# A review of the application of OceanGuard® in Australia

Date: August 2021

# Document Control Sheet

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| **Report title** | A review of the application of OceanGuard® in Australia |
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| **Authors** | Brad Dalrymple, Michael Wicks. |
| **Date** | August 2021 |
| **Synopsis** | This report provides an analysis of the application of OceanGuard® 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 OceanGuard® technology is a gully pit basket designed to fit within new and existing gully pits to remove pollution from stormwater runoff.

This report provides a review of the performance of OceanGuard®, and of its suitability for application within Australia. This review has shown that OceanGuard® 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:** OceanGuard® has been accepted by many of the most stringent stormwater quality regulators within Australia and overseas.
- **Case studies and performance monitoring:** Over 20,000 OceanGuard® (and previous generation Enviropod®) technologies have been installed within Australia by Ocean Protect – and stormwater treatment performance monitoring has been undertaken for three (3) sites (including two sites in Australia) operating in 'real world' conditions, all showing significant reductions in pollutant concentrations.
- **Peer reviews:** Two (2) separate peer reviews have been undertaken in relation to treatment performance monitoring of the OceanGuard® (and Enviropod®). These peer reviews were undertaken by Damian McCann from AWC and Professor Ataur Rahman from the University of Western Sydney University, NSW, Australia. Mr McCann undertook a review of the monitoring of the OceanGuard® at Western Sydney University (up to May 2021) and confirmed that this monitoring complied with *Stormwater Quality Improvement Device Evaluation Protocol* (Stormwater Australia, 2018 Version 1.3) and Water by Design's (2010) *MUSIC Modelling Guidelines*. Professor Goonetilleke undertook a peer review of the stormwater treatment performance monitoring site at Kuranda, Queensland, Australia, and his peer review report states that "*I … can confirm the validity of the information presented in the document.*"
- **Applicability to local conditions:** For applications across Australia, the OceanGuard® 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:
    - OceanGuard® 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 project specific sites and the monitoring sites.
    - OceanGuard® operates with a constant 200micron pore aperture filter bag. 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 the treatment performance of OceanGuard® within Australia be modelled using a gross pollutant trap treatment node within MUSIC, with stormwater treatment performance consistent with either the (i) values observed (and summarised in Table 2-1) for the OceanGuard® performance monitoring at Western Sydney University or (ii) Council approved values given in Table 3-1 – up to the design treatment flow rate (of 20 litres/second).

# Contents

## List of Figures



## List of Tables

# 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).

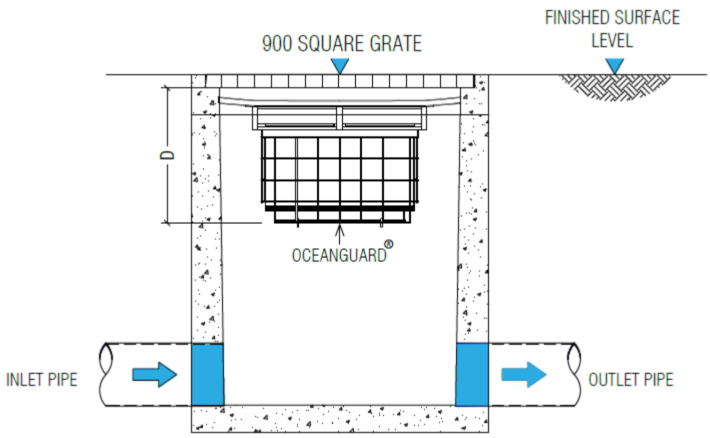
## 1.2 OceanGuard® overview

The OceanGuard® technology is a gully pit basket designed to fit within new and existing gully pits to remove pollution from stormwater runoff. The system has a choice of filtration liners, designed to remove gross pollutants, total suspended solids and attached pollutants as either a stand-alone technology or as part of a 'treatment train' (with stormwater treatment assets located downstream to provide further treatment).

Figure 1-1 illustrates the components of an OceanGuard®, and Figure 1-2 provides example section drawings of an OceanGuard® installation. Example photos of OceanGuard® are provided in Figure 1-3. Further information in relation to the design and management of OceanGuard® technologies is provided in Appendices F to H.


Source: Ocean Protect (2020)

**Figure 1-1 OceanGuard® components**




Source: Ocean Protect (2020)

**Figure 1-2 Standard Configuration of OceanGuard®**

**Figure 1-3 Example photos of OceanGuard®**

As illustrated in Figure 1-1, an OceanGuard® has the following key components:

- **Flow Diverter:** to direct flow into the unit for filtration of stormwater flows and includes an in-built rigid bypass to divert stormwater overflows in high-intensity and peak storm flows
- **Filtration Bag:** which is interchangeable and is available as a 'coarse' material or 'fine grade' (200micron) filtration bag.
- **Filtration Cage:** which is a supporting cage that that allows for the use of larger filtration bags.

The key function of OceanGuard® is to remove pollutants from stormwater. During a storm, runoff enters the gully pit basket. As illustrated in Figure 1-2, the standard OceanGuard configuration treats surface flow only, but it is occasionally necessary to treat pipe flow or grated strip/trench drain (see Appendix E).

Physical filtration is the key treatment process applied by the OceanGuard® 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 OceanGuard® technology within Australia
- A review of the methods for modelling the treatment performance of OceanGuard® technologies (and, if appropriate, identify a recommended method).

# 2 Review of Suitability of OceanGuard® in Australia

## 2.1 Preamble

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

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

## 2.2 Research and development

The design and implementation of the OceanGuard® technology has been developed by Ocean Protect based on over twenty years of research and development, testing and field monitoring.

The OceanGuard® technology has design elements and removal performance that are the same as some off-patent technologies, such as the previous generation EnviroPod® technology previously sold by Stormwater360 Australia under licence. A letter describing the equivalence of the OceanGuard® to Enviropod® is provided in Appendix A.

## 2.3 Case studies

Since 2001, the OceanGuard® (and previous generation Enviropod®) technology has been installed in a variety of applications to meet regulatory requirements set by authorities throughout Australia.

Over 20,000 OceanGuard® (and previous generation Enviropod®) technologies have been installed within Australia by Ocean Protect.

## 2.4 Government approvals

With the exception of Ipswich City Council and Noosa Shire Council, all Councils within Queensland and NSW allow OceanGuards® to be installed on privately owned sites. Brisbane City Council and Whitsunday Regional Council have also installed OceanGuards® (and/ or the previous generation, Enviropod®) in public areas.

OceanGuard® (or previous generation EnviroPod®) has also been accepted by many of the most stringent stormwater quality regulators within other parts of Australia and overseas, including:

- Blacktown City Council
- Washington State Department of Ecology (TAPE) GULD – Basic, Phosphorus
- New Jersey Department of Environmental Protection (NJ DEP)

- North Carolina Department of Environmental Quality (NC DEQ)

## 2.5 Treatment performance monitoring

Table 2-1 provides a summary of three recent examples of OceanGuard® (and Enviropod®) operating in 'real world' conditions where treatment performance monitoring has been undertaken.

**Table 2-1 Summary of recent treatment performance case studies of OceanGuard® (and Enviropod®)**

| Location | Site details | Methodology summary | Performance summary | Further information* |
|---|---|---|---|---|
| Western Sydney University, Kingswood, NSW, Australia | • Single OceanGuard®<br>• 400m$^2$ catchment (car park, 100% impervious)<br>• Mean rainfall 717mm per year | • Monitored by Ocean Protect and ALS<br>• 16-month monitoring period (March 2020 to June 2021)<br>• 16 sampling events<br>• Influent & effluent analysed for solids and nutrients | • 52, 65 and 41% TSS, TP and TN concentration reduction efficiency ratio respectively | • Appendix D<br>• Appendix I |
| Kuranda, Queensland, Australia | • Single Enviropod® and cartridge media (StormFilter®)<br>• Ca. 220m$^2$ Road catchment | • Monitored by Ocean Protect (Stormwater360)<br>• 20-month monitoring period (April 2008 to December 2009)<br>• 6 sampling events | • 99%, 47% and 44% for TSS, TP and TN load removal respectively (for combined Enviropod and StormFilter system). | • Wicks et al (2011)<br>• Appendix I |
| Newmarket/ Grafton area, Auckland, New Zealand | • Single Enviropod® | • Monitored by Tonkin & Taylor<br>• 5-month monitoring period (March to August 2002)<br>• Subsequent lab. study completed by Auckland University | • Ca. 100% removal of sediment greater than 100 micron. | • Butler et al (2002)<br>• Appendix I |

## 2.6 Peer reviews

Two (2) separate peer reviews have been undertaken in relation to treatment performance monitoring of the OceanGuard® (and Enviropod). These peer reviews were undertaken by the following personnel:

- Damian McCann from AWC
- Professor Ataur Rahman from the University of Western Sydney

These peer reviews are provided in Appendices B and C respectively, and summarised in the following sub-sections.

### 2.6.1 Peer review by Damian McCann

Damian McCann of AWC undertook a review of the OceanGuard®, with a particular focus on "compliance with Stormwater Australia's *SQIDEP* (Version 1.3) and the Water by Design *MUSIC*

*Modelling Guidelines* (2010), specifically Section 4.8" for the performance monitoring of the OceanGuard® at Western Sydney University (see Table 2-1). Mr McCann's review included all available performance monitoring data at this site site up until May 2021.

Key findings from Mr McCann's peer review report (provided in Appendix B) include the following:

- "field testing of the OceanGuard Gully Pit System conducted at the Western Sydney complies with the requirement of SQIDEP (v1.3) Field Evaluation pathway", with pollutant reduction metrics given (see Appendix B)
- The OceanGuard® complies with the *MUSIC Modelling Guidelines* (Water by Design, 2010)
- "As OceanGuard only uses physical filtration processes, differing climate conditions (variations in temperate, rainfall intensity) are unlikely to affect the effectiveness of system's ability to remove pollutants" and "We believe the performance observed in Western Sydney is transferrable to other locations since the key variables are treatment flow rate and catchment characteristics"

### 2.6.2 Peer review by Professor Ashantha Goonetilleke

Professor Ashantha Goonetilleke from the Queensland University of Technology was commissioned by Ocean Protect to undertake a peer review of the *Kuranda Stormwater Treatment System Field Evaluation* (Vigar et al 2010), later described by Wicks et al (2011) (and summarised in Table 2-1 and given in Appendix I). As described in Table 2-1, the site included a single Enviropod® and cartridge media (StormFilter®) system.

This peer review report is provided in Appendix C, and states that "*I … can confirm the validity of the information presented in the document*."

## 2.7 Applicability to local conditions

As described in 1.2 (and noted in Mr McCann's peer review, see Section 2.6.1), OceanGuard® 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 project specific sites and the monitoring sites described in Section 2.5.

Regardless of rainfall intensity and duration, the OceanGuard® operates with a constant 200micron pore aperture filter bag as the bag is made from a nylon monofilament weave. 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. It should be noted, however that minimum (to get meaningful outcomes from a % reduction perspective) and maximum (not to overstate % reductions) influent concentrations set out in various field sampling protocols have been adhered to reduce the variability of performance expectations.

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.

## 2.8 Conclusion

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

# 3 Modelling OceanGuard® treatment performance

## 3.1 Preamble

This section describes and assesses potential methods for modelling the treatment performance of OceanGuard®, 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 OceanGuard® technology be modelled using the ‘Gross Pollutant Trap’ (GPT) or ‘generic’ treatment nodes within MUSIC.

The pollutant removal provided by the OceanGuard® is modelled within MUSIC by adjusting the pollutant removal ‘transfer functions’ within the GPT 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 OceanGuard® technologies.

The pollutant removal transfer function values vary across jurisdictions within Australia. Table 3-1 summarises the stormwater treatment performance for OceanGuard® accepted by Councils within Australia.

**Table 3-1 OceanGuard® Treatment Performance Accepted by Councils within Australia**

<table>
<tr><th rowspan="2">Parameter</th><th colspan="4">% Reduction*</th></tr>
<tr><th>GPs</th><th>TSS</th><th>TP</th><th>TN</th></tr>
<tr><td>Blacktown City Council</td><td>95</td><td>54</td><td>30</td><td>21</td></tr>
<tr><td>Logan City Council</td><td>100</td><td>52</td><td>67</td><td>41</td></tr>
<tr><td>City of Gold Coast</td><td>100</td><td>31</td><td>18</td><td>13</td></tr>
<tr><td>Majority of all other Councils (including Brisbane City, Ipswich City and Sunshine Coast Regional Councils)</td><td>100</td><td>Up to 75% based on the following transfer function relationship:
<table>
<tr><th>Input (mg/L)</th><th>Output (mg/L)</th><th>% Removal</th></tr>
<tr><td>0</td><td>0</td><td>0%</td></tr>
<tr><td>20.8</td><td>8</td><td>61.5%</td></tr>
<tr><td>40.3</td><td>14.1</td><td>65.0%</td></tr>
<tr><td>60.6</td><td>19.3</td><td>68.2%</td></tr>
<tr><td>79.3</td><td>23.4</td><td>70.5%</td></tr>
<tr><td>99.9</td><td>26.9</td><td>73.1%</td></tr>
<tr><td>121</td><td>30</td><td>75.2%</td></tr>
</table></td><td>30</td><td>21</td></tr>
</table>

*: Removal up to design flow rate (of 20 litres/ second per OceanGuard®). All flows greater than this flow rate are assumed to be receive zero pollutant removal.

The performance values accepted by Logan City Council are based on the Dalrymple et al (2021) paper that assessed the performance of a single OceanGuard® at Western Sydney (summarised in Table 2-1). All other approved performances were based on the Wicks et al (2011) paper assessing the performance of a single Enviropod® and cartridge media (StormFilter®) at Kuranda, Queensland – and these performances were subsequently approved prior to undertaking treatment performance monitoring of an OceanGuard® at Western Sydney University.

All approved stormwater treatment performance values apply a design treatment flow rate for OceanGuard of 20 litres/ second. This treatment flow rate is based on the testing described by Butler et al (2002) where a flow rate up to 20 litres/ second was applied to a single Enviropod® (previous generation to the OceanGuard®). This is conservative given that the Enviropod® tested by White et al (2002) for Brisbane and Gold Coast City Councils achieved a treatment flow rate, prior to bypass and pre-loaded with debris, of in excess of 100 litres/second. It should be noted that the plan dimensions of each basket from each study was both slightly smaller for Butler et al (2002) and slightly larger for White et al (2002), and we have therefore proposed and obtained approval for a conservative design treatment flow rate of 20 litres/second. Standard drawings for the OceanGuard® (outlining available basket sizes) are provided in Appendix G. Both of the aforementioned papers are also provided in Appendix I.

## 3.4 Recommendation

It is recommended that the treatment performance of OceanGuard® within be modelled using a GPT treatment node (as described above), with stormwater treatment performance consistent with either the (i) values observed (and summarised in Table 2-1) for the OceanGuard® performance monitoring at Western Sydney University or (ii) Council approved values given in Table 3-1 – up to the design treatment flow rate (of 20 litres/second).

# 4 Conclusion

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

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

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

It is recommended that a GPT treatment node (in eWater's MUSIC software) be applied in modelling the performance of OceanGuard®, with stormwater treatment performance consistent with either the (i) values observed (and summarised in Table 2-1) for the OceanGuard® performance monitoring at Western Sydney University or (ii) Council approved values given in Table 3-1 – up to the design treatment flow rate (of 20 litres/second).

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# Appendix A Letter describing equivalence of OceanGuard® relative to EnviroPod® technology

This appendix provides a letter from Ocean Protect (3 March 2019) describing the equivalence of OceanGuard® technology to EnviroPod® technology.

3rd March, 2019.

**Introducing the OceanGuard™ gully pit basket**

The OceanGuard™ technology is a gully pit basket designed to fit within new and existing gully pits to remove pollution from stormwater runoff. The system has a choice of filtration liners, designed to remove gross pollutants, total suspended solids and attached pollutants as either a stand-alone technology or as part of a treatment train with our StormFilter or Jellyfish filtration products.

Gully pit baskets and associated technology have been available in Australia and overseas for more than 20 years. The OceanGuard™ technology has design elements and removal performance that are the same as some off-patent technologies, such as the previous generation EnviroPod previously sold by Stormwater360 Australia under licence. The OceanGuard™ is our in-house gully pit basket product.

The OceanGuard™ technology has the following features:

- Flow Diverter: Directs flow into the unit for filtration of stormwater flows and includes an in-built rigid bypass to divert stormwater overflows in high-intensity and peak storm flows.
- Filtration Bag: Removable coarse (gross pollutant removal) and fine grade (200micron) filtration bags.
- Filtration Cage: A supporting cage that allows for the use of larger filtration bags.

The OceanGuard™ meets all previous performance data and current approvals across Australia in terms of pollutant removal, flow rate and head loss.

For further information about our OceanGuard™ product, its performance and applications, please contact the Ocean Protect team.

Yours Faithfully,

**Michael Wicks**
Director

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# Appendix B Peer review report by Damian McCann of OceanGuard®

As described in Section 2.6.1, Damian McCann from AWC was commissioned by Ocean Protect to undertake a peer review of the OceanGuard®, with a particular focus on confirming "compliance with Stormwater Australia's *SQIDEP* (Version 1.3) and the Water by Design *MUSIC Modelling Guidelines* (2010), specifically Section 4.8" for the performance monitoring of the OceanGuard® at Western Sydney University. Mr McCann's review included all available performance monitoring data at the Western Sydney University site up until May 2021. This study is summarised in Table 2-1.

This appendix provides the peer review report of the OceanGuard® prepared by Damian McCann from AWC.

Brad Dalrymple

Ocean Protect

29 Chetwynd Street

Loganholme QLD 4129

16th June 2021

AWC Reference: 1-201228_OceanGuard_SQIDEP_Review_Final

Dear Brad,

**RE: OceanGuard SQIDEP and MUSIC Modelling Review**

Australian Wetlands Consulting (AWC) was commissioned to audit the performance monitoring of the OceanGuard gully basket System in Australia and confirm compliance with Stormwater Australia's *SQIDEP (Version 1.3) and the* Water by Design *Music Modelling Guidelines (2010),* specifically Section 4.8.

Ocean Protect supplied the following materials pertaining to the performance monitoring:

- *A review of the application of OceanGuard in Logan City, Queensland, Australia* (Ocean Protect, May 2021) which includes information on current approvals, case studies, performance monitoring, review of applicability to local conditions in Logan City
- Stormwater treatment performance for OceanGuard gully basket at Western Sydney, Kingsford, NSW (Appendix C in the above report)
- A Microsoft excel file *OceanGuard WSC SQIDEP Compliance 210519* containing data and statistical analysis from the monitoring undertaken at Western Sydney University (WSU), Kingswood, NSW
- Laboratory Chain of Custodies (COC) documentation and Certificates of Analysis from samples collected during monitoring undertaken at WSU
- Individual storm reports containing event hydrographs with information of rainfall, flow data and aliquot data monitoring undertaken at WSU
- WSU Maintenance reports
- MUSIC model for the OceanGuard gully basket at Western Sydney, Kingsford (and associated calculations)
- Photos of monitoring site at WSU

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Based on a review of the information provided, summary of pollution reduction efficiencies in Table 1 and remote site inspection, AWC confirm that the field testing of the OceanGuard Gully Pit System conducted at the Western Sydney complies with the requirements of SQIDEP (v1.3) Field Evaluation pathway as shown in Table 2 attached.

The following key information needs to be highlighted with regards to any Treatment Claims that can be made for the OceanGuard system evaluated under the SQIDEP framework:

- The tested device claims to have a design Treatable Flow Rate (TFR) of 20 L/s. Maximum peak flow rate (PFR) reached twice during the trial was 10.28L/s, which is the limit of the flow meter used in the trial. It is recommended that another meter is installed and the study continue until the likely higher flow rates which occurred can be confirmed
- A paired t-test has indicated that TSS, TP and TN have achieved significance of over 90%
- Pollutant concentration reduction claims achieved during the trials are shown in Table 1
- The system TSS efficiency ratio may be higher than that observed in field monitoring due to low concentrations in influent (mean 53.3,g/L, significantly lower than that recommended in MUSIC guidelines) combined with chipping on the chamber wall as described. On 14th February 2020, it was noticed that small flakes of concrete from the pit chamber walls and floor were observed within the devices chamber. It was anticipated that these flakes would flow downstream, contributing to elevated solids levels in effluent samples without being first sampled at the inlet reducing the systems reduction efficiency. On 12th June 2020, works were undertaken to seal the pit chamber with waterproofing to prevent small particles from the pit chamber walls and floor entering the effluent sampler

*Table 1 Summary of pollution reduction at OceanGuard, UWS, Kingswood, Sydney*

| Analyte | Median CRE (%) | Average CRE (%) | Efficiency Ratio (%) |
|---|---|---|---|
| TSS | 56 | 52 | 52 |
| TP | 60 | 56 | 66 |
| TN | 21 | 22 | 41 |

As OceanGuard only uses physical filtration process, differing climate conditions (variations in temperature, rainfall intensity) are unlikely to affect the effectiveness of system's ability to remove pollutants.

## Conclusion

AWC has reviewed the performance trial of the OceanGuard proprietary device and supporting data from the trial in Kingswood, NSW. We confirm the trial is consistent with SQIDEP V1.3 and the following performance was observed:

| Parameter | Value |
|---|---|
| Treatable Flow Rate (L/s) | 10.28 |
| Pollutant Reduction % (TSS;TP;TN) | 52; 66; 41 |

We have also reviewed the information provided against the MUSIC Modelling Guidelines (2010) and confirm the modelling configuration proposed is consistent with the guideline and an accurate representation of the trial; apart from the observed treatable flow rate which is an apparent limitation of the flow meter used, with MUSIC predicting a maximum flow rate of 45L/s at the WSU trial site.

We believe the performance observed in western Sydney is transferrable to other locations since the key variables are treatable flow rate and catchment characteristics.

I hope this summary is clear but please contact me with any questions.

Your sincerely,

Damian McCann

Director

**Attachment 1**

*Table 2 Assessment of the OceanGuard Biofiltration System performance monitoring undertaken at Western Sydney against SQIDEP (v1.3) requirements (the respective page number where the requirement is discussed in SQIDEP v1.3 is shown for ease of reference).*

| SQIDEP Requirement | Initial AWC comments | Compliance | Ocean Protect Response | Final AWC comments / compliance |
|---|---|---|---|---|
| Catchment area (p14) | 400m² | Y | | |
| Land Use (p14) | Car Park | Y | | |
| Percentage Impervious cover (p14) | 100% | Y | | |
| Aerial photos (p14) | Figure C-1 | Y | | |
| Site Photos (p14) | Figures C-1 and C-2 | Y | | |
| Potential pollutant sources (p14) | Vehicles, vegetation, human litter. | Y | | |
| Site map showing: (p14)<br>• Catchment area<br>• Drainage system layout<br>• Treatment device<br>• Sampling points | Catchment area was defined by land survey and site inspections and are described in performance review | Y | | |
| Treatable flow rate (TFR) (p14) | 20L/s. Provided in stormwater treatment performance review however this flow rate was not observed during the trial. | N | | Two TFR of 10.28L/s has been observed in the trial. Ongoing monitoring may capture storm events which produce a larger flow rate consistent with precedent studies, e.g. Butler et al 2002 who recorded a flow rate of 20L/s with no bypass. |
| Rainfall ≤ 5 min time interval (p15) | Measured at 1minute intervals. Details provided in performance review UWS report | Y | | |
| Rainfall ≤ 0.25mm increments (p15) | Two 0.25mm tip bucket rain gauges | Y | | |
| Rainfall -Location shown on site map (p15) | Shown in figure C-1 of UWS report. Aerial photo of site, catchment and equipment | Y | | |
| Rainfall - Checked, cleared | 2x Gauges used. Factory | Y | | |

| SQIDEP Requirement | Initial AWC comments | Compliance | Ocean Protect Response | Final AWC comments / compliance |
|---|---|---|---|---|
| of debris and calibrated at least two times during the testing period (p15) | calibrated and recalibration not required. Checked for debris and cleaned regularly. Maintenance reports attached | | | |
| Rainfall - Protected from excessive wind velocities (p15) | Rain gauge was installed in accordance with manufactures instructions. The tipping bucket itself is designed to be shielded from the wind. Details provided in WSU report. | Y | | |
| Min 15 events (p15-16) | Results for all 16 qualifying storms until 7th[th] April 2021 at Western Sydney are provided in WSU report table C-4 | Y | | |
| Achieve at least 90% statistical significance between paired samples of influent and effluent (p15-16) | Paired t-test have has indicated that TSS, TP and TN have achieved a significance of over 90%. | Y | | |
| Each monitoring program will need to identify the period delineating the end of one event and beginning of the next – typically 24hrs or the time taken to reset monitoring equipment (p15-16) | Table C-3 provides the date of each event and the sampling duration in hours. | Y | | |
| Hydrographs for each event to demonstrate the program has representatively captured the event (p15-16) | Information provided within table C-3 coinciding with hydrographs individual storm reports show sampling had captured event | Y | | |
| Min 2 peak inflows from the sampled events should exceed 75% of the design TFR of the device + 1 ≥ than its design TFR (p15-16) | TFR is 20L/s. Peak flows recorded within the monitoring data were 10.28L/s on 25th March and 29th April 2020. | N | | |

| SQIDEP Requirement | Initial AWC comments | Compliance | Ocean Protect Response | Final AWC comments / compliance |
|---|---|---|---|---|
| Events to be sufficiently distributed throughout the monitoring period to capture seasonal influences on storm conditions<br><br>&<br><br>The independent evaluation panel must be satisfied that the qualifying storms includes a good range of storm event (longer and shorter duration) (p15-16) | Monitoring occurred between Dec 2019 and March 2021 with a range of rainfall events characteristics sampled.<br><br>Number of events per season are evident in WSU report:<br>• Summer: 5<br>• Autumn: 6<br>• Winter: 2<br>• Spring: 2<br><br>Spring and winter slightly under-represented when compared to rainfall data | Y | | |
| 50% of qualifying storms should include the first 70% storm hydrograph coverage (p15-16) | Table C-1 and hydrographs have been provided within individual storm reports for each event with the WSU report | Y | | |
| Flow measurement at the inlet and outlet are recommended. Monitoring of bypass flows is optional, however, at a minimum the monitoring information should be sufficient to identify periods when device is operating in bypass (p17) | ISR within WSU report distinguishes inflow rates only. Outflow and bypass flows were not recorded within study. Bypass occurs when total flow is more than the treatment flow, except in very small part of the catchment contributes to the bypass without going to the treatment. No bypass flows were recorded within study | Y | | |
| The QAPP should identify whether effluent characterization accounts for total storm flow, including bypass if it occurs (p17) | Bypass did not occur during WSU study | NA | | |
| Outlet flow should be | Bypass did not occur | Y | | |

| SQIDEP Requirement | Initial AWC comments | Compliance | Ocean Protect Response | Final AWC comments / compliance |
|---|---|---|---|---|
| sampled either prior to or after mixing with bypass flow and Claims identify the inclusions/exclusion of bypass flows (p17) | during WSU study, but outlet sampling has been indicated as being sampled after mixing with bypass | | | |
| Make, model and procedures and schedule for calibration, inspection and cleaning shall be provided (p20) | Influent and effluent sampler: ISCO 6712 Portable Automated sampler configured for 9.5L wide-mouthed carboy bottles.<br><br>The influent sampler was equipped with an ISCO730 Bubbler Weir module, connected directly to the ISCO 6712 sampler, and installed within a pre-configured and calibrated 152mm diameter Thel-mar Weifor influent flow measurement and sample pacing<br><br>The bubblers were regularly checked and calibration by submersing the weir in water and setting the depth on the sampler with the bubbler module to the depth measured. 'Equipment calibration and maintenance reports are provided | Y | | |
| Rainfall (p20) | The rain gauge is factory-calibrated and needs no further calibration (As manufactures recommendations). Routine maintenance is required to check for debris and blockages | Y | | |
| Flow proportional sampling | At least 8 aliquots were | Y | | |

| SQIDEP Requirement | Initial AWC comments | Compliance | Ocean Protect Response | Final AWC comments / compliance |
|---|---|---|---|---|
| requires at least 80% of the submitted events have at least 8 aliquots collected from both the rising and falling limbs of the hydrograph to form the composite sample (p21) | collected in 80% of events sampled with details provided in Table C-3 and ISR with WSU report. | | | |
| Sample blanks for field and analytical testing to be supplied (p21) | Provided in COC within WSU supporting documentation | Y | | |
| COC documents identifying sample collection, collection agency, collection time, preservation used, laboratory receipt of sample and sample collection shall be provided (p21) | Provided within supporting documentations | Y | | |
| NATA accreditation (p21) | Evidence of NATA accreditation has been provided in certificates of analysis within WSU supporting documentations. | Y | | |
| Method of analysis detailed (p21) | Analytical methods stated in Table C-2 of performance review | Y | | |
| Non-detects (p23) Effluent sample results below the limit of detection (LOD) shall be set at 0.5 x LOD and must be accompanied by a sensitivity analysis showing impact on performance metrics of adopting both LOD and 0). | Ocean protect excel file summary WSU Data refers to table 4 (for results and recommended sensitivity testing). | Y | | |
| Performance metrics (p25) Analysis should clearly indicate how treatment and bypass flows (either external or internal to the device) have been accounted for in the presentation of results. | Detail on how treatment and bypass flows have been accounted for is provided within results provided | Y | | |
| Average and Median Concentration Removal | Details are provided in table c-5 of the report. | Y | | |

| SQIDEP Requirement | Initial AWC comments | Compliance | Ocean Protect Response | Final AWC comments / compliance |
|---|---|---|---|---|
| Efficiency (p25) | Also highlighted in AWC review summary | | | |
| Event Mean Concentration and Mass Discharge (p30)<br>The event mean concentration and Mass Discharge variability are required to verify the ability of the device to manage large variability in EMCs and mass discharges.<br><br>Box and whisker plots should be prepared for influent and effluent EMCs as well as mass loads (where presented).<br><br>The number of EMCs and mass loads contributing to each distribution should be clearly indicated. | The required results including EMCs and box and whisker plots are provided in results section of the report and accompanying spreadsheet.<br><br>Box and whisker plots for influent and effluent EMCs are presented in figure C-7 and clearly show EMCs in scatter plot graphs in Figure C-6 | | | |

# References

Butler K, Ockleston G, Foster M (2002), *Auckland City's field and laboratory testing of stormwater catchpit filters*.

