LIVING RIVERS
WSUD ASSET AUDIT

MAY 2017

Prepared by Alluvium Consulting Australia for Melbourne Water

TABLE OF CONTENTS

01	02	03	04	05	06
Audit	Method	Findings Bioretention + Tree pit	Findings Wetland	Discussion	Appendix
+ *Scope* + *Objectives* + *Key questions* + *Asset selection*	+ *Condition assessment* + *Key performance indicators*	+ *Key issues* + *Causes*	+ *Key issues* + *Causes*	+ *Recommendations*	+ *Individual asset condition* + *Maintenance requirements* + *Rectification requirements*

1.Audit scope and objectives

AUDIT SCOPE

Melbourne Water is seeking an audit of the Water Sensitive Urban Design (WSUD) assets that have been supported or part-funded through its Living Rivers Program.

The Melbourne Water Living Rivers Program is an ongoing program that has helped to realise the construction of more than 250 Water Sensitive Urban Design (WSUD) assets in the last 10 years.

This project is an audit of **95 WSUD assets** that have been supported or part-funded through its Living Rivers Program and now owned and managed by Councils.

AUDIT OBJECTIVES

The objectives of the audit are to evaluate condition of WSUD assets to determine:

1. The extent to which they are delivering their intended functions

2. The type of problems that exist

3. The causes underlying the problems

The findings of this audit will inform the Living Rivers program on how it can deliver future projects and assets that are robust and enduring.

KEY QUESTIONS

By addressing the three objectives, the audit aims to answer the following six key questions:

1. Are assets providing the intended stormwater treatment function? What is the extent of maintenance and rectification required to bring assets back to the desired level of service?

2. Are assets valued by the community by contributing to an aesthetically attractive place?

3. What are the underlying causes for asset underperformance or failure? Are they associated to the design, construction, establishment or operation/maintenance phase of the asset lifespan?

4. How does asset age affect stormwater treatment function?

5. Has there been an improvement in design and construction over time?

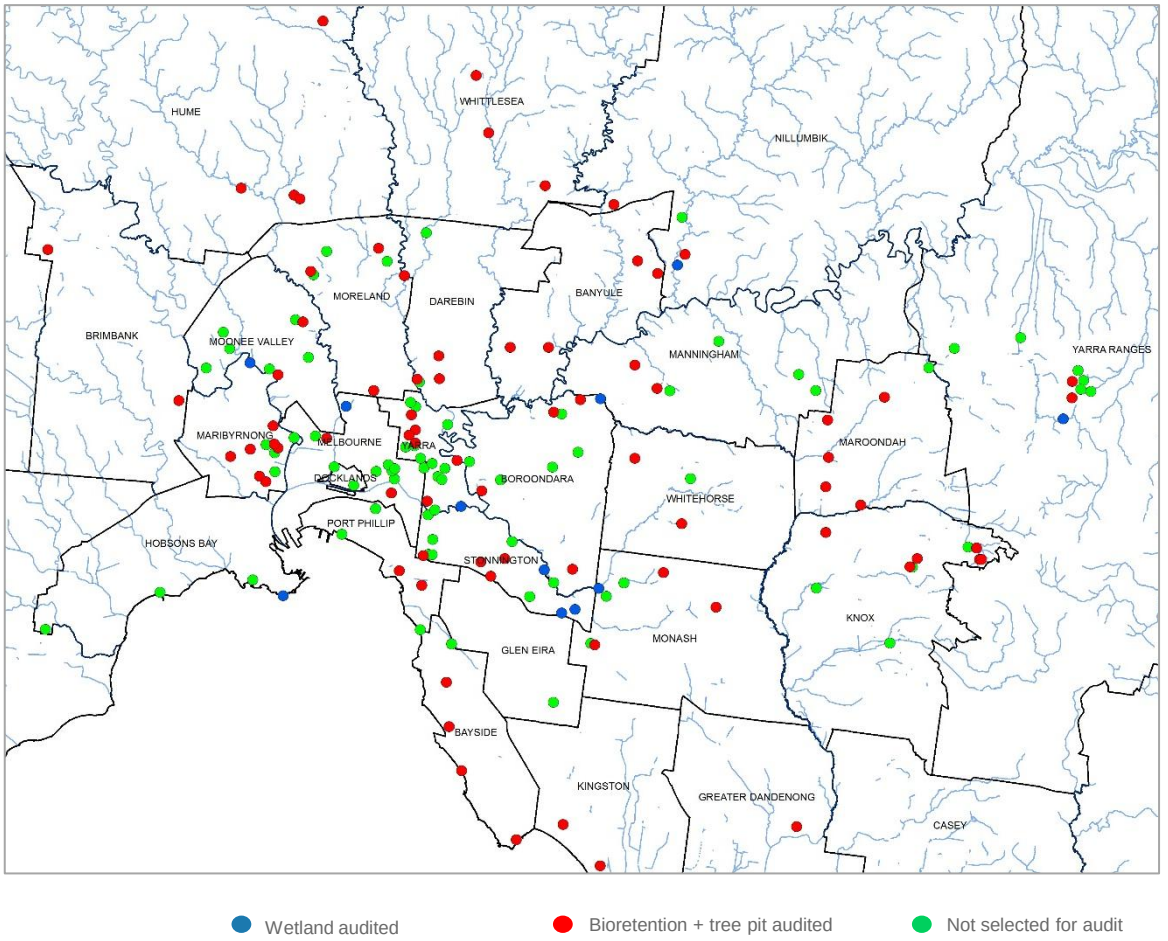
6. What improvements are required to specifications and future designs?

ASSET SELECTION

95 assets were selected for the audit

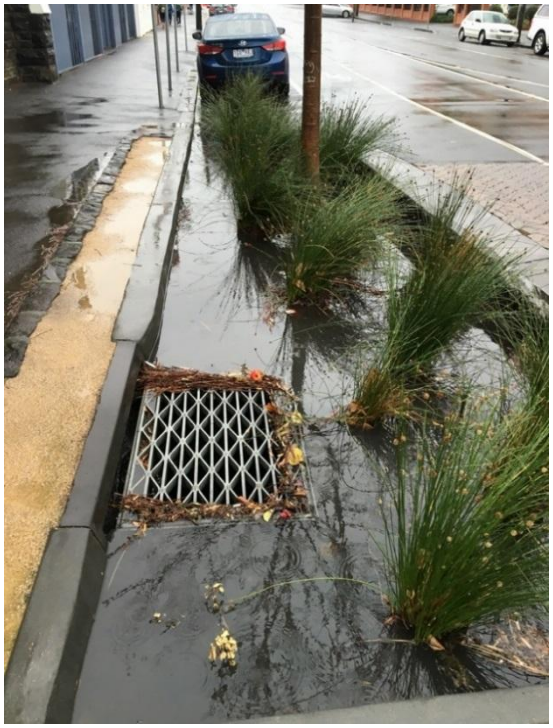
WSUD assets were selected to achieve a spread of:

- Age (1 -10 years old)
- Ownership (22 Councils in total)
- Asset type (Wetlands, bioretention systems and tree pits)

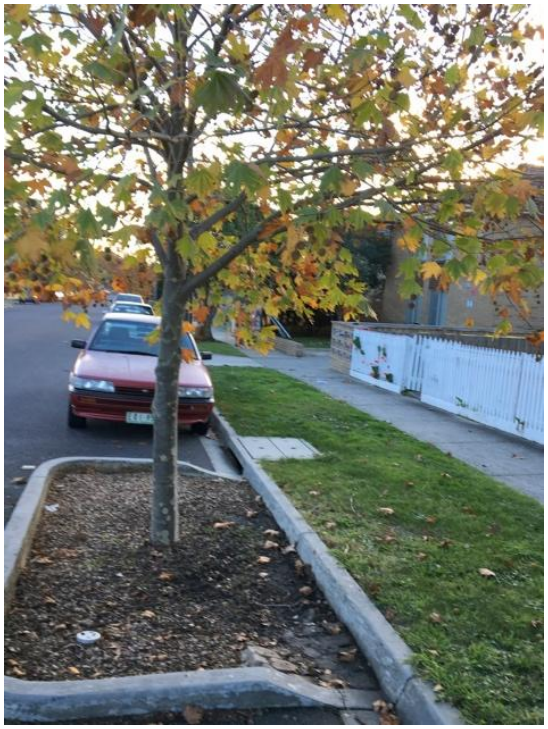


ASSET TYPE

57 bioretention systems, 25 tree pits and 13 wetlands were selected for the audit.



Bioretention system



Tree pit

Wetland

ASSET AGE AND RELEVANT GUIDELINES AND STANDARDS

Most of the assets audited were constructed more than 5 years ago when fewer design guidelines and specifications were available

Asset construction year in context of relevant guidelines available at the time of construction

2. Method

METHOD

The audit consisted of a dry and wet weather inspection. Data was collected on a range of performance indicators to assess asset stormwater treatment function and aesthetic function.

(See Appendix A for template)

The method involved 4 key tasks:

1. *Dry weather inspection*
2. *Wet weather inspection*
3. *Review of design documentation*
4. *Data analysis and reporting*

A particular focus of this method was to ensure that at least half of the assets were inspected during **wet weather** to confirm hydraulic operation and performance of the assets.

2.1 Stormwater treatment function

KEY PERFORMANCE INDICATORS – BIORETENTION + TREE PIT

The following key performance indicators were assessed as good, moderate or poor

Performance indicator	Condition rating: Good (1)	Condition rating: Moderate (2)	Condition rating: Poor (3)
Inlet performance (visual assessment)	No blockage	Partial blockage of inlet causing some bypass of flow around system	Blockages impact flows entering the system
Permeability (Visual assessment + particle size distribution measurements of surface samples)	• Low sediment deposition evident across the surface (from surface excavations) • Measured silt and clay content of surface sediment < 20 %	• Moderate sediment deposition evident across the surface (from surface excavations) • Measured silt and clay content of surface sediment between 20-50 %	• High sediment deposition evident across the surface (from surface excavations) • Measured silt and clay content of surface sediment > 50 %
Extended detention depth (EDD) (Visual assessment + level measurements)	As per design intent	50-80% of the design intent	< 50 % of the design intent
Surface levels (Visual assessment + level measurements)	Correct levels and even surface with good distribution of water across the surface	Correct levels with some small depressions or mounds present with limited impact on distribution of water across the surface	Levels affecting distribution of water across the surface (including short circuit, preferential flow paths etc.)
Plant health and density (Visual assessment)	• Healthy vegetation • Good vegetation cover (>80 %)	• Signs of plant stress • Poor health in < 20 % of plants • Moderate vegetation cover (50-70 %)	• Vegetation is dying back • Poor health in > 20 % of plants • Poor vegetation cover (< 40%)
Outlet and underdrainage (Visual assessment)	No blockage	Partial blockage of outlet causing some redirection of flows through the system	Blockages impacting flows leaving the system

Data on a range of other performance indicators were also collected (see Appendix A for WSUD Asset Inspection Checklist). Note that permeability, EDD and surface levels were assessed differently to the checklist in Appendix A.

KEY PERFORMANCE INDICATORS – BIORETENTION AND TREE PIT

	Inlet performance	Permeability	Extended detention depth (EDD)	Surface levels	Plant density
Condition rating: Good (1)					
	Clear inlet	Silt and clay content < 20 %	EDD as per design	Distribution across surface	Plant density (>80%)
Condition rating: Moderate (2)					
	Partially blocked inlet	Silt and clay content 20-50%	Compromised EDD	Some area not engaged	Plant density (50-70 %)
Condition rating: Poor (3)					
	Completely blocked inlet	Silt and clay content > 50%	Significantly reduced EDD	Large area not engaged	Plant density (<40 %)

KEY PERFORMANCE INDICATORS – WETLAND

The following performance indicators were assessed as good, moderate or poor

Performance indicator	Condition rating: Good (1)	Condition rating: Moderate (2)	Condition rating: Poor (3)
Inlet performance (Visual assessment)	No blockage	Partial blockage of inlet causing some bypass of flow around system	Blockages impact flows entering the system
Sediment accumulation (in sediment pond) (Visual assessment and spot check height measurements where possible)	Some accumulated sediment resulting in small reduction in sediment pond capacity	Accumulated sediment resulting in around 50 % reduction in sediment pond capacity	Accumulated sediment resulting in more than 50 % reduction in sediment pond capacity
Plant health and density (Visual assessment)	• Healthy vegetation • Good vegetation cover in planted areas (>80 %)	• Signs of plant stress • Poor health (signs of disease, pests) in < 20 % of plants • Moderate vegetation cover in planted areas (50-70 %)	• Vegetation is dying back • Poor health (signs of disease, pests) in > 20 % of plants • Poor vegetation cover in planted areas (< 40%)
Outlet performance (Visual assessment)	No blockage	Partial blockage of outlet causing some redirection of flows through the system	Blockages impacting flows leaving the system

Data on a range of other performance indicators were also collected (see Appendix A for WSUD Asset Inspection Checklist). A number of indicators such as variation of water level, detention time and presence of preferential flow pathways require observation, and data collection and analysis over a longer time period. This was out of scope for this audit.

KEY PERFORMANCE INDICATORS – WETLAND

	Inlet/outlet performance	Sediment accumulation	Plant density
Condition rating: Good (1)			
	Clear inlet	Low levels of sediment accumulation	Plant cover (>80%)
Condition rating: Moderate (2)			
	Partially blocked inlet	Accumulated sediment (approx. 50 %)	Plant cover (50-70%)
Condition rating: Poor (3)			
	Completely blocked inlet	Accumulated sediment (full sediment pond)	Plant cover (<40%)

INDICATIVE STORMWATER TREATMENT RATING

Each asset was rated as good, underperforming or failed

An **indicative stormwater treatment rating** for each asset was determined based on assessment of the key performance indicators presented before.

Each asset was rated as good, underforming or failed using the following approach.

Good asset – An asset where all performance indicators are being met and the asset is providing the level of stormwater treatment intended.

Underperforming asset – An asset where one or two performance indicators are not being met and the asset is only partially providing the level of stormwater treatment intended.

Failed asset – An asset that has stopped functioning and is therefore no longer providing the level of stormwater treatment intended. It is not meeting a range of performance indicators or has a key design flaw or performance deficiency that is preventing water from entering, passing through the asset and leaving the asset appropriately.

IDENTIFYING CAUSES FOR ASSET UNDERPERFORMANCE OR FAILURE

The underlying cause for asset underperformance or failure was determined for each asset

A number of causes may explain asset underperformance or failure including:

Design faults/issues – undersized structures, incorrect levels, miscalculated water regime (e.g. undersized/oversized systems), incorrect plant species and density, excessive use of gravel mulch, design promoting scour and preferential flow paths

Poor construction – constructed asset not meeting the design intent (e.g. finished levels are not as per design such as incorrect filter media levels, incorrect inlet/pit levels)

Poor establishment – Poor plant establishment e.g. inadequate irrigation, plant replacement etc. during establishment phase

Lack of scheduled or reactive maintenance – No sediment removal from filter media surface, blocked inlets, blocked pits and underdrains, no repairs to damaged structures, no intervention to maintain the required plant density or prevent mass plant failure.

Unusual influences – Actions that affect the function of an asset because its function is not well understood or was not conceived at the time of the implementation e.g. gravel mulch filling resulting in reduced extended detention depth, construction activity, change in catchment pollutant type/loads, high foot traffic etc.

2.2 Aesthetic function

AESTHETIC RATING

Value to the community from an aesthetics perspective was rated as either good, moderate or poor

Performance indicators for asset aesthetic function were derived from the Water Sensitive Cities Study – “Designing raingardens for community acceptance” (by Dobbie. M.F).

An overall aesthetic rating was determined for each asset based on the following performance indicators:

1. Suitability of asset softscape and hardscape
2. Diversity of plants (palette and number of species) (bioretention systems and wetlands only)
3. Perception of asset being cared for
4. Greenness
5. Inclusion of trees (bioretention systems only)

Descriptors for each performance indicators are described on the following page.

