A review of the application of Jellyfish® in Australia

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Document Control Sheet

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Synopsis	This report provides an analysis of the application of Jellyfish® technology as a stormwater treatment asset within Australia.

Executive Summary

Over recent decades, the implementation of stormwater control measures (SCMs) to achieve a more 'water sensitive' urban environment and reduce the hydrologic and water quality impacts of urban development has increased across Australia (and overseas). The Jellyfish® is a SCM that utilises membrane filtration cartridges with high filtration surface area and flow capacity, typically integrated below ground (within an underground chamber).

This report provides a review of the performance of Jellyfish®, and of its suitability for application within Australia. This review has shown that Jellyfish® is an appropriate stormwater treatment asset type for application in Australian urban environments. This finding considers a range of factors, including the following:

- **Government approvals:** Jellyfish® has been accepted by many of the most stringent stormwater quality regulators within Australia and overseas, including Brisbane City Council, Gold Coast City Council, Moreton Bay Regional Council, Logan City Council, Sunshine Coast Regional Council, and Blacktown City Council.
- **Case studies:** Since 2017, approximately 1300 Jellyfish® technologies have been installed within Australia by Ocean Protect. Prior to this, the licence for Jellyfish® distribution was held by Holcim Australia.
- **Performance monitoring:** Stormwater treatment performance monitoring has been undertaken for two (2) sites with Jellyfish® technologies (including one site in Australia, at West Ipswich, Queensland) operating in 'real world' conditions, both showing significant reductions in pollutant concentrations.
- **Peer review:** Alluvium's Tony Weber was commissioned by Ocean Protect to undertake a peer review of the monitoring undertaken of the Jellyfish® at West Ipswich, Queensland – with data assessed against the City of Gold Coast's *Development Application Requirements and Performance Protocol for Proprietary Devices*" (issued August 2015). As outlined in Mr Weber's peer review report, he determined that "*"it would appear that the testing of the Jellyfish stormwater treatment device generally complies with the requirements of the (City of Gold Coast) protocol"*
- **Applicability to local conditions:** For applications across Australia, the Jellyfish® is expected to achieve similar pollutant load removal rates to those observed at the aforementioned monitoring sites. This is for a combination of reasons, including:
  - Jellyfish® uses physical (filtration) treatment processes – and these are highly unlikely to be significantly impacted by differences in climate conditions (e.g. temperatures, rainfall frequencies/ amounts) between sites the monitoring sites and other sites within Australia.
  - Jellyfish® operates with minimum contact time across a membrane filter. Thus, variations in performance will predominantly be subject to sediment particle size, influent concentrations and speciation (nutrient solubility) rather than locality.

It is recommended that a generic treatment node (in eWater's MUSIC software) be applied in modelling the performance of Jellyfish®. Within Queensland and NSW, Stormwater treatment performance should be consistent with the values given in Table 3-1 where available. For areas external to Queensland and NSW, it is generally recommended to apply observed pollutant concentration reductions consistent with that approved by Brisbane City Council (given in Table 3-1) or from the monitoring site at West Ipswich, Queensland (given in Table 2-1).

it is recommended that the treatment performance of Jellyfish® be modelled using a generic treatment node within MUSIC, with stormwater treatment performance consistent with the values approved by Brisbane City Council (as outlined in Table 3-1) or observed pollutant concentration reductions from the monitoring site at West Ipswich, Queensland (given in Table 2-1).

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1 Introduction

1.1 Background

It is commonly understood that unmitigated urban stormwater is a key contributor to reduced water quality and waterway health in Australia and internationally. Traditional urban development and associated stormwater drainage practices of conveying stormwater runoff to waterways as efficiently as possible (providing minimal opportunities for treatment and reuse) have been recognised as being unsustainable and inappropriate due to changed catchment hydrology (e.g. increased frequency and volume of stormwater flows) and increased stormwater pollutant loads to waterways and associated ecological impacts.

Water Sensitive Urban Design (WSUD) is an internationally recognised concept that offers an alternative to traditional development practices, providing a holistic approach to the design of urban development that aims to minimise the negative impacts on the natural water cycle and protect the health of waterways (South East Queensland Healthy Waterways Partnership 2006). Over recent decades, the implementation of stormwater control measures (SCMs) to achieve a more 'water sensitive' urban environment and reduce the hydrologic and water quality impacts of urban development has increased across Australia (and overseas).

1.2 Jellyfish® Overview

The Jellyfish® is a SCM that utilises membrane filtration cartridges with high filtration surface area and flow capacity, typically integrated below ground (within an underground chamber). The Jellyfish® is designed to remove a range of pollutants, including floatables, trash, oil, debris, TSS, fine silt-sized particles, and particulate-bound pollutants (e.g. nutrients, metals and hydrocabons).

Figure 1-1 illustrates the components of a Jellyfish®, and Figure 1-2 illustrates the components of the Jellyfish® tentacle. Example photos of Jellyfish® are provided in Figure 1-3. Further information in relation to the design and management of Jellyfish® technologies is provided in Appendix A and Appendix B respectively.

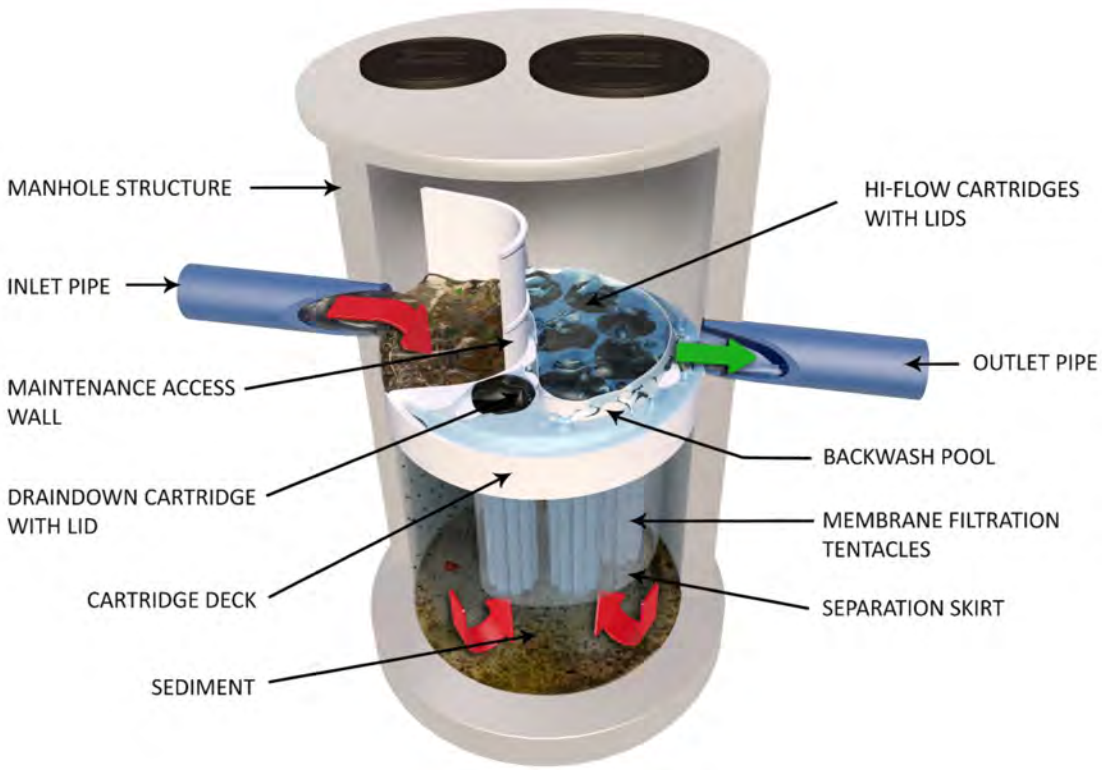

Figure 1-1 Jellyfish® components

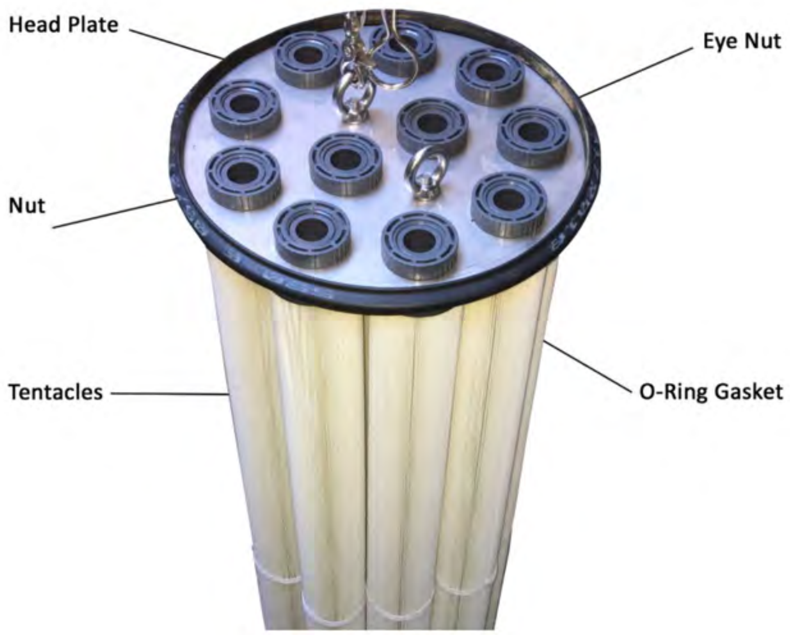

Figure 1-2 Jellyfish® tentacle components

Source: Ocean Protect (2020)

Figure 1-3 Example photos of Jellyfish®

The key function of Jellyfish® is to remove pollutants from stormwater. During a storm, the upstream bypass structure directs low flows to the Jellyfish®. The system builds driving head, traps floating pollutants behind the Maintenance Access Wall (MAW) and drives flow below the cartridge deck where a separation skirt around the cartridges isolates oil, litter and debris outside the filtration zone. As a result of the upstream driving head, water is conveyed up from the treatment chamber through membrane tentacles and into the backwash pool. Once the water has filled the backwash pool, water overflows the weir and exits via the outlet pipe.

Once the rain event subsides, flow reverses such that the water in the backwash pool flows back into the lower chamber. This passive backwash extends cartridge life and prepares the system for the next rainfall event. The drain down cartridge(s) located outside the backwash pool enables water levels to balance.

Physical filtration is the key treatment process applied by the Jellyfish® technology for the removal of all pollutants, including sediment and sediment-bound pollutant (e.g. phosphorus, nitrogen, heavy metals, pathogens and organic micropollutants).

1.3 Report objectives

The objectives of this report are to provide the following:

- A review of the application of the Jellyfish® technology within Australia
- A review of the methods for modelling the treatment performance of Jellyfish® technologies (and, if appropriate, identify a recommended method).

2 Review of Suitability of Jellyfish® in Australia

2.1 Preamble

This section provides a review of the suitability of Jellyfish® for Australian conditions, based on the following aspects:

- Government approvals
- Case studies
- Treatment performance monitoring
- Peer review
- Applicability to local conditions.

2.2 Government approvals

Jellyfish has been accepted by some of the most stringent stormwater quality regulators accepted by many of the most stringent stormwater quality regulators within Australia and overseas, including:

- Brisbane City Council
- Gold Cast City Council
- Logan City Council
- Moreton Bay Regional Council
- Sunshine Coat Regional Council
- Wollondilly Shire Council
- Campbelltown City Council
- Blacktown City Council
- Washington State Department of Ecology (TAPE) GULD – Basic, Phosphorus
- New Jersey Corporation of Advanced Technology (NJCAT)
    - Field Performance per TARP Tier II Protocol
- Canada ISO 14034 Environmental Management – Environmental Technology Verification (ETV)

2.3 Case studies

Since 2017, approximately 1200 Jellyfish® technologies have been installed within Australia by Ocean Protect. Prior to this, the licence for Jellyfish® distribution was held by Holcim Australia.

2.4 Treatment performance monitoring

Table 2-1 provides a summary of two recent examples of Jellyfish® operating in 'real world' conditions where treatment performance monitoring has been undertaken.

Table 2-1 Summary of recent treatment performance case studies of Jellyfish®

Location	Site details	Methodology summary	Performance summary	Further information*
Gainesvile, Florida	• Jellyfish® device • Catchment area 486 to 909m^2 (depending on wind) (car park, 100% impervious) • Mean rainfall 1280 mm per year	• Monitored by University of Florida Engineering School of Sustainable Infrastructure and Environment • 13-month monitoring period (May 2010 and June 2011) • 25 sampling events • Influent & effluent analysed for solids and nutrients	• 89, 59 and 51% TSS, TP and TN median concentration reduction respectively	• Imbrium Stems Corporation (2012)
West Ipswich, Queensland, Australia	• Jellyfish® device • Commercial facility • 1678m^2 catchment (approx. 550m^2 of roof area and 1128m^2 of impervious driveways and parking lots) • Mean rainfall 964 mm per year	• Monitored by Queensland University of Technology • 15-month monitoring period (June 2014 to September 2015) • 17 sampling events • Influent & effluent analysed for solids and nutrients	• 89, 55 and 50% TSS, TP and TN median concentration reduction respectively	• Goonetilleke et al (2017), provided in Appendix C • Kelly et al (2018), provided in Appendix C.

2.5 Peer review

Alluvium's Tony Weber was commissioned by Ocean Protect to undertake a peer review of the monitoring undertaken of the Jellyfish® at West Ipswich (summarised in Table 2-1), with the data assessed against City of Gold Coast's *Development Application Requirements and Performance Protocol for Proprietary Devices*" (issued August 2015).

This peer review report is provided in Appendix D, and states that

> "it would appear that the testing of the Jellyfish stormwater treatment device generally complies with the requirements of the CoGC protocol and provides indicative performance of the device treatment capabilities for flows passing through the device. Given the high level of consistency between the results of the Florida and Ipswich studies, the final median concentration reduction efficiencies obtained in the Ipswich study are likely to be a very good indication of the performance of the device in reducing relevant pollutant concentrations".

2.6 Applicability to local conditions

As described in 1.2, Jellyfish® uses physical (filtration) treatment processes – and these are highly unlikely to be significantly impacted by differences in climate conditions (e.g. temperatures, rainfall frequencies/ amounts) between the monitoring sites described in Section 2.4 and specific locations within Australia.

Regardless of rainfall intensity and duration, the Jellyfish® operates with minimum contact time across a membrane filtration surface. Thus, variations in performance will predominantly be subject to sediment particle size, influent concentrations and speciation (nutrient solubility) rather than locality. For example, as described by Neumann et al (CSIRO 2010). it is easier to achieve higher pollutant load removal rates when runoff has higher pollutant concentrations.

Solubility of nutrients is also critically important to the total nutrient pollutant removal performance. The removal of soluble pollutants such as ammonium or ortho-phosphate tend to be more difficult to remove than solids as the removal pathways/mechanisms are not only dictated by media contact time, sediment particle size, sediment density and concentration, but also competing pollutants ie, selective removal of soluble pollutants such as ammonium vs metals (Pb, Cu & Zn etc) typically found in urban runoff. Sites with low Dissolved Inorganic Nitrogen (DIN, sum of Ammonium, Nitrite and Nitrate) tend yield lower Nitrogen removals than sites with higher proportions of Total Kjeldahl Nitrogen (TKN) which is predominantly solid.

2.7 Conclusion

Based on the information presented in the above sections, Jellyfish® is considered to be an appropriate stormwater treatment asset type for application in urban environments within Australia.

3 Modelling Jellyfish® treatment performance

3.1 Preamble

This section describes and assesses potential methods for modelling the treatment performance of Jellyfish® technologies, and identifies the most appropriate method.

3.2 Modelling software

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is a software tool that simulates the behaviour of stormwater in urban catchments. MUSIC is the preferred tool for demonstrating the performance of stormwater quality treatment systems (Water By Design 2010, BMT WBM 2015).

Within MUSIC, the user is required to specify source nodes, which represent the stormwater flow and pollutant generating areas of the site being modelled. Treatment nodes can also be included to simulate (and assess) the operation of any stormwater treatment devices (e.g. biofiltration) within the site being modelled.

3.3 Treatment node options

As outlined in the previous section, MUSIC models the performance of stormwater treatment devices using 'treatment nodes'. A range of treatment nodes are available within MUSIC. It is recommended that the Jellyfish® technology be modelled using the 'generic' treatment node within MUSIC.

The pollutant removal provided by the Jellyfish® is modelled within MUSIC by adjusting the pollutant removal 'transfer functions' within the generic treatment node for gross pollutants (GPs), total suspended solids (TSS), total phosphorus (TP), and total nitrogen (TN). The high flow bypass rate should equal the maximum treatment flow capacity of the given Jellyfish® technologies.

The pollutant removal transfer function values vary across jurisdictions within Queensland and NSW. Table 3-1 summarises the stormwater treatment performance for Jellyfish® typically applied.

Table 3-1 Applied stormwater treatment performances for Jellyfish® in Queensland and NSW

Local government area	% Reduction				Comments
	GPs	TSS	TP	TN	
Blacktown City Council	75%	89%	54%	45%	
Brisbane City Council	99%	90%	65%	54%	
Gold Coast City Council	100%	86.7%	52.2%	45.8%	
Logan City Council	99%	87%	55%	43%	
All other Councils in Queensland	99%	93%	57%	50%	*: Jellyfish currently not approved in Ipswich City Council and Noosa Shire Council.

3.4 Recommendation

It is recommended that the treatment performance of Jellyfish® be modelled using a generic treatment node (as described above). Stormwater treatment performance should be consistent with the values given in Table 3-1 where available. For areas external to Queensland and NSW, it is generally recommended to apply observed pollutant concentration reductions consistent with that approved by Brisbane City Council (given in Table 3-1) or from the monitoring site at West Ipswich, Queensland (given in Table 2-1).

4 Conclusion

This report has provided a review of the performance of Jellyfish®, and of their suitability for application within Australia. This review has included the following:

- Overview of case studies of Jellyfish® and associated Government approvals
- Review of treatment performance monitoring for Jellyfish® operating in 'real world' conditions

This review has shown that Jellyfish® is an appropriate stormwater treatment asset type for application in Australian urban environments.

It is recommended that a generic treatment node (in eWater's MUSIC software) be applied in modelling the performance of Jellyfish®. Within Queensland and NSW, Stormwater treatment performance should be consistent with the values given in Table 3-1 where available. For areas external to Queensland and NSW, it is generally recommended to apply observed pollutant concentration reductions consistent with that approved by Brisbane City Council (given in Table 3-1) or from the monitoring site at West Ipswich, Queensland (given in Table 2-1).

5 References

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Appendix A Jellyfish® Technical Design Guide

This appendix provides a technical design guide for Jellyfish®, produced by Ocean Protect.

