STORMWATER QUEENSLAND

31 August 2026

Stormwater Queensland
E: admin@stormwaterqueensland.asn.au

RE: Can wet sump gross pollutant traps be expected to reliably remove suspended solids and nutrients?

This correspondence seeks to provide guidance to the stormwater industry in Queensland regarding the ability of wet sump gross pollutant traps (GPTs) to reliably remove suspended solids and nutrients from incoming stormwater flows.

Based on available science (reviewed below), the balance of evidence suggests that if GPTs are appropriately designed, installed, maintained and managed, they would be anticipated to reliably provide significant reductions in the concentrations of suspended solids and some reductions in total phosphorus. However, only modest removal of nutrients is likely to be typically achieved. This is largely owing to the large portion of total nitrogen (TN) in urban stormwater consisting of the dissolved forms of nitrogen (N) that are not removed through physical processes (i.e. those mechanisms used in GPTs). Stormwater Queensland is unaware of any existing wet sump GPTs, tested or otherwise, that have capability of removing the dissolved nutrient fractions. This casts reasonable doubt over any claims suggesting high removal rates of phosphorus (P) and any significant N removal from a wet sump GPT, regardless of the technology type.

Furthermore, the risk of nutrient release of wet sump GPTs under sub-optimal maintenance practices presents a very real risk of an increase in some of the most harmful to the environment (when excessive) forms of N being generated in the sump.

Stormwater Queensland has drawn these conclusions using the best available scientific data which is summarised in the accompanying review of GPT performance, provided on the following pages.

Continuous deflection type screening device technologies (CDTSDs) are recognised as a high performance wet sump GPT. We recommend CDTSDs be modelled in MUSIC using the “Generic” node with removal rates (up to the treatment flow rate of the specific model) of up to a maximum of 100% for gross pollutants, 40% for total suspended solids, 10% for total phosphorus, and zero for total nitrogen. The same maximum removal rates are recommended regardless of the tool used to determine performance assessment. Significantly lower removal rates would be anticipated if CDTSDs are not suitably designed, installed and/ or maintained appropriately – and/ or if stormwater inflows to the CDSTD have lower concentrations than typical urban conditions (e.g. if stormwater is treated prior to flowing to the CDSTD). Lower pollutant removal rates are also anticipated for other types of wet sump GPTs (relative to CDTSDs).

These recommendations are based on:

- a total of six (6) published ‘real world’ performance monitoring studies of CDTSDs operating under typical conditions (noting that we recognise this a small dataset);
- analyses of performance monitoring studies provided in the International Stormwater BMP Database (Clary et al 2002) for ‘hydrodynamic separators’ (a type of wet sump GPT); and
- determinations for a CDTSD by *The State of Washington Department of Ecology Emerging stormwater treatment technologies (TAPE) program*.

- our understanding of the fundamental physical, chemical and biological removal process upon which all CDTSDs rely upon.

Any available studies which suggest statistically significant departure from the pollutant reduction efficiencies for any CDTSDs are considered by Stormwater Queensland to be outliers to the current body of evidence, which should not be relied upon to establish alternative pollutant reduction efficiencies.

Stormwater Queensland fully endorses and promotes the need for further research regarding stormwater pollutant loads and treatment asset performance, and acknowledge that in time this may shift the body of evidence regarding potential pollutant removal efficiencies. In the interim, the recommended upper limit of performance adopts a pragmatic position in line with the weight of evidence. Specifically, Stormwater Queensland considers that, in order to accept the findings of stormwater device efficacy testing suggesting pollutant removal efficiencies substantially greater than our recommended maximums, a demonstration of the following would be required:

- A fundamental shift in underlying removal processes in a CDTSDs sufficient to explain statistically significant improvements in these pollutant reductions efficiencies. For example, to significantly increase total nitrogen removal would require enhanced biological removal pathways.
- That stormwater used in testing has a pollutant makeup (including nutrient speciation) in line with wider evidence. We note that building a database of urban runoff and stormwater pollutants would greatly assist in the industry's progressive understanding of runoff quality, and in time it is possible that the baseline understanding of pollution will shift, justifying reconsideration of performance claims.

Further information is provided on the following pages. However, please contact Stormwater Queensland if further clarification if required.

Yours faithfully.

Stormwater Queensland

Introduction

Background

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. ‘Gross Pollutant Traps’ (GPTs) are one of the most commonly applied type of SCMs.

