

Costing WSUD and conventional drainage maintenance in Perth

Scoping report – for discussion

Prepared for the
Water Sensitive Transition Network

By Urbaqua

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1 INTRODUCTION

1.1 Project motivation

The cost of vegetated asset maintenance is routinely used as a barrier for the implementation of water sensitive urban design (WSUD) solutions. Although some cost information is available, it is patchy and out of date. There is a need for a comprehensive assessment of the costs of WSUD asset maintenance to facilitate a comparison with the costs of conventional drainage asset maintenance. This information can then be fed into life cycle benefit cost assessments and business cases.

Objective

This project aims to collect data from WA local governments and develop a high quality data set that will support continued investment in WSUD assets and guide Local Governments, designers and developers in the selection and design of vegetated WSUD treatment systems.

1.2 Background

Although the significant environmental and social benefits from vegetated WSUD infrastructure are widely recognised, the maintenance of these systems is perceived to be more expensive than that of traditional stormwater or park assets. This is further exacerbated by the wide range of WSUD solutions that can be implemented in new development and through retrofitting which result in significant variability of outcome, and a lack of awareness of the different maintenance requirements of each system.

A greater understanding of the life cycle costs associated with the different treatment systems will help Local Government and the development industry, including hydrologists, engineers, landscape architects, and asset and parks managers to make informed decisions regarding the appropriate application of WSUD technology.

Although Brisbane City Council in 2007 and Melbourne Water in 2013 have attempted to gather information on the lifecycle and maintenance costs of WSUD assets, no data has been compiled for Western Australia. This was recognised by the Water Sensitive Transition Network in 2017 and the *Vision and Transition Strategy for a Water Sensitive Greater Perth Implementation Plan 2019–2021* contains two actions as follows:

Action 3.1 - Document and quantify benefits of public and private open space and green infrastructure, including maintenance costs, to support ongoing maintenance commitments by local governments (link to action 4.7)

Target - Gather financial information on lifecycle benefits and costs of WSUD vs conventional drainage/POS with a focus on maintenance and share comparison via a database of information (Research Sub-committee)

Action 4.7: Share economic valuation methods to support business cases for different scales and beneficiaries (including maintenance of water sensitive systems). (Link to action 3.1)

Target - Life cycle cost/benefit information for a range of treatments at various scales is readily accessible. Develop a business case for maintenance that is used by local governments to obtain support for appropriate levels of resourcing. (Technical Capacity and Partnerships sub-committee)

This project will aim to address Action 3.1 in full and action 4.7 in part.

1.3 Project delivery

The project included the following tasks.

1. Seek preliminary guidance on information needs
2. Review and summarise publicly available information
3. Collect and compile data from WA local governments
4. Industry consultation via a workshop
5. Complete spreadsheet and prepare report on findings

1.3.1 Preliminary input from local government

Officers from 18 local governments were asked about the information that would assist them to improve WSUD asset maintenance. Responses were received from the Cities of Bayswater, Swan, Gosnells, Canning, Mandurah, Kwinana, Mandurah, Wanneroo and Armadale and the Shire of Mundaring.

The responses revealed that most local governments sought information on biofilters, swales, tree pits, living streams and gross pollutant traps (GPTs) (Appendix 1). Feedback from local governments also suggested that it would be valuable to understand the different maintenance and replacement/renewal requirements of each type of asset. Accordingly, the project was expanded to include this information.

1.3.2 Publicly available information

A search was undertaken for publicly available information on the cost of WSUD and drainage asset maintenance in Western Australia and nationally. This information is summarised in Appendix 2. It became apparent; however, that much of the available information is nearly 10 years old and so likely to be out of date. The most recent information compiled for Melbourne Water was a report by Parsons Brinkerhoff in 2013. A report on the cost of maintaining bioretention systems was also released by Water by Design (Qld) in 2015. Since then, no new data has been compiled and most maintenance manuals refer to these key references. Recent advice from Stormwater NSW suggests that as "a rule of thumb when planning construction of a stormwater treatment device, a budget allowance of 3-5% of the capital cost (per year) is recommended."

Accordingly, this information has been provided for reference only, and used primarily to "sense-check" the information collected in Task 3.

1.3.3 Data from WA local governments

A request for information was made to 18 local governments in Perth seeking information as follows:

It would be appreciated if you could send through any data you have collected that is relevant to the maintenance of WSUD and/or drainage assets, preferentially in excel format.

We are interested in information relating to the cost of design, construction, establishment, maintenance and/or replacement activities.

We will use this information to develop a high quality data set that can guide Local Governments, designers and developers in the selection and design of vegetated WSUD treatment systems.

The types of assets we are interested in include:

- Sand filters (leaky side entry pits)
- Underground infiltration cells
- Detention basins (unfenced multi-use POS, dry out between storm events)
- Biofilters (containing media)
- Raingardens (in-situ soils)
- Conveyance swales (dry out between storm events)
- Tree pits (could combine with either raingarden or biofilter depending on media)
- Living streams (permanently wet or ephemeral)
- Constructed wetlands
- Drainage pit and pipe networks
- Fenced drainage sumps
- Trapezoidal drains
- Gross pollutant traps

It is recognised that it is unlikely that you will have access to data on individual costs, so any of the following information would also be appreciated:

- Average hours required to maintain particular systems;
- Rates for staff time
- Types of activities undertaken and associated costs
- Areas able to be serviced/person/day
- Cost for contracted maintenance and reports provided (which include activities, time & costs)

If this information is available but not compiled, the opportunity exists for one of our research assistants to assist with the gathering of data. If this is the case, please let us know and we would appreciate the opportunity to work with you to compile the information.

Although data was received from nine Local Governments, there was no consistency in the type of information collected and it was not possible to create a benchmark for comparison.

1.3.4 Industry consultation

Local Government officers representing either the Engineering/Asset/Operations teams or Environment teams from Belmont, Canning, Kwinana, Mandurah, Murray, Swan, Victoria Park, and Wanneroo were contacted individually to obtain additional detailed information. This included:

- Current maintenance programs (traditional drainage assets versus WSUD assets);
- Scheduling of maintenance programs (regular or responsive);
- Tracking of maintenance activity;
- Drainage maintenance budget allocation; and
- Recommendations on how to better fund, plan, and deliver WSUD asset maintenance.

A varying level of information was received from Local Government officers due to variation in knowledge of WSUD assets themselves, maintenance records, and knowledge of how different

teams maintained different element of assets. A summary of this information is presented in section 3.2 below.

A workshop will be held with local government and industry to discuss preliminary findings. Initially, the intent of the workshop was to share the preliminary assessment of data and confirm the assets to be reported and obtain feedback on how the information should be presented so it is most useful for industry and local governments. However, as it has not been possible to gather as much data as expected, the aim of this workshop will need to be revised. It is suggested that the workshop is held to bring Local Government engineering, environmental and asset staff together to discuss key barriers to effective maintenance in general and document a way forward.

2 SUMMARY OF PUBLICLY AVAILABLE INFORMATION

A search was undertaken for publicly available information on the cost of WSUD asset maintenance across Australia. This information is summarised in Table 1.

A key finding is that very little data exists on the cost of WSUD asset maintenance. Most documents refer to a limited number of studies which are:

- Lifecycle Cost of Water Sensitive Urban Design (WSUD) Treatment Systems. Summary report. A report for Brisbane City Council – City Design (draft, Ecological Engineering, 2007)
- Water Sensitive Urban Design Life Cycle Costing –Data Analysis Report for Melbourne Water (Parsons Brinckerhoff, 2013)
- Guide to the cost of maintaining bioretention systems (Water by Design, 2015)

The most recent compilation of information was undertaken by SERCUL for the City of Melville in 2019 and Stormwater NSW, 2020 although no new cost information was included in either document. It is also noted that Stormwater NSW recommends allocating a budget of 3-5% of the capital cost of the stormwater treatment device (per year).

Key aspects of note are:

- WSUD assets are comprised of multiple components (hard infrastructure, geotextiles, specialised media, vegetation) which require differing types of maintenance and expertise;
- Maintenance of different components of WSUD systems are often undertaken by different Local Government teams;
- Maintenance costs and activities vary between and within WSUD asset types;
- Factors that impact on cost include asset type, size and location; maintenance service level; need for traffic management; and external vs inhouse delivery;
- Maintaining vegetated systems requires regular (almost monthly) visits and this is (generally) a lower cost than rectification (when things go wrong);
- Maintenance during establishment is 2 to 5 times the routine cost when functioning;
- Systems with trees are cheaper to maintain than systems with understory plants alone;
- Maintaining isolated assets costs more than maintaining groups of systems in the same street;
- Maintenance costs are lower for assets that are well designed and constructed.

With regards to maintenance costs of each WSUD stormwater asset type, the following ranges for routine maintenance activities were noted:

- Biofilter - \$1 to \$30/m2/year
- Tree pit - \$5 to \$35/m2/year
- Swale - \$1 to \$5/m2/year
- Dry (ephemeral) detention basins – no estimates available
- Constructed wetland - <\$1 to \$10/m2/year
- Gross pollutant trap - \$100 - \$1000 per visit

Melbourne Water developed a useful summary that includes indicative maintenance and installation costs for WSUD assets (Figure 1), although it is noted that the indicated function and applicability may vary under WA conditions.

<div>✓ High applicability</div> <div>✓ Medium applicability</div> <div>✓ Low applicability</div>	Bioretention swales	Bioretention basins /raingardens	Vegetated swales/ buffer strips	Sand filters	Sedimentation basins	Constructed wetlands	Ponds and shallow lakes	Rainwater tanks
FUNCTION:								
Water quality treatment	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓	✓
Flow attenuation	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓
Stormwater conveyance	✓✓✓	✓	✓✓✓	✓	✓	✓	✓	✓
Particle size removal								
Coarse-Medium particles 5000 µm-125 µm	■	■	■	■	■	■		
Fine particulates 125 µm-10 µm	■	■	■	■	■	■		
Very fine/Colloidal particulates 10 µm-0.45 µm	■		■			■		
Dissolved particles <0.45 µm								
Additional function		Landscape value	Aesthetic appeal Habitat values		Landscape value	Habitat, visual & recreation amenity	Habitat, visual & recreation amenity	Stormwater re-use
APPLICABILITY:	Median strip/ verge	Streets	Median strip/ verge/parks	Streets/many	Pre-treatment to wetland	Parks/vacant land	Aesthetic/ post wetland	On-property
Area requirement	Larger areas (with limited public access)	Limited space	Larger areas (with limited public access)	Limited space	Large areas	Large areas	Large areas	Limited space
Slope considerations and approach to site constraints	Gentle slopes (< 5%). Where slopes exceed 5%, flow spreaders or check dams may be required.	Flat land. Where land is sloped terraces can be used.	Gentle slopes (< 5%). Where slopes exceed 5%, flow spreaders or check dams may be required.	Suitable for steeper slopes	Flat land	Flat land	Suitable for steep land	Suitable on most sites
Level of flow control	Conveyance	Discharge	Conveyance	Discharge	Discharge	Discharge	Discharge	Source
INDICATIVE COSTS:								
Installation costs	Moderate	Moderate	Low	Low/ Moderate	High	High	High	Low
Maintenance costs	Moderate	Moderate	Moderate/ High	Moderate	Moderate/High	Moderate	Moderate	Low

Indicative costs: Indicative costs for comparison purposes only

Installation costs: Based on the treatment's total installed cost per hectare of catchment. Broad approximations are as follows:

- High: Greater than \$1500 per hectare of catchment;
- Moderate: Between \$500 and \$1500 per hectare of catchment; and
- Low: Less than \$500 per hectare of catchment

Maintenance costs: Based on the cost per hectare per annum for each treatment type. Broad estimates are as follows:

- High: Greater than \$250 per hectare of catchment per annum;
- Moderate: Between \$100 and \$250 per hectare of catchment per annum; and
- Low: Less than \$100 per hectare of catchment per annum.