Dalrymple B, Wicks M. (2021). *A review of the application of OceanGuard® in Logan City, Australia*. Prepared on behalf of Ocean Protect.

Drapper D, Lucke T (2015). *Characterisation of Stormwater Pollutants from Various Catchment types in South-east Queensland*. Presented at the 2015 WSUD & IECA Conference.

Duncan H.P. (1999). *Urban Stormwater Quality: A Statistical Overview (Report 99/3).* CRC for Catchment Hydrology.

Stormwater Australia (2018) *Stormwater Quality Improvement Device Evaluation Protocol. Version 1.2 December 2018.*

Water by Design (2010). *MUSIC Modelling Guideline, Version 1.0.*

Water by Design (2018). *Draft MUSIC Modelling Guideline, November 2018, Consultation Draft.* A Healthy Land and Water Initiative.

# Appendix C Peer Review Report by Professor Ashantha Goonetilleke of Kuranda Stormwater Treatment System Field Evaluation

As described in Section 2.6, Professor Ashantha Goonetilleke from the Queensland University of Technology was commissioned by Ocean Protect to undertake a peer review of the *Kuranda Stormwater Treatment System Field Evaluation* (Vigar et al 2010), later described by Wicks et al (2011) (and summarised in Table 2-1 and given in Appendix I).

This appendix provides the peer review by Professor Ashantha Goonetilleke.

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15th March 2011

**KURANDA STORMWATER TREATMENT SYSTEM FIELD EVALUATION**

I have peer reviewed the report dated 15th October 2010, on the Kuranda Stormwater Treatment System field evaluation prepared by Stormwater 360. I find the report to be a factual evaluation of the data obtained from the field study. The data evaluation and the conclusions derived have been presented using clear and precise terminology which is easy to read and understand. It is also important to note that any identified shortcomings in the system has been highlighted and discussed in an open manner.

It is quite evident that the data collection has been based on a very rigourous and technically demanding monitoring program. This adds further credibility to the field evaluation undertaken. I have personally inspected the field set up at Kuranda and also assessed the sample collection and testing protocols and can confirm the validity of the information presented in the document.

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# Appendix D Stormwater treatment performance for OceanGuard® gully basket at Western Sydney, Kingswood, NSW

## D.1 Preamble

As outlined in Section 2.5, stormwater treatment performance monitoring has been undertaken for a OceanGuard® at Western Sydney University, Kingswood, NSW, Australia. This appendix describes the methodology and results of that assessment.

## D.2 Background

As outlined in Section 2.3, over 20,000 OceanGuards® (and previous generation Enviropods®) have been installed within Australia. Treatment performance monitoring of the Enviropod® technology has been undertaken in Kuranda, Queensland, Australia – and monitoring has also been undertaken of Enviropods® at two separate sites in Auckland, New Zealand.

The Enviropod® at the site in Kuranda described by Wicks et al (2011) was part of a 'treatment train' consisting of the Enviropod® and cartridge media (StormFilter®) treatment system, and this was monitored by Ocean Protect (formerly Stormwater360 Australia) during a 20-month period between 2008 and 2009.

The first Enviropod® monitored in Auckland is described by Enviropod Holdings Ltd (2001) and was monitored over a 7-month period in 2000. The second Enviropod® monitored in Auckland is described by Butler et al (2002) and was monitored over a 5-month period in 2002.

Ocean Protect and the Engineering Department of the Western Sydney University subsequently developed and implemented an OceanGuard® to obtain further evidence of its performance within Australia.

## D.3 Methodology

### D.3.1 Site details

The site is located at a car park in Western Sydney University, Kingswood, NSW, Australia (hereafter referred to as 'the site'). The car park is swept periodically, but minor amounts of sediment and organic debris are typically present at the car park. The carpark consists entirely of an impervious asphalt surface and has a high usage rate.

An aerial photo of the site from February 2020 is shown in Figure D-1.


**Figure D-1 Aerial photo of the site, catchment & equipment**

An OceanGuard® gully pit insert was installed within an existing gully pit within the car park. The system receives runoff from an area of 400m$^2$ (which is 100% impervious), determined by land survey and site inspections. The catchment is illustrated in Figure 1.

The gully pit insert was installed at the site in August 2019. The gully pit is a 900mm x 600mm square pit, and the gully pit insert has a fine grade (200 micron) bag of 300mm depth, with a design treatable flow rate of 20 litres/ second.

Example photos of the gully pit insert, sampling facilities and catchment at the site are provided in Figure 2. A conceptual diagram of the gully pit insert installed at the site is provided in Figure 3. A schematic of the system is provided in Figure 3.

**Stormwater treatment performance for OceanGuard® gully basket at Western Sydney, Kingswood, NSW**

**Figure D-2 Example photos of the gully pit insert, sampling facilities and catchment at the site**

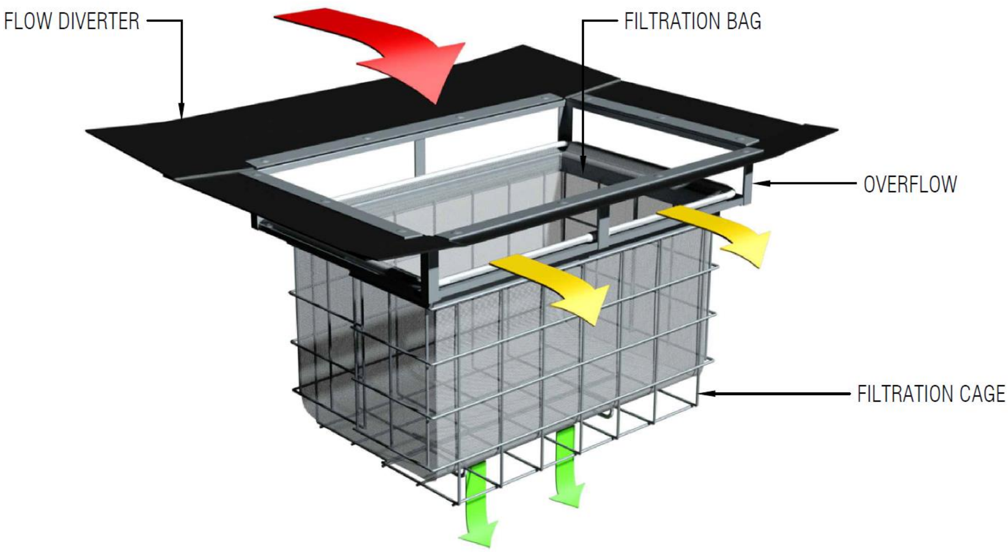



**Figure D-3 Conceptual diagram of OceanGuard® gully pit insert at site**

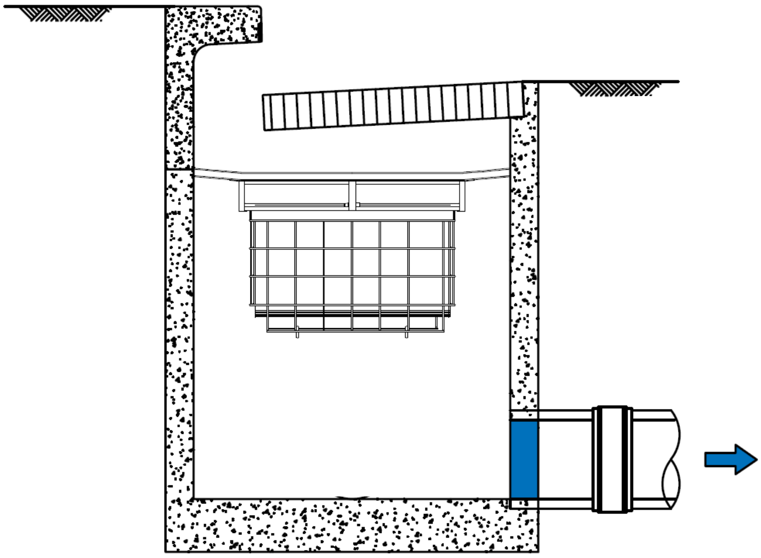


**Figure D-4 Schematic section drawing of OceanGuard® gully pit insert at the site**

The gully pit insert at the site has been maintained in accordance with typical/ standard maintenance procedures for these assets. In summary, the system is maintained approximately every four (4) months, with maintenance undertaken on 14 February 2020, 4 June 2020, 27 November 2020 and 25 March 2021.

Any material on the outer flaps is brushed into the 200-micron bag and is removed from the gully pit insert. The contents are emptied, removing any debris and litter, and the bag is inspected. and placed back into the gully pit insert.

It should be noted that when cleaning the pit of debris during maintenance on 14 February 2020, it was noticed that 'flakes' (small particles) of concrete from the pit chamber walls and floor were observed within the chamber, which would be anticipated to flow downstream (and contribute to elevated solids levels in effluent samples at the site). It is likely that this flaking of concrete from the pit chamber walls and floor was occurring throughout the duration of the monitoring period until 12 June 2020. On 12 June 2020, works were undertaken to seal the pit chamber with waterproofing to prevent small particles from the pit chamber walls and floor entering the effluent sampler.

## D.3.2 Sampling design

The equipment and sampling techniques used for this study were in accordance with the Project Plan developed by Ocean Protect in consultation with both City of Gold Coast's (2016) *Development Application Requirements and Performance Protocol for Proprietary Devices* and Stormwater Australia's (2018) *Stormwater Quality Improvement Device Evaluation Protocol Field Monitoring*. The Project Plan generally satisfied most conditions outlined in both field testing protocols detailed below in Table D-1.

**Table D-1 Summary of required field testing protocol at site**

| Criteria | Requirement |
|---|---|
| Minimum number of aliquots | > 8 |
| Minimum storm coverage | > 50% of storms have >70% hydrograph coverage |
| Antecedent dry period | > 6 hours |
| Minimum Rainfall Depth | minimum required to take a composite sample |
| Minimum Storm Duration | 5 minutes |

Ocean Protect personnel were responsible for the installation, operation, and maintenance of the sampling equipment. Ocean Protect personnel provided sample retrieval, system reset, and sample submittal activities for all events up to and including 4 September 2020, whilst ALS were responsible for these tasks for subsequent events. Water sample processing and analysis was performed by ALS.

A small double-door cabinet was provided, installed, maintained, and operated by Ocean Protect personnel for sampling purposes. The cabinet is a fully enclosed, self-contained stormwater monitoring system, specially designed and built by Ocean Protect for remote, extended-deployment stormwater monitoring. The design allows for remote control of sampling equipment, eliminates confined space entry requirements, and streamlines the sample and data collection process and operation of the equipment.

Influent and effluent water quality samples were collected using individual ISCO 6712 Portable Automated Samplers configured for 9.5 litre wide-mouth carboy bottles with disposable sample liners for sample collection. The samplers were connected to one 12V DC battery recharged with a solar panel mounted to the roof of the shipping container. The influent sampler was equipped with an ISCO 730 Bubbler Weir module, connected directly to the ISCO 6712 sampler, and installed within a pre-configured and calibrated 152mm diameter Thel-mar Weir (in accordance with manufacturers instructions) for influent flow measurement and sample pacing. The ISCO 6712 effluent sampler was setup as a “slave” and triggered from pulses received from the influent sampler at specific flow volumes pre-determined for every storm event. Flow rates were recorded every minute.

The bubblers were regularly checked for calibration by submersing the weir in water and confirming/setting the depth of water on the sampler with the bubbler module to the depth measured. The tables for the flow against height are provided by Thel-mar LLC and input into the samplers.

Rainfall was measured at 1-minute intervals using two 0.25mm resolution ISCO 674 tipping bucket-type rain gauges, factory-calibrated, securely installed on a post and regularly inspected. The ISCO 674 rain gauge was connected directly to the ISCO 6712 Influent sampler. The sample intake for each automated sampler was connected to an ISCO low profile stainless steel sample strainer (9/16″ diameter, 6″ length, with multiple ¼″ openings) via a length of 3/8″ ID Acutech Duality PTFE tubing. The rain-gauge is factory calibrated and does not require further calibration except to ensure there is nothing obstructing or interfering with the tip bucket. The rain gauge was installed and maintained according to manufacturer’s instructions, and checked and cleared of debris regularly. The rain gauge was located on a post and protected from excessive wind velocities that could skew accuracy of measurement. The two (2) rain gauges were installed approximately 1 m apart and results were compared periodically to ensure accuracy. An additional ISCO 674 rain gauge was located 100m away for reference and redundancy.

Sample strainers and flow measurement equipment were secured to the invert of the influent and effluent pipes using stainless steel spring rings with all components supplied and setup in general accordance with ISCO's guidelines. Each sampler was also connected to a computer to allow for complete data access. Cameras were installed in the pit to additionally confirm the presence of bypass flows for all storm events.

Samplers were programmed to enable the sampling program to trigger on flow. Once enabled, the samplers collected flow-proportional samples allowing the specified pacing volume to pass before taking a sample. The sample collection program was a one-part program developed to maximize the number of water quality aliquots/samples collected as well as the coverage of the storm event for an anticipated rainfall depth. Influent and effluent sample collection programs were configured to collect a minimum of eight aliquots per bottle. Due to the variability among predicted precipitation events, the sample pacing specifications were varied (flow pacing and aliquot volume) in consultation with the most up-to-date precipitation forecasts and programmed by Ocean Protect personnel prior to every storm event.

Following a precipitation event, Ocean Protect personnel communicated with the automated sampling equipment to confirm sample collection and then dispatch personnel to retrieve the samples and reset the automated sampling equipment. Samples where then split using the appropriate Bel-Art's Churn Splitter – one for the influent and one for the effluent to reduce the likelihood of contamination and to provide subsamples in accordance with the manufacturer's guidelines. Sub-samples were delivered to ALS (a NATA-accredited laboratory) on ice (<4o C) and accompanied by chain-of-custody documentation and analysis was carried out in accordance with Table C-2.

**Table D-2 Water quality analytical parameters and methods for the site**

| Parameter | Abbreviation | Analytical method | Limit of Reporting |
|---|---|---|---|
| Ammonia as N | Amm.N | APHA 4500 NH3- - G | 0.01 mg/L |
| Nitrate + Nitrite as N | NOx | APHA VCl3 reduction 4500 NO3- + NO2-B | 0.01 mg/L |
| Nitrate as N | - | APHA VCl3 reduction 4500 NO3- + NO2-B | 0.01 mg/L |
| Nitrite as N | - | APHA 4500 NO2- - I | 0.01 mg/L |
| Total Kjeldahl Nitrogen (TKN) as N | TKN | APHA 4500 Norg – D + APHA 4500 NH3-G | 0.1 mg/L |
| pH (pH units) | pH | APHA 4500 H+ - B | 0.01 pH units |
| Phosphorus Total as P | TP | APHA 4500 P - F | 0.01 mg/L |
| Filtered Total Phosphorous as P | Ortho-P | APHA 4500 P - F | 0.01 mg/L |
| Phosphorus Reactive as P | DP | APHA 4500 P – F | 0.01 mg/L |
| Solids - Suspended Solids - Standard level | TSS | APHA 2540 D | 5 mg/L |

### D.3.3 Sampling events

The gully pit insert has been monitored between March 2020 and June 2021, with a total of sixteen (16) runoff events recorded during this period. Figure D-5 illustrates the timing of the sampling events compared to a time series of rainfall data recorded at the site. Table D-3 also provides a summary of recorded rainfall at the site and flow discharged from the system.

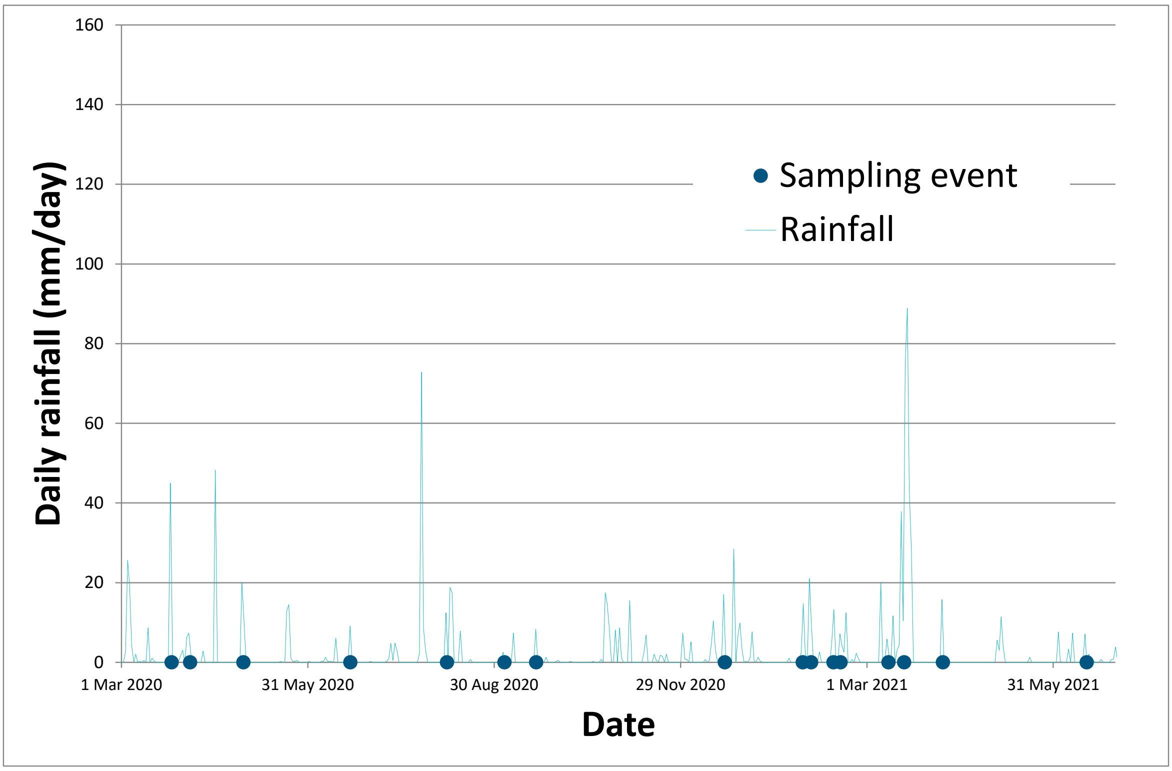



**Figure D-5 Time series of site rainfall and timing of sampling events**

Table D-3 Summary of recorded rainfall and flow data for site

| Event Date | Max. rainfall intensity (mm/hr) | Mean rainfall intensity (mm/hr) | Total rainfall (mm) | Duration of rainfall (hr) | Total runoff volume (L) | Peak flow (L/s) | Mean flow (L/s) | Sampling duration (hr) | Sampling coverage (%) | Number of aliquots |
|---|---|---|---|---|---|---|---|---|---|---|
| 25 Mar 2020 | 88.90 | 2.63 | 45.21 | 10.17 | 67744 | 10.28 | 1.10 | 2.22 | 35% | 80 |
| 3 Apr 2020 | 15.24 | 0.69 | 7.37 | 3.62 | 3651 | 1.53 | 0.10 | 3.18 | 88% | 9 |
| 29 Apr 2020 | 71.12 | 1.95 | 20.07 | 3.27 | 40319 | 10.28 | 1.09 | 0.37 | 15% | 40 |
| 21 Jun 2020 | 30.48 | 0.74 | 9.14 | 5.40 | 1963 | 2.85 | 0.04 | 2.07 | 25% | 6 |
| 7 Aug 2020 | 10.16 | 0.73 | 12.45 | 10.12 | 8456 | 0.97 | 0.14 | 10.15 | 98% | 34 |
| 4 Sep 2020 | 5.08 | 0.20 | 2.54 | 5.92 | 669 | 0.37 | 0.01 | 5.18 | 90% | 5 |
| 20 Sep 2020 | 12.70 | 0.65 | 8.38 | 5.87 | 7514 | 1.68 | 0.16 | 3.72 | 90% | 35 |
| 21 Dec 2020 | 7.62 | 0.92 | 18.80 | 13.35 | 7309 | 0.55 | 0.10 | 13.37 | 99% | 25 |
| 28 Jan 2021 | 5.08 | 0.41 | 19.56 | 41.22 | 16525 | 1.76 | 0.10 | 41.03 | 98% | 55 |
| 1 Feb 2021 | 68.58 | 2.52 | 30.99 | 5.27 | 18450 | 6.61 | 0.42 | 7.58 | 99% | 62 |
| 12 Feb 2021 | 15.24 | 0.67 | 18.29 | 20.08 | 7165 | 1.17 | 0.07 | 18.30 | 97% | 24 |
| 16 Feb 2021 | 33.02 | 0.57 | 5.33 | 7.67 | 1345 | 2.58 | 0.04 | 0.25 | 89% | 9 |
| 11 Mar 2021 | 5.08 | 0.52 | 5.84 | 4.23 | 4590 | 0.78 | 0.11 | 4.40 | 98% | 19 |
| 19 Mar 2021 | 45.72 | 2.31 | 242.57 | 97.90 | 63133 | 2.94 | 0.17 | 63.75 | 80% | 68 |
| 7 Apr 2021 | 40.64 | 0.92 | 15.75 | 10.18 | 2448 | 2.49 | 0.04 | 9.12 | 98% | 13 |
| 16 Jun 2021 | 12.70 | 0.73 | 7.11 | 2.70 | 1407 | 0.71 | 0.04 | 2.60 | 96% | 28 |

## D.4 Results & discussion

Table D-4 provides the results of the monitoring. Table D-5 provides the calculated concentration reduction efficiencies (CREs). Table D-6 provides a statistical summary of the monitoring results. Table D-7 provides the influent nitrogen speciation percentages. Table D-8 also provides a comparison of influent EMC values recorded at the site and those given in MUSIC modelling guidelines within Australia by Water By Design (2010), BMT WBM (2015) and Melbourne Water (2018). Table D-9 provides a comparison of the percentage fraction of total nitrogen as dissolved nitrogen against that recommended in the E2DesignLab (2015) report *Development Application Requirements and Performance Protocol for Proprietary Devices on the Gold Coast*. Table D-10 also provides a comparison of influent nitrogen speciation data for the site with runoff data for other sites within Australia and E2DesignLab (2015) recommended values. Plots and box plots of recorded influent and effluent concentrations are also provided in Figure D-6 and Figure D-7.

## Stormwater treatment performance for OceanGuard® gully basket at Western Sydney, Kingswood, NSW

### Table D-4 Results of treatment performance monitoring

| Event Date | TSS (mg/L) Influent | TSS (mg/L) Effluent | DP (mg/L) Influent | DP (mg/L) Effluent | TP (mg/L) Influent | TP (mg/L) Effluent | NOx (mg/L) Influent | NOx (mg/L) Effluent | $NH_3$ (mg/L) Influent | $NH_3$ (mg/L) Effluent | DIN (mg/L) Influent | DIN (mg/L) Effluent | TKN (mg/L) Influent | TKN (mg/L) Effluent | TN (mg/L) Influent | TN (mg/L) Effluent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 Mar 2020 | 26 | 8 | *0.005* | *0.005* | 0.070 | 0.040 | 0.200 | 0.200 | 0.180 | 0.250 | 0.380 | 0.450 | 0.200 | 0.300 | 0.400 | 0.500 |
| 3 Apr 2020 | 16 | 11 | *0.005* | *0.005* | 0.050 | 0.020 | 0.040 | 0.030 | 0.090 | 0.050 | 0.130 | 0.080 | 0.400 | 0.200 | 0.440 | 0.230 |
| 29 Apr 2020 | 92 | 72 | *0.005* | *0.005* | 0.500 | 0.150 | 0.110 | 0.080 | 0.200 | 0.180 | 0.310 | 0.260 | 0.500 | 0.400 | 0.610 | 0.480 |
| 21 Jun 2020 | 250 | 108 | *0.070* | *0.060* | 0.420 | 0.170 | 0.070 | 0.080 | 0.250 | 0.240 | 0.320 | 0.320 | 1.500 | 0.800 | 1.570 | 0.880 |
| 7 Aug 2020 | 11 | 10 | *0.010* | *0.005* | 0.100 | 0.010 | 0.130 | 0.200 | 0.510 | 0.270 | 0.640 | 0.470 | 0.900 | 0.300 | 1.030 | 0.500 |
| 4 Sep 2020 | 102 | 74 | *0.005* | *0.005* | 0.120 | 0.100 | 0.790 | 0.640 | 0.460 | 0.430 | 1.250 | 1.070 | 1.900 | 1.500 | 2.690 | 2.140 |
| 20 Sep 2020 | 52 | 32 | *0.005* | *0.005* | 0.060 | 0.050 | 0.120 | 0.120 | 0.140 | 0.100 | 0.260 | 0.220 | 0.300 | 0.500 | 0.420 | 0.620 |
| 21 Dec 2020 | 19 | 6 | *0.005* | *0.005* | 0.190 | 0.020 | 0.190 | 0.210 | 0.190 | 0.200 | 0.380 | 0.410 | 0.400 | 0.300 | 0.590 | 0.510 |
| 28 Jan 2021 | 62 | 12 | *0.005* | *0.005* | 0.090 | 0.060 | 0.280 | 0.210 | 0.560 | 0.350 | 0.840 | 0.560 | 1.100 | 0.800 | 1.380 | 1.010 |
| 1 Feb 2021 | 22 | 10 | *0.005* | *0.005* | 0.260 | 0.020 | 0.080 | 0.050 | 0.080 | 0.060 | 0.160 | 0.110 | 0.200 | 0.200 | 0.280 | 0.250 |
| 12 Feb 2021 | 31 | 10 | *0.005* | 0.040 | 0.080 | 0.080 | 0.230 | 0.240 | 0.150 | 0.340 | 0.380 | 0.580 | 1.000 | 0.800 | 1.230 | 1.040 |
| 16 Feb 2021 | 12 | *2.5* | *0.005* | *0.005* | 0.060 | 0.030 | 0.080 | 0.070 | 0.130 | 0.070 | 0.210 | 0.140 | 0.200 | 0.200 | 0.280 | 0.270 |
| 11 Mar 2021 | 22 | 9 | *0.005* | *0.005* | 0.140 | 0.050 | 0.360 | 0.250 | 0.270 | 0.210 | 0.630 | 0.460 | 0.700 | 0.700 | 1.060 | 0.950 |
| 19 Mar 2021 | 62 | 7 | *0.010* | *0.005* | 0.320 | 0.010 | 0.030 | 0.005 | 0.330 | 0.005 | 0.360 | 0.010 | 4.000 | 0.050 | 4.030 | 0.055 |
| 7 Apr 2021 | 91 | 42 | *0.005* | *0.005* | 0.270 | 0.110 | 0.510 | 0.190 | 0.180 | 0.140 | 0.690 | 0.330 | *0.500* | 0.400 | 1.010 | 0.590 |
| 16 Jun 2021 | 61 | 37 | *0.020* | *0.005* | 0.160 | 0.100 | 0.370 | 0.370 | 0.260 | 0.260 | 0.630 | 0.630 | 1.200 | 0.600 | 1.570 | 0.970 |
| **Mean** | 58.2 | 28.2 | 0.011 | 0.011 | 0.181 | 0.064 | 0.224 | 0.184 | 0.249 | 0.197 | 0.473 | 0.381 | 0.938 | 0.503 | 1.16 | 0.69 |
| **Median** | 41.5 | 10.5 | *0.005* | *0.005* | 0.130 | 0.050 | 0.160 | 0.195 | 0.195 | 0.205 | 0.380 | 0.370 | 0.600 | 0.400 | 1.02 | 0.55 |

*: Italicised values were recorded as below the laboratory level of reporting (LOR), and are presented as being equal to half of the LOR.