Initially, GPTs were designed to capture mainly litter and debris, but they have evolved and studies have demonstrated their ability to not only capture those pollutants, but also capture suspended sediment and particulate-bound nutrients and heavy metals (Neumann et al 2010).

There are broadly five (5) categories of GPTs (Neumann et al 2010):

- Gravity separators
- Direct screening devices
- Vortex-type devices
- Continuous deflection type screening devices
- Others (e.g. inclined screens, combinations).

Any claims of higher than expected pollutant reductions for GPTs, specifically those that act as wet sumps, is questioned based on the available literature as described below. From the above categories of GPTs, continuous deflection type screening devices (CDTSDs) are likely considered the most effective type of wet sump GPT and have the most extensive performance monitoring data available, and are subsequently described in more detail in the text below.

Continuous deflection type screening devices

Continuous deflection type screening devices (CDTSDs) are an engineered device that combine a vortex/ hydrodynamic separation with a non-blocking screening system (Neumann et al 2010) to remove litter, gross pollutants, sediment and associated pollutants from stormwater runoff as either a stand-alone technology or as part of a ‘treatment train’ (with stormwater treatment assets located downstream to provide further treatment). These devices are also often referred as “non clogging” or “indirect screen” GPTs.

Given the vortex action and unique, self-cleaning screen of CDTSDs, they are likely to provide significantly higher gross pollutant and solids removal relative to other types of wet sump GPTs.

Performance monitoring studies & approvals

CDTSDs have been the subject of significant independent research including that undertaken by the Co-operative Research Centre for Catchment Hydrology (Australia), Monash University (Australia), University of California Los Angeles and Portland State (Contech Stormwater Solutions, 2007). Tables 1 and 2 provides a summary of six (6) examples of CDS® technologies (a type of CDTSD technology) operating in ‘real world’ conditions in Australia and USA respectively where treatment performance monitoring has been undertaken.

Table 1 Summary of predicted treatment performance case studies for CDS® technologies in Australia

Reference	Location	Stie details	Methodology summary	Performance summary
Allison et al (1998)	Coburg, Victoria, Australia	• CDS unit • 50-ha catchment (35% commercial, 65% residential land use) • Mean rainfall 660mm per year	• Monitored by Allison et al • 12-month monitoring period (May 1996 to May 1997) • 7 sampling events • gross pollutants analysed • Flow-rates and volumes measured	• "Practically all gross pollutants trapped by the stormwater were trapped by the CDS device (i.e. 100% removal rate)" (Allison et al, 1998).
Walker et al (1999)			• Monitored by Walker et al (1999) • 15-month monitoring period (November 1996 to February 1998) • 15 storm events sampled using autosamplers • Influent & effluent analysed for solids, nutrients • Flow-rates and volumes measured	• During storm events, for TSS, "the CDS unit effectively reduced concentration levels above 75 mg/L, with a mean removal efficiency of approximately 70%. For concentration levels below 75 mg/L, TSS removal was highly variable" (Walker et al, 1999). • During storm events, "removal rates for TP were found to be approximately 30%, although there were occasions when downstream concentrations were found to be higher than the inflows" (Walker et al, 1999). • During storm events, "removal rates for TN were found to be highly erratic" (Walker et al, 1999). • Mean annual TSS and TP loads removal of 65 and 21% respectively.
Birch et al (2009)	Chiswick (Western Sydney), NSW, Australia	• 3m-diameter CDS unit • 60-ha urban catchment • Mean rainfall 911mm per year	• Monitored by Birch et al • 27-month monitoring period (June 2018 to September 2020) • 6 storm events sampled using autosamplers • Influent & effluent analysed for solids, nutrients, faecal coliforms and metals	• Mean concentration removal efficiencies: TSS 28%; TP 4%; TKN 10%, NOx -4%. • Decreases in faecal coliforms for high flow events, but increases in low flow events. • Low and highly variable removals for trace metals.