OCEAN PROTECT

Jellyfish Filter

Technical Design Guide

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Rev: *1* ***Last Updated:*** *March 2019*

Introduction

The Ocean Protect Jellyfish® filter is a compact, below ground stormwater treatment device, configured offline to capture pollutants in stormwater run-off. The Jellyfish filter uses high flow rate membrane filtration at low driving head with a large surface area to filter stormwater. By incorporating pre-treatment with light-weight membrane filtration, the Jellyfish Filter removes floatables, litter, oil, debris, TSS, fine silt-sized particles, and a high percentage of particulate-bound pollutants; including phosphorus and nitrogen, metals and hydrocarbons. The large surface area membrane cartridges, combined with up flow hydraulics, frequent backwashing, and rinsable/reusable cartridges ensure long-lasting performance.

Operational Overview

During a storm, the upstream bypass structure directs low flows to the Jellyfish. The system builds driving head, traps floating pollutants behind the Maintenance Access Wall (MAW) and drives flow below the cartridge deck where a separation skirt around the cartridges isolates oil, litter and debris outside the filtration zone. As a result of the upstream driving head, water is conveyed up from the treatment chamber through membrane tentacles and into the backwash pool. Once the water has filled the backwash pool, water overflows the weir and exits via the outlet pipe.

Once the rain event subsides flow reverses such that the water in the backwash pool flows back into the lower chamber. This passive backwash extends cartridge life and prepares the system for the next rainfall event. The drain down cartridge(s) located outside the backwash pool enables water levels to balance.

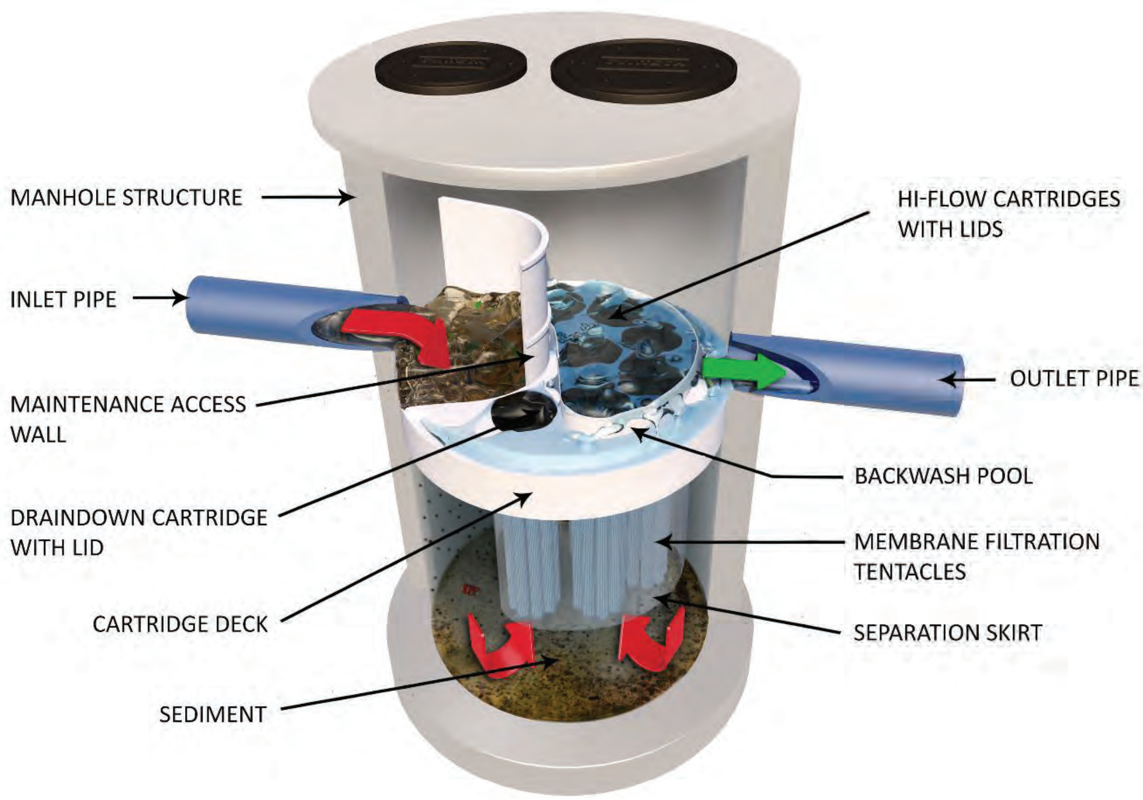

Figure 1: Jellyfish operation

Features

Each Jellyfish system consists of the following components:

- Maintenance Access Wall (MAW)
- Separation Skirt
- Filtration Zone (High-flow cartridges)
- Backwash Pool
- Drain-down cartridges

The Maintenance Access Wall is connected to the stormwater inlet pipe. It allows for the dissipation of flows and capture of floatable pollutants whilst reducing the quantity of coarse material and debris entering the Filtration Zone. The Separation Skirt provides further protection of the cartridges from coarse materials and hydrocarbons.

The High-flow and draindown cartridges available from Ocean Protect are offered in a 1375mm length. Each cartridge consists of 11 tentacles that are washable and re-usable. Each cartridge has a large surface area membrane together with a flow rate per cartridge of 5L/s providing the most compact footprint available on the market.

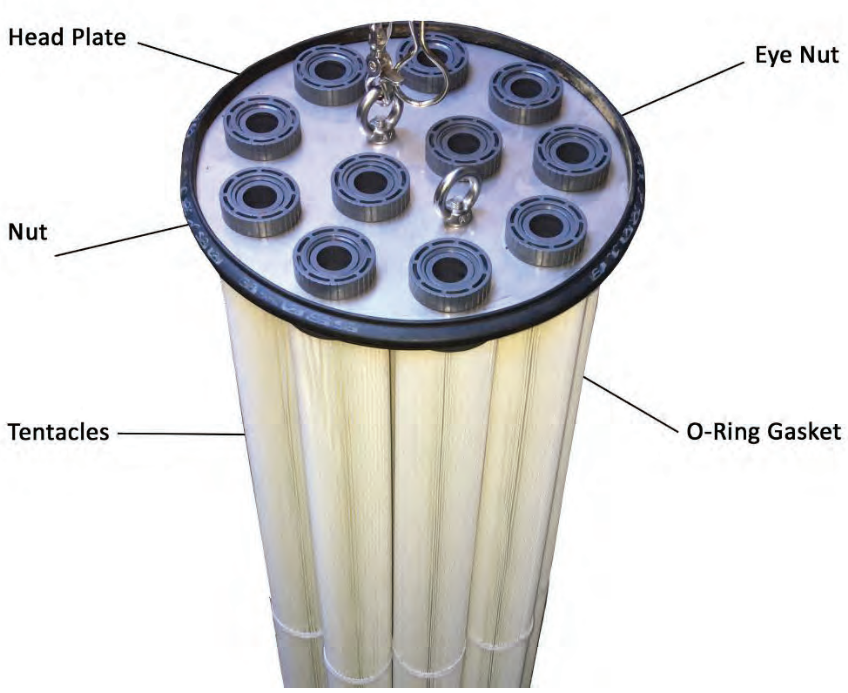

Figure 2: Jellyfish tentacle components

There are 2 hydraulic loss options for the Jellyfish system. Typically, 460mm of hydraulic loss is adopted, however for low drop sites, the designed hydraulic loss can be reduced to 230mm. The flow rates, head loss, and head drop for each system are shown in table 1 below.

Hydraulic Loss (mm)	High Flow cartridge flow rate (L/s)	Drain Down cartridge flow rate (L/s)	Minimum hydraulic drop (mm)
460	5.0	2.5	150
230	2.5	1.25	150

Table 1: Jellyfish cartridge details

Configurations

The Jellyfish treatment system can be housed in a variety of ways such that it suits the site specific requirements for flowrate, hydraulics, accessibility and footprint restrictions. The standard configuration offered by Ocean Protect is pre-cast concrete manholes. These systems are simple to install, as they arrive on site after being manufactured offsite to suit site specific requirements (pipe size, inlet/outlet orientation, levels etc.). Larger cast-in-place Jellyfish filter vaults are available to treat larger flows. Pre-cast Manhole Jellyfish Filter systems pre-configured (pipe size, location, unit height etc.) prior to arrival upon site for ease of installation.

Figure 3: Jellyfish precast manhole

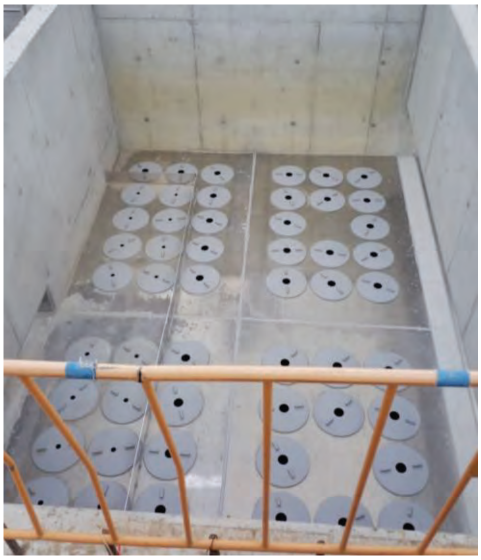

Figure 4: Jellyfish vault

Performance and Select Approvals

While laboratory testing provides a means to generate hydraulic and basic performance data, all filtration devices should also be complemented with long-term field data evaluations. As a minimum, field studies should generally comply with a recognised field testing protocol, for example, the Technology Acceptance Reciprocity Partnership (TARP) or the Technology Assessment Protocol – Ecology (TAPE) in the USA.

To be considered valid, all field monitoring programs should be peer reviewed by a reputable third party and replicate local pollutant concentrations including soluble fractions of nutrients together with rainfall. Ocean Protect has undertaken such field testing both locally in Australia and overseas, copies of the supporting articles are available upon request.

For almost 10 years the Jellyfish system has been successfully installed in a variety of applications to meet regulatory requirements set by authorities throughout Australia.

Specifically Jellyfish has been accepted by some of the most stringent stormwater quality regulators around the globe including;

- Brisbane City Council
- Wollondilly Shire Council
- Campbelltown City Council
- Blacktown City Council
- Washington State Department of Ecology (TAPE) GULD – Basic
- New Jersey Corporation of Advanced Technology (NJCAT)
    - Field Performance per TARP Tier II Protocol

- Canada ISO 14034 Environmental Management – Environmental Technology Verification (ETV)

Please contact your Ocean Protect representative to obtain the Jellyfish Filter approval status in your area.

Maintenance

Every manufactured filtration device will eventually need routine maintenance. The question is how often and how much it will cost. Proper evaluation of long-term maintenance costs should be a consideration when selecting a manufactured treatment device.

Jellyfish Filter cartridges are light weight and reusable and minor maintenance of the filter cartridges is performed by removing, rinsing and reusing the cartridge tentacles. Vacuum extraction of captured pollutants in the sump is recommended at the same time.

Full cartridge replacement intervals differ by site due to varying pollutant loading and type, and maintenance frequency and replacement is anticipated to be every 2-5 years.

Maintenance support

Ocean Protect provides flexible options and contract terms. A detailed maintenance guide and mass load calculation spreadsheet is available upon request.

For further information please refer to the Jellyfish Operations and Maintenance Manual (**click here**).

Design Basics

The design requirements of any Jellyfish system is detailed in 3 typical steps.

1. Hydraulic Design
2. Water Quality Design
3. Mass Load Design

1. Hydraulic Design

All Jellyfish systems must be designed to ensure that the hydraulic requirements of the system are met without adversely impacting the upstream hydraulics (limiting the likelihood of localised flooding). Table 1 (page 3) details the available head loss options. The designer must initially select an option and ensure the corresponding head loss can be catered for.

For a Jellyfish Filter head loss does not have to equal head drop. Head loss should be achieved through a differential of height between the inlet and outlet pipes, at a minimum of 150mm with the remainder created by an upstream diversion weir.

Jellyfish cartridges have a unique backflush mechanism that is passively activated at the end of each storm peak to increase the longevity of each cartridge. Consequently, captured pollutants are stored within the system and in order to minimise scour peak flows into the cartridge bay need to be limited. Specifically when peak flows surpass the combined cartridge treatment flow rate the system needs to be arranged off-line.

It is also necessary to consider the impacts that tail water/submergence has on all stormwater treatment devices. In the case of the Jellyfish, tailwater can adversely affect the long term cartridge operation. As such measures should be implemented during design to ensure that the system can operate effectively. If this cannot be achieved on your project an alternative treatment option, such as StormFilter, should be considered

2. Water Quality Design

Ocean Protect recommends and uses the widely endorsed Model for Urban Stormwater Improvement Conceptualisation (MUSIC), which makes it easy to correctly sizing an appropriate Jellyfish system for your site.

A complimentary design service which includes MUSIC modelling is provided by the Ocean Protect engineering team. Simply email your project details to design@oceanprotect.com.au or alternatively you can always call one of our engineers for a discussion or to arrange a meeting in your office. The team will provide you with an efficient design containing details of the devices required to meet your water quality objectives together with budget estimates, product drawings and the MUSIC (.sqz) file.

Alternatively, you can download the MUSIC treatment nodes for the Ocean Protect products from our website (www.oceanprotect.com.au).

When designing/modelling a Jellyfish system for water quality purposes in MUSIC, a single generic treatment node is utilised. The generic treatment node is utilised with relevant removal efficiencies inserted. These parameters can vary based on the jurisdiction (authority) of your project, relevant details can be obtained from Ocean Protect. The high-flow bypass figure is adjusted within the node to represent the treatable flow rate required to obtain water quality targets. Once finalised this figure can be matched with the system flow rates provided in Appendix 1.

All details such as drawings, specifications and maintenance manuals can also be downloaded for integration into your project's documentation. Additionally the Ocean Protect team is available to review your model and provide additional assistance and guidance on the configuration of the StormFilter system(s) for your project.

3. Mass Load Design

At the completion of your water quality design process (as above) it is necessary that maintenance frequency is considered in order to prevent excessive ongoing maintenance requirements. Ocean Protect recommends a minimum minor maintenance frequency of 6 months (rinsing) for the Jellyfish.

All filtration devices occlude overtime, consequently they have a maximum sediment capacity (TSS load). By analysing the mean annual load figures for the Jellyfish generic treatment node, the total annual retained TSS can be determined. To determine the minimum cartridge quantity required by mass load design, the annual retained TSS should be divided by the relevant cartridge sediment capacity. The Ocean Protect team can provide assistance and details on this process.

In determining the final cartridge quantity for your project, you must utilise the largest number of cartridges obtained from undertaking Water Quality and Mass Load design steps.

Appendix 1 – Jellyfish Precast Manhole Standard Configurations

Unit ID	High-flow Cartridges	Drain-down Cartridges	Flow Rate (L/s)	Approximate unit Diameter (m)
JF1200-1-1	1	1	7.5	1.2
JF1200-2-1	2	1	12.5	
JF2250-3-1	3	1	17.5	2.25
JF2250-4-1	4	1	22.5	
JF2250-5-1	5	1	27.5	
JF2250-6-1	6	1	32.5	
JF2250-7-2	7	2	40	
JF2250-8-2	8	2	45	
JF2250-9-2	9	2	50	
JF2250-10-2	10	2	55	
JF3250-11-2	11	2	60	3.25
JF3250-12-2	12	2	65	
JF3250-13-3	13	3	72.5	
JF3250-14-3	14	3	77.5	
JF3250-15-3	15	3	82.5	
JF3250-16-3	16	3	87.5	
JF3250-17-3	17	3	92.5	
JF3250-18-3	18	3	97.5	
JF3250-19-4	19	4	105	
JF3250-20-4	20	4	110	
JF3250-21-4	21	4	115	
JF3250-22-4	22	4	120	
JF3250-23-4	23	4	125	
JF3250-24-4	24	4	130	
JF3250-25-5	25	5	137.5	
JF3250-26-5	26	5	142.5	
JF3250-27-5	27	5	147.5	
JF3250-28-5	28	5	152.5	

Appendix B Jellyfish® Operation & Maintenance Manual

This appendix provides an operation and maintenance manual for Jellyfish®, produced by Ocean Protect.

Jellyfish Filter

Operations & Maintenance Manual

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Introduction

The primary purpose of stormwater treatment devices is to capture and prevent pollutants from entering waterways, maintenance is a critical component of ensuring the ongoing effectiveness of this process. The specific requirements and frequency for maintenance depends on the treatment device and pollutant load characteristics of each site. This manual has been designed to provide details on the cleaning and maintenance processes for the Jellyfish Filter as recommended by the manufacturer.

The Jellyfish Filter is a stormwater quality treatment technology featuring high surface area and high flow rate membrane filtration at low driving head. By incorporating pre-treatment with light-weight membrane filtration, the Jellyfish Filter removes floatables, trash, oil, debris, TSS and a high percentage of particulate-bound pollutants; including phosphorus and nitrogen, metals and hydrocarbons.

Why do I need to perform maintenance?

Adhering to the maintenance schedule of each stormwater treatment device is essential to ensuring that it functions properly throughout its design life.

During each inspection and clean, details of the mass, volume and type of material that has been collected by the device should be recorded. This data will assist with the revision of future management plans and help determine maintenance interval frequency. It is also essential that suitably qualified and experienced personnel carry out all maintenance (including inspections, recording and reporting) in a systematic manner.

Maintenance of your stormwater management system is essential to ensuring ongoing at-source control of stormwater pollution. Maintenance also helps prevent structural failures (e.g. prevents blocked outlets) and aesthetic failures (e.g. debris build up), but most of all ensures the long term effective operation of the Jellyfish.

Health and Safety

Access to a Jellyfish unit requires removing heavy access covers/grates, and entry into a confined space. Pollutants collected by the Jellyfish will vary depending on the nature of your site. There is potential for these materials to be harmful. For example, sediments may contain heavy metals, carcinogenic substances or objects such as broken glass and syringes. For these reasons, all aspects of maintaining and cleaning your Jellyfish require careful adherence to Occupational Health and Safety (OH&S) guidelines.

It is important to note that the same level of care needs to be taken to ensure the safety of non-work personnel. As a result, it may be necessary to employ traffic/pedestrian control measures when the device is situated in, or near areas with high vehicular/pedestrian activity.

