



Guide to the Cost of Maintaining Bioretention Systems

Version 1, February 2015

waterbydesign

 Healthy Waterways Initiative





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This document was authored and produced by Jack Mullaly of Healthy Waterways.

Water by Design

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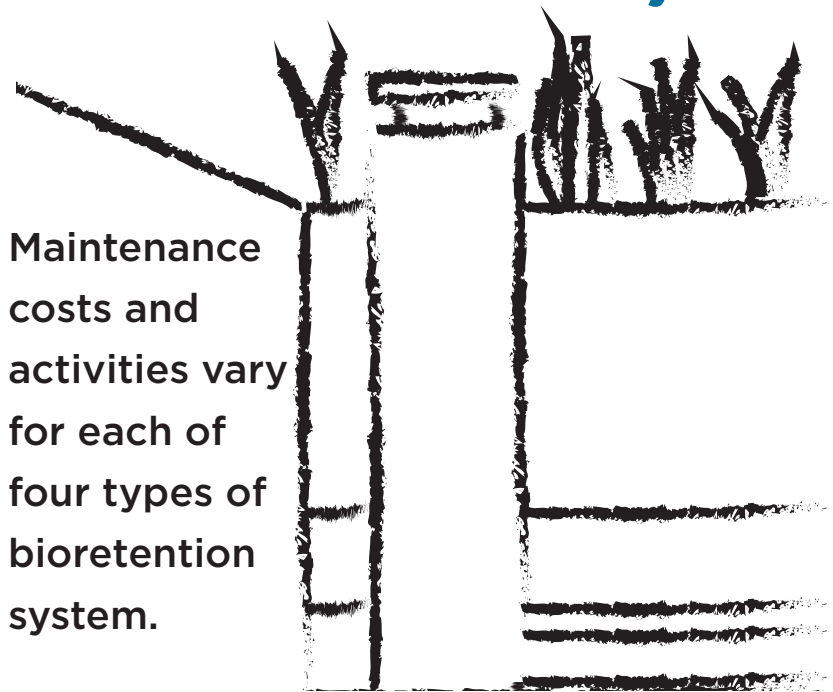


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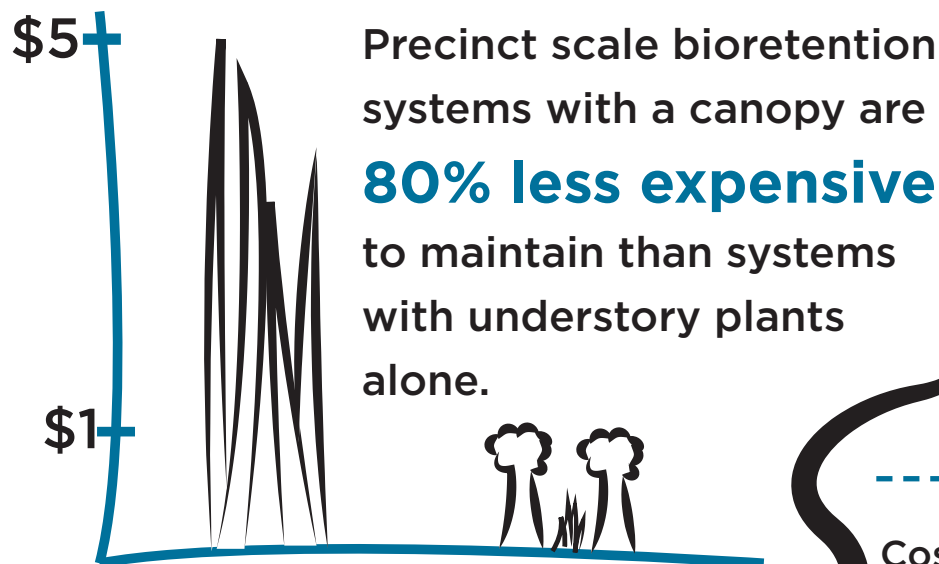
Efficient Maintenance

Costs and activities vary



Maintenance costs and activities vary for each of four types of bioretention system.

Maintaining bioretention systems with understory plants **requires 8 to 12 visits per year.**



Zero snakes or rats were found in bioretention systems while collecting data for this report.

Costs are expressed per square meter of filter media.

They do not include administration. They do include maintenance of the entire asset.

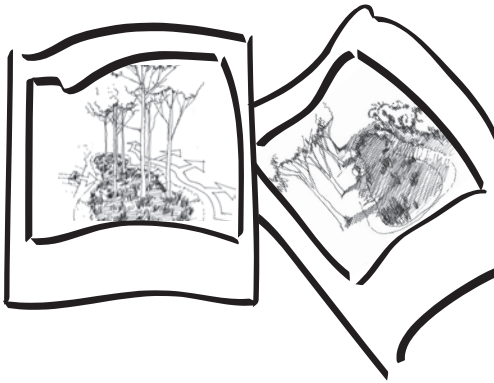
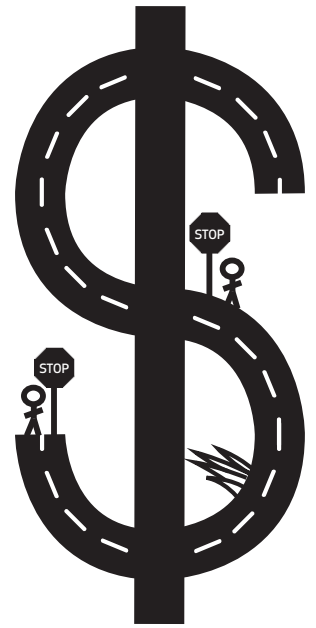


Only **14%** of the datasets included **sediment removal** as a **regular maintenance activity**.

The sediment came from upstream house building sites.



Maintaining isolated streetscape bioretention systems may **cost twice as much** as maintaining groups of systems located in the same street.



626 photographs were **taken** while collecting data for this project.



Bioretention Rectification

(noun)

the act of taking a poorly performing or dysfunctional bioretention system and undertaking remedial works to restore it to a functional state

Bioretention Maintenance (noun)

the act of taking an established, and relatively well functioning bioretention system, and undertaking the necessary actions to ensure that it continues to function relatively well

INTRODUCTION



Photo: Jack Mullaly, Healthy Waterways

INTRODUCTION

1. INTRODUCTION

Bioretention systems are a form of infrastructure used to minimise the impact of stormwater from urban areas upon creeks, rivers and bays. The first bioretention system was installed in Queensland in 2001. They are now being installed in Queensland at a rapid rate in order to treat stormwater and comply with legislated requirements.

Like all forms of infrastructure, bioretention systems require maintenance in order to operate effectively. Despite being a relatively new form of infrastructure, a wealth of information is available on how to maintain bioretention systems. For example, see Healthy Waterways' publications *Maintaining Vegetated Stormwater Assets* and *Rectifying Vegetated Stormwater Assets*.

In spite of the information available, many bioretention systems do not receive the maintenance that they require in order to operate effectively. In part this is due to a lack of publicly available information to date on the cost of maintaining bioretention systems. This makes it difficult for organisations wishing to establish a maintenance regime to accurately cost the necessary works.

Definition of Maintenance

For the purpose of this document, maintenance is defined as *"taking an established, and relatively well functioning bioretention system, and undertaking the necessary actions to ensure that it continues to function relatively well"*. For more information see Section 3.

This document brings together knowledge from across Queensland on the cost of maintaining bioretention systems, and compiles it for the first time in a publicly accessible format.

This document would not be possible without the contribution of maintenance data from organisations across Queensland and Australia. If you have data on the cost of maintaining bioretention systems that you would like to contribute to future versions of this document please contact Healthy Waterways at info@waterbydesign.com.au or on 07 3177 9100.

1.1. How to use this document

This document is divided into six sections. Figure 1 outlines the content contained within each section.