Table 2 Summary of predicted treatment performance case studies for CDS® technologies in USA

Reference	Location	Stie details	Methodology summary	Performance summary
Strynchuck et al (2000)	Brevard County, Florida, USA	• CDS unit • 24.5-ha catchment (road, industrial, vacant and commercial land usage) • Mean rainfall 1227mm per year	• Monitored by Brevard County • Monitoring between April 1998 and March 1999 • 5 storm events sampled by autosamplers • Influent & effluent analysed for TSS and TP • Flow-rates and volumes measured	• Removal efficiency for TSS and TP of 52% and 31% respectively.
Herngren et al (2007)	Baton Rouge, Louisiana, USA	• CDS unit, 500mm screen height, 500mm screen diameter, 200mm oil baffle installed for one event • 1088m^2 catchment (road, 100% impervious) • Mean rainfall 1595mm per year	• Monitored by Louisiana State University • 6-month monitoring period (April to October 2004) • 3 sampling events • Influent & effluent analysed for solids • Flow-rates and volumes measured	• 79-94% of particles above 75µm removed. • 21-57% of particles between 25-75µm removed. • 4-43% of particles smaller than 25µm.
Contech Engineered Solutions (2010)	Point pleasant, Orange County, New Jersey, USA	• High Efficiency CDS unit model PMSU20_25 (CDS2025) • 0.8-ha catchment (bank building and car parking, 78% impervious) • Mean rainfall 1227mm per year	• Monitored by Sovereign Consulting (with Contech installation, operation and maintenance of sampling equipment) • Monitoring between January and November 2008 • 19 storm events sampled by autosamplers • Influent & effluent analysed for solids • Flow-rates and volumes measured	• Significant reductions for suspended solids loads were observed between influent and effluent sampling locations: SSC (<2000µm) 98%, TSS-SM (<2000µm) 95%, TSS-EPA (<2000µm) 95%, SSC (<500µm) 97%, and SSC (<50µm) 65%.

As summarised in Tables 1 and 2, studies assessing the performance of CDS® technologies have shown significant reductions in concentrations and loads of solids and total phosphorus, but limited or “highly erratic” removal of nitrogen. These findings are similar to the analyses presented in the *International Stormwater BMP Database* (Clary et al 2002), which cites median concentration reduction efficiencies for ‘hydrodynamic separation devices’ [1] (a type of wet sump GPT) of 38% and 5% for TSS and TP respectively, and “no significant difference in concentrations” for TN for each of the three (3) statistical analyses undertaken for the database.

The *State of Washington Department of Ecology Emerging stormwater treatment technologies (TAPE)* program has also determined that the CDS Stormwater Treatment System (a type of CDTSD) has a “General Use Level Designation (GULD) for pretreatment use” only [2]. As defined in the *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies Technology Assessment Protocol – Ecology* (Howie et al 2024), this designation correlates to a performance of greater than or equal to 50% TSS removal for a TSS influent of between 100 and 200mg/L) but zero removal for nutrients.

For further comparison, Table 3 presents a summary of TSS, TP and TN concentration efficiency ratios (ERs) for available ‘real world’ bioretention performance monitoring studies.

---

[1] *The International Stormwater BMP Database* (Clary et al 2002) defines “Hydrodynamic Separation Devices” as “manufactured devices providing gravitational settling using swirl concentrators, screens, and baffles”.

