CRC for
Water Sensitive Cities

Protecting our catchments using water sensitive urban design: learnings from high groundwater case studies.

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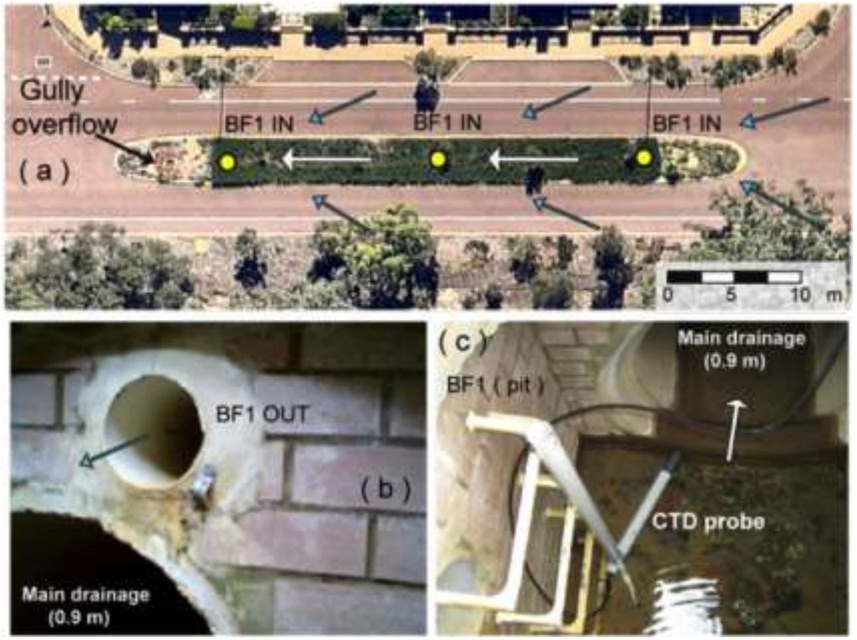
An Australian Government Initiative

CRC AUSTRALIA

The Glades, Byford

- 15.3 ha residential development
- Duplex soils, seasonally high groundwater that incorporates perched water into continuous saturated soil column.
- Biofilters (raingarden and bioretention basin) completed in 2010
- Gingin loam used as media, with underlying slotted sub-soil pipe.
- Raingardens collect and treat surface runoff from impervious areas (BF1).
- Raingardens and catchment drain into bioretention basin (BF4).

The raingarden



- Size: 40 m x 4.5 m x 0.55 m
- Storage volume: 24 m^3
- Catchment: 0.21 ha
- Filter media: Red Gingin loam
- Outlet: gully overflow + slotted sub-surface

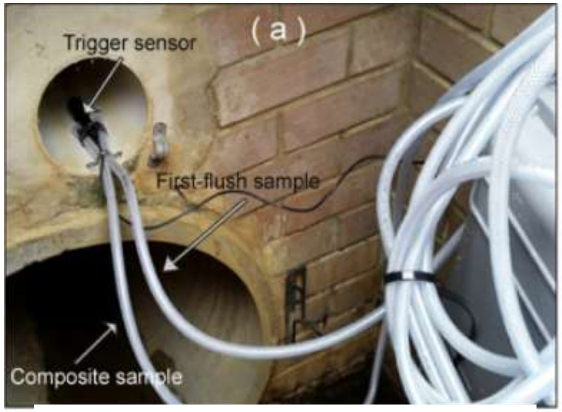
The bioretention basin

- Size: 0.35 m deep, 1200 m^2 surface area
- Storage volume: 370 m^3
- Catchment: 8.7 ha, 27% impervious
- Filter media: Red Gingin loam
- Outlet: Spillway + slotted sub-surface