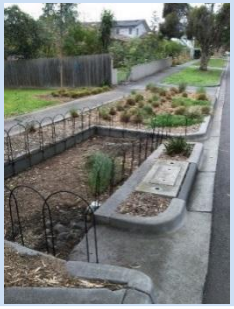
To derive an overall score for asset aesthetic function, different weighting have been applied to the performance indicators. More weighting has been placed on the “Perception of asset being care for” given its immediate impact on aesthetics e.g. an asset with high litter accumulation has an immediate impact on aesthetics, more so than an asset with poor plant diversity but with no litter.

KEY PERFORMANCE INDICATORS

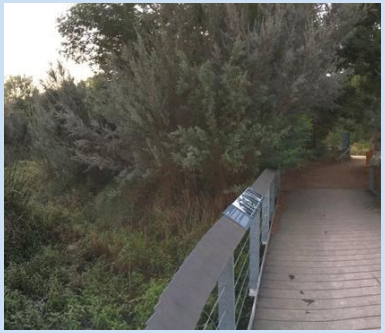
The condition of each performance indicator was assessed as good, moderate or poor

Performance indicator	Condition rating: Good (1)	Condition rating: Moderate (2)	Condition rating: Poor (3)
Suitability of asset softscape and hardscape (in context of land use, surrounding vegetation, residential gardens etc.)	Planting style suits broader landscape	Planting style suits broader landscape but maintenance is required	Planting style does not suit broader landscape
Diversity of plants (palette and number of species)	• >3 plant species • Suitable palette (variety of plants for water quality and aesthetic functions)	• 2-3 plants species • Narrow palette (mostly plants for water quality function)	• Monoculture
Perception of asset being cared for	No impact on aesthetics : • Minimal rubbish and coarse sediment accumulation • Minor leaf litter present (< 20 % cover) • Limited weed cover (<10 % cover) • Good to moderate vegetation cover (>80 %) • Healthy vegetation • Plants in an orderly frame (including loose and strappy plants) and skilled maintenance/pruning evident • No nuisance fauna • Signage present	Some impact on aesthetics : • Rubbish present and coarse sediment accumulation • Leaf litter present (<40 % cover) • Low to moderate weed cover (20-30%) • Good to moderate vegetation cover (50-70 %) with signs of plant stress in < 20% plants • Plants slightly overgrown but generally in an orderly frame suggesting maintenance/pruning is required • Some nuisance fauna • Signage vandalised or worn out	Major impact on aesthetics : • Large amount of rubbish and coarse sediment accumulation • Leaf litter (> 40 %) • High weed cover (> 50 %) • Poor vegetation cover (<40 %) with signs of plant stress in > 20 % of plants • Plants messy and out of scale with a clear lack of maintenance/pruning • Significant nuisance fauna • No signage
Greenness	Mostly green foliage	Mix of green and brown foliage, suits broader landscape	Mostly brown foliage, does not suit broader landscape
Inclusion of trees	Tree included and appropriate in context of broader landscape	Tree included but some characteristics are problematic (e.g. high leaf litter, aggressive root system)	No tree included

KEY AESTHETIC INDICATORS – BIORETENTION + TREE PIT

	Suitability of asset softscape and hardscape	Diversity of plants (Number of species)	Perception of asset being cared for	Greenness
Condition rating: Good				
	Planting style suits landscape	> 3 species and inclusion of species for aesthetic	No litter, no weed, moderate cover, plants in orderly frame	Mostly green foliage
Condition rating: Moderate				
	Planting style suits landscape but maintenance required	2-3 species	Some litter, plants overgrown in need of pruning	Mix of green and brown foliage
Condition rating: Poor				
	Poor cover. Loose and strappy plants do no suit tidy landscape	Monoculture	Weeds and no plants (in needs of maintenance	Mostly brown foliage. Does not suit green surroundings.

KEY AESTHETIC INDICATORS – WETLAND

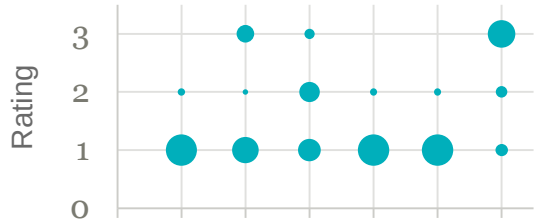
Performance indicator	Suitability of asset softscape and hardscape	Diversity of plants (number of species)	Perception of asset being cared for	Greenness
Condition rating: Good (1)				
	Suitable planting style (surrounding bushland)	> 3 species	No litter, no weed, moderate cover, plants in orderly frame	Mostly green foliage
Condition rating: Moderate (2)				
	Small section of overgrown plants (tall species) in tidy surroundings	2-3 species dominating	Plant dying back at several locations	Mix of green and brown foliage
Condition rating: Poor (3)				
	Large area with strappy and loose plants (pvergrown) in tidy surroundings	1 species dominating	Significant algae, litter, weeds, and plants in poor health and density	Large area with plant die off

3. FINDINGS
Bioretention + tree pit

3.1 Stormwater treatment function

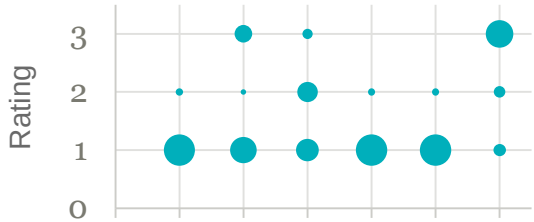
3.2 Aesthetic function

Refer to Appendix B for condition rating of each asset, including maintenance and rectification requirements



3.1 Bioretention + Tree pit

Stormwater treatment function



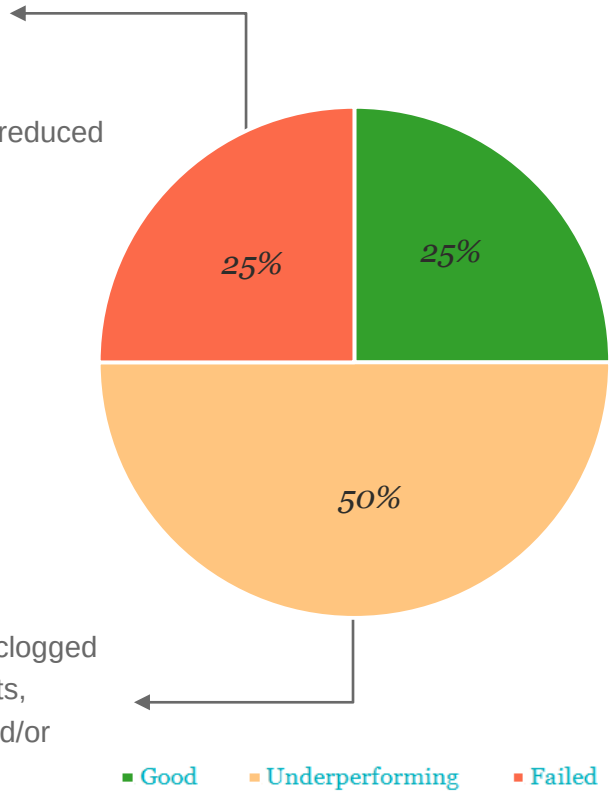
STORMWATER TREATMENT RATING

Approximately 25 % assets are providing the level of stormwater treatment intended, with 50 % underperforming and 25 % failing.

Failed assets

Key issues are:

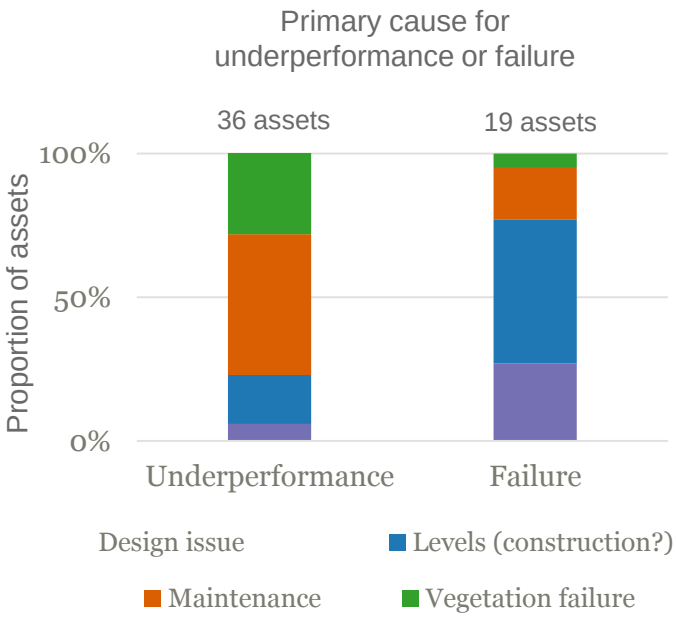
- Blocked inlets
- Incorrect levels and significantly reduced EDD
- Poor plant density
- Severely clogged filter media



Underperforming assets

Key issues are:

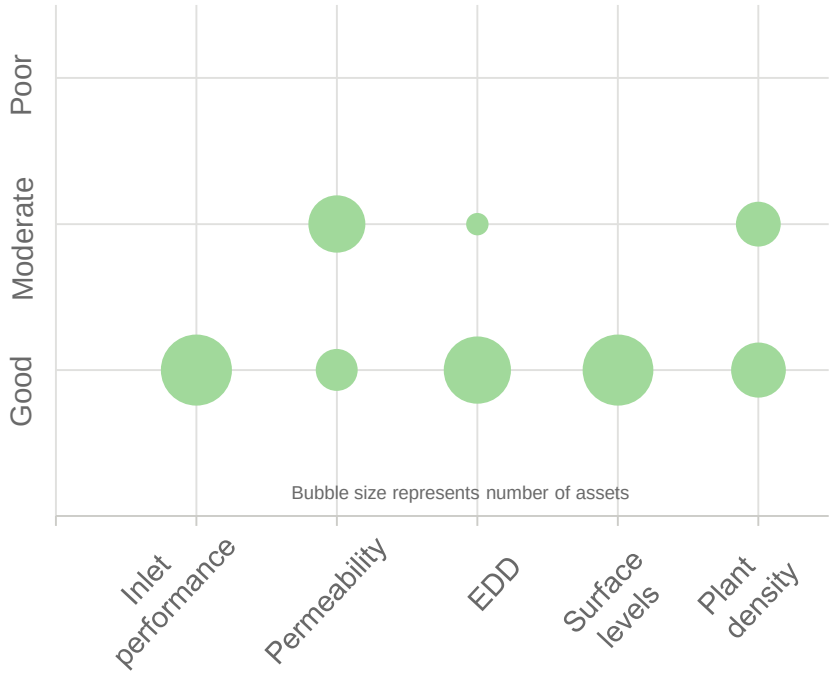
- Bioretention systems – partially clogged filter media, partially blocked inlets, compromised levels and EDD and/or moderate plant density
- Tree pits – partially blocked inlets and partially clogged filter media.



ASSETS WITH ‘GOOD’ TREATMENT PERFORMANCE

Assets with good aesthetics generally have:

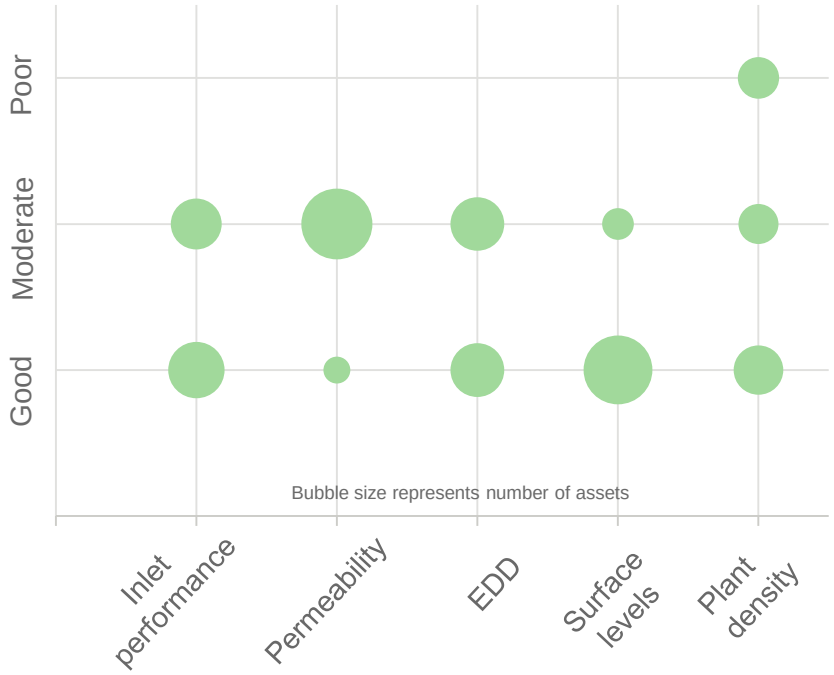
- No blockages
- Good to moderate permeability
- EDD as per design
- Even surface
- Good to moderate plant density



UNDERPERFOMING ASSETS

Underperforming assets have:

- Moderate permeability and reduced EDD
- Partially blocked inlets
- Moderate plant density
- A number of assets with poor plant density but good hydraulic performance



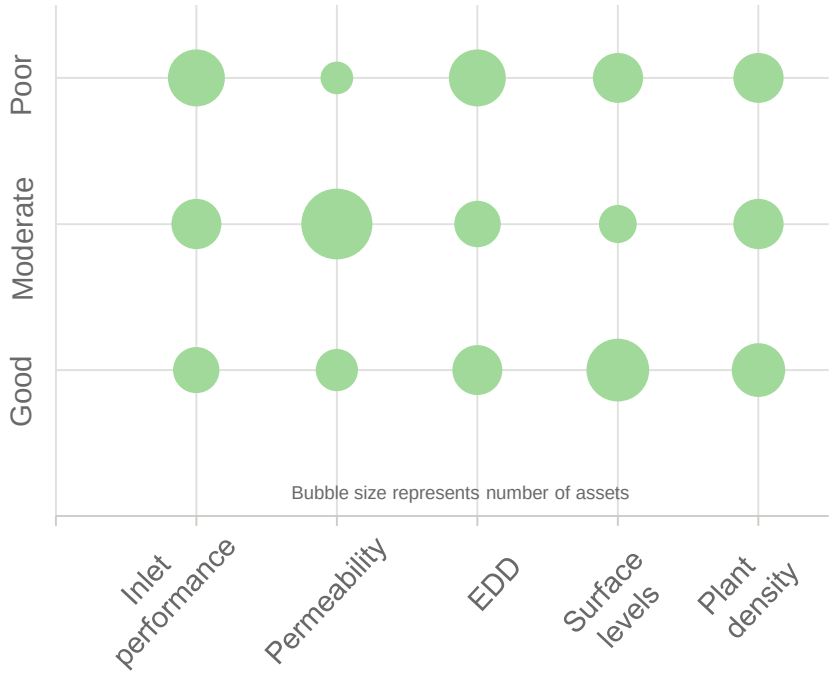




FAILED ASSETS

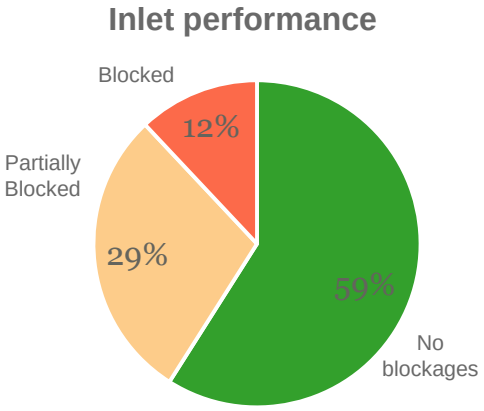
Failed assets have:

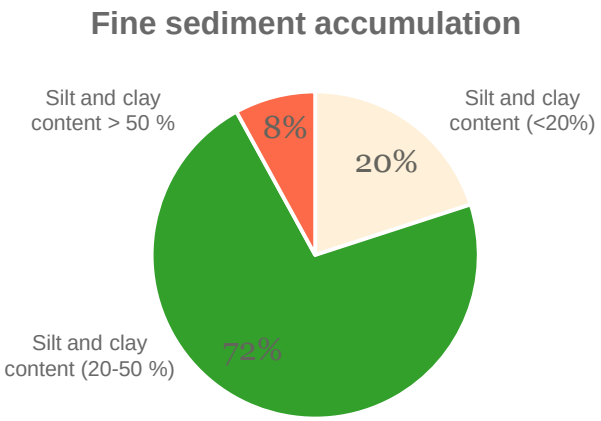
- Completely blocked inlets
- Significantly reduced EDD
- Incorrect levels
- Poor permeability

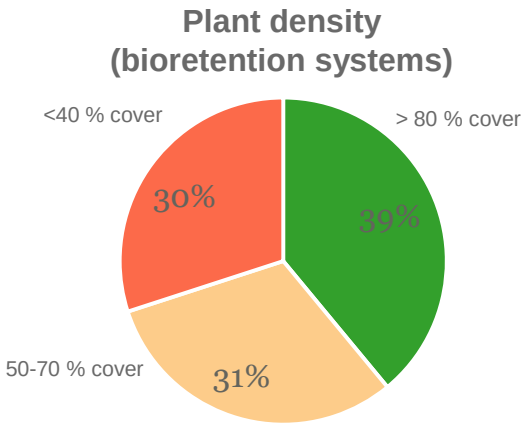


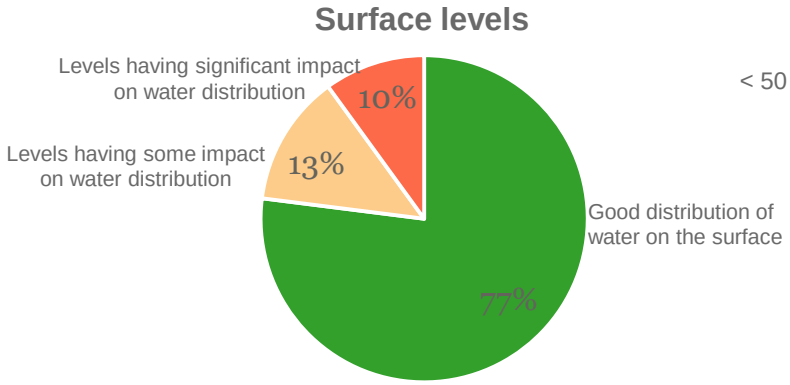
STORMWATER TREATMENT FUNCTION – PERFORMANCE INDICATORS

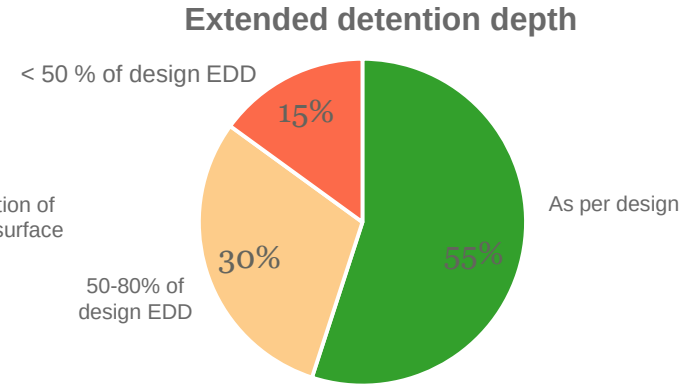
Assets generally have good inlet performance, moderate levels of fine sediment accumulation, appropriate levels but often compromised EDD, and vegetation often in moderate to poor condition. More detailed findings on each performance indicator are provided on pp. 30-36.











Refer to section 2.1 descriptors of each indicator

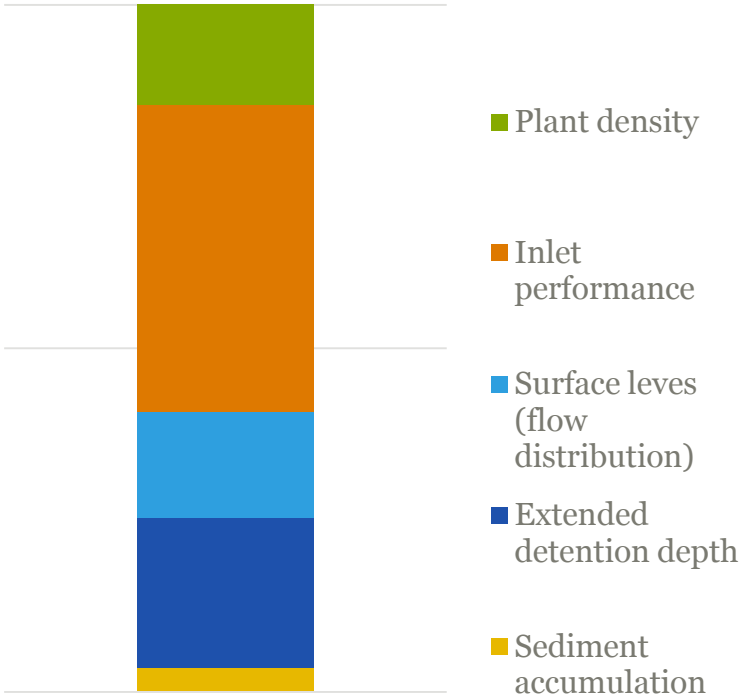
■ Good ■ Moderate ■ Poor

STORMWATER TREATMENT FUNCTION – KEY PERFORMANCE INDICATORS

For the assets audited, the key indicators that influenced stormwater quality rating were 1) Inlet performance, 2) Surface levels and 3) Extended detention depth

The bar chart illustrates the degree of influence that each indicator has on the stormwater treatment function for all of the bioretention systems and tree pits audited.

Inlet performance, EDD and surface levels had the most influence. This is not to say that planting or sediment accumulation are not important items. Rather, underperformance or failure of the assets audited was more likely to be associated with problems to the inlet, surface levels and/or EDD.



Contribution of each indicator to stormwater treatmetn rating for audited assets

OTHER PERFORMANCE INDICATORS

Assets generally have functioning outlets and under drainage. Few assets have minor erosion issues and minor damage to hydraulic structures.

Filter media: All assets audited use the specified filter media. The surface is generally free of moss and in most cases there is no evidence of unusual pollutant loads e.g. from construction activity, oils, etc.

Erosion: Minor erosion is common at the inlet zone in assets with no rock protection. Otherwise, there is generally no erosion or scour observed at the interface of the filter media with the inlet or outlet structures.

Damage to hydraulic structures: Outlet/overflow pits, inlets, and edges are generally in good condition with no damage.

Outlet and underdrainage: Outlets are generally functioning well (no blockages). Underdrains have been observed to be functioning well during wet weather inspection. Inspection of maintenance pipes when available revealed no unusual levels of standing water at base of system that would indicate poor drainage.

Gravel mulch: 60 % of assets have gravel mulch. While good for aesthetics and weed suppression, this can prevent plant propagation.

Bare patches: It is common to see signs of plant stress and die-off at the inlet zone (sediment smothering and high flows) and along preferential flow paths (high flows).

1. INLET PERFORMANCE

Inlets performance is generally good with blockages attributed to design faults or lack of maintenance

Asset inlets are generally performing well.

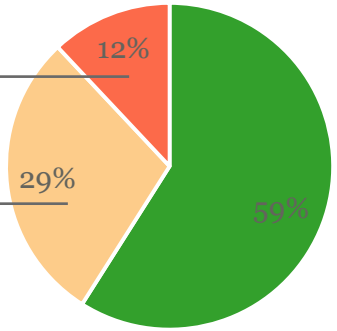
Inlets in moderate condition (resulting in some bypass) is due to excessive sediment accumulation or vegetation growth at the inlet zone, requiring maintenance. Some assets also have inlet designs that are prone to blockages.

Inlets in poor condition (resulting in significant bypass) can be attributed to design issues (e.g. surcharge pits prone to blockages). A small proportion of assets have completely blocked inlets and require maintenance.

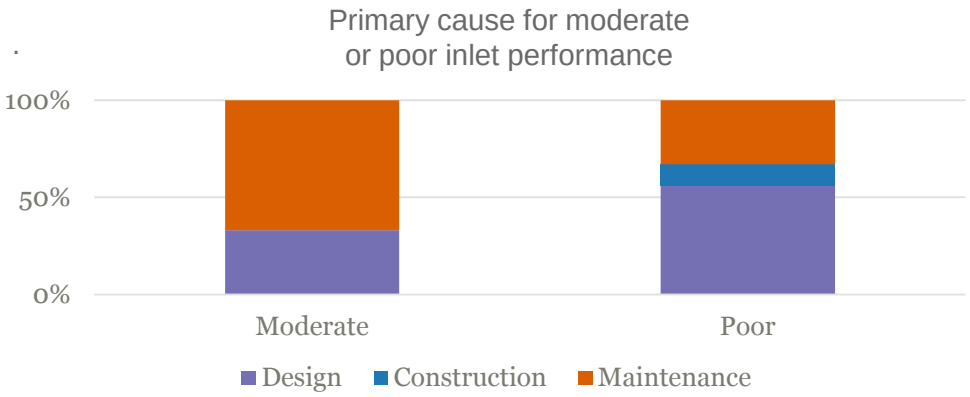
Asset 10
Blocked surcharge pit

Asset 4
Poor levels resulting in bypass

Asset 49
Plants blocking inlet



% of assets by inlet performance



Asset 58
Blocked inlet

Asset 28
Blocked inlet (litter accumulation)

Asset 65
Blocked inlet

FUNCTIONAL INLETS

Functioning inlets typically have drop down and wide openings to minimise risk of blockages.

Assets with good inlet performance generally have multiple inlets, have inlets that are adequately sized, with drop down to promote flow into the system.

The inlet zone should be kept free of vegetation to minimise inlet blockages. It can also include a small sediment forebay to collect coarse sediment and rock beaching to reduce flow velocities and risk of scouring.

.





2. SEDIMENT ACCUMULATION

72 % of assets have moderate level of sediment accumulation with a further 8 % having severely clogged filter media

Sediment samples were collected across the filter media surface for half of the assets and tested for particle size distribution.

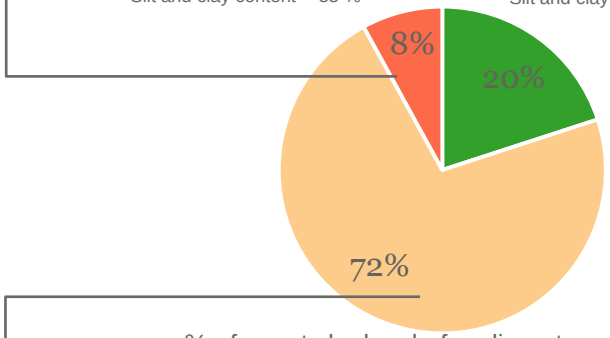
Moderate levels of fine sediment accumulation were found on the surface, with a silt and clay content varying between 20-50 % (equivalent to an infiltration rate of 10-50 mm/hr noting that the design infiltration rate is typically 100 mm/hr).

Excessive fine sediment accumulation was found in only 8 % of assets, with a silt and clay content > 50 % (equivalent infiltration rate < 10 mm/hr).

Fine sediment accumulation was generally distributed across the filter surface but higher deposition occurred at the inlet zone (characterised by higher silt and clay content), particularly for assets with point source inlets (e.g. pipe or kerb cuts).

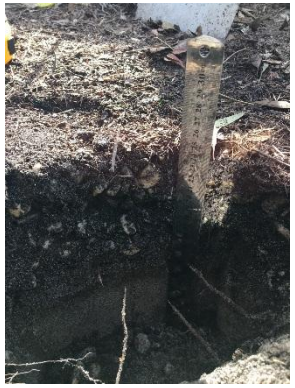
Asset 78
Excessive fine sediment deposition
Silt and clay content = 55 %

Asset 26
Excessive fine sediment deposition
Silt and clay = 57 %



% of assets by level of sediment accumulation

Asset 39
Thin layer of fine sediment deposition
Silt and clay content = 44 %



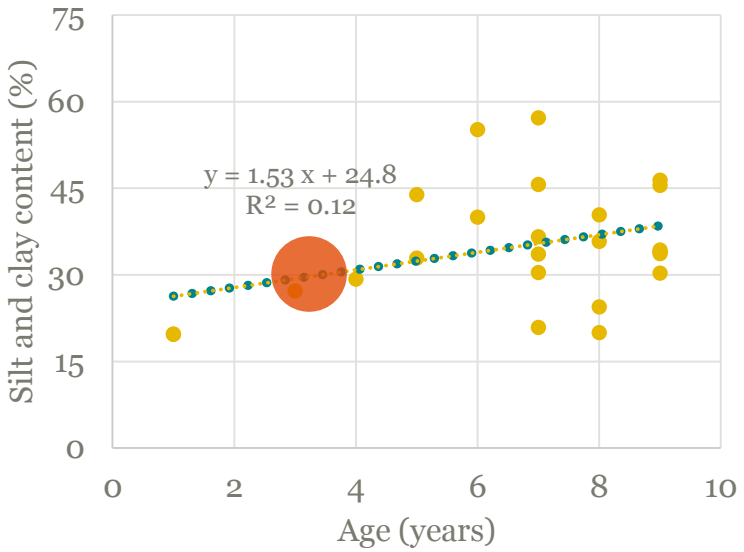
Asset 17
Moderate fine sediment deposition
Silt and clay content = 34 %

2. SEDIMENT ACCUMULATION (CONT.)

Generally, there is a build-up of fine sediment (resulting in a silt and clay content of 30 % on the filter media surface) within 3-4 years.

There is a weak relationship between silt and clay content and asset age. This is expected as sediment load can vary with many factors including catchment type. This relationship exclude assets with poor surface levels and blocked inlets. It also excludes assets in semi-urbanised catchments (with a large proportion of pervious surfaces) as the silt and clay fraction in these systems can exceed 50 % after 4 years.

The relationship indicates that assets can accumulate a moderate level of sediment (e.g. silt and clay content of 30%) within 3-4 years.



The recommendation therefore is that fine sediment is scraped off the filter media surface every 3-4 years and more frequently for systems in catchments with high sediment loads. It is good practice to rake the surface of the filter media once a year to break up any built-up of sediment. Good plant density will also help to maintain permeability of the filter media.

3. FLOW DISTRIBUTION (SURFACE LEVELS)

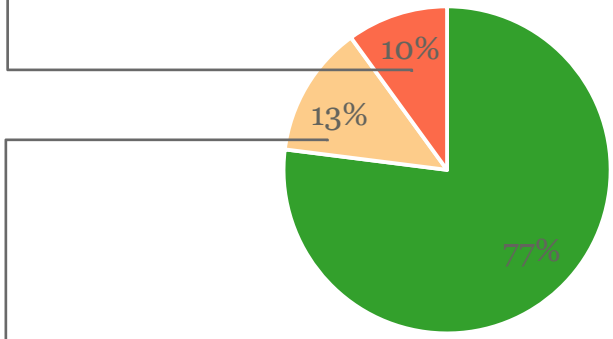
Assets generally have correct levels (as per design) and surfaces that are flat. Problems with levels can arise at construction and over time.

Assets are generally constructed as per design, and have correct levels and surfaces that are flat, resulting in good distribution of water across the surface. For assets where a moderate or significant proportion of the surface is not engaged, issues include:

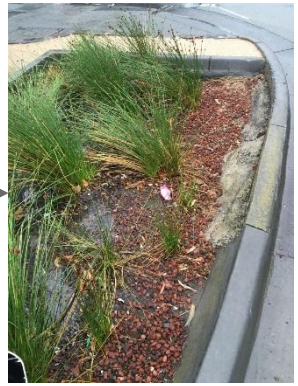
- Surfaces that are not flat (compared to design) with issues arising either at construction or over time from accumulation of coarse sediment
- Scour /preferential flow paths
- Outlet pit flush with inlet promoting short circuit (particularly in assets where the outlet pit is in close proximity to the inlet).