[2] https://fortress.wa.gov/ecy/ezshare/wq/tape/technologiesiFrame.html#GULD

Table 3 Summary of 'real world' bioretention performance monitoring studies

Reference	Biofiltration system details	Methodology summary	TSS ER (%)	TP ER (%)	TN ER (%)
Dalrymple et al (2022)	Western Sydney, NSW, Australia; installed April 2018, 1.45m area (0.34% of catchment); 0.53m deep Filterra® filter media; Bush Christmas' Lilly Pilly (*Syzygium australe*).	17 real events after 'establishment'; flow & water quality monitored; 2019-21	81%	83%	49%
Shaw et al (2006)	Falls Church Virginia, USA; installed April 2018, 3.3m^2 area (0.7% of catchment); 0.53m deep Filterra® filter media; unidentified shrub/ tree.	16 real events; flow and water quality monitored; 2004-2005	88%	60%	- (40% for TKN)
Herrera (2014)	Bellingham, Washington, USA; 2.2m^2 area (0.13% of catchment); installed 2007, 0.53m deep Filterra® filter media; unidentified shrub/ tree.	22 real events; water quality monitored in 2013	94%	70%	-
Contech (2016)	Virginia Beach, Virginia, USA; 2.2m^2 area (unknown catchment area); installed 2007, 0.53m deep Filterra® filter media; unidentified shrub/ tree.	92 real events; water quality monitored; 2008-2016	90%	66%	49%
Smolek et al (2018)	North Carolina State University, Fayetteville, North Carolina, USA; installed 2012, 2.2m^2 area (0.22% of catchment); 0.53m deep Filterra® filter media; Crepe myrtle (*Lagerstroemia* spp).	34 real events; flow & water quality monitored; 2013-14	95%	64%	27%
Birch et al (2005)	Sydney, NSW, Australia; 420m^2 biofiltration system (approx..4% of catchment); up to 1.1m deep filter media (1:6 mixture of zeolite and coarse, pure quartzitic sand with a mean diameter of 2 mm.); unknown planting.	9 real events; water quality monitored; between October & December 1999	50%	65%	N/A
Hunt et al (2006)	Greensborough, North Carolina, USA; constructed 2000-01; two cells, 10m^2 each (5% of catchment); both with 1.2m 'organic sandy soil' filter, cell G1 included 0.45 to 0.6m internal water storage, approx. 20m^2 area; planted with river birch, common rush, yellow flag iris & sweetbay.	11 real events; flow & water quality monitored; 2002-03	N/A	-409% (G1), -2900% (G2),	224% (G1), -312% (G2)
Davis (2007)	Maryland, USA; installed 2003; 2 parallel cells, 26m2 area each (2.2% of catchment), Cell A 0.9m filter (50% sand, 30% topsoil, 20% hardwood mulch) with 80mm surface hardwood, Cell B as per Cell A but with 0.3m anaerobic sump (sand & newspaper mix); vegetated.	12 real events; water quality monitored; 2003-04	22% (Cell A), 41% (Cell B)	74% (Cell A), 68% (Cell B)	N/A
Hatt et al (2009)	Monash University, VIC, Australia; 3 cells, each 1.5m^2 area (1% of catchment); 0.5m deep filter media (Cell 1, sandy loam; Cell 2, 80% sandy loam, 10% vermiculite,	Real events; water quality data for 38 events; flow data	87% (Cell 1), 92% (Cell 2),	-2140% (C1), -1286%	18% (Cell 1), 0% (Cell 2),

Reference	Biofiltration system details	Methodology summary	TSS ER (%)	TP ER (%)	TN ER (%)
	10% perlite, by volume; Cell 3, 80% sandy loam, 10% compost, 10% hardwood mulch, by volume; dense planting (native sedges & rushes).	for 28 events; monitored 2006-2007	90% (Cell 3)	(C2), -1423% (C3)	18% (Cell 3)
Roberts et al (2012)	Wakerley, QLD, Australia; constructed 2007; 3 cells (955m^2 each, 0.3% of catchment) with upstream sediment basin; sandy loam filter media; 0.9m saturated zone in Cell 3; variety of plant species.	53 to 74 real events for each cell; water quality monitored 2009-10	36% (Cell 1), 53% (Cell 2), 44% (Cell 3)	25% (Cell 1), 34% (Cell 2), 38% (Cell 3)	-28% (Cell 1), -11% (Cell 2), 19% (Cell 3)
Johnson et al (2019)	Chapel Hill, North Carolina, USA; constructed 2001; 90m^2 area (14% of catchment in 2002-03; 8% of catchment 2003-present); 1.2m deep sandy filter media; perennial grasses, trees & shrubs.	1st study: 10 real events; flow & water quality monitored; 2002-2003	N/A	-21% (1st), 39% (2nd)	-38% (1st), 26% (2nd)
Bonneau et al (2020)	Melbourne, VIC, Australia; 1800m2 biofiltration system (0.5% of catchment); 0.8m average filter depth (0.35m sandy loam, 0.1m sand, 0.05m gravel, 0.3m scoria) – with bottom 0.5m being a submerged zone (of un-lined basin); densely vegetated with a mixture of swamp grasses (e.g. *Centella cordi folla*, *Amphibromus nervosus*), sedges (e.g. *Carex appressa*) and common spike rush (e.g. *Eleocharis acuta*).	13 real events analysed for water quality; 2013-2016	93%	84%	73%

As summarised in Table 3, in general, performance monitoring studies generally demonstrate that pollution removal efficiencies for bioretention systems are typically significantly higher than that observed in studies of CDTSDs.

Limitations to performance of wet sump GPTs

There are two (2) key limitations to the ability of wet sump GPTs (such as CDTSDs) to remove solids and nutrients:

- Sole reliance on physical treatment processes (at relatively high loading rates) to improve water quality.
- Resuspension and/or release of retained pollution.

This is described further below.