Figure 1: Summary of treatment function, applicability and cost (Source: Melbourne Water 2011)

Table 1: Summary of maintenance activity and cost via WSUD asset type

Asset type	Maintenance Activities	Frequency of Maintenance Activities	Maintenance Activity Cost	Reference
Biofilters/Raingardens/ bioretention systems (contain media)	Weed control	4-6 weeks	Small scale (isolated systems): \$20-\$30/m ² /fm/yr Small scale (grouped systems): \$10-\$15/m ² /fm/yr Precinct scale (grasses & sedges): \$5/m ² /fm/yr, \$1m ² /fm/yr Precinct scale (grasses, sedges, shrubs&trees): \$1m ² /fm/yr Large systems (grasses&sedges): \$5/m ² /fm/yr; Large systems (grass, sedges,shrubs&trees): \$1/m ² /yr fm = filter media	WSUD Guidelines, South Eastern Councils (Melbourne Water, 2013); Water by Design, 2015
	Litter removal	4-6 weeks		
	Replanting	Irregular-complete if required		
	Scour control	Rare-complete if required		
	Sediment removal	Irregular-complete if required		
	Sediment forebay of filter media	Irregular-complete if required		
Bioretention swales (contain media)	Establishment maintenance	2 weekly	2 to 5 x routine cost	WSUD Life Cycle Costing, Parsons Brinckerhoff for Melbourne Water, 2013
	Routine - aesthetic: Litter removal and weeding	as desired - location dependent		
	Routine - functional: Visual inspections, Vegetation maintenance, Sediment removal	monthly to 3 monthly	Inhouse estimates / case studies for bioretention basin: \$3 to \$5 /yr/m ² (400 to 700 m2)	
	Renewal-Filter: Sediment removal and disposal-low level contaminated	2-5 years		
	Renewal-Filter. Resetting-minor (replace top 100mm filter media and plants)	10-15 years	\$50 to \$100 /m ²	
	Renewal-Filter. Resetting-major (including pipes, underdrainage pipes, filter media and plants)	Asset is not functioning (due to poor quality construct or subsequent damage)	\$100 to 250/m ²	
	Renewal-Damage: vandalism, removal blockages, erosion/relevelling/earthworks	as required		
	Infrastructure: check for damage, repairment, check outlet points	3 monthly and following storm events		
	Renewal-Horticultural: replanting - expected 5%, pruning, mulching, soil additives, pest control etc.	Annually / as required		
On Street raingardens/Tree pits (contain media)	Routine - functional: Visual inspections Maintaining plant density / replanting Weeding and removal diseased plants/ sediment removal	monthly to 3 monthly	Contracted rates for on street raingardens: Small (< 50 m2) = \$20 to \$35 /yr/m2 Med (100 m2) = \$15 /yr/m2 Large (> 250 m2) = \$5 to \$10 /yr/m2 Inhouse estimates / case studies for on street raingardens: \$5 to \$16 /yr/m ² (< 100 m2)	WSUD Life Cycle Costing, Parsons Brinckerhoff for Melbourne Water, 2013
	On-site infiltration test, manage erosion, repair damage, filter media replacement	as required		

Asset type	Maintenance Activities	Frequency of Maintenance Activities	Maintenance Activity Cost	Reference
	Minor reset: incl filter and plants (average size: 10m ²)		\$50-\$100/m ²	Raingarden filter replacement – case study (review of contract quotes), Alan West, City of Kingston, 30/11/2011
	Major reset: incl. underdrainage and full landscape (average size: 15-100m ²)		\$150-\$250 /m ²	
Vegetated swales/ Conveyance swales/Buffer Strips (no media)	Debris & sediment removal	On-going/as required		WSUD Guidelines, South Eastern councils, Melbourne water, 2013
	Check inlet erosion protection	Routine inspections following significant storm events		
	Vegetation Maintenance	Intensive during plant establishment (first 2 years), then as needed.		
	Sediment removal, disposal-low level	2-5 years		WSUD Life Cycle Costing, Parsons Brinckerhoff for Melbourne Water, 2013
	Visual inspections, maintaining plant density/ replanting, weeding and removal, mowing, removal of blockages at inlet/outlet.	1-3 monthly		
	Reset, replanting/turfing	10-15 yrs		
	Mowing	2-3 times per year	\$1.62/100m ²	WSUD Design-Greater Adelaide Region Technical Manual- December 2010
	General grass care	Grass maintenance area is top width+3m length	\$16.2/100 m ²	
	Debris/litter removal	\$0.95/m ²	\$0.95/m ²	
	Reseeding/Fertilisation	Area revegetated is 1% of maintenance per area per year	\$0.65/m ²	
	Inspection and general administration	Inspection once per year	\$1.35/m ²	
	Buffer strip litter removal and mowing		\$2.5/m ²	Upper Parramatta River Catchment Trust, 2004
Constructed wetlands	Debris removal	On going/ as required		WSUD Guidelines South Eastern Councils, Melbourne water, 2013
	Check inlet erosion protection	After significant rainfall events ; immediately after following installation		
	Removal of accumulated sediments	As required during first two years if poor site erosion management during construction, but sedimentation basin should prevent.		
	Vegetation maintenance	Intensive during plant establishment (first 2 years) then as needed.		

Asset type	Maintenance Activities	Frequency of Maintenance Activities	Maintenance Activity Cost	Reference
	Renewal maintenance: invasive weed control, removal debris, sediment removal and disposal, revegetation, tree removal)	Following major rain events	Small to med (2,200 m2) = \$18 to 22 /m ² /yr	WSUD Life Cycle Costing, Parsons Brinckerhoff for Melbourne Water, 2013/ Ensuring WSUD Succeeds, (Wyndham City Council) – Michael McGlade presentation to Clearwater 12 Feb 09
	Establishment maintenance (activities as per routine)		2 to 5 x routine cost	WSUD Life Cycle Costing, Parsons Brinckerhoff for Melbourne Water, 2013
	Routine - functional: Visual inspections Maintaining plant density / replanting Litter/organics/debris removal Weeding and removal diseased/dead vegetation	monthly to 3 monthly	1289.7*A ^{-0.794} Small (500 m2) = \$9.3 /m ² /yr Med (5,000 m2) = \$1.5 /m ² /yr Large (50,000 m2) = \$0.2 /m ² /yr note: max estimate = \$10/m ² /yr as little data above this range	
	Decommissioning: removal, waste disposal and landscaping	infinite 7 (in theory) 50 years 8 (for life cycle costing)		
Sedimentation Basins	Sediment removal and disposal	2 to 5 yr		WSUD Life Cycle Costing, Parsons Brinckerhoff for Melbourne Water, 2013
	Debris removal	On going/ as required		WSUD Guidelines, South Eastern councils, Melbourne water, 2013
	Check inlet erosion protection	After significant rainfall events, immediately following installation		
	Removal of accumulated sediments	When basin is more than half full of accumulated sediment (typically every 5 years)		
Detention basin/system Cost data for dry/ephemeral detention systems is limited. Alternative method of costing these systems is to examine the costs of similar systems, such as ponds and swales.	Removal of accumulated litter and debris	Middle and the end of wet season		Stormwater management manual for Western Australia, Department of Water, Government of WA, 2007
	Irrigation, nutrient, pest management			
	Removal of accumulated sediment in the forebay	5-7 years, or when accumulated sediment exceeds 10% of the basin volume.		
Permeable paving	Monitoring: accumulated sediment, removal of blockages, ponding of water following rainfall events	3 month and following storm events		WSUD Maintenance guidelines. Melbourne water, 2013

Asset type	Maintenance Activities	Frequency of Maintenance Activities	Maintenance Activity Cost	Reference
	bedding material-level of pavement surface	annually		
	underdrain-check inspection openings for sediment accumulation, flush underdrain to remove sediment	annually		
Inground GPTs	Inground cleanout-basket cleanout	2-4monthly	typical"\$750/visit. Range: \$500-\$1500 (\$ to L)	WSUD Life Cycle Costing, Parsons Brinckerhoff for Melbourne Water, 2013
	In ground cleanout-vacuum eduction		Typical:\$900/visit. Range: \$400-\$1200 (\$ to L)	
	Primary treatment type-side entry pit trap (SEPT)		typical: \$100 / visit (based on large contracts with up to 300 SEPTs) range: \$100 to \$5,000	
	GPT Trash Rack Disposal and recycling (in Sydney)		\$250/tonne	Powel, 2018
	GPT-WET SUMP cleaning		\$130/tonne for large systems, \$280/ tonne for small systems.	Maintenance guidelines for stormwater Treatment Measures, Stormwater NSW, 2020
	Typical cleaning(suction)	1-6 month	\$500-\$2,000	
	Cleaning with Clamshell grab or basket		\$400-\$1500	
	Disposal and recycling		\$250/tonne	
	GPT-Trash Rack cleaning	1-6 month	\$500-\$2,000	
Infiltration trenches/systems	Visual inspection	once per month	\$100	Maintenance guidelines for stormwater Treatment Measures, Stormwater NSW, 2020
	Hydraulic conductivity	once per year	\$4,000 for 3-4 sites	

Disclaimer The cost estimates provided should be used as the basis for developing a maintenance budget – they are provided for comparative purposes only and the dollar values quoted in the table have not been adjusted for inflation. For example, if the source of cost estimate is a 2002 reference, the dollar values are in 2002 (except where otherwise stated.)

3 COLLECTED DATA

Local governments across the Perth and Peel region were asked to provide any available data that is relevant to the maintenance of WSUD and/or drainage assets, preferentially in excel format. This included information relating to the cost of design, construction, establishment, maintenance and/or replacement activities. As a guide, the following types of assets were provided as examples of the information being sought:

- Sand filters (leaky side entry pits)
- Underground infiltration cells
- Detention basins (unfenced multi-use POS, dry out between storm events)
- Biofilters (containing media)
- Raingardens (in-situ soils)
- Conveyance swales (dry out between storm events)
- Tree pits (could combine with either raingarden or biofilter depending on media)
- Living streams (permanently wet or ephemeral)
- Constructed wetlands
- Drainage pit and pipe networks
- Fenced drainage sumps
- Trapezoidal drains
- Gross pollutant traps

Information in a range of formats and detail was received from Belmont, Canning, Kwinana, Mandurah, Murray, Rockingham, Swan and Wanneroo.

3.1 Costs

Attempts were made to obtain the cost of drainage maintenance on a per unit area of asset (\$/lineal m or \$/m²) and unit catchment area basis. However, minimal maintenance cost information was available from local governments in WA. Some information was prepared by the City of Wanneroo for vegetated WSUD systems as follows:

- Biofiltration systems: ~\$30/ m² / year
- Swales: ~\$85 / m² / year (based on a catchment with 1,000 m² verge swales)

Maintenance cost information was also available for major living streams and wetlands in the City of Canning, associated primarily with tasks such as weed control, watering, infill planting and rubbish removal, as follows:

- Anvil Way Living Stream: ~\$12,000/year (~9,000m², therefore ~\$1.30 / m² / year)
- Bannister Creek: ~\$122,000 - \$190,000 /year (~320 lineal m, therefore ~\$380-\$600 / lineal m / year)
- Lambertia Creek: \$30,000 - \$50,000/year
- Wharf St constructed wetlands: ~\$44,000/year (~10,000 m², therefore \$4.40 / m² / year, or 365 lineal m, therefore ~\$120 / lineal m / year)

There are significant variations in the cost of maintaining vegetated WSUD systems of the same type. While the maintenance cost estimates provided here are a useful guide, consideration should be given to the site specific circumstances affecting cost for each asset. Contextual factors which affect the cost of maintenance can include the assets size, objectives or values of the asset (i.e. systems valued for their visual and recreational amenity tend to receive higher levels of maintenance than those simply providing for flood protection) and the sites physical

constraints. Average expenditure on each asset can also be significantly influenced by the managers available resources rather the sites needs informing what is invested.

More information was available on the costs of maintaining hard drainage assets, estimated as follows:

- Gross Pollutant Trap: ~\$250 - \$370 per clean (cleaning frequency, where available, varied between 1-3 times per year).
- Stormwater pit assets (Side Entry pits, Gully Pits, Bubble up pits, Manhole, Soakwells): ~\$88 each per year.
- Sump maintenance - \$300 annually plus \$20,000 - \$50,000 fence replacement and clean out cost every 10-20 years.

3.2 Comparing conventional drainage with WSUD stormwater assets

Although there is insufficient information to quantify the costs of conventional drainage vs WSUD stormwater assets, it is possible, through the consideration of available information, to indicatively show the difference between the costs associated with different phases of the asset lifecycle (Figure 2). This may assist in supporting the business case for installation and improve understanding of budget allocation for maintenance over time.

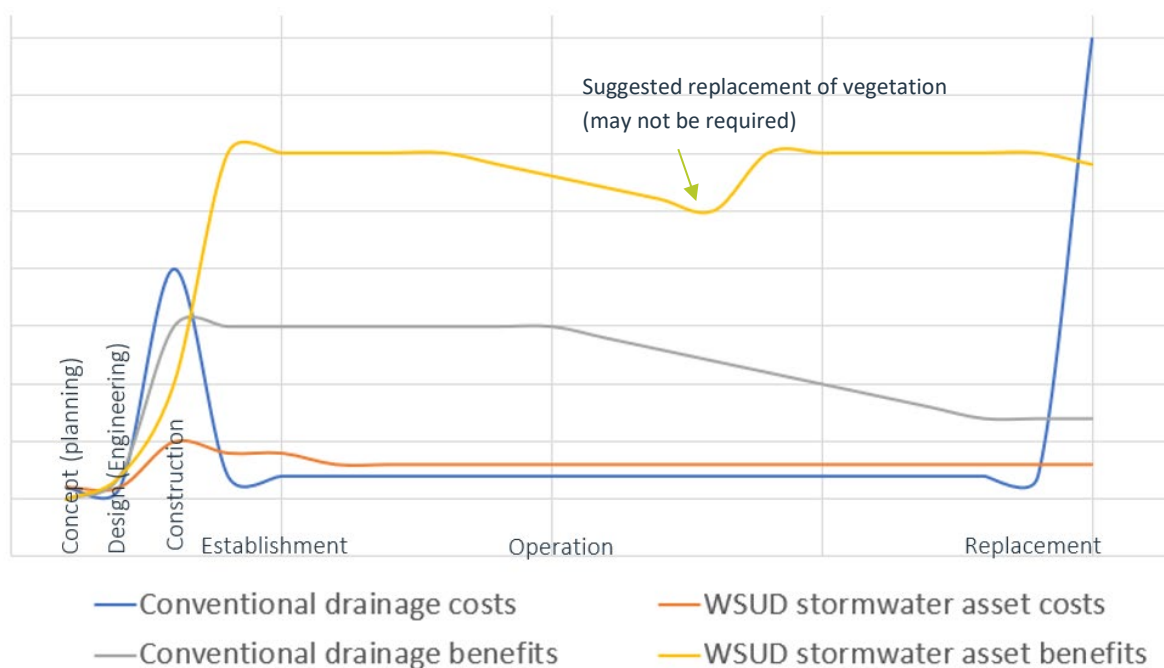


Figure 2: Indicative lifecycle costs and benefits of conventional drainage assets and WSUD stormwater assets (costs are not cumulative)

As shown in Figure 2, the costs of planning and design of both types of drainage systems is comparable. Construction costs of conventional systems at a catchment level are known to be higher than vegetated assets, due to the large underground, concrete pipe and pit networks associated with conventional systems. Where this pipe network is reduced through on-site management and use of vegetated, surface systems (i.e. WSUD approaches), this has resulted in significant cost savings. It is recognised; however, that the cost of constructing a living stream is greater than the cost of a piped solution when considered at an individual asset level.