Asset 33
Overflow pit level flush with inlet level

Asset 42
Preferential flow path



% of assets with surface level issues



Asset 50
Surface not flat – some area not engaged

Asset 65
Surface level of filter media higher than inlet level

4. EXTENDED DETENTION DEPTH (EDD)

55% of assets have an EDD close to the design intent. 30 % of assets have a reduced EDD and 15 % have significantly compromised EDD.

55 % of assets have an EDD close to the design intent.

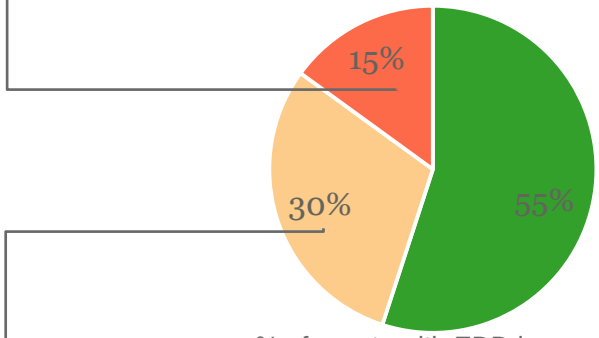
30 % were found to have an EDD between 50-80% of the design EDD. Excessive topping of gravel mulch was often observed to reduce the EDD. This can occur at the time of construction or from maintenance activities.

15 % assets have significantly reduced EDD (EDD less than 50 % of the design intent). For these assets, it is likely that levels were incorrect at the completion of construction.

.

Asset 4
Overflow pit flush with rock mulch: No EDD

Asset 49
Overflow pit crest level flush with filter media level: No EDD



% of assets with EDD issues

Asset 13
Reduced EDD compared to design

Asset 51
Reduced EDD compared to design

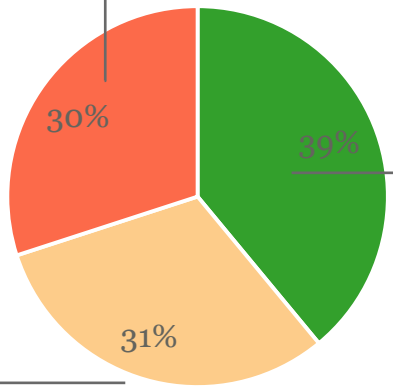
5. PLANT DENSITY AND HEALTH

Asset 24
Plants in poor heath and poor cover

Vegetation condition in bioretention systems is a key issue

30% of bioretention systems audited have poor vegetation cover (< 40%), 31 % have moderate vegetation cover (50-70%) and 39 % having good vegetation cover (>80%).

All tree pits were rated ‘good’. Trees are generally in good health and have good canopy cover.



Asset 3
Plants in good health and close to 100 % cover

Asset 45
Plants with moderate health and approx. 50 % cover

5. PLANT DENSITY AND HEALTH

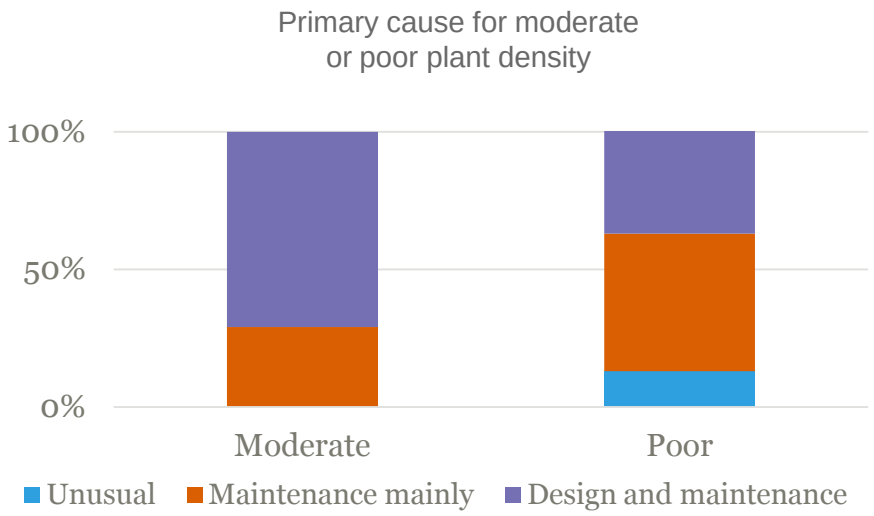
Plant health and density in moderate condition can generally be attributed to a combination of design and maintenance.

Whilst it is difficult to attribute exact causes for plant condition from site inspections alone, causes can be classified into 1) combination of design and maintenance (e.g. use of gravel mulch, no plant replacement/infilling over time) 2) lack of maintenance mainly (clear lack of attention to plant health and establishment) and 3) unusual (e.g. planting not carried out at the time of construction).

For the 30 % of bioretention systems that have moderate vegetation density, this can be attributed partly to the use of gravel mulch which can restrict plant growth and spread (60% of assets have gravel mulch).

Planting success can be achieved by ensuring the design specifies an appropriate plant density, regular maintenance (e.g. replacing dead and diseased plants, infilling gaps in vegetation), and more attention during the plant establishment period.

.



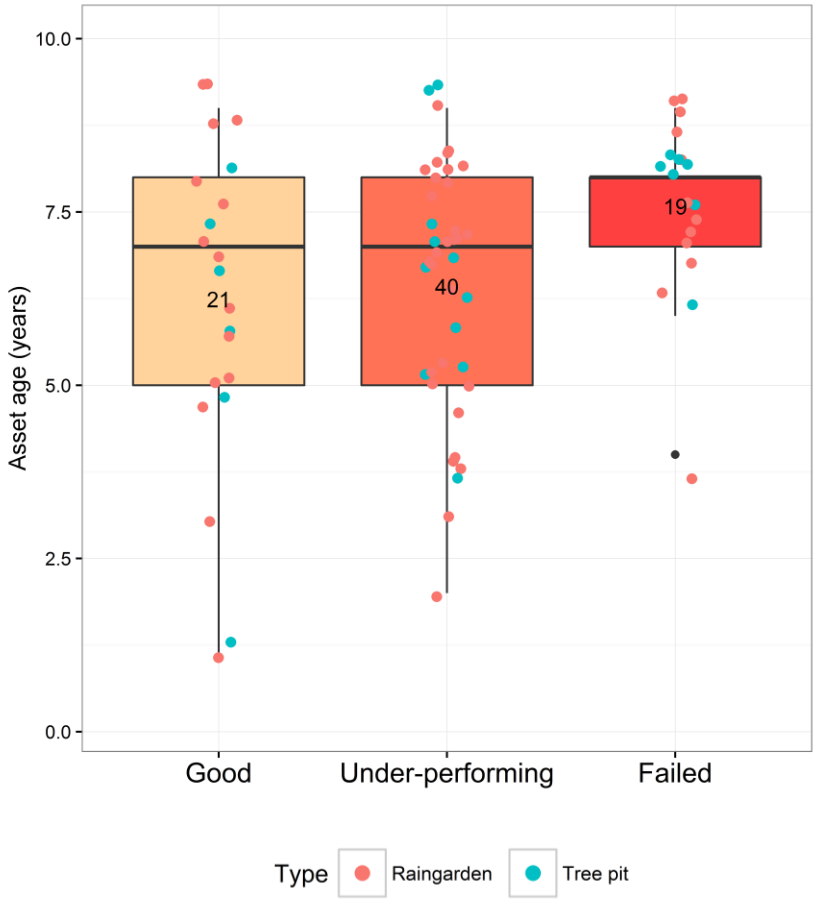
ASSET CONDITION BY ASSET AGE

Failed assets are generally more than 5 years old. Assets < 5 years old are generally well designed and constructed. This indicates an improvement in WSUD design and construction.

The bulk of the assets audited were > 5 years old and can range in condition (from good to failed).

Failed assets are generally older than > 5 years old. Asset failure can be attributed to inlet design faults or incorrect levels, and assets are likely to have failed from an early stage (see page 26 for causes of asset failure).

On the other hand, assets < 5 years old are generally well designed and constructed (with correct levels), and are functioning well or underperforming (but not failing). Overall, this indicates that there has been an improvement in WSUD design and construction.



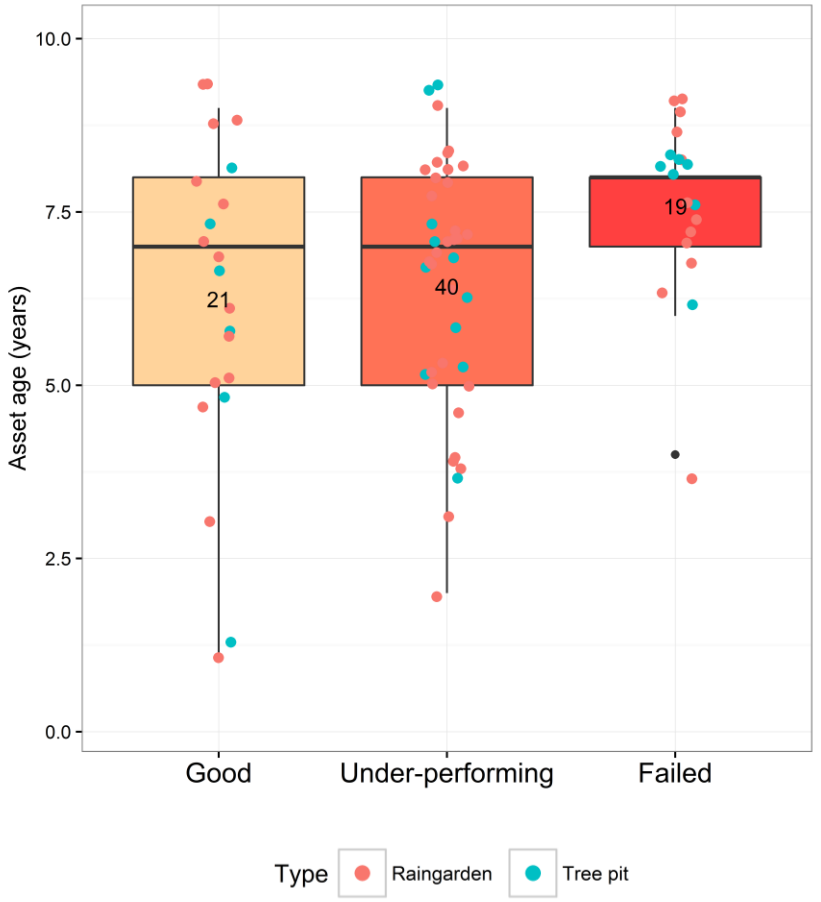
ASSET CONDITION BY ASSET TYPE

Bioretention systems and tree pits can both under-perform or fail

Blocked inlets and incorrect surface levels were observed in both bioretention system and tree pits.

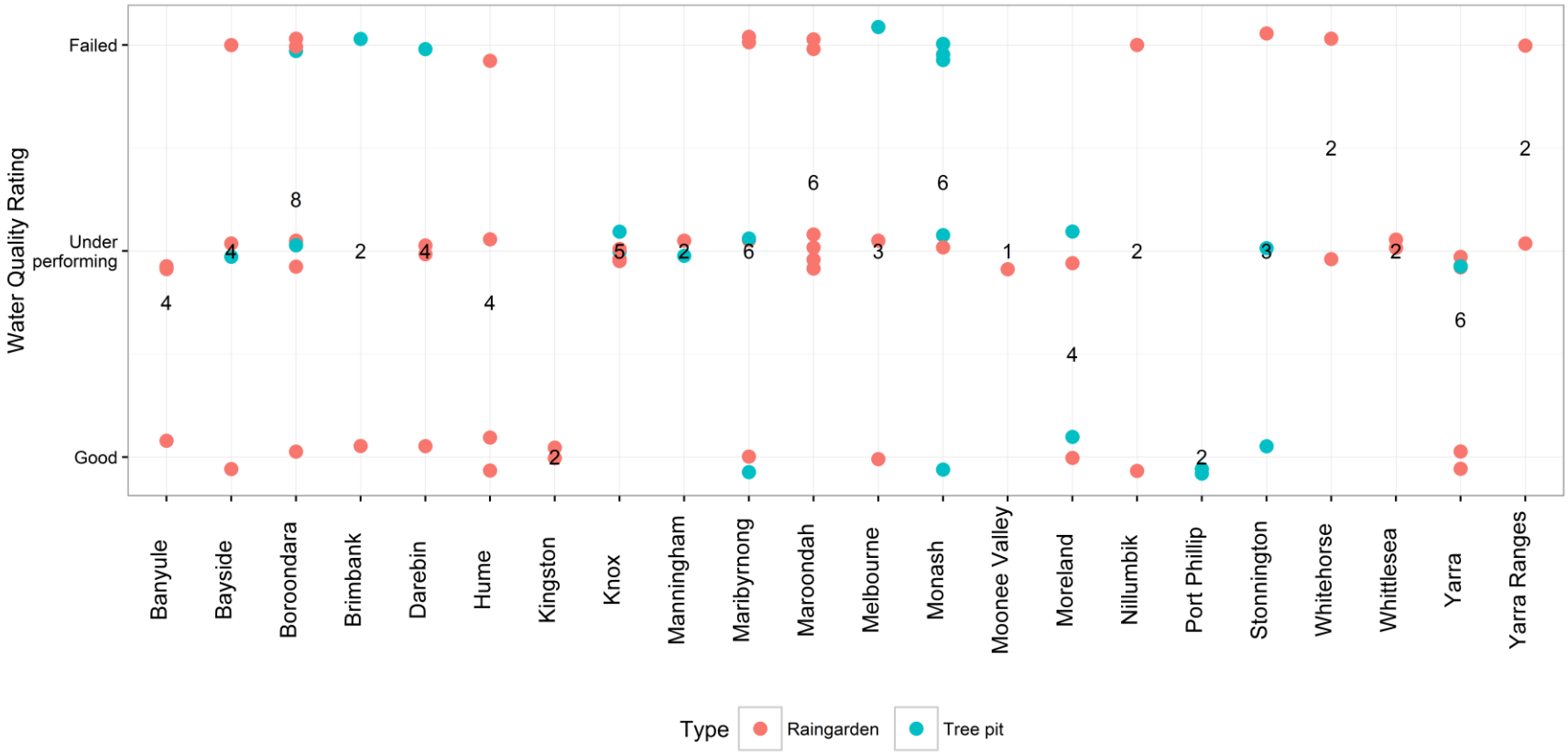
EDD reduction in bioretention systems can be attributed to incorrect levels or excessive gravel mulch topping, and in tree pits often to coarse sediment accumulation (tree pits generally have a small filter surface area with no inlet sedimentation zone).

In terms of planting success, trees in tree pits are generally in good health with good size canopies, whereas small plant life-forms in bioretention systems can often show sign of stress and often have moderate to poor cover.



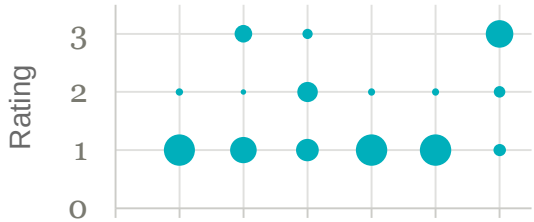
ASSET CONDITION BY COUNCIL

13/22 councils have assets that have failed. Councils generally have assets that vary in condition.