Sole reliance on physical treatment processes

As described above, wet sump GPTs (such as CDTSDs) rely solely on physical treatment processes to remove solids and particulate-bound pollutants, and these physical treatment processes are applied at a higher loading rate (flow per unit of treatment area) relative to other SCMs (such as bioretention, wetlands, and filter cartridges). There are no chemical and/ or biological treatment processes (as observed in, for example, bioretention) typically present within wet sump GPTs to significantly improve stormwater quality. Subsequently, wet sump GPTs provide no significant treatment mechanism for the removal of dissolved pollutants, such as dissolved inorganic nitrogen and orthophosphate.

Several stormwater monitoring studies (such as Dalrymple et al (2020), Dalrymple et al (2022), Drapper et al (2015), Parker (2010), Hatt et al (2009) Taylor et al (2005)) have demonstrated that dissolved inorganic nitrogen appears in significant concentrations within stormwater from urban areas. E2DesignLab (2015) also states that approximately 50% of total nitrogen in stormwater from urban areas is dissolved inorganic nitrogen. Blacktown City Council (2020) also requires that representative sites for proprietary stormwater quality improvement device testing must have a minimum of 25% dissolved inorganic nitrogen.

Resuspension and/ or release of retained pollution

The removal of retained pollution from wet sump GPTs is typically recommended to occur approximately every twelve months (Stormwater NSW, Ocean Protect 2024). In the absence of the removal of retained pollution from wet sump GPTs, however, it is likely that some pollution retained (after each inflow event) will be released from the wet sump environment of the GPT. This is evidenced by studies, such as Walker et al (1999) and Greenway et al (2002), which observed increases in pollutant concentrations (particularly nutrients) across CDTSDs. This is likely due to a combination of:

- Rainfall intensity and resulting large flow volumes through the GPT contributing to a resuspension of fine-grade and/ or organic material from the wet sump of the GPT (to downstream areas).
- Release of dissolved pollutants.

Various studies, such as Allison et al (1998), have shown that a large proportion of the gross pollutants transported in urban stormwater is organic matter. As evidenced in Tables 1 and 2, CDTSDs retain nearly all gross pollutants, hence the majority of the organic material transported from upstream catchments will be retained within the wet sump of a CDTSD. These materials are retained under water and there is the possibility of mineralization of organic material and desorption of nutrients due to the reduced dissolved oxygen levels and redox potential in the containment sump. These processes can transform the relatively stable forms of particulate-bound nutrients into more readily available soluble forms. These increased concentrations of dissolved nutrients can then be ‘flushed’ from the GPT during the initial stages of a subsequent storm event (Walker et al 1999, Greenway et al 2002).

For wet sump GPT applications, the following actions are recommended (Walker et al 1999):

- Regular maintenance of GPTs to minimise physical resuspension of sump material during high-flow events.
- Downstream stormwater treatment systems (e.g. bioretention, wetland, cartridge system) for improved pollutant removal and compliance with best practice stormwater pollutant load removal targets (such as those required under the *State Planning Policy*).

Application to local conditions

As described above, wet sump GPTs (such as CDTSDs) use 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 local conditions and the monitoring sites described in Tables 1 and 2.

Regardless of rainfall intensity and duration, CDTSDs operate with a unique circular screen. 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 (2010), it is easier to achieve higher pollutant load removal rates when runoff has higher pollutant concentrations.

Solubility of nutrients is also critically important to the total nutrient pollutant removal performance. The removal of soluble pollutants such as ammonium or ortho-phosphate tend to be more difficult to remove than solids as the removal pathways/mechanisms are not only dictated by filter contact time, sediment particle size, sediment density and concentration, but also competing pollutants i.e., 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 (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.

Modelling performance

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

Modelling software

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is a software tool from eWater 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.

Treatment node options

As outlined in the previous section, MUSIC models the performance of stormwater treatment devices using ‘treatment nodes’. It is recommended that CDTSDs be modelled using the ‘Gross Pollutant Trap’ (GPT) or ‘generic’ treatment nodes within MUSIC.

The pollutant removal provided by CDTSDs can be modelled within MUSIC by adjusting the pollutant removal ‘transfer functions’ within the GPT or generic treatment node for gross pollutants (GPs), total suspended solids (TSS), total phosphorus (TP), and total nitrogen (TN). The high flow bypass rate should equal the maximum treatment flow capacity of the given device/ model.