The operational costs associated with WSUD stormwater assets are perceived to be higher than conventional pit and pipe systems, largely as a result of the more regular requirements for removal of litter and weeding of surface systems. This review found; however, that the costs may be more comparable. For example, the cost of cleaning pits at \$88 per pit per year, is comparable to the cost of 1m² of swale and a third of the cost of 1m² of biofilter per year (although it is recognised that this is not comparing “like with like” costs as the number of assets will depend on catchment size and characteristics). The high cost of cleaning GPTs is noted, as is the cost of sump maintenance, although the significant cost only occurs every few years.

The unquestionable difference is associated with replacement costs, as there are significant replacement costs associated with conventional systems, although this is recognised as usually being a 50-year cost, whereas WSUD systems do not require complete replacement. This difference in costs was highlighted by Indigo Shire in Victoria, in their drainage asset management plan (Figure 3).

Drainage Asset	Quantity	Replacement Value 2011 (\$)
Pipes	60,439 m	9,401,983
Pits	1,859 no.	2,567,951
Inlets/ Outlets	468 no.	321,706
Open Channels	1,658 m	* n.a.
Storage Basins: Retention Basins	2 no.	* n.a.
Wetlands	3 no. (total 8 no. Ponds)	* n.a.
TOTAL		\$12,291,640

* These assets do not require periodic renewal (only maintenance) and have not been assessed for replacement value

Figure 3: Excerpt from Indigo Shire Drainage Asset Management Plan (2012)

And although outside the scope of this report, there is mounting evidence of the significant additional benefits that are realised from the installation and maintenance of WSUD stormwater assets. These benefits include urban heat mitigation; enhanced biodiversity (vegetation and fauna); recharge of groundwater systems; improved water quality of groundwater, waterways and wetlands; increased property values; and improved mental and physical health of communities. This is in addition to the flood protection and stormwater nuisance management functions (benefits) provided by conventional drainage systems. Further information on the value of these benefits is available on the Cooperative Research Centre for Water Sensitive Cities website (www.watersensitivecities.org.au).

3.3 Maintenance practices

In response to the initial stakeholder survey, it was identified that there was a need for a greater level of clarity around the types of maintenance activities that are required for vegetated WSUD assets. Accordingly, information on current maintenance practices was sought through interviews with a range of local government officers and obtained in varying levels of detail from the following local government areas:

- Belmont;
- Canning;
- Kwinana;
- Mandurah;
- Murray;
- Swan;
- Victoria Park; and
- Wanneroo.

Some common maintenance practices were identified across all local governments from which information was available. In particular, maintenance practices are divided between hard drainage assets (including pit and pipe networks, underground infiltration cells, and Gross Pollutants Traps) which are typically planned, budgeted, and delivered by Engineering/Infrastructure/Operations teams; and soft or green assets (biofilters, detention basins, swales, rain gardens and tree pits) which are typically planned, budgeted, and delivered by Parks/Environment/Conservation/Leisure teams.

Hard drainage assets are typically maintained on a regular schedule and involve:

- Educting pits (side entry pits, soak wells, gully pits, bubble-up pits, manholes, underground infiltration cells);
- Jetting of drainage networks lines; and/or
- Cleaning Gross Pollutant Traps and other litter/sediment management systems;

Soft or green drainage assets are maintained on a reactive basis by some local governments, and on a regular schedule by others, and activities include:

- Litter and debris removal;
- Mowing;
- Pruning;
- Spraying (weed control); and/or
- Infill planting (less commonly).

Excavation of sumps, basins and other larger scale assets (which may also include vegetated areas as part of green drainage assets) to remove sediment/debris, upgrade, and/or increase storage capacity are most likely undertaken by Engineering/Infrastructure/Operations teams.

Maintenance activities are either undertaken internally or by subcontractor with input from the relevant local government team (for example, timing of maintenance activity based on an environmental risk assessment undertaken by the Environment team).

Maintenance activities are generally tracked and recorded, but not necessarily using a consistent method or software, and only in detail when a significant issue has been identified. Local governments were generally divided between considering whether enough budget was allocated to drainage maintenance activities or not. Where resources were considered to be constrained, the frequency of drainage maintenance activity was decreased, or reactive maintenance only was undertaken as necessary based on community complaint or flood risk. Maintenance of larger hard assets were prioritised over smaller, vegetated assets (such as rain gardens) by some local governments when under budgetary constraint.

Some key issues identified by local government with respect to delivering effective drainage maintenance included:

- Limited resourcing to undertake effective on-going maintenance (often resulting in reactive instead of preferred scheduled maintenance);
- Lack of communication or involvement between drainage asset designers/those providing approval and asset maintenance teams;
- Lack of analysis or consideration of total life cycle cost of drainage assets; and
- Inadequate asset maintenance tracking.

More detailed information provided by individual Local Government officers is presented below and summarised in Table.

Belmont

WSUD assets at the City of Belmont are maintained on a regular schedule of approximately six (6) weeks, typically involving the clearing of rubbish, debris and other blockages from each system, as well as pruning of vegetation. Hard assets such as Gross Pollutant Traps, underground infiltration cells, and pits are also maintained on a regular schedule and cleaned approximately three (3) times per year.

While the Parks, Leisure and Environment team and/or the Natural Areas team maintain vegetated assets (including constructed wetlands, tree pits, and minor swales), maintenance of hard assets is arranged externally by the City's Works Department. However, the Environment team provides input into the tender for hard asset maintenance contracts via preparation of environmental risk assessments. In particular, the Environment team will make recommendations around key issues such as timing of maintenance works to coincide with weather events.

Maintenance activities are tracked, but not in significant detail unless a significant issue has been identified. The maintenance budget at Belmont is generally considered adequate for the current program, for both WSUD and hard assets.

More involvement by the Environment team in the design of WSUD assets would be recommended, from a maintenance perspective.

Canning

Maintenance of drainage assets in the City of Canning is currently mostly reactive, however, a long-term project to develop a City-wide planned maintenance program is currently underway. Operational staff generally undertake most WSUD asset maintenance within the local government areas.

Maintenance of larger WSUD assets within the City is shared and managed by multiple land managers. Anvil way Living stream, Liege Street Wetland and Wharf street wetland are managed by a working group formed under the Drainage and Nutrient Intervention Program. Maintenance agreements for these sites are reviewed annually by group members who include the City, DBCA, SERCUL and Water Corporation. Bannister Creek and Lambertia Creek sites are managed by the City, SERCUL, Bannister Creek Catchment Group and Water Corporation. Water Corporation are responsible for hard infrastructure and maintenance within water bodies, while City of Canning and SERCUL undertake maintenance of fencing, weeding and surrounding infill planting of native vegetation.

The City has recently installed a number of raingardens along Cecil Avenue, as part of a major upgrade to the City Centre. The City has established a special team to maintain the streetscape which undertakes all tasks associated with maintaining the streets, paving, trees, biofilters, bins and other street furniture. This is a new initiative and the City recognises the larger range of skills and activities required to be undertaken by this team.

Kwinana

Maintenance of hard assets (sumps, pits, and pipes) at the City of Kwinana is managed by the Infrastructure Operations team, after handover from the Asset and Development teams. Parks and Environment manage all vegetated systems, involving as a minimum annual weed spraying and adhoc basin inspections. Maintenance is delivered by a combination of internal (e.g. spraying) and external teams, mostly on a reactive basis.

Maintenance activities are tracked by the Operations team using the RAM asset management system. The maintenance budget is generally considered adequate for hard asset maintenance.

Mandurah

A large number of different WSUD assets require maintenance in the City of Mandurah, including swales, tree pits, detention basins, rain gardens, and underground infiltration cells (Stormtech, Atlantis, and Hume cells). WSUD asset maintenance is generally outsourced by the Works/Operations team (which includes the Parks and Civil/Infrastructure teams). The Parks team manages maintenance of vegetated systems while Civil/Infrastructure manages delivery of hard asset (pit, pipe, GPTs, and underground infiltration cells) maintenance.

Maintenance is delivered via a combination of mostly reactive and some regular programs. Regular maintenance involves the eduction of hard assets on an annual basis and WSUD assets in POS are tended to approximately every eight (8) weeks.

Murray

Given the Shire of Murray is a relatively small, semi-rural local government area, most of its drainage infrastructure is comprised of open drains and pits, with a small number of WSUD assets (~10-15) constructed in conjunction with the Peel Harvey Catchment Council (PHCC).

The Shire Operations team (which includes both Civil/ Asset and Parks teams) undertakes both construction and maintenance of drainage assets. External subcontractors are only used for significant works such as pipe blockages or replacement of larger hard assets. Vegetation within assets (including spraying, pruning and planting) is maintained by Parks and Environment teams. Maintenance is generally undertaken on an adhoc basis, but drainage systems are generally considered low maintenance due to their design (mostly simple open drains and pits) and therefore are not considered to require a scheduled program.

The Shire of Murray Operations' maintenance budget is fixed each year, with additional budget only provided for specific improvements. Given that resources are significantly limited, the focus of maintenance works is usually on major issues. PHCC support for managing WSUD assets used to be greater, however involvement of the PHCC in managing WSUD assets has significantly reduced in recent years. The Shire Executive generally recognises and supports the need for drainage infrastructure improvements, as long as they are determined to be significant.

Only requests for maintenance from the community are tracked by the Shire Operations team, otherwise internal, adhoc maintenance is reported directly to management for action. Limited resources are considered to be the greatest constraint to adequate maintenance delivery.

Swan

Maintenance of both hard assets and vegetated WSUD assets is scheduled on a regular basis in the City of Swan. While maintenance of hard assets, involving works such as educting of pits and other engineering maintenance, is delivered by external subcontractors, maintenance of WSUD vegetation is undertaken internally by the Parks team. However, weed spraying is undertaken by both Parks and Engineering teams, where Engineering weed spray around kerbs, footpaths and other engineering infrastructure, and Parks weed spray remaining POS and other vegetated assets.

Eduction of hard assets occurs as part of a 3-4 year program, and inspection and maintenance of biofiltration areas occurs every five (5) weeks, involving rubbish and debris removal, weed spraying, and infrequent infill planting when budget is available. Problem areas, such as assets close to deciduous trees, are targeted for maintenance on an annual basis before the start of winter.

Rain gardens are considered the lowest priority with respect to drainage assets, while hard assets, pits and pipes are considered the highest due to flood risk management and ease of maintenance.

There are currently a significant number of rain gardens located in the front verges of private properties which make these difficult to maintain, mostly due to damage by landowners by parking on them or mowing them. There is a strong preference by Operations team to move rain gardens into POS areas where they cannot be easily damaged, there is no need for traffic control, and are in the one place, resulting in easier and less resource-intensive maintenance. While the Operations team is generally supportive of WSUD assets, installing WSUD assets just for the sake of it is not considered practical, and there is a preference for subdivision designs which combine both conventional and WSUD assets where each are most suitable and practical. As such, the Operations team would recommend more input into the subdivision design process to ensure drainage assets are constructed to be as practical for maintenance as possible.

Victoria Park

The majority of drainage assets in the Town of Victoria Park are fenced sumps connected by pipes and pits. A significant number of Water Corporation assets are also included within the local government area; however, these are maintained by the Water Corporation. WSUD assets include a small number of swales and tree pits. Maintenance is currently undertaken by the Parks team with respect to vegetation (mowing, pruning, and weeding) and the Engineering team with respect to upgrades and cleaning of hard assets (such as cleaning of sediments, rubbish and debris around sump outfalls and pits). Maintenance is undertaken by teams on an as needs basis due to budget constraints, however, maintenance teams would strongly prefer resources to deliver a regular, planned maintenance program. Maintenance activity is typically tracked by the Engineering team.