### Table D-5 Concentration reduction efficiencies

| Event Date | TSS CRE% | DP CRE% | TP CRE% | NOx CRE% | $NH_3$ CRE% | TKN CRE % | DIN CRE% | TN CRE% |
|---|---|---|---|---|---|---|---|---|
| 25 Mar 2020 | 69% | 0% | 43% | 0% | -39% | -50% | -16% | -25% |
| 3 Apr 2020 | 31% | 0% | 60% | 25% | 44% | 50% | 63% | 48% |
| 29 Apr 2020 | 22% | 0% | 70% | 27% | 10% | 20% | 19% | 21% |
| 21 Jun 2020 | 57% | 14% | 60% | -14% | 4% | 47% | 0% | 44% |
| 7 Aug 2020 | 9% | 50% | 90% | -54% | 47% | 67% | 36% | 51% |
| 4 Sep 2020 | 27% | 0% | 17% | 19% | 7% | 21% | 17% | 20% |
| 20 Sep 2020 | 38% | 0% | 17% | 0% | 29% | -67% | 18% | -48% |
| 21 Dec 2020 | 68% | 0% | 89% | -11% | -5% | 25% | -7% | 14% |
| 28 Jan 2021 | 81% | 0% | 33% | 25% | 38% | 27% | 50% | 27% |
| 1 Feb 2021 | 55% | 0% | 92% | 38% | 25% | 0% | 45% | 11% |
| 12 Feb 2021 | 68% | -700% | 0% | -4% | -127% | 20% | -34% | 15% |
| 16 Feb 2021 | 79% | 0% | 50% | 13% | 46% | 0% | 50% | 4% |
| 11 Mar 2021 | 59% | 0% | 64% | 31% | 22% | 0% | 37% | 10% |
| 19 Mar 2021 | 89% | 50% | 97% | 83% | 98% | 99% | 3500% | 99% |
| 7 Apr 2021 | 54% | 0% | 59% | 63% | 22% | 20% | 109% | 42% |
| 16 Jun 2021 | 39% | 75% | 38% | 0% | 0% | 50% | 0% | 38% |
| **Mean** | 53% | -32% | 55% | 15% | 14% | 21% | 243% | 23% |
| **Median** | 56% | 0% | 59% | 16% | 22% | 21% | 28% | 21% |

*: Negative (red) values show a recorded increase in pollutant concentrations across the system.

## Stormwater treatment performance for OceanGuard® gully basket at Western Sydney, Kingswood, NSW

### Table D-6 Statistical summary of monitoring results

| Analyte | no. of events | Range of Influent EMCs (mg/L) | Median Influent EMC (mg/L) | Mean Influent EMC (mg/L) | Range of Effluent EMCs (mg/L) | Median Effluent EMC (mg/L) | Mean Effluent EMC (mg/L) | Median Conc. Removal Efficiency (Mean CRE, %) | Efficiency Ratio (ER, %)* |
|---|---|---|---|---|---|---|---|---|---|
| TSS | 16 | 11 - 250 | 41.5 | 58.2 | 2.5 - 108 | 10.5 | 28.2 | 56% | 52% |
| DP | 16 | *0.005 - 0.07* | *0.005* | 0.011 | *0.005* - 0.06 | *0.005* | 0.011 | 0% | 0% |
| TP | 16 | 0.05 - 0.5 | 0.130 | 0.181 | 0.01 - 0.17 | 0.050 | 0.064 | 59% | 65% |
| NOx | 16 | 0.03 - 0.79 | 0.160 | 0.224 | *0.005* - 0.64 | 0.195 | 0.184 | 16% | 18% |
| $NH_3$-N | 16 | 0.08 - 0.56 | 0.195 | 0.249 | *0.005* - 0.43 | 0.205 | 0.197 | 22% | 21% |
| DIN | 16 | 0.13 - 1.25 | 0.380 | 0.473 | 0.01 - 1.07 | 0.370 | 0.381 | 21% | 19% |
| TKN | 16 | 0.2 - 4 | 0.600 | 0.938 | 0.05 - 1.5 | 0.400 | 0.503 | 28% | 23% |
| TN | 16 | 0.28 - 4.03 | 1.020 | 1.162 | 0.055 - 2.14 | 0.55 | 0.69 | 21% | 41% |

*: Efficiency Ratio = (average inlet EMC – average outlet EMC)/ average inlet EMC

### Table D-7 Influent nitrogen speciation percentages

| Event Date | % of NOx as % of TN | $NH_3$ as % of TN | DIN as % of TN | TKN as % of TN |
|---|---|---|---|---|
| 25 Mar 2020 | 50% | 45% | 95% | 50% |
| 3 Apr 2020 | 9% | 20% | 30% | 91% |
| 29 Apr 2020 | 18% | 33% | 51% | 82% |
| 21 Jun 2020 | 4% | 16% | 20% | 96% |
| 7 Aug 2020 | 13% | 50% | 62% | 87% |
| 4 Sep 2020 | 29% | 17% | 46% | 71% |
| 20 Sep 2020 | 29% | 33% | 62% | 71% |
| 21 Dec 2020 | 32% | 32% | 64% | 68% |
| 28 Jan 2021 | 20% | 41% | 61% | 80% |
| 1 Feb 2021 | 29% | 29% | 57% | 71% |
| 12 Feb 2021 | 19% | 12% | 31% | 81% |
| 16 Feb 2021 | 29% | 46% | 75% | 71% |
| 11 Mar 2021 | 34% | 25% | 59% | 66% |
| 19 Mar 2021 | 1% | 8% | 9% | 99% |
| 7 Apr 2021 | 50% | 18% | 68% | 50% |
| 16 Jun 2021 | 24% | 17% | 40% | 76% |
| **Mean** | 24% | 28% | 52% | 76% |
| **Median** | 26% | 27% | 58% | 74% |

## Stormwater treatment performance for OceanGuard® gully basket at Western Sydney, Kingswood, NSW


**Figure D-6 Plots of recorded influent and effluent concentrations at the site**

## Stormwater treatment performance for OceanGuard® gully basket at Western Sydney, Kingswood, NSW

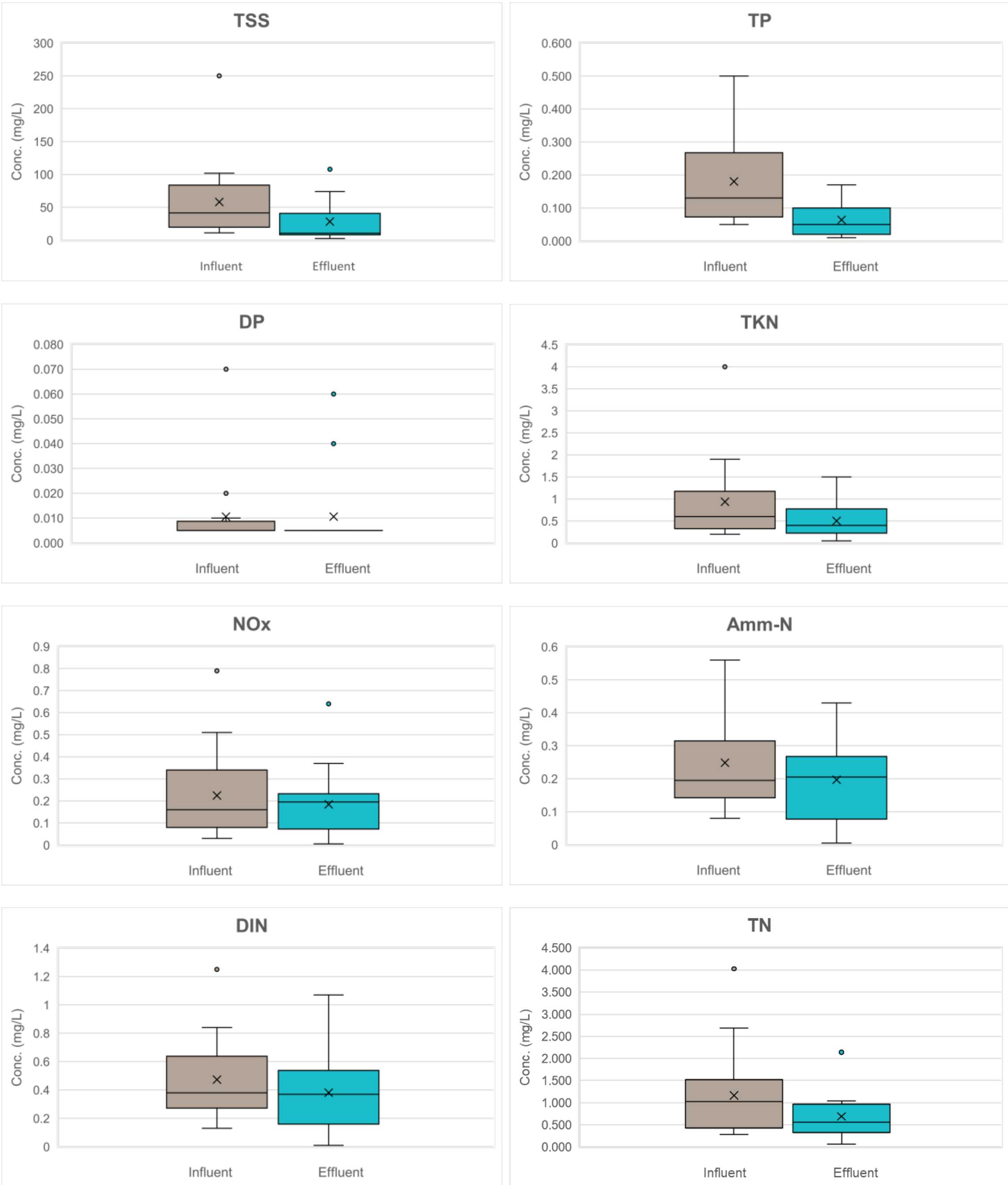



**Figure D-7 Box plots of recorded influent and effluent concentrations at the site**

**Table D-8 Comparison of site influent EMC with MUSIC guideline EMC values**

| Parameter | Site Influent Mean (mg/L) | Water By Design (2010)[1] | BMT WBM (2015)[2] | eWater, Melbourne Water (2016)[3] |
|---|---|---|---|---|
| TSS EMC | 58.2 | 269 | 269 | 270 |
| TP EMC | 0.181 | 0.501 | 0.501 | 0.500 |
| TN EMC | 1.162 | 1.82 | 2.19 | 2.20 |

1: Values are from Event Mean Concentrations (EMCs) for 'Urban residential roads' as given by Water By Design (2010) *MUSIC Modelling Guidelines*

2: Values are for EMC for sealed roads as given by BMT WBM (2015) *NSW MUSIC Modelling Guidelines*

*3:* Values are default values from for urban residential for the eWater MUSIC software, which are recommended for application by Melbourne Water *(2016) MUSIC Guidelines - Recommended input parameters and modelling approaches for MUSIC.*

**Table D-9 Comparison of site influent % dissolved nitrogen with E2DesignLab (2015) recommended values**

| Parameter | Site | | E2DesignLab (2015)[1] | |
|---|---|---|---|---|
| | Mean | Range | Typical | Minimum |
| % fraction of TN dissolved | 52% | 9 to 95% | Approx. 50% | 40% |

1: Values are from E2DesignLab (2015) *Development Application Requirements and Performance Protocol for Proprietary Devices on the Gold Coast*, August 2015.

**Table D-10 Comparison of site influent nitrogen speciation with runoff data for other sites within Australia and DesignFlow (2015) recommended values**

| Location | NOx as a % of TN | $NH_3$-N as a % of TN | Organic N as a % of TN | TKN as a % of TN |
|---|---|---|---|---|
| Site mean | 24 | 28 | - | 76 |
| Site range | 1-50 | 8-50 | - | 50-99 |
| 'Typical fraction' cited by E2DesignLab (2015) | 25-40 | 10-20 | 45-70 | 55-75 |
| 'Minimum fraction' cited by E2DesignLab (2015) | 20 | 5 | - | - |
| Drapper et al (2015) | 22 | 16 | - | 35 |
| Parker (2010) bioretention basin | 28 | 19 | 53 | 72 |
| Parker (2010) wetland inlet big | 26 | 12 | 68 | 80 |
| Parker (2010) wetland inlet small | 37 | 21 | 41 | 62 |
| Taylor et al (2005) [2] | 36 | 13 | 52 | 65 |
| Birch et al (2005) | 32 | - | - | 68 |
| Hatt et al (2009), Monash University | 36 | 4 | 55 | 64 |
| Hatt et al (2009), McDowall | 37 | 19 | 48 | 63 |

1: Concentration values are average values unless otherwise stated

2: Source: Parker (2010)

### Suspended solids

Reductions in TSS concentrations were recorded for all events, with a concentration reduction efficiency ratio of 52% (with concentration reductions ranging from 9 to 89%).

TSS concentrations in stormwater flowing from the car park catchment (and entering the gully pit insert) were significantly lower than that recommended in given MUSIC guidelines for comparable land usages. For example, the mean TSS concentration recorded in inflows to the gully pit insert was 58.2 mg/L, significantly lower than the Water by Design (2010), BMT WBM (2015) and eWater (2016) guideline recommended EMC values of 269 and 270mg/L. As described by Neumann et al (2010), for example, it is easier for SCMs to achieve higher pollutant concentration reduction rates when runoff has higher pollutant concentrations. Higher TSS concentration reductions would subsequently be anticipated for OceanGuard® gully pit inserts receiving flows with TSS concentrations similar to values recommended in the aforementioned guidelines.

It is clear that the observed 'flaking' of concrete from the pit chamber walls and floor into the pit chamber (described in Section C.3.1) would have contributed to elevated TSS concentrations in the effluent samples (and subsequently contributed to observed lower TSS concentration reductions) until the sealing of the pit chamber on 12 June 2020. This anomaly negatively biased the results for TSS as some of the particles measured within the TSS effluent for each storm were derived from the pit and not sampled as stormwater from the influent sample. Prior to the rectification works and given no bypassing of storm flows were evident, analysis of the effluent particle size distribution showed particles greater than the pore aperture of the filter liner in outlet flows, ie 200micron. Subsequent particle size distribution analysis after the sealing of the pit chamber indicated no particles in the effluent greater than 200micron. Therefore, the gully pit insert would have achieved higher TSS removal efficiencies than recorded in the monitoring results until 12 June 2020.

### Nutrients

TP and TN concentration reduction efficiency ratios observed across the system were 65% and 41% respectively. Total phosphorus and nitrogen EMCs observed in flows to the gully pit insert at the site were significantly lower than that recommended by aforementioned MUSIC guidelines. As for TSS, the ability of any SCM to reduce nutrient concentrations would be decreased at lower inflow concentrations.

The majority of the recorded phosphorus concentrations observed in flows to and from the gully pit insert consisted of particulate phosphorus, with relatively low concentrations of dissolved phosphorus. For nitrogen, a mean of 52% of recorded inflow concentrations were dissolved (ranging from 9 to 95%), which complies with the recommended minimum mean of 40% given by E2DesignLab (2015). The percentage of nitrogen speciation for NOx and $NH_3$ comply with the recommended minimum fractions given by E2DesignLab (2015), and proportions of nitrogen species are similar to values observed at other sites (presented in Table 10).

## D.5 Conclusion

Stormwater treatment performance testing was undertaken for an OceanGuard® located in a car park at Western Sydney University, Kingswood, NSW, Australia. The sampling and monitoring protocol was designed and implemented in consultation with both City of Gold Coast's (2016) *Development Application Requirements and Performance Protocol for Proprietary Devices* and Stormwater Australia's (2018) *Stormwater Quality Improvement Device Evaluation Protocol Field Monitoring*.

The performance testing at the site demonstrated that the OceanGuard® was able to achieve significant reductions in stormwater pollutant concentrations, with a concentration reduction efficiency ratio for TSS, TP and TN of 52, 65 and 41% respectively. These concentration reductions were achieved despite relatively low concentrations for TSS, TP and TN in incoming stormwater flows (which would be expected to decrease potential concentration reductions), and 'flaking' of concrete from the pit chamber walls and floor prior to 12 June 2020.

# Appendix E MUSIC modelling of OceanGuard® at University of Western Sydney

## E.1 Preamble

As described in Section 3.2, MUSIC is the preferred tool for demonstrating the performance of stormwater quality treatment systems (Water By Design 2010, BMT WBM 2015). As described in Section 3.4, OceanGuard® can be modelled in MUSIC using a gross pollutant treatment node.

This appendix describes the methodology and results of modelling the OceanGuard® at Western Sydney (described in Appendix D) as a gross pollutant trap node (in MUSIC), with comparisons made between MUSIC predictions and monitoring data recorded at the site.

## E.2 Methodology

### E.2.1 Software

The eWater CRC MUSIC software (Version 6) has been used in these assessments. This is the latest version of MUSIC (at the time of report writing).

### E.2.2 Source node

Within MUSIC, the user is required to specify source nodes. The source nodes represent the stormwater flow and pollutant generating areas of the site.

A single source node was used to represent the catchment flowing to the OceanGuard® at the site. A summary of the source node properties used in the MUSIC modelling is provided in Table E-1.

**Table E-1 Summary of source node properties applied in modelling**

| Parameter | Unit | Value | Comments |
|---|---|---|---|
| Land usage classification | - | Urban residential roads | Unless otherwise stated, rainfall-runoff and pollutant export properties in accordance with Water By Design (2010) |
| Area | ha | 0.040 | See Appendix D. |
| Imperviousness | % | 100% | |
| TSS/ TP/ TN EMC's | mg/L | Varies | Pollutant concentrations as recorded in site monitoring (for influent, See Table D-4). In the absence of a recorded concentration corresponding to rainfall events within the modelling event, the previous recorded concentrations available are applied for flows from the catchment (represented by the source node). |
| Estimation method | - | Mean | See above for assumptions related to pollutant concentrations. No stochastic generation of pollutants assumed. |

### E.2.3 Treatment node

A single gross pollutant node was used to represent the OceanGuard® at the site. A summary of the treatment node properties used in the MUSIC modelling is provided in Table E-2. The layout of the source and treatment nodes within MUSIC is illustrated in Figure E-1.

**Table E-2 Summary of treatment node properties applied in modelling**

| Parameter | Unit | Value | Comments |
|---|---|---|---|
| **Inlet properties** | | | |
| Low-flow bypass | $m^3/s$ | 0 | All flows enter system. |
| High-flow bypass | $m^3/s$ | 0.02 | Equal to design treatment flow rate. Refer to Section 3.4 for further information. |
| **Percentage concentration reductions (up to high flow bypass)** | | | |
| Gross pollutants | % | 100 | Anticipated reduction given 200-micron bag applied. |
| Total suspended solids | % | 52 | Concentration efficiency ratios, as observed at site over modelling period (March 2020 to June 2021). See Table D-6. |
| Total phosphorus | % | 65 | |
| Total nitrogen | % | 41 | |

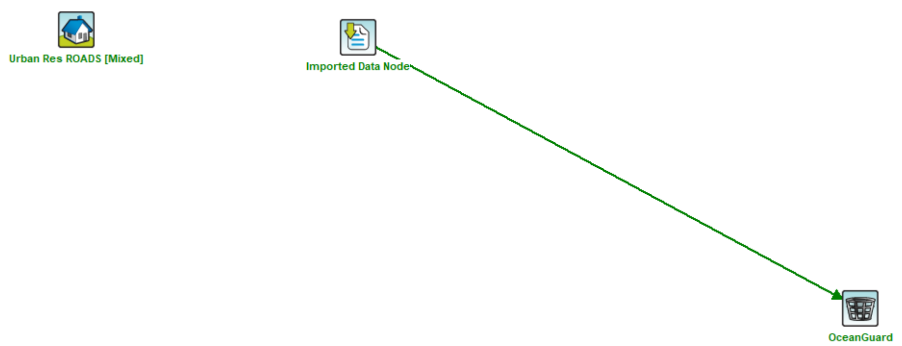



**Figure E-1 Layout of MUSIC model for site**

### E.2.4 Meteorological data

Modelling was performed from 20 March 2020 to 30 June 2021, using 6-minute rainfall data recorded at the site and monthly areal PET from Parramatta (provided within MUSIC). This period includes all site monitoring data (16 qualifying events).

## E.3 Results

Table E-3 presents a comparison of the predicted average annual flows and pollutant loads for the site against observed concentration efficiency ratio (ER) (between 1 March 2020 and 30 June 2021). Table E-4 presents a comparison of the recorded influent and effluent concentrations at the site (as part of site monitoring, described in Appendix D). It should be noted that the pollutant concentration statistics from MUSIC are only for periods where flow was predicted in MUSIC (i.e. results exclude all periods of zero flow).

**Table E-3 Comparison of Predicted Average Annual Flows and Loads for Site against observed concentration efficiency ratio (20 March 2020 to 30 June 2021)**

| Parameter | Average annual flows and loads predicted in MUSIC | | | Observed Concentration Efficiency Ratio (%) |
|---|---|---|---|---|
| | Sources | Residual | % Reduction | |
| Flow (ML/year) | 0.304 | 0.304 | 0 | N/A |
| TSS (kg/year) | 20.50 | 10.20 | 50% | 52% |
| TP (kg/year) | 0.065 | 0.025 | 61% | 65% |
| TN (kg/year) | 0.382 | 0.227 | 41% | 41% |
| Gross pollutants (kg/year) | 8.34 | 0.0523 | 99% | N/A |

**Table E-4 Comparison of recorded influent and effluent concentrations recorded at site and as predicted by MUSIC (20 March 2020 to 30 June 2021)**

| Parameter | Unit | Value predicted by MUSIC[1] | Value using site monitoring data[2] |
|---|---|---|---|
| Maximum flow rate | L/s | 45.4 | 10.276* |
| TSS mean influent concentration | - | 56 | 66 |
| TP mean influent concentration | ha | 0.182 | 0.204 |
| TN mean influent concentration | % | 1.10 | 1.33 |
| TSS mean effluent concentration | mg/L | 26.8 | 31.8 |
| TP mean effluent concentration | mg/L | 0.062 | 0.071 |
| TN mean effluent concentration | mg/L | 0.65 | 0.78 |
| TSS ER | % | 52% | 52% |
| TP ER | % | 66% | 65% |
| TN ER | % | 41% | 41% |

1: Values are only for periods where flow was predicted (i.e. results exclude all periods of zero flow).

2: See Appendix D.

## Flows

The MUSIC analysis of the period between 20 March 2020 and 30 June 2021 predicts a volumetric flow reduction of zero across the OceanGuard®.

As per Table C-4, two peak flow rates of 10.276L/s have been recorded over the monitoring period, whilst a peak flow rate of 45.4L/s was predicted in the MUSIC modelling. The design treatment flow rate of the OceanGuard is, however, 20 litres/ second, but the maximum flow rate that the current flow meter records is 10.276L/s. There are plans to reconfigure the outlet flow meter to record higher flow rates (if present). As predicted by MUSIC, it is likely that flow rates higher than 10.276L/s but have not been recorded.

The peak flow rate predicted by MUSIC of 45.4/s is higher than the reported design treatment flow rate of 20L/s but lower that that observed in the Enviropod® tested by White et al (2002) for Brisbane and Gold Coast City Councils that achieved a treatment flow rate, prior to bypass and pre-loaded with debris, of in excess of 100 litres/second. This is consistent with anecdotal evidence that indicates bypass has not occurred in the OceanGuard® at the site to date.

## Pollutants

The average pollutant concentration and load reductions observed in MUSIC are very similar to those observed at the site.

## Summary

It is likely that MUSIC (and associated gross pollutant treatment node) provides a reasonable prediction of pollutant load and concentration reductions for the OceanGuard® at the site. It should, however, be noted that this comparison utilises the recorded performance data at just one site.

# Appendix F OceanGuard® Technical Design Guide

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

# OceanGuard

# Technical Design Guide

# Table of Contents



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

## Introduction

The OceanGuard technology is a gully pit basket designed to fit within new and existing stormwater pits targeting pollution in stormwater runoff. The system is offered with a choice of filtration bag liners, designed to remove gross pollutants, total suspended solids and attached pollutants. It can be adopter as a stand-alone technology or as part of a treatment train with our StormFilter or Jellyfish filtration products.

The filtration bag, filtration cage and flow diverter work together to maximise the flow treated, pollutant capture, hydraulic efficiency and ultimately retaining captured pollutants dry. OceanGuard pit inserts are highly effective, easy to install and simple to maintain.

## Operational Overview

The OceanGuard is installed into field or kerb inlet gully pits. The flow diverter at top of the unit has a rigid recycled plastic HDPE skirt that is installed against the walls directing all incoming stormwater flows into the filtration bag.

The stormwater is then filtered via direct screening through the filtration bag liner ensuring that any debris larger than the openings in the filtration bag are captured and retained.

During large storm events the water elevation in the filtration bag can rise and peak flows are internally bypassed through slots created in the flow diverter which has no moving parts that may prematurely fail.

At the end of the storm event debris and stormwater rest at the base of the filtration bag where the stored material will start to dry until the next storm event.

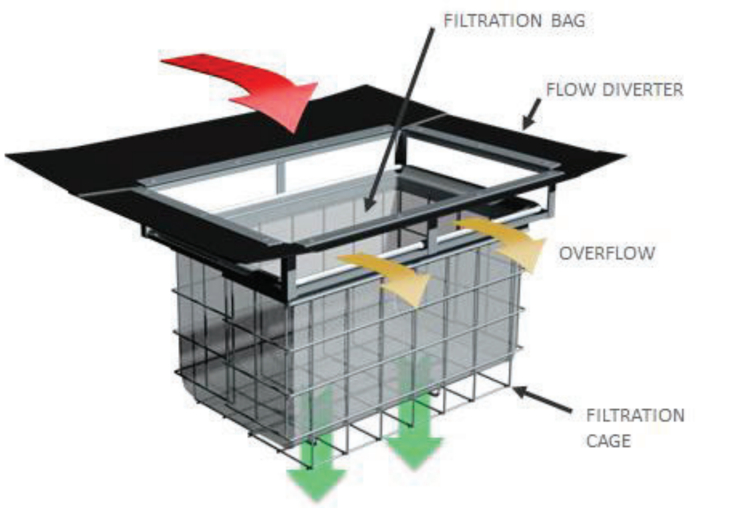



*Figure 1: OceanGuard components*

## Features

The OceanGuard technology has the following features:

- Flow Diverter
  Directs flow into the unit for filtration of stormwater flows and includes an in-built rigid bypass to divert stormwater overflows in high-intensity and peak storm flows.
- Filtration Bag
  Removable coarse (gross pollutant removal) and fine grade (200micron) filtration bags.
- Filtration Cage
  The supporting cage that allows for the use of larger filtration bags.

The OceanGuard can also be fitted with an oil/hydrocarbon adsorbent material (optional) to capture and retain oil and grease. The adsorbent material is contained in socks that are designed to ensure maximum contact with stormwater as it enters the gully pit.

The OceanGuard is designed to be easily retrofitted into new and existing stormwater pits, requiring no construction or land take. The OceanGuard is often the most practical solution and reduces the pollutant load and maintenance burden on downstream infrastructure.

## Configurations

The OceanGuard can fit a range of pits typically found in Australia including, kerb entry, rear entry with grated drain entry as well as field gully pits. There are multiple sizes to suit pits ranging in plan dimensions of *450 x 450mm – 1200 x 1200mm*. Additional custom sizes are available to suit circular and non-standard pits.

The standard OceanGuard configuration treats surface flow only, see figure 2. In some instances, it may be necessary to treat pipe flow, see figure 3. Remember to limit the upstream catchment to the basket to no more than 1000m$^2$ (or DN300mm pipe) otherwise the peak flows may cause structural damage to the OceanGuard. Furthermore, to assist design checks by a suitable qualified engineer need to be undertaken to ensure the upstream catchment is not excessively large. Please note that the OceanGuard technology is not a replacement for an in-line gross pollutant trap.

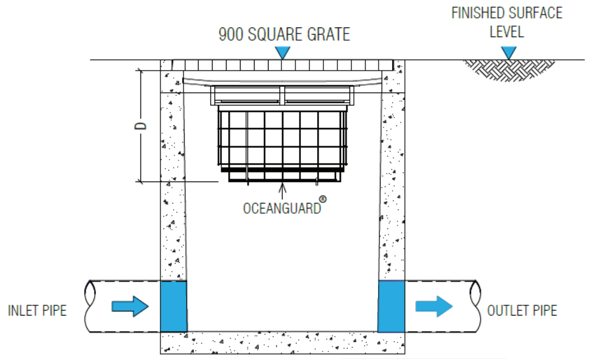



*Figure 2: Standard configuration – surface flow*

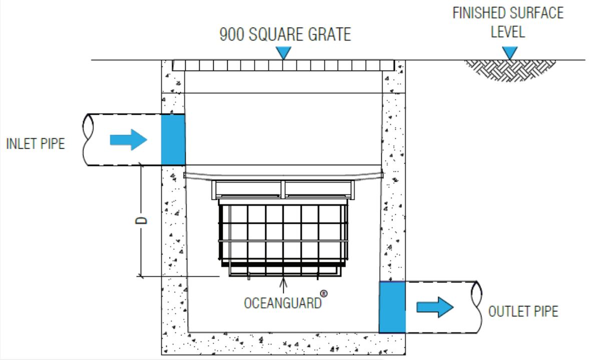



*Figure 3: Example configuration – pipe flow*

Another typical configuration required, is where the runoff collected by grated strip or trench drains needs to be treated, see figure 4.