Personnel health and safety

Whilst performing maintenance on the Jellyfish, precautions should be taken in order to minimise (or, if possible, prevent) contact with sediment and other captured pollutants by maintenance personnel. The following personal protective equipment (PPE) is subsequently recommended:

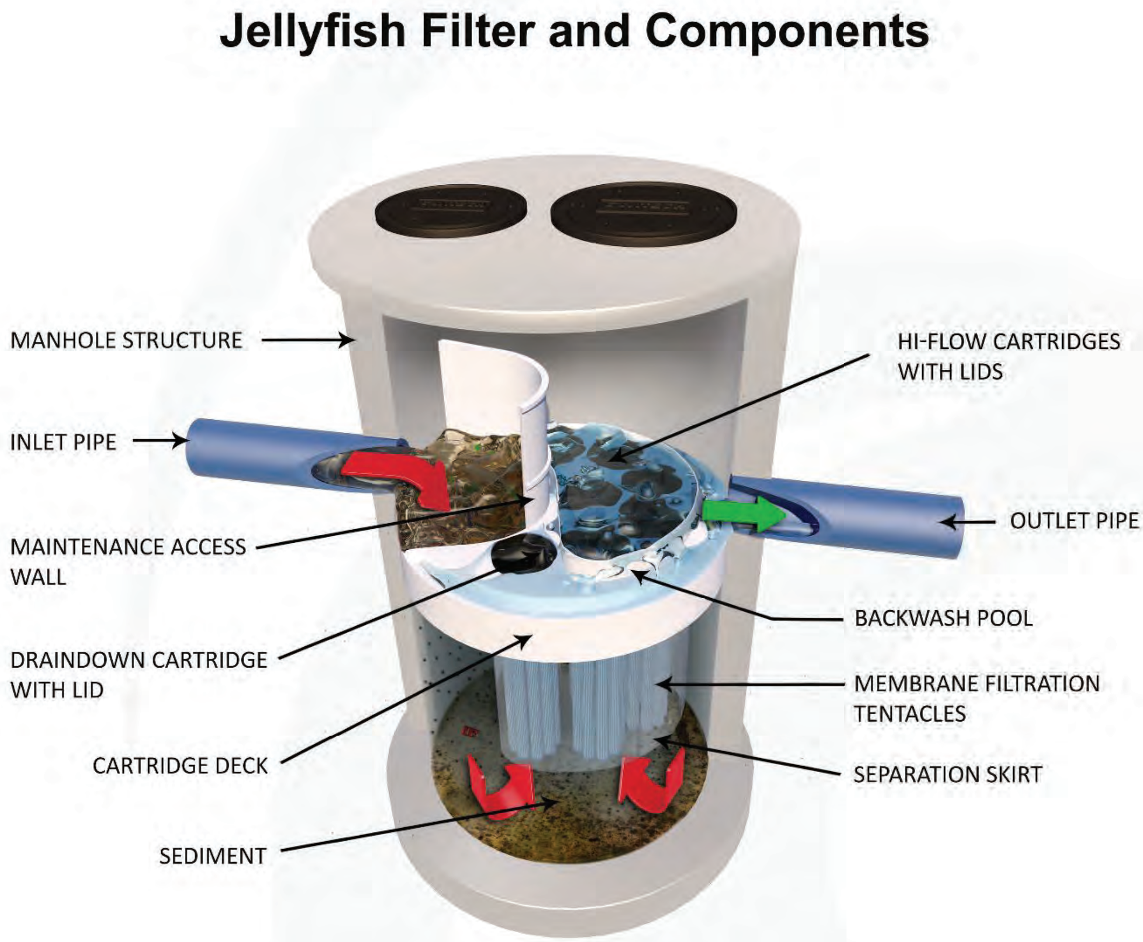
- Puncture resistant gloves
- Steel capped safety boots
- Long sleeve clothing, overalls or similar skin protection
- Eye protection
- High visibility clothing or vest

During maintenance activities, it may be necessary to implement traffic control measures. Ocean Protect recommend that a separate site-specific traffic control plan is implemented as required to meet the relevant governing authority guidelines.

Whilst some aspects of Jellyfish maintenance can be performed from surface level, there will be a need to enter the Jellyfish pit (confined space) for both minor and major services. It is recommended that all maintenance personnel evaluate their own needs for confined space entry and compliance with relevant industry regulations and guidelines. Ocean Protect maintenance personnel are fully trained and carry certification for confined space entry applications.

How does it Work?

Stormwater enters the Jellyfish system through the inlet pipe where floatable pollutants are captured behind the maintenance access wall. As stormwater enters the treatment chamber a separation skirt ensures the retention of oils whilst simultaneously protecting the filtration cartridges and allowing coarse particles to settle below on the chamber floor. Stormwater then passes through the Jellyfish cartridges and onto the Jellyfish deck, at this point the backwash pool will fill and overflow allowing treated stormwater to exit via the outlet pipe.



As the storm event subsides, the treated water held in the backwash pool passes back through the high flow cartridges into the treatment chamber. This passive backwash helps to clear the cartridge surface by dislodging sediment onto the chamber floor. The drain down cartridge(s) located outside the backwash pool enables water levels to balance, leaving the cartridge deck level free of standing water.

Maintenance Procedures

To ensure optimal performance, it is advisable that regular maintenance is performed. Typically the Jellyfish requires a service every 6 months, additionally as the Jellyfish cartridges capture pollutants they will need to be replaced (expected cartridge life is 2-5 years with a maximum cartridge life of 5 years).

Primary Types of Maintenance

The table below outlines the primary types of maintenance activities that typically take place as part of an ongoing maintenance schedule for the Jellyfish.

	Description of Typical Activities	Frequency
Minor Service	Removal & rinsing of cartridges Wash down of deck level Removal of large floatable pollutants Removal of accumulated sediment (if required)	Every 6 Months
Major Service	Replacement of Jellyfish cartridges	As required

Maintenance requirements and frequencies are dependent on the pollutant load characteristics of each site. The frequencies provided in this document represent what the manufacturer considers to be best practice to ensure the continuing operation of the device is in line with the original design specification.

Minor Service

This service is designed to assess the condition of the Jellyfish cartridges and record necessary information that will establish whether a major service is required.

1. Establish a safe working area around the access point
2. Remove access covers
3. Using a vacuum unit or net remove any floatable gross pollutants contained behind the maintenance access wall
4. Using a vacuum unit decant the water until the level drops below the base of the cartridges
5. Remove Jellyfish cartridges*
    a. Remove cartridge lid
    b. Remove cartridges vertically from chamber, lifting from eye nut lifting points only
    c. Replace and secure cartridge lid back into deck to reduce trip hazards during maintenance
6. Unscrew all 11 tentacles from the cartridge head plate, keep all components for reassembly*
7. Rinse each tentacle individually NOTE: excessive water pressure may damage the tentacles
    a. Position tentacle in a container (to capture runoff) with the open end facing down
    b. Rinse entire length of cartridge using only low pressure water source (e.g. garden hose).
    c. Evaluate and note the condition of the tentacles
    d. Ensure runoff is disposed appropriately
    e. Re-assemble cartridges ready for reinstallation*
8. Wash down deck level to remove any built up sediment (if required)
9. Measure the level of accumulated sediment in the chamber if depth is greater than 300mm use vacuum unit to remove sediment.
10. Re-install Jellyfish cartridges
    a. Remove cartridge lid
    b. Lower cartridge into chamber, lifting from eye nut lifting points only
    c. Insert cartridge vertically into cartridge receptacle, and secure cartridge lid back in place
11. Replace access covers

**Refer appendix 1 for Jellyfish Cartridge Schematic*

Major Service (Filter Cartridge Replacement)

For the Jellyfish system a major service is a reactionary process based on the outcomes from the minor service.

Trigger Event	Maintenance Action
Rinsing does not remove accumulated sediment from the tentacles	Replace Jellyfish tentacles[1]
Jellyfish tentacles are damaged	Replace Jellyfish tentacles[1]
Jellyfish cartridges have been in operation for 5 years	Replace Jellyfish tentacles[1]

[1] Replacement filter tentacles and components are available for purchase from Ocean Protect.

This service is designed to return the Jellyfish device back to optimal operating performance

1. Establish a safe working area around the access point
2. Remove access covers
3. Using a vacuum unit or net remove any floatable gross pollutants contained behind the maintenance access wall
4. Using a vacuum unit decant the water until the level drops below the base of the cartridges
5. Remove Jellyfish cartridges*
    a. Remove cartridge lid
    b. Remove cartridges vertically from chamber, lifting from eye nut lifting points only
    c. Replace and secure cartridge lid back into deck to reduce trip hazards during maintenance
6. Unscrew all 11 tentacles from the cartridge head plate for disposal, keep all components for fixing of new tentacles to existing head plate*
7. Wash down deck level to remove any built up sediment (if required)
8. Use vacuum unit to remove accumulated sediment and pollutants in the chamber
9. Install replacement tentacles into each head plate*
10. Install Jellyfish cartridges
    a. Remove cartridge lid
    b. Lower cartridge into chamber, lifting from eye nut lifting points only
    c. Insert cartridge vertically into cartridge receptacle, and secure cartridge lid back in place
11. Replace access covers

**Refer appendix 1 for Jellyfish Cartridge Schematic*

Additional Types of Maintenance

Occasionally events on site can make it necessary to perform additional maintenance to ensure the continuing performance of the device.

Hazardous Material Spill

If there is a spill event on site, the Jellyfish unit should be inspected and serviced accordingly. Specifically, all captured pollutants and liquids from within the unit should be removed and disposed in accordance with any additional requirements that may relate to the type of spill event. Additionally, it will be necessary to inspect the filter cartridges and assess their contamination, depending on the type of spill event it may be necessary to replace the filtration cartridges.

Blockages

The Jellyfish treatment system is designed to operate in an offline arrangement, where an upstream high flow bypass structure is in used. In the unlikely event that flooding occurs upstream of the Jellyfish system, the following steps should be undertaken to assist in diagnosing the issue and determining the appropriate response.

1. Inspect the upstream diversion structure to ensure that it is free of debris and pollutants
2. Inspect the Jellyfish unit checking both the inlet and outlet pipes for obstructions (e.g. pollutant build-up, blockage), which if present, should be removed.

Major Storms and Flooding

In addition to the scheduled activities, it is important to inspect the condition of the Jellyfish after a major storm event. The focus is to inspect for damage and higher than normal sediment accumulation that may result from localised erosion. Where necessary, damaged components should be replaced and accumulated pollutants should be removed and disposed.

Disposal of Waste Materials

The accumulated pollutants found in the Jellyfish must be handled and disposed of in a manner that is in accordance with all applicable waste disposal regulations. When scheduling maintenance, consideration must be made for the disposal of solid and liquid wastes. If the filter cartridges have been contaminated with any unusual substance, there may be additional special handling and disposal methods required to comply with relevant government/authority/industry regulations.

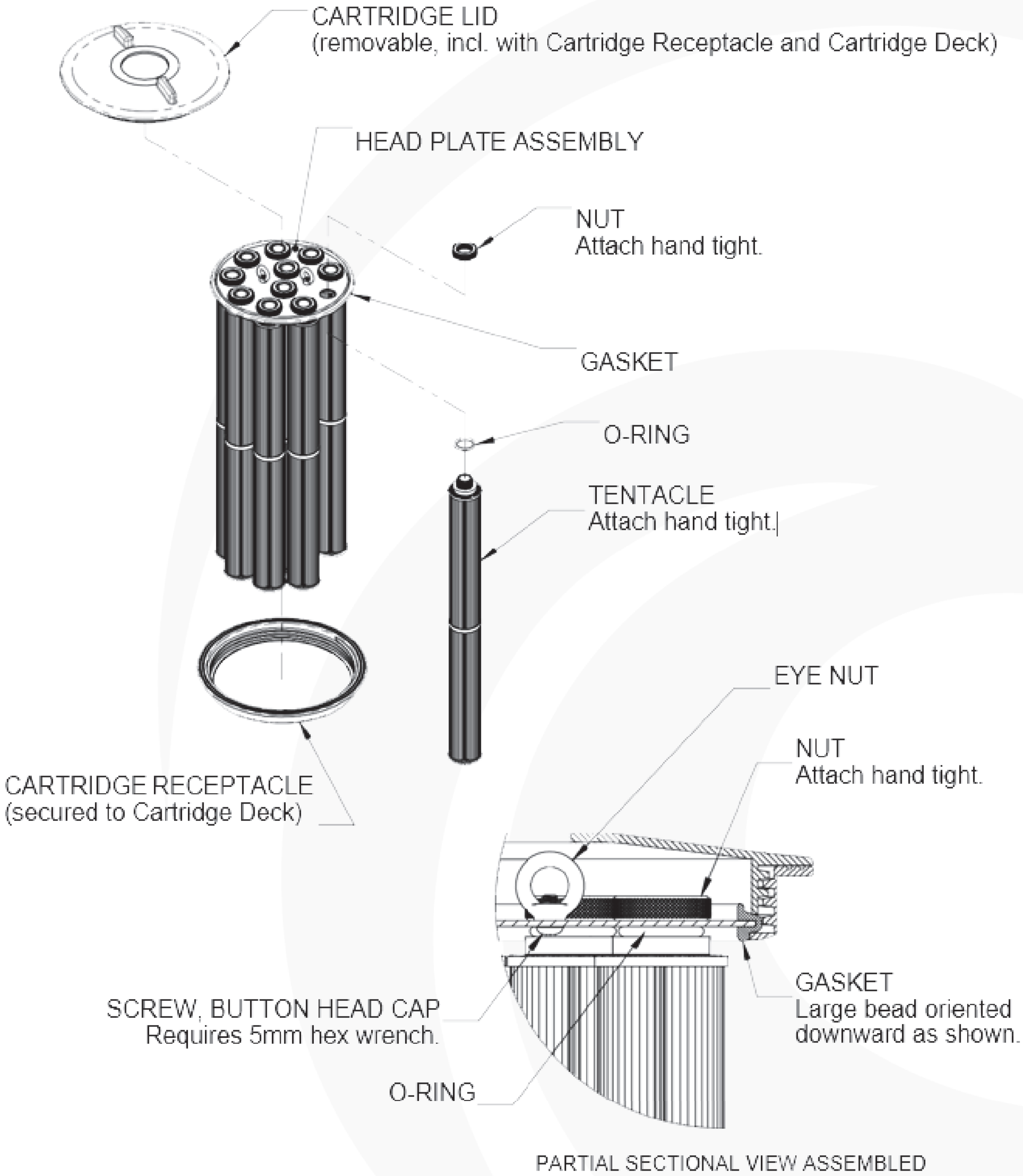
Maintenance Services

With over a decade and a half of maintenance experience Ocean Protect has developed a systematic approach to inspecting, cleaning and maintaining a wide variety of stormwater treatment devices. Our fully trained and professional staff are familiar with the characteristics of each type of system, and the processes required to ensure its optimal performance.

Ocean Protect has several stormwater maintenance service options available to help ensure that your stormwater device functions properly throughout its design life. In the case of our Jellyfish system we offer long term pay-as-you-go contracts, pre-paid once off servicing and replacement cartridges.

For more information please visit www.OceanProtect.com.au

Appendix 1 – Jellyfish Cartridge Schematic



Appendix C Technical Papers Describing Stormwater Treatment Performance Monitoring of Jellyfish®

Table 2-1 provides a summary of a Jellyfish® operating in ‘real world’ conditions at West Ipswich where treatment performance monitoring has been undertaken. This appendix provides two technical papers describing the stormwater treatment performance monitoring undertaken at this site.

HUMES AUSTRALIA

EVALUATION OF TREATMENT PERFORMANCE OF THE JELLYFISH® FILTER INSTALLATION AT IPSWICH

FINAL REPORT ON THE FIELD MONITORING PROGRAM

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17th February 2017

EXECUTIVE SUMMARY

Background

The Jellyfish® Filter is an engineered stormwater quality treatment technology featuring membrane filtration in a compact stand-alone treatment system. Jellyfish® Filter was tested for field performances by the University of Florida (UoF) over a 13-month period spanning May 28, 2010 to June 27, 2011. However, verification of Florida study outcomes and further performance testing under Australian climatic conditions was considered essential for the introduction of the Jellyfish® Filter to the local market. Accordingly, Queensland University of Technology (QUT) was requested by Humes Australia to undertake a comprehensive field based monitoring study to verify the performance of the treatment device under South East Queensland (SEQ) climatic conditions.

QUT adopted a two phase approach to assess the treatment performances. The first phase consisted of assessing the compatibility of performance characteristics reported in UoF (2011) to South East Queensland (SEQ) climatic conditions. Phase 1 of the study has been completed and reported in August 2013 (Goonetilleke et al. 2013). The second phase consisted of evaluating the treatment performance under SEQ climatic condition by undertaking a field monitoring program centred on a device installed at Ipswich. This report reports the outcomes of Phase 2 of the study.

Study approach

For this study, the Jellyfish® Filter installed at a recently developed commercial facility located at 292 Brisbane Street, West Ipswich 4305, QLD was used. The system was installed such that detailed monitoring could be undertaken. The monitoring system installed included a flow measuring device, rain gauge and discrete automatic sample collection equipment at the inlet and outlet of the Jellyfish® Filter. Sampling equipment was programmed to trigger based on the occurrence of rainfall.

Runoff samples originating from qualifying rainfall events with a minimum of three antecedent dry days and more than 2.6mm rainfall depth were tested for water quality parameters. Altogether, samples from seventeen rainfall events were tested and evaluated as part of this study. The parameters tested included, total suspended solids (TSS), total nitrogen (TN), nitrate, total Kjeldhal nitrogen (TKN), phosphate, total phosphorus (TP) and total organic carbon (TOC), total petroleum hydrocarbons (TPH) and heavy metals (HM). Laboratory testing was undertaken at a NATA registered laboratory (Advanced Analytical Laboratory).

Summary conclusions

The key findings of the study are:

- For the seventeen events monitored, median concentration reduction efficiencies for TSS, TN and TP are 89%, 50% and 54%, respectively. These performance values are comparable with the Florida monitoring study where performance was reported as 89%, 51% and 59% concentration reduction for TSS, TN and TP, respectively.

- The Jellyfish® Filter system registered near complete removal of particles greater than 200µm. For particle sizes less than 200µm, the removal was similar for the different particle size ranges.
- Comparison of monitored rainfall events confirms that these are within the envelope of typical rainfall events for the Brisbane region. Events are also comparable to the events monitored in Florida.
- Inflow quality of the monitored events is well within the expected stormwater quality from urban catchments in the Brisbane region. The comparison was made based on MUSIC parameters, where were considered as typical stormwater quality in Brisbane catchments.

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1. Background

The Jellyfish® Filter is an engineered stormwater quality treatment technology featuring membrane filtration in a compact stand-alone treatment system. The system is designed to remove a wide variety of stormwater pollutants. The Jellyfish® Filter integrates pre-treatment and filtration with a passive self-cleaning mechanism. The system utilises membrane filtration cartridges with high filtration surface area and flow capacity and designed to operate under relatively low driving head compared to conventional filter systems. Performance of the Jellyfish® Filter as a stormwater treatment device had been tested and deemed appropriate for the US market (UoF, 2011).