Drainage infrastructure is generally considered a high priority by the Town Executive due to the need for flood management, particularly in higher risk locations in close proximity to the river. While WSUD assets have not traditionally been prioritised in the past, the community is becoming more vocal for an increase in green spaces and trees. Therefore this may provide an opportunity to construct more WSUD assets, particularly as part of the implementation of the Town's Urban Forest Strategy.

However, construction and maintenance of drainage assets are undertaken by two different teams with maintenance often considered as afterthought as part of asset design. Therefore greater input by the Operations team into construction of assets is highly recommended in order to ensure the most efficient and effective use of maintenance resources, and successful performance of the assets.

Wanneroo

Drainage assets are regularly maintained within the City of Wanneroo with vegetated asset maintenance (mowing, pruning) delivered by the Parks and Conservation team, and hard asset (pits, soakwells, and GPTs educted every 6 months) maintenance delivered by the Engineering team. A ten (10) yearly program of pipe network (1,500 km) jetting is also

delivered; however, the ideal program schedule is five (5) years. This is currently not possible due to resource constraints. In general, the asset maintenance budget is not considered large enough to provide maintenance at the level required to for drainage assets to properly function. However, an intense street sweeping program is being implemented in order to minimise and determine the optimal frequency of maintenance requirements.

Parks and Conservation, and Engineering teams generally communicate well with respect to maintenance but there is currently no system set up to record and track maintenance activity within the City.

The majority of the City Executive is considered to be supportive of WSUD, and the City has a directive for implementation of WSUD. However, the installation of WSUD assets to meet community or Council expectations is not always appropriate given constraints around impracticality of maintenance of assets (particularly on residential verges and there is a preference by Engineering to keep WSUD assets in POS to minimise this), and restricted access. The lack of communication between teams designing/constructing, and those eventually maintaining the assets, is an area identified for improvement. A lack of understanding of total lifecycle cost of WSUD assets is also considered to be an issue with respect to planning, budgeting and delivery of WSUD asset maintenance.

Table: Summary of local government drainage infrastructure maintenance practices

Local Government	Staff team - soft / green assets	Staff team - hard assets	Maintenance schedule	Tracking	Budget	Internal / external	Recommendations
Belmont (Nicole Davey, Coordinator Environment)	Parks, Leisure & Environment or Natural Areas	Works Dept (with input from Environment with respect to external works/tender preparation)	Regular: - 6 weekly	Tracked, not in detail unless significant issue	Adequate for all maintenance	External: hard asset maintenance Internal (Parks): vegetated assets	More involvement in design of WSUD systems
Canning (Rebecca Clifford, Drainage Engineer) (Giles Pickard)			Mostly reactive – long-term project to develop planned maintenance program			DNIP Working Group share maintenance of Liege, Anvil & Wharf St WSUD systems (CoC, DBCA, Water Corporation & SERCUL))	
Mandurah (Justin Temmen, Senior Drainage Engineer, Engineering Services)	Operations - Parks	Operations – Infrastructure / Civil / Drainage	Mostly reactive Some regular: - 8 weekly (POS assets only) - annual education of pit, pipe GPTs and subsurface assets			External: hard asset maintenance	
Murray (Chris Pretorius, Manager Operations)	Operations – Parks	Operations – Drainage	Reactive (mostly open drains & pits. Not considered to have high maintenance systems requiring regular activity)	Community requests for drainage maintenance are tracked only	Constrained Fixed budget, can apply for additional budget for specific, significant issues PHCC provided initial budget for construction of few WSUD biofiltration systems at drain outlets	All maintenance is internal except for larger works (pipe blockages, replacement of broken pits) - external	More resources to move from reactive to planned maintenance
Kwinana (Paul Kher, Technical Officer, Infrastructure Operations)	Parks	Operations	Mostly reactive Some regular: - annual basin spraying	Tracked by Operations (RAM asset management system)	Adequate for hard asset maintenance Probably fixed	Maintenance delivered by a combination of internal (e.g. spraying) and external crews	Some maintenance should occur in response to weather events rather than scheduled basis

Local Government	Staff team - soft / green assets	Staff team - hard assets	Maintenance schedule	Tracking	Budget	Internal / external	Recommendations
Swan (Liam Smart, Development Parks & Reserves Officer, Asset Management Operations)	Parks Engineering (weed spraying of hardstand, kerbs/footpaths)	Engineering	Regular: - 5 weekly (spraying, infill if leftover budget) - 3-4 yr education program of hard assets - annual education at problem sites (deciduous trees etc)		Constrained	External: hard asset maintenance Internal (Parks): vegetated assets	More resources Remove rain gardens from verges & incorporate into POS to consolidate assets, more practical maintenance
Victoria Park (Brendan Nock, Environment Officer)	Parks Engineering (excavation/ removal of sediments/debris, major upgrades)	Engineering	Mostly reactive	Probably recorded by Engineering	Constrained Budget for drainage prioritised when public liability an issue (flood risk etc.)	Internal, except for Water Corporation assets	More resources to move from reactive to planned maintenance Community increasingly vocal: transformation of sumps into green WSUD systems & spaces Removal of traditional / flush kerbing
Wanneroo (Cameron Healy, Coordinator Engineering Maintenance, Asset Maintenance)	Parks & Conservation	Engineering	Regular: - Biannual (6 months) education of pits & GPTs - 10 yearly network jetting (ideally 5 years)	Communication between Parks & Engineering, but no official system set up to record & track	Constrained	Internal	More resources to increase frequency of maintenance More involvement between drainage asset designers and asset maintenance teams Consideration of lifecycle costs when designing WSUD Not to install WSUD systems for WSUDs sake, in POS & not on verges – impractical maintenance required as a result

4 DISCUSSION

Although the cost of WSUD asset maintenance has repeatedly been suggested as a barrier to the implementation of these systems, the findings from this scoping exercise suggest the reasons are more complex than just cost. The following provides a summary of key issues, findings and next steps.

4.1 Key issues

1. Skills and knowledge – Maintenance of WSUD assets requires knowledge of both vegetated systems and hard drainage assets so that all functions are understood and are maintained. These skills are traditionally held by separate teams, leading to disconnected maintenance delivery where only one function was only addressed at a time (i.e. either flood protection or general aesthetics for example).
2. Available resources – There is a general lack of support for spending on services (people) in preference to civil works. This is compounded by budgetary processes that are often disjointed and ad-hoc.
3. Planning, monitoring and audit – There is a lack of planning, tracking and/or recording of maintenance activities that are undertaken. This leads to a lack of understanding regarding what/when activities are required; reduced knowledge transfer and capacity building within maintenance teams and the wider agency; and an inability to justify budgets or quantify benefits.
4. Executive support – Maintenance is more effective in areas where there is an awareness of the multiple outcomes and associated cost benefits that WSUD assets provide and where this aligns with community values and goals.
5. Team integration – There is often a lack of communication between asset management teams and asset design and construction teams, including planning and/or engineering. This reduces the ability of local government teams to learn from experience and identify local preferences for particular designs or methods of construction. There is also a lack of shared learning across the industry, as knowledge on WSUD maintenance acquired by one local government is not shared with other local governments, which reduces the ability of the industry to adapt and improve practices.

4.2 Key findings

Local Governments are generally not collecting maintenance data (cost or activities) and cannot quantify the cost or benefits of WSUD assets. Thus, it is not possible to compare the cost of WSUD system maintenance with conventional drainage solutions at this time. However, this may not be necessary to justify spending in this area, as Local Governments and the community are increasingly recognising the multiple benefits that WSUD solutions provide and therefore these outcomes are being prioritised for community and environmental benefit.

Maintenance activities are largely known; however, there is still a perceived need for an instruction manual of some sort. Although the types of activities are generally consistent across the various asset types, the timing and magnitude of the activities will vary considerably. Factors that influence this include asset type; location; access; size; community interest; construction; maintenance service level; need for traffic management; and external vs inhouse delivery. It is also noted that the activities required during establishment are generally different to (and greater than) what is

required in a fully constructed/operational catchment. Some additional guidance is provided in Appendices 2 and 3.

There is considerable variability in how maintenance activities are delivered across WA local governments. In many instances, the planning of activities is undertaken separately to the delivery of activities. Options for delivery include hiring external contractors; allocating responsibility for various aspects to engineering, parks or natural areas teams; or through area-based teams. Discussion with local government officers suggests that a greater level of success occurs where natural areas-type teams are used due to the knowledge associated with keeping plants healthy, but this can be problematic if the stormwater management function of the system is not understood. It is also noted that programs are more successful where activities are scheduled routinely, as this keeps costs down due to preventing smaller issues from getting bigger and becoming more expensive to manage.

Aligning maintenance activities with agency goals and multiple outcomes (e.g. enhanced biodiversity, urban canopy, community wellbeing, efficient infrastructure) provides support for maintenance budgets. This can also remove the need for justification via traditional cost benefit analysis.

Local governments that support continued skills development and learning are likely to have more effective maintenance programs. However, there is still a need to share this across local governments so that a greater number of agencies/locations can benefit from local knowledge and trials.

There is also a need to ensure the skills and knowledge held by maintenance staff are incorporated as early as possible into the planning, design, assessment and construction of options by planners and engineers.

4.3 Suggested way forward

It is suggested that greater clarity is sought from Local Government regarding the sort of information they need to support improved maintenance practices. This could be in one or more of the following forms:

1. providing an evidence based justification of costs to support inclusion of WSUD assets into the public realm. This could be extended to a cost-benefit analysis that also considers non-monetary benefits if desirable;
2. support for getting budget for maintenance activities;
3. improving knowledge so design and construction practices improve; and/or
4. improving knowledge so maintenance delivery is improved.

Options for obtaining this input include via an on-line survey and/or an industry workshop. The industry workshop could be about "Learning from within and across local governments" and ask questions such as (i) What is enough budget? (ii) Who should do it? and (iii) What does success look like?- what strategies are available to reduce maintenance costs/activities?. These questions could be answered through case studies presented by a range of Local Governments, with discussion to follow.

Alternatively, a more proactive approach could be taken to obtaining the information where a number of workshops are held with individual Local Governments. Given the difficulty in obtaining information from local governments observed from this project, this approach may be more successful in increasing the likely level of response (gathering information to work with). The workshops would involve a range of staff from planning, landscape, asset, parks and engineering

in which issues and learnings from specific examples across the local government area would be shared and the officers would work together on a way forward.

The findings of the individual local government workshops could then be brought together in a symposium where the lessons are shared, and the industry works together to identify best practice options.

Should industry desire more quantitative information, it is suggested that a number of research case studies are established that would allow comparison of costs on a catchment basis. This is likely to require considerable research effort, such as via a Masters project, to identify reference catchments and track and quantify activities over time.

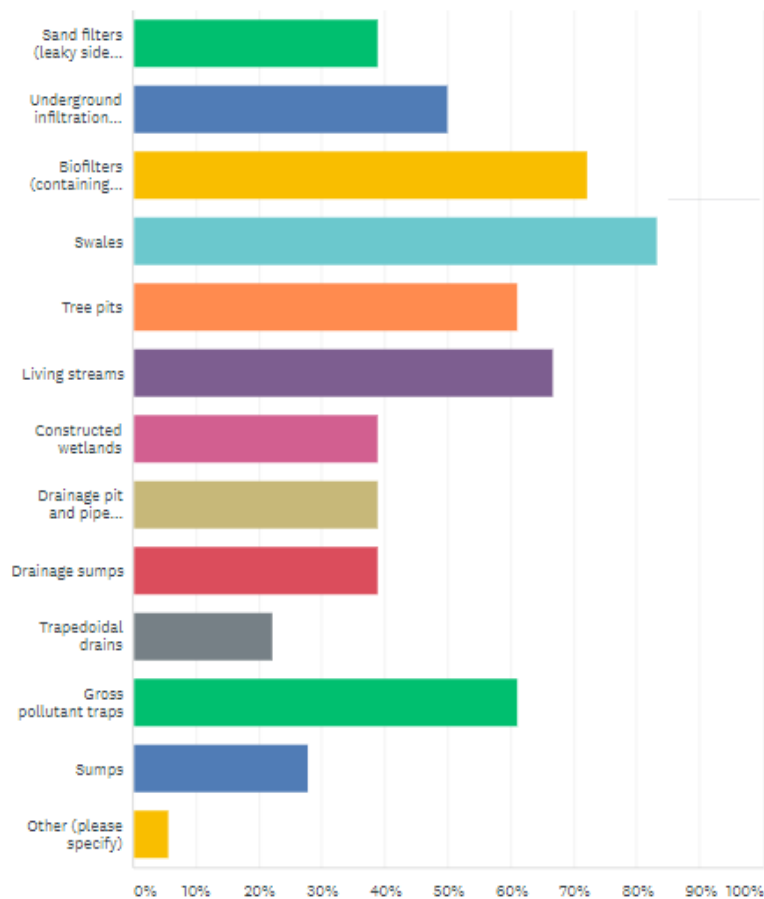
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APPENDIX 1: RESPONSES TO INITIAL SURVEY