Figure 1: Structure and Content of this Document

Section 1 - Introduction	Explains why it is important to understand the cost of maintaining bioretention systems. Describes each of the sections within this document. Outlines other literature that is available that can assist with managing and maintaining bioretention systems.
Section 2 - Types of Bioretention Systems	Describes four types of bioretention system that are useful for understanding maintenance costs. The cost of maintenance varies between, and is relatively constant within each type.
Section 3 - Defining Maintenance	Defines bioretention maintenance. Distinguishes maintenance from related activities such as rectification.
Section 4 - Costs and Activities Involved in Maintaining Bioretention Systems	Explains what is currently known about the cost of maintaining bioretention systems, and what activities are associated with this. Costs, activities and frequencies of maintenance are provided for each type of bioretention system described in Section 2.
Section 5 - Sources of Maintenance Data	Describes each of the sources of bioretention maintenance data that underpin the costs presented in Section 4.

INTRODUCTION

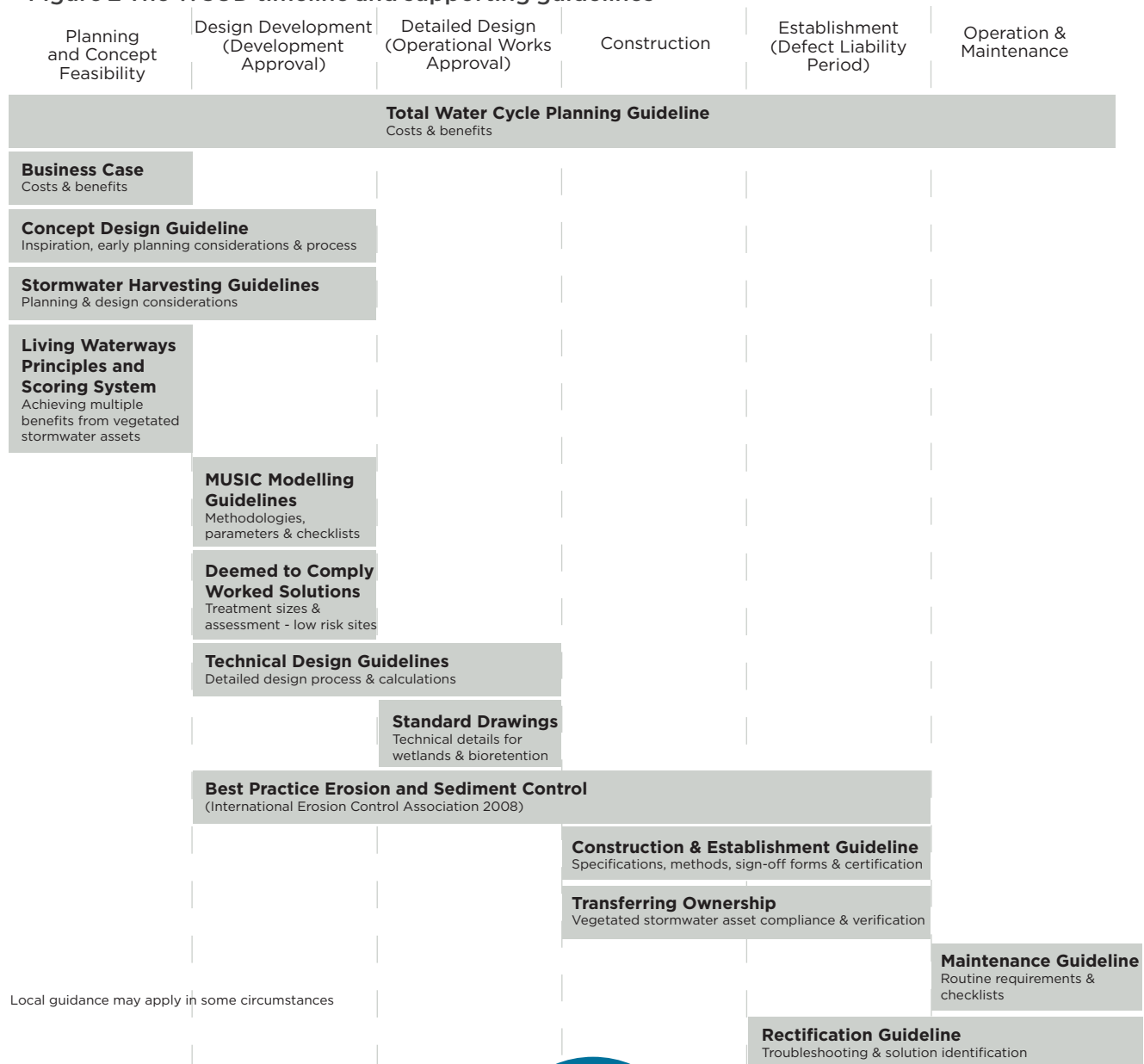
1.2. Existing Bioretention Resources

A comprehensive suite of guidelines has been developed by Healthy Waterways to support with implementing water sensitive urban design in Queensland. Many of these guidelines pertain to bioretention systems (Figure 2).

In addition, a variety of resources have been published by other organisations on what it costs to maintain bioretention systems.

- Review of Street Scale WSUD in Melbourne (Somes and Crosby, 2007)
- Life-Cycle Costs of Water Sensitive Urban Design (WSUD) Treatment Systems: Summary Report (Ecological Engineering, 2007)
- Business Case for Best Practice Stormwater Management (Water by Design)
- Water Sensitive Urban Design Life Cycle Costing Data (Melbourne Water, 2013)

Figure 2 The WSUD timeline and supporting guidelines





TYPES OF BIORETENTION SYSTEMS



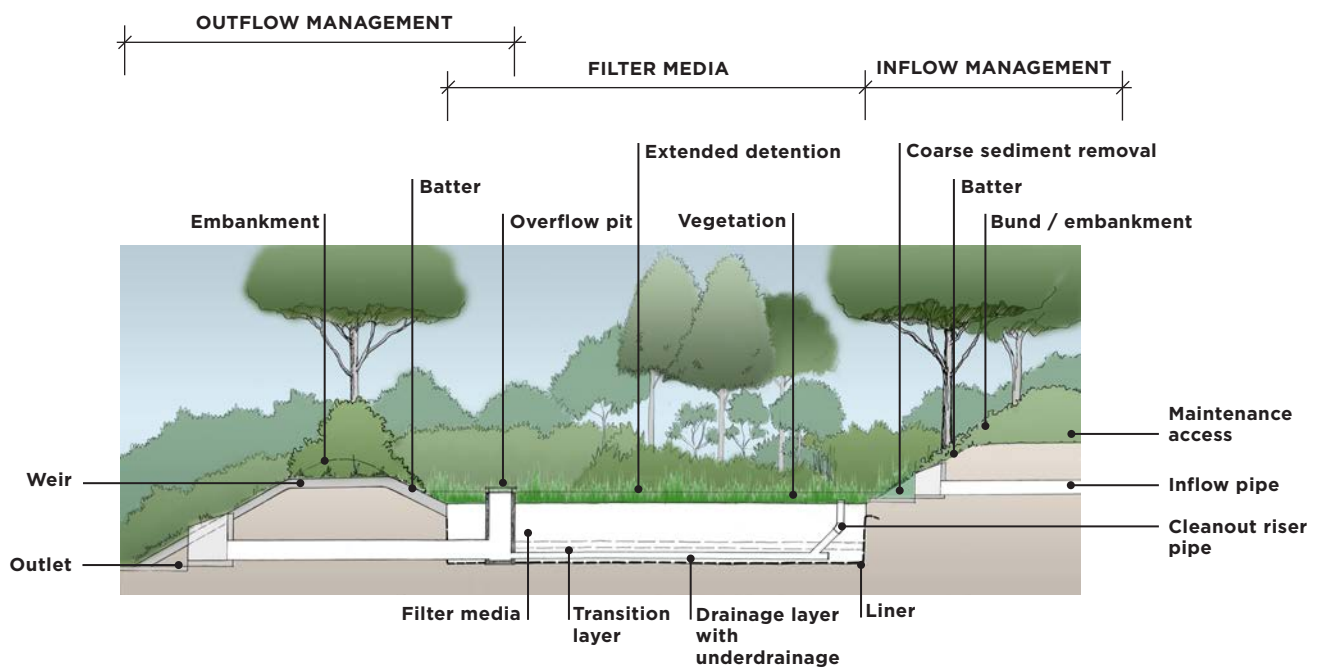
Photo: Jack Mullaly, Healthy Waterways

TYPES OF BIORETENTION SYSTEMS

2. TYPES OF BIORETENTION SYSTEMS

Bioretention systems come in many shapes and sizes, and vary in appearance (Figure 3). These variations affect the cost and activities required to maintain each system. In spite of this variation, several generic types of bioretention system can be used to group bioretention systems with similar maintenance requirements.