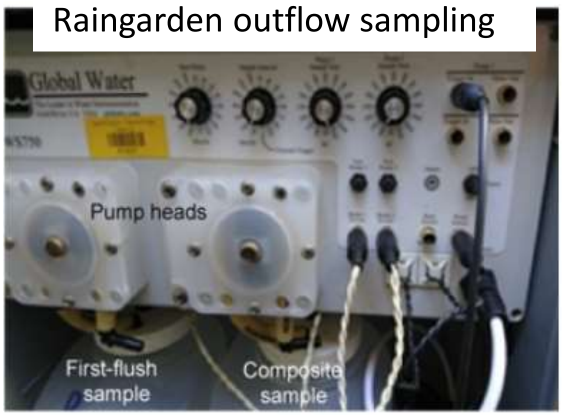
Water balance monitoring

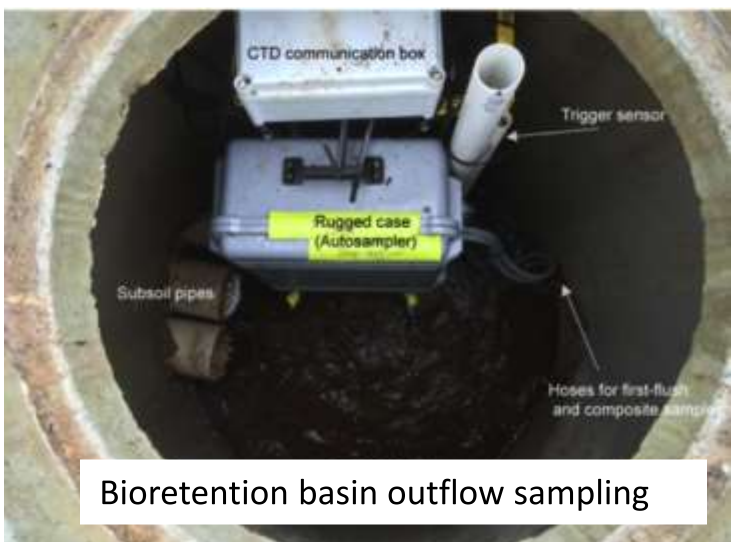
- Monitoring inflows and outflows, <u>during events</u>
- Water level sensors, CTD probes, cameras