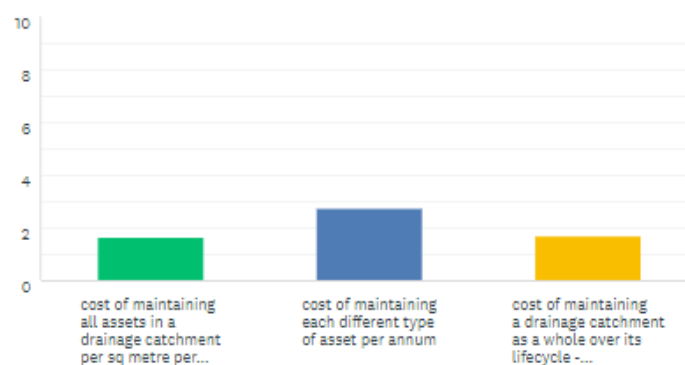
Which drainage asset types would you like information on? (select all that apply)

Answered: 18 Skipped: 0



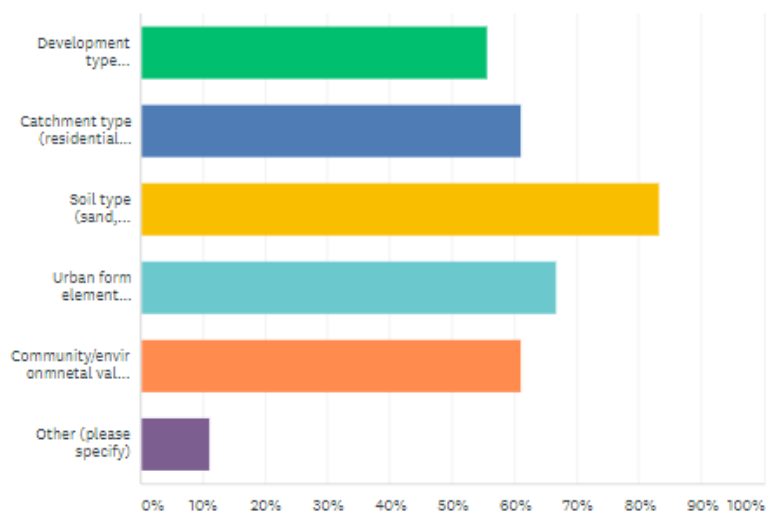
What format of information would be most useful? (please rank)

Answered: 16 Skipped: 2



Which site characteristics do you think will influence maintenance costs? (select all that apply)

Answered: 18 Skipped: 0



What other information would be useful to your LG?

WSUD in steep sites

Updated information on the most effective locally native plants for biofiltration as well as most effective planting methods (eg density) and whether soil amendments or additives are necessary/recommended eg mulch. BAL information - implications for fire proneness when planting streams, drains etc

How to manage and dispose of material retrieved from filters / pollutant traps

Maintenance plan and guidelines for BMPs.

Maintenance/ Management plan requirements and frequency of maintenance

People should know why we provide WSUD. if they don't see a value of it. then they don't see any benefit out of maintaining them. This is the problem we have.

Specific maintenance and replacement/renewal requirements to specific type of drainage asset. Eg plant replacement requirements, media replacement requirements.

Level of Service

Maintenance program and associated costs to allow councils to budget

APPENDIX 2: WSUD ASSET MAINTENANCE ACTIVITIES

Most maintenance activities are common to WSUD stormwater assets. It may be helpful to consider tasks that have a civil function and those which have a landscape function, although it is noted that systems with healthy plants are generally considered to be functioning hydraulically.

Key activities are:

- Removing litter and debris
- Controlling weeds
- Repairing minor erosion
- Unblocking inlets and outlets
- Removing sediment
- Managing filter media
- Managing mosquitoes
- Managing high or low water levels
- Replanting
- Managing algae

Those of relevance to each WSUD asset type are detailed in next section.

Table 2: Tips for maintenance tasks

Activity	Consider	How to address
<p>Removing litter and debris</p> 	<p>Vegetation is designed to trap sediment, litter and debris</p>	<p>Remove large objects by hand so as not to damage vegetation</p>
<p>Controlling weeds</p> 	<p>Be aware of local noxious weeds</p> <p>Understand direction of catchment flows and sources of weeds</p> <p>Frequent weeding is often more effective (and cheaper) than large scale, occasional weeding.</p> <p>Re-plant appropriate (and a variety of) species to manage weeds</p>	<p>WSUD infrastructure is small enough that manual removal is the most effective method of weed control.</p> <p>Remove weeds before they seed.</p> <p>Only use herbicides if rectification and revegetation are needed. Do not use herbicides if inundated or rain is expected.</p>

Activity	Consider	How to address
<p>Repairing minor erosion</p> 	<p>Erosion is usually due to excessive flows or flow channelisation</p> <p>Consider if it is a design fault that needs to be rectified</p>	<p>Reduce the grade of the flow path and revegetate area to eliminate high velocity or channelised flows</p> <p>Add small amount of rock pitching</p> <p>Replace filter media/soil</p> <p>Replant with tube stock where bare spots are present</p>
<p>Unblocking inlets and outlets</p> 	<p>Check for blocked inlets/ outlets each time an asset is inspected and undertake necessary works</p> <p>Identify source of blockage and minimise if possible</p>	<p>Remove litter or debris blocking inlets or outlets</p> <p>Remove with appropriate equipment. Try not to damage any plants but re-plant as necessary</p>
<p>Removing sediment</p> 	<p>Sediment will eventually kill the plants so remove excess (>60% of the area) where possible</p> <p>If plants need to be removed to clear excessive sediment, replace immediately.</p> <p>Where contaminated sediment is a possibility, consider the need for testing to ensure appropriate disposal.</p>	<p>Remove sediment if >10cm depth. Avoid damaging any vegetation or surface of asset.</p> <p>Dispose of removed sediment appropriately, particularly where pollutants or contaminants may be a factor.</p> <p>Ensure removed sediment disposed off-site to ensure it is not transported downstream.</p>

Activity	Consider	How to address
<p>Managing filter media</p> 	<p>If the plants are healthy, the filter media is working</p> <p>Check for:</p> <ul style="list-style-type: none"> • Minor erosion or scour • Sediment accumulation • Biofilms/ algal blooms • Ponding of water following rainfall events • Permanently boggy/pooled areas • Plant health 	<p>Adjust surface levels</p> <p>Remove sediment</p> <p>Scarify filter media surface</p> <p>Plant additional plants (vary species)</p> <p>Replace filter media</p>
<p>Managing mosquitoes</p>	<p>Avoid stagnant water</p> <p>Most WSUD systems should dry out within 72 hours of a rainfall event (except constructed wetlands)</p>	<p>Where permanent water exists, remove floating debris and possibly introduce native fish or bat boxes</p>
<p>Managing high or low water levels</p> 	<p>Vegetation should be appropriate to the water level conditions i.e. 'wetland' vegetation in areas that receive the most water and 'dryland' vegetation in fringing areas.</p>	<p>If there is a design fault rectification works such as replacement of vegetation with more tolerant species or installation of weirs or choke points may be required</p>
<p>Replanting</p> 	<p>A variety of species is more resilient</p> <p>Understand which plants perform best in dry, ephemeral and wet systems</p> <p>Locally native works best</p> <p>Consider fire hazard requirements</p>	<p>Use tube stock where possible</p> <p>Water during establishment</p>

Activity	Consider	How to address
Managing algae 	Use fertiliser only when necessary and never in areas of native vegetation	Recognise areas with legacy nutrients in groundwater Avoid creation of permanent water bodies

APPENDIX 3: MAINTENANCE OF PARTICULAR WSUD ASSETS

The vegetated WSUD stormwater assets are generally defined under the following categories.

- Biofilter
- Tree pit
- Swale
- Dry (ephemeral) detention basins
- Constructed wetland
- Gross pollutant trap

A summary of each type of assets and its maintenance requirements are provided below. It should be noted that gross pollutant traps are not generally considered to be a WSUD asset; however, their value in protecting WSUD assets is noted and their maintenance requirements are therefore presented here.

Biofilters

Biofilters, also known as raingardens, bioretention systems or bio-infiltration systems are excavated basins or trenches that are filled with porous filter media and planted with vegetation to remove pollutants from stormwater runoff (DoW, 2011). Their flexible design allows them to be incorporated into many different situations (i.e. roadside, within POS and within lots).

Biofilters typically consist of a series of layers designed to remove sediments and nutrients from stormwater before discharging into the groundwater or downstream drainage if required (Figure 4). Stormwater ponds at the surface of the raingarden, slowly infiltrates through the filter media and is then discharged (Melbourne Water, 2013). Water quality treatment occurs through nutrient sorption and pollutant decomposition by the vegetation, soil and bacteria (DoW, 2011). The key functional components of a biofilter are described in Figure 4.

Maintenance

The maintenance objectives for biofilters are to ensure that the asset can:

- Remove nutrients and pollutants from stormwater;
- Retain stormwater to the design capacity; and
- Convey stormwater in excess of design retention capacity.

Key issues/indicators for biofilter maintenance		
Vegetation health	Inlet/outlet blockage	Erosion and sedimentation

The recommended maintenance schedule for biofilters is shown in Table 3.

Design function

Note: Depending on insitu soil, transition and drainage layers may not be required if direct infiltration of treated stormwater to surrounding soils is possible. See CRCWSC 2015 guidelines for diagrams demonstrating submerged zones, outlets, etc.

Aid aesthetics, assist in pollutant removal and maintain hydraulic conductivity of filter media
Sedimentation of primary sediments and metals

Soil filters fine sediments and colloidal particles

Soil layer for plants to grow in

Sorption of metals and nutrients by filter particles

Liner is required to:

- prevent exfiltration into surrounding soils and create a submerged zone (in conjunction with a raised outlet),
- ensure stormwater is treated through the biofilter media instead of lost to surrounding soils,
- prevent contamination of filter media from in situ soils and water (if this is an issue),
- if sensitive structures nearby require protection (i.e. form an impermeable barrier between the biofilter and the structure), or
- if interaction with shallow groundwater is not desirable.

Include a carbon source to improve chemical processes in soil and promote vegetation health

Nutrient sorption and pollutant decomposition by soil and bacteria

Separates filter layer from drainage layer to avoid clogging and stop transition of the filter media and leaching of the fine particles into the drainage layer

Free draining layer containing pipe (if required)

Subsoil pipe can aid in watertable control (unlined systems) and in the case of desirable shallow groundwater interaction. It is also required in impervious systems to collect and convey water

Infiltration from base if applicable

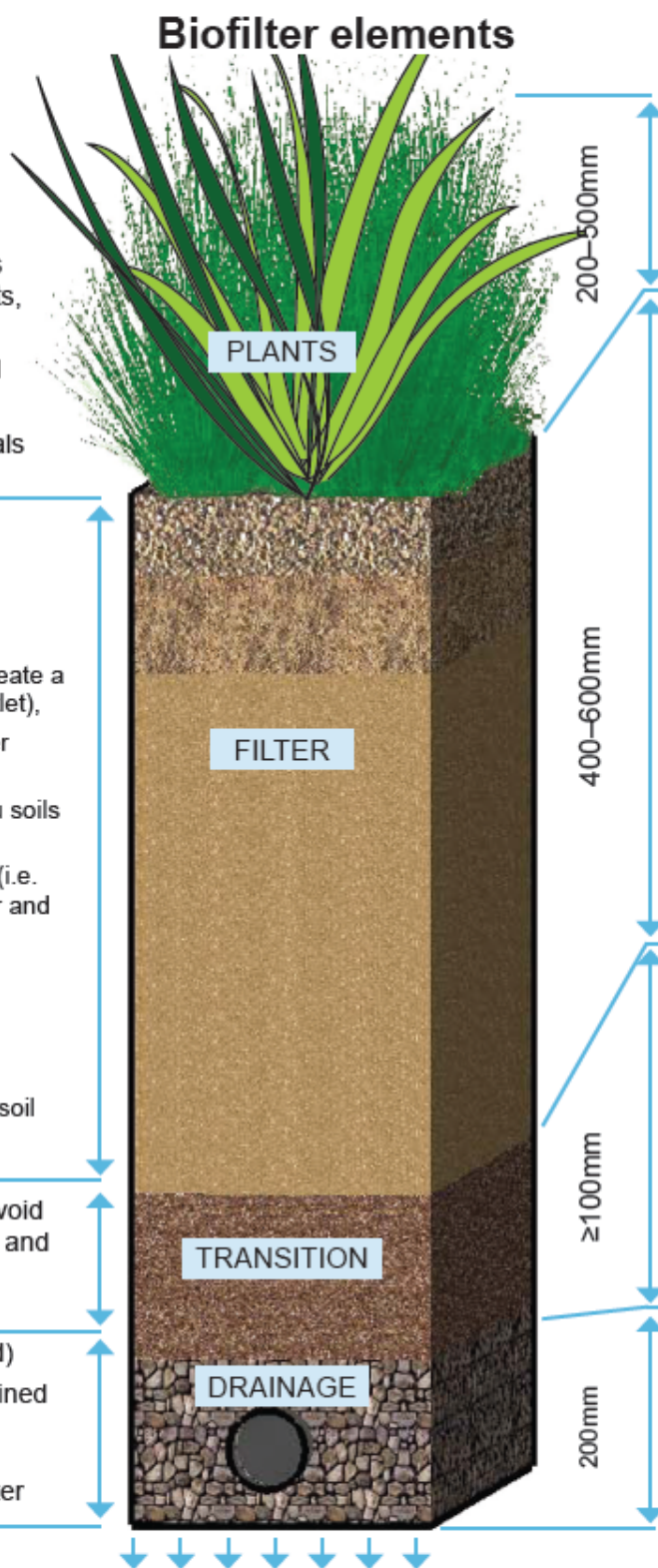


Figure 4: Typical biofilter design (Source: New Water Ways)