Figure 3 Components of a typical bioretention system



TYPES OF BIORETENTION SYSTEMS

2.1. Bioretention Street Trees

Location: Road reserve and carparks

Size: Filter media area <3m²

Vegetation: Primarily trees, but shrubs, grasses, sedges and groundcovers can be used

Other information: Where shrubs, sedges and groundcovers are not used, much of the bioretention street tree footprint may be covered by a solid surface such as a tree grate

Figure 4: A Bioretention Street Tree



Photo: Brad Dalrymple, BMT WBM

Figure 5: A Bioretention Street Tree



Photo: Brad Dalrymple, BMT WBM

Figure 6: Several Bioretention Street Trees

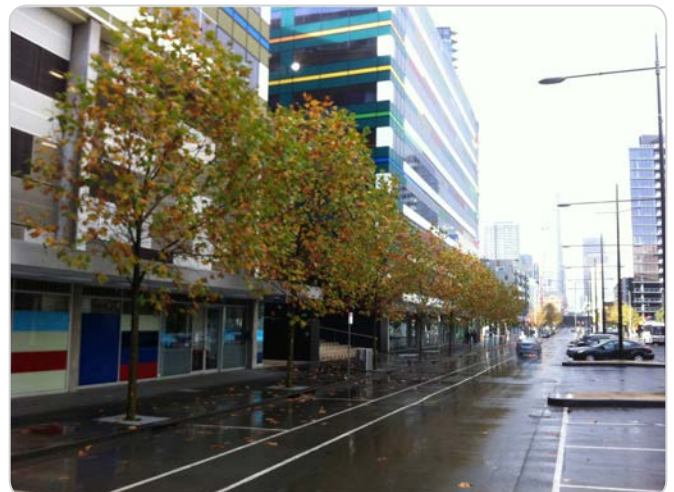


Photo: Brad Dalrymple, BMT WBM

TYPES OF BIORETENTION SYSTEMS

2.2. Streetscape, Car Park and Civic Space Bioretention Systems

Location: Road reserve, carparks, traffic calming build outs or civic spaces

Size: Filter media area typically 5 - 50m²

Vegetation: Typically grasses and sedges, however shrubs and trees are also used

Other information: Stormwater typically enters via surface runoff rather than piped inflows. A sediment forebay may be present.

Figure 7: A Civic Space Bioretention System



Photo: Jack Mullaly

Figure 8: A Streetscape Bioretention System



Photo: Paul Dubowski, BMT WBM

Figure 9: A Streetscape Bioretention System



Photo: Jack Mullaly

Figure 10: A Car Park Bioretention System



Photo: Jack Mullaly

TYPES OF BIORETENTION SYSTEMS

2.3. Precinct Scale Bioretention Systems

Location: Within parkland or drainage reserves, and/ or adjacent to bushland

Size: Filter media area typically 100 – 800m²

Vegetation: Two distinct vegetation styles exist. Systems planted in the first style contain only low growing species such as grasses and sedges. Systems planted in the second style contain both a canopy and an understory

Other information: A sediment forebay may be present.

Figure 11: A Precinct Scale Bioretention System With a Canopy



Photo: Jack Mullaly, Healthy Waterways

Figure 12: A Precinct Scale Bioretention System With Only Understory Plants



Photo: Paul Dubowski, BMT WBM

Figure 13: A Precinct Scale Bioretention System



Photo: Jack Mullaly

Figure 14: A Precinct Scale Bioretention System With Only Understory Plants



Photo: Jack Mullaly

TYPES OF BIORETENTION SYSTEMS

2.4. Large Bioretention Systems

Location: Within parkland or drainage reserves, and/ or adjacent to bushland

Size: Filter media area greater than 800m²

Vegetation: Two distinct vegetation styles exist. Systems planted in the first style contain only low growing species such as grasses and sedges. Systems planted in the second style contain both a canopy and an understory

Other information: Compared to precinct scale bioretention systems, large bioretention systems often contain a sediment basins and/ or flow distribution system to manage the large inflows that they receive. A sediment forebay will not normally be present as a sediment basin is likely to be performing the function of capturing coarse sediment.

Figure 15: The First of Three Cells in a Large Bioretention System



Photo: Jack Mullaly

Figure 16: A Sediment Basin Upstream of a Bioretention System



Photo: Jack Mullaly

Figure 17: A Large Bioretention System



Photo: Jack Mullaly

DEFINING MAINTENANCE



Photo: Jack Mullaly, Healthy Waterways

DEFINING MAINTENANCE

3. DEFINING MAINTENANCE

For the purpose of this document, maintaining a bioretention system is defined as ***“taking an established, and relatively well functioning bioretention system, and undertaking the necessary actions to ensure that it continues to function relatively well.”***

Maintaining a bioretention system is different to rectifying a bioretention system. Rectification involves ***“taking a poorly performing or dysfunctional bioretention system and undertaking remedial works to restore it to a functional state.”***

This document does not address rectifying

dysfunctional bioretention systems. For further information on this topic, see Rectifying Vegetated Stormwater Assets (Water by Design, 2012).

Figures 18 and 19 provide examples of bioretention systems in a suitable condition to undertake maintenance. Note the presence of healthy vegetation, and the absence of weeds, sediment and structural faults.

Figure 20 and 21 provide examples of bioretention systems that are not in a suitable condition to undertake maintenance. Note the immature vegetation, high numbers of weeds and / or structural faults. These systems require rectification.

Figure 18: A System Ready for Maintenance



Photo: Jack Mullaly

Figure 19: A System Ready for Maintenance



Photo: Jack Mullaly, Healthy Waterways

Figure 20: A System With Clogged Filter Media and Aquatic Weeds Requiring Rectification



Photo: Jack Mullaly

Figure 21: A System With a Scour Hole



Photo: Jack Mullaly

COSTS AND ACTIVITIES INVOLVED IN MAINTAINING BIORETENTION SYSTEMS



Photo: Jack Mullaly, Healthy Waterways

COSTS AND ACTIVITIES INVOLVED IN MAINTAINING BIORETENTION SYSTEMS

4. COSTS AND ACTIVITIES INVOLVED IN MAINTAINING BIORETENTION SYSTEMS

Table 1 provides a summary of the costs and activities involved in maintaining a variety of different types of bioretention systems.

The summary presented is drawn from maintenance data collected from a range of bioretention systems (see Section 5), as well as general observations of a wide number of bioretention basins over time.

Sections 4.1 to 4.4 provide further information on the costs and activities involved in maintaining each type of bioretention basin described in Table 1.

4.1. Precinct Scale Bioretention Systems

Ten maintenance datasets were available for precinct scale bioretention systems. Of these, six contained only an understory, while four contained both a canopy and an understory.



From the data available, it appears that precinct scale bioretention systems with only understory plants can be maintained for \$5/m²fm/yr. For this money, the primary maintenance activities are weed and litter control. They are conducted on a four to six week rotation. Weed control is primarily undertaken using herbicides, while litter is removed by hand. Less frequent maintenance activities include fixing localised scour by hand, replanting, as well as removing accumulated sediment. These activities are undertaken on a reactive basis and rarely required.