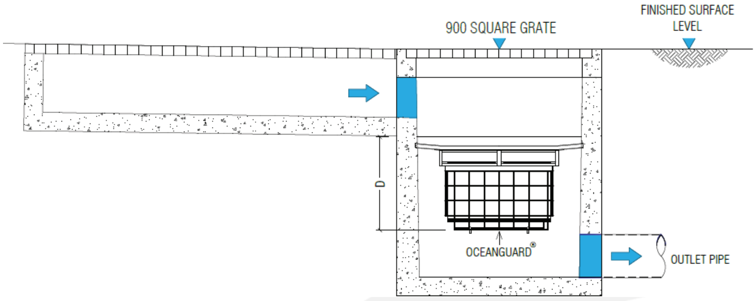



*Figure 4: Example configuration – Grated strip/trench drain*

## Performance

Typically, laboratory testing provides a means to generate hydraulic and basic performance data, but it should also be complemented with long-term field data. Gully pit baskets that operate under unrestricted flows require both a combination lab and field studies to accurately understand performance.

Ocean Protect has and is undertaking field testing locally in Australia and copies of the supporting articles are available upon request from Ocean Protect.

Gully pit baskets and associated technology have been available in Australia and overseas for more than 20 years. The OceanGuard technology has design elements and removal performance that are the same as some off-patent technologies, such as the previous generation EnviroPod previously sold by Stormwater360 Australia (Now Ocean Protect) under licence.

The OceanGuard meets all previous performance data and current approvals across Australia in terms of pollutant removal, flow rate and head loss. Please contact your Ocean Protect representative for more information.

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

## Maintenance

Maintenance of the OceanGuard is simple effective and seldom requires confined space entry or specialised equipment, often being completed by hand without the need of vacuum equipment. Simply remove the OceanGuard from the pit with the tags provided and invert the bag into a waste bin. Inspect the liner and brush by hand or spray with a pressure washer if required to rejuvenate the filtration bag. Record the information and replace the filtration bag.

*Inspection & Cleaning*

The Ocean Guard® system should be inspected at regular intervals from 1-2 months during the first year of installation to ensure optimum performance. The frequency at which the OceanGuard will need to be maintained will depend on site activities, land uses, catchment area and this size of OceanGuard installed, 1-6 times annually (3-4 typ.).

For further information please refer to the OceanGuard Operations and Maintenance Manual.

# Design Basics

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

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

## 1. Hydraulic Design & Configuration

All OceanGuard inserts 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).

## 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 StormFilter 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 an OceanGuard system for water quality purposes in MUSIC, a single GPT node is utilised. The GPT 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. When modelling, the high-flow bypass is modified in node by adding the total number of Ocean Guards installed and multiplying this number by 20L/s, eg 10 x Ocean Guards = $0.2m^3/s$.

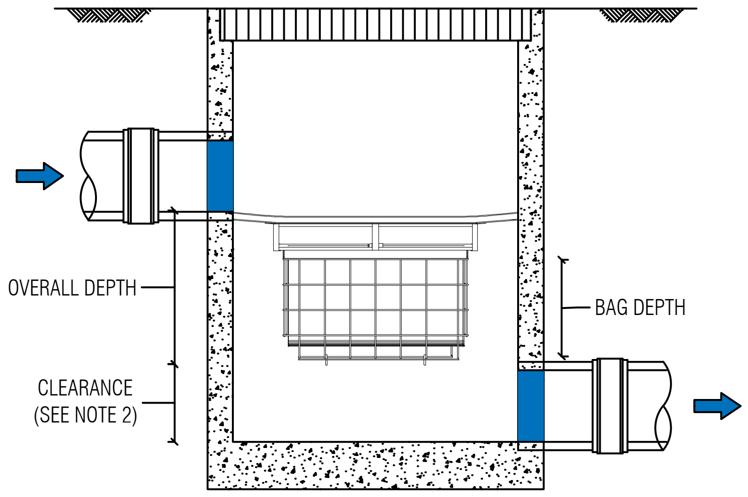
All details such as drawings, specifications and maintenance manuals can also be downloaded for integration into your project's documentation. Additionally the Ocean Protect team is available to review your model and provide additional assistance and guidance on the configuration of the OceanGuard system(s)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

## 3. Mass Load Design

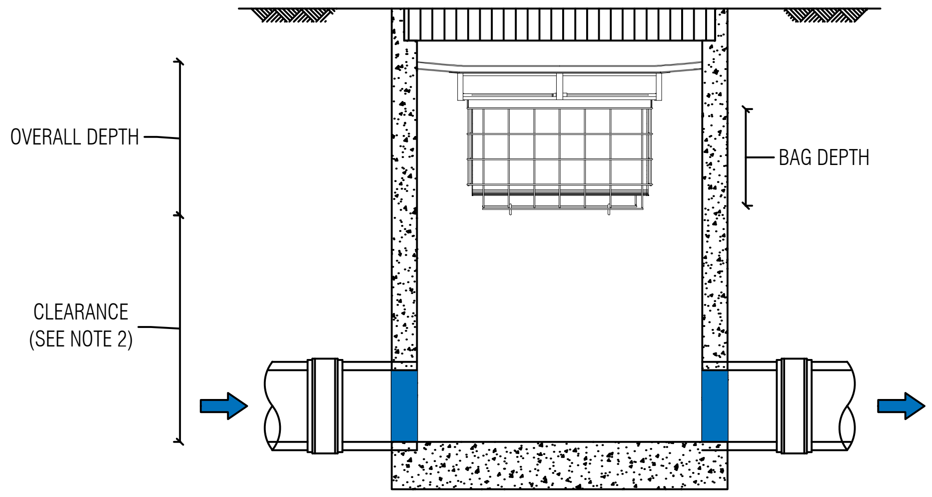
Always be mindful of the magnitude of upstream catchment areas pay particular attention to perceived dirty or high loading sites. The Ocean Protect team can provide assistance and details on this process.

# Appendix G OceanGuard® Standard Drawing

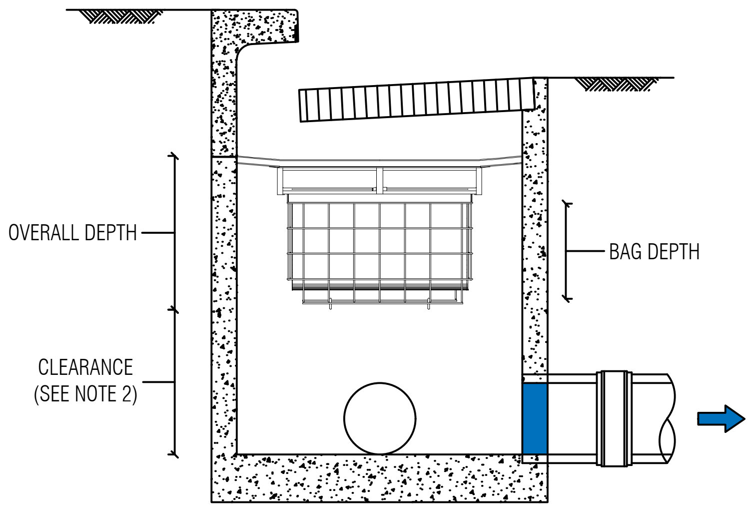
This appendix provides a standard drawing of a typical arrangement for OceanGuard®, produced by Ocean Protect.



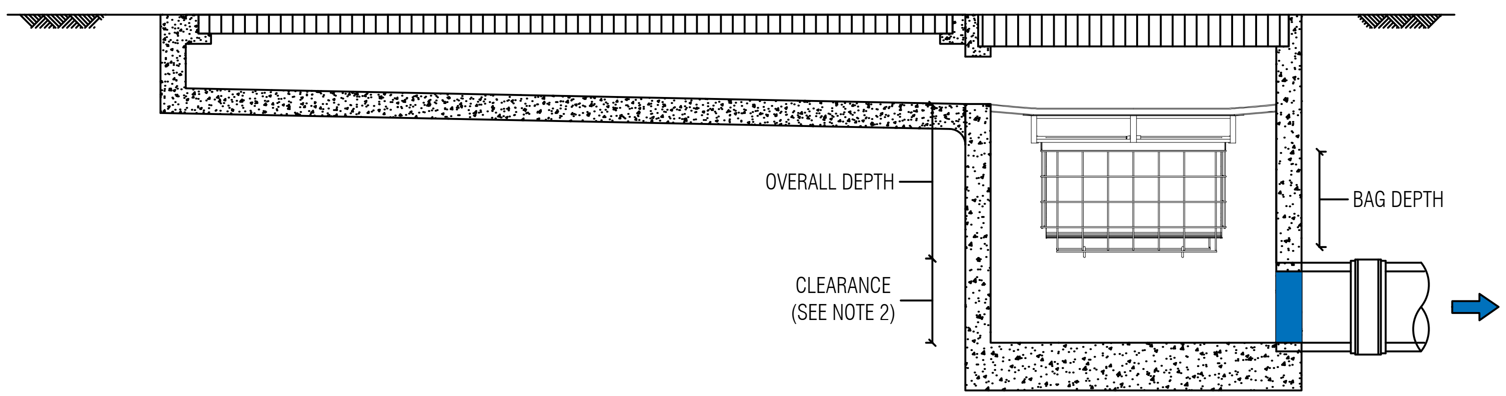

PIPE FLOW CONFIGURATION




SURFACE FLOW CONFIGURATION




SURFACE FLOW CONFIGURATION

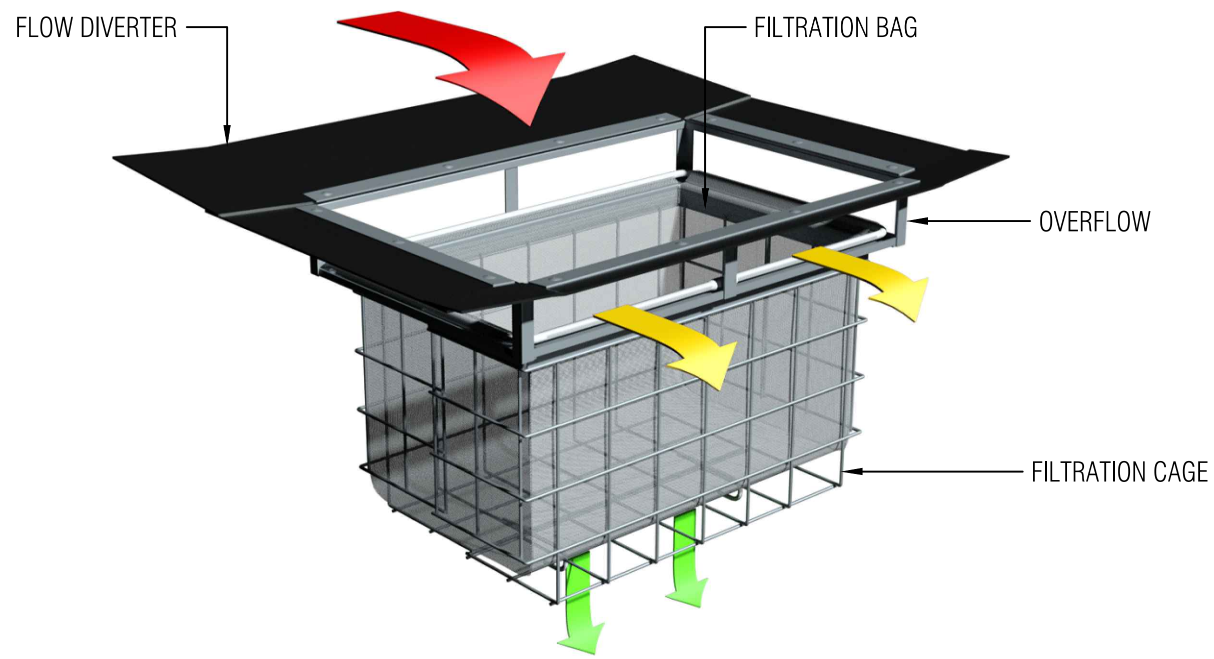



GRATED STRIP DRAIN CONFIGURATION

| PLAN ID | MAXIMUM PIT PLAN DIMENSIONS |
|---|---|
| S | 450mm x 450mm |
| M | 600mm x 600mm |
| L | 900mm x 900mm |
| XL | 1200mm x 1200mm |

| DEPTH ID | BAG DEPTH | OVERALL DEPTH |
|---|---|---|
| 1 | 170 | 270 |
| 2 | 300 | 450 |
| 3 | 600 | 700 |

| | | DEPTH ID | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| PLAN ID | S | ■ | | |
| | M | ■ | ■ | |
| | L | ■ | ■ | ■ |
| | XL | ■ | ■ | ■ |




GENERAL NOTES

1. THE MINIMUM CLEARANCE DEPENDS ON THE CONFIGURATION (SEE NOTE 2) AND THE LOCAL COUNCIL REQUIREMENTS.
2. CLEARANCE FOR ANY PIT WITHOUT AN INLET PIPE (ONLY USED FOR SURFACE FLOW) CAN BE AS LOW AS 50mm. FOR OTHER PITS, THE RECOMMENDED CLEARANCE SHOULD BE GREATER OR EQUAL TO THE PIPE OBVERT SO AS NOT TO INHIBIT HYDRAULIC CAPACITY.
3. OCEAN PROTECT PROVIDES TWO FILTRATION BAG TYPES:- 200 MICRON BAGS FOR HIGHER WATER QUALITY FILTERING AND A COARSE BAG FOR TARGETING GROSS POLLUTANTS.
4. DRAWINGS NOT TO SCALE.

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TYPCIAL ARRANGEMENTS
SPECIFICATION DRAWING

# Appendix H OceanGuard® Operation & Maintenance Manual

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

OceanGuard™

# Operations & Maintenance Manual

# Table of Contents



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

# 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 as recommended by the manufacturer.

The OceanGuard technology is a gully pit basket designed to fit within new and existing gully pits to remove pollution from stormwater runoff. The system has a choice of Filtration liners, designed to remove gross pollutants, total suspended solids and attached pollutants as either a standalone technology or as part of a treatment train with our StormFilter or Jellyfish Filtration products. OceanGuard pit baskets are highly effective, easy to install and simple to maintain.

## 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 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 OceanGuard.

# Health and Safety

Access to pits containing an OceanGuard typically requires removing (heavy) access covers/grates, but typically it is not necessary to enter into a confined space. Pollutants collected by the OceanGuard 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 sharp objects such as broken glass and syringes. For these reasons, there should be no primary contact with the waste collect and all aspects of maintaining and cleaning your OceanGuard 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 OceanGuard pit insert, precautions should be taken in order to minimise (or when possible prevent) contact with sediment and other captured pollutants by maintenance personnel. In order to achieve this the following personal protective equipment (PPE) is recommended:

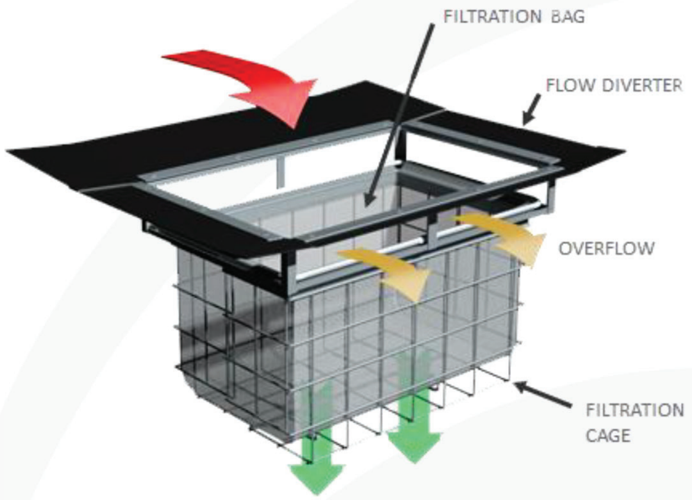
- Puncture resistant gloves
- Steel capped safety boots,
- Long sleeve clothing, overalls or similar skin protection
- Eye protection
- High visibility clothing or vest

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.

The OceanGuard pit insert is designed to be maintained from surface level, without the need to enter the pit. However depending on the installation configuration, location and site specific maintenance requirements it may be necessary to enter a confined space occasionally. 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.

# How does it Work?

OceanGuard is designed to intercept stormwater as it enters the stormwater pits throughout a site. The OceanGuard has diversion panels that sit flush with the pit walls, this ensures that as stormwater enters at the top of the pit it is directed to the middle of the insert where the Filtration bag is situated. The filtration bag allows for screening to occur removing 100% of pollutants greater than the opening of the filtration material (200micron, 1600micron bags available).




During larger rain events the large flows overflow slots in the flow diverter of the OceanGuard ensure that the conveyance of stormwater is not impeded thus eliminating the potential for surface flooding. As the flow subsides, the captured pollutants are held in the OceanGuard Filtration bag dry. The waste then starts to dry which reduces the magnitude of organic material decomposition transitioning between maintenance intervals.

# Maintenance Procedures

To ensure that each OceanGuard pit insert achieves optimal performance, it is advisable that regular maintenance is performed. Typically the OceanGuard requires 2-4 minor services annually, pending the outcome of these inspections additional maintenance servicing may be required.

## 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 OceanGuard.

| | Description of Typical Activities | Frequency |
|---|---|---|
| **Minor Service** | Filter bag inspection and evaluation<br>Removal of capture pollutants<br>Disposal of material | 2-4 Times Annually |
| **Major Service** | Filter Bag Replacement<br>Support frame rectification | 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 return the OceanGuard device back to optimal operating performance. This type of service can be undertaken either by hand or with the assistance of a Vacuum unit.

### Hand Maintenance

1. Establish a safe working area around the pit insert
2. Remove access cover/grate
3. Use two lifting hooks to remove the filtration bag
4. Empty the contents of the filtration bag into a disposal container
5. Inspect and evaluate the filtration bag
6. Inspect and evaluate remaining OceanGuard components (i.e. flow diverter, filtration cage and supporting frame)
7. Rejuvenate filtration bag by removing pollutant build up with a stiff brush, additionally the filtration bag can be washed using high pressure water
8. Re-install filtration bag and replace access cover/grate

### Vacuum Maintenance

1. Establish a safe working area around the pit insert
2. Remove access cover/grate
3. Vacuum captured pollutants from the filtration bag
4. Remove filtration bag
5. Inspect and evaluate the filtration bag
6. Inspect and evaluate remaining OceanGuard components (i.e. flow diverter, filtration cage and supporting frame)
7. Rejuvenate filtration bag by removing pollutant build up with a stiff brush, additionally the filtration bag can be washed using high pressure water
8. Re-install filtration bag and replace access cover/grate

## Major Service (Filter Bag Replacement)

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

| Trigger Event from Minor Service | Maintenance Action |
|---|---|
| Filtration bag inspection reveals damage | Replace the filtration bag[1] |
| Component inspection reveals damage | Perform rectification works and if necessary replace components[1] |

[1] Replacement filtration bags and components are available for purchase from Ocean Protect.

## Additional Reasons 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, all OceanGuard pits that potentially received flow should be inspected and cleaned. Specifically all captured pollutants from within the filtration bag should be removed and disposed in accordance with any additional requirements that may relate to the type of spill event. All filtration bags should be rejuvenated (replaced if required) and re-installed.

### Blockages

The OceanGuards internal high flow bypass functionality is designed to minimise the potential of blockages/flooding. In the unlikely event that flooding occurs around the stormwater pit the following steps should be undertaken to assist in diagnosing the issue and implementing the appropriate response.

1. Inspect the OceanGuard flow diverter, ensuring that they are free of debris and pollutants
2. Perform a minor service on the OceanGuard
3. Remove the OceanGuard insert to access the pit and inspect both the inlet and outlet pipes, ensuring they are free of debris and pollutants

### Major Storms and Flooding

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

## Disposal of Waste Materials

The accumulated pollutants found in the OceanGuard 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 filtration bag has 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 OceanGuard system we offer long term pay-as-you-go contracts, pre-paid once off servicing and replacement filter bags.

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

# Appendix I Technical Papers Describing Stormwater Treatment Performance Monitoring of OceanGuard®

Table 2-1 provides a summary of three (3) recent examples of OceanGuard® operating in 'real world' conditions where treatment performance monitoring has been undertaken. This appendix provides technical papers describing the stormwater treatment performance monitoring undertaken for each of these sites.

water e-journal
Online Journal of the Australian Water Association
ISSN 2206-1991
Volume 6 No 1 2021
https://doi.org/10.21139/wej.2021.001

# "Gully pit inserts" shown to reduce pollutants in stormwater

## Samples from runoff filtered through a stormwater control measure show a reduction in suspended solids and nutrient species

B Dalrymple, M Wicks, W Jones, B Allingham

## ABSTRACT

'Gully pit inserts' (or 'gully baskets') are a commonly applied stormwater control measure given they can often be easily integrated into gully pits with no impact to the usability of the area. Stormwater treatment performance monitoring has been undertaken for a gully pit with a fine grade (200-micron) bag of 300mm depth in a car-park in Western Sydney, NSW, Australia. The gully pit insert receives runoff from a 100% impervious car-park area of 400m$^2$. Influent and effluent water quality samples were collected using automated samplers, which were connected to pre-configured and calibrated flow analysis of treated effluent and sample pacing with remote communication and data access. Collected samples were delivered to and analysed in a NATA-accredited laboratory for pH and concentrations of suspended solids and nutrient species. Monitoring was undertaken between December 2019 and March 2021, with a total of fifteen (15) runoff events recorded during this period. The performance testing demonstrated that the gully pit insert was able to achieve significant reductions in stormwater pollutant concentrations, with a concentration reduction efficiency ratio for total suspended solids, total phosphorus and total nitrogen of 52, 67 and 41% respectively.

**Keywords:** Gully pit; stormwater management; stormwater quality.

## INTRODUCTION

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. 'Gully pit inserts' (or 'gully baskets') are a commonly applied SCM given they are often easily integrated into gully pits with no impact to the usability of the area and demonstrated ability to retain pollutants otherwise conveyed downstream into stormwater infrastructure and waterways.

The OceanGuard® technology is a gully pit insert designed to fit within new and existing gully pits to remove pollution from stormwater runoff. The system has a choice of filtration liners, designed to remove gross pollutants, total suspended solids and attached pollutants as either a stand-alone technology or as part of a 'treatment train' with other stormwater treatment assets that provide additional treatment.

Study authors and the Engineering Department of the Western Sydney University subsequently developed and implemented a gully pit insert testing regime to obtain further field-based evidence of its performance within Australia.

# METHODOLOGY

## Site details

The site is located at a carpark in Western Sydney, Kingswood, NSW, Australia (hereafter referred to as 'the site'). The carpark is swept periodically, but minor amounts of sediment and organic debris are typically present at the site. The carpark consists entirely of an impervious asphalt surface and has a high usage rate.

An aerial photo of the site from February 2020 is shown in Figure 1.


**Figure 1:** Aerial photo of the site, catchment & equipment

An OceanGuard® gully pit insert was installed within an existing gully pit within the car park. The system receives runoff from a 100% impervious area of 400m$^2$, determined by land survey and site inspections. The catchment is illustrated in Figure 1.

The gully pit insert was installed at the site in August 2019. The gully pit is a 900mm x 600mm square pit, and the gully pit insert has a fine grade (200 micron) bag of 300mm depth, with a design treatable flow rate of 20 L/s (Ocean Protect, 2020).

Example photos of the gully pit insert, sampling facilities and catchment at the site are provided in Figure 2. A conceptual diagram of the gully pit insert installed at the site is provided in Figure 3. A schematic of the system is provided in Figure 4.

**Figure 2:** Example photos of the gully pit insert, sampling facilities and catchment at the site

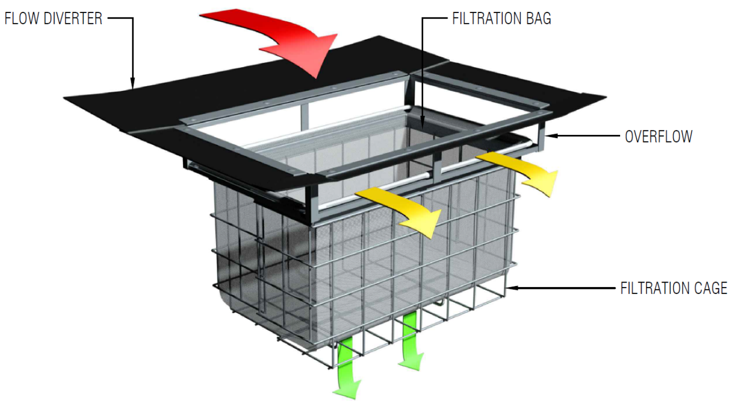



**Figure 3:** Conceptual diagram of gully pit insert at site

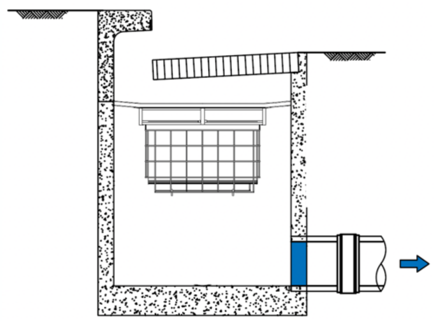


**Figure 4:** Schematic section drawing of gully pit insert at the site

The gully pit insert at the site has been maintained in accordance with typical/ standard maintenance procedures for these assets. In summary, the system is maintained approximately every four (4) months, with maintenance undertaken on 14 February 2020,4 June 2020, 27 November 2020 and 25 March 2021.

Any material on the outer flaps is brushed into the 200-micron bag and is removed from the gully pit insert. The contents are emptied, removing any debris and litter, and the bag is inspected. and placed back into the gully pit insert.

It should be noted that when cleaning the pit of debris during maintenance on 14 February 2020, it was noticed that 'flakes' (small particles) of concrete from the pit chamber walls and floor were observed within the chamber, which would be anticipated to flow downstream and contribute to contributing to elevated solids levels in effluent samples at the site. It is likely that this flaking of concrete from the pit chamber walls and floor was occurring throughout the duration of the monitoring period until 12 June 2020. On 12 June 2020, works were undertaken to seal the pit chamber with waterproofing to prevent small particles from the pit chamber walls and floor entering the effluent sampler.

## Sampling design

The equipment and sampling techniques used for this study were in accordance with the Project Plan developed by Ocean Protect in consultation with both City of Gold Coast's (2016) *Development Application Requirements and Performance Protocol for Proprietary Devices* and Stormwater Australia's (2018) *Stormwater Quality Improvement Device Evaluation Protocol Field Monitoring*. The Project Plan incorporated criteria from each protocol and a summary of conditions for the field-testing protocol are summarised below in Table 1.

**Table 1:** Summary of required field testing protocol at site

| Criteria | Requirement |
|---|---|
| Minimum number of aliquots | > 80% of storms have at least 8 aliquots |
| Minimum storm coverage | > 50% of storms have >70% hydrograph coverage |
| Antecedent dry period | > 6 hours |
| Minimum Rainfall Depth | minimum required to take a composite sample |
| Minimum Storm Duration | 5 minutes |

Ocean Protect personnel were responsible for the installation, operation, and maintenance of the sampling equipment. Ocean Protect personnel provided sample retrieval, system reset, and sample submittal activities for all events up to and including 4 September 2020, whilst ALS were responsible for these tasks for subsequent events. Water sample processing and analysis was performed by ALS.

A small double-door cabinet was provided, installed, maintained, and operated by Ocean Protect personnel for sampling purposes. The cabinet is a fully enclosed, self-contained stormwater monitoring system, specially designed and built by Ocean Protect for remote, extended-deployment stormwater monitoring. The design allows for remote control of sampling equipment, eliminates confined space entry requirements, and streamlines the sample and data collection process and operation of the equipment.

Influent and effluent water quality samples were collected using individual ISCO 6712 Portable Automated Samplers configured for 9.5 litre wide-mouth carboy bottles with disposable sample liners for sample collection. The samplers were connected to one 12V DC battery recharged with a solar panel mounted to the roof of the shipping container. The influent sampler was equipped with an ISCO 730 Bubbler Weir module, connected directly to the ISCO 6712 sampler, and installed within a pre-configured and calibrated 152 mm diameter Thel-mar Weir for influent flow measurement and sample pacing. The ISCO 6712 effluent sampler was setup as a 'slave' and triggered from pulses received from the influent sampler at specific flow volumes pre-determined for every storm event. Flow rates were recorded every minute.

The bubblers were regularly checked for calibration by submersing the weir in water and confirming/setting the depth of water on the sampler with the bubbler module to the depth measured. The tables for the flow against height are provided by Thel-mar LLC and input into the samplers.