3.2 Bioretention + Tree pit

Aesthetic function



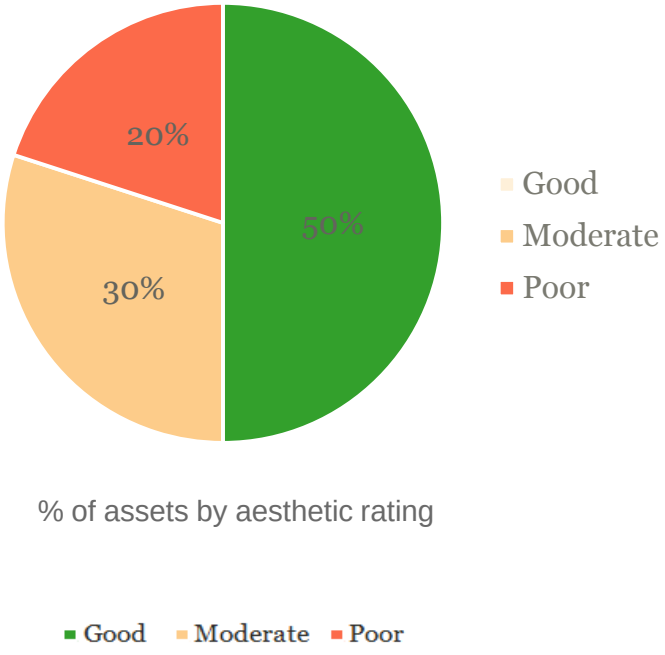
AESTHETIC RATING

50 % of assets are providing good aesthetic benefit. 30 % of assets (bioretention systems) require maintenance to improve aesthetics. 20 % of assets (bioretention systems) are in poor condition and require complete replanting.

Half of the assets audited are providing good aesthetic benefit. Stand-alone tree pits were all rated ‘good’ as trees have good canopies and are in good health. Tree pits with grated lids also keep accumulated litter/rubbish out of sight.

Assets in moderate condition are “in need of maintenance” and tend to have moderate vegetation cover, stressed vegetation, and moderate levels of leaf litter or rubbish.

Assets in poor condition generally have poor vegetation cover and require complete replanting to improve aesthetics.



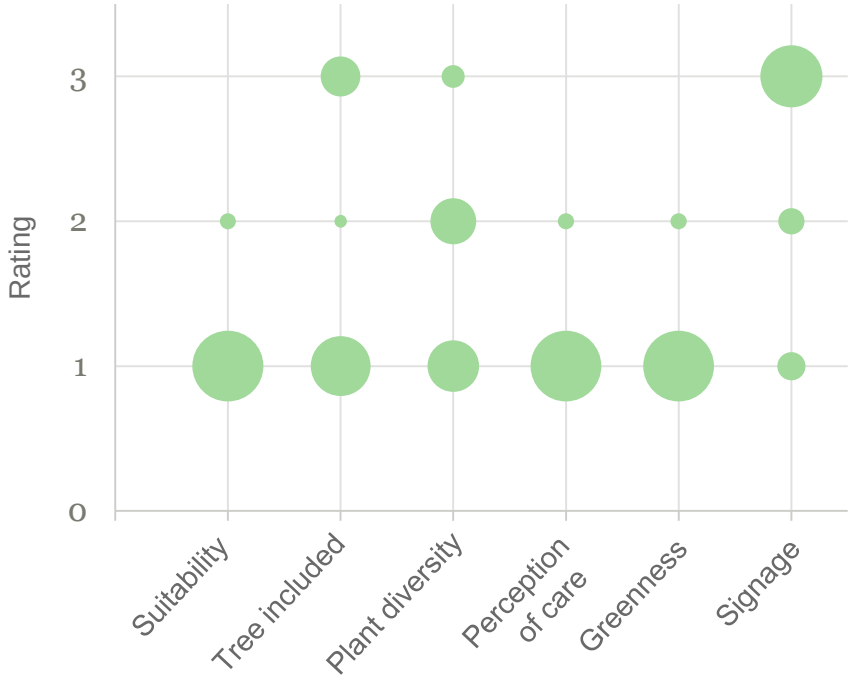
% of assets by aesthetic rating

‘GOOD’ AESTHETICS

Assets with good aesthetics generally have:

- Plant species and planting style (formal) that suits the broader landscape, and planting scale that is in proportion to landscape elements.
- Good (>3 plant species) to moderate (2-3 plant species) plant diversity
- Good (> 80 %) to moderate (50-70 %) plant cover, healthy plants, and good ‘cues of care’ (minimal rubbish, leaf litter, evidence of pruning but not necessarily signage)

They also add ‘greenness’ or complement the landscape well.



Asset 66

Asset 45

Asset 1

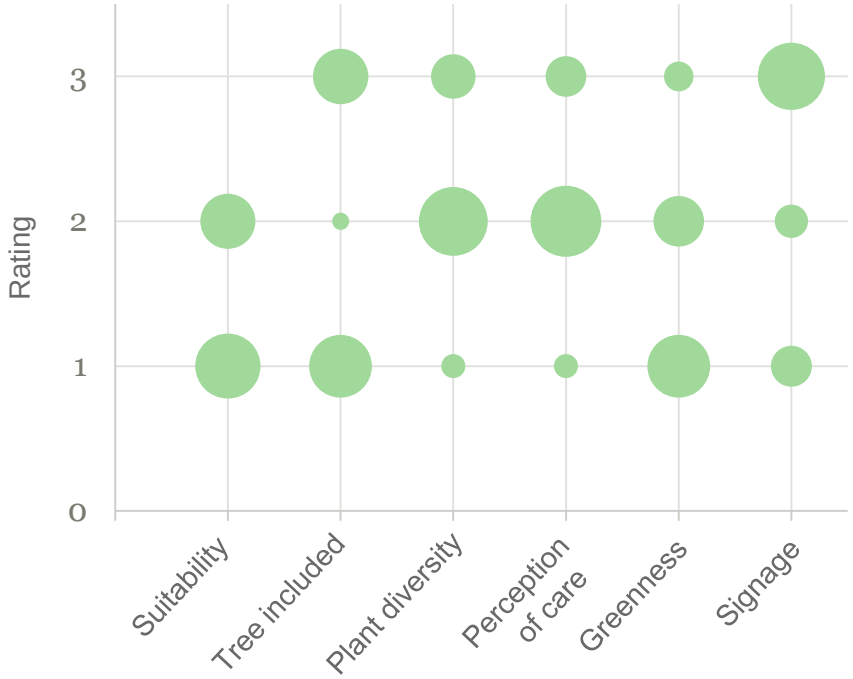
Asset 3

Asset 35

‘MODERATE’ AESTHETICS

Assets with moderate aesthetics generally have:

- Plant species and planting style that suits the broader landscape but in some cases require maintenance (e.g. overgrown vegetation or messy look).
- Moderate (2-3 plant species) plant diversity and in some cases poor (1 plant species)
- Perception on “in need of care” – Moderate (50-70 %) plant cover, in some cases with stressed vegetation. 6/26 assets also had rubbish, 8/26 assets had leaf litter and 2/26 assets had moderate weed cover (20-30 % cover).



Asset 28

Asset 9

Asset 58

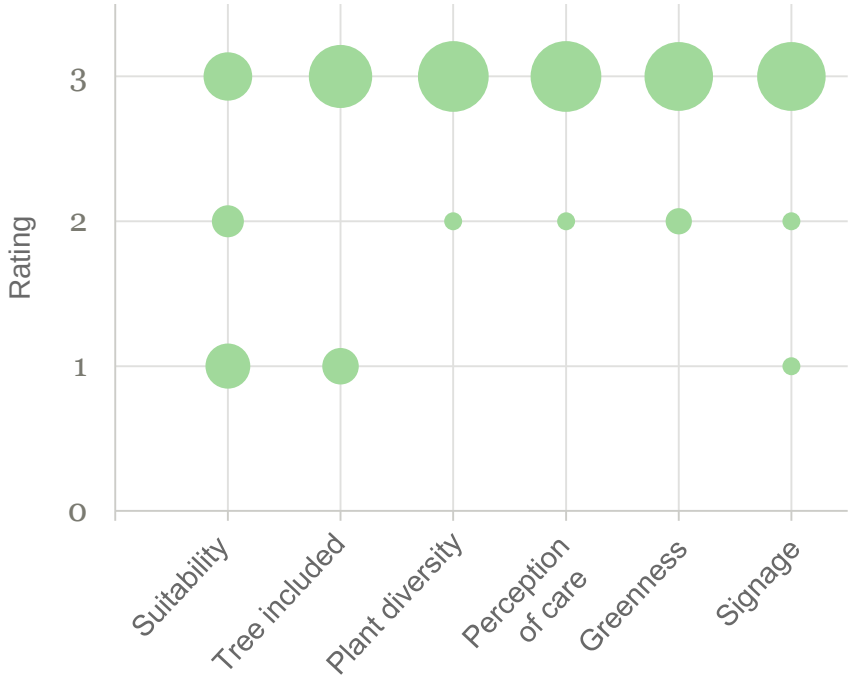
Asset 48

Asset 34

‘POOR’ AESTHETIC

Assets with poor aesthetic generally have:

- Poor plant diversity (1 species) and poor vegetation cover (< 40 %) and consequently poor perception of care and ‘greenness’.



Asset 30

Asset 42

Asset 20

Asset 15

Asset 17

OTHER OBSERVATIONS

Plant diversity: Bioretention system design only consider species for water quality purposes and not for aesthetics. The number of species observed in bioretention systems is generally less than three.

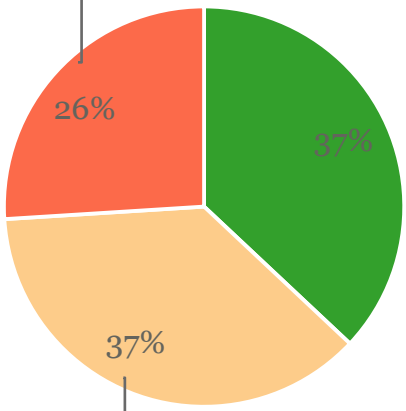
Rubbish and leaf litter: Rubbish accumulation affect aesthetics in 20 % of assets. Leaf litter was an issue at the time of the audit (autumn/winter), affecting aesthetics in approx. 40 % of assets.

Weed and nuisance fauna were not key issues in bioretention systems and tree pits audited

Signage: 15 % of assets have signage in good condition. 12 % of assets have signage in poor condition (faded and hard to read).

PERFORMANCE INDICATOR – PERCEPTION OF CARE

Assets generally vary in their perception of being 'cared' for, with maintenance generally required. Vegetation health and cover is a good cue of care



% of assets with good, moderate or poor perception of care

Good Moderate Poor

Poor perception associated with poor vegetation cover, and often with moderate leaf litter and rubbish. 1 asset had high leaf litter load and another had nuisance fauna

Asset 30

Asset 33

Asset 67

Moderate perception associated with moderate vegetation cover, poor or no maintenance (e.g. overgrown plants or excessive pruning), and leaf litter, rubbish or weed present

Asset 54

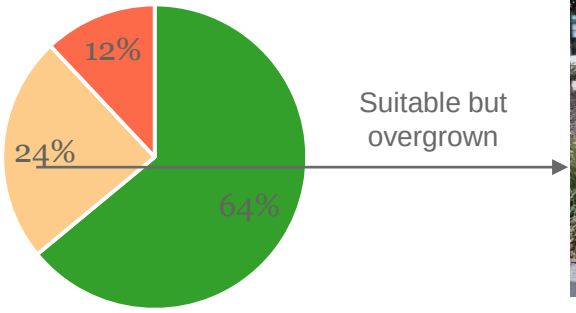
Asset 48

Asset 14

PERFORMANCE INDICATORS (CONT.)

Small plant lifeforms used generally suit the broader landscape. Planting selection and density can improve to add 'greenness'. Plant diversity can also improve to boost aesthetics.

Suitability of softscape



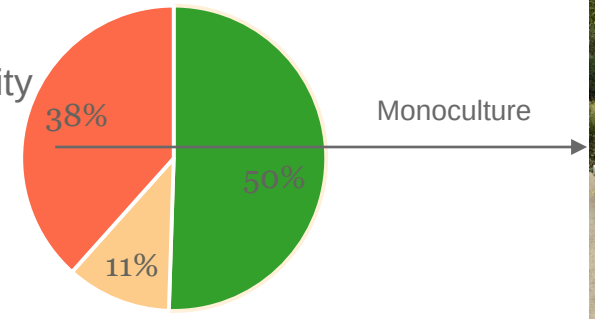
Suitable but overgrown

Asset 47

Asset 18

Asset 9

Plant diversity



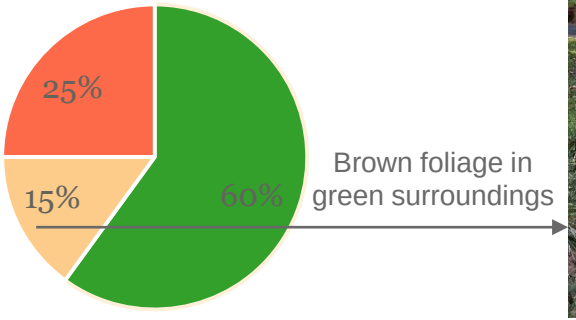
Monoculture

Asset 3

Asset 40

Asset 13

Greenness

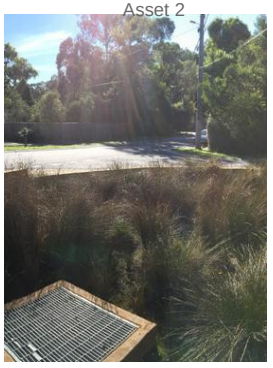


Brown foliage in green surroundings

Asset 28

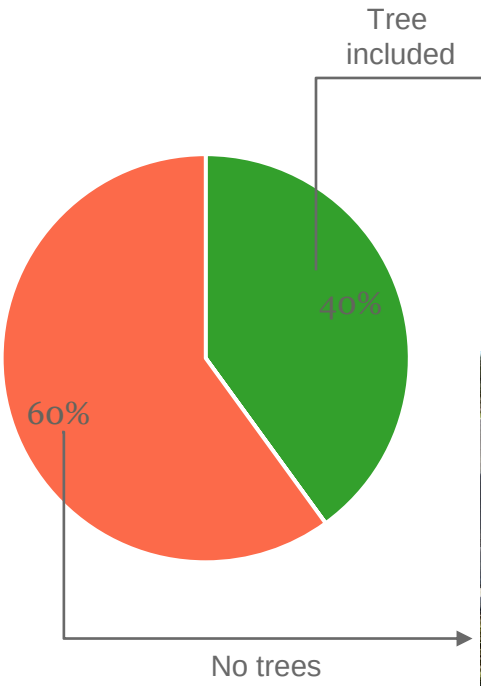
Asset 43

Asset 2



PERFORMANCE INDICATORS – INCLUSION OF TREES

40 % of bioretention systems have trees.



% of assets with and without trees

Asset 35

Asset 22

Asset 51

Asset 36

Asset 24

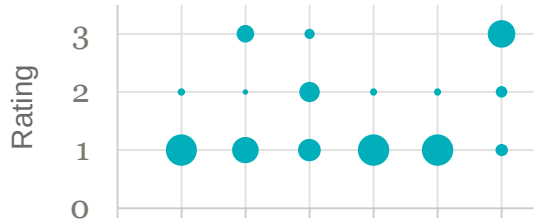
Asset 42

4. Findings
Wetlands

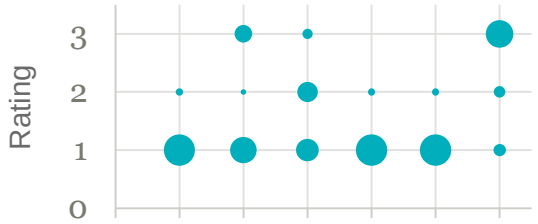
4.1 Stormwater treatment function

4.2 Aesthetic function

Refer to Appendix B for condition rating of each asset, including maintenance and rectification requirements



4.1 Stormwater treatment function



STORMWATER TREATMENT RATING

13 wetlands were audited. 8 wetlands are likely to be delivering good to moderate stormwater quality function, with 5 wetlands in poor condition.

The ability of a wetland to deliver its stormwater treatment depends on several performance indicators. Data on a number of key indicators have been collected from this audit but several indicators have not, such as water level fluctuation, bathymetry levels, sizing of asset relative to catchment. As a result, the stormwater quality rating has been based on limited number of indicators and is indicative only.