Further performance testing under Australian climatic conditions was considered essential for the introduction of the Jellyfish® Filter to the local market. Accordingly, Queensland University of Technology (QUT) was requested by Humes Australia to undertake a comprehensive field based monitoring study to verify the performance of the treatment device under South East Queensland (SEQ) climatic conditions.

A two phase approach was adopted by QUT to assess the treatment performance of the Jellyfish® Filter. The first phase consisted of assessing the compatibility of performance characteristics reported in UoF (2011) to South East Queensland (SEQ) climatic conditions using advanced statistical approaches for performance replication of the device. The second phase consisted of evaluating the treatment performance under SEQ climatic condition by undertaking a field monitoring program centred on a device installed at Ipswich.

Phase 1 of the study has been completed and reported in August 2013 (Goonetilleke et al. 2013). This report is the final report of the field monitoring program under Phase 2. In this report, the treatment performance of the Jellyfish Filter installed at Ipswich is discussed.

2. Monitoring System

2.1 Site Description

The site is a recently developed commercial facility located at 292 Brisbane Street, West Ipswich 4305, QLD. The site has a total area of $1678m^2$ with approximately $550m^2$ of roof area and $1128m^2$ of impervious driveways and parking lots. Figure 1 shows the layout of the development, including the stormwater drainage network.

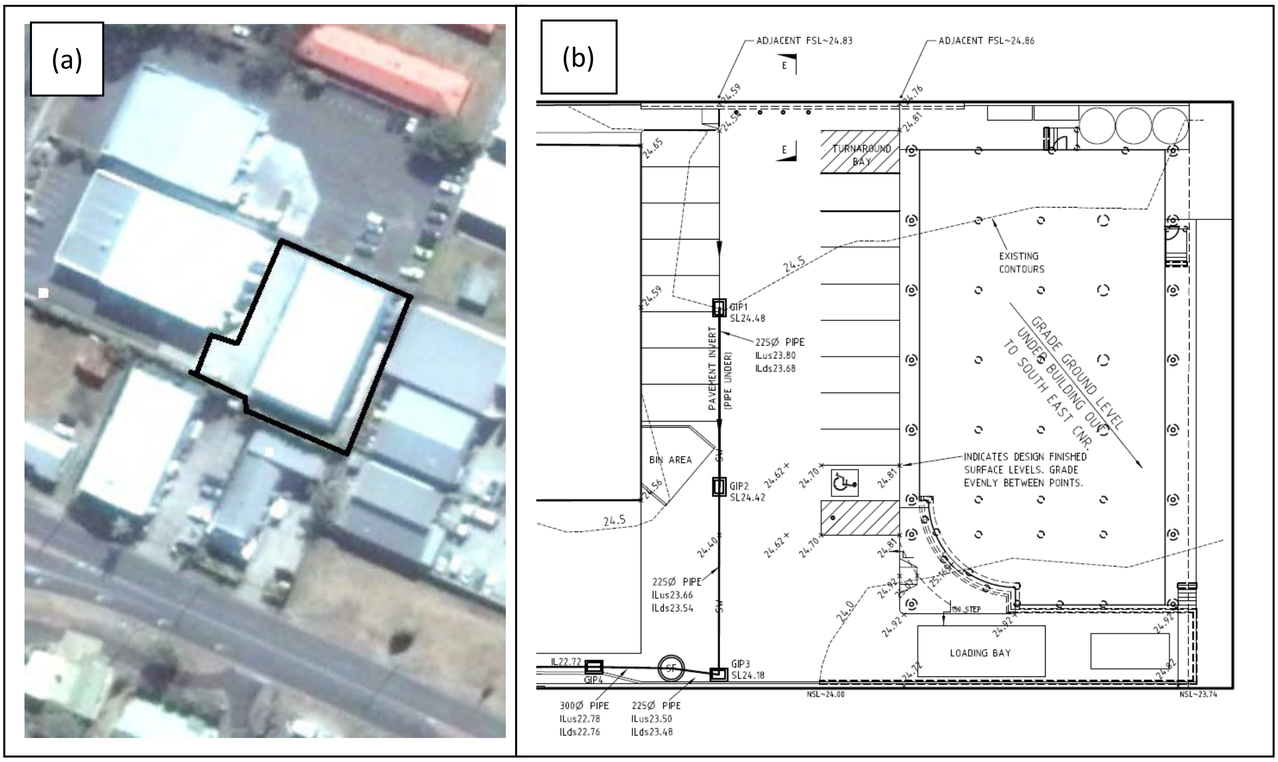


Figure 1. Study site: (a) aerial view; (b) drainage network plan

The stormwater drainage at the site is handled by a piped, subsurface network. Driveway runoff from the site enters the drainage network via grated manholes while downpipes from the roof are directed to rainwater tanks, and the overflow pipe to the closest stormwater drainage manhole. The treatment device is fitted as a part of the drainage network after the last grated manhole within the site as shown in Figure 2.

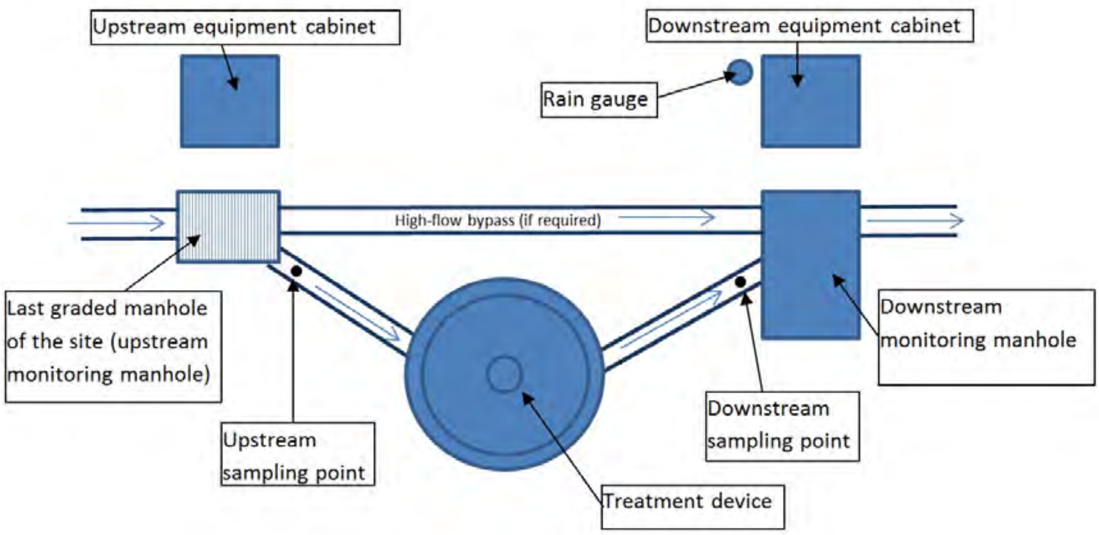


Figure 2. Monitoring system layout

2.2 Instrumentation and Sampling Methodology

Automatic sampling stations were installed at two sampling points as shown in Figure 2. The upstream sampling point was equipped with a flow measuring device and an automatic sample collection system while the downstream sampling point was only equipped with an automatic sample collection system. A tipping bucket rain gauge was installed as part of the field monitoring system. A schematic of the field monitoring system is shown in Figure 3.

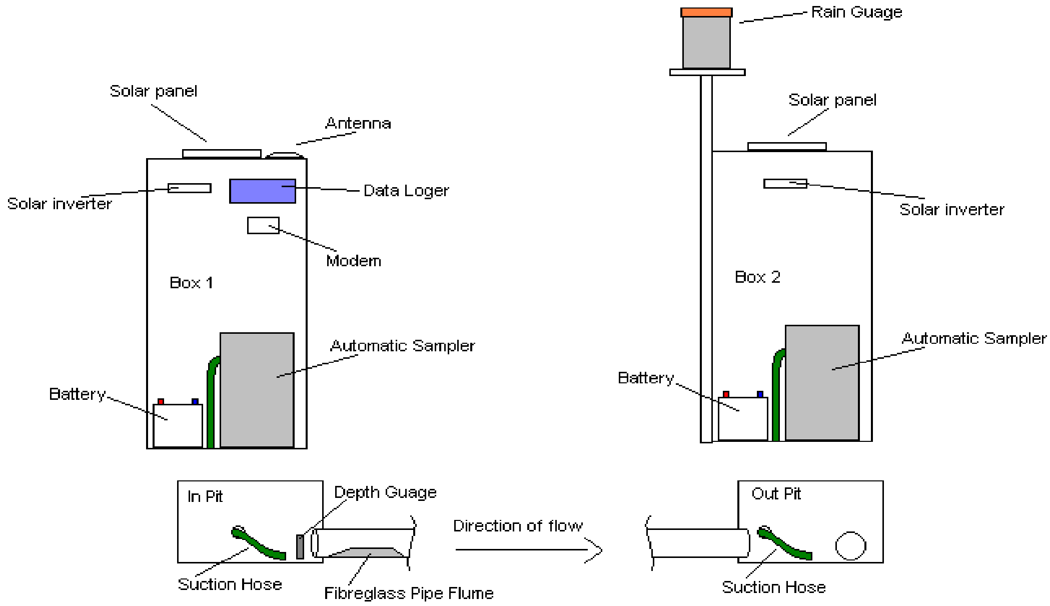


Figure 3. Schematic of the two sampling points

The flow measuring device installed at the upstream sampling point consists of a high accuracy Control Logic LMP307 pressure transducer with a range of 0-1 and a pipe insert Palmer-Bowlus flume (8 inch). The pressure transducer was mounted on the wall of the manhole just upstream of the flume so that depth measurements can be translated to flow using the rating table associated with the flume. The flume device and the pressure transducer operation were calibrated over a range of flow rates prior to the commencement of the monitoring program.

Two ISCO 6712 automatic samplers with capacity to hold 24 samples were installed to collect runoff samples from upstream and downstream sampling points as shown in Figure 3. Automatic samplers werere housed in weatherproof security cabinets close to each sampling point. The suction hoses were kept as short as possible to reduce head loss. Sampling stations were equipped with data loggers, battery and solar chargers to ensure independent operation. The RIMCO RIM7499 tipping bucket rain gauge installed to measure rainfall has a resolution of 0.2mm. The rain gauge was mounted on a three metre pole as shown in Figure 3 to reduce the impact of rain shadow created by any neighbouring buildings. A Bureau of Meteorology operated rain gauge is situated approximately 600m away from the study site.

2.3 Sample Handling and Testing

A carefully formulated methodology was adopted for the selection of appropriate rainfall events for evaluation, runoff sample collection and sample handling and testing. Only runoff samples originating from rainfall events with a minimum of three antecedent dry days and more than 2.6mm rainfall depth were tested. These rainfall events were classified as qualifying events. This was to ensure that there are representative contributions from both driveways/parking lots and roof runoff as well as to ensure that there was appreciable accumulation of pollutants on the impervious surfaces. The automatic samplers were programmed to collect discrete samples.

The samplers were programmed to trigger based on the occurrence of rainfall. Sampling intervals were programmed to vary based on the intensity of the rainfall received. Runoff samples collected from a qualifying rainfall event were combined to form a composite sample (Event Mean Concentration – EMC). Representative aliquots of samples were extracted using a churn sample splitter (Bel-Art Products) and submitted to a NATA registered laboratory (Advanced Analytical Laboratory) for analysis. The parameters tested and the test methods adopted are listed in Table 1. An aliquot of the same sample was submitted to the QUT laboratories for the analysis of particle size distribution (PSD). Sample collection, handling and transport were undertaken in accordance with AS/NZS 5667.1:1998.

Table 1. List of parameters and test methods

Parameter	Method
pH	APHA (2012) Method 4500
Electrical conductivity	APHA (2012) Method 2510B
Heavy metals – Fe , Al, Mn , Cu, Cr, Pb, Ni, Zn, Cd	US EPA 200.8/3050B/6010B US EPA (1994), US EPA (1996a, b),
Total nitrogen, NO_3, TKN	APHA (2012) Method 4500 by discrete analyser with persulphate digestion
Total phosphorus, FRP (orthophosphate P)	APHA (2012) Method 4500 by discrete analyser with persulphate digestion
Total suspended solids	APHA (2012) Method 2540 D
Total organic carbon	APHA (2012) Method 5310 by TOC analyser
Total petroleum hydrocarbon (C6-C36)	NEPM 2013
Particle size distribution	Laser diffraction method using a Malvern Mastersizer instrument

3. Results and Discussion

The evaluation of the seventeen qualifying rainfall events which occurred over a 15 month period from 28th June 2014 to 26th September 2015 is discussed in this report. Rainfall information for the monitored events are presented in Table 2.

Table 2. Characteristics of monitored events

Date Sampled	Rainfall Depth (mm)	Rainfall Duration (minutes)	Peak Intensity (mm/hr)	Number of Samples Taken
2014-06-28	5.2	19	57	3
2014-08-16	33	1222	27.4	24
2014-08-27	7.2	128	13.7	14
2014-09-25	8.6	214	18.9	4
2014-10-13	7	597	15.4	13
2014-10-27	3	36	10.3	7
2014-11-06	5.2	36	20.6	8
2014-11-28	4.8	182	15.1	11
2014-12-06	11.2	277	20.6	24
2015-03-19	10.2	204	41.1	15
2015-04-01	21.4	203	49.7	24
2015-04-30	9	760	10.3	24
2015-05-18	11.2	209	29.1	22
2015-06-30	4.2	427	10.3	10
2015-08-26	2.8	531	6.2	8
2015-09-17	24.6	105	45.6	19
2015-09-26	16.4	215	50.4	18

As evident from Table 2, the seventeen monitored events consist of rainfall depths ranging from 2.8mm to 33mm. The peak runoff rate through the system varies from 0.3L/s to 222.9L/s.

3.1 Parameter Concentration Values

As shown in Table 2, runoff samples were collected at the inlet and outlet for laboratory analyses. The laboratory test results for the monitored events are given in Table 3 and Table 4. Table 3 gives the test results for the primary water quality parameters including total suspended solids (TSS), total nitrogen (TN), nitrate, total Kjeldhal nitrogen (TKN), phosphate, total phosphorus (TP) and total organic carbon (TOC). Table 4 gives the test results for total petroleum hydrocarbons (TPH) and heavy metals commonly present on urban surfaces. Both tables include practical quantification limits specific for the test instrument used.

Table 3. Water quality parameters: Solids, nutrients and organic carbon

Sampling Point	Date sampled	pH	EC	TSS	Nitrate	TKN	TN	Phosphate	TP	TOC
	Units	pH unit	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	PQL	1.0	1	2	0.01	0.1	0.1	0.01	0.02	1.0
Inflow	2014-06-28	6.4	40	180	0.19	1.1	1.3	<0.01	0.24	5
Outflow		6.8	120	13	0.11	1.2	1.3	0.03	0.24	5
Inflow	2014-08-16	7.3	70	170	0.33	2.4	2.8	0.18	0.41	9
Outflow		7.1	50	2	0.28	0.2	0.5	0.02	0.03	4
Inflow	2014-08-27	7	120	19	0.42	0.6	1.1	0.06	0.093	4
Outflow		6.9	70	2	0.17	0.3	0.5	0.02	0.05	2
Inflow	2014-09-25	6.9	150	26	1.9	1.7	3.1	0.02	0.17	9
Outflow		6.6	55	4	0.28	0.8	1.1	<0.01	0.06	6
Inflow	2014-10-13	7	125	25	0.79	1	1.9	0.05	0.17	7
Outflow		7	140	4	0.31	1.5	1.9	0.03	0.12	6
Inflow	2014-10-27	6.7	145	51	0.73	5.2	6	0.27	0.53	32
Outflow		6.9	130	10	0.82	1.5	2.3	0.07	0.17	18
Inflow	2014-11-06	6.8	105	74	0.58	2.6	3.2	0.36	0.31	11
Outflow		6.8	80	8	0.61	1	1.6	0.06	0.08	8
Inflow	2014-11-28	6.4	145	21	1.3	4.4	5.7	0.27	0.49	22
Outflow		6.5	100	5	0.69	1.8	2.5	0.04	0.095	13
Inflow	2014-12-06	6.7	100	13	0.71	1.3	2	0.07	0.19	11
Outflow		6.8	90	<2	0.62	0.7	1.3	0.01	0.07	8
Inflow	2015-03-19	6.8	80	18	0.45	0.8	1.3	0.05	0.14	8
Outflow		6.6	50	3	0.25	0.7	1	0.03	0.09	6
Inflow	2015-04-01	7.4	110	30	0.87	0.7	1.6	0.09	0.11	4
Outflow		9	100	4	0.7	0.2	0.9	0.04	0.07	3
Inflow	2015-04-30	7.4	115	20	0.34	0.7	1	0.05	0.11	5
Outflow		7.1	160	3	0.16	0.1	0.3	0.06	0.11	5
Inflow	2015-05-18	6.6	65	11	0.35	1.2	1.6	0.07	0.16	7
Outflow		7.1	90	5	0.44	1.1	1.5	0.04	0.1	4
Inflow	2015-06-30	7.2	145	26	0.8	2	2.9	0.15	0.26	7
Outflow		7.3	130	2	0.12	0.9	1	0.03	0.07	5
Inflow	2015-08-26	6.6	150	80	1.8	2.7	4.4	0.14	0.35	16
Outflow		7.2	220	3	0.1	2.2	2.3	0.17	0.27	10
Inflow	2015-09-17	6.8	80	140	0.45	2	2.4	0.01	0.24	6
Outflow		7	95	2	0.66	0.6	1.3	0.01	0.08	8
Inflow	2015-09-26	6.7	90	78	0.32	1.9	2.3	0.01	0.22	9
Outflow		7	110	2	0.31	0.7	1	0.01	0.1	5

Note:

PQL – Practical quantification limit

Table 4. Water quality parameters: total petroleum hydrocarbons and heavy metals

Sampling Point	Date	TPH C6-C9	TPH C10-14	TPH C15-28	TPH C29-36	Al	Cd	Cr	Cu	Fe	Mg	Ni	Pb	Zn
	Units	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	PQL	25	50	100	100	0.05	0.001	0.002	0.002	0.05	0.005	0.003	0.006	0.005
Inflow	2014-06-28	<25	<50	<100	<100	3	<0.001	0.012	0.039	3.8	0.12	0.005	0.01	0.3
Outflow		<25	150	200	<100	0.2	<0.001	0.002	0.015	1.2	0.13	<0.003	<0.006	0.041
Inflow	2014-08-16	<25	<50	<100	<100	4	<0.001	0.018	0.069	4.6	0.16	0.012	0.012	0.75
Outflow		<25	<50	<100	<100	0.05	<0.001	0.006	0.012	<0.05	0.012	<0.003	<0.006	0.017
Inflow	2014-08-27	<25	<50	<100	<100	0.74	<0.001	0.004	0.01	0.68	0.023	<0.003	<0.006	0.11
Outflow		<25	<50	<100	<100	0.08	<0.001	<0.002	0.005	0.17	0.023	<0.003	<0.006	0.024
Inflow	2014-09-25	<25	<50	140	<100	0.94	<0.001	0.008	0.026	0.96	0.034	<0.003	<0.006	0.18
Outflow		<25	<50	120	<100	0.08	<0.001	0.007	0.01	0.11	0.013	<0.003	<0.006	0.027
Inflow	2014-10-13	<25	<50	160	110	0.75	<0.001	0.004	0.016	0.86	0.037	<0.003	<0.006	0.15
Outflow		<25	<50	180	110	0.093	<0.001	0.002	0.005	0.95	0.099	<0.003	<0.006	0.032
Inflow	2014-10-27	<25	100	570	240	1.8	<0.001	0.009	0.038	2.1	0.13	0.005	0.01	0.43
Outflow		<25	98	450	200	0.19	<0.001	0.002	0.012	1.1	0.087	<0.003	<0.006	0.06
Inflow	2014-11-06	<25	<50	160	<100	1.9	<0.001	0.007	0.025	2.3	0.11	0.004	0.007	0.29
Outflow		<25	<50	160	<100	0.19	<0.001	<0.002	0.007	0.34	0.032	<0.003	<0.006	0.035
Inflow	2014-11-28	<25	<50	230	<100	1	<0.001	0.006	0.026	1.2	0.081	0.004	0.0094	0.35
Outflow		<25	<50	250	120	0.2	<0.001	0.003	0.022	0.49	0.064	<0.003	<0.006	0.045
Inflow	2014-12-06	<25	<50	180	110	0.57	<0.001	0.006	0.016	0.63	0.034	<0.003	<0.006	0.13
Outflow		<25	<50	170	<100	0.07	<0.001	0.003	0.011	0.12	0.03	<0.003	<0.006	0.027
Inflow	2015-03-19	<25	<50	150	<100	0.47	<0.001	0.004	0.015	0.52	0.033	<0.003	<0.006	0.14
Outflow		<25	<50	140	<100	0.09	<0.001	0.002	0.008	0.2	0.036	<0.003	<0.006	0.057
Inflow	2015-04-01	<25	<50	120	<100	0.52	<0.001	0.003	0.0093	0.58	0.018	<0.003	<0.006	0.13
Outflow		<25	<50	110	<100	0.07	<0.001	<0.002	0.004	0.13	0.019	<0.003	<0.006	0.04
Inflow	2015-04-30	<25	<50	<100	110	0.82	<0.001	0.005	0.009	0.8	0.021	<0.003	<0.006	0.11
Outflow		<25	<50	<100	<100	0.05	<0.001	<0.002	0.002	0.52	0.067	<0.003	<0.006	0.012
Inflow	2015-05-18	<25	<50	<100	<100	0.31	<0.001	<0.002	0.008	0.32	0.017	<0.003	<0.006	0.1
Outflow		<25	<50	<100	<100	<0.05	<0.001	<0.002	0.003	0.36	0.048	<0.003	<0.006	0.016
Inflow	2015-06-30	<25	<50	<100	<100	0.68	<0.001	0.003	0.013	0.68	0.02	<0.003	<0.006	0.11
Outflow		<25	<50	<100	<100	0.06	<0.001	<0.002	0.004	0.25	0.037	<0.003	<0.006	0.021
Inflow	2015-08-26	<25	<50	340	170	2	<0.001	0.007	0.031	2.4	0.092	0.006	0.006	0.32
Outflow		<25	65	250	100	0.05	<0.001	<0.002	0.004	1.1	0.14	<0.003	<0.006	0.023
Inflow	2015-09-17	<25	<50	<100	<100	2.9	<0.001	0.01	0.027	3.3	0.14	0.005	0.0094	0.33
Outflow		<25	<50	<100	<100	0.09	<0.001	<0.002	0.005	0.27	0.035	<0.003	<0.006	0.026
Inflow	2015-09-26	<25	<50	140	<100	1.5	<0.001	0.013	0.022	1.8	0.082	0.004	<0.006	0.26
Outflow		<25	<50	<100	<100	0.11	<0.001	<0.002	0.004	0.69	0.094	<0.003	<0.006	0.023

3.2 Treatment Performance

Measured concentrations representing inflows to the treatment device and outflows from the device were used for determining the treatment performance. Treatment performance was evaluated for TSS, TN and TP as these are the primary stormwater quality parameters. The estimated treatment performance is shown in Table 5. Performance is presented in the form of average and median concentration reduction efficiencies (CRE) for TSS, TN and TP.

Table 5. Treatment performances

Date sampled	TSS (mg/L)			TN (mg/L)			TP (mg/L)		
	Inflow	Outflow	C R E	Inflow	Outflow	C R E	Inflow	Outflow	C R E
2014-06-28	180	13	92.8	1.3	1.3	0.0	0.24	0.24	0.0
2014-08-16	170	2	98.8	2.8	0.5	82.1	0.41	0.03	92.7
2014-08-27	19	2	89.5	1.1	0.5	54.5	0.093	0.05	46.2
2014-09-25	26	4	84.6	3.1	1.1	64.5	0.17	0.06	64.7
2014-10-13	25	4	84.0	1.9	1.9	0.0	0.17	0.12	29.4
2014-10-27	51	10	80.4	6	2.3	61.7	0.53	0.17	67.9
2014-11-06	74	8	89.2	3.2	1.6	50.0	0.31	0.08	74.2
28/11/2014	21	5	76.2	5.7	2.5	56.1	0.49	0.095	80.6
6/12/2014	13	1	92.3	2	1.3	35.0	0.19	0.07	63.2
19/03/2015	18	3	83.3	1.3	1	23.1	0.14	0.09	35.7
1/04/2015	30	4	86.7	1.6	0.9	43.8	0.11	0.07	36.4
30/04/2015	20	3	85.0	1	0.3	70.0	0.11	0.11	0.0
18/05/2015	11	5	54.5	1.6	1.5	6.3	0.16	0.1	37.5
30/06/2015	26	2	92.3	2.9	1	65.5	0.26	0.07	73.1
26/08/2015	80	3	96.3	4.4	2.3	47.7	0.35	0.27	22.9
17/09/2015	140	2	98.6	2.4	1.3	45.8	0.24	0.08	66.7
26/09/2015	78	2	97.4	2.3	1	56.5	0.22	0.1	54.5
Averages	58	4		2.6	1.3		0.25	0.11	
Average of C R E			87.2			44.9			49.7
Median of C R E			89.2			50.0			54.5

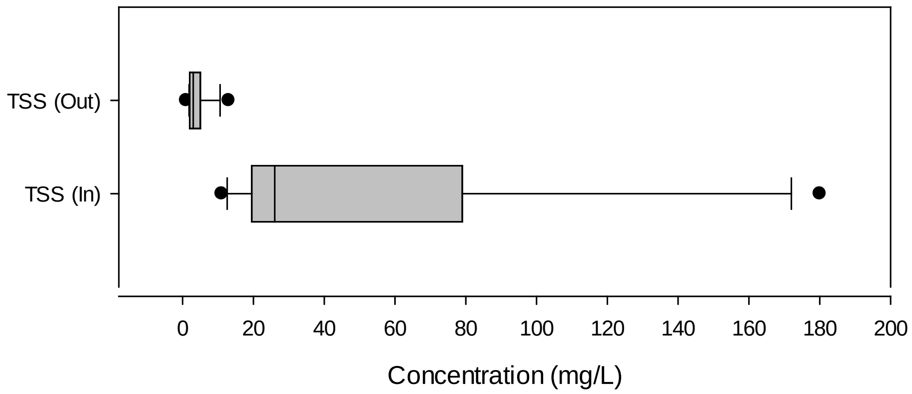
Notes:

1. CRE – Concentration reduction efficiency. CRE is percentage reduction in concentration with respect to inflow concentration for individual events.
2. Concentrations less than the practical quantification limit (PQL) was replaced by 50% of PQL for performance calculations.

As evident in Table 5, median concentration reduction efficiency for TSS, TN and TP are 89.2 %, 50 % and 54.5 %, respectively. These can be considered as true representations of the performance of the Jellyfish® Filter, particularly due to the size of the data set. Use of median values as performance indicators is particularly applicable when a data set is log-normally distributed. Accordingly, the dataset was tested for normal and log-normal distributions in Section 4.3.

The treatment performance in relation to concentration reductions of TSS, TN and TP are presented in the form of Box-Whisker plots in Figure 4. Figure 4 (a) indicate a significant reduction in TSS in the outflow. This aligns with the treatment performance for TSS shown in Table 5. According to Figure 4 (b), TN and TP concentrations in the outflow also show significant reductions.

(a)



(b)

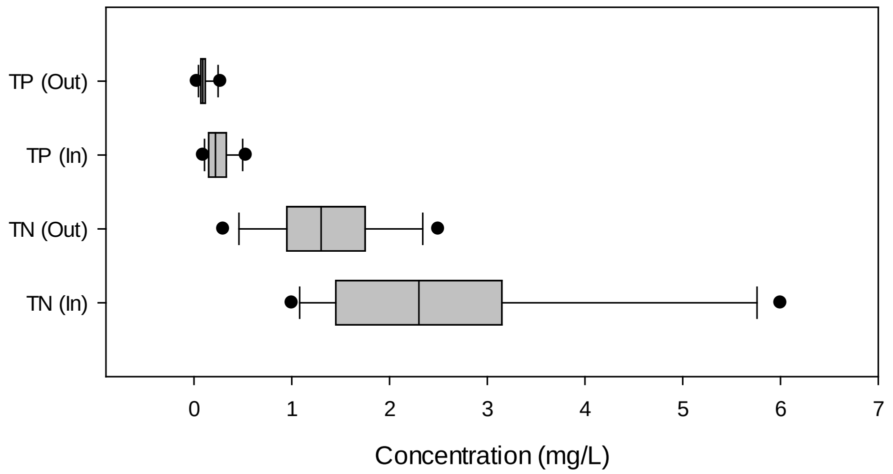


Figure 4. Box-Whisker plots for Jellyfish® Filter performance (a) TSS; (b) TN and TP

Statistical significance tests were also undertaken to further consolidate the performance evaluations presented in Table 5 and Figure 4. The analysis included paired t test and Mann-Whitney U test. The outcomes from the statistical analysis are presented in Table 6.

Log-transformed data were used for the statistical tests and variances of the distributions were assumed to be the same. As shown in Table 6, ‘p’ value for the paired ‘t’ test result was less than 0.05 for inflow and outflow concentrations of TSS, TN and TP. This suggests that the difference between inflow concentrations and outflow concentrations are significantly different in terms of TSS, TN and TP. Similarly, the Mann-Whitney U test indicate significant differences in inflow and outflow concentrations in terms of TSS, TN and TP. Based on these results, it can be concluded that the Jellyfish® Filter demonstrates significant pollutant concentration reductions.

Table 6. Statistical Significance of Jellyfish® Filter Performances

Analysis	Paired ‘t’ test		Mann-Whitney U test		
	T-value	p-value	W	2-tailed p	Significance
TSS (In) vs TSS (Out)	8.32	0.000	904	0.000	Yes
TN (In) vs TN (Out)	7.16	0.000	758	0.020	Yes
TP (In) vs TP (Out)	7.02	0.000	782	0.005	yes

3.3 Particle Size Distribution

The particle size distribution (PSD) of the collected stormwater samples were determined using laser diffraction technology and the results are presented in Figure 5 and Figure 6. Event based PSD analysis outcomes are presented in Table 7. As the PSD can be influenced by site and climate characteristics and the antecedent dry period, the average distribution is presented including upper and lower limits for inflow and outflow samples.

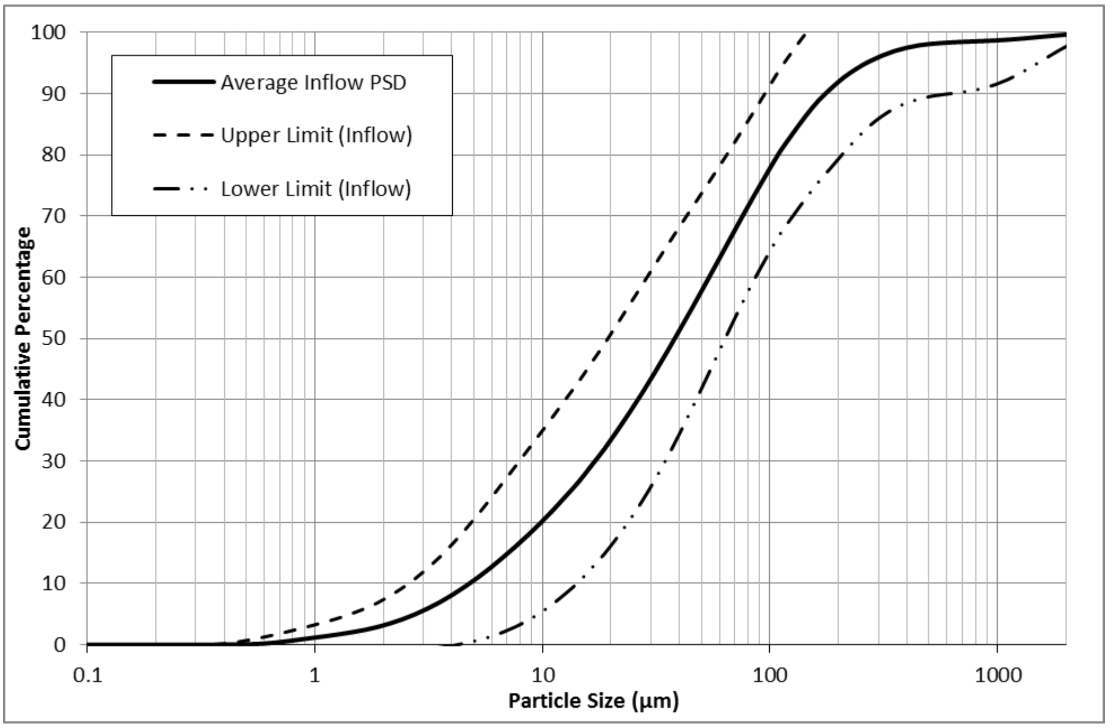


Figure 5 Particle size distributions for inflow samples

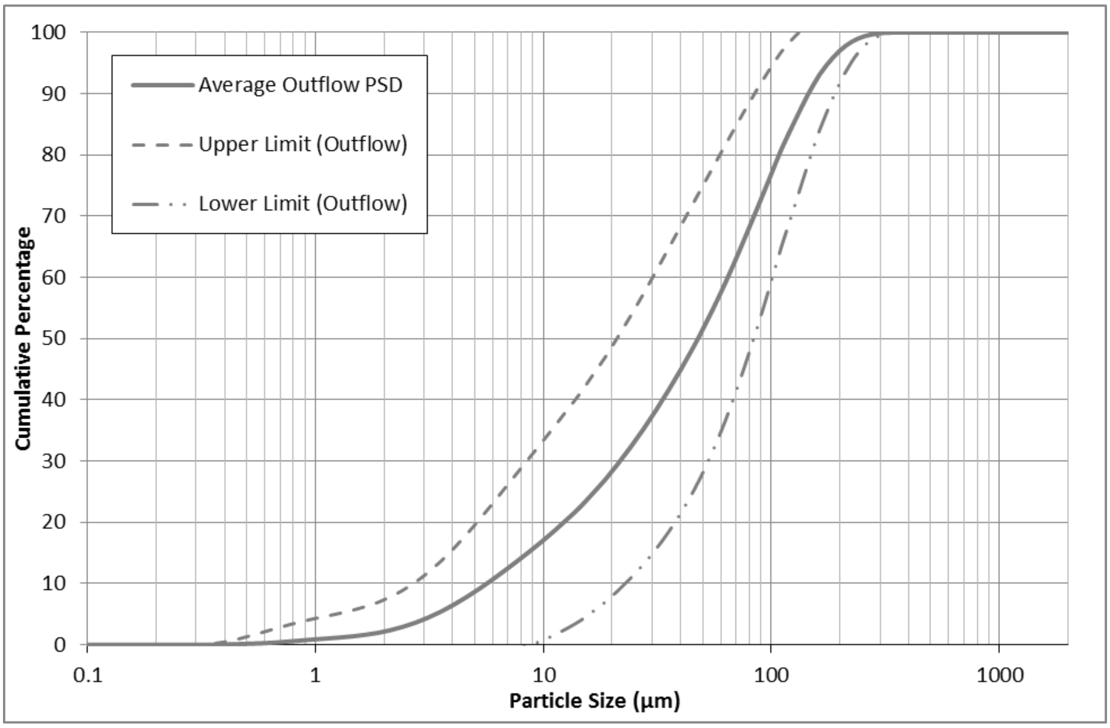


Figure 6 Particle size distributions for outflow samples

Table 7. Event based PSD

Event Date	Inflow PSD (µm)			Outflow PSD (µm)		
	d10	d50	d90	d10	d50	d90
2014-06-29	na	na	na	na	na	na
2014-08-17	na	na	na	na	na	na
2014-08-28	na	na	na	na	na	na
2014-09-26	7	55	1260	9	55	144
2014-10-14	5	35	144	6	50	146
2014-10-28	2	27	111	7	70	186
2014-11-07	5	35	163	7	45	144
2014-11-28	2	21	111	2	18	86
2014-12-06	5	36	240	8	67	150
2015-03-19	11	55	186	9	46	185
2015-04-01	9	52	186	5	31	144
2015-04-30	6	46	272	5	31	111
2015-05-18	5	35	140	6	52	127
2015-06-30	5	46	255	8	55	175
2015-08-26	4	27	163	12	73	168
2015-09-17	16	48	97	12	48	97
2015-09-26	6	36	78	5	31	317

As evident from Figure 5 and 6, the Jellyfish® Filter has removed particles >200 µm size range almost completely. However, particles >200 µm size range represents less than 10%

of total inflow particles by volume. For the particle size range <200 µm, inflow and outflow PSD show similar patterns. This highlights the fact that the removal of particles achieved by Jellyfish® Filter is mostly spread across the entire particle size distribution.

4. Characteristics of the Monitoring Program

Demonstration of the validity of the events monitored and the data obtained is critical in performance monitoring of treatment devices. Accordingly, the characteristics of the monitored events and the data obtained from laboratory testing were compared with previous studies.