Recommendation

It is recommended that the treatment performance CDTSDs within Queensland be modelled using a GPT or generic treatment node (as described above), with stormwater treatment performance consistent with the values summarised in Table 4 up to the design treatment flow rate for the specific CDTSD.

Table 4 Recommended maximum treatment performance for continuous deflection type screening devices

Pollutant	Maximum removal efficiency (%)[1]	References[2]
Gross pollutants	100%	Based on Allison et al (1998), Walker et al (1999) and high rates of sediment removal observed in other studies.
Total suspended solids	40%	Based on Walker et al (1999), noting MUSIC modelling guidelines (Healthy Land and Water 2018, BMT WBM 2015, eWater 2016) recommend applying a storm event mean concentration of 269 to 270mg/L.
Total phosphorus	10%	Based on Walker et al (1999), Birch et al (2009) and Strynchuck et al (2000).
Total nitrogen	0%	Based on Walker et al (1999) and Birch et al (2009).

1: Removal up to design flow rate. All flows greater than this flow rate are assumed to be receive zero pollutant removal.

2: References are summarised in Tables 1 and 2.

Given the vortex action and unique, self-cleaning screen of CDTSDs, they are likely to provide significantly higher gross pollutant and solids removal, relative to other types of wet sump GPTs. Subsequently, lower pollutant removal rates are recommended for other types of wet sump GPTs (relative to CDTSDs).

It should also be noted that the pollutant removal efficiencies cited in Table 4 would only be applicable for "un-treated" stormwater flow – i.e. with no additional stormwater treatment asset types upstream of the CDSTD. If additional stormwater treatment asset types (that are predicted to reduce pollutant concentrations), the predicted removal efficiencies of any CDSTD would be significantly lower than the values given in Table 4.

References

Allision R A, Walker T A, Chiew F H S, O'Neill I C, McMahon T A, 1998, *From roads to rivers – gross pollutant removal from urban waterways*, Report 1998/6, May 1998, Cooperative Research Centre for Catchment Hydrology.

Birch G F, Matthai C, 2009, *Efficiency of a continuous deflective separation (CDS) unit in removing contamintants from urban stormwater*, Urban Water Journal 2009, 1-9.

Birch G F, Fazeli M .S, Matthai C, 2005, *Efficiency of an infiltration basin in removing contaminants from urban stormwater*, Environmental Monitoring and Assessment, I0I, 23-38.

Blacktown City Council, 2020, *Water sensitive urban design (WSUD) developer handbook – MUSIC modelling and design guide*.

BMT WBM (2015). *NSW MUSIC Modelling Guidelines*. Prepared for Greater Sydney Local Land Services.

Bonneau J, Fletcher T D, Costelloe J F, Poelsma P J, James R B, Burns M J, 2020, *The hydrologic, water quality and flow regime performance of a bioretention basin in Melbourne, Australia*, Urban Water Journal, 2020, Vol 17, No. 4.

Clary J, Jones J, Leisenring M, Hobson P, Strecker E, 2020, *International Stormwater BMP Database: 2020 Summary Statistics*, The Water Research Foundation.

Colwill G M, Peters C J, and Perry R, 1984, *Water Quality of Motorway Runoff*, TRRL Supp, Rpt 823, Crowthorne, Berkshire, England.

Contech Engineered Solutions, 2010, N*JCAT Technology Verification – High Efficiency Continuous Deflective Separator (CDS®)*, January 2010.

Contech Engineered Solutions, 2014, *NJCAT Technology Verification – High Efficiency Continuous Deflective Separator (CDS®) Stormwater Treatment Device*, September 2014.

Contech Stormwater Solutions, 2007, *Contech Engineered Solutions, 2014, NJCAT Technology Verification – High Efficiency Continuous Deflective Separator (CDS®) Stormwater Treatment Device*, September 2014, June 2007.

Contech Engineering Solutions, 2016, *Filterra® Performance Over Time*.

Davis, A.P., 2007. *Field performance of bioretention: water quality*. Environ. Eng. Sci. 24, 1048e1064.

Department of Infrastructure, Local Government and Planning, 2017, *State Planning Policy*. Queensland Government.

Dalrymple B, Wicks M, Jones W, Allingham B, 2021, *"Gully pit inserts" shown to reduce pollutants in stormwater*, Australian Water Association Water e-Journal, Vol 6, No.1.

Dalrymple B, Wicks M, Jones W, Allingham B, 2022, Biofiltration's effect on removing pollutants in stormwater, Australian Water Association Water e-Journal, Vol 7, No.2.