The basis of this maintenance strategy is that bioretention systems require two criteria to be satisfied in order to function. First, the filter media must drain freely. Plants with vigorous root systems

Maintenance cost rates

The bioretention maintenance costs in this paper are presented in terms of dollars per square meter of filter media per year (\$X/m²fm/yr). This cost includes maintenance of both the filter media area, and the batters.

Consider a precinct scale bioretention system planted with grasses and sedges. Imagine it has a filter media area of 126m² and a total footprint (including both filter media, batters and a sediment forebay) of 350m². To obtain an estimate of the cost to maintain the entire bioretention system, multiply the filter media area by the maintenance cost presented in Table 1 (\$5/m²fm/yr) as shown below.

$$\begin{aligned} \text{Estimated cost} &= \text{filter media area} \times \text{unit rate} \\ &\text{from Table 1} \\ &= 126\text{m}^2 \times \$5/\text{m}^2\text{fm}/\text{yr} \\ &= \$630/\text{yr} \end{aligned}$$

The data used to inform the maintenance costs presented in this paper were collected over a number of years, however all figures presented have been adjusted in accordance with inflation, and are presented in 2014 dollars. Cost include maintenance activities only, and exclude program administration.

have been shown to maintain filter media porosity over time by constantly breaking up the filter media through root growth and die back. Secondly the system needs to contain appropriate plants to facilitate pollutant removal. The maintenance strategy described above focuses on ensuring that the plants originally installed in the bioretention system survive over time in order to maintain both filter media porosity and pollutant removal. Weeds are controlled in order to ensure that they do not outcompete and kill the desirable vegetation. Litter is controlled to ensure that it does not get flushed into downstream waterways, does not block structures such as trash racks and outlet pits, and to ensure that an acceptable level of aesthetics are maintained.

COSTS AND ACTIVITIES INVOLVED IN MAINTAINING BIORETENTION SYSTEMS

The data for precinct scale bioretention systems with both a canopy and an understory tells a different story to that for systems with only an understory. From the data available, precinct scale bioretention systems with both a canopy and an understory can be maintained for <\$1/ m²fm/yr.

The reason that systems with both a canopy and an understory are so much less expensive than those with only an understory, appears to be that the canopy shades out weeds, while leaf drop inhibits weed growth (Figures 22 and 23). This

allows the desirable vegetation to prosper with little competition, and reduces the need for regular weed control. In such systems, the only regular maintenance required is litter removal. Even then, this is only required in high profile systems where the litter is likely to be seen and to generate public complaints.

Sections 5.10 and 5.14 provide examples of precinct scale bioretention systems with canopies that have gone many years without any dedicated maintenance.

Figure 22: Some grass and weeds on the edge of a bioretention system



Photo: Jack Mullyaly

COSTS AND ACTIVITIES INVOLVED IN MAINTAINING BIORETENTION SYSTEMS

Figure 23: Shade and leaf drop suppresses weeds within the middle of the system shown in Figure 22



Photo: Jack Mullaly

Table 1: A Summary of the Costs and Activities Involved in Maintaining a Variety of Different Types of Bioretention Systems.

BIORETENTION SYSTEM TYPE	VEGETATION TYPE	COST ¹	ACTIVITIES	FREQUENCY	SOURCES
Bioretention Street Trees	Trees	At present there are very few bioretention street trees in Queensland. No maintenance data was obtained.			
Streetscape/Car Park Bioretention Systems	Understory only (grasses & sedges)	\$20 to \$30/m ² fm/yr (isolated systems ²)	Weed control Litter removal Replanting	4 - 6 weeks 4 - 6 weeks Irregular - complete if required	Datasets 11 and 12
		\$10 to \$15/m ² fm/yr (grouped systems ²)	Scour control Sediment removal from coarse sediment forebay or filter media	Rare - complete if required Irregular - complete if required	
<p>There are a significant number of streetscape or carpark bioretention systems in Queensland with both a canopy and understory that appear to function well, however no maintenance data was available for these sites.</p>					
Precinct Scale Bioretention Systems	Canopy and understory (grasses, sedges, shrubs and trees)				
	Understory only (grasses and sedges)	\$5/m ² fm/yr	Weed control Litter removal Replanting	4 - 6 weeks 4 - 6 weeks Rare - complete if required	Datasets 1, 2, 5, 6, 8, 9 and 13
			Scour control	Rare - complete if required	
			Sediment removal from coarse sediment forebay or filter media	Rare - complete if required	
	Canopy and understory (grasses, sedges, shrubs and trees)	<\$1/ m ² fm/yr	Weed control Litter removal Replanting Scour control Sediment removal from coarse sediment forebay or filter media	Rare - complete if required Rare - complete if required Rare - complete if required Rare - complete if required Rare - complete if required	Datasets 7, 10 and 14

Table 1: I A Summary of the Costs and Activities Involved in Maintaining a Variety of Different Types of Bioretention Systems. (cont)

BIORETENTION SYSTEM TYPE	VEGETATION TYPE	COST ¹	ACTIVITIES	FREQUENCY	SOURCES
Large Bioretention Systems	Understory only	≥\$5/m ² fm/yr	Weed control	4 – 6 weeks	Datasets 3 and 4
	I.e. Grasses and sedges		Litter removal Replanting Scour control Sediment removal from coarse sediment forebay or filter media Sediment removal from sediment basin	4 – 6 weeks Rare – complete if required Rare – complete if required If sediment pond is present, not applicable, otherwise rare (complete if required) If sediment pond is present, every 5 years, otherwise not applicable	
	Canopy and understory I.e. Grasses, sedges, shrubs and trees	≥\$1/m ² fm/yr	Weed control Litter removal Replanting Scour control Sediment removal from coarse sediment forebay or filter media Sediment removal from sediment basin	4 – 6 weeks 4 – 6 weeks Rare – complete if required Rare – complete if required If sediment pond is present, not applicable, otherwise rare (complete if required) If sediment pond is present, every 5 years, otherwise not applicable	Nil

Definitions

Rare – maintenance activity unlikely to be required in any given year if asset is appropriately designed, constructed and maintained
Irregular – maintenance activity may occur once or more in any given year, but not on a regular basis

Notes

¹all costs are presented as \$X per square meter of filter media per year and in 2014 Australian Dollars

² Streetscape/ car park bioretention system maintenance costs are strongly related to traffic control requirements. Individual systems are likely to need traffic control for maintenance. Systems located in close proximity may be able to share traffic control, dramatically reducing costs.

COSTS AND ACTIVITIES INVOLVED IN MAINTAINING BIORETENTION SYSTEMS

4.2. Streetscape, Car Park and Civic Space Bioretention Systems

Two maintenance datasets were available for streetscape, carpark and civic space bioretention systems (see Sections 5.11 and 5.12). Both datasets included maintenance data on systems with only, or primarily, understory plants. There are many streetscape bioretention systems in Queensland with a canopy (Figure 24), however no maintenance data could be obtained for these.

Figure 24: A Streetscape Bioretention System With a Canopy



Photo: Jack Mullaly, Healthy waterways

From the data available, it appears that maintaining isolated streetscape, carpark and civic space bioretention systems is likely to cost \$20 to \$30/ m²fm/yr. Where multiple systems are located in the same street, costs may be as little as half this number (\$10 to \$15/ m²fm/yr). Activities consist of weed control (using herbicides) and litter control (by hand) on a four to six week rotation. Less frequent activities include fixing localised scour by hand, replanting, as well as removing accumulated sediment. These activities are undertaken on a reactive basis as required.