Nutrient monitoring



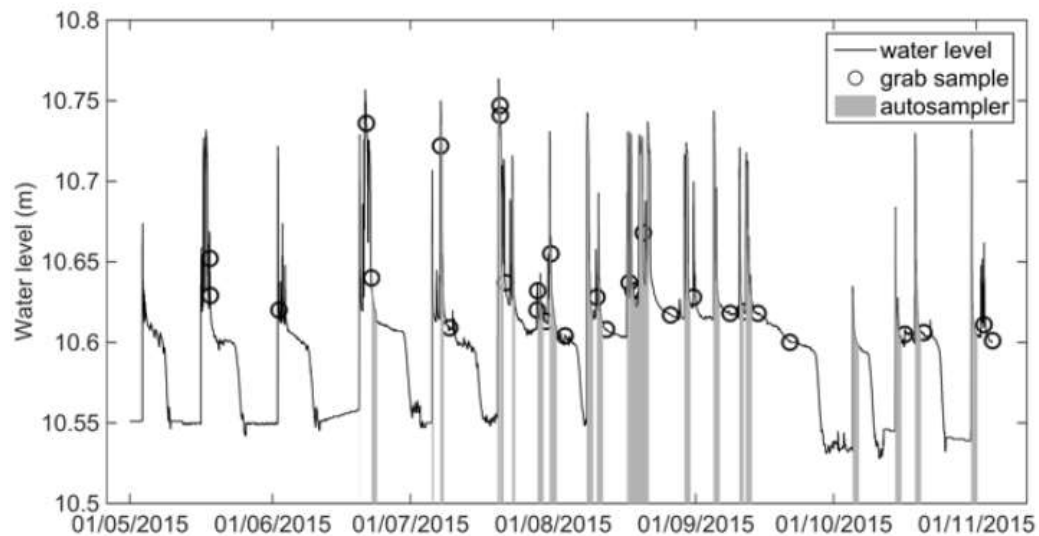
Raingarden outflow sampling





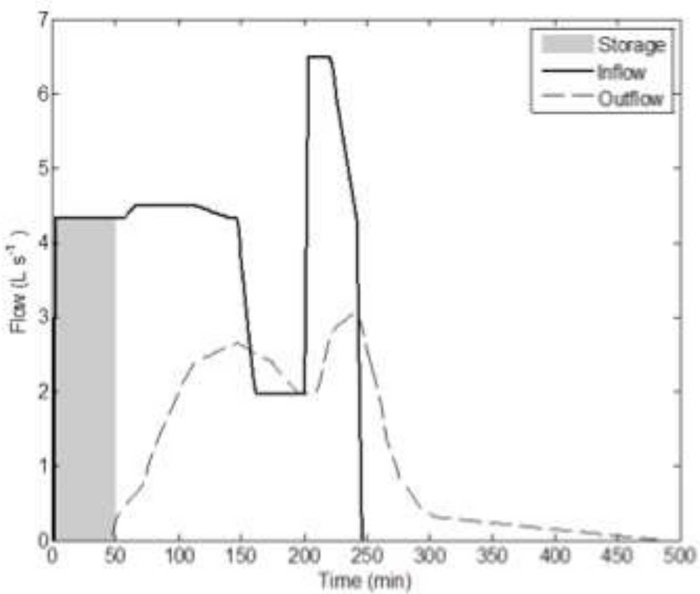
Bioretention basin outflow sampling

- Grab sampling
- Autosampling of some storms events, triggered by flows



Bioretention basin event sampling

150 min: 4.3 L/s
45 min: 2 L/s
45 min: 6.5 L/s



Raingarden dosing trial

60 m^3 in total applied

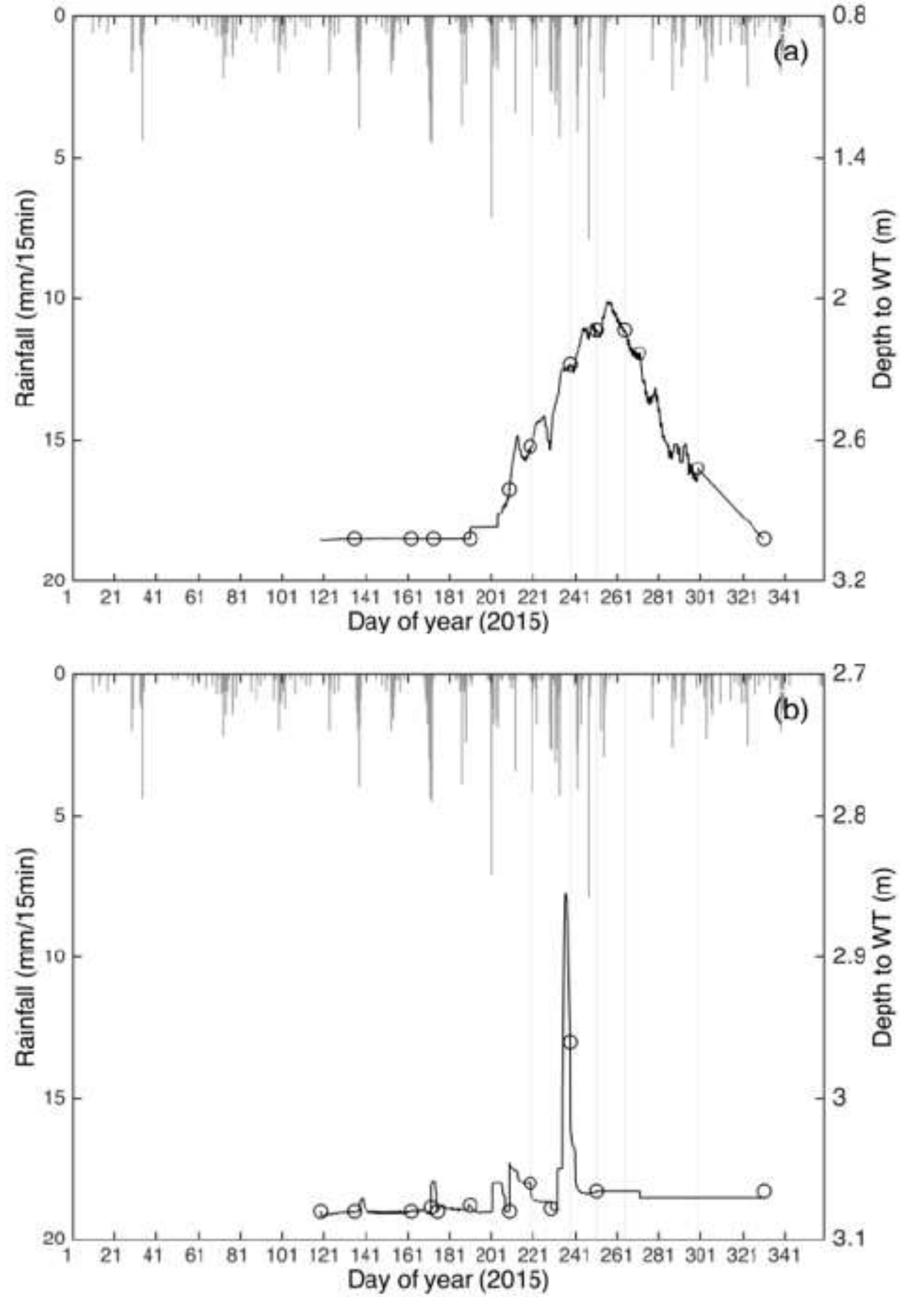
~10% exfiltration to surrounding soils
~45% evaporation and biological use
~45% through media to outflow

13 m^3 required to generate outflow
19 m^3 required to wet up raingarden
31 m^3 required to generate surface gully overflow.