Table 3: Biofilter maintenance schedule

Frequency	Inspection element	Maintenance activity
3 to 4 monthly	Vegetation	<ul style="list-style-type: none"> Inspect plant and health cover Replace dead plants to maintain consistent vegetation density Remove weeds Prune plants (if required)
	Erosion / scour	<ul style="list-style-type: none"> Check for evidence of preferential flow paths Replace filter media in eroded areas Add rock protection around inlets (if required)
	Sediment accumulation	<ul style="list-style-type: none"> Check for sediment accumulation within: <ul style="list-style-type: none"> Inlet Filter media Mulch layer Outlet Clear inlet and outlet points
	Mulch	<ul style="list-style-type: none"> Check depth and even distribution of mulch Check mulch is not touching plant stems Replace mulch (if required. Denser planting is preferred to the use of mulch)
	Infrastructure	<ul style="list-style-type: none"> Check infrastructure for damage and repair as required
Following major rainfall events	Filter media	<ul style="list-style-type: none"> Monitor ponding and check for permanently boggy/pooled areas Scarify filter media if required
	Gross pollutants and sediment	<ul style="list-style-type: none"> Inspect inlet and outlet points for sediment, litter and debris Clear as required
Annually	Subsoil pipe (where relevant)	<ul style="list-style-type: none"> Inspect opening for underdrain for sediment accumulation and water level Flush underdrain if required
	Filter media	<ul style="list-style-type: none"> Check for sediment accumulation Remove if required
5 years	Condition assessment	<ul style="list-style-type: none"> Infiltration rate of media (see appendix D) health of vegetation effectiveness of maintenance activities likely timeframes for renewal

Rectification

Where potential issues are not being addressed by routine maintenance, rectification may be required. The actions required to address the observed issues are outlined in the table below.

Table 4: Biofilter rectification issues, causes and actions

Potential issues	Causes	Actions
<i>Clogging of filter media, reducing infiltration (indicated by pooling and/or poor plant health)</i>	Sediment accumulation, organic litter accumulation, incorrect filter media specification, algal blooms	Removing sediment or scarifying filter media surface Removing leaf litter Increasing plant density Replacement of filter media
<i>Erosion</i>	Excessive flows, lack of infrastructure to dissipate flows, or lack of vegetation cover	Replacing filter media in eroded areas Adding rock protection around inlets Replanting dead plants
<i>Loss of mulch</i>	High flows and erosion	Remove mulch and increase planting Secure with jute matting or nets
<i>Loss of vegetation (may indicate other problems with function)</i>	Incorrect infiltration rate of media Weed encroachment Incorrect species type for climate	Remove weeds Water plants (establishment and extended dry periods) Replacement of plants Pruning (where applicable)
<i>Structural damage</i>	Vehicle damage Vandalism	Repair as required Install signage to educate community about function and benefits

Key references for biofilter design

Adoption Guidelines for Stormwater Biofiltration Systems (2015, Cooperative Research Centre for Water Sensitive Cities & Payne, Hatt, Deletic, Dobbie, McCarthy, & Chandrasena).

Vegetation guidelines for stormwater biofilters in the south-west of Western Australia (2014, Monash Water for Liveability Centre, Oversby, B., Payne, E., Fletcher, T., Byleveld, G., & Hatt, B.).

Practice Note: Vegetation guidelines for stormwater biofilters in the southwest of Western Australia (2014, Monash Water for Liveability Centre, Oversby, B., Payne, E., Fletcher, T., Byleveld, G., & Hatt, B.)

Tree pits

Tree pits are biofilters generally built into the side of roads that receive stormwater runoff from roads. Tree pits can be used in place of conventional street tree/side entry pit systems. The stormwater runoff provides a valuable water source for maintaining street trees in a drying climate.

Tree pits treat runoff from small rainfall events, through filtration, extended detention and some biological uptake of nutrients. Overflow from larger rainfall events may bypass the tree pit and flow along the street into the downstream stormwater management system. Detention cells at the base of the pit may be connected to conventional stormwater pipes to manage overflows from larger events where necessary (New Water Ways fact sheet, 2016).

Key components of tree pits commonly include the plant, inlet and outlet structure, root barrier, filter media and stormwater drainage connection. These are depicted in Figure 6. The use of mulch is generally not recommended due to common issues with inlet levels and blockage of water flows.



Figure 5: Tree pit, Muirfield Rd, Dunsborough

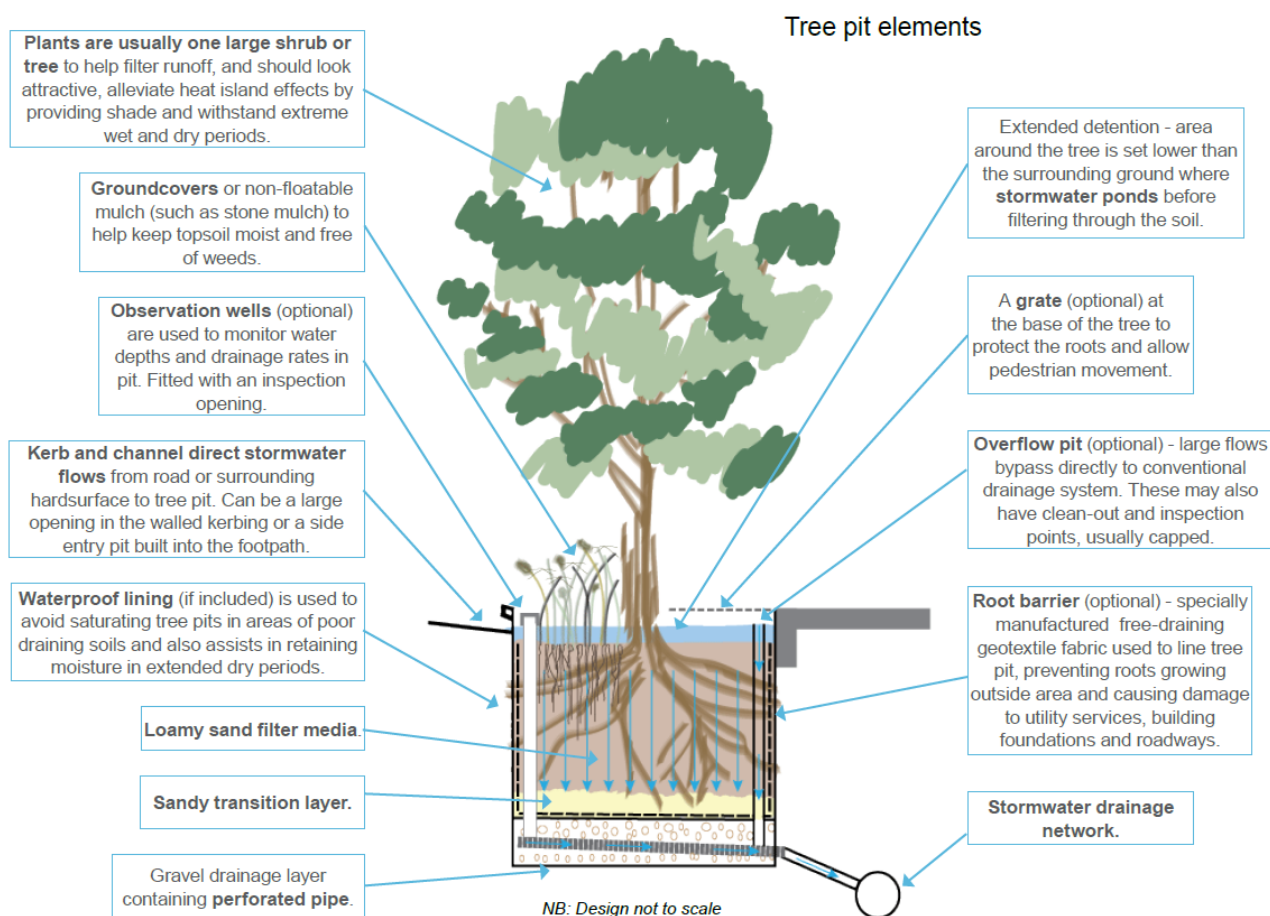


Figure 6: Typical tree pit design (Source: New Water Ways)

Maintenance

The maintenance objectives for tree pits are to ensure that the asset can:

- Remove nutrients and pollutants from stormwater;
- Retain stormwater to the design capacity; and
- Convey stormwater in excess of design retention capacity.

Key issues/indicators for tree pit maintenance

Tree health

Inlet/outlet levels (water flow)

Standing water/blocked media

Table 5: Tree pit maintenance schedule

Frequency	Inspection element	Maintenance activity
3 to 4 monthly	Sediment accumulation	<ul style="list-style-type: none"> • Check for sediment accumulation within: • Inlet • Filter media • Outlet • Clear inlet and outlet points
	Vegetation	<ul style="list-style-type: none"> • Inspect plant health (disease, pests, poor growth) • Check plant stability • Remove weeds (avoid use of herbicides) • Prune tree (if required)
	Mulch (where applicable)	<ul style="list-style-type: none"> • Check depth and even distribution of mulch • Check mulch is not touching tree trunk • Replace mulch (if required)
	Civil components	<ul style="list-style-type: none"> • Check infrastructure for physical damage, concrete cracking and subsidence • Repair as required
Following major rainfall events	Filter media	<ul style="list-style-type: none"> • Monitor ponding and check for permanently boggy/pooled areas • Scarify filter media if required
	Gross pollutants and sediment	<ul style="list-style-type: none"> • Inspect inlet and outlet points for sediment, litter and debris • Clear as required
Annually	Subsoil pipe (if relevant)	<ul style="list-style-type: none"> • Inspect opening for underdrain for sediment accumulation and water level • Flush underdrain if required
	Filter media	<ul style="list-style-type: none"> • Check for sediment accumulation • Remove if required
5 years	Condition assessment	<ul style="list-style-type: none"> • Infiltration rate of media (see appendix D) • health of vegetation • effectiveness of maintenance activities • likely timeframes for renewal

Rectification

Where potential issues are not being addressed by routine maintenance, rectification may be required. The actions required to address the observed issues are outlined in the table below.

Table 6: Tree pit rectification issues, causes and actions

Potential issues	Causes	Actions
<i>Tree death or loss of low vegetation (may indicate other problems with function)</i>	Incorrect species type for climate Incorrect infiltration rate of media Weed encroachment	Water plants (establishment and extended dry periods) Remove weeds Replace plants Prune the tree (where applicable)
<i>Structural damage</i>	Vehicle damage Vandalism	Install tree barriers or wheel stops Repair as required Provide signage on benefits of trees and function of tree pit
<i>Clogging of filter media, reducing infiltration (indicated by pooling and/or poor plant health)</i>	Sediment accumulation, organic litter accumulation, incorrect filter media specification, algal blooms	Removing sediment or scarifying filter media surface Removing leaf litter Increasing plant density Replacement of filter media
<i>Erosion</i>	Excessive flows, lack of infrastructure to dissipate flows, or lack of vegetation cover	Replacing filter media in eroded areas Adding rock protection around inlets Replanting dead plants
<i>Loss of mulch (where relevant)</i>	High flows and erosion	Remove mulch and increase planting of low vegetation Secure with jute matting or nets

Swales

A vegetated swale is a broad, shallow channel with vegetation covering the side slopes and base. Swales can be placed within public open space, within the median and along the shoulders of main roads (DoW, 2007). Key functions of a swale are to:

- collect and convey stormwater flows;
- promote infiltration and groundwater recharge;
- reduce stormwater peak flow rates and discharge volumes, and
- remove sediments.

Swales vegetated with local native plants increase biodiversity and create habitats in urban areas.



Key components of a swale are depicted in Figure 7.