Compared to precinct scale bioretention systems, the data shows streetscape, car park and civic space systems to be significantly more costly to maintain. It is difficult to know for sure why this is the case, however possible causes include:

- **Travel and setup time** - Streetscape, car park and civic space bioretention systems are typically much smaller than precinct scale bioretention systems. Therefore servicing the same total area of bioretention system will require more time to visit a large number of systems, plus additional time to set up at each site.
- **Traffic control** - Streetscape, car park and civic space bioretention system may require traffic control ensure the safety of maintenance crews.
- **Ratio of perimeter to surface area** - As bioretention systems become smaller, there perimeter becomes larger relative to their total surface area or filter media area. The result is that per square meter, smaller systems are more prone to weed invasion from surrounding areas.
- **Community Expectations** - Streetscape, car park and civic space bioretention systems are often located in high profile locations. This may result in higher community expectations from them visually, and a higher level of maintenance to satisfy this expectation.

COSTS AND ACTIVITIES INVOLVED IN MAINTAINING BIORETENTION SYSTEMS

4.3. Large Bioretention Systems

While there are many large bioretention systems in Queensland, almost no maintenance data is available for them. Data was available for two large bioretention systems, although they differed from typical large systems in that neither were located downstream from a sediment basin. There are however similarities with precinct scale bioretention systems, that allow an informed estimate of their maintenance costs to be made. For example, both precinct scale and large bioretention systems often follow similar planting styles, including both a canopy and understory, or only understory plants. Key differences include:

- Large bioretention systems are by their nature bigger systems. To maintain a given area of bioretention system requires visiting a smaller number of individual assets, and thus less travel time. On the other hand, any materials handled on site (e.g. weeds or equipment) will need to be handled more, as the centre of the system will be further from the nearest point a vehicle can typically access (e.g. the perimeter).
- Large bioretention systems are typically located in large catchments and receive larger inflows. They often require additional infrastructure such as sediment ponds and high flow bypasses to protect the filter media from large inflows. This additional infrastructure requires maintenance not included in a precinct scale bioretention system.
- When large bioretention systems receive small inflows, these often do not extend across the entire filter media surface. Instead, only the filter media surface near the inlets receives water. As a result, plants growing near the inlets often thrive, while those growing furthest from the inlets struggle and even die, allowing weeds to establish within the system. This problem is less common in precinct scale bioretention systems because they are smaller.

For these reasons it is concluded that large bioretention systems require similar maintenance activities and frequencies to precinct scale

bioretention systems, with the following likely differences:

- Additional cleaning on an irregular basis of the sediment basin (if present).
- Additional weed control on a regular basis to the perimeter of the sediment basin (if present).
- Additional mowing or weed management to the high flow bypass.
- Where a sediment basin or other energy dissipation is not present, additional works to repair scour around inlets.

On this basis it is concluded that large bioretention systems are likely to cost equal to, or greater than precinct scale bioretention systems. Specifically:

- $\geq \$1/\text{m}^2\text{fm}/\text{yr}$ where both a canopy and understory are present
- $\geq \$5/\text{m}^2\text{fm}/\text{yr}$ where only understory plants are present.



Figure 25: A sediment basin



Photo: Jack Mullaly

COSTS AND ACTIVITIES INVOLVED IN MAINTAINING BIORETENTION SYSTEMS

4.4. Bioretention Street Trees



At present there are very few bioretention street trees in Queensland. No maintenance data was obtained.

4.5. Implications of less regular maintenance

The maintenance regimes detailed in Sections 5.1 to 5.4 are based around regular proactive maintenance every four to six weeks to control weed growth, with other activities undertaken on an irregular, reactive basis.

Where resources are constrained, it is important to consider the implications of reducing maintenance frequencies. Observations of unmaintained bioretention systems clearly show that when maintenance frequencies are dramatically reduced (or maintenance does not occur at all), weeds invade the system and desirable vegetation is killed. A study by Logan City Council (Mullaly 2012) concluded that undertaking maintenance on bioretention systems once a year was approximately ten times more costly than undertaking maintenance on a more proactive basis as described in Table 1. This difference in cost was primarily caused by the cost of purchasing new plants to replace those killed through weed invasion.

It is possible that slightly reducing the frequency of maintenance (perhaps to every eight to ten weeks for a system with understory plants only) may reduce costs with no appreciable decrease in asset condition, however the data available is not sufficiently detailed to assess this.

4.6. Comparisons With Other Published Data on Bioretention Maintenance Costs

Section 2 lists four other publications dealing with the cost of maintaining bioretention systems. These publications demonstrate how knowledge of bioretention system maintenance costs has grown

over the past decade. Earlier publications, while useful for the time, typically did not distinguish between maintenance costs for different types of bioretention system and in some cases they were based on cost estimates rather than actual data. More recent publications such as Melbourne Water (2014) distinguish between different bioretention system types and sizes.

The maintenance cost data presented in this report are consistent with that contained in the publications listed in Section 2, and builds upon them by:

- further distinguishing maintenance costs by bioretention types
- investigating the influence of proximity of systems on streetscape, carpark and civic space bioretention system maintenance
- exploring how bioretention maintenance cost varies with vegetation type and size.

4.7. Other Factors Affecting Maintenance Costs

In addition to the maintenance activities, frequencies and bioretention types identified in previous sections, a range of other factors exist that may affect bioretention maintenance cost. Individuals involved in bioretention maintenance report their influence, however the data is not available at present to quantify their impact. These factors include:

- seasonal variations in maintenance requirements
- the quality of maintenance access
- the location of the bioretention basin outlet pipe (those pipes, particularly small ones, that discharge to low lying, regularly inundated land often become obscured and may be more likely to block)
- the frequency of lateral inflows over batters and the associated risk of scour.