Rainfall was measured at 1-minute intervals using two 0.25mm resolution ISCO 674 tipping bucket-type rain gauge, factory-calibrated, securely installed on a post and regularly inspected. The ISCO 674 rain gauge was connected directly to the ISCO 6712 Influent sampler. The sample intake for each automated sampler was connected to an ISCO low-profile stainless-steel sample strainer (9/16″ diameter, 6″ length, with multiple ¼″ openings) via a length of 3/8″ ID Acutech Duality PTFE tubing. The rain-gauge is factory calibrated and does not require further calibration except to ensure there is nothing obstructing or interfering with the tip bucket. The rain gauge was installed and maintained according to manufacturer's instructions and checked and cleared of debris regularly. The rain gauge was located on a post and protected from excessive wind velocities that could skew accuracy of measurement. An additional ISCO 674 rain gauge was located 100 m away for reference and redundancy.

Sample strainers and flow measurement equipment were secured to the invert of the influent and effluent pipes using stainless steel spring rings with all components supplied and setup in general accordance with ISCO's guidelines. Each sampler was also connected to a computer to allow for complete data access. Cameras were installed in the pit to additionally confirm the presence of bypass flows for all storm events.

Samplers were programmed to enable the sampling program to trigger on flow. Once enabled, the samplers collected flow-proportional samples allowing the specified pacing volume to pass before taking a sample. The sample collection program was a one-part program developed to maximise the number of water quality aliquots/samples collected as well as the coverage of the storm event for an anticipated rainfall depth. Influent and effluent sample collection programs were configured to collect a minimum of eight aliquots per bottle. Due to the variability among predicted precipitation events, the sample pacing specifications were varied (flow pacing and aliquot volume) in consultation with the most up-to-date precipitation forecasts and programmed by Ocean Protect personnel prior to every storm event.

Following a precipitation event, Ocean Protect personnel communicated with the automated sampling equipment to confirm sample collection and then dispatch personnel to retrieve the samples and reset the automated sampling equipment. Samples where then split using the appropriate Bel-Art's Churn Splitter – one for the influent and one for the effluent to reduce the likelihood of contamination and to provide subsamples in accordance with the manufacturer's guidelines. Sub-samples were delivered to ALS (a NATA-accredited laboratory) on ice (<4$^{o}$ C) and accompanied by chain-of-custody documentation and analysis was carried out in accordance with Table 2.

**Table 2:** Water quality analytical parameters and methods for the site

| Parameter | Abbreviation | Analytical method | Limit of Reporting |
|---|---|---|---|
| Ammonia as N | Amm.N | APHA 4500 NH3- - G | 0.01 mg/L |
| Nitrate + Nitrite as N | NOx | APHA VCl3 reduction 4500 NO3- + NO2-B | 0.01 mg/L |
| Nitrate as N | - | APHA VCl3 reduction 4500 NO3- + NO2-B | 0.01 mg/L |
| Nitrite as N | - | APHA 4500 NO2- - I | 0.01 mg/L |
| Total Kjeldahl Nitrogen (TKN) as N | TKN | APHA 4500 Norg – D + APHA 4500 NH3-G | 0.1 mg/L |
| pH (pH units) | pH | APHA 4500 H+ - B | 0.01 pH units |
| Phosphorus Total as P | TP | APHA 4500 P - F | 0.01 mg/L |
| Filtered Total Phosphorous as P | Ortho-P | APHA 4500 P - F | 0.01 mg/L |
| Phosphorus Reactive as P | DP | APHA 4500 P – F | 0.01 mg/L |
| Solids - Suspended Solids - Standard level | TSS | APHA 2540 D | 5 mg/L |

## Sampling events

The gully pit insert was monitored between December 2019 and March 2021, with a total of fifteen (15) runoff events recorded during this period. Figure 5 illustrates the timing of the sampling events compared to a time series of rainfall data recorded at the site. Table 3 also provides a summary of recorded rainfall at the site and flow discharged from the system.

A total of three (3) runoff events were excluded from the analyses. One event (on 31 March 2020) was excluded due to recording elevated influent total nitrogen concentrations above the allowable limit within the Project Plan. One event (on 30 April 2020) was excluded due to the recording elevated influent total phosphorus concentrations being above the allowable limit within the Project Plan. The other excluded event (21 May 2020) was due to the sampling system being off-line for the installation of a solar panel by Western Sydney University personnel.

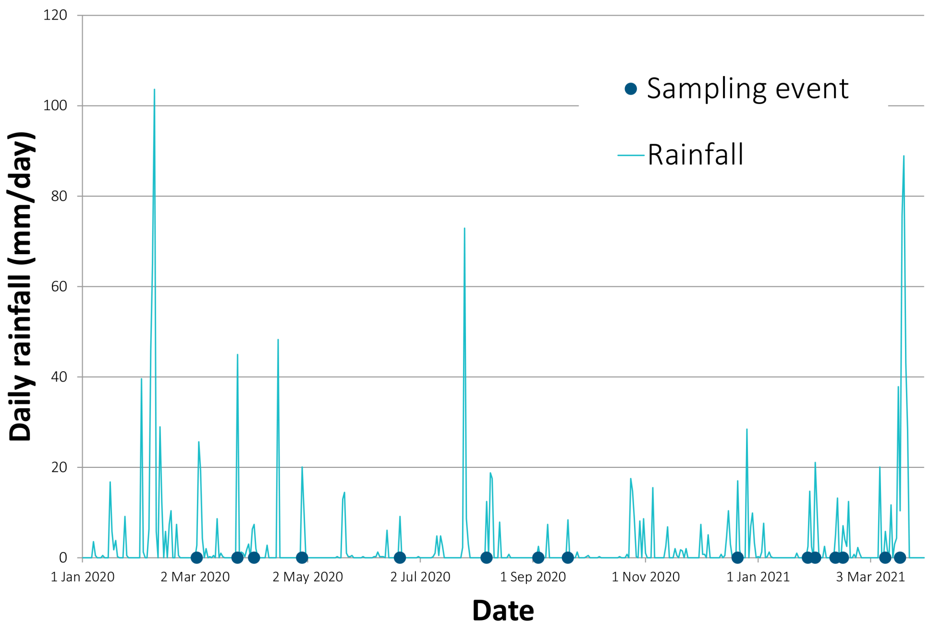



**Figure 5:** Time series of site rainfall and timing of sampling events

**Table 3:** Summary of recorded rainfall and flow data for site

| Event Date | Max. rainfall intensity (mm/hr) | Mean rainfall intensity (mm/hr) | Total rainfall (mm) | Duration of rainfall (hr) | Total runoff volume (L) | Peak flow (L/s) | Mean flow (L/s) | Sampling duration (hr) | Sampling coverage (%) | Number of aliquots |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 Mar 2020 | 27.94 | 1.04 | 28.45 | 6.77 | 14163 | 2.76 | 0.14 | 6.77 | 96% | 52 |
| 25 Mar 2020 | 88.90 | 2.63 | 45.21 | 2.22 | 67744 | 10.28 | 1.10 | 2.22 | 36% | 80 |
| 3 Apr 2020 | 15.24 | 0.69 | 7.37 | 3.17 | 3651 | 1.53 | 0.10 | 3.18 | 86% | 9 |
| 29 Apr 2020 | 71.12 | 1.95 | 20.07 | 0.37 | 40319 | 10.28 | 1.09 | 0.37 | 16% | 40 |
| 21 Jun 2020 | 30.48 | 0.74 | 9.14 | 2.07 | 1963 | 2.85 | 0.04 | 2.07 | 26% | 6 |
| 7 Aug 2020 | 10.16 | 0.73 | 12.45 | 10.15 | 8456 | 0.97 | 0.14 | 10.15 | 98% | 34 |
| 4 Sep 2020 | 5.08 | 0.20 | 2.54 | 5.18 | 669 | 0.37 | 0.01 | 5.18 | 88% | 5 |
| 20 Sep 2020 | 12.70 | 0.65 | 8.38 | 3.70 | 7514 | 1.68 | 0.16 | 3.72 | 90% | 35 |
| 21 Dec 2020 | 7.62 | 0.92 | 18.80 | 13.37 | 7309 | 0.55 | 0.10 | 13.37 | 99% | 25 |
| 28 Jan 2021 | 5.08 | 0.41 | 19.56 | 41.03 | 16525 | 1.76 | 0.10 | 41.03 | 99% | 55 |
| 1 Feb 2021 | 68.58 | 2.52 | 30.99 | 7.58 | 18450 | 6.61 | 0.42 | 7.58 | 99% | 62 |
| 12 Feb 2021 | 15.24 | 0.67 | 18.29 | 18.30 | 7165 | 1.17 | 0.07 | 18.30 | 96% | 24 |
| 16 Feb 2021 | 33.02 | 0.57 | 5.33 | 0.25 | 1345 | 2.58 | 0.04 | 0.25 | 83% | 9 |
| 11 Mar 2021 | 5.08 | 0.52 | 5.84 | 4.38 | 4590 | 0.78 | 0.11 | 4.38 | 98% | 19 |
| 19 Mar 2021 | 45.72 | 2.31 | 242.57 | 63.73 | 63133 | 2.94 | 0.17 | 63.73 | 80% | 68 |

## RESULTS & DISCUSSION

Table 4 provides the results of the monitoring. Table 5 provides the calculated concentration reduction efficiencies (CREs). Table 6 provides a statistical summary of the monitoring results. Table 7 provides the influent nitrogen speciation percentages recorded at the site. Table 8 provides a comparison of influent event mean concentration (EMC) values recorded at the site and those given in MUSIC modelling guidelines within Australia by Water By Design (2010), BMT WBM (2015) and Melbourne Water (2018). Table 9 provides a comparison of the percentage fraction of total nitrogen as dissolved nitrogen against that recommended in the E2DesignLab (2015) report *Development Application Requirements and Performance Protocol for Proprietary Devices on the Gold Coast*. Table 10 also provides a comparison of influent nitrogen speciation data for the site with runoff data for other sites within Australia and E2DesignLab (2015) recommended values.

**Table 4:** Results of treatment performance monitoring

| Event Date | TSS (mg/L) Influent | TSS (mg/L) Effluent | DP (mg/L) Influent | DP (mg/L) Effluent | TP (mg/L) Influent | TP (mg/L) Effluent | NOx (mg/L) Influent | NOx (mg/L) Effluent | $NH_3$ (mg/L) Influent | $NH_3$ (mg/L) Effluent | DIN (mg/L) Influent | DIN (mg/L) Effluent | TKN (mg/L) Influent | TKN (mg/L) Effluent | TN (mg/L) Influent | TN (mg/L) Effluent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 Mar 2020 | 20 | 16 | *0.005* | *0.005* | 0.180 | 0.070 | 0.130 | 0.100 | 0.160 | 0.090 | 0.290 | 0.190 | 0.400 | 0.300 | 0.53 | 0.40 |
| 25 Mar 2020 | 26 | 8 | *0.005* | *0.005* | 0.070 | 0.040 | 0.200 | 0.200 | 0.180 | 0.250 | 0.380 | 0.450 | 0.200 | 0.300 | 0.40 | 0.50 |
| 3 Apr 2020 | 16 | 11 | *0.005* | *0.005* | 0.050 | 0.020 | 0.040 | 0.030 | 0.090 | 0.050 | 0.130 | 0.080 | 0.400 | 0.200 | 0.44 | 0.23 |
| 29 Apr 2020 | 92 | 72 | *0.005* | *0.005* | 0.500 | 0.150 | 0.110 | 0.080 | 0.200 | 0.180 | 0.310 | 0.260 | 0.500 | 0.400 | 0.61 | 0.48 |
| 21 Jun 2020 | 250 | 108 | 0.070 | 0.060 | 0.420 | 0.170 | 0.070 | 0.080 | 0.250 | 0.240 | 0.320 | 0.320 | 1.500 | 0.800 | 1.57 | 0.88 |
| 7 Aug 2020 | 11 | 10 | 0.010 | *0.005* | 0.100 | 0.010 | 0.130 | 0.200 | 0.510 | 0.270 | 0.640 | 0.470 | 0.900 | 0.300 | 1.03 | 0.50 |
| 4 Sep 2020 | 102 | 74 | *0.005* | *0.005* | 0.120 | 0.100 | 0.790 | 0.640 | 0.460 | 0.430 | 1.250 | 1.070 | 1.900 | 1.500 | 2.69 | 2.14 |
| 20 Sep 2020 | 52 | 32 | *0.005* | *0.005* | 0.060 | 0.050 | 0.120 | 0.120 | 0.140 | 0.100 | 0.260 | 0.220 | 0.300 | 0.500 | 0.42 | 0.62 |
| 21 Dec 2020 | 19 | 6 | *0.005* | *0.005* | 0.190 | 0.020 | 0.190 | 0.210 | 0.190 | 0.200 | 0.380 | 0.410 | 0.400 | 0.300 | 0.59 | 0.51 |
| 28 Jan 2021 | 62 | 12 | *0.005* | *0.005* | 0.090 | 0.060 | 0.280 | 0.210 | 0.560 | 0.350 | 0.840 | 0.560 | 1.100 | 0.800 | 1.38 | 1.01 |
| 1 Feb 2021 | 22 | 10 | *0.005* | *0.005* | 0.260 | 0.020 | 0.080 | 0.050 | 0.080 | 0.060 | 0.160 | 0.110 | 0.200 | 0.200 | 0.28 | 0.25 |
| 12 Feb 2021 | 31 | 10 | *0.005* | 0.040 | 0.080 | 0.080 | 0.230 | 0.240 | 0.150 | 0.340 | 0.380 | 0.580 | 1.000 | 0.800 | 1.23 | 1.04 |
| 16 Feb 2021 | 12 | *2.5* | *0.005* | *0.005* | 0.060 | 0.030 | 0.080 | 0.070 | 0.130 | 0.070 | 0.210 | 0.140 | 0.200 | 0.200 | 0.28 | 0.27 |
| 11 Mar 2021 | 22 | 9 | *0.005* | *0.005* | 0.140 | 0.050 | 0.360 | 0.250 | 0.270 | 0.210 | 0.630 | 0.460 | 0.700 | 0.700 | 1.06 | 0.95 |
| 19 Mar 2021 | 62 | 7 | 0.010 | *0.005* | 0.320 | 0.010 | 0.030 | 0.005 | 0.330 | 0.005 | 0.360 | 0.010 | 4.000 | 0.050 | 4.03 | 0.06 |
| **Mean** | 53.3 | 25.8 | 0.010 | 0.011 | 0.176 | 0.059 | 0.189 | 0.166 | 0.247 | 0.190 | 0.436 | 0.355 | 0.913 | 0.490 | 1.10 | 0.66 |
| **Median** | 26.0 | 10.0 | *0.005* | *0.005* | 0.120 | 0.050 | 0.130 | 0.120 | 0.190 | 0.200 | 0.360 | 0.320 | 0.500 | 0.300 | 0.61 | 0.50 |

*: TSS = total suspended solids; DP = dissolved/ reactive phosphorus; TP = total phosphorus; NOx = nitrogen oxides; nitrate + nitrite as nitrogen; DIN = dissolved inorganic nitrogen; TKN = total Kjeldahl nitrogen; TN = total nitrogen. Italicised values were recorded as below the laboratory level of reporting (LOR), and are presented as being equal to half of the LOR.

**Table 5**: Concentration reduction efficiencies

| Event Date | TSS CRE% | DP CRE% | TP CRE% | NOx CRE% | $NH_3$ CRE% | TKN CRE % | DIN CRE% | TN CRE% |
|---|---|---|---|---|---|---|---|---|
| 3 Mar 2020 | 20% | 0% | 61% | 23% | 44% | 25% | 53% | 25% |
| 25 Mar 2020 | 69% | 0% | 43% | 0% | -39% | -50% | -16% | -25% |
| 3 Apr 2020 | 31% | 0% | 60% | 25% | 44% | 50% | 63% | 48% |
| 29 Apr 2020 | 22% | 0% | 70% | 27% | 10% | 20% | 19% | 21% |
| 21 Jun 2020 | 57% | 14% | 60% | -14% | 4% | 47% | 0% | 44% |
| 7 Aug 2020 | 9% | 50% | 90% | -54% | 47% | 67% | 36% | 51% |
| 4 Sep 2020 | 27% | 0% | 17% | 19% | 7% | 21% | 17% | 20% |
| 20 Sep 2020 | 38% | 0% | 17% | 0% | 29% | -67% | 18% | -48% |
| 21 Dec 2020 | 68% | 0% | 89% | -11% | -5% | 25% | -7% | 14% |
| 28 Jan 2021 | 81% | 0% | 33% | 25% | 38% | 27% | 50% | 27% |
| 1 Feb 2021 | 55% | 0% | 92% | 38% | 25% | 0% | 45% | 11% |
| 12 Feb 2021 | 68% | -700% | 0% | -4% | -127% | 20% | -34% | 15% |
| 16 Feb 2021 | 79% | 0% | 50% | 13% | 46% | 0% | 50% | 4% |
| 11 Mar 2021 | 59% | 0% | 64% | 31% | 22% | 0% | 37% | 10% |
| 19 Mar 2021 | 89% | 50% | 97% | 83% | 98% | 99% | 3500% | 99% |
| **Mean** | 51% | -39% | 56% | 13% | 16% | 19% | 255% | 21% |
| **Median** | 57% | 0% | 60% | 19% | 25% | 21% | 36% | 20% |

*: Negative (red) values show a recorded increase in pollutant concentrations across the system.

**Table 6:** Statistical summary of monitoring results

| Analyte | no. of events | Range of Influent EMCs (mg/L) | Median Influent EMC (mg/L) | Mean Influent EMC (mg/L) | Range of Effluent EMCs (mg/L) | Median Effluent EMC (mg/L) | Mean Effluent EMC (mg/L) | Median Conc. Removal Efficiency (Mean CRE, %) | Efficiency Ratio (ER, %) |
|---|---|---|---|---|---|---|---|---|---|
| TSS | 15 | 11 - 250 | 26.0 | 53.3 | *2.5* - 108 | 10.0 | 25.8 | 57% | 52% |
| DP | 15 | *0.005* - 0.07 | *0.005* | 0.010 | *0.005* - 0.06 | *0.005* | 0.011 | 0% | -10% |
| TP | 15 | 0.05 - 0.5 | 0.120 | 0.176 | 0.01 - 0.17 | 0.050 | 0.059 | 60% | 67% |
| NOx | 15 | 0.03 - 0.79 | 0.130 | 0.189 | *0.005* - 0.64 | 0.120 | 0.166 | 19% | 13% |
| $NH_3$-N | 15 | 0.08 - 0.56 | 0.190 | 0.247 | *0.005* - 0.43 | 0.200 | 0.190 | 25% | 23% |
| DIN | 15 | 0.13 - 1.25 | 0.360 | 0.436 | 0.01 - 1.07 | 0.320 | 0.355 | 21% | 19% |
| TKN | 15 | 0.2 - 4 | 0.500 | 0.913 | 0.05 - 1.5 | 0.300 | 0.490 | 36% | 21% |
| TN | 15 | 0.28 - 4.03 | 0.610 | 1.103 | 0.055 - 2.14 | 0.50 | 0.66 | 20% | 41% |

*: Efficiency Ratio = (average inlet EMC – average outlet EMC)/ average inlet EMC

**Table 7:** Influent nitrogen speciation percentages recorded at site

| Event Date | % of NOx as % of TN | $NH_3$ as % of TN | DIN as % of TN | TKN as % of TN |
|---|---|---|---|---|
| 3 Mar 2020 | 25% | 30% | 55% | 75% |
| 25 Mar 2020 | 50% | 45% | 95% | 50% |
| 3 Apr 2020 | 9% | 20% | 30% | 91% |
| 29 Apr 2020 | 18% | 33% | 51% | 82% |
| 21 Jun 2020 | 4% | 16% | 20% | 96% |
| 7 Aug 2020 | 13% | 50% | 62% | 87% |
| 4 Sep 2020 | 29% | 17% | 46% | 71% |
| 20 Sep 2020 | 29% | 33% | 62% | 71% |
| 21 Dec 2020 | 32% | 32% | 64% | 68% |
| 28 Jan 2021 | 20% | 41% | 61% | 80% |
| 1 Feb 2021 | 29% | 29% | 57% | 71% |
| 12 Feb 2021 | 19% | 12% | 31% | 81% |
| 16 Feb 2021 | 29% | 46% | 75% | 71% |
| 11 Mar 2021 | 34% | 25% | 59% | 66% |
| 19 Mar 2021 | 1% | 8% | 9% | 99% |
| **Mean** | 23% | 29% | 52% | 77% |
| **Median** | 25% | 30% | 57% | 75% |

**Table 8:** Comparison of site influent EMC with MUSIC guideline EMC values

| Parameter | Site Influent Mean (mg/L) | Water By Design (2010)[1] | BMT WBM (2015)[2] | eWater, Melbourne Water (2016)[3] |
|---|---|---|---|---|
| TSS EMC | 53.3 | 269 | 269 | 270 |
| TP EMC | 0.176 | 0.501 | 0.501 | 0.500 |
| TN EMC | 1.10 | 1.82 | 2.19 | 2.20 |

1: Values are from Event Mean Concentrations (EMCs) for ‘Urban residential roads’ as given by Water By Design (2010) *MUSIC Modelling Guidelines*

2: Values are for EMC for sealed roads as given by BMT WBM (2015) *NSW MUSIC Modelling Guidelines*

*3:* Values are default values from for urban residential for the eWater MUSIC software, which are recommended for application by Melbourne Water *(2016) MUSIC Guidelines - Recommended input parameters and modelling approaches for MUSIC.*

**Table 9:** Comparison of site influent % dissolved nitrogen with E2DesignLab (2015) recommended values

| Parameter | Site | | E2DesignLab (2015)[1] | |
|---|---|---|---|---|
| | Mean | Range | Typical | Minimum |
| % fraction of TN dissolved | 52% | 9 to 95% | Approx. 50% | 40% |

1: Values are from E2DesignLab (2015) *Development Application Requirements and Performance Protocol for Proprietary Devices on the Gold Coast*, August 2015.

**Table 10:** Comparison of site influent nitrogen speciation with runoff data for other sites within Australia and E2DesignLab (2015) recommended values

| Location | NOx as a % of TN | $NH_3$-N as a % of TN | Organic N as a % of TN | TKN as a % of TN |
|---|---|---|---|---|
| Site mean | 23 | 29 | - | 77 |
| Site range | 1-50 | 8-50 | - | 50-99 |
| 'Typical fraction' cited by E2DesignLab (2015) | 25-40 | 10-20 | 45-70 | 55-75 |
| 'Minimum fraction' cited by E2DesignLab (2015) | 20 | 5 | - | - |
| Drapper et al (2015) | 22 | 16 | - | 35 |
| Parker (2010) bioretention basin | 28 | 19 | 53 | 72 |
| Parker (2010) wetland inlet big | 26 | 12 | 68 | 80 |
| Parker (2010) wetland inlet small | 37 | 21 | 41 | 62 |
| Taylor et al (2005) [2] | 36 | 13 | 52 | 65 |
| Hunt et al (2006), Greensboro G1[2] | 25 | 18 | 56 | 74 |
| Hunt et al (2006), Greensboro G2[2] | 37 | 16 | 40 | 56 |

1: Concentration values are average values unless otherwise stated

2: Source: Parker (2010)

## Suspended solids

Reductions in TSS concentrations were recorded for all events, with a concentration reduction efficiency ratio of 52% (with concentration reductions ranging from 9 to 89%).

TSS concentrations in stormwater flowing from the car park catchment (and entering the gully pit insert) were significantly lower than that recommended in given MUSIC guidelines for comparable land usages. For example, the mean TSS concentration recorded in inflows to the gully pit insert was 53.3 mg/L, significantly lower than the Water by Design (2010), BMT WBM (2015) and Melbourne Water (2016) guideline recommended EMC values of 269 and 270mg/L.

As described by Neumann et al (2010), for example, it is easier for SCMs to achieve higher pollutant concentration reduction rates when runoff has higher pollutant concentrations. Higher TSS concentration reductions would subsequently be anticipated for gully pit inserts receiving flows with TSS concentrations similar to values recommended in the aforementioned guidelines.

It is clear that the observed 'flaking' of concrete from the pit chamber walls and floor into the pit chamber (described in Section 2.1) would have contributed to elevated TSS concentrations in the effluent samples (and subsequently contributed to observed lower TSS concentration reductions) until the sealing of the pit chamber on 12 June 2020. This anomaly negatively biased the results for TSS as some of the particles measured within the TSS effluent for each storm were derived from the pit and not sampled as stormwater from the influent sample. Prior to the rectification works and given no bypassing of storm flows were evident, analysis of the effluent particle size distribution showed particles greater than the pore aperture of the filter liner in outlet flows, i.e. 200micron. Subsequent particle size distribution analysis after the sealing of the pit chamber indicated no particles in the effluent greater than 200micron. Therefore, the gully pit insert would have achieved higher TSS removal efficiencies than recorded in the monitoring results until 12 June 2020.

## Nutrients

TP and TN concentration reduction efficiency ratios observed across the system were 67% and 41% respectively. Total phosphorus and nitrogen EMCs observed in flows to the gully pit insert at the site were significantly lower than that recommended by aforementioned MUSIC guidelines. As for TSS, the ability of any SCM to reduce nutrient concentrations would be decreased at lower inflow concentrations.

The majority of the recorded phosphorus concentrations observed in flows to and from the gully pit insert consisted of particulate phosphorus, with relatively low concentrations of dissolved phosphorus. For nitrogen, a mean of 52% of recorded inflow concentrations were dissolved (ranging from 9 to 95%), which complies with the recommended minimum mean of 40% given by E2DesignLab (2015). The percentage of nitrogen speciation for NOx and $NH_3$ comply with the recommended minimum fractions given by E2DesignLab (2015), and proportions of nitrogen species are similar to values observed at other sites (presented in Table 10).

### Further investigations

The aforementioned stormwater treatment performance monitoring is anticipated to continue until approximately the end of 2021 to obtain further confidence in relation to the performance of the gully pit insert. Samples are also likely to be collected for the subsequent analysis of additional water quality indicators (e.g. hydrocarbons, heavy metals, bacteria) to assess the influent concentrations of these water quality indicators (if detectable) and the associated performance of the gully pit insert to reduce these concentrations.

## CONCLUSION

Stormwater treatment performance testing was undertaken for a gully pit insert located in a car park at Western Sydney, NSW, Australia. The sampling and monitoring protocol was designed and implemented in consultation with both City of Gold Coast's (2016) *Development Application Requirements and Performance Protocol for Proprietary Devices* and Stormwater Australia's (2018) *Stormwater Quality Improvement Device Evaluation Protocol Field Monitoring*.

The performance testing at the site demonstrated that the gully pit insert was able to achieve significant reductions in stormwater pollutant concentrations, with a concentration reduction efficiency ratio for TSS, TP and TN of 52, 67 and 41% respectively. These concentration reductions were achieved despite relatively low concentrations for TSS, TP and TN in incoming stormwater flows (which would be expected to decrease potential concentration reductions), and 'flaking' of concrete from the pit chamber walls and floor.

Stormwater treatment performance monitoring at the site will continue until approximately the end of 2021 to obtain further confidence in relation to the performance of the gully pit insert.

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Brad is a Principal Environmental Engineer at Ocean Protect. Brad has over twenty years' experience in various projects associated with environmental engineering, and has CPEng and RPEQ accreditation. Brad has been responsible for the planning, design and implementation of integrated water management and water sensitive urban design strategies for a range of applications – from many small-scale 'retrofit' projects, several high-profile and award winning master-planned communities, and catchments and regions.

**Michael Wicks**

Michael has owned the company for almost a decade and leads the business' technical direction and oversees research and development. He is responsible for new product development and managing the engineering design team at Ocean Protect ensuring cost-effective environmental outcomes for developments. He has a Bachelor of Engineering (Civil) from the University of Western Sydney and has 20+ years' experience in the sector. He has sat on the committees of the NSW, Victoria and Queensland Storm Water Associations.

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Warren Jones is the Lead Engineer and Engineering Manager at Ocean Protect. Warren plays a key role in shaping Ocean Protect's stormwater field testing capabilities, providing expertise from design and implementation through to collection and analysis. He has also designed, developed and deployed multiple software programs focused on automation of tasks and retrieval of information.

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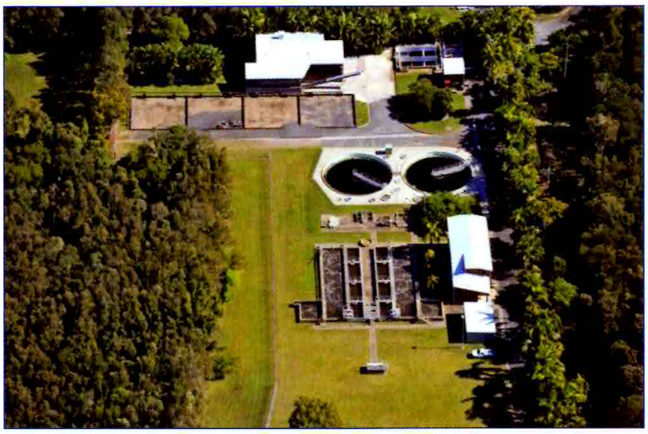
# contents

Residents at Buru in Queensland map their water system. See page 73.



