuel spills

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.

3.9 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, which maximises 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 coarse litter
- acts as a deterrent to public access

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

Figure 21 shows an example of uneven vegetation in a wetland. It is important to quickly re-establish vegetation in bare areas before weeds establish.

Figure 21 Uneven vegetation cover in a wetland and after transplanting

Photos: Robin Allison, DesignFlow

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. (For wetlands, looks for plants growing in similar depths of water.) Otherwise, refer to the *Technical Design Guidelines* or a person with a good understanding of aquatic vegetation. Plant at a density of between 6–10 plants per m2 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 of 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 Swamp Hens) or where the water level cannot be maintained at a constant low level (10 cm), replant using larger seedlings or plants. This is because swamp hens tend to pull seedlings out and high water levels often drown the 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.

Refer to the *Construction and Establishment Guidelines* 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*.

3.10 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; and 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 out 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 invasions 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 B-1). The growth of weeds within bioretention systems can reduce vegetation health, cover, and diversity, and result in an excessive organic layer accumulating on the surface of the filter material. Dense weeds within swales can reduce the flow capacity of the asset and increase the risk of flooding.

Sediment basins and wetlands
Enriched nutrient conditions and open water provides ideal habitat for aquatic weeds within sediment basins and constructed wetlands. Emergent aquatic plants (i.e. Cumbungi) and semi-aquatic weeds (i.e. para grass) colonise and grow well within the planted marsh zones and ephemeral margins (Table B-1). Common terrestrial weeds readily grow on the batters (Table B-1).

ACTIONS
Ideally, remove or control all weed species within an asset as part of a regular maintenance program. This is mandatory for declared weeds. A low level of undeclared weed cover may be okay if it does not hinder the functioning of an asset. However, early detection and action should cost less and result in higher success rates for managing weeds.

The main aspects of controlling weeds in vegetated stormwater assets are:

- 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*.

When managing weeds, 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

Determining the source or cause of weeds will help to determine the most appropriate weed control strategy.

Understanding a weed's 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 of the infestation.

There is a range of methods commonly used to control weeds within vegetated stormwater assets (see below). An integrated approach, where a number of control methods are used in a co-ordinated 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.

Many aquatic weed species are able to re-grow 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 OF WEEDS

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, such as herbicides.

SLASHING

Slashing is an effective strategy to prevent weeds from flowering and seeding. Slashing is particularly useful for controlling isolated weed infestations but is not an effective method for eradicating weeds. Slashing can be undertaken using either a hand-held brush-cutting machine or a tractor equipped with a slashing implement.

BIOLOGICAL

Biological control uses insects and disease 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 control it easily 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 draw-down 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 or no stormwater runoff.

HERBICIDES

Herbicides are a common method used to control weeds growing in vegetated stormwater assets. Chemical weed control is often more cost-effective than mechanical methods and is particularly effective at controlling large weed infestations.

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, take care to 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 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 weed's stem 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 protection 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; and waterproof hat or hood.

STEAMING

The direct application of heated steam can control weeds. Applying steam removes the plant's outer, waxy coating and breaks cellular structures, resulting in discoloration 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.

3.11 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, which is 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 the 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.*

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.*

3.12 Managing algal or moss growth on bioretention systems

ISSUE

Constant wetting of the filter surface of a bioretention system may result in the growth of algal or moss. Algae can be identified as a green/brown coloured coating or biofilm on the surface of the filter media, as shown in Figure 22. Filamentous algae may also appear on the surface of the filter media and often appears as a dense mat of fine green filaments (see Section 3.11). Moss is easy to identify because it looks like a thick green carpet as shown in Figure 23.

In most circumstances, minor algal and moss growth on the surface of a bioretention system will not be detrimental to infiltration rates. However, excessive algal growth or moss can clog the filter surface and prevent infiltration, and indicate that either base flows are entering the asset or there are problems with the infiltration rate. If infiltration in a bioretention system is reduced or not occurring (see Figure 18), 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*.

Figure 22 Algae growing on the filter media surface

Photo: Leon Rowlands, Sunshine Coast Council

Figure 23 Moss growing on the filter bed surface

Photo: Paul Dubowski, Healthy Waterways

FOUR RECORDING INSPECTIONS AND MAINTENANCE

4.1 Overview

Use the checklists in this section when undertaking inspections and maintenance in order to record the condition of assets (i.e. 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 i.e. inspect the surrounds and then move on to inspect specific elements of the asset e.g. the inlet, banks 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*.