SOURCES OF MAINTENANCE DATA

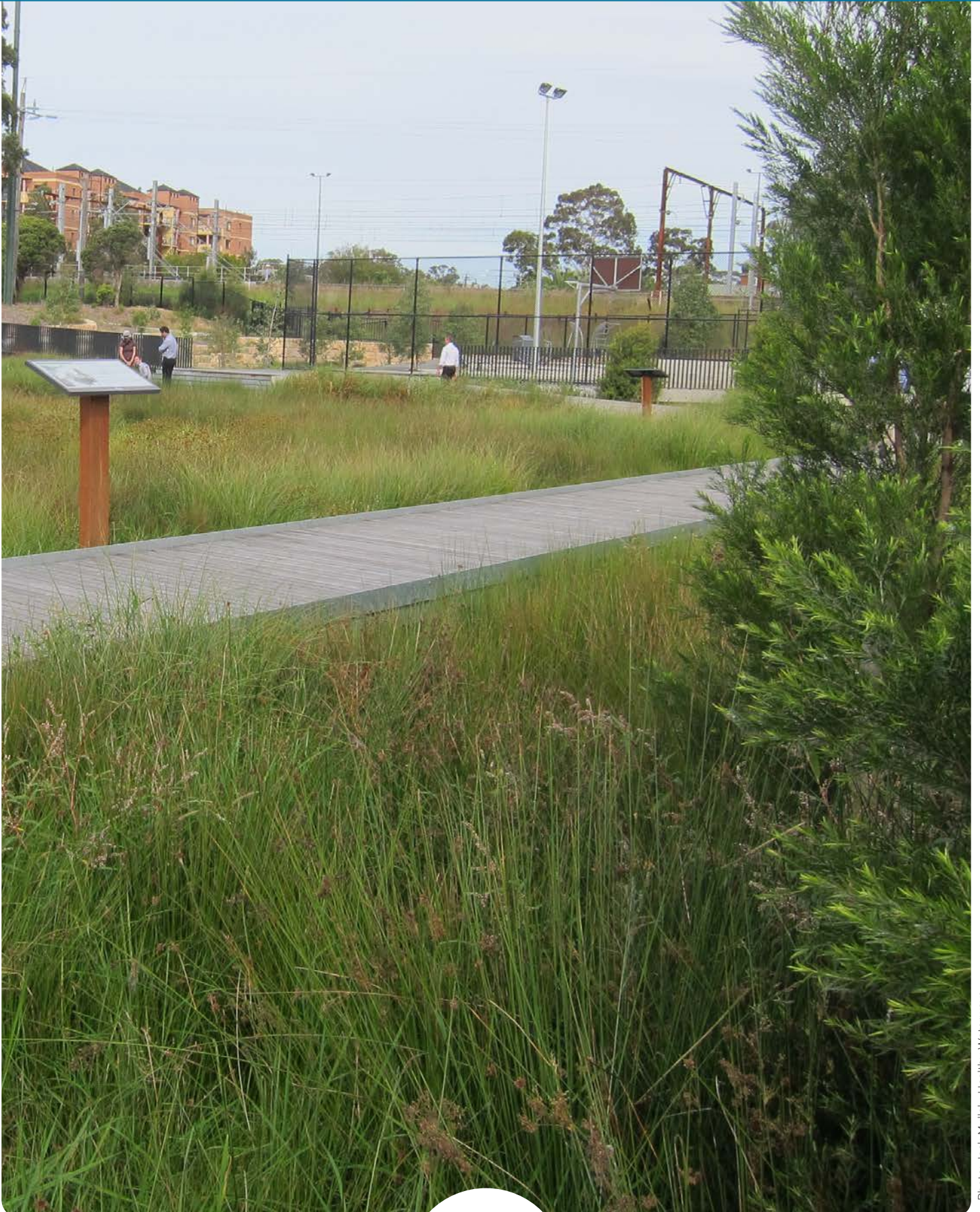


Photo: Jack Mullaly, Healthy Waterways

SOURCES OF MAINTENANCE DATA

5. SOURCES OF MAINTENANCE DATA


The following sections describe the sites for which maintenance data was available, and how each site contributed to the knowledge outlined in Table 1.

5.1. Dataset 1 - Precinct Scale - Understory Plants

Data was available for a precinct scale bioretention system located in a park. The system has a filter media area of 180m² and was installed in 2008. Originally it was planted with only understory plants in the filter media, and grass on the batters. In 2011, rectification works were undertaken to remove weeds, install energy dissipaters at the inlet, replant the system and create a buffer around the system to prevent the grass from invading the filter media surface (Figure 26). The data used in this paper was collected in the first 12 months after the rectification works were completed.

During this 12 month period, the works undertaken included weeding, removing litter, repairing minor scour at the inlet and occasional replacement of plants (typically recently planted tubestock that were vandalised) (Figure 27). Maintenance was undertaken at approximately four week intervals.

The civil aspects of the system (e.g. inlet and outlet) were also inspected, albeit during separate visits to the system. No defects were found and no works undertaken on the civil aspects of the systems during the period that data was collected.

 Maintenance during the 12 month period equated to \$4.60 per square meter of filter media per year.

Dataset 1 - Key Site Details

Location - South East Queensland

Ownership as data collected - Local Government

Number of assets - 1

Filter media area - 180m²

Year asset commissioned - 2008

Year asset data collected - 2011

Vegetation type - Understory plants

Figure 26: Immediately after rectification works



Photo: Jack Mullaly

Figure 27: During the period when data was collected



Photo: Jack Mullaly

SOURCES OF MAINTENANCE DATA

5.2. Dataset 2 - Precinct Scale - Understory Plants

Data was available for a precinct scale bioretention system in South East Queensland. The bioretention system contained a filter media area of 480m² plus vegetated batters to create a total asset size of approximately 950m². The system is located adjacent to, and accepted runoff from, an industrial lot that was yet to be developed.

12 months of maintenance was undertaken on the system during 2011. At the beginning of the maintenance period, the system was well established, with a dense cover of desirable understory plants, and some weeds (Figure 28). The site, and others like it in the vicinity, was prone to illegal dumping. For example, car tyres, used chemical drums and other containers (Figure 29) were found in the system during the maintenance period. Maintenance during the 12 month period that data was collected consisted of weeding and removing litter. Maintenance was undertaken approximately every four weeks.


 Maintenance during the 12 month period equated to \$3.50 per square meter of filter media per year (Figure 29).

Figure 28: Prior to maintenance



Photo: Jack Mullaly

Dataset 2 - Key Site Details

Location - South East Queensland

Ownership as data collected - Local Government

Number of assets - 1

Filter media area - 480m²

Year asset commissioned - Pre 2008

Year asset data collected - 2011

Vegetation type - Understory plants

Figure 29: Illegal dumping in the system



Photo: Jack Mullaly

Figure 30: During the period when data was collected



Photo: Jack Mullaly

SOURCES OF MAINTENANCE DATA


5.3. Dataset 3 - Large - Understory Plants

Data was available for a large bioretention system located adjacent to parkland in South East Queensland (Figures 31 and 32). The bioretention system's filter media area was 1730m². The system was installed in 2011 and the data collected during the following twelve months. The data provided specific information on maintenance costs and activities in months one to three, four to six and seven to twelve

The system was planted with grasses and sedges. Unusually for a large bioretention system, this system did not have an upstream sediment basin, nor was it split into smaller precinct scale cells.

Maintenance consisted of weeding, litter removal, and removing mulch from young plants. Maintenance was conducted at the following intensity and frequency:

- months one to three - eight hours each week
- months four to six - eight hours per fortnight
- months seven to twelve - nine hours per month.

 The average maintenance cost over the twelve month period was \$4.69 per square meter of filter media per year. The maintenance cost for months seven to twelve was \$3 per square meter of filter media per year.

While all data is presented here, the costs for months seven to twelve is considered most representative of the ongoing (rather than establishment) costs of maintaining this bioretention system.

Dataset 3 - Key Site Details

Location - South East Queensland

Ownership as data collected - Developer

Number of assets - 1

Filter media area - 1730m²

Year asset commissioned - 2011

Year asset data collected - 2012

Vegetation type - Understory plants

Figure 31: During the period when data was collected



Photo: Jack Mullaly, Healthy Waterways

Figure 32: During the period when data was collected

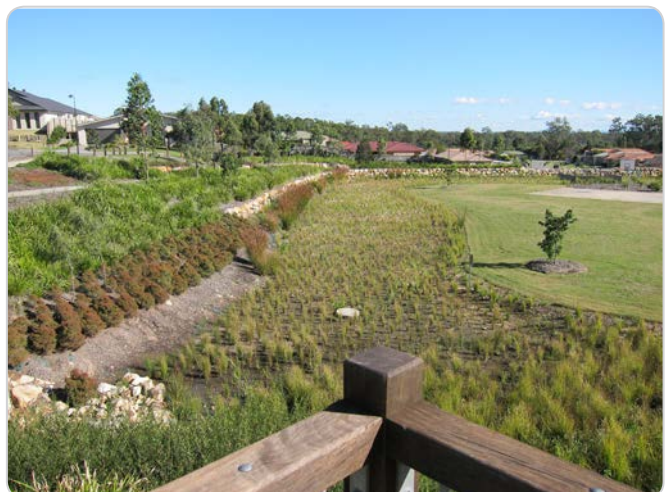


Photo: Jack Mullaly, Healthy Waterways

SOURCES OF MAINTENANCE DATA

5.4. Dataset 4 - Large - Understory Plants

Data was available for a large bioretention system located adjacent to a park in South East Queensland (Figures 33 and 34). The system had a filter media area of 2070m². The system was installed in 2011 and the data collected during the following twelve months. The data provided specific information on maintenance costs and activities in months one to three, four to six and seven to twelve.

The system was planted with grasses and sedges. The system was located downstream of a sediment basin and a constructed wetland, however maintenance for these two components are not included in the costs presented here.

Maintenance consisted of weeding, litter removal, and removing mulch from young plants. Maintenance was conducted at the following intensity and frequency:

- months one to three - four hours per week
- months four to six - four hours per fortnight
- months seven to twelve - five hours per month.



The average maintenance cost over the twelve month period was \$2.02 per square meter of filter media per year. The maintenance cost for months seven to twelve was \$1 per square meter of filter media per year.