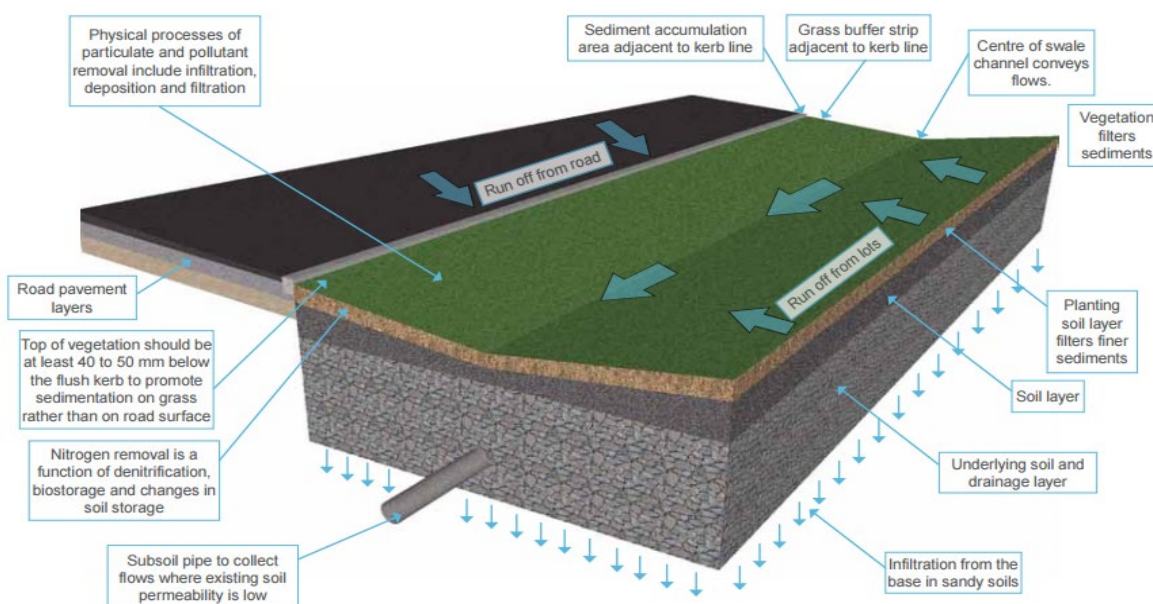


Figure 7: Key components of a swale (Source: New Water Ways)

Maintenance

The maintenance objectives for a vegetated swale system are to:

- Retain hydraulic and pollutant removal efficiency; and
- Maintain a dense, healthy vegetation cover.

Key issues/indicators for swale maintenance		
Vegetation health	Inlet/outlet blockage	Erosion and sedimentation

Debris and blockages should be regularly cleared, ideally before winter and after major storm events. This should include removal of accumulated sediments to avoid further transportation during subsequent high flow events (DoW, 2007).

Channels should be examined for damaged areas, and ruts and holes should be repaired to maintain flow paths and prevent ponding.

The recommended maintenance schedule for vegetated swales is shown in Table 7.

Table 7: Vegetated swale maintenance schedule

Frequency	Inspection element	Maintenance activity
3 to 4 monthly	<i>Vegetation</i>	<ul style="list-style-type: none"> Inspect plant health and cover Prune plants (if required) Mow (if required) Remove weeds (avoid herbicides) Replace dead plants to maintain consistent vegetation density
	<i>Inlet/outlet blockage</i>	<ul style="list-style-type: none"> Check for and remove any blockages
	<i>Erosion</i>	<ul style="list-style-type: none"> Check for erosion/scouring Check for preferential flow paths Replace soil/filter media in eroded areas Replant eroded areas
Annually	<i>Sediment accumulation</i>	<ul style="list-style-type: none"> Check for accumulation Remove if required
5 years	<i>Condition assessment</i>	<ul style="list-style-type: none"> Infiltration rate of media (see appendix D) health of vegetation effectiveness of maintenance activities likely timeframes for renewal

Rectification

Where potential issues are not being addressed by routine maintenance, rectification may be required. The actions required to address the observed issues are outlined in the table below.

Table 8: Vegetated swale rectification issues, causes and actions

Potential issues	Causes	Actions
<i>Sediment accumulation</i>	<ul style="list-style-type: none"> Function of a swale 	<ul style="list-style-type: none"> Install upstream sediment traps
<i>Erosion</i>	<ul style="list-style-type: none"> Preferential flow paths High velocity due to steep grade 	<ul style="list-style-type: none"> Replace soil/filter media in eroded areas Replant eroded areas Install rock
<i>Blocking of inlet/outlet – not freely draining</i>	<ul style="list-style-type: none"> Levels constructed incorrectly Sediment accumulation 	<ul style="list-style-type: none"> Flush bubble-up/ inlet/ outlet Reconstruct/simplify inlet/outlet structures

Potential issues	Causes	Actions
<i>Loss of vegetation (may indicate other problems with function)</i>	<ul style="list-style-type: none"> • Incorrect infiltration rate of media • Weed encroachment • Incorrect species type for climate 	<ul style="list-style-type: none"> • Remove weeds • Water plants (establishment and extended dry periods) • Replace plants • Pruning (where applicable)
<i>Structural damage</i>	<ul style="list-style-type: none"> • Vehicle damage • Vandalism 	<ul style="list-style-type: none"> • Repair as required • Install signage to educate community about function and benefits

Detention basin

Constructed detention basins primarily serve to capture and store stormwater to prevent excessive runoff and channel erosion in receiving environments, and as areas to remove particulate-based contaminants and sediment (DoW, 2007). Detention basins can also provide wetland habitat and encourage biodiversity.

Typically, a 'dry or ephemeral' detention basin will have its lowest point located above the maximum groundwater level so it drains after each storm event to provide the full storage volume for the next one. Other key design features include controlled inlet and outlet structures, shallow graded banks and substrate that facilitates infiltration. These are depicted in Figure 8.

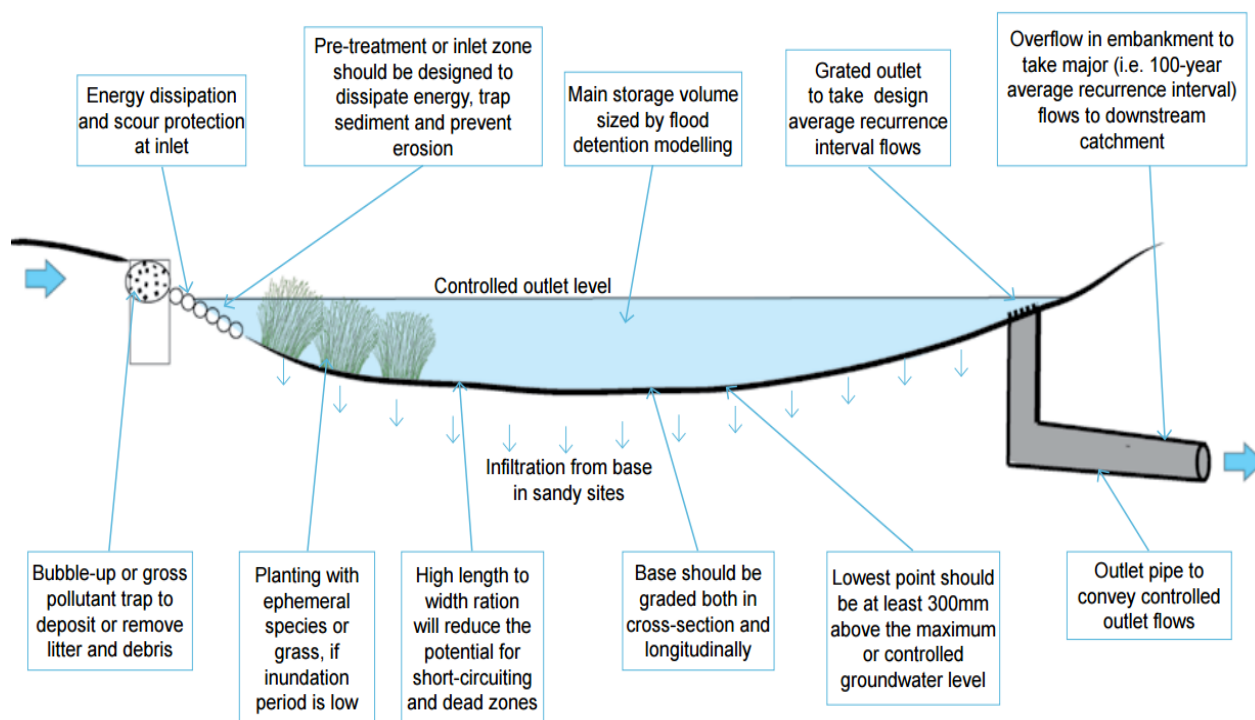


Figure 8: Typical design for detention basin (Source: New Water Ways)

Maintenance

The maintenance objectives for detention basins include:

- Maintaining storage capacity;
- Ensuring public safety; and
- Minimising risk of mosquito and midge breeding.

Key issues/indicators for detention basin maintenance

Standing water

Blocked Inlet/outlet

Erosion and sedimentation

The following maintenance schedule is recommended for detention basins.

Table 9: Detention basin maintenance schedule

Frequency	Inspection element	Maintenance activity
3 to 4 monthly	Vegetation	<ul style="list-style-type: none"> Inspect plant and health cover Replace dead plants to maintain consistent vegetation density Remove weeds
6 monthly	Inlet/Outlet	<ul style="list-style-type: none"> Check for structural damage that may impact functionality or pose risk to public safety and repair as required Check for blockages from sediment, litter or debris and remove if required
	Batter slopes	<ul style="list-style-type: none"> Check for signs of erosion or collapse surrounding basin and repair if required Check for isolated pools/depressions that could provide habitat for mosquitos Remove any litter
	Vegetation	<ul style="list-style-type: none"> Inspect vegetation cover on batters, minimum 80% cover is recommended (minimal bare patches) Inspect plant health, remove dead vegetation and replace to maintain consistent density
	Basin	<ul style="list-style-type: none"> Check for sediment accumulation, sediment removal is required if sediment accumulation impacts the storage capacity of the basin by more than 10% Check for weeds (emergent, floating or submerged) and remove if required Remove any litter Check for unusual odours, colours or substances that may indicate remediation is required Inspect for algal mats, maximum surface coverage of 10% on subsequent inspections is acceptable
5 years	Condition assessment	<ul style="list-style-type: none"> Infiltration rate of media (see appendix D) health of vegetation effectiveness of maintenance activities likely timeframes for renewal

Rectification

Where potential issues are not being addressed by routine maintenance, rectification may be required. The actions required to address the observed issues are outlined in the table below.

Table 10: Detention basin rectification issues, causes and actions

Potential issues	Causes	Actions
<i>Ponding</i>	Function of a detention basin	Create level changes and plant appropriate vegetation Amend soil to improve infiltration Educate the community to reduce complaints
<i>Sediment accumulation</i>	Function of a detention basin	Install upstream sediment traps Create level changes and plant appropriate vegetation Remove sediment
<i>Erosion of batters or basin</i>	Preferential flow paths High velocity due to steep grade	Install (small amounts) rock pitching, appropriate vegetation or jute matting Create level changes Replace soil/filter media in eroded areas Replant eroded areas
<i>Blocking of inlet/outlet</i>	Levels constructed incorrectly Sediment accumulation	Flush bubble-up/ inlet/ outlet Reconstruct/simplify inlet/outlet structures
<i>Loss of vegetation (may indicate other problems with function)</i>	Incorrect species type for climate and/or area of basin (i.e. use of wetland species in dry areas and dryland species in wet areas) Weed encroachment	Replace plants with appropriate species for conditions Remove weeds Water plants (establishment and extended dry periods) Pruning (where applicable)
<i>Structural damage</i>	Vehicle damage Vandalism	Repair as required Install signage to educate community about function and benefits

Constructed wetland

Constructed wetlands are vegetated detention areas that are designed and built specifically to remove pollutants from stormwater runoff (DoW, 2007). As complex and highly active biological systems, wetlands use a variety of processes to intercept, transform and remove pollutants from stormwater. Depending on their design, constructed wetlands can also serve to attenuate larger storm events; retaining runoff and reducing peak flows into downstream environments which in turn can provide protection from erosion and flooding (DoW, 2007).

These wetlands can also provide flora and fauna habitat in areas where many natural ephemeral wetlands have been filled or removed and can be incorporated into restoration plans for natural drainage lines (DoW & SRT, 2007).

Constructed wetlands typically consist of an inlet zone (or inlet pond) that receives the initial stormwater influx in order to remove coarse sediment and regulate flow rates into the downstream macrophyte zone where the majority of water treatment occurs (Figure 9). Other functional components are described in Table 11.