DesignFlow, 2015, *Development Application Requirements and Performance Protocol for Proprietary Devices on the Gold Coast*, February 2015, Internal report.

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

eWater, 2014, *MUSIC by eWater User Manual*.

Greenway, M., Le Muth, M., and Jenkins, G., 2002. *Monitoring spatial and temporal change in stormwater quality through a series of treatment trains: a case study – Golden Pond, Brisbane, Australia*. In: 9th International conference on urban drainage, 8–12 September 2002, Portland, Oregon.

Hatt B E, Fletcher T D, Deletic A, 2009, *Hydrologic and pollutant removal performance of stormwater biofiltration systems at the field scale*, Journal of Hydrology.

Healthy Land and Water, 2018, *MUSIC Modelling Guidelines (Consultation Draft)*, Healthy Land and Water Limited, Brisbane, Queensland.

Herngren L, Wolfgramm B, Powell M, 2007, *Fine sediment removal using a continuous deflective separation unit*, International Conference on Water Sensitive Urban Design, Sydney, NSW.

Herrera Environmental Consultants. 2014. *Technical Evaluation Report – Filterra® System Phosphorus Treatment and Supplemental Basic Treatment Performance Monitoring*. Prepared for Americast Inc.

Hoffman E J, Latimer J S, Mills G L, Quinn J G, 1982, *Petroleum Hydrocarbons in Urban Runoff from a Commercial Land Use Area*, Journal (Water Pollution Control Federation), November 1982, Vol 54, No 11, pp. 1517-1525 Melbourne Water (2018). MUSIC Guideline – Recommended input parameters and modelling approaches for MUSIC users in Melbourne Water's service area.

Howie D C, Milesi P E C, 2024, *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies Technology Assessment Protocol - Ecology (TAPE)*, For the Water Quality Program – Washington State Department of Ecology Olympia, Washington.

Hunt, W., Jarrett, A. R., Smith, J. T., & Sharkey, L. J. 2006. *Evaluating Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina*. Journal of Irrigation and Drainage Engineering, 2006, 132(6), 600-608.

Johnson J P, Hunt W F, 2019, *A Retrospective Comparison of Water Quality Treatment in a Bioretention Cell 16 Years Following Initial Analysis*, Journal of Sustainability.

Neumann, L N, Sharma A, 2010, *Literature Review on Performance Testing Approaches for Gross Pollutant Traps*. CSIRO: Water for a Healthy Country National Research Flagship.

Ocean Protect. 2024, *OceanSave® Operation and Maintenance Manual*.

Parker, N. 2010. *Assessing the Effectiveness of Water Sensitive Urban Design in Southeast Queensland*. Thesis submitted towards Masters of Engineering. Queensland University of Technology.

Roberts S J, Fletcher T D, Garnett L, Deletic A, 2012, *Bioretention saturated zones: do they work at the large-scale?* WSUD 2012 Conference, Melbourne, Australia.

Smolek A P, Anderson A R, Hunt W F. 2018. *Hydrologic and Water-Quality Evaluation of a Rapid-Flow Biofiltration Device*. Journal of Environmental Engineering 144(2), February 2018.

Shaw L Y, Stanford R S, 2006, *Field Evaluation of the Filterra® Stormwater Bioretention Filtration System*, submitted to Filterra Division of Americast Inc, University of Virginia.

State of Washington Department of Ecology Emerging stormwater treatment technologies (TAPE), https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies

State of Washington Department of Ecology Emerging stormwater treatment technologies (2018), *General Use Level Designation for Pre-treatment (TSS) for Contech Engineered Solutions CDS® System*.

Stormwater NSW, 2020, *Guidelines for the maintenance of stormwater treatment measures*.

Strynchuck J, Royal J, England G, 2000, *Using a CDS Unit for Sediment Control in Brevard County, Florida*, Joint Conference on Water Resource Engineering and Water Resources Planning and Management 2000.

Taylor G D, Fletcher T D, Wong T H F, Breen P F, Duncan H P, 2005, *Nitrogen Composition in Urban Runoff – Implications for Stormwater Management*. Water Research, Vol 39, pp 1982-1989.

Walker T A, Allison R A, Wong T H F, Wootton R M, 1999, *Removal of suspended solids and associated pollutants by a CDS gross pollutant trap*, Report 99/2, February 1999, Cooperative Research Centre for Catchment Hydrology.