4.1 Comparison of Rainfall Characteristics

It was important to confirm that the range of rainfall events monitored is within the range of typical rainfall events for the monitored region. At the same time, it was also important to compare the events monitored in the current study with the events monitored by the previous UoF (2011) study. In this regard, rainfall evens recorded at Brisbane weather station in 2004 was selected as representative for the region. The Phase 1 of the study undertaken confirmed that 2004 represents a rainfall year with average annual rainfall depth and hence can be considered as a representative year (Goonetilleke et al. 2013). Accordingly, the events monitored in the current study are plotted with Brisbane events from 2004 and events monitored in UoF (2011) study as shown in Figure 7.

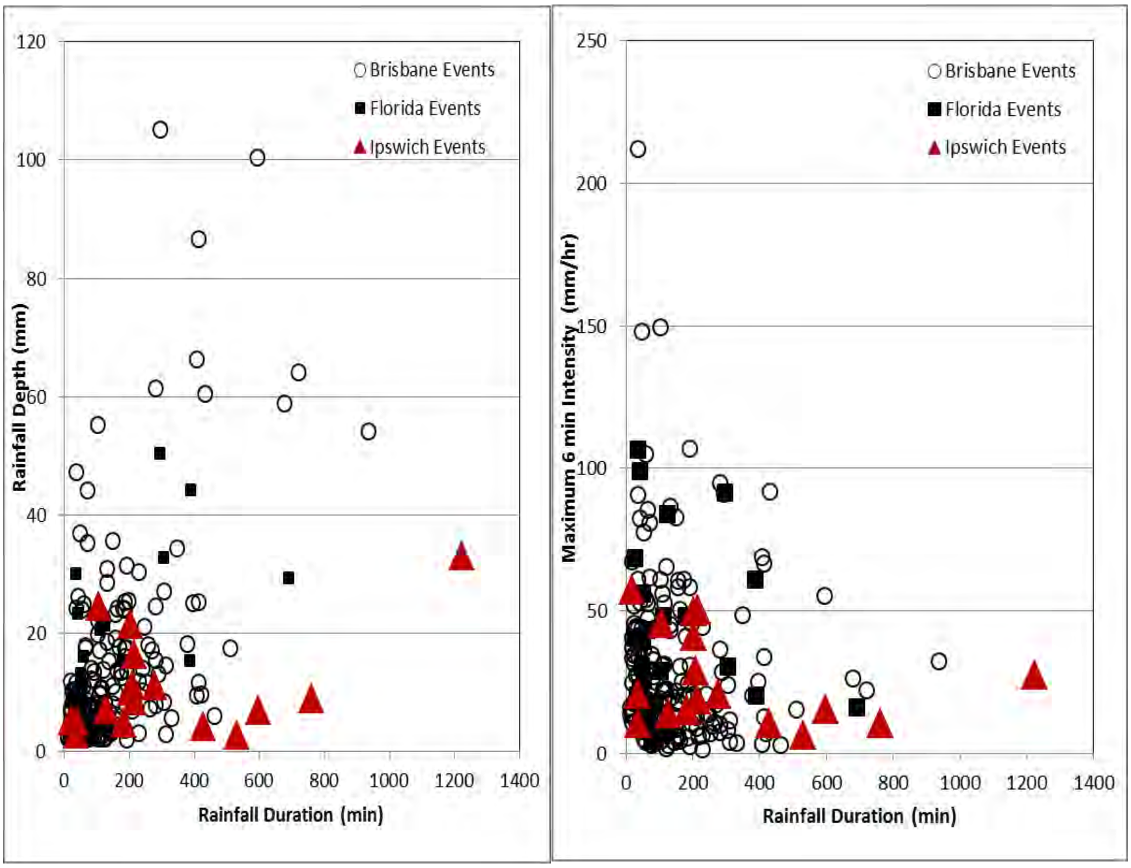


Figure 7. Comparison of rainfall events

As evident in Figure 7, events monitored in this study are well within the envelope created by the other two sets of rainfall events, thus confirming the representativeness of the monitored events in this study. The comparison was undertaken using three basic parameters for characterising rainfall events, namely, rainfall depth, rainfall duration and maximum 6 minute intensity.

4.2 Comparison of Inflow Water Quality Data

Stormwater inflow concentrations were compared with typical values from urban areas in SEQ and Florida as shown in Figure 8 and Figure 9. Typical inflow stormwater quality was considered equivalent to MUSIC concentration parameter values for the Brisbane region. Two monitoring programs undertaken by QUT in the SEQ region were compared against Florida data and presented in UoF (2011).

MUSIC parameters are typically presented as mean and standard deviation of a long-term data set. Since the primary requirement of this comparison is to justify the fact that measured data are within those statistical limits, mean and 1.96 times the standard deviation is presented as positive and negative error bars in Figure 8 and 9. It is typically considered that 1.96 times the standard deviation as positive and negative error bars represent 95% of the data ranges of the assessed population. Means and 95% error bars are presented for urban residential, industrial, commercial and rural residential areas for comparison. Similar statistical measures of Florida and Ipswich water quality data are presented for direct comparison. Original Florida and Ipswich water quality data are also presented as scattered data sets (x axis is not relevant) in Figure 8 and 9.

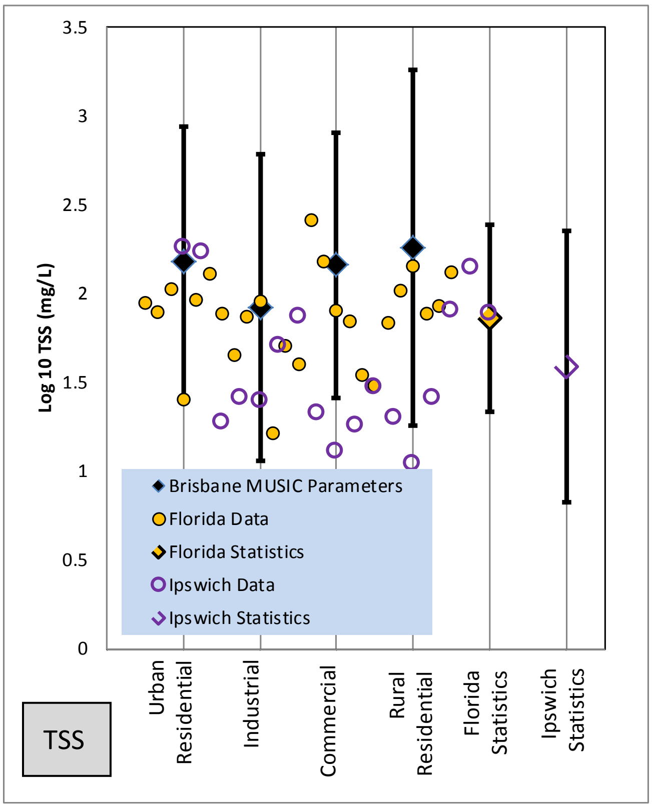


Figure 8. Comparison of Ipswich inflow TSS concentrations with typical Brisbane and Florida data

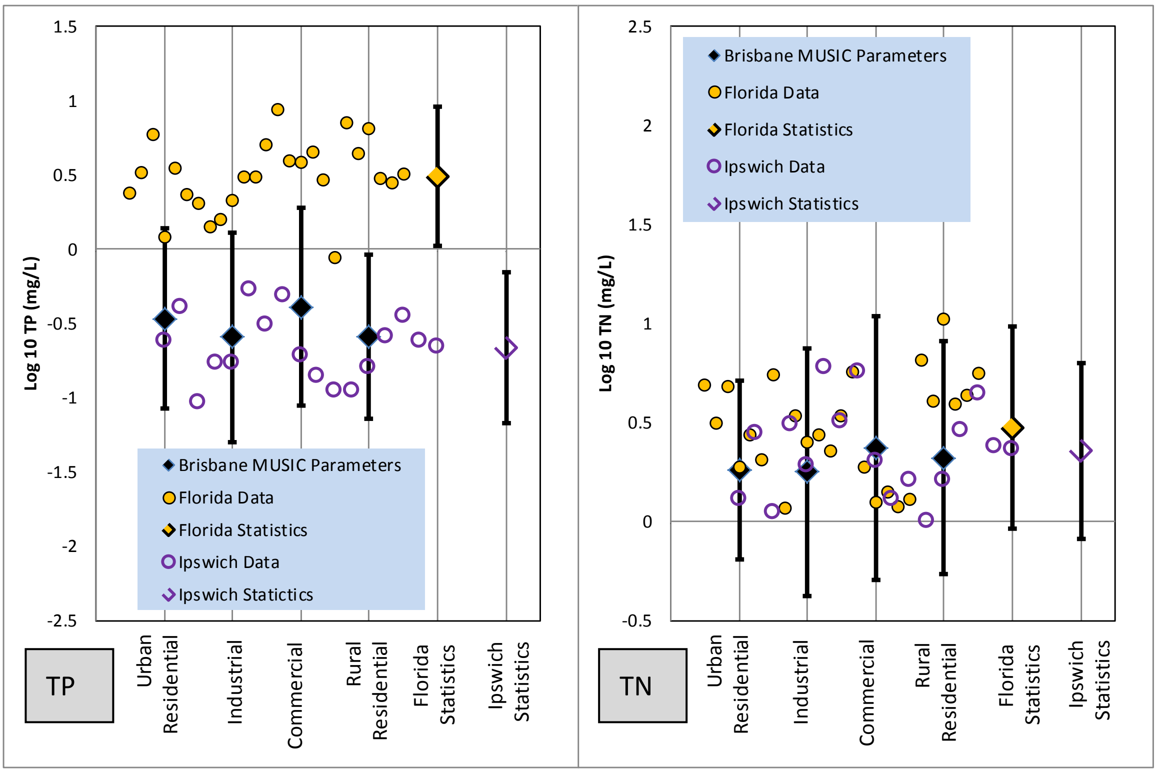


Figure 9. Comparison of Ipswich inflow TN and TP concentrations with typical Brisbane and Florida data

As evident from Figure 8 and Figure 9, stormwater quality at the monitored site is well within the envelope of expected Brisbane water quality characteristics. Particularly, TP concentrations are within the typical concentrations for Brisbane, though they show differences with Florida data. It is hypothesised that soil characteristics and landscape management practices would have influenced phosphorus levels reported in the UoF (2011) study.

4.3 Comparison of Statistical Distributions of Measured Data

Confirmation that the monitored events are common in comparison to the regional norms in terms of statistical distributions is important. In this regard, stormwater quality data from Queensland urban catchments is commonly regarded as log-normally distributed. For confirmation of this fact, measured data sets in this study were investigated for compatibility with normal and log-normal distributions. This was done based on Anderson-Darling normality test using Minitab 16 statistical software. Both, the original data set and log-transformed data set were investigated. For interpretations, p-values less than 0.05 were considered as not-normally distributed. Summarised outcomes of the analysis are presented in Table 8.

As evident in Table 8, all inflow date sets show p values greater than 0.05. This confirms the log-normally distributed nature of inflow water quality. Inflow water quality is equivalent to catchment stormwater quality, confirming that the catchment selected for performance monitoring was appropriate.

Table 8. Outcomes of Anderson-Darling normality test

	TSS		TN		TP	
	In	Out	In	Out	In	Out
Original data set (p value)	0.005	0.005	0.012	0.045	**0.051**	0.006
Log transformed data set (p value)	**0.079**	0.021	**0.546**	**0.108**	**0.07**	0.007

4.4 Comparison of Treatment Performance

Event based performance of a treatment device can be influenced by a range of factors including inflow pollutant concentrations and the characteristics of the events. Sections 4.1 and 4.2 suggested the similarities between events from the Ipswich and Florida monitoring programmes in terms of rainfall events and inflow pollutant concentrations except TP. Based on this findings, it can be concluded that the performance of the Jellyfish® Filter installed at Ipswich and Florida are comparable.

Table 9 presents the median pollutant removal efficiencies in relation to TSS, TN and TP. It is evident that all three removal efficiencies are of a similar order of magnitude for both monitoring programs. TSS and TN removal efficiencies are closely comparable and can be primarily attributed to having similar inflow quality as shown in Figure 8 and Figure 9. TP removal efficiency do not show a significant difference (see Figure 9), where performance at Florida is slightly better. This could be attributed to high inflow concentrations of phosphorous (TP) in Florida compared to Ipswich data.

Table 9. Comparison of pollutant removal performance

Monitoring Program	Median Removal Efficiency (%)		
	TSS	TN	TP
Florida	89	51	59
Ipswich (SEQ)	89	50	54

5. SUMMARY

This final report primarily provides an assessment of the field performance monitoring of the Jellyfish® Filter device. The key findings are:

- For the seventeen events monitored, median concentration reduction efficiencies for TSS, TN and TP are 89%, 50% and 54%, respectively.
- Comparison of particle size distribution of inflow and outflow samples confirmed the removal of particles across all the particle size ranges. Particularly, particles greater than 200µm are subjected to near complete removal.
- Comparison of monitored rainfall events suggests that these are within the envelope of typical rainfall events for Brisbane and are equivalent to events monitored in Florida.
- Monitored stormwater quality in terms of TSS, TN and TP are well within the expected stormwater quality for the Brisbane region.
- Performance characteristics observed in the current monitoring study are comparable with the performance reported in the previous Florida study (UoF, 2011).

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Evaluation of Treatment Performance of a Stormwater Treatment Membrane Filter under Australian Conditions

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Abstract

Stormwater runoff transports a range of pollutants and is a significant non-point source of urban water pollution. Effective removal of stormwater pollutants requires treatment technologies that are appropriate to site constraints, as well as rainfall and pollutant load characteristics. A range of engineered stormwater treatment systems are marketed by various commercial vendors. Assessing their performance requires quantification of inputs and outputs to receiving environments under diverse event durations, flows, and loads, Herr and Sansalone (2015).

In line with these recommendations the treatment performance of a device has been assessed with a field monitoring program centered on a device installed at Ipswich in South East Queensland. The findings to date of the field monitoring are as follows:

- For the seven qualifying events monitored, median concentration reduction efficiencies for TSS, TN and TP are 89%, 55% and 65%, respectively.
- Comparison of monitored rainfall events suggests that these are within the envelope of typical rainfall events for Brisbane and are equivalent to events monitored in Florida.
- Monitored stormwater quality in terms of TSS, TN and TP are well within the expected stormwater treatment quality for the Brisbane region.
- Performance characteristics observed in this field monitoring study are comparable with the performance reported in the previous Florida study.

Keywords: Performance comparison; Performance evaluation; Stormwater quality; Stormwater treatment

1. Introduction

Stormwater runoff transports a range of pollutants and is a significant non-point source of urban water pollution. Effective removal of stormwater pollutants requires treatment technologies that are appropriate to site constraints, as well as rainfall and pollutant load characteristics. A range of engineered stormwater treatment systems are marketed by various commercial vendors. Assessing their performance requires quantification of inputs and outputs to receiving environments under diverse event durations, flows, and loads, Herr and Sansalone (2015).

The Jellyfish® Filter is an engineered stormwater quality treatment technology featuring membrane filtration in a compact stand-alone treatment system that is designed to remove a wide variety of stormwater pollutants. The Jellyfish® Filter integrates pre-treatment and filtration with a passive self-cleaning mechanism. The system utilizes membrane filtration cartridges with high filtration surface area and flow capacity and designed to operate under relatively low driving head compared to conventional filter systems. Performance of the Jellyfish® Filter as a stormwater treatment device had been tested and deemed appropriate for the US market (UoF, 2011).

Extensive field testing of the Jellyfish® Filter treatment device had been undertaken in the US by University of Florida. However, further performance testing under Australian climatic conditions was considered essential for the introduction of the Jellyfish® Filter to the local market. Accordingly, Queensland University of Technology (QUT) was requested by Humes Australia to undertake a comprehensive field based monitoring study to verify the performance of the treatment device under South East Queensland (SEQ) climatic conditions.

A two phase approach was adopted by QUT to assess the treatment performance of the Jellyfish® Filter. The first phase consisted of assessing the compatibility of performance characteristics reported in UoF (2011) to South East Queensland (SEQ) climatic conditions using advanced statistical approaches. The second phase consisted of evaluating the treatment performance under SEQ climatic condition by undertaking a field monitoring program centered on a device installed at Ipswich, South East Queensland.

Phase 1 of the study has been completed and reported in August 2014 (Egodawatta et al. 2014). This paper follows on from Phase 1 and presents the findings to date of the field monitoring program currently being undertaken as Phase 2.

2. Monitoring System

2.1 Site Description

The site is a recently developed commercial facility located at 292 Brisbane Street, West Ipswich 4305, QLD. The site has a total area of 1678m2 with approximately 550m2 of roof area and 1128m2 of impervious driveways and parking lots. Figure 1 shows the layout of the development, including the stormwater drainage network.