Assets in good condition

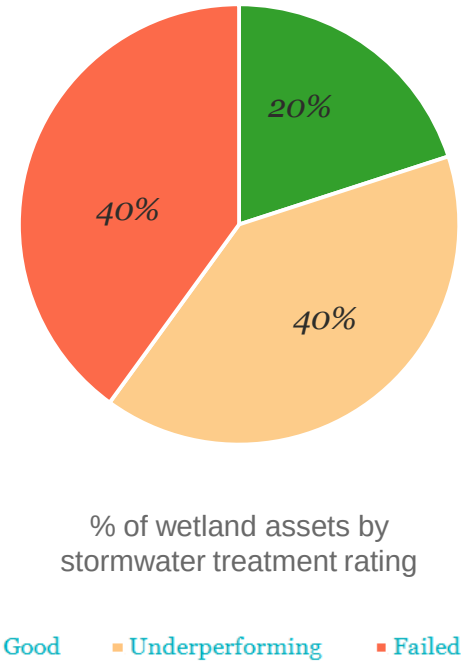
20 % of assets are likely to be providing the stormwater treatment function intended. These assets have good vegetation cover (>80 %) and generally have suitable water depths in emergent zones.

Underperforming assets

40 % of wetlands are likely to be underperforming due to moderate or poor plant density. In a number of assets for which detailed design drawings were available, water depths in designated planted zones were unsuitable (deeper than current recommendation). Assets generally require rectification to improve planting success e.g. reducing water depths.

Failed assets

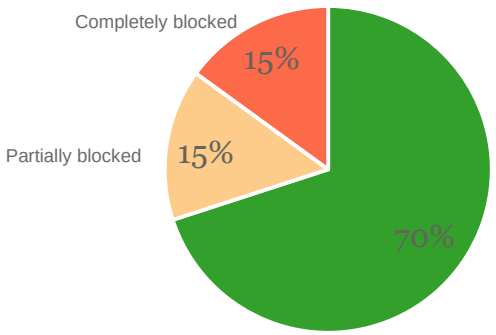
Wetlands in poor condition were due to a combination of factors – partially to fully blocked inlets, poor plant density and full sediment pond.



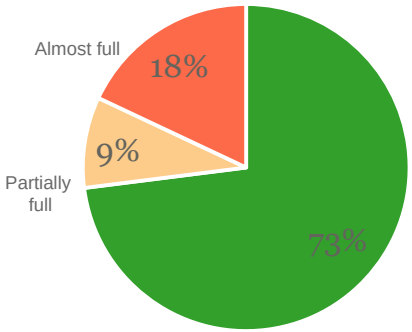
PERFORMANCE INDICATORS

30 % of assets have blocked inlets. 20 % of assets have sediment pond with almost no remaining capacity. 60 % of assets have poor vegetation cover (<40 %).

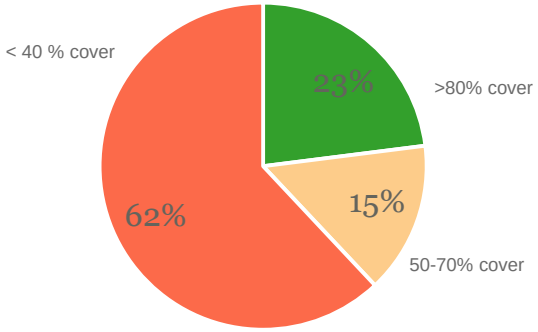
Inlet performance

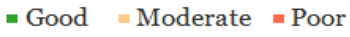


Sediment accumulation in sediment pond



Plant density





Refer to section 2.1 descriptors of each indicator

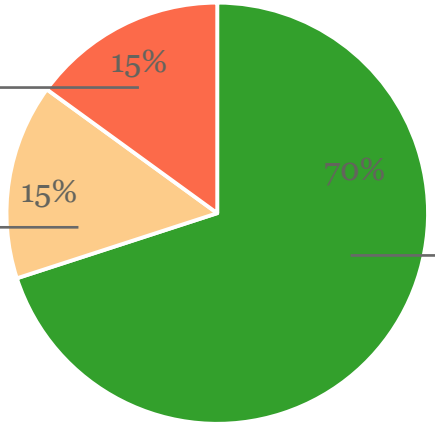
1. INLET PERFORMANCE

Wetland inlets are generally functioning well with no blockages

2 out of the 13 wetlands audited have completely blocked inlets and another 2 wetlands have partially blocked inlets. Maintenance is required to unblock and keep inlets functional.

Asset 86
Completely blocked inlet

Asset 83
Partially blocked inlet



% of assets by inlet performance

Asset 80
Functioning inlet – no blockages

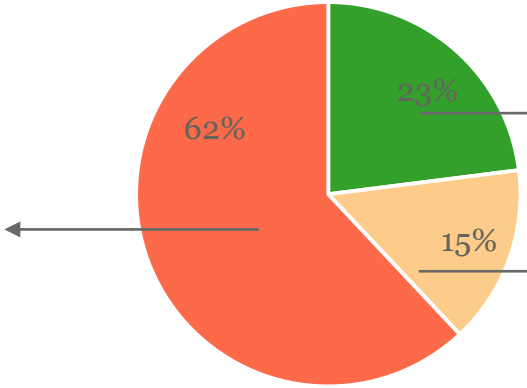
2. PLANT DENSITY

Planting success in wetlands is a key issue

10 out of 13 wetlands audited have moderate vegetation cover (50-70%) or poor cover (< 40%). In a number of assets for which detailed design drawings were available, water depths in designated planted zones were unsuitable (deeper than current recommendation). It is also possible that more attention is required at the plant establishment and maintenance phase (first 2 years) to improve planting success in wetlands.

Asset 79
Plant density < 40 %

Asset 80
Plants failing to establish in newly constructed wetland given no apparent flow management during establishment phase

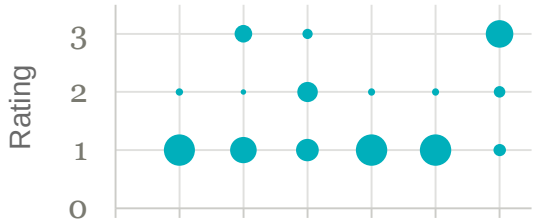


% of assets with good, moderate or poor plant cover

Asset 76
Plants in good health and close to 100 % cover

Asset 74
Planted areas with 50-70% plant cover

4.2 Aesthetic function



AESTHETIC RATING

11 out of 13 wetlands audited are likely to be providing value to the community by contributing to an aesthetically pleasing place (with 4 assets requiring maintenance).

Assets in good condition

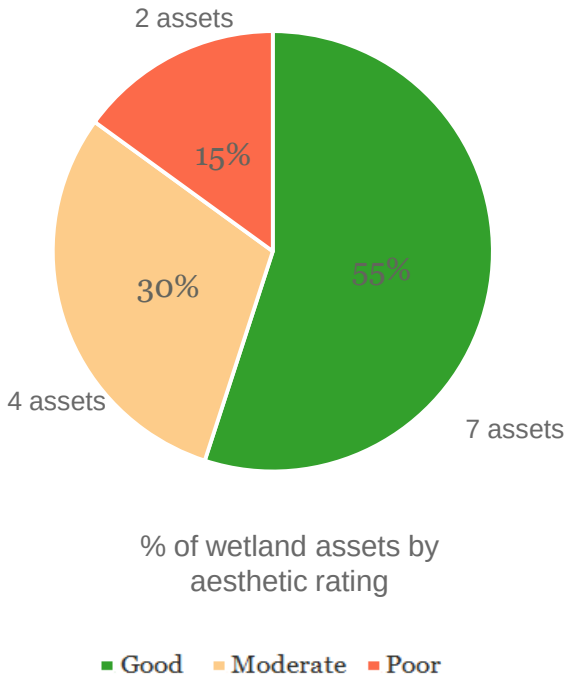
Wetlands audited generally have suitable planting style in the macrophyte zone (i.e. suitable species) in context of the broader landscape but often have poor plant density. Except for two assets, there were no issues with weed cover or rubbish. Most assets have good batter vegetation (>80% cover) with plants in good health with a variety of plant types (e.g. a mix of monocots, shrubs and trees). This help to maintain the asset aesthetics to a good to moderate condition.

Assets in moderate condition

Assets in moderate condition are “in need of maintenance” requiring removal of dead plants, improving flow into wetland to avoid dry areas, cutting back overgrown vegetation, and improving batter vegetation

Assets in poor condition

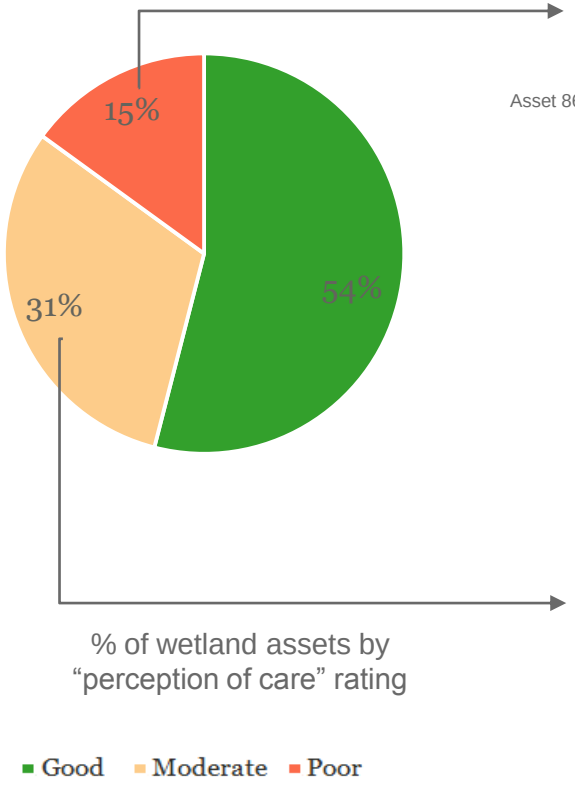
Two wetlands are in poor condition and require significant works to improve aesthetics (including unblocking inlets to improve flow into otherwise dry wetland, removing weeds in macrophyte zone and along batters, replanting macrophyte zone and batters, and removing excessive algae and rubbish)



% of wetland assets by aesthetic rating

PERFORMANCE INDICATOR – PERCEPTION OF CARE

Assets generally have a good perception of being 'cared' for. Condition of batter vegetation is a good cue of care.



Poor perception of care associated with a combination poor vegetation cover (both macrophyte zone and batters), weed cover and rubbish.

Asset 81

Asset 86

Moderate perception of care associated with significant presence of dead vegetation, significant section of batters and landscaped area requiring vegetation.

Asset 82

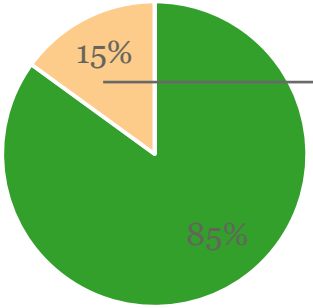
Asset 75

Asset 80

PERFORMANCE INDICATORS (CONT.)

Batter vegetation is generally in good condition (good cover and health) with variety of species and plant types. Consequently, the following indicators have been rated good to moderate.

Suitability of softscape



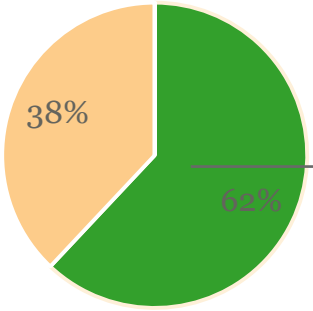
Suitable but in need of maintenance


Asset 84 (Overgrown veg)


Asset 84 (Plant die off)


Asset 82 (Plant die-off)

Plant diversity



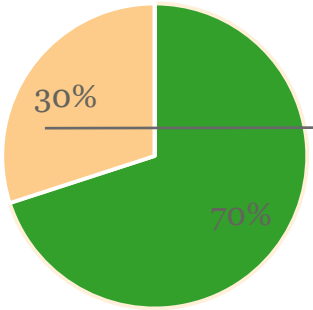
Good mix of plant types along batters and macrophyte zone


Asset 79


Asset 84


Asset 76

Greenness



Plant stress and die-off in wetland


Asset 82


Asset 75


Asset 81 (dry wetland – blocked inlet)

4. Discussion + recommendations

RECAP OF AUDIT OBJECTIVES AND KEY QUESTIONS

The objectives of the audit were to evaluate condition of WSUD assets to determine:

1. The extent to which they are delivering their intended functions

2. The type of problems that exist

3. The causes underlying the problems

By addressing these objectives, the audit aimed to answer the following six questions:

1. Are assets providing the intended stormwater treatment function? What is the extent of maintenance and rectification required to bring asset back to the desired level of performance?

2. Are assets valued by the community by contributing to an aesthetically attractive place?

3. What are the underlying causes for asset underperformance or failure? Are they associated to the design, construction, establishment or maintenance phase of the asset lifespan?

4. How does asset age affect stormwater treatment function?

5. Has there been an improvement in design and construction over time?

6. What improvements are required to specifications and future designs?

ARE ASSETS PROVIDING THE INTENDED STORMWATER QUALITY IMPROVEMENT FUNCTION?

50 % of bioretention systems and tree pits are underperforming and require maintenance to achieve the level of stormwater treatment intended. Failed assets require rectification.

Condition	Proportion of assets	Key issues	Maintenance requirement	Rectification requirement
Good	25 %		• Scrape fine sediment from filter media surface • Infill planting	
Under performing	50 %	• Compromised hydraulic performance • Moderate plant cover (50-70% cover)	• Unblock inlets (higher maintenance frequency for inlets prone to blockages) • Scrape off fine sediment from filter media surface • Infill planting	• 8 assets also require minor rectification to surface levels to allow water to distribute evenly across the surface • 9 assets require EDD to be reinstated to design specifications
Failed	25 %	• Poor hydraulic performance • Moderate to poor plant cover (< 40 % cover)	• Unblock inlets (higher maintenance frequency for inlets prone to blockages) • Scrape off fine sediment from filter media surface	• Rectify inlet • Rectify finished surface levels • Rectify inlet/outlet levels • Replanting as part of rectification works or because current plant cover is poor

Refer to Appendix B for individual asset condition, maintenance and rectification requirements

WHAT ARE THE UNDERLYING CAUSES FOR ASSET UNDERPERFORMANCE OR FAILURE?

Bioretention and tree pits:

Whilst plant cover was a key issue observed in bioretention systems, hydraulic issues were mostly responsible for asset to underperform or fail. Hydraulic issues were related to inlet design faults, blocked inlets (inadequate maintenance), compromised EDD and/or incorrect finished levels (attributed to construction not meeting design intent).

Wetlands:

Plant density in wetlands was the key issue for assets to underperform or fail. This was attributed to unsuitable water depths (design issue). For instance, in a number of assets for which detailed design drawings were available, design water depths in planted zones were unsuitable (e.g. deeper than current recommendations). More attention is also required at the plant establishment phase (first two years) to improve planting success such as water level management, irrigation, plant netting etc.

ARE ASSETS VALUED BY THE COMMUNITY?

About half of the assets are contributing to an aesthetically attractive place, with 30 % of assets requiring minor maintenance to improve aesthetics and 20 % requiring more major works.

About half of the assets audited (bioretention systems, tree pits and wetlands included) are contributing to an aesthetically attractive place. The rest of the assets require minor maintenance or major works (e.g. replanting) to improve aesthetics.

Litter, rubbish and coarse sediment capture in bioretention systems and tree pits were the key issues that impacted on aesthetics. Over-grown plants and signs of plant stress (e.g. brown foliage and plants dying back) also give the perception of “inadequate care” particularly when adjacent landscape is in good condition. Design should consider species selection to achieve aesthetic outcomes. Plants should be included along batters and around bioretention systems – this can help to maintain aesthetics even when filter media plants are stressed. Design should also avoid excessive use of gravel mulch.

Tree pits commonly have grated lid which keep sediment and litter accumulation out of sight. Trees were generally found to be in good health and have good size canopies, and therefore aesthetically attractive and contributing to other functions such as shading. Tree pits were found to suit constrained spaces and dense urban landscapes.