While all data is presented here, the costs for months seven to twelve is considered most representative of the ongoing (rather than establishment) costs of maintaining this bioretention system.

Dataset 4 - Key Site Details

Location - South East Queensland

Ownership as data collected - Local Government

Number of assets - 1

Filter media area - 2070m²

Year asset commissioned - 2011

Year asset data collected - 2012

Vegetation type - Understory plants

Figure 33: During the period when data was collected



Photo: Jack Mullaly, Healthy Waterways

Figure 34: During the period when data was collected



Photo: Jack Mullaly, Healthy Waterways

SOURCES OF MAINTENANCE DATA

5.5. Dataset 5 - Precinct Scale - Understory Plants


Data was available for a precinct scale bioretention systems located adjacent to a park in South East Queensland (Figure 35). The system had a filter media of 215m².

The system was installed in 2010 and the data collected during the following twelve months. The data provided specific information on maintenance costs and activities in months one to three, four to six and seven to twelve

The system was planted with grasses and sedges. Unusually for a precinct scale bioretention system, and particularly for one this small, this bioretention system was located downstream of a sediment basin (Figure 36). Sediment basin maintenance costs are not included in the figures presented here.

Maintenance consisted of weeding, litter removal, and removing mulch from young plants. The system was constructed with sugar cane mulch on the bioretention system surface. Unusually, the mulch was not pinned down with jute netting. Maintenance intensities were therefore increased due to regular clearing of mulch from young plants. Maintenance was conducted at the following intensity and frequency:

- months one to three - three hours per week
- months four to six - three hours per fortnight
- months seven to twelve - four hours per month

 The average maintenance cost over the twelve month period was \$14.87 per square meter of filter media per year. The maintenance cost for months seven to twelve was \$9 per square meter of filter media per year.

While all data is presented here, the costs for months seven to twelve is considered most representative of the ongoing (rather than establishment) costs of maintaining this bioretention system.

Dataset 5 - Key Site Details

Location - South East Queensland

Ownership as data collected - Developer

Number of assets - 1

Filter media area - 215m²

Year asset commissioned - 2010

Year asset data collected - 2011

Vegetation type - Understory plants

Figure 35: During the period when data was collected



Photo: Jack Mullaly

Figure 36: Upstream sediment basin



Photo: Jack Mullaly

SOURCES OF MAINTENANCE DATA

5.6. Dataset 6 - Grouped Data

Lumped data was available for a group of 113 bioretention systems of varying types. Figure 37 one of the bioretention systems contained within the group of assets for which data was available.

Maintenance consisted entirely of weeding, carried out eight times per year, at a cost of \$0.84 per square meter of filter media per year.

The asset owner stated that this regime was sufficient to maintain the asset, providing it was well constructed and established initially.

Dataset 6 - Key Site Details

Location - South East Queensland

Ownership as data collected - Local Government

Number of assets - 113

Filter media area - Variable

Year asset commissioned - Variable

Year asset data collected - 2013

Vegetation type - Variable

Figure 37: Example of a bioretention system from dataset 6



Photo: Jack Mullaly

SOURCES OF MAINTENANCE DATA

5.7. Dataset 7 - Precinct Scale - Canopy and Understory

Information on maintenance activities but not costs was available for a group of precinct scale bioretention systems constructed since 2007 in South East Queensland.

All systems were initially planted with grasses and sedges in the filter media, and a mix of species, including trees surrounding the systems. Over time, some systems have seen a decrease in plant cover within the filter media (Figure 38), while others continue to maintain high plant cover (Figure 39) and have seen natural recruitment of species (including trees) within the filter media (Figure 40).

Maintenance consists of weeding (a combination of hand pulling and spraying with glyphosate), litter removal and pruning. This is completed on a fortnightly rotation during summer. During winter, a fortnightly inspection is undertaken, and maintenance completed when needed. The contractor noted that the systems were high profile, and thus maintenance intensity was largely dictated by the need for the systems to appear aesthetically pleasing. The contractor noted that where aesthetics were less of a priority, maintenance frequency could be reduced without compromising functionality. The contractor estimated that reducing both activities in summer, and inspections in winter, to a four week rotation would be sufficient to maintain function.

Figure 38: System suffering from reduced plant numbers



Photo: Jack Mullaly, Healthy Waterways

Dataset 7 - Key Site Details

Location - South East Queensland

Ownership as data collected - Private

Number of assets - 4

Filter media area - Variable

Year asset commissioned - Variable from 2007 on

Year asset data collected - 2014

Vegetation type - Understory plants and surrounding canopy

Figure 39: System with high plant cover



Photo: Jack Mullaly

Figure 40: Colonisation of filter media by Casuarina trees



Photo: Jack Mullaly, Healthy Waterways

SOURCES OF MAINTENANCE DATA

5.8. Dataset 8 - Precinct Scale - Canopy and Understory

Data was available for a precinct scale bioretention system located in South East Queensland. The system was constructed in 2009, and contained 437m² of filter media. The system was planted with a mixture of grasses, sedges and trees (Figure 41). At the time that data was collected, houses were still being constructed in the catchment, and thus large amounts of sediment and gravel were present in the sediment forebay (Figure 42). A thick layer of fine sediment was located on the bioretention system's surface (Figure 43).

The data available for the system consisted of costs and activities involved in capital upgrades, initial rectification works, and ongoing maintenance activities. The activities for which data was available were:

- installation of a gravel maintenance access track
- sediment removal
- inspection of the sediment forebay
- replanting
- purchase of tubestock
- litter removal
- weed control.

Maintenance costs for the asset varied depending on which costs were considered to be maintenance (rather than rectification):

- Installation of the maintenance access track was considered a capital upgrade because it should have been provided during initial construction.
- Sediment removal was considered to be rectification because the system was commissioned too early, and house construction was still ongoing within the bioretention system's catchment.
- Maintenance of the system commenced some time after the system was constructed. When weeds in bioretention systems are not regularly managed, they often outcompete and kill desirable vegetation (Mullaly, 2012). Replanting costs were therefore considered more likely to be rectification than maintenance.
- Litter removal, weed control and inspection of the sediment forebay were regular activities and thus were considered maintenance.

Where maintenance was considered to be litter removal, weed control and inspection of the sediment forebay, maintenance of the system was \$4.26 per square meter of filter media per year. Where plant supply and replanting were also included, maintenance costs increased to \$10.64 per square meter of filter media per year.



Figure 41: After rectification works



Photo: Jack Mullaly, Healthy Waterways

SOURCES OF MAINTENANCE DATA

Figure 42: Sediment accumulation on the system's surface



Photo: Jack Mullaly, Healthy Waterways

Dataset 8 - Key Site Details

Location - South East Queensland

Ownership as data collected - Local Government

Number of assets - 1

Filter media area - 437m²

Year asset commissioned - 2009

Year asset data collected - 2014

Vegetation type - Understory plants and surrounding canopy

Figure 43: Coarse sediment from upstream building sites in the coarse sediment forebay



Photo: Jack Mullaly, Healthy Waterways

SOURCES OF MAINTENANCE DATA

5.9. Dataset 9 - Precinct Scale - Understory Plants

Data was available for a precinct scale bioretention system located in South East Queensland. The system was constructed in 2009, and contained 543m² of filter media. The system was planted with a mixture of grasses and sedges, with some trees around the perimeter (Figure 44). At the time that data was collected, houses were still being constructed in the catchment, and thus sediment was present in the sediment forebay (Figure 45).

The data available for the system consisted of costs and activities involved in capital upgrades, initial rectification works, and ongoing maintenance activities. The activities for which data was available were:

- installation of a gravel maintenance access track
- sediment removal
- inspection of the sediment forebay
- replanting (Figure 46)
- purchase of tubestock
- litter removal
- weed control.