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.

Water quality monitoring is not recommended to determine the performance of every vegetated stormwater asset, as it is a specialised field that is complex and costly. If asset owners want to perform more water quality monitoring of their assets, monitor 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 assets that have a similar design.

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's 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's 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			

* 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

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
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 declared weeds (or declared weeds 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's 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's 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			

* 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

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
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, whereby 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/clean out points	Clean out points not damaged and end caps securely in place			
Litter	Maximum 1 piece litter per 4 m^2			
Unusual odours, colours, or substances (e.g. oil and grease)	None detetcted			
Vegetation	Minimum 95% vegetation cover (minimal bare batches)			
	Plants healthy and free from disease			
	Average plant height > 500 mm			

* 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

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
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* 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 maintening the inlet zone of a wetland.

ASSET TYPE	**Constructed wetland**	**ASSET ID**
Date		
Date of last rainfall		**Weather**
Officer's 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's 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 litter per 4 m2			

*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

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
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 0.3m below the normal level			
Vegetation	Minimum 80% vegetation cover on batters and in water up to 300mm deep (higher if the vegetation provides a public-safety exclusion role)			
	Average plant height > 500 mm above normal water level			
	Plants healthy and free from disease			
Weeds (emergent, floating, or submerged)	No declared weeds (or declared weeds are controlled)			
	Maximum 10% cover of weeds			
Algal mats	Maximum 10% cover of algal mats on two consecutive inspections			

* 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

What to look for	Performance Indicator (PI)	Condition rating *	Maintenance undertaken**	Additional work needed
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's 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's 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 batches)			

* 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

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
	Average plant height > 500 mm Plants healthy and free from disease			
Weeds (emergent, floating or submerged)	No declared weeds (or declared weeds 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			

* 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

What to look for	Performance Indicator (PI)	Condition rating*	Maintenance undertaken**	Additional work needed
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

FIVE **REFERENCES**

Department of Environment (1998). *Draft Guidelines for the Assessment and Management of Contaminated Land*. Queensland Government, http://www.derm.qld.gov.au/register/p00090aa.pdf

Water by Design. *Construction and Establishment Guidelines: Swales Bioretention Systems and Wetlands*. Healthy Waterways Ltd, Brisbane.

Water by Design. *Maintaining Vegetated Stormwater Assets*. Healthy Waterways Ltd, Brisbane.

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

Water by Design. *Technical Design Guidelines*. Healthy Waterways Ltd, Brisbane.

SIX **APPENDICES**

Appendix A Assessing sediment contamination and disposal needs

Figure A-1 shows the steps involved in testing and disposing of sediment from a vegetated stormwater asset.

Figure A-1 Testing and disposing of sediment from vegetated stormwater assets

STEP 1 - SITE ASSESSMENT

Are there any industrial land uses or a highway in the catchment of the system?

Does the sediment have an offensive smell or oily film etc?

Are there any activities in the catchment that are likely to cause land contamination (e.g. in Queensland, 'Notifiable Activities' under Schedule 3 of the *Environmental Protection Act 1994)*?

Are there any sites in the catchment that are known to be contaminated or potentially contaminated (e.g. in Queensland, sites listed on the Environmental Management Register or Contaminated Land Register)?

YES ↓ NO ↓

STEP 2 - TESTING

Complete simple soil assessment using field kit eg. Soil pH test available from CSIRO

Does the soil test indicate the sediment is contaminated or do concerns remain regarding contamination?

NO →

STEP 4 - DISPOSAL

Transport sediment to approved landfill or dispose safely onsite

YES ↓

NO

STEP 3 - ADDITIONAL TESTING

Organise independent qualified soil/ sampling testing to confirm extent and type of contamination.
Is contamination confirmed?

YES ↓

STEP 4– DISPOSAL

Contamination consultant or licensed waste removal contractor to remove the contaminated soil/sediment in accordance with relevant local or state legislation and policy (e.g. in Queensland, the *Environmental Protection Act (1994)* and the *Guidelines for the Assessment and Management of Contaminated Land* (Department of Environment, 1998)

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 (third edition) by C. Lamp and F. Collet (1989), Inkata Press, Australia.