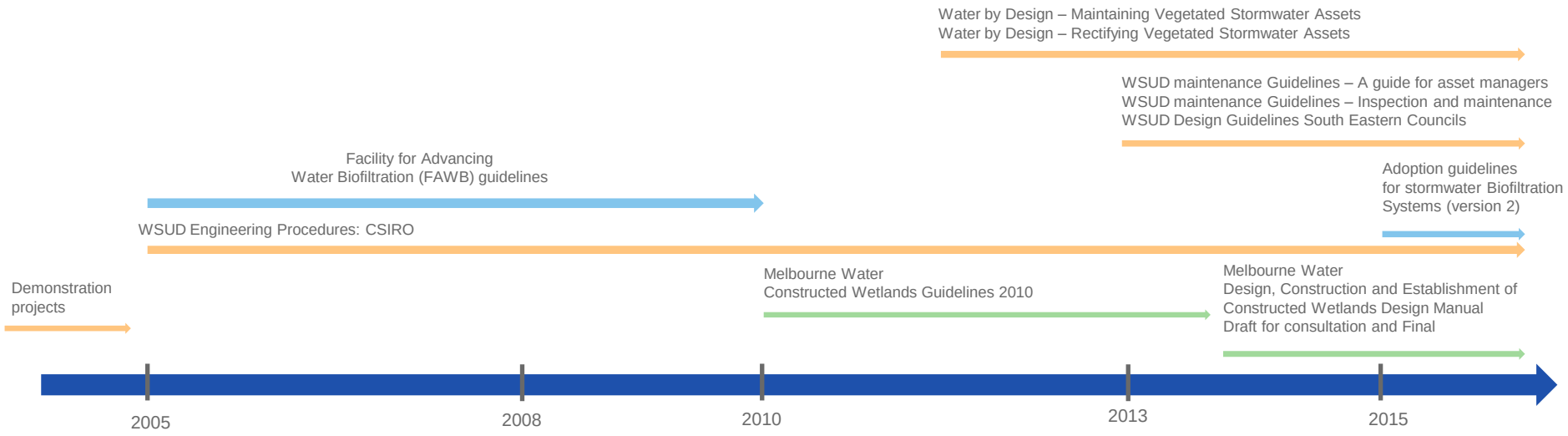
Wetland batter vegetation is generally in good condition (good cover and health) with variety of species and plant types. This contribute positively to the site aesthetics even when plants in the wetland are stressed, overgrown or have poor densities. Litter and rubbish affected aesthetics in only two out of thirteen wetlands inspected.

WSUD OVER TIME

This audit has shown that asset design and construction has improved over time. This reflects that the industry is maturing with comprehensive guidelines and specifications now available.

Asset design and construction has improved over time. Bioretention systems and tree pits constructed in the last 5 years are well designed and have no major construction issues. All wetlands constructed in the last 4 years have good plant cover with planted zones likely to have been designed with suitable water depths.

A maturing industry, supported by improving guidelines and specifications, means good design and construction practices can now be expected. Proper supervision is required at the construction phase to ensure well-constructed assets, and at the establishment phase to ensure planting success. Assets that are well designed and constructed should perform as intended but require ongoing maintenance to prevent asset underperformance or failure.



RECOMMENDATIONS – BIORETENTION + TREE PIT

Based on the findings from this audit, the following recommendations are made:

Design

- Avoid inlet design that are prone to blockages. Inlets should include a drop down, sized appropriately and the inlet zone area should be kept free of vegetation to ensure no obstruction to flows entering the asset.
- If gravel mulch is preferred, ensure a thin layer of 50 mm is used.
- Ensure adequate planting density to improve planting success. Promote greater diversity of plants to improve aesthetics
- Where suitable, consider including trees in bioretention systems (a minimum filter media depth of 700 mm is recommended).

Construction

- Use construction hold points, particularly to ensure finished surface levels, and inlet/outlet levels are as per design.

Establishment

- Give particular attention at the plant establishment phase to improve planting success. This may include irrigation and management of flows into the asset during plant establishment.

RECOMMENDATIONS – BIORETENTION + TREE PIT (CONT.)

Maintenance

- Ongoing maintenance is required, particularly to ensure inlets remain functional (no blockages), filter media remains permeable and vegetation in good health and density. Maintenance activities should ensure water distribution across the surface and EDD are not affected (e.g. from mulching and filter media topping). Consider use of markers to act as cues for maintenance crew.
- Fine sediment accumulated on the filter media surface should be scraped off every 3-4 years and more frequently for systems in catchments with high sediment loads. It is good practice to rake the surface of the filter media once a year to break up any built-up of sediment. Good plant density will also help to maintain permeability of the filter media.

RECOMMENDATIONS – WETLAND

Based on the findings from this audit, the following recommendations are made:

Design

- Ensure water depths for designated planting zones are appropriate. Emergent zones should not be deeper than 350 mm.

Construction

- Use construction hold points, particularly to ensure finished surface levels (and water depths) are as per design.

Establishment

- Give particular attention at the plant establishment phase to improve planting success. This should include management of flows into the asset, plant netting, and irrigation.

Maintenance

- Ongoing maintenance is required, particularly to ensure inlets and outlets remain functional (no blockages) and plant health and cover remain in good condition.

OVERALL RECOMMENDATIONS

Capacity building

- Support capacity building in Councils to undertake WSUD asset management, WSUD asset audits and inspections, and ongoing maintenance.

Future assets

- Fund assets/projects that are likely to receive adequate ongoing maintenance
- Request design drawings, design reports, MUSIC models and survey data at the completion of projects

Audit

- Undertake audit of constructed assets every two years to ensure assets are being maintained (and rectified) to the service level required

Future projects

- Consider a project to collect qualitative data on WSUD asset performance from asset owners and managers. This will provide richer data beyond what an audit type exercise can provide.
- Consider funding rectification of assets identified in this audit. Rectifying non-functioning assets can often have a better cost rate (e.g. $/kg of pollutant removed) than constructing new assets.

Acknowledgements

Melbourne Water would like to acknowledge the support provided by all Councils involved as part of the audit.

Appendix A

WSUD Asset Inspection Checklist

Bioretention inspection checklist - Condition assessment

Task Item	Performance target	Condition Rating Good	Condition Rating Moderate	Condition Rating Poor
		(1 point)	(2 points)	(3 points)
		No maintenance required	*Planned maintenance required*	*Corrective maintenance required*
Surrounds				
Damage/removal of structures	No damage, erosion or issues / removal of structures	• Stable structures • No vandalism impacting amenity	• Minor damage • Does not pose risk to structural integrity or asset function	• Major damage • Poses risk to structural integrity, public safety or asset function
Rubbish	No litter present	• No litter present	• Some litter present • Diminished aesthetics and /or causing some visible blockage	• Large amount of litter present • Heavily impacting aesthetics and/or blocking flows
Inlet				
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)	• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)
Blockage	No blockage	• No blockage	• Partial blockage of inlet or outlet structure or causing some redirection of flows through the system	• Blockages impacting flows entering or leaving the asset
Damage/removal of structures	No damage, erosion or issues / removal of structures	• Stable structures • No vandalism impacting amenity	• Minor damage • Does not pose risk to structural integrity or asset function	• Major damage, poses risk to structural integrity, public safety or asset function
Batters				
Sediment accumulation	No accumulated sediment impeding flows or vegetation growth	• No accumulated sediment	• Some accumulated sediment (covering <40% of surface) • Causing some redirection of flows through the system	• Accumulated sediment covering more than 40% of the surface • Impeding flows • Smothering vegetation
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)	• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)
Vehicle/pedestrian damage	No compaction, plant loss, vandalism impacting system function	• No compaction, plant loss, vandalism impacting system function	• Minor compaction, plant loss • Does not pose risk to structural integrity or asset function	• Significant compaction, plant loss • Poses risk to structural integrity, public safety or asset function
Surface levels	Even surface with no depressions or mounds	• Even surface with no depressions or mounds	• Some small depressions or mounds present • Limited impact on flows through the asset	• Level of surface is impacting flows through the asset (e.g. short circuiting flows, blocking flows and / or reduced extented detention depth) • Isolated pools created in the surface
Rubbish	No litter present	• No litter present	• Some litter present • Diminished aesthetics and /or causing some visible blockage	• Large amount of litter present • Heavily impacting aesthetics and/or blocking flows
Leaf litter	No accumulated leaf litter causing blockages or impeding flows or vegetation growth	• No leaf litter present	• Some wet and decaying leaf matter present (covering <40% of surface) • Aesthetic issue • Some obstruction of flow paths	• Large amount wet and decaying leaf matter present (covering >40% of the surface) • Impacting vegetation growth • Obstructing flow paths and blocking inlets or outlets
Plant health / disease	Good vegetation health	• Healthy vegetation	• Vegetation is stressed • Poor health (signs of disease, pests) in less than 20% of plants	• Vegetation is dying back • Poor health (signs of disease, pests) in more than 20% of plants
Plant density	Good vegetation densities covering >80% of the planted surfaces	• Good vegetation cover in planted areas (>80% cover / >6 plants per m2)	• Moderate vegetation cover in planted areas (50-70% cover)	• Poor vegetation cover in planted areas (<40% cover)
Weeds / nuisance plants	Limited weed cover with no delcared weed species	• Limited weed cover (<10%) and no declared weed species	• Low/Moderate weed cover (20-30%) and no declared weed species	• High weed cover (>50%) and/or declared weed species present
Nuisance fauna	No nuisance fauna	• No nuisance fauna	• Some nuisance fauna but limited impact on aesthetics, water quality and/or vegetation growth	• Significant nuisance fauna issues • Heavily impacting aesthetics, vegetation growth and/or water quality
Permeable vegetated base				
Sediment accumulation	• No accumulated sediment	• Some accumulated sediment (covering <40% of surface) • Causing some redirection of flows through the system	• Accumulated sediment covering more than 40% of the surface • Impeding flows • Smothering vegetation	• Some accumulated sediment (covering <40% of surface) • Causing some redirection of flows through the system
Erosion	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)	• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)	• Partial blockage of inlet or outlet structure or causing some redirection of flows through the system
Permeability - media/permeable surface	Infiltration / hydraulic capacity of the system is preserved	• Surface ponding (100 - 300mm) for bioretention systems is drawn down over 1 - 3 hrs after inflow to the system has stopped following rainfall. No surface ponding for permeable paving.	• Surface ponding observed for longer than normal (more than 3 hours), and other indicators of potential impacts on media permeability (silt on surface,)	• Surface ponding (100 - 300mm) remains more than 12 hrs after inflow to the system has stopped following rainfall.
Vehicle/pedestrian damage	No compaction, plant loss, vandalism impacting system function	• No compaction, plant loss, vandalism impacting system function	• Minor compaction, plant loss • Does not pose risk to structural integrity or asset function	• Significant compaction, plant loss • Poses risk to structural integrity, public safety or asset function
Surface levels	Even surface with no depressions or mounds	• Even surface with no depressions or mounds	• Some small depressions or mounds present • Limited impact on flows through the asset	• Level of surface is impacting flows through the asset (e.g. short circuiting flows, blocking flows and / or reduced extented detention depth) • Isolated pools created in the surface
Rubbish	No litter present	• No litter present	• Some litter present • Diminished aesthetics and /or causing some visible blockage	• Large amount of litter present • Heavily impacting aesthetics and/or blocking flows

Task Item	Performance target	Condition Rating Good	Condition Rating Moderate	Condition Rating Poor
		(1 point)	**(2 points)**	**(3 points)**
		No maintenance required	*Planned maintenance required*	*Corrective maintenance required*
Leaf litter	No accumulated leaf litter causing blockages or impeding flows or vegetation growth	• No leaf litter present	• Some wet and decaying leaf matter present (covering <40% of surface) • Aesthetic issue • Some obstruction of flow paths	• Large amount wet and decaying leaf matter present (covering >40% of the surface) • Impacting vegetation growth • Obstructing flow paths and blocking inlets or outlets
Plant health / disease	Good vegetation health	• Healthy vegetation	• Vegetation is stressed • Poor health (signs of disease, pests) in less than 20% of plants	• Vegetation is dying back • Poor health (signs of disease, pests) in more than 20% of plants
Plant density	Good vegetation densities covering >80% of the planted surfaces	• Good vegetation cover in planted areas (>80% cover / >6 plants per m2)	• Moderate vegetation cover in planted areas (50-70% cover)	• Poor vegetation cover in planted areas (<40% cover)
Weeds / nuisance plants	Limited weed cover with no delcared weed species	• Limited weed cover (<10%) and no declared weed species	• Low/Moderate weed cover (20-30%) and no declared weed species	• High weed cover (>50%) and/or declared weed species present
Nuisance fauna	No nuisance fauna	• No nuisance fauna	• Some nuisance fauna but limited impact on aesthetics, water quality and/or vegetation growth	• Significant nuisance fauna issues • Heavily impacting aesthetics, vegetation growth and/or water quality
Outlet and underdrainage				
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)	• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)
Blockage	No blockage	• No blockage	• Partial blockage of inlet or outlet structure or causing some redirection of flows through the system	• Blockages impacting flows entering or leaving the asset
Damage/removal of structures	No damage, erosion or issues / removal of structures	• Stable structures • No vandalism impacting amenity	• Minor damage • Does not pose risk to structural integrity or asset function	• Major erosion • Poses risk to structural integrity, public safety or asset function
Notes				
Notes				

Bioretention inspection checklist - Condition assessment

Date	1/05/2016
Weather	Clear
Date of last rainfall	1/05/2016
WSUD Type	Bioretention
Inspected by	**Dale**
Site address	**Example 1 street**
Site ID	4
Asset name	**Example 1 street raingarden**
Asset ID	10401

Task Item	Score (1, 2 or 3)	Condition summary
Surrounds		
Damage/removal of structures		
Rubbish		
Inlet		
Erosion		
Blockage		
Damage/removal of structures		
Batters		
Sediment accumulation		
Erosion		
Vehicle/pedestrian damage		
Surface levels		
Rubbish		
Leaf litter		
Plant health / disease		
Plant density		
Weeds / nuisance plants		
Nuisance fauna		
Permeable vegetated base		
Sediment accumulation		
Erosion		
Permeability - media/permeable surface		
Vehicle/pedestrian damage		
Surface levels		
Rubbish		

Task Item	Score (1, 2 or 3)	Condition summary
Leaf litter		
Plant health / disease		
Plant density		
Weeds / nuisance plants		
Nuisance fauna		
Outlet and underdrainage		
Erosion		
Blockage		
Damage/removal of structures		
Notes		
Notes		