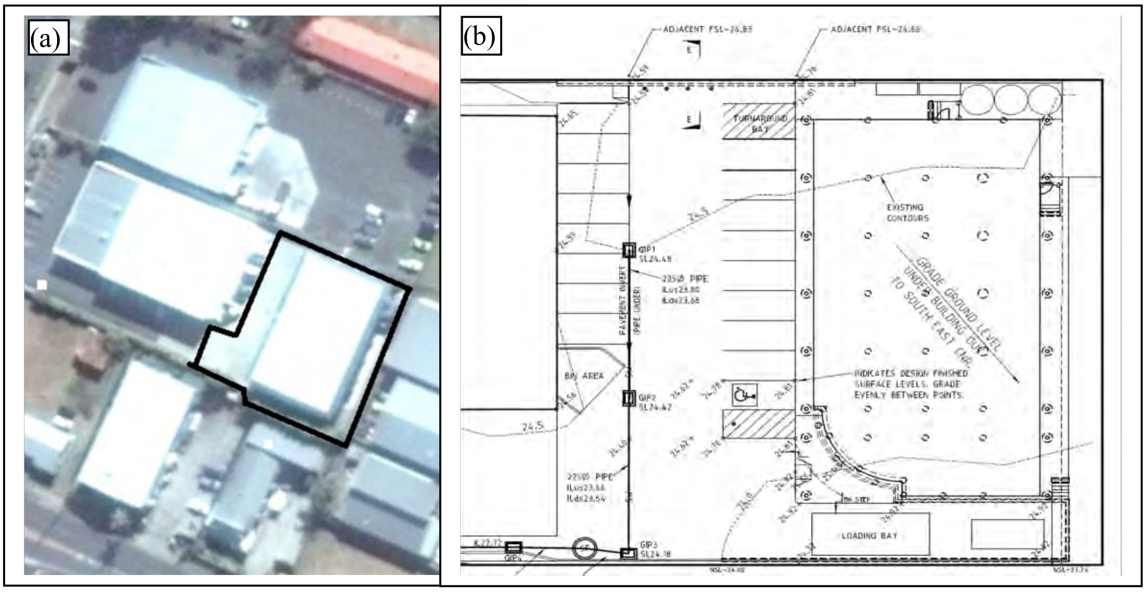

Figure 1. Study Site: (a) Aerial View; (b) Drainage Network

The stormwater drainage at the site is handled by a piped, subsurface network. Driveway runoff from the site enters the drainage network via grated field inlet pits while downpipes from the roof are directed to rainwater tanks, and the overflow pipe to the closest field inlet. The treatment device is fitted as a part of the drainage network after the last grated manhole within the site as shown in Figure

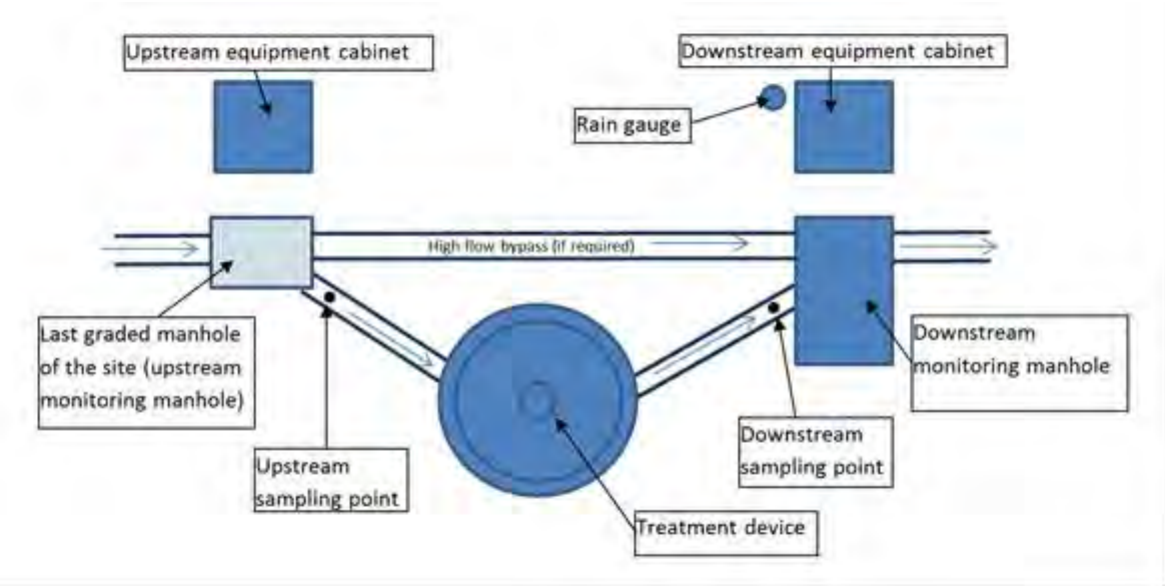

Figure 2. Monitoring System Layout

2.2 Instrumentation and Sampling Methodology

Automatic sampling stations are installed at two sampling points as shown in Figure 2. The upstream sampling point is equipped with a flow measuring device and an automatic sample collection system while the downstream sampling point is equipped with an automatic sample collection system. A tipping bucket rain gauge is installed as part of the field monitoring system. A schematic of the field monitoring system is shown in Figure 3.

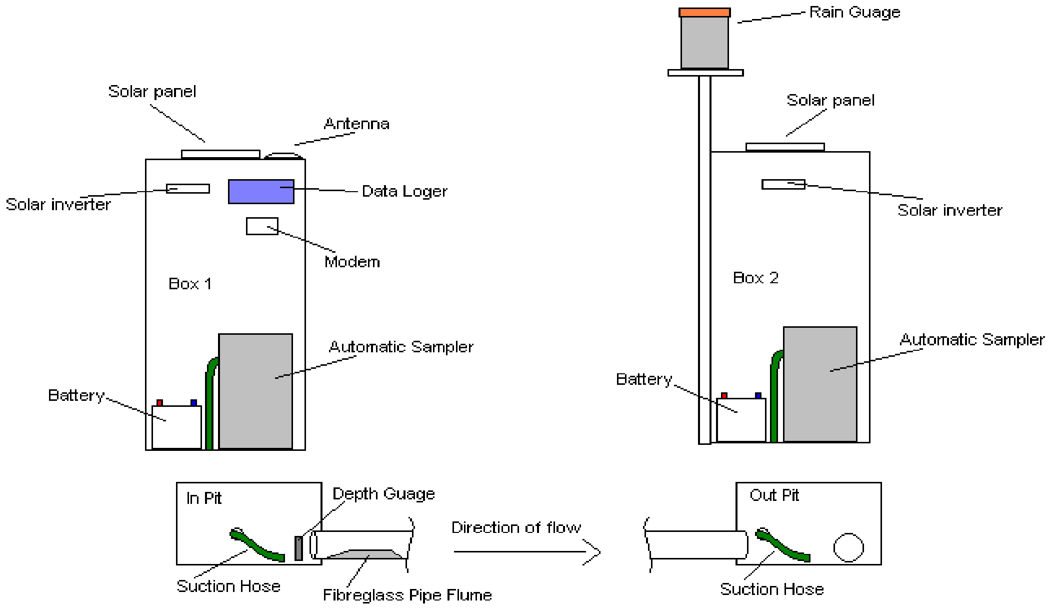

Figure 3. Schematic of the Two Sampling Points

The flow measuring device installed at the upstream sampling point consists of a high accuracy Control Logic LMP307 pressure transducer with accuracy of 0.1% and a pipe insert Palmer-Bowlus flume (8 inch). The pressure transducer is mounted on the wall of the field inlet pit just upstream of the flume so that depth measurements can be transformed to flow using the rating table associated with the flume. The flume device and the pressure transducer operation were calibrated over a range of flow rates prior to the commencement of the monitoring program.

Two ISCO 6712 automatic samplers with capacity to hold 24 samples are installed to collect runoff samples from upstream and downstream sampling points as shown in Figure 3. The samplers are housed in weatherproof security cabinets close to each sampling point. The suction hoses are kept as short as possible to reduce head loss. Sampling stations are equipped with data loggers, battery and solar chargers to ensure independent operation. The RIMCO RIM7499 tipping bucket rain gauge installed to measure rainfall has a resolution of 0.2mm. The rain gauge is mounted on a three meter pole as shown in Figure 3 to reduce the impact of the rain shadow created by any neighboring buildings. A Bureau of Meteorology operated rain gauge is situated approximately 600m away from the study site.

2.3 Sample Handling and Testing

A carefully formulated methodology was adopted for the selection of appropriate rainfall events for evaluation, runoff sample collection and sample handling and testing. Only runoff samples originating from rainfall events with a minimum of three antecedent dry days and more than 2.6mm rainfall depth were tested. These rainfall events were classified as qualifying events. This was to ensure that there are representative contributions from both driveways/parking lots and roof runoff as well as to ensure that there was appreciable accumulation of pollutants on the impervious surfaces. The automatic samplers were programmed to collect discrete samples.

The samplers were programmed to trigger based on the occurrence of rainfall. Sampling intervals were programmed to vary based on the intensity of the rainfall received. Runoff samples collected from a qualifying rainfall event are combined to form a composite sample (Event Mean Concentration – EMC). Representative aliquots of samples were extracted using a churn sample splitter (Bel-Art Products) and submitted to a NATA registered laboratory (Advanced Analytical Laboratory) for analysis. The parameters tested and the test methods adopted are listed in Table 1. Sample collection, handling and transport were undertaken in accordance with AS/NZS 5667.1:1998.

Table 1. List of Parameters and Test Methods

Parameter	Method
pH	APHA (2012) Method 4500
Electrical conductivity	APHA (2012) Method 2510B
Total metals – Fe , Al, Mn , Cu, Cr, Pb, Ni, Zn, Cd	US EPA 200.8/3050/6010B by ICPMS
US EPA (1994), US EPA (1996),	
Total nitrogen, NO_3, TKN	APHA (2012) Method 4500 by discrete analyser with persulphate digestion
Total phosphorus, FRP (orthophosphate P)	APHA (2012) Method 4500 by discrete analyser with persulphate digestion
Total suspended solids (103oC)	APHA (2012) Method 2540 D
Total organic carbon	APHA (2012) Method 5310 by TOC analyser
Total petroleum hydrocarbon (C10-C40), silica gel	NEPM 2011 (draft)

3. Results and Discussion

The outcomes from the evaluation of seven qualifying rainfall events that occurred over a 5 month period from 28th June 2014 to 7th November 2014 are presented in this paper. Rainfall and runoff data for the monitored events are presented in Table 2.

Table 2. Characteristics of Monitored Events

Date Sampled	Rainfall Depth (mm)	Rainfall Duration (minutes)	Peak Intensity (mm/hr)	Number of Samples collected
28/06/2014	5.2	19	57	3
16/08/2014	33	1222	27.4	24
27/08/2014	7.2	128	13.7	14
25/09/2014	8.6	214	18.9	4
13/10/2014	7	597	15.4	13
27/10/2014	3	36	10.3	7

3.1 Parameter Concentration Values

The laboratory test results for the monitored events are given in Table 3 and Table 4.

Table 3. Water Quality Parameters: Solids, Nutrients and Organic Carbon

Sampling Point	Date sampled	pH	EC	TSS	Nitrate	TKN	TN	Phosphate	TP	TOC
	Units	pH unit	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	PQL	1.0	1	2	0.01	0.1	0.1	0.01	0.02	1.0
Inflow	28/06/2014	6.4	40	180	0.19	1.1	1.3	<0.01	0.24	5
Outflow		6.8	120	13	0.11	1.2	1.3	0.03	0.24	5
Inflow	16/08/2014	7.3	70	170	0.33	2.4	2.8	0.18	0.41	9
Outflow		7.1	50	2	0.28	0.2	0.5	0.02	0.03	4
Inflow	27/08/2014	7	120	19	0.42	0.6	1.1	0.06	0.093	4
Outflow		6.9	70	2	0.17	0.3	0.5	0.02	0.05	2
Inflow	25/09/2014	6.9	150	26	1.9	1.7	3.1	0.02	0.17	9
Outflow		6.6	55	4	0.28	0.8	1.1	<0.01	0.06	6
Inflow	13/10/2014	7	125	25	0.79	1	1.9	0.05	0.17	7
Outflow		7	140	4	0.31	1.5	1.9	0.03	0.12	6
Inflow	27/10/2014	6.7	145	51	0.73	5.2	6	0.27	0.53	32
Outflow		6.9	130	10	0.82	1.5	2.3	0.07	0.17	18
Inflow	06/11/2014	6.8	105	74	0.58	2.6	3.2	0.36	0.31	11
Outflow		6.8	80	8	0.61	1	1.6	0.06	0.08	8

Note: PQL – Practical Quantification Limit

Table 4. Water Quality Parameters: Total Petroleum Hydrocarbons and Metals

Sampling Point	Date sampled	TPH C6-C9	TPH C10-14	TPH C15-28	TPH C29-36	Al	Cd	Cr	Cu	Fe	Mg	Ni	Pb	Zn
	Units	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	PQL	25	50	100	100	0.05	0.001	0.002	0.002	0.05	0.005	0.003	0.006	0.005
Inflow	28/06/2014	<25	<50	<100	<100	3	<0.001	0.012	0.039	3.8	0.12	0.005	0.01	0.3
Outflow		<25	150	200	<100	0.2	<0.001	0.002	0.015	1.2	0.13	<0.003	<0.006	0.041
Inflow	16/08/2014	<25	<50	<100	<100	4	<0.001	0.018	0.069	4.6	0.16	0.012	0.012	0.75
Outflow		<25	<50	<100	<100	0.05	<0.001	0.006	0.012	<0.05	0.012	<0.003	<0.006	0.017
Inflow	27/08/2014	<25	<50	<100	<100	0.74	<0.001	0.004	0.01	0.68	0.023	<0.003	<0.006	0.11
Outflow		<25	<50	<100	<100	0.08	<0.001	<0.002	0.005	0.17	0.023	<0.003	<0.006	0.024
Inflow	25/09/2014	<25	<50	140	<100	0.94	<0.001	0.008	0.026	0.96	0.034	<0.003	<0.006	0.18
Outflow		<25	<50	120	<100	0.08	<0.001	0.007	0.01	0.11	0.013	<0.003	<0.006	0.027
Inflow	13/10/2014	<25	<50	160	110	0.75	<0.001	0.004	0.016	0.86	0.037	<0.003	<0.006	0.15
Outflow		<25	<50	180	110	0.093	<0.001	0.002	0.005	0.95	0.099	<0.003	<0.006	0.032
Inflow	27/10/2014	<25	100	570	240	1.8	<0.001	0.009	0.038	2.1	0.13	0.005	0.01	0.43
Outflow		<25	98	450	200	0.19	<0.001	0.002	0.012	1.1	0.087	<0.003	<0.006	0.06
Inflow	06/11/2014	<25	<50	160	<100	1.9	<0.001	0.007	0.025	2.3	0.11	0.004	0.007	0.29
Outflow		<25	<50	160	<100	0.19	<0.001	<0.002	0.007	0.34	0.032	<0.003	<0.006	0.035

Note: PQL – Practical Quantification Limit

3.2 Treatment Performance

Measured concentrations representing inflows to the treatment device and outflows from the device was used for determining the treatment performance. Treatment performance was evaluated for TSS, TN and TP as these are the most common stormwater quality parameters. The estimated treatment performance is shown in Table 5.

Table 5. Concentration Reduction Efficiency and Efficiency Ratio

Date sampled	TSS (mg/L)			TN (mg/L)			TP (mg/L)		
	Inflow	Outflow	CRE	Inflow	Outflow	CRE	Inflow	Outflow	CRE
28/06/2014	180	13	92.8	1.3	1.3	0.0	0.24	0.24	0.0
16/08/2014	170	2	98.8	2.8	0.5	82.1	0.41	0.03	92.7
27/08/2014	19	2	89.5	1.1	0.5	54.5	0.093	0.05	46.2
25/09/2014	26	4	84.6	3.1	1.1	64.5	0.17	0.06	64.7
13/10/2014	25	4	84.0	1.9	1.9	0.0	0.17	0.12	29.4
27/10/2014	51	10	80.4	6	2.3	61.7	0.53	0.17	67.9
06/11/2014	74	8	89.2	3.2	1.6	50.0	0.31	0.08	74.2
Average	78	6		2.8	1.3		0.27	0.11	
Average CRE			88.5			44.7			53.6
Median CRE			89.2			54.5			64.7

Note:

1. CRE – Concentration reduction efficiency. CRE is the percentage reduction in concentration with respect to inflow concentration for individual events.
2. Concentrations less than Practical Quantification Limit (PQL) was replaced by 50% of detection limit for performance calculations.

It is commonly known that the average of a small sample set can be far from the true mean of a population. In this respect, median values could be a true representative of performance indicators. This is particularly true when a data set is log-normally distributed rather than normally distributed. As evident in Table 5, median of the percentage concentration reduction efficiencies for TSS, TN and TP are 89.2%, 54.5% and 64.7%, respectively. Average values (mean) for the same parameters are less than 10% difference from the median except for TP. This indicates consistency in treatment performance of the Jellyfish® Filter for all the events investigated.

4. Comparison of Treatment Performance with Previous Studies

Demonstrating the validity of the data obtained and estimated performance is critical in field monitoring. Accordingly, the data obtained and estimated performance was compared with treatment performance reported in previous studies.

4.1 Comparison of Rainfall Data

It was considered important to demonstrate that the range of rainfall events monitored is within the range of rainfall typical to local conditions. At the same time, it was also important to compare the events monitored with the events monitored by the UoF (2011) study. Accordingly, the events monitored in this study are plotted with typical Brisbane events from 2004 (selected as a representative year) and events monitored in UoF (2011) study as shown in Figure 4. Phase 1 of the study undertaken confirmed that 2004 represents a rainfall year with average annual rainfall depth and hence can be considered as a representative year (Egodawatta et al. 2014). As evident in Figure 4, events monitored in this study are well within the envelope created by the other two sets of rainfall data, thus confirming the representativeness of the monitored events in this study.

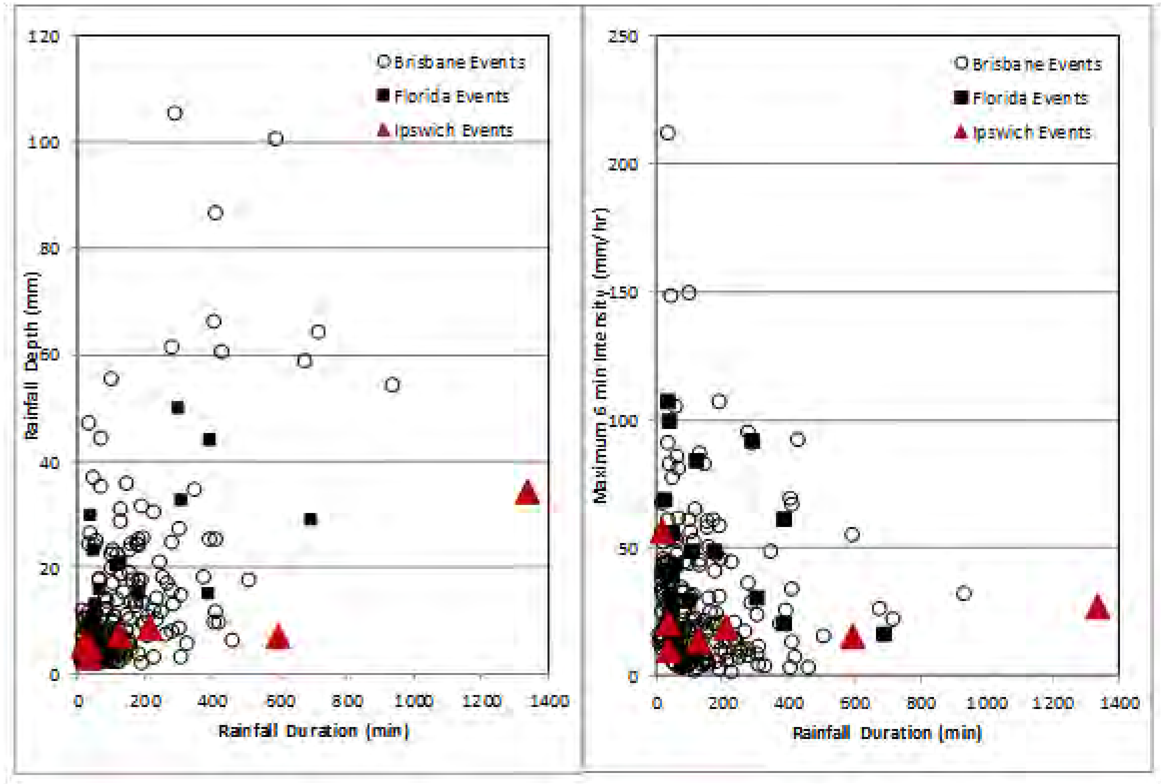

Figure 4. Comparison of Rainfall Events

4.2 Comparison of Inflow Water Quality Data

Additionally, the stormwater inflow concentrations were evaluated with respect to typical values from urban areas in SEQ and Florida as shown in Figure 5 and Figure 6. Typical inflow stormwater quality was considered equivalent to MUSIC concentration parameter values for the Brisbane region. Two monitoring programs undertaken by QUT in the SEQ region are also included in the comparison. Inflow concentrations for Florida were obtained from UoF (2011).