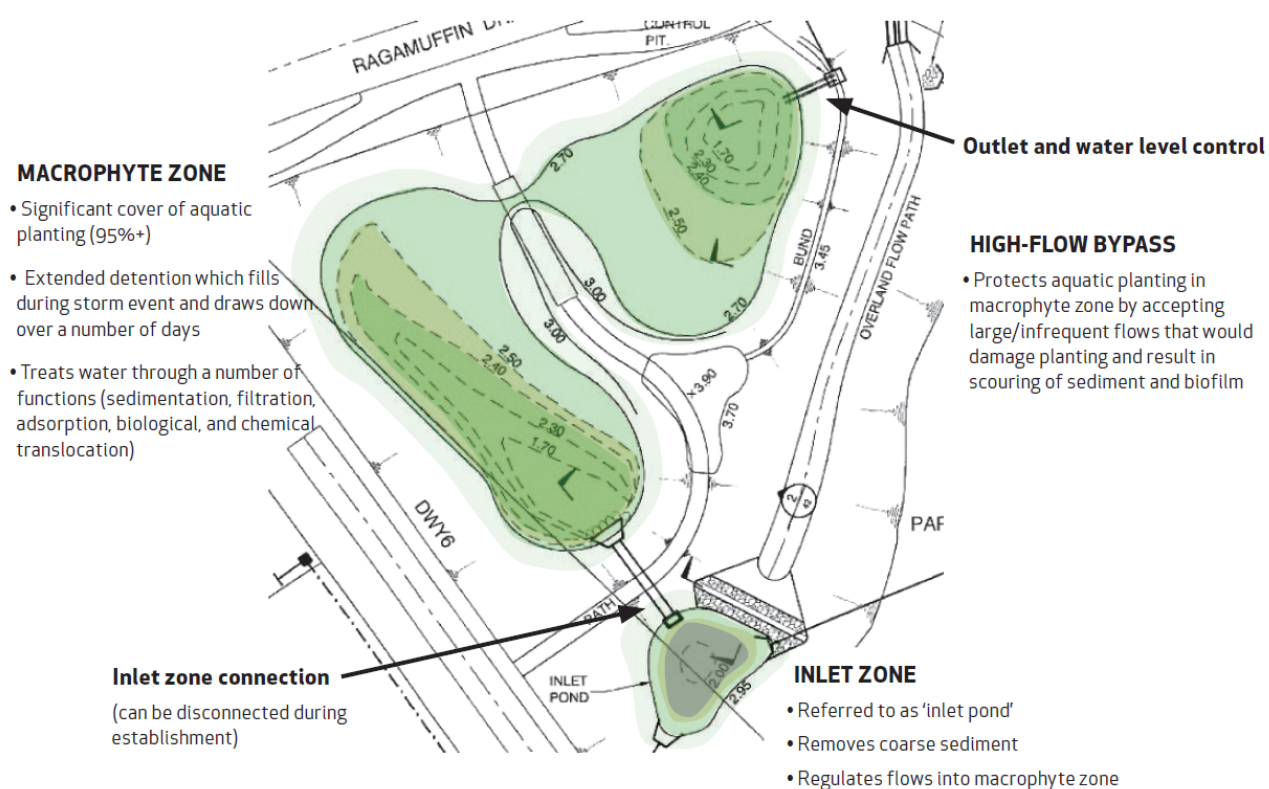


Figure 9: Typical layout of a constructed wetland (Water by Design, 2012)

Table 11: Functional components of a constructed wetland (DoW, 2007)

Component	Function
Inlet	A deep inlet pond that attenuates high flows to protect the vegetated treatment area.
Basins/Creek lines	These low flow areas form the main treatment zone. Shallow, wide, meandering streams with a series of vegetated and open basins increase detention times and increase habitat types to promote nutrient removal.
Outlet	Controls discharges to downstream waterways. Typically consists of a weir and/or riser type arrangement designed to provide uniform detention.
High-flow bypass	Swale or piping connected to the inlet zone, designed to divert infrequent high flows around the main treatment area in order to protect the sensitive wetland conditions.

Changes in environmental conditions can greatly influence wetland processes (DoW, 2007). Nutrients are absorbed and processed by vegetation and microorganisms in the water column and sediment (DPaW, 2016) (Figure 10).

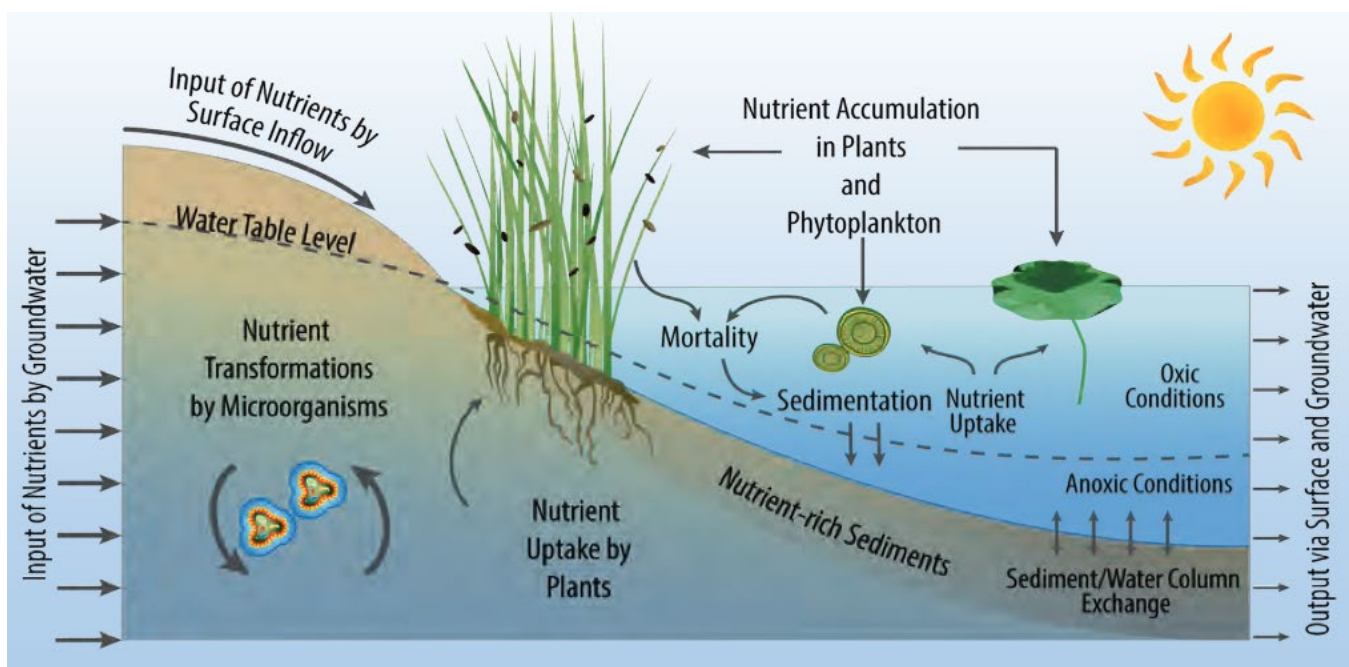


Figure 10: Mechanisms of stormwater treatment in constructed wetlands (DPaW, 2016)

Mosquito and midge management

High density vegetation, if not designed appropriately, can create small areas of stagnant water providing suitable breeding conditions for midge and mosquitoes. Wetland design and maintenance should include consideration of mosquito and midge control.

Deep-water zones (>60 cm) are generally free of surface vegetation, however mosquito larvae are generally controlled through predation, physical disturbance, or depletion of food resources (DoH, 2011).

Shallow-water zones are of greater concern when considering mosquito and midge management. Water levels within constructed wetlands will vary through natural changes in groundwater levels and surface inflow. Drying of the wetland interrupts the breeding cycle of mosquito larvae in the sedge bed zone and provides natural control (DoW, 2007). Additional control can be achieved through ensuring the long axis of the wetland is parallel to the prevailing wind direction (taken to be the most common during spring/summer) (DoH, 2011). Wind disturbance creates wave action and disrupts mosquito and midge survival.

Management must include the capacity and funding to undertake routine harvesting of vegetation by maintenance staff to limit midge and mosquito problems (DoH, 2011).

Maintenance

The maintenance objectives for constructed wetlands include:

- Maintaining nutrient and pollution removal capacity;
- Ensuring public safety; and
- Minimising risk of mosquito and midge breeding.

Key issues/indicators for constructed wetland maintenance

Sediment accumulation

Algal blooms

Nuisance insects

Vegetation death

Table 12: Constructed wetland maintenance schedule

Frequency	Inspection element	Maintenance activity
6 monthly	Surrounds	<ul style="list-style-type: none"> • Check for damage to structures that may pose a risk to public safety or structural integrity and repair as required
	Inlet	<ul style="list-style-type: none"> • Check inlet is structurally sound and there is no evidence of erosion • Check for blockages from sediment*, litter or debris and remove as required
	Vegetation	<ul style="list-style-type: none"> • Inspect vegetation density • Remove dead plants • Plant new vegetation if required to maintain consistent vegetation density • Check for weeds (emergent, floating or submerged) - Remove as required, maximum of 10% weed coverage should be allowed

Frequency	Inspection element	Maintenance activity
		<ul style="list-style-type: none"> Inspect for algal mats - maximum cover of 10% coverage on consecutive inspections should be allowed
	Water	<ul style="list-style-type: none"> Check for odours, colours or substances that are unusual Inspect water levels, check for isolated pools/depressions that could provide mosquito habitat Wetland may need rectification if water quality is observed to be unsatisfactory
	Downstream outfall	<ul style="list-style-type: none"> Check for erosion at outlet Check for structural damage and repair if required Check for blockages due to sediment, litter and debris and remove as required
Following major rainfall events	Inlet/Outlet	<ul style="list-style-type: none"> Check for blockages from sediment, litter or debris and remove if required Check for erosion/scouring
5 years	<i>Condition assessment</i>	<ul style="list-style-type: none"> Health of vegetation Effectiveness of maintenance activities Likely timeframes for renewal

*Consideration should be given to the risks associated with removing sediment from inlet zone. Disturbing the sediment could release heavy metals, hydrocarbons and excess nutrients into the downstream system.

Rectification

Where potential issues are not being addressed by routine maintenance, rectification may be required. The actions required to address the observed issues are outlined in the table below.

Table 13: Constructed wetland rectification issues, causes and actions

Potential issues	Causes	Actions
<i>Sediment accumulation</i>	Function of constructed wetland	Install upstream sediment traps Create level changes and plant appropriate vegetation Remove sediment
<i>Algal blooms</i>	Excessive nutrients, insufficient wetland area, incorrect residence times, weather conditions	Removal of algal mat via surface skimmers, rakes or other mechanical means Increase size/change shape of wetland and/or dredging of sediments Install water quality treatment upstream Increase vegetation or install floating wetlands

Potential issues	Causes	Actions
		Consider oxygenation via fountain or pump and/or treatment with phosphorous inactivation product
Nuisance insects	Standing water	<p>Increase water movement through changes to inlets/outlets and/or pumps/fountains</p> <p>Remove floating debris and introduce native fish or bat boxes</p> <p>Plant additional vegetation to increase habitat for macroinvertebrate predators</p>
Loss of vegetation (may indicate other problems with function)	<p>Incorrect species type for climate and/or area of basin (i.e. use of wetland species in dry areas and dryland species in wet areas)</p> <p>Weed encroachment</p>	<p>Replace plants with appropriate species for conditions</p> <p>Remove weeds</p> <p>Water plants (establishment and extended dry periods)</p> <p>Pruning (where applicable)</p>
Erosion of batters and/or banks	<p>Preferential flow paths</p> <p>High velocity due to steep grade</p>	<p>Install (small amounts) rock pitching, appropriate vegetation or jute matting</p> <p>Create level changes</p> <p>Replace soil/filter media in eroded areas</p> <p>Replant eroded areas</p>
Blocking of inlet/outlet	<p>Levels constructed incorrectly</p> <p>Sediment accumulation</p>	<p>Flush bubble-up/ inlet/ outlet</p> <p>Reconstruct/simplify inlet/outlet structures</p>
Structural damage	<p>Vehicle damage</p> <p>Vandalism</p>	<p>Repair as required</p> <p>Install signage to educate community about function and benefits</p>

References for constructed wetlands in WA

Department of Parks and Wildlife, 2016, *Performance assessment of the Anvil Way Compensation Basin Living Stream 2004–13, Summary report – February 2016*, Department of Parks and Wildlife, Bentley

Department of Parks and Wildlife, 2016, *Performance assessment of the Wharf Street Constructed Wetland 2009–14, Summary report - February 2016*, Department of Parks and Wildlife, Bentley

Gross pollutant traps

Gross pollutant traps (GPTs) are installed in stormwater infrastructure systems to retain gross pollutants by physical screening or rapid sedimentation techniques.

Maintenance

Regular inspection and cleaning of GPTs is essential to maintain their performance and prevent the devices from blockages or releasing pollutants. Poorly managed GPTs can increase the risk of upstream flooding (Engineers Australia, 2006).

- Cleaning prior to wet season is essential
- Health and safety procedures need to be developed to address handling trapped litter, such as sharps, and working inside the confined space of the GPT.

Table 14: GPT maintenance schedule

Frequency	Inspection element	Maintenance activity
Annually	Pollutant trap	<ul style="list-style-type: none"> • Inspect for accumulation of litter and debris and remove if required • Inspect for sludge accumulation and remove if required
	Inlet/Outlet	<ul style="list-style-type: none"> • Inspect inlet and outlet for blockages from litter, debris or sediment and clear if required
5 years	<i>Condition assessment</i>	<ul style="list-style-type: none"> • effectiveness of maintenance activities • likely timeframes for renewal



Client: Water Corporation and Water Sensitive Transition Network

Report	Version	Prepared by	Reviewed by	Submitted to Client	
				Copies	Date
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