Tree pit inspection checklist - Condition assessment

Task Item	Performance target	Condition Rating Good	Condition Rating Moderate
		(1 point)	**(2 points)**
		No maintenance required	*Planned maintenance required*
Surrounds			
Damage/removal of structures	No damage, erosion or issues / removal of structures	• Stable structures • No vandalism impacting amenity	• Minor damage • Does not pose risk to structural integrity or asset function
Rubbish	No litter present	• No litter present	• Some litter present • Diminished aesthetics and /or causing some visible blockage
Inlet			
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)
Blockage	No blockage	• No blockage	• Partial blockage of inlet or outlet structure or causing some redirection of flows through the system
Damage/removal of structures	No damage, erosion or issues / removal of structures	• Stable structures • No vandalism impacting amenity	• Minor damage • Does not pose risk to structural integrity or asset function
Permeable vegetated base			
Sediment accumulation	• No accumulated sediment	• Some accumulated sediment (covering <40% of surface) • Causing some redirection of flows through the system	• Accumulated sediment covering more than 40% of the surface • Impeding flows • Smothering vegetation
Erosion	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)	• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)
Permeability - media/permeable surface	Infiltration / hydraulic capacity of the system is preserved	• Surface ponding (100 - 300mm) for bioretention systems is drawn down over 1 - 3 hrs after inflow to the system has stopped following rainfall. No surface ponding for permeable paving.	• Surface ponding observed for longer than normal (more than 3 hours), and other indicators of potential impacts on media permeability (silt on surface,)
Vehicle/pedestrian damage	No compaction, plant loss, vandalism impacting system function	• No compaction, plant loss, vandalism impacting system function	• Minor compaction, plant loss • Does not pose risk to structural integrity or asset function
Surface levels	Even surface with no depressions or mounds	• Even surface with no depressions or mounds	• Some small depressions or mounds present • Limited impact on flows through the asset
Rubbish	No litter present	• No litter present	• Some litter present • Diminished aesthetics and /or causing some visible blockage
Leaf litter	No accumulated leaf litter causing blockages or impeding flows or vegetation growth	• No leaf litter present	• Some wet and decaying leaf matter present (covering <40% of surface) • Aesthetic issue • Some obstruction of flow paths
Plant health / disease	Good vegetation health	• Healthy vegetation	• Vegetation is stressed • Poor health (signs of disease, pests) in less than 20% of plants
Plant density	Good vegetation densities covering >80% of the planted surfaces	• Good vegetation cover in planted areas (>80% cover / >6 plants per m2)	• Moderate vegetation cover in planted areas (50-70% cover)
Weeds / nuisance plants	Limited weed cover with no delcared weed species	• Limited weed cover (<10%) and no declared weed species	• Low/Moderate weed cover (20-30%) and no declared weed species
Nuisance fauna	No nuisance fauna	• No nuisance fauna	• Some nuisance fauna but limited impact on aesthetics, water quality and/or vegetation growth
Outlet and underdrainage			
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)
Blockage	No blockage	• No blockage	• Partial blockage of inlet or outlet structure or causing some redirection of flows through the system
Damage/removal of structures	No damage, erosion or issues / removal of structures	• Stable structures • No vandalism impacting amenity	• Minor damage • Does not pose risk to structural integrity or asset function
	Notes		
Notes			

Tree pit inspection checklist - Condition assessment

Date	1/05/2016
Weather	Clear
Date of last rainfall	1/05/2016
WSUD Type	Tree pit
Inspected by	**Dale**
Site address	**Example 1 street**
Site ID	4
Asset name	**Example 1 street swale**
Asset ID	10401

Condition Rating Poor	Task Item	Condition summary
(3 points)		
Corrective maintenance required		
	Surrounds	
• Major damage • Poses risk to structural integrity, public safety or asset function	**Damage/removal of structures**	
• Large amount of litter present • Heavily impacting aesthetics and/or blocking flows	**Rubbish**	
	Inlet	
• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)	**Erosion**	
• Blockages impacting flows entering or leaving the asset	**Blockage**	
• Major damage, poses risk to structural integrity, public safety or asset function	**Damage/removal of structures**	
	Permeable vegetated base	
• Some accumulated sediment (covering <40% of surface) • Causing some redirection of flows through the system	**Sediment accumulation**	
• Partial blockage of inlet or outlet structure or causing some redirection of flows through the system	**Erosion**	
• Surface ponding (100 - 300mm) remains more than 12 hrs after inflow to the system has stopped following rainfall.	**Permeability - media/permeable surface**	
• Significant compaction, plant loss • Poses risk to structural integrity, public safety or asset function	**Vehicle/pedestrian damage**	
• Level of surface is impacting flows through the asset (e.g. short circuiting flows, blocking flows and / or reduced extented detention depth) • Isolated pools created in the surface	**Surface levels**	
• Large amount of litter present • Heavily impacting aesthetics and/or blocking flows	**Rubbish**	
• Large amount wet and decaying leaf matter present (covering >40% of the surface) • Impacting vegetation growth • Obstructing flow paths and blocking inlets or outlets	**Leaf litter**	
• Vegetation is dying back • Poor health (signs of disease, pests) in more than 20% of plants	**Plant health / disease**	
• Poor vegetation cover in planted areas (<40% cover)	**Plant density**	
• High weed cover (>50%) and/or declared weed species present	**Weeds / nuisance plants**	
• Significant nuisance fauna issues • Heavily impacting aesthetics, vegetation growth and/or water quality	**Nuisance fauna**	
	Outlet and underdrainage	
• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)	**Erosion**	
• Blockages impacting flows entering or leaving the asset	**Blockage**	
• Major erosion • Poses risk to structural integrity, public safety or asset function	**Damage/removal of structures**	
	Notes	
	Notes	

Wetland inspection checklist - Condition assessment

Task Item	Performance target	Condition Rating Good	Condition Rating Moderate	Condition Rating Poor
		(1 point)	**(2 points)**	**(3 points)**
		No maintenance required	*Planned maintenance required*	*Corrective maintenance required*
Surrounds				
Damage/removal of structures	No damage, erosion or issues / removal of structures	• Stable structures • No vandalism impacting amenity	• Minor damage • Does not pose risk to structural integrity or asset function	• Major damage • Poses risk to structural integrity, public safety or asset function
Rubbish	No litter present	• No litter present	• Some litter present • Diminished aesthetics and /or causing some visible blockage	• Large amount of litter present • Heavily impacting aesthetics and/or blocking flows
Inlet				
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)	• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)
Blockage	No blockage	• No blockage	• Partial blockage of inlet or outlet structure or causing some redirection of flows through the system	• Blockages impacting flows entering or leaving the asset
Damage/removal of structures	No damage, erosion or issues / removal of structures	• Stable structures • No vandalism impacting amenity	• Minor damage • Does not pose risk to structural integrity or asset function	• Major damage, poses risk to structural integrity, public safety or asset function
Batters				
Sediment accumulation	No accumulated sediment impeding flows or vegetation growth	• No accumulated sediment	• Some accumulated sediment (covering <40% of surface) • Causing some redirection of flows through the system	• Accumulated sediment covering more than 40% of the surface • Impeding flows • Smothering vegetation
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)	• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)
Vehicle/pedestrian damage	No compaction, plant loss, vandalism impacting system function	• No compaction, plant loss, vandalism impacting system function	• Minor compaction, plant loss • Does not pose risk to structural integrity or asset function	• Significant compaction, plant loss • Poses risk to structural integrity, public safety or asset function
Surface levels	Even surface with no depressions or mounds	• Even surface with no depressions or mounds	• Some small depressions or mounds present • Limited impact on flows through the asset	• Level of surface is impacting flows through the asset (e.g. short circuiting flows, blocking flows and / or reduced extented detention depth) • Isolated pools created in the surface
Rubbish	No litter present	• No litter present	• Some litter present • Diminished aesthetics and /or causing some visible blockage	• Large amount of litter present • Heavily impacting aesthetics and/or blocking flows
Leaf litter	No accumulated leaf litter causing blockages or impeding flows or vegetation growth	• No leaf litter present	• Some wet and decaying leaf matter present (covering <40% of surface) • Aesthetic issue • Some obstruction of flow paths	• Large amount wet and decaying leaf matter present (covering >40% of the surface) • Impacting vegetation growth • Obstructing flow paths and blocking inlets or outlets
Plant health / disease	Good vegetation health	• Healthy vegetation	• Vegetation is stressed • Poor health (signs of disease, pests) in less than 20% of plants	• Vegetation is dying back • Poor health (signs of disease, pests) in more than 20% of plants
Plant density	Good vegetation densities covering >80% of the planted surfaces	• Good vegetation cover in planted areas (>80% cover / >6 plants per m2)	• Moderate vegetation cover in planted areas (50-70% cover)	• Poor vegetation cover in planted areas (<40% cover)
Weeds / nuisance plants	Limited weed cover with no delcared weed species	• Limited weed cover (<10%) and no declared weed species	• Low/Moderate weed cover (20-30%) and no declared weed species	• High weed cover (>50%) and/or declared weed species present
Nuisance fauna	No nuisance fauna	• No nuisance fauna	• Some nuisance fauna but limited impact on aesthetics, water quality and/or vegetation growth	• Significant nuisance fauna issues • Heavily impacting aesthetics, vegetation growth and/or water quality
Open water zone				
Sediment accumulation	No accumulated sediment impeding flows or vegetation growth	• No accumulated sediment	• Some accumulated sediment (covering <40% of surface) • Causing some redirection of flows through the system	• Accumulated sediment covering more than 40% of the surface • Impeding flows • Smothering vegetation
Water levels	Water level depths and drawdown suitable to support healthy plant growth	• Water level variation as designed (with appropriate drawdown of attenuated flow following rainfall, dry periods are not extensive (<70 days/year)) • Diverse vegetation confirms confidence in appropriate water level variation.	• Some concerns about water level variation but impact on treatment performance is expected to be small.	• Significant concerns about water level variation. • Impact on treatment performance is expected to be significant.
Rubbish	No litter present	• No litter present	• Some litter present • Diminished aesthetics and /or causing some visible blockage	• Large amount of litter present • Heavily impacting aesthetics and/or blocking flows
Weeds / nuisance plants	Limited weed cover with no delcared weed species	• Limited weed cover (<10%) and no declared weed species	• Low/Moderate weed cover (20-30%) and no declared weed species	• High weed cover (>50%) and/or declared weed species present
Floating plants	No nuisance floating plants present	• No nuisance floating plants present	• Low/Moderate cover (20-30%) • Mechanical removal of nuisance floating plants is effective in managing blooms	• Nuisance floating plant blooms are problematic, impacting on wetland performance and too extensive to remove mechanically
Water quality (oil slicks, odour, algae)	No water quality issues (oil slicks, odours, algae)	• No water quality issues (oil slicks, odours, algae)	• Some minor water quality issues visible (oil slicks, odours, algae) but no major impact on aesthetics or water quality	• Significant water quality issues (oil slicks, odours, algae) • Heavily impacting aesthetics and/or water quality
Nuisance fauna	No nuisance fauna	• No nuisance fauna	• Some nuisance fauna but limited impact on aesthetics, water quality and/or vegetation growth	• Significant nuisance fauna issues • Heavily impacting aesthetics, vegetation growth and/or water quality
Mosquitos	No nuisance populations of mosquitoes	• No isolated depressions which can become breeding sites when water levels recede • Deep pools provide refugia for predators • No dead or rafting vegetation	• Potential mosquito habitats observed (e.g. isolated pools, rafting vegetation)	• Nuisance populations of mosquitoes observed and/or reported by local community.
Aquatic macrophyte zone				
Sediment accumulation	No accumulated sediment impeding flows or vegetation growth	• No accumulated sediment	• Some accumulated sediment (covering <40% of surface) • Causing some redirection of flows through the system	• Accumulated sediment covering more than 40% of the surface • Impeding flows • Smothering vegetation
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)	• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)
Vehicle/pedestrian damage	No compaction, plant loss, vandalism impacting system function	• No compaction, plant loss, vandalism impacting system function	• Minor compaction, plant loss • Does not pose risk to structural integrity or asset function	• Significant compaction, plant loss • Poses risk to structural integrity, public safety or asset function
Surface levels	Even surface with no depressions or mounds	• Even surface with no depressions or mounds	• Some small depressions or mounds present • Limited impact on flows through the asset	• Level of surface is impacting flows through the asset (e.g. short circuiting flows, blocking flows and / or reduced extented detention depth) • Isolated pools created in the surface
Rubbish	No litter present	• No litter present	• Some litter present • Diminished aesthetics and /or causing some visible blockage	• Large amount of litter present • Heavily impacting aesthetics and/or blocking flows

Task Item	Performance target	Condition Rating Good	Condition Rating Moderate	Condition Rating Poor
		(1 point)	**(2 points)**	**(3 points)**
		No maintenance required	*Planned maintenance required*	*Corrective maintenance required*
Leaf litter	No accumulated leaf litter causing blockages or impeding flows or vegetation growth	• No leaf litter present	• Some wet and decaying leaf matter present (covering <40% of surface) • Aesthetic issue • Some obstruction of flow paths	• Large amount wet and decaying leaf matter present (covering >40% of the surface) • Impacting vegetation growth • Obstructing flow paths and blocking inlets or outlets
Plant health / disease	Good vegetation health	• Healthy vegetation	• Vegetation is stressed • Poor health (signs of disease, pests) in less than 20% of plants	• Vegetation is dying back • Poor health (signs of disease, pests) in more than 20% of plants
Plant density	Good vegetation densities covering >80% of the planted surfaces	• Good vegetation cover in planted areas (>80% cover / >6 plants per m2)	• Moderate vegetation cover in planted areas (50-70% cover)	• Poor vegetation cover in planted areas (<40% cover)
Weeds / nuisance plants	Limited weed cover with no delcared weed species	• Limited weed cover (<10%) and no declared weed species	• Low/Moderate weed cover (20-30%) and no declared weed species	• High weed cover (>50%) and/or declared weed species present
Floating plants	• No nuisance floating plants present	• No nuisance floating plants present	• Low/Moderate cover (20-30%) • Mechanical removal of nuisance floating plants is effective in managing blooms	• Nuisance floating plant blooms are problematic, impacting on wetland performance and too extensive to remove mechanically
Water quality (oil slicks, odour, algae)	• No water quality issues (oil slicks, odours, algae)	• No water quality issues (oil slicks, odours, algae)	• Some minor water quality issues visible (oil slicks, odours, algae) but no major impact on aesthetics or water quality	• Significant water quality issues (oil slicks, odours, algae) • Heavily impacting aesthetics and/or water quality
Nuisance fauna	No nuisance fauna	• No nuisance fauna	• Some nuisance fauna but limited impact on aesthetics, water quality and/or vegetation growth	• Significant nuisance fauna issues • Heavily impacting aesthetics, vegetation growth and/or water quality
Mosquitos	No nuisance populations of mosquitoes	• No isolated depressions which can become breeding sites when water levels recede • Deep pools provide refugia for predators • No dead or rafting vegetation	• Potential mosquito habitats observed (e.g. isolated pools, rafting vegetation)	• Nuisance populations of mosquitoes observed and/or reported by local community.
Outlet and underdrainage				
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	• No erosion	• Minor erosion • Does not pose risk to structural integrity, public safety or asset function (e.g. limited short circuiting of flows)	• Major erosion • Posing risk to structural integrity, public safety or asset function (e.g. short circuiting of the majority of flows)
Blockage	No blockage	• No blockage	• Partial blockage of inlet or outlet structure or causing some redirection of flows through the system	• Blockages impacting flows entering or leaving the asset
Damage/removal of structures	No damage, erosion or issues / removal of structures	• Stable structures • No vandalism impacting amenity	• Minor damage • Does not pose risk to structural integrity or asset function	• Major erosion • Poses risk to structural integrity, public safety or asset function
Notes				
Notes				

Wetland inspection checklist - Condition assessment

Date	1/05/2016
Weather	Clear
Date of last rainfall	1/05/2016
WSUD Type	Wetland
Inspected by	**Dale**
Site address	**Example 1 street**
Site ID	4
Asset name	**Example 1 street raingarden**
Asset ID	10401

Task Item	Score (1, 2 or 3)	Condition summary
Surrounds		
Damage/removal of structures		
Rubbish		
Inlet		
Erosion		
Blockage		
Damage/removal of structures		
Batters		
Sediment accumulation		
Erosion		
Vehicle/pedestrian damage		
Surface levels		
Rubbish		
Leaf litter		
Plant health / disease		
Plant density		
Weeds / nuisance plants		
Nuisance fauna		
Open water zone		
Sediment accumulation		
Water levels		
Rubbish		
Weeds / nuisance plants		
Floating plants		
Water quality (oil slicks, odour, algae)		
Nuisance fauna		
Mosquitos		
Aquatic macrophyte zone		
Sediment accumulation		
Erosion		
Vehicle/pedestrian damage		
Surface levels		
Rubbish		

Task Item	Score (1, 2 or 3)	Condition summary
Leaf litter		
Plant health / disease		
Plant density		
Weeds / nuisance plants		
Floating plants		
Water quality (oil slicks, odour, algae)		
Nuisance fauna		
Mosquitos		
Outlet and underdrainage		
Erosion		
Blockage		
Damage/removal of structures		

Notes

Notes

Appendix B

Individual Asset Condition