An aerial view of the Suncoast Sewage Treatment Plant. See page 58.

## TECHNICAL FEATURES (INDICATES THE PAPER HAS BEEN REFEREED)

# NUTRIENTS AND SOLIDS REMOVAL BY AN ENGINEERED TREATMENT TRAIN

## Field evaluation of a gully pit insert and cartridge media filter

M Wicks, N Vigar, M Hannah

### Abstract

The performance claims for individual stormwater treatment devices is often open to debate, as much of the data available has not been subjected to robust scrutiny and/or the claims are unable to be replicated. The following article summarises the results from a field trial of two such devices: an EnviroPod® and a StormFilter®, arranged in series (or a 'treatment train') treating runoff from a small road catchment on Streets Creek, Kuranda, west of Cairns in Far North Queensland.

This field trial complements an earlier research project undertaken on the same system by James Cook University. Data was collected from six storm events, predominantly during the dry seasons of 2008 and 2009, and includes simultaneous sampling of both the flow rate and water quality on the inflows to, and outflows from, the treatment train for a suite of particulate and soluble stormwater pollutants. Influent concentrations for both Phosphorus and Nitrogen were found to be half to one-third of concentrations reported in the literature as typical for urban catchments in Australia.

One storm was also analysed for an expanded suite of nitrogen analytes, which determined that more than half the load was in soluble form. Furthermore, results from the field trial and research project indicated that this treatment train system has the potential to achieve meaningful load reductions of Suspended Solids (up to 99%), Phosphorus (up to 70%) and Nitrogen (up to 45%) through the use of conventional screening, filtration and ion-exchange removal technologies.

### Introduction

Livingston and McCarron (1992) identified that pollution loads (gross pollutants, sediment and nutrients) in stormwater increase proportionally with the degree of urbanisation in the catchment. Most consent authorities in Australia have established pollution removal efficiencies to be achieved prior to discharge from the urban catchment (eg, NSW Department of Environment and Climate Change (DECC) 2007 recommends Suspended Solids (SS) 85%, Total Phosphorus (TP) 65%, and Total Nitrogen (TN) 45%) and/or Event Mean Concentrations (EMCs) in any stormwater discharged into natural ecosystems (e.g. ANZECC 2000 recommends turbidity 2-15 Nephelometric Turbidity Units (NTU), TP 0.01 mg/L and TN 0.15 mg/L for river systems in tropical Australia).

In general, each pollutant is removed from the water column using a specific physical, chemical or biological process. Arranging these processes in sequence provides a treatment train approach that addresses and treats the whole pollutant load. There is, however, a paucity of published peer-reviewed scientific information validating the removal efficiency of each element or device used within a treatment train – let alone the performance of the treatment train itself. The research referred to herein provides information to validate the performance claims of an EnviroPod® gully trap and a StormFilter ® cartridge arranged in series as a treatment train.

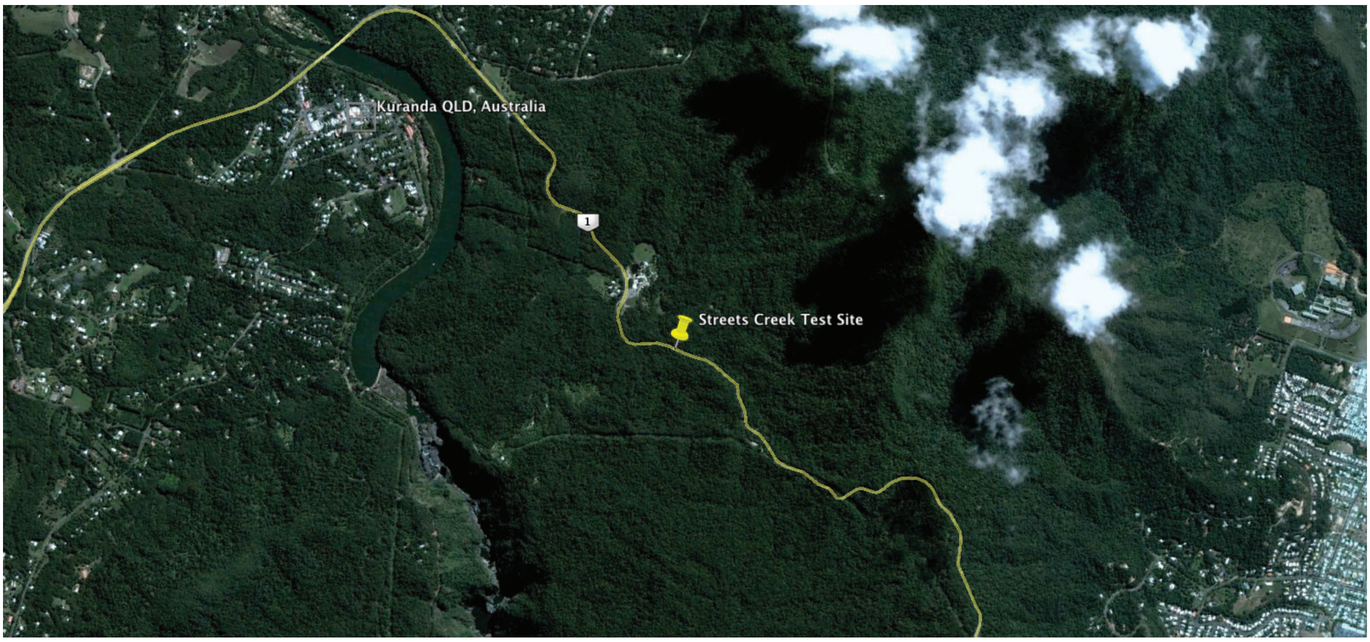



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**Figure 1. Location of the Kuranda Test Site.**

## Background

This field trial follows a previous research project undertaken by the School of Earth and Environmental Sciences, James Cook University (JCU), as part of a wider investigation into the impacts of road runoff on the Kuranda Range Road watershed, near Cairns (Munksgaard and Lottermoser, 2008), which discharges into the sensitive environment of Streets Creek. JCU reported on the quality of the watershed's receiving waters, the chemical characterisation of the road runoff and the performance of the system over four runoff events.

JCU found that the system "had a high retention capacity for suspended sediment and by implication particulate metals". Conversely, they reported that the "treatment train" had only a "modest retention capability for dissolved (filtered) metals". In addition, JCU identified that the treatment train system was, in fact, responsible for a significant net export of zinc. On the basis of their data, nutrient levels in the road runoff were low, and do not constitute a water quality concern at Streets Creek. However, they also reported significant retention of both TN and TP. The JCU study, which, in their own words "do[es] not constitute a full evaluation of the EnviroPod/StormFilter treatment system", found the system achieved substantial removal of Total Nitrogen (45%), Total Phosphorus (70%), Total Aluminium (71%), Total Nickel (73%), Total Lead (60%) and Total Copper (58%). On the other hand, it identified potential releases of Suspended Solids under 500 microns, as well as dissolved zinc and copper.

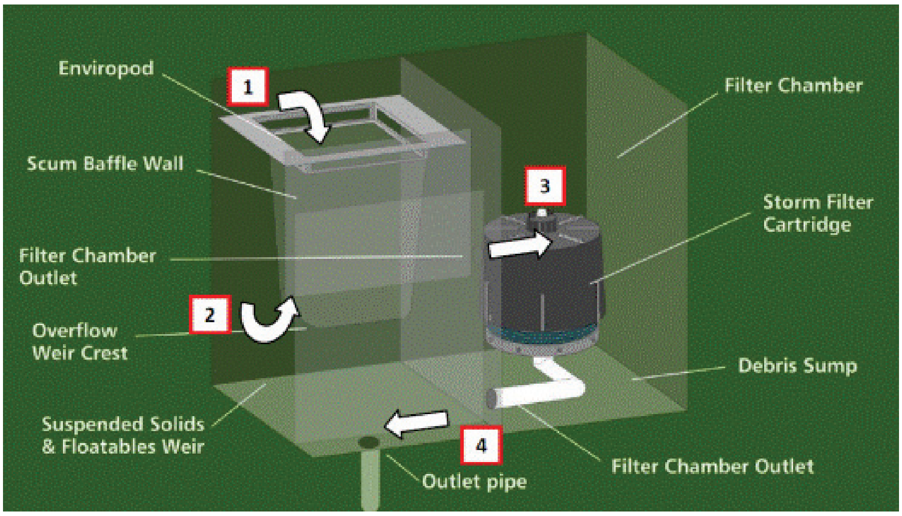


**Figure 2. Schematic of the SYSTEM treatment train.**

One explanation for the above-mentioned releases is that they could be related to the anaerobic conditions present in either the standing water within the wet-sump or, in the case of zinc, corrosion of the exposed galvanised protection on the steel components. Given the substantial removal of suspended solids, nutrients and total metals, it appears unlikely that the dissolved copper and zinc, observed in the outflows, was associated with a release of the under-500 micron sediment fraction.

It was largely to address these issues and better understand the sources of these copper and zinc releases that Stormwater360 undertook a further field evaluation of the treatment train system, which is the subject of this evaluation.

**Table 1. Water quality analytical parameters.**

| Parameter | Abbreviation | Analytical Method* | Units | Limit of Reporting | Analysed by |
|---|---|---|---|---|---|
| Electrical Conductivity | EC | APHA 2510B | µS/cm | 1 | Cairns Water |
| pH | pH | APHA 4500-H+ | - | 0.1 | Cairns Water |
| Suspended Solids above 500 microns | SS > 500 micron | 500 micron sieve & APHA 2540B | mg/L | 1 | Cairns Water |
| Volatile Suspended Solids above 500 microns | SS Vol. > 500 micron | 500 micron sieve & APHA 2540E | mg/L | 0.1% Dry Solids | Cairns Water |
| Suspended Solids below 500 microns | SS < 500 micron | APHA 2540B; equiv. ASTM D-3977-97 | mg/L | 1 | Cairns Water |
| Volatile Suspended Solids below 500 microns | SS Vol. < 500 micron | APHA 2540E | mg/L | 0.1% Dry Solids | Cairns Water |
| Suspended Solids | SS | Calculated | mg/L | - | - |
| Volatile Suspended Solids | SS Vol. | Calculated | mg/L | - | - |
| Total Phosphorus | TP | APHA 4500-P | mg/L P | 0.02 | Cairns Water |
| Total Nitrogen | TN | APHA 4500-N | mg/L N | 0.05 | Cairns Water |
| Total Kjeldahl Nitrogen | TKN | Calculated | mg/L N | - | - |
| Ammonia Nitrogen (Ammonium Nitrogen) | NH3-N | APHA 4500-NH3 | mg/L N | 0.05 | Cairns Water |
| Nitrate/Nitrite (Total Oxidised Nitrogen) | NO3-/NO2--N | APHA 4500-NO3 | mg/L N | 0.01 | Cairns Water |
| Total Organic Carbon | TOC | APHA 5310-B | mg/L | 1 | ALS |
| Dissolved Organic Carbon | DOC | APHA 5310-B | mg/L | 1 | ALS |
| Particle Size Distribution (Laser Diffraction) | PSD | Malvern Mastersizer S | micron | 0.05 | QUT |

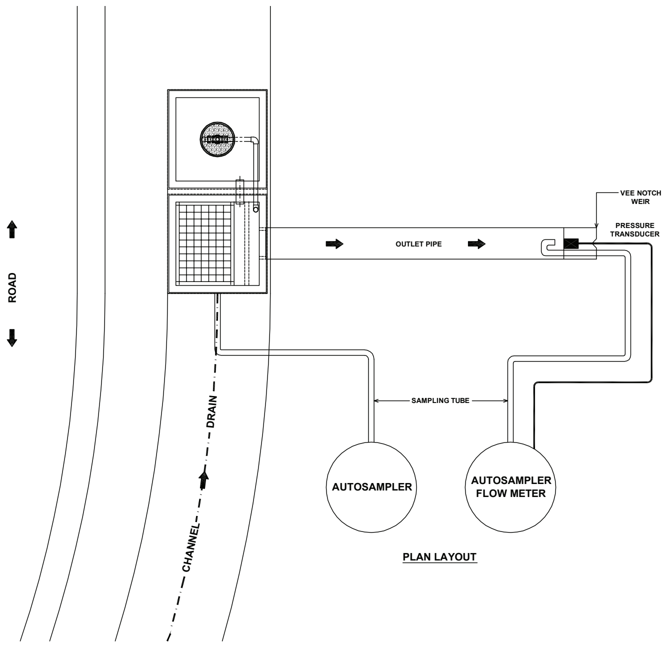


**Figure 3. Schematic of the sampling location.**

## Sampling Procedure and Equipment

A graphical representation of the system is shown in Figure 2. The direction of flow through the gully pit insert (EnviroPod®) and into the cartridge media filter (StormFilter®) is shown in sequence from 1 to 4. The gully pit insert is intended to treat most flows and filter solids above 100 μm while containing contaminants in a dry state.

After treatment by the gully pit insert, water is filtered radially through the media cartridge (outside to inside). The media cartridge had a nominal flow rate of 0.95 L/s (at 46 cm head, when the cartridge is primed) and a peak flow rate of *ca.* 1.3 L/s (at maximum 0.88 m head prior to bypass). The ZPG™ media used was a proprietary blend containing perlite (50%), granular activated carbon (GAC, 10%) and zeolite (40%).

The system samples were collected using automated influent and effluent samplers (Figure 3), collecting continuous flow and precipitation data and water quality simultaneously. The influent sampler was programmed to send an SMS alert to Stormwater360, via the GSM cellular network, when the sampling program was triggered. A dial-up connection was then made to each sampler to download data for analysis.

To qualify as a representative sample, the following criteria were specified.

I. Collection of at least three simultaneous influent and effluent samples per storm;

II. Samples must have been collected while the treatment system operated within design flow rates (not in bypass);

III. The sampled portion of the storm event must represent at least 60% of the storm total flow volume;

IV. A minimum of six data sets must be collected for a full performance evaluation.

Antecedent dry period was not identified as a constraint, due to the impervious nature of the catchment and the absence of a base flow; however, at least a three-day antecedent dry period was preferred. If the storm was deemed to qualify, Stormwater360 would inform Cairns Water and Waste Laboratory Services (Cairns Water, NATA accreditation # 14204) that samples required collection and analysis. Analysis was performed by Cairns Water and Waste Laboratory Services, ALS Laboratory Group – Brisbane (ALS, NATA accreditation # 825). All water quality parameters for qualifying storms were sent to an independent peer reviewer at Queensland University of Technology (QUT), ensuring transparency of data. Test methods for water quality analysis used for this study are provided in Table 1.

Gross pollutants were not monitored as part of this study, although significant quantities were captured. Previous monitoring by White *et al*. (2001) demonstrated that the Enviropod® filter retained all (100%) litter up to an approach flow of 100L/sec.

## Results and Discussion

The system was installed at the Streets Creek site in March 2006 and remained an active treatment and sampling site for four years until being decommissioned in March 2010. Stormwater360 monitored the system from April 2008 to December 2009. During this time, the unit was maintained annually, prior to the onset of each dry season. Complete maintenance involved removing all sediments and debris from the system, gully pit insert and replacing the cartridge media. The gully pit insert required additional manual maintenance approximately once per year.

Maintenance frequencies for the study were conducted in line with the systems standard operational lifecycle. Due to the nature of the catchment and size, there was an absence of a base flow or dry weather flows. Potential pollutant leaching of soluble contaminants was, however, still accounted for; organic debris left within the system was allowed to break down between maintenance periods and permitted to be sampled by the effluent sampler during storm events.

A summary of the principal analytes sampled is contained in Table 2.

## Suspended Solids

ANZECC (2000), DECC (2007) and Fletcher *et al*. (2004) have identified suspended solids as a stressor of aquatic ecosystems. In addition, many of the other pollutants, such as metals, hydrocarbons etc, are transported attached to the suspended solids and sediment. The system achieved an SSC

**Table 2. Summary of results.**

| Analyte | No. of events | Range of Influent EMCs (mg/L) | Median Influent EMC (mg/L) | Range of Effluent EMCs (mg/L) | Median Effluent EMC (mg/L) | Mean Removal Efficiency (Sum of Loads) |
|---|---|---|---|---|---|---|
| SSC | 6 | 75 to 4384 | 1181 | 8 to 63 | 20 | 99% |
| SSC < 500 micron | 6 | 48 to 180 | 105 | 8 to 62 | 20 | 78% |
| TP | 6 | 0.08 to 0.19 | 0.123 | 0.02 to 0.15 | 0.055 | 47% |
| TN | 6 | 0.6 to 1.5 | 1.045 | 0.2 to 0.9 | 0.615 | 44% |
| TKN | 6 | 0.6 to 1.2 | 1.007 | 0.175 to 0.800 | 0.515 | 49% |
| NH3-N | 6 | 0.05 to 0.15 | 0.050 | 0.05 to 0.07 | 0.050 | 31% |
| TOC | 6 | 3 to 16 | 7 | 3 to 10 | 5 | 32% |
| DOC | 6 | 3 to 12 | 7 | 3 to 11 | 6 | 21% |

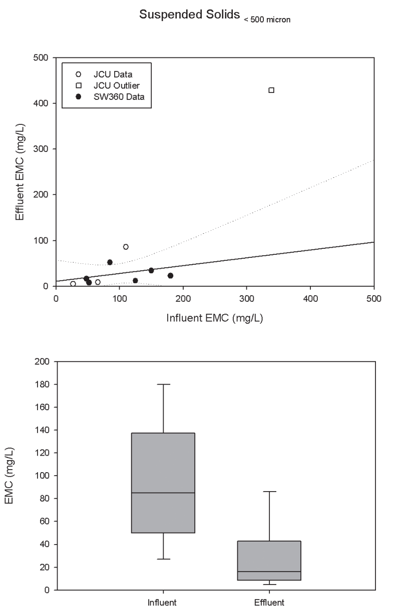


**Figure 4. SS <500micron data (JCU + SW360).**

aggregate load reduction of 99%. SSC (ie, SSC is defined as the sum of SS <500 micron and SS >500 micron) is 'suspended' in the sense that all these particles were sufficiently suspended to reach the system. However, SS <500 micron represents what is more commonly understood by the term 'suspended solids'. It excludes coarse settleable sediment, which, while being a management issue, does not represent such an acute threat to water quality.

Figure 4 shows influent and effluent data (Stormwater360) for SS <500 micron, together with the results published by JCU. In the scatter plot, the filled-in circles represent data from the trial reported herein, and open circles represent data from the previous JCU's research project. The exception is the JCU outlier represented as an open square, which has not been included in this evaluation. The line of best fit shown as a solid straight line was calculated by a least squares linear regression for all data points except the JCU outlier (intended to be informational only). Its relative slope provides an appreciation of the trend of the removal efficiency for the treatment train. The dotted curves represent the 95% confidence limits for these same data points. The true statistical significance of the regression lines is open to interpretation and requires further investigation, due to the limited number of data points available for this analysis.

Over the six storms analysed by Stormwater360, the influent EMC for SS <500 micron was in the range of 48 to 180 mg/L with a median influent EMC of 105 mg/L. Duncan (1999) literature review determined that the median concentration for most land uses (roofs excepted) lies between 71 mg/L (forested catchments) and 232 mg/L (urban roads). Fletcher *et al*. (2004) recommend using a value of *ca.* 120 mg/L for roads and *ca.* 100 mg/L for most other land uses. Both sources propose a median value of *ca.* 40 mg/L for forested catchments. The influent concentration of Suspended Solids at Streets Creek is within the typical range of average annual EMCs proposed within the literature; however, no data was collected during large wet-season storm events. Consequently, the median influent EMC reported herein should not be regarded as indicative of an annual median value.

Effluent EMCs recorded for SS <500 micron were in the range of 8 to 62 mg/L. The median effluent EMC was 20 mg/L. Mean removal efficiency for SS<500 micron, calculated by aggregate load reduction, was 78%. It is evident from Figure 4 that the Stormwater360 and JCU data sets are in relatively good agreement with each other, with the exception of the JCU outlier, which represents the first storm from JCU's research project. This storm was deemed an outlier for all water quality parameters due to possible sampling errors and has been removed from the analyses. The box plot in Figure 4 shows that the combined dataset is also clustered around an influent EMC of *ca.*100 mg/L and an effluent EMC of *ca.*20 mg/L. In practical terms, 10 mg/L approximates the system's irreducible EMC for under-500 micron suspended solids. The box plot in Figure 4 indicates that, over the course of two trials, the effluent EMCs from the system, were typically within the range of 10 to 40 mg/L.

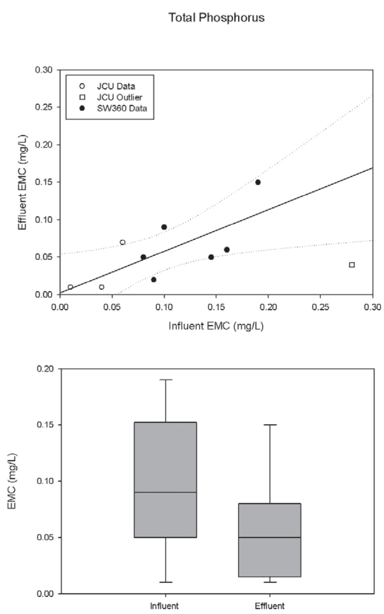


**Figure 5. Total Phosphorus (SW360 and JCU combined).**

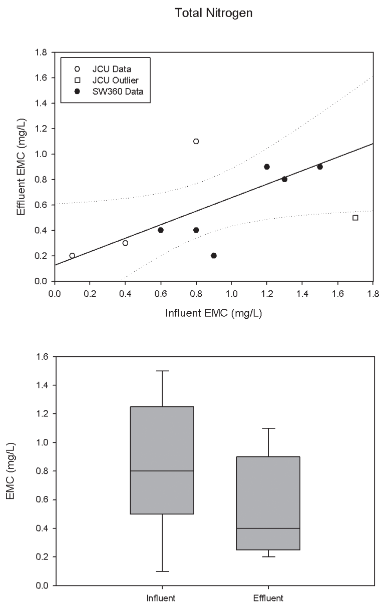


**Figure 6. Total Nitrogen (SW360 and JCU combined).**

Particle size distribution (PSD) by laser diffraction was performed for the SS <500 micron fraction for three storms during the Stormwater360 evaluation. Inspection of the three cases analysed consists of particles between *ca.* 10 microns and 200 microns in diameter. There is substantial variation between the three events.

- Storm 2 influent PSD centred at *ca.* 20 microns for a removal efficiency of approximately 65%;
- Storm 3 influent PSD centred at *ca.* 100 microns for a removal efficiency of approximately 85%;
- Storm 6 influent PSD centred at *ca.* 35 microns for a removal efficiency of approximately 75%.

Generally, the higher removal efficiency would be expected for the coarser samples, and this was the case for all three storms sampled.

## Total Nutrients

The system achieved an aggregate load reduction for total phosphorus (TP) of 47% (note, JCU recorded a load reduction of 70%), the median influent and effluent EMCs for TP were 0.123 mg/L and 0.055 mg/L respectively (refer to Table 2). Duncan (1999) and Fletcher *et al.* (2004) recorded EMCs within a similar range and Fletcher (2004) recommends mean TP concentrations of between 0.25 and 0.50 mg/L for most land uses. Similarly, BMP Database (2010) suggests that a typical range for TP concentrations in stormwater is from 0.11 to 0.38 mg/L, across a range of land uses. In this context it is apparent that the influent TP concentration at the Kuranda site is towards the very low end of published data. Consequently, the 47%

**Table 3. Nitrogen results from Storm 6.**

| Phase | Analyte | Influent EMC (mg/L) | Effluent EMC (mg/L) | Mean Removal Efficiency (Sum of Loads) |
|---|---|---|---|---|
| Total (dissolved and particulate) | TN | 0.8 | 0.4 | 50% |
| | TKN | 0.8 | 0.34 | 58% |
| | NH3-N | 0.15 | 0.07 | 53% |
| | Org-N | 0.65 | 0.27 | 58% |
| | NO3-/NO2--N | 0.01 | 0.06 | -500% |
| Dissolved | TN | 0.4 | 0.3 | 25% |
| | TKN | 0.39 | 0.23 | 41% |
| | NH3-N | 0.16 | 0.073 | 54% |
| | Org-N | 0.23 | 0.157 | 32% |
| | NO3-/NO2--N | 0.01 | 0.07 | -600% |
| Particulate (by calculation) | TN | 0.4 | 0.1 | 75% |
| | TKN | 0.41 | 0.11 | 73% |
| | NH3-N | 0 | 0 | N/A |
| | Org-N | 0.41 | 0.11 | 73% |
| | NO3-/NO2--N | 0 | 0 | N/A |

reduction recorded in the Stormwater360 trial could be related to the difficulty in removing TP at very low influent EMCs, and a much higher removal rate (similar to the 70% recorded by JCU) could be expected as the influent EMC increased.

The system achieved an aggregate load reduction for total nitrogen (TN) of 44%, while the median influent and effluent EMCs for TN were 1.045 mg/L and 0.615 mg/L respectively (Table 2). Again, this influent EMC is low with respect to most of the published data and, according to Duncan (1999), it correlates well with the median for data from forested catchments (0.95 mg/L), but is significantly lower than the median for roads (2.2 mg/L) or urban catchments (2.5 mg/L). Fletcher *et al.* (2004) recommends using a typical total nitrogen value of at least 2 mg/L for most land uses, with the exception of forested catchments.

The total nitrogen results from JCU and SW360 are presented in Figure 6. The spread of influent EMCs is broad, but removal efficiency appears relatively consistent and substantial. This is in spite of the low influent concentrations. TN is generally considered to be predominantly soluble, which is best removed by biological uptake or denitrification (in an anaerobic environment). Consequently, the consistent removal of TN exhibited by the system deserves further consideration. The majority (*ca.* 95%) of the total nitrogen load at Kuranda is TKN and a breakdown of TN species is contained in Table 3.

A small proportion of this TKN load (*ca.* 5%) is ammonia nitrogen, which implies that *ca.* 90% of the total nitrogen load is present as organic nitrogen, in either soluble or particulate forms. An expanded nitrogen suite analysis was conducted for Storm 6, and filtered (0.45 micron) and unfiltered samples were processed in order to establish whether the removal processes, for this event, involved particulate removal or removal of dissolved species. Essentially, the entire TN load was present as TKN and *ca.* 20% of this was ammonia-N (Table 3).

The entire ammonia-N load was soluble, and the treatment train system achieved 54% removal of this species. The remainder (*ca.* 80%) of the TN/TKN load was present as organic nitrogen, of which *ca.* 35% was dissolved. Overall, 73% removal of particulate organic nitrogen and 32% removal of dissolved organic nitrogen was achieved.

Given the removal efficiency for suspended solids, the high removal of particulate organic nitrogen is understandable. Removal mechanisms for dissolved organic nitrogen are less obvious. It is possible that there is some adsorption to the 'schmutzdecke' (bio-film) that develops on the cartridge; another possibility is removal under the anaerobic conditions within the standing water within the wet-zones, being the wet-sump and around the base of the cartridge.

When runoff first enters the StormFilter®, it initially displaces the standing water in the wet-zones. Any pollutants in the standing water are sampled by the effluent sampler (once they have passed through the StormFilter® cartridge), but they are not sampled by the influent sampler. Furthermore, the last of the runoff to enter the cartridge during a storm event does not necessarily pass through the filter cartridge during that event and may be retained within the wet-sump until the next storm event, whereupon it is displaced. When the (particulate or dissolved) organic nitrogen converts to ammonia in the anaerobic wet sump, it can be removed as ammonia-N by the zeolite.

**Table 4. Grab samples from wet sump.**

| Date | Antecedent Dry Period (days) | Report # | Diss. Cu (mg/L) | Diss. Zn (mg/L) | DOC (mg/L) | Diss. N (mg/L) | Diss. NH3-N (mg/L) | Diss. NOx--N (mg/L) |
|---|---|---|---|---|---|---|---|---|
| 07/07/2008 | 8 | 40627 | 0.011 | 0.053 | 17 | - | - | - |
| 20/02/2009 | 6 | 42998 | 0.001 | 0.016 | - | 2.4 | 2.39 | <0.01 |
| 06/05/2009 | 19 | 43826 | 0.005 | 0.082 | 16 | 7.2 | 5.85 | 0.72 |
| 21/07/2009 | 79 | 44703 | 0.004 | 0.083 | 20 | 3.4 | 2.24 | 0.025 |

Periodic grab samples from the wet-sump indicate that most of the TN load in the standing water is present as ammonia-N at concentrations that are two orders of magnitude higher than typical influent ammonia-N concentrations. As such, ammonia-N is, possibly, generated in the wet-zones by anaerobic decomposition of organic nitrogen in the inter-storm event periods. This has two important implications: 1): the load of ammonia-N passed to the StormFilter® cartridge is significantly higher than is suggested by the influent EMC, which implies that the removal rates for ammonia-N removal may be an under-estimate; and 2): by converting organic nitrogen to ammonia-N in the wet-zones and then removing this ammonia, the system has the potential to remove soluble organic-N.