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

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

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

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

Electronic resources

The Environmental Weeds of Australia (CD), Centre for Biological Information Technology, University of Queensland. Order from www.cbit.uq.edu.au/software/enviroweeds

On-line resources

Weedbusters www.weedbusters.info

Weeds to wack www.saveourwaterwaysnow.com.au/01_cms/details.asp?ID=51

WEEDeck (Weeds Australia) www.weeds.org.au/weedeck.htm, www.sainty.com.au

Weeds of National Significance www.weeds.gov.au/weeds/lists/wons.html

Weed identification (Brisbane City Council) www.brisbane.qld.gov.au/BCC:BASE::pc=PC_2519

WEEDeck

The *WEEDeck* pocket guide series, initiated by the National Weeds Strategy Executive Committee, is a handy guide for maintenance staff to identify common weed species in the field. It consists of more than 280 pocket-sized, full-colour weed identification cards. *WEEDeck* pocket guides can be tailored to include the common weed species found within a particular region and may also include noxious weeds that are likely to occur. The *WEEDeck* cards can be purchased from www.sainty.com.au.

Declared weeds

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 for consistent management across states.

State legislation may also declare weeds. In Queensland, the *Land Protection (Pest and Stock Route Management) Act 2002* has three categories of declared weeds, which are plant species that have, or could have, serious economic, environmental, or social impacts.

Class 1: A weed species that has the potential to become a very serious pest in the future. Landholders are required by law to keep their land free of Class 1 weeds and must not introduce, keep, release, transport, or sell Class 1 weeds without a permit.

Class 2: A weed species that has already spread over substantial areas of Queensland, but its impact is serious and needs to be controlled to avoid spreading onto properties that are still free of the weed. Landholders must try to keep their land free of Class 2 weeds and must not keep, release, transport, or sell Class 2 weeds without a permit.

Class 3: A weed species that is commonly established in parts of Queensland. A notice may be served on a landholder to take reasonable action to remove the weed if it is causing, or has the potential to cause, an adverse impact on a nearby 'environmentally significant area'. It is an offence to sell, introduce, release, or supply a Class 3 weed.

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

Common weeds species

Common weed species encountered in stormwater treatment assets are shown in Table B-1.

Table B-1 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	Class 2
Limnocharis flava	Limnocharis	Emergent	SB, W	
Sagittaria platyphylla	Sagittaria	Emergent	SB, W	
Alternanthera philoxeroides	Alligator Weed	Emergent	SB, W, SW	Class 1
Hygrophila costata	Hygrophila	Emergent	SB, W	Class 1
Gymnocoronis spilanthoides	Senegal tea	Emergent	SB, W	Class 1
Heteranthera reniformis	Kidney leaf	Emergent	SB, W	
Ludwigia peruviana	Peruvian primrose	Emergent	SB, W, B	Class 1
Typha domingensis/ orientalis	Cumbungi	Emergent	W, SW	
Salvinia molesta	Salvinia	Floating	SB, W	Class 2
Eichhornia crassipes	Water Hyacinth	Floating	SB, W	Class 2
Pistia stratoites	Water Lettuce	Floating	SB, W	Class 2
Nymphaea mexicana	Yellow Water Lily	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	Class 2
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	Silver Leaf 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	Class 3
Ligustrum sinense	Chinese privet	Terrestrial	SB, W, B, SW	Class 3
Schinus terebinthifolius	Broad-leaf pepper tree	Terrestrial	SB, W, B, SW	Class 3
Cyperus eragrostis	Umbrella sedge	Emergent	W, SW	
Celtis sinensis	Chinese celtis	Terrestrial	W, B, SW	Class 3
Pennisetum setaceum	African fountain grass	Terrestrial	B, SW	Class 3
Conyza spp.	Fleabane	Terrestrial	B, SW	
Setaria sphacelata	Setaria	Terrestrial	SB, W, B, SW	
Sphagneticola trilobata	Singapore daisy	Terrestrial	B, SW	
Tradescantia fluminensis	Wandering dew	Terrestrial	SB, W, B, SW	

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

** Under the *Queensland Land Protection (Pest and Stock Route Management) Act 2002*

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 it is possible for the plant to 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 Cumbungi 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

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. Ball-shaped, white flower heads on stalks to about 9 cm, originating from the leaf-stem nodes.