Water table dynamics

Groundwater levels monitored in two locations.

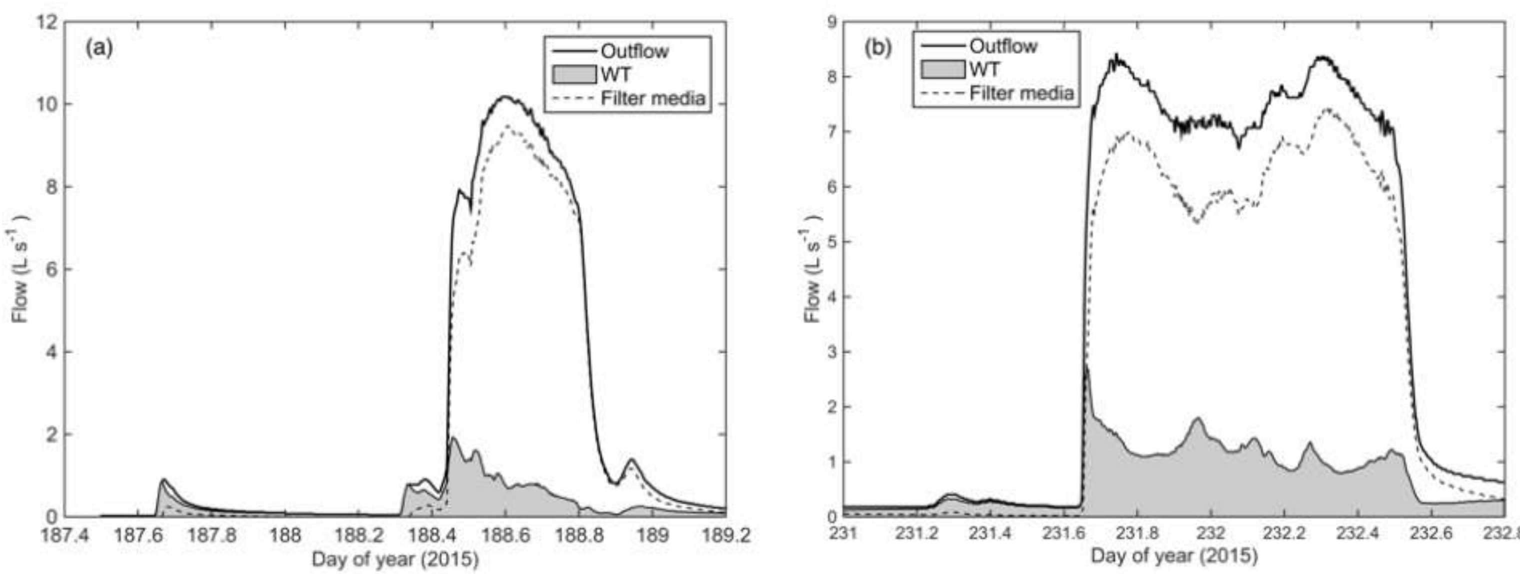
Water table levels varied 0.3 – 0.8 m over the year.