## Discussion

The results for Storm 6 represent a snapshot of one storm, and should not be considered as comprehensive; they do suggest, however, that the main TN removal pathways for the treatment train is the efficient removal of particulate organic nitrogen, complemented by the sorptive removal of soluble ammonia-N and organic-N.

Very often TN removal is treated as a key performance benchmark for stormwater treatment practices. This is potentially problematic, given the apparent variation in the nature of the TN load. In a comprehensive study of nitrogen composition in Melbourne (Taylor *et al*., 2005), *ca.* 25% of the load was present as particulate organic nitrogen. The remainder was soluble and, of these species, oxidised nitrogen predominated over dissolved organic nitrogen and ammonia-N.

Taylor *et al*. (2005) inferred that either 'removing' the water by infiltration or denitrification (ie, in the anaerobic zone of bio-retention practices) would be necessary to achieve significant TN reduction. Fletcher *et al*. (2004) reported that the TN composition measured in wet weather samples for various land uses in the Sydney and Illawarra regions was extremely variable. For urban catchments, median oxidised nitrogen concentrations were in the range 0.09 to 0.42 mg/L, while the median TN concentration range was 0.65 to 2.32 mg/L.

The oxidised nitrogen represents a much smaller proportion of the TN load than was observed by Taylor *et al*. (2005) for Melbourne data. In a study of nutrient build-up on urban roads in the Gold Coast, Miguntanna *et al*. (2010) found that oxidised nitrogen comprised only *ca.* 10% of the TN load, across three different land uses, and most of the TN load was present as TKN and a significant proportion of this was particulate in nature. Consequently, the measured TN load from the Gold Coast catchments is similar to that measured at the Streets Creek, Kuranda site, providing applicability of Nitrogen removals to various urban land uses.

## Conclusions

The results from this field trial generally correlate well with an earlier study at this site by JCU (Munksgaard and Lottermoser, 2008). The data collection from this study has been based on a rigorous and technically demanding monitoring program, which adds further credibility of the results (Goonetilleke, 2010). From an operational perspective, the system captured an appreciably large sediment load requiring annual cleaning to maintain its operational effectiveness.

The EnviroPod®/StormFilter® treatment train achieved 78% removal for suspended solids under 500 microns, which approximates the long-term environmental target recommended by NSW DECC (2007), QLD DERM (2010) for South East Queensland (SEQ) and consistent with the 80% reduction target of many consent authorities in the US.

The runoff at Streets Creek contained very low levels of phosphorus and nitrogen. Total Phosphorus removal was between 45% and 70% respectively in both the Stormwater360 field trial and the JCU research project, which approximates the NSW DECC (2007) and QLD DERM (2010) SEQ long-term environmental targets of 65% and 60% respectively, and is better than expected given the low influent EMCs. Total Nitrogen removal was consistent, substantial and in agreement with the NSW DECC (2007) and QLD DERM (2010) SEQ 45% long-term environmental target, despite the proximity of the influent EMC to the irreducible concentration of the treatment train. The removal of nitrogen was particularly noteworthy, given that the debris captured and stored within the treatment train was not included in the influent load into the system, but may have been sampled as a soluble leachate by the effluent sampler.

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# Evaluation of Gully Pit Inlet Litter Control Systems

# Final Report

## PROJECT NUMBER: 23 68261

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# TABLE OF CONTENTS

## SUMMARY

Stormwater pollution control is usually managed near source or at the end of a drainage system. The Brisbane City Council and Gold Coast City Council are currently investigating several options of managing stormwater litter at the source utilising their Lip-in-Line Gully Pit (small lintel).

A range of devices are currently available to collect litter using the gully pit, however there is limited information regarding;

- The effect on the inlet hydraulic capture performance, and
- the effectiveness of litter capture.

Four litter control systems were evaluated for both on-grade and sag conditions with varying approach flows up to 320 L/sec. Test results and observations included:

- The horizontal bar placed across the inlet had little effect on hydraulic capture for on-grade slopes. However for sag conditions and at flows above 200 L/sec, the hydraulic capture capacity was reduced. Depths at invert were up to 50mm greater for the case without litter and up to 120mm greater with litter.
- Both the mesh and tray basket inserts were ineffective in collecting and retaining litter. Both systems had no significant effect on the hydraulic capture capacity of the gully pit.
- The Enviropod basket is capable of collecting and retaining considerable amounts of pollution at flow rates up to 320 L/sec. Resuspension of pollution occurred at flows above 100 L/sec, however the unit still retained up to 70% of pollution at 1% longitudinal slope at an approach flow of 320 L/sec. The Enviropod basket affected the hydraulic capture capacity of the gully pit at 12% grade due to blockage caused by litter trapped in the overflow outlet.

# 1. INTRODUCTION AND PREAMBLE

Brisbane City Council engaged the Urban Water Resources Centre to undertake a hydraulic evaluation of various litter control systems for a typical Lip-in-Line Gully Pit.

Hydraulic testing was undertaken using a short (2400mm) lintel inlet with the roll top kerb and channel and flows ranging from 0L/sec to 340L/sec at longitudinal grades of 1%, 4% and 12%. Testing was undertaken with the following gully pit litter control systems:

- A 36mm diameter horizontal bar placed across the mid point of inlet opening (as shown in Appendix A),
- meshed pit insert,
- a tray basket (900x500x150), and
- standard Enviropod trash basket.

Testing was carried out using the full-size road test rig at the University of South Australia. A standard litter sample was developed and used for the evaluation. Litter comprised of 80% organics (leaves) and 20% paper, plastic and sediment. A modified litter sample (Appendix B) was used for the evaluation of the horizontal bar system. It contained a greater proportion of larger litter, including plastic food and drink containers, plastic bags and aluminium cans.

Briefly, the aim of the evaluation was to:

- Determine the litter capture performance characteristics of each system, and
- determine the effect that each litter control system has on the inlet hydraulic capture performance.

## 2. TEST SPECIFICATION AND PROCEDURE

**Test specification:**

- Approach flows ranging from 0 – 320 L/sec.
- Channel longitudinal slopes:
  - 1%, 4% and 12% (3 off)
  - "Sag" 0% slope for all configurations.
- Road pavement modelled to simulate asphaltic construction (hot-mix) seal (Manning's "n" = 0.014).
- Crossfall slope of 3.3%.
- Kerb type: Roll-top type kerb-and-channel currently set-up on Road Rig.
- Lintel: Small (S) as per Gold Coast City Council (Drawing 59301).
- BCC perpendicular support bar grate

**Procedure:**

The test procedure involved:

(i) Add the pollution (10L) to an approach flow of 25 L/sec.
(ii) Observe and record the amount of pollution retained.
(iii) Increase approach flow and record capture flow.
(iv) Observe and record amount of pollution retained.

These procedures were repeated several times during each test to assess the effect of increasing flows on litter and hydraulic capture performance.

Testing and evaluation for each of the litter control systems were slightly different.

**36mm diameter horizontal bar**.

Testing of the horizontal bar was conducted with the modified litter sample only. It was accepted that the inlet would collect most organic litter and have no effect on the capture performance of the bar inlet configuration.

**Meshed Pit insert.**

Testing was conducted to determine capture efficiency of the meshed insert under fully blocked conditions. The insert was fabricated from sheet metal hence simulating blocked conditions. Testing was conducted using the standard litter sample.

**Litter Crate Basket (900x500x150).**

Assessment of collection performance, type of litter collected and comments on re-suspension and effect on hydraulics (with basket fully laden) for the standard litter basket was carried out.

**Enviropod Basket.**

The Enviropod insert required modifications to withstand the force of the high approach flow. The plastic sides on the top of the basket were replaced with sheet metal and strengthened.

NB: A new plastic was being tested during this trial. Subsequently a plastic with increased strength and durability designed to withstand flows greater than 320l/s is now used on all Enviropod units.

# 3. TEST RESULTS AND OBSERVATIONS

## 3.1 36mm horizontal bar.

Testing was undertaken to determine the effect on hydraulics and capture performance of the lip in line gully inlet with a bar placed horizontally across the inlet. The modified litter sample was used for this test and was added to the gutter at an approach flow of 25L/s. The flow rate was increased up to 320L/s and amounts of litter retained on the inlet were observed at each increment. "Sag" results, calculated as depth at inlet, are shown in Figure 3.

**Test results and observations:**

**Litter Capture Performance.**

The table below shows percentages of litter added that is retained on the grate or by the bar for varying approach flow.

| SLOPE | APPROACH FLOW L/s | % LITTER RETAINED |
|---|---|---|
| 1% | 25 | 100 |
| | 85 | 88 |
| | 243 | 82 |
| | 320 | 76 |
| | | |
| 4% | 25 | 88 |
| | 60 | 82 |
| | 120 | 76 |
| | 180 | 18 |
| | 320 | 18 |
| | | |
| 12% | 25 | 94 |
| | 60 | 30 |
| | 240 | 30 |
| | 320 | 6 |

**Discussion:**

For the 1% longitudinal slope, 76% of the litter was retained at an approach flow of 320L/sec (see Figure 1). The remaining 24% passed through the inlet beneath the bar or bypassed the inlet. The high capture efficiency is due to the lower approach flow velocities at flatter grades. The majority of litter retained in front of the bar was plastic bottles and milk cartons.

At the steep (12%) slope the inlet retained 30% of litter at an approach flow of 60L/sec. The high velocity forced the majority of litter past the inlet. At an approach flow of 320L/s only a plastic bag remained stuck on the grate.

Figure 1: Pollution remaining after 320L/sec at 1% slope.

The horizontal bar caused a build up of litter at the downstream end of the inlet. Water was observed 'jetting' over the downstream transition, due to the litter caught, at higher approach flows and more significantly at steeper slopes (see Figure 2).

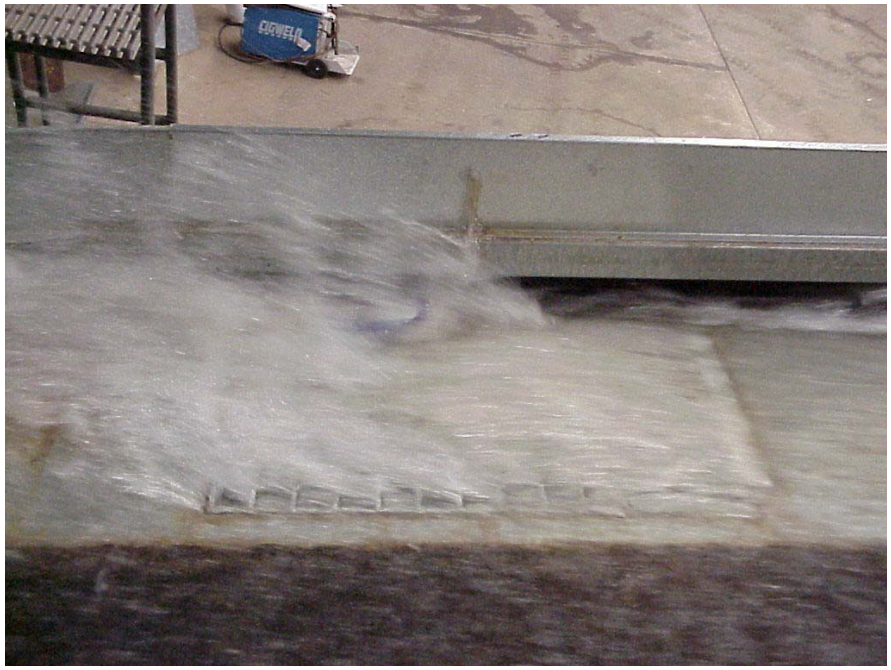

Figure 2: Water 'jetting' due to build up of pollution.

**Hydraulic performance.**

**On-grade tests:**

The reinforcing bar did not effect the hydraulic capture performance of the inlet for on-grade tests.

**Sag tests:**

Under sag conditions, the bar alone significantly reduced capture capacity (see Figure 3). The flow pond depth at invert was up to 50mm greater for the case with the horizontal bar. Testing was also conducted to assess the effect on pond depths at invert with litter retained by the horizontal bar. As expected, the litter reduced the capacity of the inlet to capture flow, with pond depth increase up to 120mm greater for the same approach flow. Litter retained by the horizontal bar further reduced the hydraulic capacity of the gully pit.

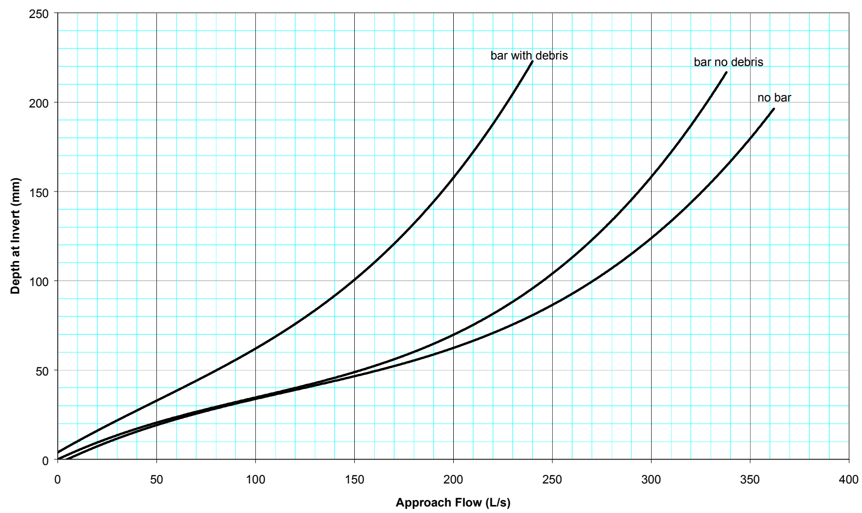


Figure 3: “Sag” Reinforcing Bar “0” Grate.

### 3.2 “Meshed” pit insert.

The meshed pit inlet configuration (see Appendix A) was modified to simulate fully blocked conditions. For this reason, a steel plate was used instead of mesh.

**Test results and observations:**

Observations from the testing were:

**Litter capture performance.**

- At 1% and 4% slope, all litter was captured by the inlet (at 25L/sec), however only 5% of the 10L of litter was retained by the insert for both longitudinal slopes. This litter was resuspended and passed through the inlet when flow was increased to 60L/sec.
- At 12% slope and approach flow of 25L/sec, 10% of the 10L of litter was retained in the inlet box. This material was mostly semi-buoyant litter (wet leaves) which either sank to the bottom or remained in suspension. The grate captured a small proportion of litter. However when the test was repeated at 25L/sec remobilisation of the captured material in the inlet occurred and only 5% was retained. At 60L/sec

all litter had passed through the chamber except for an aluminium can.

**Hydraulic performance.**

**On-grade:**

The mesh insert did not significantly effect the hydraulic capture performance of the gully pit for all longitudinal slopes.

**Sag:**

At 0% (sag) longitudinal slope, the mesh insert caused the inlet to reach ‘orifice’ condition sooner (ie. at a smaller approach flow).

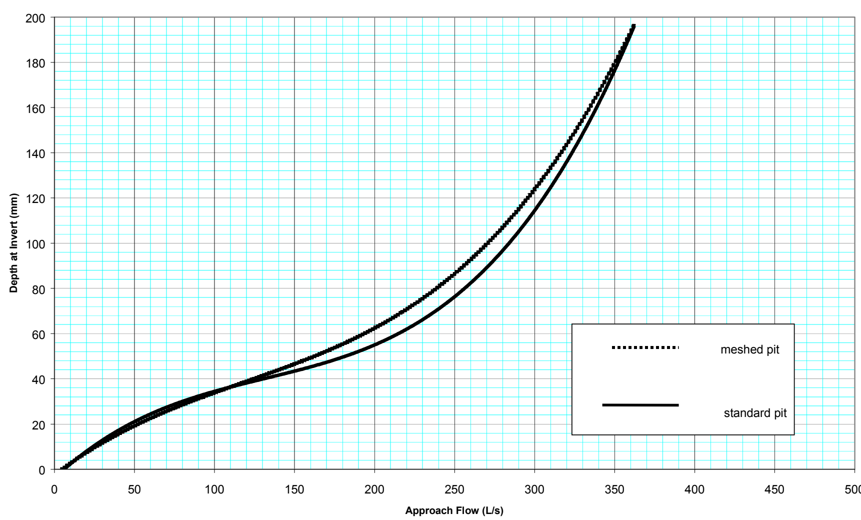


Figure 4: Sag “0” Grate results – meshed pit insert

**Discussion:**

From the observations above, the ‘blocked’ meshed insert had no significant effect on the hydraulic capture performance (on-grade) of the inlet. All floatable litter passed through the chamber at 25L/sec and semi-buoyant litter was remobilised at flows greater than 25L/sec.

For the sag condition, the insert affected the hydraulic capture between 150-340L/sec. Above 340L/sec it would appear that the capture (orifice) was controlled by the inlet opening.

### 3.3 Tray Basket

The tray basket insert (Appendix A) was tested for capture and hydraulic performance under similar conditions.

**Test results and observations:**

**Litter capture performance.**
**On-grade**

- 40% of the litter added to the approach flow (25L/sec) was retained in the basket for all on-grade longitudinal slopes.
- Once the basket became blocked nearly all (90%) of pollution added thereafter bypassed the basket.
- At the steeper (12%) grade the basket was more effective in capturing the litter.
- As the approach flow increased, the litter capture performance of the basket was marginally better at the 12% grade than for 1% and 4%. However, when subjected to an approach flow of 330L/sec, only 2% of the pollution was retained in the basket for all grades.

**Sag**

- The pit was bisected for the sag test to simulate flow from opposing directions (see Figure 5). The basket retained 80% of the litter with the approach flow set at 50L/sec. However it did not retain any of the larger plastic litter.

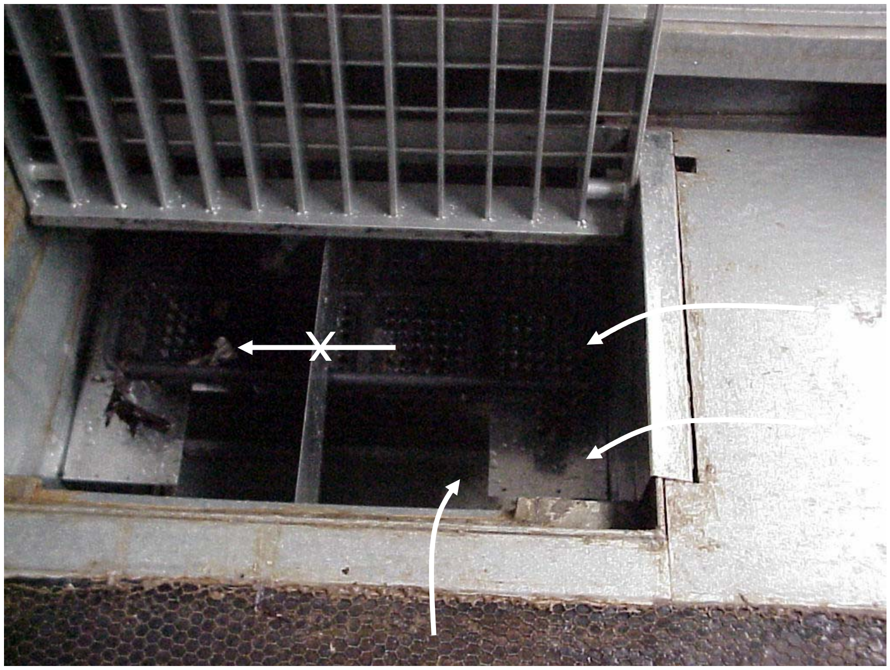

Figure 5: Modified tray basket setup for Sag test.

**Hydraulic capture performance.**

**On-grade:**

The effect of the basket on the hydraulic performance of the pit was insignificant.

**Sag:**

The basket caused the pond depth to increase, resulting in “orifice” flow conditions at lower flows (see Figure 6).

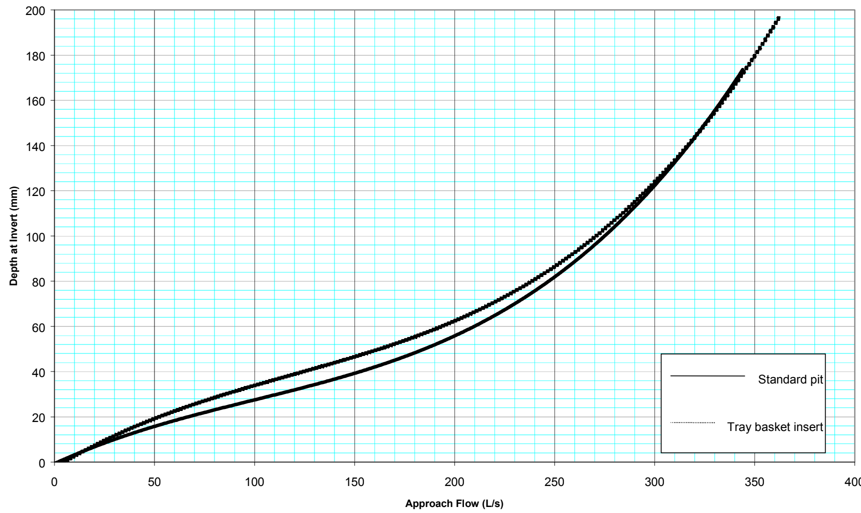


Figure 6: Sag results - tray basket.

### 3.4 Enviropod Testing

Hydraulic testing, including high chamber water level (CWL) pre-testing, and pollution capture performance testing was carried out for the Enviropod basket. Two basket (collection bag) types were assessed; a coarse and a fine fabric.

**Test results and observations:**

During initial tests, plastic sheeting on both the front and back sides of the basket failed when subjected to high flows (>100L/sec). The sides were subsequently replaced with sheet metal.

Litter Capture Performance

**On-grade**

During the initial tests, all of the litter (10L) was captured with approach flow set at 25L/sec. It was decided to increase the amount of litter until bypass occurred. 30L of litter was collected (at 25L/sec) before bypass.

1% grade:

- All litter was collected and retained up to an approach flow of 100L/sec for both collection baskets.
- Approximately 15% of the litter had bypassed the unit at 200L/sec due to resuspension.
- The finer mesh basket retained 70% of litter after an approach flow of 320 L/sec and the coarse basket retained 65%.
- The mesh in both baskets became blocked after a flow of 320 L/sec and held water for a short period after flow was stopped.
- As the flow dropped from 320L/sec to below 50L/sec some of the pollutants attached to the fabric dislodged from the sides. The low flow effectively washed the litter off the basket sides (see Figure 7).

Figure 7: Self cleansing action of basket at low flows.

4% longitudinal slope:

- At an approach flow of 200L/sec, the water level in the basket was higher (100mm below invert) for the finer meshed basket than the coarse mesh (200mm below invert). The higher water level in the pit can be attributed to the reduced size in mesh of the basket.
- Both baskets retained 55% of debris after an approach flow of 320 L/sec.

12% longitudinal slope:

- The water level in the pit rose above the overflow level at 100L/sec therefore resulting in small losses.
- After 320L/sec the coarse mesh basket retained 65% of debris while the fine meshed basket retained 60%.

**Sag**

For the sag test, the basket was bisected in half to simulate flow approaching from opposite directions. 20L of litter was used for the sag litter tests because of the high capture capacity of the basket before bypass. The following observations were made:

- With the coarse mesh the basket retained 50% of the 20L of litter after being subjected to an approach flow of 340L/sec. The bag became considerably coated with larger sized litter (mostly organics).
- With the fine mesh, only 10% of the 20L was retained after an approach flow of 360L/sec (equivalent). The finer mesh experienced less coating on the sides of the basket. It was observed that the flow into the basket had the effect of 'washing off' some of the litter attached to the sides and therefore allowing litter to bypass the basket at higher flows.

### Hydraulic Capture Performance

### On-grade

When compared to the standard lip in line gully pit, the capture capacity of the Enviropod basket was:

- The same for 1% and 4% longitudinal tests
- At 12% grade:
  - 12L/sec less between 200 and 320 L/sec approach flow for the fine mesh basket, and
  - the same at 200L/sec for the coarse mesh basket, and 6L/sec less at an approach flow of 320L/sec.

It was observed at the 12% grade that a plastic drinking bottle and plastic bag were trapped in the overflow outlet, reducing the capture capacity of the pit insert (see Figure 8).

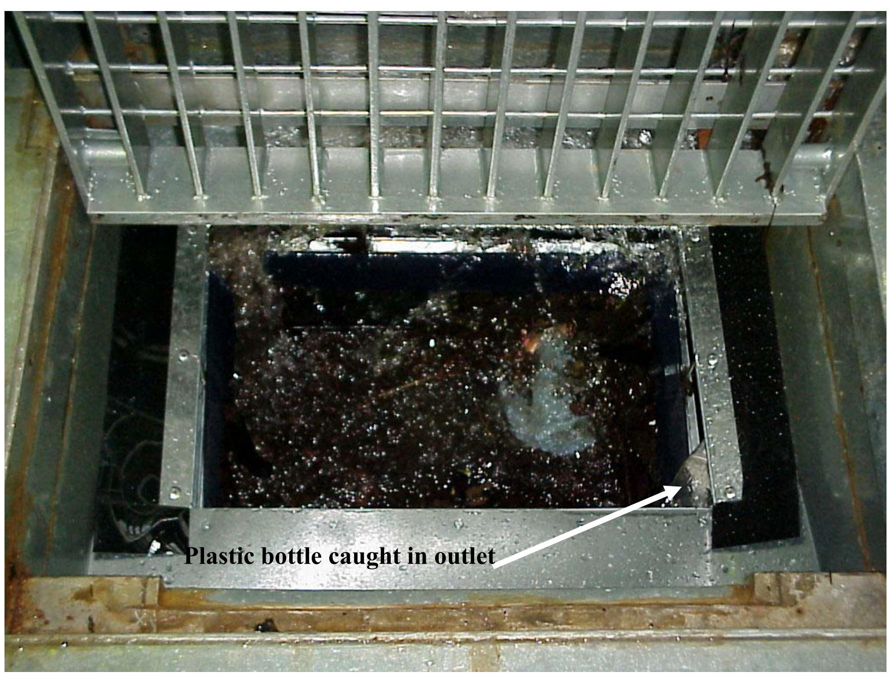


Figure 8: Litter trapped in overflow outlet.

- At 1% and 4% grades, the fine mesh basket (with litter) captured up to 5L/sec more than the coarse mesh basket at an approach flow of 320L/sec.

- At 12% longitudinal slope, the coarse mesh basket captured up to 11L/sec more than the fine mesh basket at an approach flow of 200L/sec and 8L/sec more with an approach flow of 320L/sec.

**Sag**

Four sag tests to determine hydraulic performance of the inlet were conducted; two with fine mesh (with and without litter) and two with the coarse mesh (with and without litter). This enabled a comparison of performance between the two baskets under empty and blocked conditions. The results were also compared to sag capture results with no basket. Pond depth at invert versus approach flow characteristics are provided in Figure 9.

**Fine mesh sag test**

At low to medium approach flows (up to 200L/sec) the addition of litter reduced the capture capacity of the inlet, increasing the pond depth at invert by up to 15mm. However at flows above 200L/sec there was no difference in flow pond depth at invert for the case of with and without litter.

**Coarse mesh sag test**

The effect of the coarse mesh was to increase the flow pond depth at invert by up to 15mm at flows below 200L/sec, as for the fine mesh. However the coarse mesh (with litter) showed similar flow pond depths to the fine mesh (without litter) up to 200L/sec.
The results from the sag test are presented in figure 9 below.

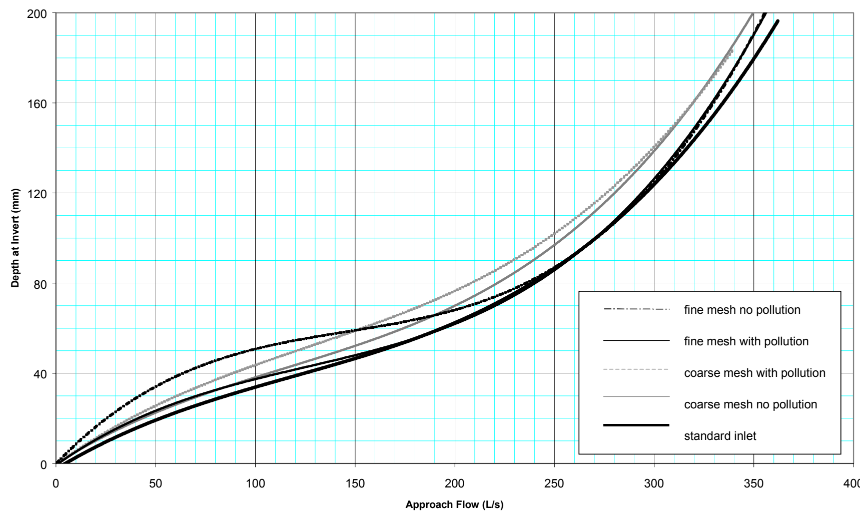


Figure 9: Sag test results (depth at invert)

**Discussion of results**

Both baskets were effective in capturing and retaining a large proportion of litter at flows up to 100L/sec. At 1% longitudinal slope the fine mesh basket was slightly better in capture performance, whilst at the 12% slope the coarse mesh basket was slightly better.