Figure 44: Shortly after rectification works



Photo: Jack Mullaly, Healthy Waterways

Maintenance costs for the asset varied depending on which costs were considered to be maintenance (rather than rectification):

- Installation of the maintenance access track was considered a capital upgrade because it should have been provided during initial construction.
- Sediment removal was considered to be rectification because the system was commissioned too early, and house construction was still ongoing within the bioretention system's catchment.
- Maintenance of the system commenced some time after the system was constructed. When weeds in bioretention systems are not regularly managed, they often outcompete and kill desirable vegetation (Mullaly, 2012). Replanting costs were therefore considered more likely to be rectification rather than maintenance.
- Litter removal, weed control and inspection of the sediment forebay were regular activities and thus were considered maintenance.

Where maintenance was considered to be litter removal, weed control and inspection of the sediment forebay, maintenance of the system was \$4.26 per square meter of filter media per year. Where plant supply and replanting were also included, maintenance costs increased to \$10.64 per square meter of filter media per year.



SOURCES OF MAINTENANCE DATA

Figure 45: Coarse sediment from upstream building sites



Photo: Jack Mullaly, Healthy Waterways

Dataset 9 - Key Site Details

Location - South East Queensland

Ownership as data collected - Local Government

Number of assets - 1

Filter media area - 543m²

Year asset commissioned - 2009

Year asset data collected - 2014

Vegetation type - Primarily understory

Figure 46: Replanting in the bioretention system




Photo: Jack Mullaly, Healthy Waterways

SOURCES OF MAINTENANCE DATA

5.10. Dataset 10 - Precinct Scale - Canopy and Understory

Data was available for a precinct scale bioretention system within a grassed area with 675m² of filter media (Figures 47, 48 and 49). It contains a mix of trees species as well as Lomandra in the filter media. It has grass on the batters. The system was constructed in 2001.

Maintenance was undertaken on the system early in it's life in order to establish the vegetation. However, with the best available data, it appears that the system has received virtually no maintenance since approximately 2005. The primary maintenance that does occur is mowing of the batters as a part of general maintenance for the surrounding grassed area. Given the lack of litter within the system, it is also likely that litter is removed periodically as a part of the maintenance of the surrounding land. There are some weeds present on the perimeter of the system, but very few further within the system. It appears that shade and leaf drop from the trees is suppressing weed growth. The underdrainage of the system has been inspected and remains clear, with no significant root ingress (Figure 50).

 Given that the maintenance of the system that is undertaken is completed as a part of maintenance for the surrounding landscaped area, the system is considered to be virtually maintenance free.

Dataset 10 - Key Site Details

Location - South East Queensland

Ownership as data collected - Local Government

Number of assets - 1

Filter media area - 675m²

Year asset commissioned - 2001

Year asset data collected - 2014

Vegetation type - Understory plants and canopy

Figure 47: Some grass and weeds on the system's edge



Photo: Jack Mullaly

Figure 48: The system in 2011



Photo: Jack Mullaly

SOURCES OF MAINTENANCE DATA

Figure 49: Shade and leaf drop suppresses weeds within the middle of the system



Photo: Jack Mullaly, Logan City Council

Figure 50: One of six underdrains showing only a few small roots in 2011



Photo: Healthy Waterways

SOURCES OF MAINTENANCE DATA

5.11. Dataset 11 - Carpark - Understory Plants

Data was available for three bioretention swales located in a car park (Figures 51, 52 and 53). The three systems had a combined filter media area of approximately 200m² and were planted with grasses and sedges. In 2011, rectification works were undertaken to remove weeds, fix scour and replant parts of the system. The data used in this paper was collected in the first 12 months after the rectification works were completed.

During this 12 month period, the works undertaken included weeding and removing litter. Maintenance was undertaken at approximately four week intervals.

The civil aspects of the system (e.g. inlet and outlet) were also inspected, albeit during separate visits to the system. No defects were found and no works undertaken on the civil aspects of the systems during the period that data was collected.


 Maintenance during the 12 month period equated to \$25.20 per square meter of filter media per year.

Figure 51: Boardwalk over one of the bioretention systems



Photo: Jack Mullaly

Dataset 11 - Key Site Details

Location - South East Queensland

Ownership as data collected - Local Government

Number of assets - 3

Filter media area - 200m² (combined)

Year asset commissioned - 2009 or earlier

Year asset data collected - 2012

Vegetation type - Primarily understory plants

Figure 52: One of the bioretention systems during rain



Photo: Jack Mullaly

Figure 53: Shortly after rectification mulch and replanting



Photo: Jack Mullaly

SOURCES OF MAINTENANCE DATA

5.12. Dataset 12 - Streetscape - Understory Plants

Data was available for 12 streetscape bioretention systems located within a single street (Figure 54). Each system had a filter media area of approximately 8m² and was planted with grasses and sedges.

Maintenance of these systems was undertaken by two people in a ute and consisted of:

- traffic control
- litter removal
- weeding (mostly by hand)
- decompacting the filter media surface (by raking or hoeing)
- cleaning out the forebay (by shovelling into a ute for disposal)
- replanting (occasional).

Maintenance was undertaken every three weeks in summer and every four weeks in winter.

Dataset 12 - Key Site Details

Location - South East Queensland

Ownership as data collected - Local Government

Number of assets - 12

Filter media area - approximately 5m² each

Year asset commissioned - pre 2010

Year asset data collected - 2014

Vegetation type - Primarily understory plants

It was noted that traffic control can constitute a major component of the cost of maintaining streetscape bioretention systems. Maintenance of the streetscape systems described here (all within one street) cost approximately \$10 - \$15 per square meter of filter media per year. It was estimated that this would double for isolated systems (i.e. those not located in the same street as other streetscape bioretention systems). This is because efficiencies in traffic control setup and travel time can be gained where multiple systems are located within the same street.



Figure 54: Two of the twelve streetscape bioretention systems



Photo: Jack Mullaly, Healthy Waterways

SOURCES OF MAINTENANCE DATA

5.13. Dataset 13 - Precinct Scale - Understory Plants

Data was available for four precinct scale bioretention systems in North Queensland located adjacent to a riparian corridor (Figures 55 and 56). Filter media area varied between systems. Each system planted with a mixture of grasses, sedges and trees. The available data was for the establishment period (i.e. shortly after construction).

✏ Maintenance was estimated to cost \$7 per square meter of filter media per year. A crew was permanently located within the surrounding development and hence this cost did not include travel, setup or pack-down costs.

Figure 55: One of the systems showing good plant establishment



Photo: DesignFlow

Dataset 13 - Key Site Details

Location - North Queensland

Ownership as data collected - Developer

Number of assets - 4

Filter media area - Variable

Year asset commissioned - Variable from 2009 on

Year asset data collected - 2014

Vegetation type - Primarily understory plants

Figure 56: One of the systems showing good plant establishment



Photo: DesignFlow

SOURCES OF MAINTENANCE DATA

5.14. Dataset 14 - Precinct Scale - Canopy and Understory


 Data was available for a precinct scale bioretention system with 65m² of filter media located adjacent to a riparian corridor in South East Queensland (Figures 57, 58 and 59). The system was constructed in 2009, and planted with grasses and sedges. It is entirely surrounded by trees. No record of maintenance could be found for this system prior to 2013 when it was identified as a potential source of data for this project. It is mostly free of weeds, and appears quite resilient, although it has been observed to retain water for several days after rain. While the retaining water, only a trickle of water leaves the system's underdrain. The system does subsequently dry out.

Figure 57: The system in 2014



Photo: Jack Mullaly, Healthy Waterways

Dataset 14 - Key Site Details

Location - North Queensland

Ownership as data collected - Developer

Number of assets - 4

Filter media area - Variable

Year asset commissioned - Variable from 2009 on

Year asset data collected - 2014

Vegetation type - Primarily understory plants

Figure 58: The system retaining water the day after rain



Photo: Jack Mullaly, Healthy Waterways

Figure 59: The system is entirely surrounded by trees



Photo: Jack Mullaly, Healthy Waterways

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6. REFERENCES

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