MUSIC parameters are typically presented as mean and standard deviation of a long-term data set. Since the requirement of this comparison was to justify the fact that measured data are within those statistical limits, mean and 1.96 times the standard deviation is presented as positive and negative error bars in Figures 5 and 6. It is typically considered that 1.96 times the standard deviation as positive and negative error bars represent 95% of the data ranges of the assessed population. Means and 95% error bars are presented for urban residential, industrial, commercial and rural residential areas for comparison. Similar statistical measures of Florida and Ipswich water quality data are presented for direct comparison. Original Florida and Ipswich water quality data are also presented as scattered data sets (x axis is not relevant) in Figure 5 and Figure 6.

As evident from Figure 5 and Figure 6, stormwater quality at the monitored site is well within the envelope of expected Brisbane water quality characteristics. Particularly, TP concentrations are within the typical concentrations for Brisbane, though they show significant differences with the Florida data. It is hypothesised that specific soil characteristics and landscape management practices would have influenced phosphorus levels reported in UoF (2011) study.

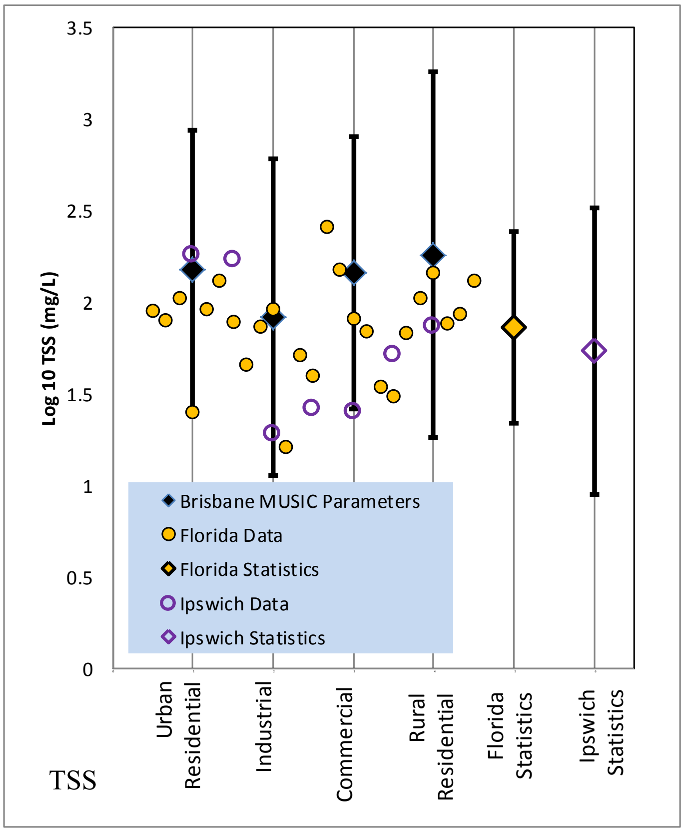

Figure 5. Comparison of Ipswich Inflow TSS Concentrations with Typical Brisbane and Florida Data

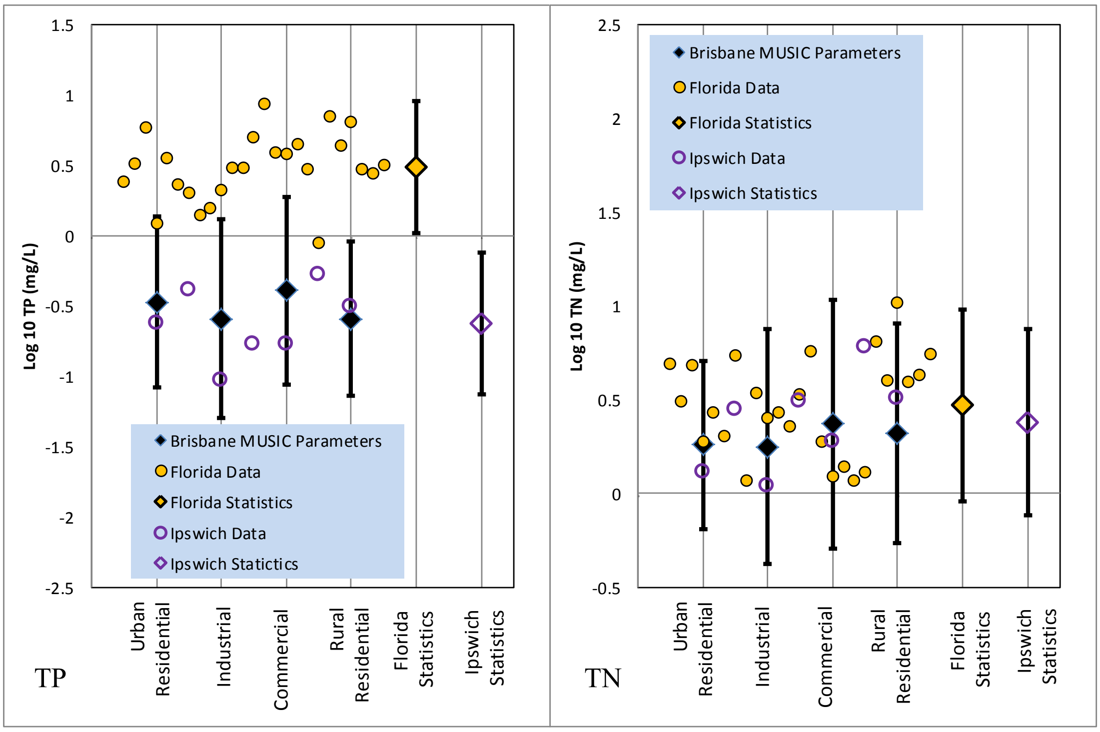

Figure 6. Comparison of the Ipswich Inflow TP and TN Concentrations with Brisbane and Florida Data

4.3 Comparison of Treatment Performance

Event based performance of a treatment device can be influenced by a range of factors including inflow concentration, flow rate and the characteristics of the events that the device has treated. This paper compares the field performance of the Jellyfish® Filter under Southeast Queensland climatic conditions with the performance shown in the Florida study. As the study is still ongoing, it is expected that further detailed analysis of treatment performance will be undertaken in the future.

Table 6. Comparison of Pollutant Removal Performance

Monitoring Program	Median Removal Efficiency (%)		
	TSS	TN	TP
Florida	89	51	59
Ipswich (SEQ)	89	55	65

Table 6 presents the median pollutant removal efficiencies in relation to TSS, TN and TP. It is evident that all three removal efficiencies are of a similar order for both monitoring programs. TSS and TN removal efficiencies are closely comparable and can be primarily attributed to having similar inflow quality as shown in Figures 5 and 6. TP removal efficiency does not show a significant difference even though inflow concentrations of phosphorous in Florida are significantly higher compared to the Ipswich values.

5. Summary

The treatment performance under SEQ climatic conditions are being assessed by undertaking a field monitoring program centered on a device installed at Ipswich in South East Queensland. The findings to date of the field monitoring are as follows:

- For the seven qualifying events monitored, median concentration reduction efficiencies for TSS, TN and TP are 89%, 55% and 65%, respectively.
- Comparison of monitored rainfall events suggests that these are within the envelope of typical rainfall events for Brisbane and are equivalent to events monitored in Florida where a comprehensive field monitoring program was undertaken.
- Monitored stormwater quality in terms of TSS, TN and TP are well within the expected stormwater treatment quality for the Brisbane region.
- Performance characteristics observed in this monitoring study are comparable with the performance reported in the previous Florida study.

MUSIC nodes have been created for the Jellyfish Filter treatment device based on all of the field test data, which can be found at the following location.

http://www.humes.com.au/precast-solutions/stormwater/stormwater-treatment/tertiary.html

6. References

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UoF, 2011, TARP field test performance monitoring of a Jellyfish® Filter JF4-2-1, Engineering School of Sustainable Infrastructure and Environment (ESSIE), University of Florida, Gainesville, Florida.

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US EPA, 1999, Method 3050B: Acid digestion of sediments, sludges, and soils, U.S. Environmental Protection Agency, Ohio.

Appendix D Peer review of Jellyfish® monitoring by Tony Weber

As outlined in Section 2.5, Alluvium's Tony Weber was commissioned by Ocean Protect to undertake a peer review of the monitoring undertaken of the Jellyfish® at West Ipswich. This appendix provides Mr Weber's peer review report.

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14 February 2020

Michael Wicks
Technical Director
Stormwater 360
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Alexandria NSW 2015

Dear Michael

Review of performance of Jellyfish performance for installation at 292 Brisbane St, West Ipswich

Background
Thank you for the opportunity to review the performance of a Jellyfish stormwater treatment device based on monitoring of such a unit installed at 292 Brisbane St, West Ipswich. We have conducted the review based on a QUT report entitled "HUMES AUSTRALIA - EVALUATION OF TREATMENT PERFORMANCE OF THE JELLYFISH® FILTER INSTALLATION AT IPSWICH - FINAL REPORT ON THE FIELD MONITORING PROGRAM", dated 17th February 2017. This report was based on data collected between 28 June 2014 and 26 September 2015. The data was also provided for review and both the report and the data were assessed against the City of Gold Coast's "Development Application Requirements and Performance Protocol for Proprietary Devices" issued August 2015.

Review findings
In assessing the report, a number of issues were identified. Overall, the report provides information on the establishment of the monitoring program, data collection activities and an assessment of the results. From this, we note the following:

1. The report only focuses on the removal of pollutants in terms of concentrations. While there is mention of flow recording and some measured flows are reported, no assessment of load reduction is indicated.
2. It would appear that only the inflow and outflow that passed through the device were monitored, there was no assessment of bypass flows. The results should therefore be considered only that which could be attributed to flow treated by the device, not it's overall performance for all flows that may flow to the device (i.e. inflows + bypass flows). While this is not necessarily a deficiency, claims regarding the performance of the device, or any use of the results in MUSIC modelling, should only be attributed to the treated flow passing through the device.
3. It was unclear from the report exactly what the nature of the land use was that was evaluated. While the text refers to commercial, the aerial imagery is more consistent with a bulky goods retailer or industrial unit. Even so, the land use surface types appear to be roof areas and carpark only, no pervious areas were observed. There also appears to be an inconsistency between the aerial imagery and the plan in the report, and there is no definition of the catchment boundary.
4. Sampling was undertaken by autosamplers triggered on rainfall, however the sampling interval was based on rainfall intensity rather than flow. It would appear that discrete samples were collected that were then subsampled to form a composite. Given that there was no information regarding flow within the report, it is uncertain how the sample intervals would relate to enabling a flow-based composite to be obtained, though there is likely to be some consistency between rainfall intensity and flow rate and the flow rate was provided in data provided for review.

5. Flow rates through the unit for 17 events monitored were between 0.3 – 222.9 L/s but it is not stated whether these were inflows into the unit or total flows (inflow + bypass). The treated flow rate of the unit provided in the data was 12.5L/s and this was exceeded on 3 of the 11 qualifying events.
6. Treatment performance was assessed for a range of parameters including TSS, TN, TKN, NOx, TP, PSD, TPH, Al, Fe, Mg, Cd, Cr, Cu, Ni, Pb and Zn.
7. The results showed that the device was capable of reducing concentrations of pollutants for all parameters, but showed the best performance for TSS, TN and TP plus heavy metals (Cd, Cr, Cu, Ni, Pb, Zn). The performance for TPHs was mixed, though most samples demonstrated some reduction across the detected TPH fractions.
8. The comparison of median concentration removal efficiency between the field study and a previous study in Florida, USA, showed very good agreement with the local stud, but it is noted that this was for a different configuration of unit and possibly different inflow concentrations.

Compliance against CoGC protocol

The samples for this assessment were collected in a period prior to and immediately following the publication of the CoGC protocol. As such, we have considered the report and data in terms of its compliance with the protocol but also have made allowance that the data could be considered collected prior to the protocol simply because the program was established and running prior to the protocol being available.

The results provided within the report and in a separate Excel spreadsheet were compared against the requirements of the August 2015 CoGC protocol. The compliance with this protocol is outlined in the following table. In addition, a compilation of treatment efficiencies based on the events that complied with the CoGC protocol is presented in Attachment A.

Table 1. *Compliance against CoGC Proprietary Devices Protocol*

Requirements	Criteria	Compliance	Notes
Location	Minimum of one Australian field test site	y	Ipswich, Queensland, Australia
Type of event	Rainfall events	y	17 rainfall events monitored
Minimum number of events	10 events with at least 7 events from a single location	y	11 qualifying rainfall events from location
Minimum rainfall depth	5mm	y	only events >5mm were assessed
Minimum inter-event time	72 hours for a minimum 5 events	y	only events for >72 hours inter-event time assessed
Device size	Full scale	y	full sized installation
Runoff characteristics	Target flow and pollutant profile of influent and effluent	y	provided
Runoff volume or peak flow	At least 3 events should exceed 75% of the treatment flow rate	y	3 events exceeded flow rate by >100%
Sampling Procedures and Techniques			
Automated sampling	Composite samples on a flow weight basis	partial	automated sampling but on rainfall intensity rather than flow weighted
Minimum number of aliquots	6 per event spread over the hydrograph	y	only complying events assessed
Hydrograph coverage	Indicative 50%	y	complete event hydrographs sampled
Manual sampling	Only for constituents that transform rapidly	n/a	
Sampling location	Inflow, outflow and overflow/bypass	partial	inflow and outflow sampled, no bypass assessment conducted
Maintenance	A typical/standard maintenance program must be in operation	unknown	no information provided
Chemical and physical analytes	PSD, TSS, TP, FRP, PP, TN, DIN, NOx, NH3	partial	all analytes except FRP, PP and NH3, other analytes also collected
Flow measurement location	Inlet, outlet and bypass	partial	bypass did not appear to be measured

Requirements	Criteria	Compliance	Notes
Precipitation	Automatic onsite rain gauge	y	
Recording intervals	1 minute or less	unknown	no information provided
Recording increments	No greater than 0.25 mm	y	0.2 mm
Rain gauge calibration	Twice during verification period	unknown	no information provided
Data analysis and reporting			
Performance indicators	TSS, TN and TP	y	
Data points to be excluded	TSS, TN or TP EMC for an individual event if the EMC is greater than one standard deviation from the overall mean for all events and greater than one standard deviation from the mean values presented in Table 2.	partial	Some TSS data (6 of 11) are greater than one standard deviation below the mean values in Table 2 of the protocol. Removal rates for these storms should be considered conservative (i.e. it is more difficult to remove low concentrations, so removal rates may be higher than these values). These events were not considered non-compliant. All TP and TN values lied within the range of data for commercial and industrial land uses.
	Individual stormwater event TSS, TP and TP EMC data if the PSD is outside the ranges provided in Figure 1. Where there is only limited PSD data is provided and the PSD is outside the ranges provided in Figure 1 then all data is excluded.	y	PSD range within the requirements of the protocol
	TN EMC data when the dissolved and particulate requirements in Table 3 are not achieved.	y	to be provided on submission
Performance indicators	Efficiency ratio, Median concentration reduction efficiency, performance trend line	y	Efficiency ratio and median concentration reduction efficiency provided
Performance variability schematics	Box and whisker plot	y	Provided in report
Statistical significance testing	Log-transformed inlet and outlet paired samples at 95% confidence interval	partial	Statistical significance for log-normal distribution assessed. Paired influent and effluent results for TSS, TP and TP statistically significant $p<0.05$

Results and conclusions

From this review, it would appear that the testing of the Jellyfish stormwater treatment device generally complies with the requirements of the CoGC protocol and provides indicative performance of the device treatment capabilities for flows passing through the device. Given the high level of consistency between the results of the Florida and Ipswich studies, the final median concentration reduction efficiencies obtained in the Ipswich study are likely to be a very good indication of the performance of the device in reducing relevant pollutant concentrations.

With regards to the above, the median concentration reduction efficiencies for this device as evidenced from the data and consistent with the CoGC protocol are:

TSS 86.7%
TP 52.2%*
TN 45.8%
**** average of ER and CRE median as difference greater than 10%***

This is based on statistically significant data pairs ($p<0.05$) and the table of results are shown below.

Table 2. *Summarised results*

Storm Event Date	Storm #	TSS (mg/L) Influent	TSS (mg/L) Effluent	TSS CRE%	TP (mg/L) Influent	TP (mg/L) Effluent	TP CRE%	TN (mg/L) Influent	TN (mg/L) Effluent	TN CRE%
16/08/2014	2	170	2	99%	0.41	0.03	93%	2.8	0.5	82%
27/08/2014	3	19	2	89%	0.093	0.05	46%	1.1	0.5	55%
13/10/2014	5	25	4	84%	0.17	0.12	29%	1.9	1.9	0%
6/11/2014	7	74	8	89%	0.31	0.08	74%	3.2	1.6	50%
6/12/2014	9	13	2	85%	0.19	0.07	63%	2	1.3	35%
19/03/2015	10	18	3	83%	0.14	0.09	36%	1.3	1	23%
1/04/2015	11	30	4	87%	0.11	0.07	36%	1.6	0.9	44%
30/04/2015	12	20	3	85%	0.11	0.11	0%	1	0.3	70%
18/05/2015	13	11	5	55%	0.16	0.1	38%	1.6	1.5	6%
17/09/2015	16	140	2	99%	0.24	0.08	67%	2.4	1.3	46%
26/09/2015	17	78	2	97%	0.22	0.1	55%	2.3	1	57%
	Number of Storm Events	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	
	Mean, mg/L	**98.4**	**3.6**	**0.865**	**0.196**	**0.082**	**0.488**	**1.927**	**1.073**	
	ER, %	**96.3%**			**58.2%**			**44.3%**		
	Median CRE, %	**86.7%**			**46.2%**			**45.8%**		
IF more than 10% difference between two methods then use Average Median CRE and ER, %		**N/A**			**52.2%**			**N/A**		

Further information around service life of the cartridges are appended to this letter report as supplied by the manufacturer.

We hope that the above information is suitable for your current requirements. Please feel free to contact us if we can be of further assistance.

Regards

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Attachment A – Complying storm performance efficiencies – Jellyfish filter

Pollutant	Efficiency ratio (% concentration reduction)*	No. of compliant events
TSS	86.7	11
TP	52.2	11
TN	45.8	11

*** efficiency ratios to be applied only to treatable flow rate, does not include bypass**

Attachment B – Service life information