The fine mesh basket resulted in lower depths at invert at the same approach flow than for the coarse mesh basket. This is due to the resuspension of litter in the basket at high approach flows. Only 10% of the 20L of litter added to the fine mesh basket was retained, where as 50% was retained by the coarse mesh basket.

### 3.5 Chamber Water Level Pre-testing

Testing was carried out to determine the effects on inlet capture as a result of high chamber water level. Tests were conducted for the 1, 4 and 12% longitudinal grades. It was observed that with the short lintel (2.4m) a high CWL of 150mm below the gutter invert did not affect the capture performance.

## 4. CONCLUSION

The main findings from the testing programme are:

- The reinforcing bar placed across the inlet had little effect on hydraulic capture for on-grade tests. However for sag conditions and at flows above 200 L/sec, the hydraulic capture capacity was reduced. Depths at invert were up to 50mm greater for the case with no pollution and up to 120mm greater with pollution. A build up of pollution on the grate, restricted by the bar, caused 'jetting' of water above the kerb.
- The crate basket was ineffective in retaining pollution above a flow rate of 25 L/sec for on-grade testing. Nearly all (90%) of pollution added to the gutter after the basket had become blocked bypassed the basket. After an approach flow of 320 L/sec only 2% of pollution was retained for all longitudinal slopes. The basket was more effective in retaining pollution under sag conditions.
- The mesh pit insert was inefficient in retaining pollution above a flow rate of 25 L/sec. Only 5% of the pollution was retained at an approach flow of 25 L/sec for the 1% and 4% longitudinal slope. 10% was retained for the 12% grade however all pollution had bypassed the pit at an approach flow greater than 60 L/sec for all slopes.
- The Enviropod basket was capable collecting and retaining large amounts of pollution and had no significant effect on the hydraulic performance of the gully pit. The basket retained up to 70% of pollution added after an approach flow of 320 L/sec. At 12% grade, litter was trapped in the overflow outlet, reducing the capture capacity of the gully pit. This could also occur for flatter grades and high approach flows. Initial testing of the basket led to some modifications to increase support under high approach flows used in the testing programme.

# AUCKLAND CITY'S FIELD AND LABORATORY TESTING OF STORMWATER CATCHPIT FILTERS

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**ABSTRACT**

The paper documents the results from a field and laboratory testing programme undertaken by Auckland City Council to compare the performance of commercial Catchpit Filter Systems (CFS). A catchpit filter takes the form of a fine-mesh filter bag that is inserted inside a standard catchpit. The need for the testing arose from the City's plans to install several hundred CFS units if they met satisfactory field and laboratory performance targets for capturing sediment washed off roads and paved surfaces.

Four suppliers volunteered CFS units for the field testing programme. Each was installed in a City street and observations made over a five-month period covering: ease of fitting, sediment retention, maintenance needs, rigidity/strength, ability to catch flows and the effects of litter/organics.

Laboratory testing was carried out on CFS units from two suppliers. The testing, carried out at the University of Auckland, sought to quantify sediment capture performance. It also sought to determine the head loss characteristics of the filter fabric to establish its potential to limit the hydraulic capacity and cause flow to bypass the CFS unit. In addition, a catchpit without the CFS unit was tested. Testing was carried out for a range of flow rates and sediment concentrations.

In summary, for a composite "street sweep sediment" sample, the CFS units were found to capture between 78% to 97% of the sediments entering the catchpit.

**KEYWORDS**

**catchpit filter systems, filter bag/fabric, performance, field observations, operation and maintenance, laboratory testing, sediment capture, head loss.**

## 1 INTRODUCTION

Auckland City lies on the isthmus between the Waitemata and Manukau harbours. The harbours and surrounding waters are used extensively for trade and recreation, and contain a number of important ecosystems. The treatment of stormwater runoff is essential if the harbour and its surrounding waters are to be preserved.

Studies have shown that by removing the sediment contained in stormwater, a large amount of the pollutants will be removed (Dept. of Land and Water Conservation NSW). It is found that pollutants attach to the sediments contained in stormwater. Traditional methods of stormwater treatment, such as sediment retention ponds, swales, and infiltration trenches, work by removing the sediment from the stormwater runoff. They often require large areas of land to function effectively. Because of the limited availability and high cost of land in the more developed parts of the City, retrofitting these large stormwater treatment devices is extremely difficult.

Catchpit Filter Systems (CFS) are essentially fine mesh bags that are inserted into street catchpits to capture sediments washed off the road in wet weather. The use of CFS as a means of stormwater treatment does not require the purchase of additional land, or the use of recreational reserves that the council may already control.

The City is considering the use of CFS devices to treat road runoff primarily in the central business district which combine high traffic volumes and limited space to employ other treatment devices.

CFS units are a relatively new method of stormwater treatment aimed at capturing stormwater pollutants close to their source. Being a relatively new treatment method, limited information was available on the operation and sediment removal performance of CFS. Previous performance investigations on some products has shown it is very difficult to carry out conclusive field testing. The City sought to identify CFS products that met their performance targets before progressing to large scale installation of CFS.

A study was carried out to compare the performance and the effectiveness of four different CFS. The four suppliers of the four different CFS all took part in the study on a voluntary basis.

The study consisted of

- A Field Trial
- Laboratory Testing

# 2 FIELD TRIAL

The aim of the field trial was to compare the operational performance of the four different CFS by observing their installation, operational performance and maintenance requirements.

The field trial was a comparative investigation of the four CFS based on qualitative observations of their operational performance under similar weather conditions. The individual catchpits or contributing catchments were not identical, requiring observations to take account of the differing characteristics. The field trial looked at the qualitative performance of the CFS under conditions that the laboratory testing could not simulate.

The field trial was undertaken by Tonkin & Taylor (T&T) in the Newmarket/Grafton area of Auckland city from 21 March to 20 August 2002.

## 2.1 FIELD TRIAL METHODOLOGY

CFS product suppliers were invited to install two CFS units in two trial catchpits identified by Auckland City. Prior to the installation of CFS, all catchpits were cleaned and downstream pipes were checked for blockages.

During the trial period, suppliers were responsible for deciding when any maintenance (including cleaning) of the CFS was required. Suppliers were also requested to meet with Auckland City's maintenance contractor, to discuss suppliers' maintenance/cleaning requirements. Suppliers were encouraged to be present during all the maintenance operations so they could direct the maintenance contractors.

Operational performance observations for each CFS product were undertaken every fortnight and during and after significant rain events. Inspections were carried out by the same two T&T staff members throughout the trial to ensure consistency of observations and records.

The performance of each of the CFS was compared on a number of attributes, as described below.

(a) Ability of the CFS to capture and retain sediment
(b) CFS maintenance characteristics
(c) CFS physical fit within the catchpits
(d) Rigidity and strength of CFS
(e) CFS ability to catch road runoff
(f) Effect of litter and organics on the CFS performance

The information from the field observations was then used to summarise the operational performance of CFS for each of the above performance criteria. These results were then used to focus selection for further laboratory testing of the CFS products.

## 2.2 FIELD TRIAL RESULTS

Of the four CFS observed in the field trials, Auckland City determined that two CFS products met operational performance requirements for their project, and these were selected for further laboratory testing.

The two selected CFS performed favourably on all six performance attributes listed in 2.1 above.

Some interesting issues encountered with some of the CFS in the field trials were:

- Unnecessary use of the CFS overflow mechanism, resulting in untreated flows.
- Mechanical overflow mechanisms such as flaps were prone to failure by blockage.
- Flows bypassing the filter bags due to gaps in the seal between the CFS and the catchpit wall. These gaps were a result of poor installation of the CFS.
- A small sediment storage capacity, which would result in a high cleaning frequency or loss of captured sediments during high flows.
- One of the CFS did not have an overflow mechanism to bypass the filter bag under high flows. This resulted in localised ponding/flooding around the catchpit when flows exceeded the filter bags capacity.
- One filter bag was seen to invert causing the sediment that had been captured to wash down the overflow mechanism and out of the outlet pipe.
- The filter bag from one of the CFS was sucked down the catchpit outlet pipe, creating a blockage and decreasing the capacity of the outlet.

## 2.3 FIELD TRIAL OUTCOMES

The two main outcomes of the field trial were

1. A CFS ability to function well is very dependant on how well it is installed. Careful specification of contract requirements and installation monitoring is required to ensure good quality control of CFS installation.
2. It is essential that CFS have an efficient and reliable overflow mechanism. Mechanical flaps observed in the field trial generally were unsuccessful.

# 3 LABORATORY TESTING

The laboratory study was conducted by Auckland Uniservices, in the School of Engineering at the University of Auckland.

The laboratory tests were used to quantify the effectiveness of the CFS under different flow rates and with different sediment particle sizes and concentrations. This provided a simplified and controlled representation of field conditions to test the relative performance of the CFS. The laboratory data also enables the performance of these products to be predicted from a measured sediment particle distribution. Laboratory tests were also carried out to determine the head loss across the two synthetic filter fabrics to establish the potential for limiting catchpit hydraulic capacity and relative overflow potential between different CFS.

## 3.1 LABORATORY TESTING METHODOLOGY

The laboratory setup consisting of a rectangular channel, wooden apron, hopper, and catchpit containing t CFS is shown schematically in Figure 2. The laboratory catchpit was constructed of plexiglas to dimensio similar to units in the field (catchpit dimensions are presented in Figure 3). The catchpit received water frorr skewed apron (sloped in the longitudinal and transverse directions at 10° and 6°, respectively, to the horizon plane) so that flow occurred primarily along the lower edge of the wooden apron.

The test procedure involved feeding synthetic road sediment, derived by adding specified amounts of siz sediments to running water, to the catchpit at various flow rates. Tests were performed for five flow rates (( l/s, 1 l/s, 4 l/s, 12 l/s, 20 l/s), four sediment concentrations (50 mg/l, 150 mg/l, 250 mg/l, 400 mg/l) and fc particle sizes (<100 μ, 100-500 μ, 500-1000 μ, 1000-10000 μ), yielding a total of 80 tests for each of t following three cases:

- Catchpit without a CFS (base case)
- Catchpit with an Enviropod CFS
- Catchpit with a Flogard CFS.

Constant inflows of synthetic runoff to the CFS were maintained for a minimum of four hydraulic retenti times, corresponding to approximately six minutes for 20 l/s and 30 minutes for 0.5 l/s. The overall C performance was based on the efficiency of sediment capture under specified flow rates, particle sizes, a sediment concentrations.

In addition, each of the three cases were tested using street sediments to simulate particle entrapment in field. The street sediments were obtained by vacuuming a number of streets in Mt Roskill within the Oak Creek catchment. The CFS tests with street sediments were conducted for flows of 4 l/s, 12 l/s and 20 l/s, w an influent sediment concentration of 250 mg/l.

Head loss tests were performed on the filter fabric by passing various flowrates across the filter fabric, a measuring the head on either side of the filter fabric using a peizometer. Figure 1 below shows a schematic the laboratory set up.

*Figure 1: Laboratory Setup for Headloss Measurements*

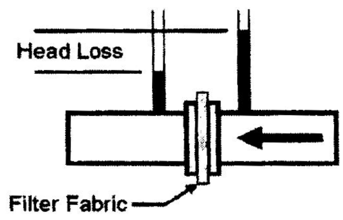


*Figure 2. Experimental setup of Catchpit*

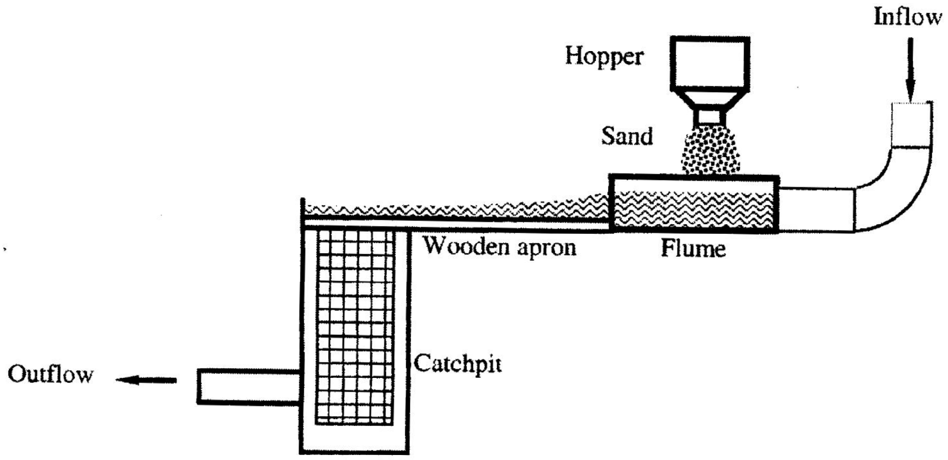
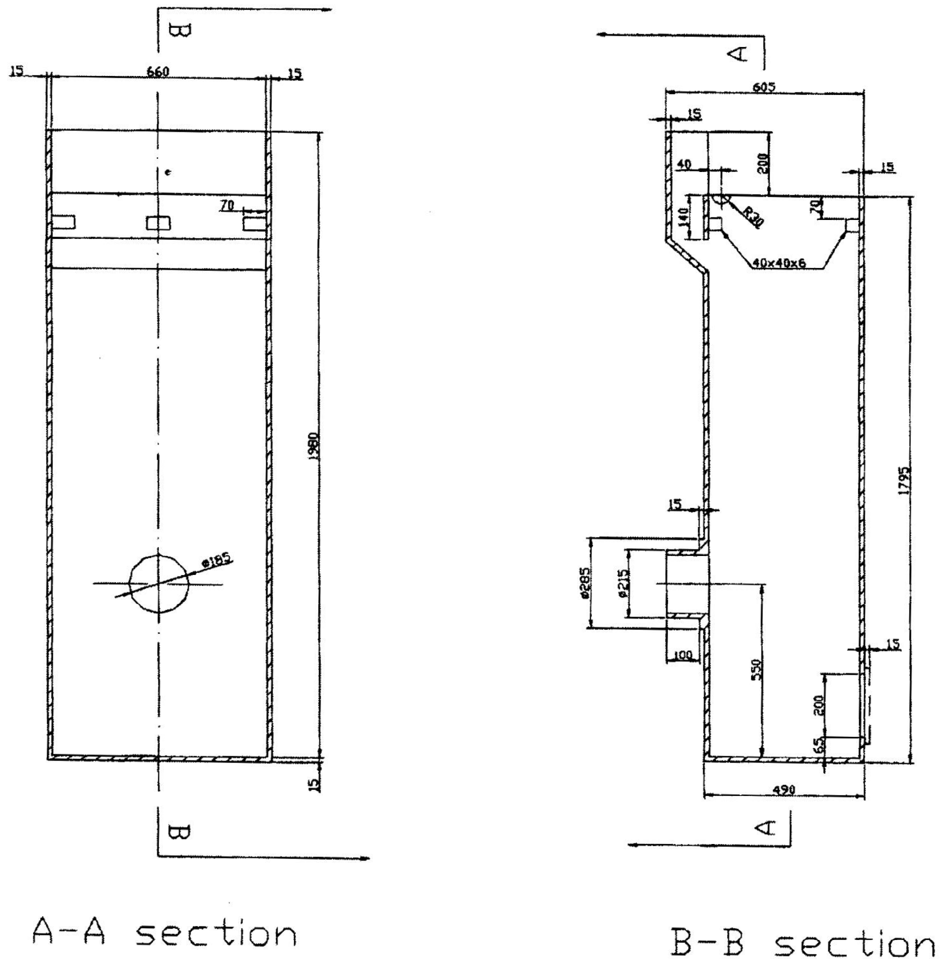



*Figure 3: Catchpit Dimensions*



## 3.2 LABORATORY TEST RESULTS

Test results for sediment removal for the three cases is presented in Figures 4, 5 and 6.

*Figure 4 - Sediment Removal for the Base Case Catchpit With No CFS*

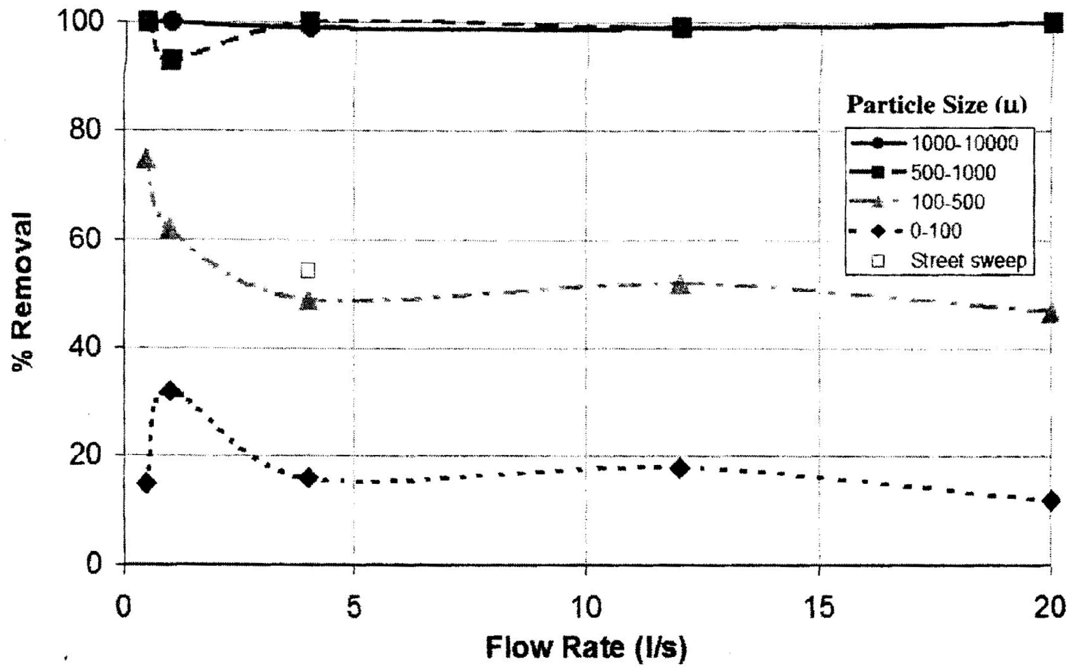



*Figure 5 - Sediment Removal by the Catchpit Containing an Enviropod CFS with a 200 μm mesh*

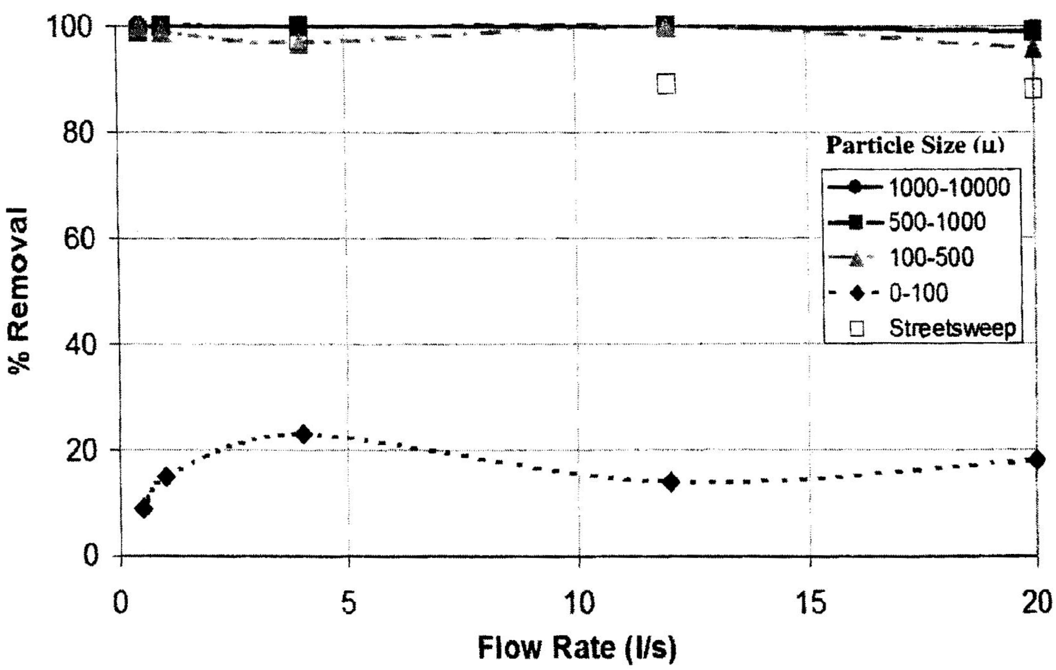


*Figure 6 - Sediment Removal by the Catchpit Containing a Flogard CFS with a 400 μm mesh*

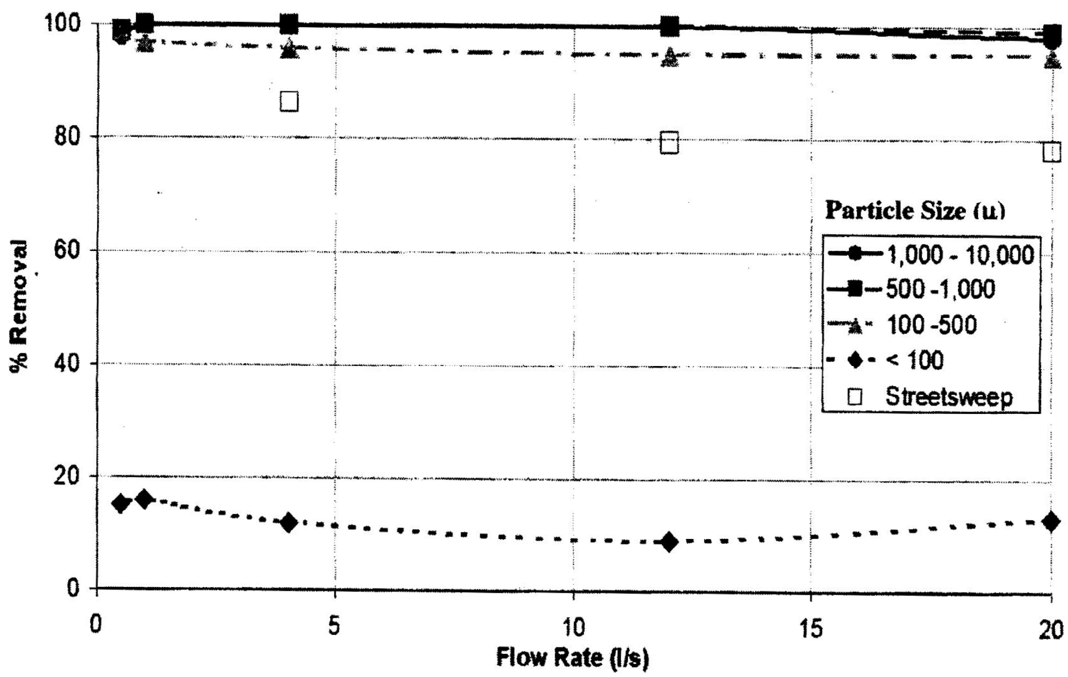



Figure 4 above shows the results in the standard catchpit without a CFS installed. Sediments larger than 500μ were completely removed for flows up to 20 l/s. The removal of 100-500μ particles decreases from 75% to 47% by increasing the flow from 0.5 l/s to 20 l/s, and only 18% of particles smaller than 100μ are trapped by the catchpit. Approximately 58% of the sediment collected from street sweepings were removed at 4 l/s.

Figures 5 and 6 show the laboratory performances of the Enviropod CFS and a Flogard CFS. The performance of both CFS was quite similar. The Enviropod CFS sediment removal efficiency was slightly greater than the Flogard for the finer sediment. These CFS remove essentially all the sediments >100μ, while the removal of sediments <100μ is similar to the standard catchpit with no CFS. The sediment removal efficiencies of the street sweep sediments at 4, 12 and 20 l/s are 97%, 89% and 88% respectively for the Enviropod CFS, and 86%, 79% and 78% respectively for the Flogard CFS. For the street sweep sediments the Enviropod CFS gave approximately 10% greater removal than the Flogard CFS due to more abundant fine sediments present in the street sweep sediments.

# 4 DISCUSSION

## 4.1 EFFECTIVENESS OF CATCHPITS

The laboratory results indicate that catchpits without CFS installed are effective at removing coarser sediments. Results show they have the potential to remove nearly 100 percent of sediments greater than 500 microns in size. Tests undertaken with road sediments collected from the Oakley Creek catchment demonstrated this related to a sediment capture efficiency of 58%. It would be expected that these efficiencies would reduce as greater volumes of sediment accumulate within the catchpit and washout of the sediment occurs due to disturbance under high flows. Similarly, efficiencies could be maintained with regular cleaning of the catchpits.

At present catchpits in Auckland City are cleaned three times per year. A more regular cleaning frequency or targeted cleaning of catchpits receiving high sediment loads may increase annual sediment capture volumes of existing catchpits. Alternatively, for new catchpits, changing the design of catchpits to increase sediment storage volume could increase sediment capture volumes. Clearly, the addition of CFS within catchpits provide a level of protection to accumulated sediments not provided in a standard catchpit.

## 4.2 ADDITIONAL BENEFIT OF CFS IN CATCHPITS

The test results show that CFS can increase sediment removal above that expected from a standard catchpit. The additional benefit of these devices is primarily in the 500-100 micron particle range. The increase in the percent removal efficiency by removing this particle range will vary depending on the constituents of the stormwater runoff. In the tests using street sediments from the Oakley Creek catchment, the addition of a CFS to the catchpit increased the overall sediment removal efficiency from 58% to almost 90%.

The removal of additional sediment may not be entirely due to sediment becoming trapped by the CFS filter material. Neither of the CFS tested had pore sizes as small as 100 microns yet both products still managed to remove particles below this size. Field trial observations found that the use of CFS resulted in less turbulence within the catchpit. The reduced turbulence may provide more favourable conditions for sedimentation and hence the removal of particles smaller than the filter bag perforations. Alternatively the particles may be adhering to the filter bag. As discussed above a valuable outcome of the installation of CFS would be the protection of accumulated sediment from washout during higher flows.

## 4.3 LABORATORY VS FIELD EFFICIENCY

It is worth noting that the above CFS sediment removal efficiencies are based on laboratory conditions. These are the sediment removal efficiencies from stormwater runoff that the CFS unit receives. In a field situation not all stormwater runoff is received by the CFS. This is due to many factors including:

- Poor installation resulting in stormwater bypassing the CFS and entering the catchpit directly.
- High flows bypassing the filter bag via the engineered overflow.
- Reduced filter capacity due to filling with sediment, increasing the incidence of engineered overflow.

## 4.4 FINDINGS

- Modified catchpits or catchpits with CFS could be a practical and economical form of sediment capture in retrofit situations such as heavily built up urban areas.
- Existing standard catchpits are capable of high annual rates of sediment capture. Logically, the more frequently they are cleaned, the greater the annual volume of sediment capture.
- At the time of this study, some CFS products compromised the hydraulic capacity of the catchpit. Clearly, any CFS system must not in any way compromise the hydraulic design capacity of an existing catchpit.
- Most current off the shelf CFS units are designed to be gross pollutant traps and/or fuel oil traps which trap only the coarser sediment particles. It appeared that most CFS products would be able to be modified to focus on sediment capture.
- The field installation of CFS products needs to carefully specified and be well supervised, especially for new entrants to the CFS market.

# 5 ENVIRONMENTAL BENEFITS

There are many stormwater treatment systems that provide various single or combined levels of environmental benefit. These systems include coarse litter traps, fuel oil removal systems, chemical traps, nutrient removal systems, sediment traps and the like.

This study has focused on the sediment capture efficiency of CFS products. Test results have shown that an appropriately maintained standard catchpit can remove the majority of sediment down to 500 microns in size.

Test results show that with the addition of CFS, the majority of sediment down to 100 microns in size can be removed.

If the removal of particles greater than 500 micron provides an opportunity to halt degradation or improve the quality of the Auckland environment then a focus on standard catchpits would be a step in the right direction. If the requirements are to remove down to 100 microns then the addition of a suitable CFS would equally be a step in the right direction.

Identification of the relationship between sediment particle size removed and the volume of various pollutants removed has not been part of this study.

## DISCLAIMER

The intent of this paper has not been to proclaim any particular CFS brand name or supplier as being "better" than another. The authors acknowledge that suppliers may have changed the character or form of CFS products since this study was carried out, and this paper should not be used as a basis for users to select one product over another.

## REFERENCES

DLWC (1998) 'The Constructed Wetlands Manual' Department of Land and Water Conservation, New south Wales, Volume 2.

## ABBREVIATIONS

CFS Catchpit Filter Systems
T&T Tonkin & Taylor Ltd Environmental & Engineering Consultants Ltd