Note: Alligator weed can easily be confused with *Ludwigia spp*. (water primrose) and *Persicaria* spp. species (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 the plant's 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

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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, DesignFlow

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 stem, and hairy leaf sheafs and nodes.

Flowering: Most of 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 herbs with flat or slightly rounded leaves (sometimes spongy) to 3 cm wide and growing to 3 m tall. Flower head 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 is able to grow in water depths to 1.5 m and often forms dense stands that out compete and reduce species diversity within the wetland vegetation.

Flowering: Mostly summer

Reproduction: Seed 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 water surfaces, 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, DesignFlow

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 is a fern so it does not flower. Fruiting bodies containing sterile spores that hang from the divided leaf.

Reproduction: Salvinia does not produce fertile spores. Spreads vegetatively by fragmentation.

Control: Physical removal, chemical, biological

Integrated control strategies that combine both physical and chemical removal 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, DesignFlow

Water hyacinth (*Eichhornia crassipes*)

Free-floating perennial aquatic plant with dark green, erect leaves, including stalk, to 60 cm land 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 enable the plant to float.

Flowering: October–July

Reproduction: 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, biological

Water hyacinth 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 and chemical removal techniques have proven to be effective at controlling water hyacinth infestations.

The integrated use of two introduced weevil species (*Neochetina eichhorniae* and *Neochetina bruchi*) has proved 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, DesignFlow

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 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: Seed and by vegetative daughter plants on the end of stolons

Control: Physical removal, chemical, biological

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; however, the plants are 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, but this method is usually impractical.

Photo: Geoff Sainty

Cabomba *(Cabomba caroliniana*)

Submerged perennial aquatic plant with slender elongated stems (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: Cabomba 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: Fertile seeds have not been verified. Cabomba reproduces vegetatively via dislodged stem fragments.

Control: Physical removal, water level management, chemical control

Cabomba 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 of Cabomba but the root system has to be killed.

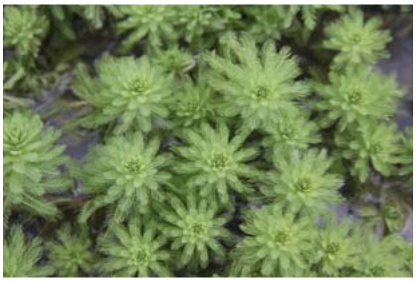

Photo: Jason Sonneman, DesignFlow

Parrot's feather (*Myriophyllum aquaticum*)

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

Plants 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: Unknown 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.

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, DesignFlow

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, DesignFlow

Yellow waterlily (*Nymphaea mexicana*)

Distinguished by broad elliptic leaves to 25 cm wide with smooth and wavy leaf margins. Distinguished by yellow flowers with pointed petal tips and vertical, knobbly rhizomes. Yellow waterlily has the potential to cover the water surface and limit the growth of other plants, which in turn reduces the habitat for micro-organism, invertebrate and fish.

Note: the widespread and common African Cape waterliliy *Nymphaea caerulea*, with showy blue flower, can be misidentified as *N. gigantea*, which is an endangered species.

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 seed bank required to re-establish the plants in 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, DesignFlow

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. Seed head 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 summer

Reproduction: Seed and vegetatively via rhizomes (runners)

Control: Physical removal, chemical control

Seedlings and small plants are most effectively removed by hand; however, 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 leave blades (to 3.5 cm wide) tapering to a long fine point and a rhizomatous root system. Leaves hairy or hairless. Open seed head (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 they now are widespread and common on roadsides, stream banks, and cleared land.

Flowering: Most of year

Reproduction: Spreads by seed and slowly from rhizomes and plants rooting from the nodes

Control: Physical removal, chemical control


Photo: Jason Sonneman, DesignFlow

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 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 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. Seed head comprising of a cluster of 2–7 spikelets (2–6 cm long). Stems often flattened and with a purple tinge.

Readily invades bare areas of soil or sites subject to frequent disturbance. Highly tolerant of extended dry periods due to 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.

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