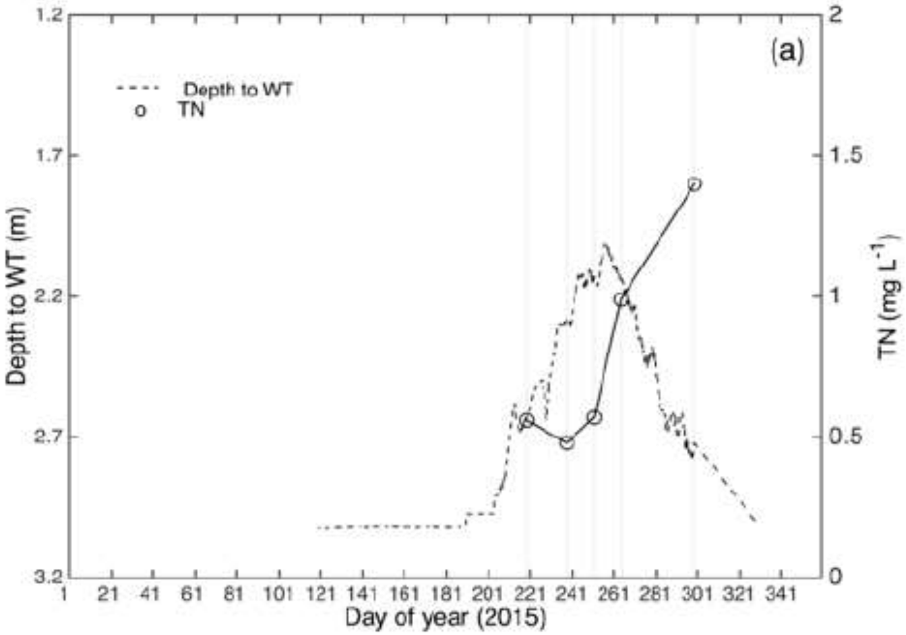


Chemical hydrograph separation of storm events

Using conductivity as a tracer of groundwater inflows.

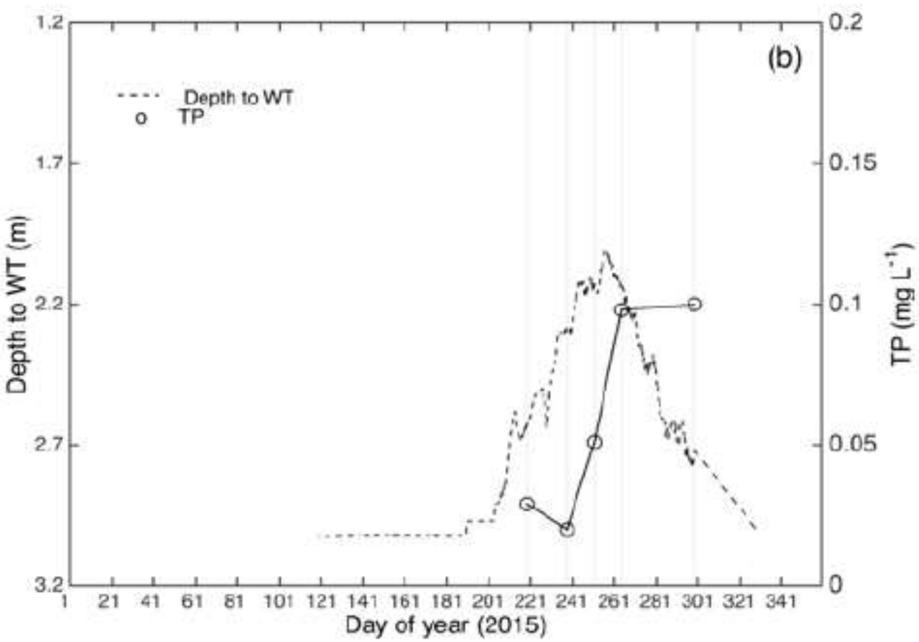
Large difference in groundwater contribution from early to late in season.





Groundwater nutrient dynamics

Both TN and TP increase with water table rise.



Raingarden flood attenuation

Event flow reduction in raingardens was excellent.
Average across monitored storm events 89%
Major events: ~30% volume retention

Table 8: Hydrologic performance of the raingarden (BF1) for events with corresponding water quality data.

Event	Inflow [L]	Outflow [L]	Retention [%]	Peak Inflow [L/s]	Peak Outflow [L/s]	Peak Flow Reduction [%]
17/5/15	37758	28832	24	14.7	2.1	86
19/6/15	84775	43813	48	15.2	3.1	80
20/7/15	83333	51658	38	22.7	4.1	82
31/7/15	13349	1416	89	8.8	0.5	95
17/8/15	27992	2424	91	11.0	0.7	93
19/8/15	21461	3326	85	7.7	0.8	90
20/8/15	27841	12045	57	9.7	1.3	87
30/8/15	20162	3051	85	10.0	0.6	94
10/9/15	15772	182	99	3.1	0.1	98

Bioretention basin flood attenuation

Event flow reduction in bioretention basin as designed.
Peak flow reduction 60 - 80%
Major events: No significant volume reduction

Event	Inflow [L]	Outflow [L]	Retention [%]	Peak Inflow [L/s]	Peak Outflow [L/s]	Peak Flow Reduction [%]
21/06/15	1166424	1071508	8	53.35	10.59	80
6/07/15	370491	332293	10	38.96	10.17	74
20/07/15	244773	206990	15	27.76	6.77	76
31/07/15	236370	171200	28	30.48	8.62	72
8/08/15	425907	360057	15	48.61	9.63	80
10/08/15	65840	47348	28	15.14	4.48	70
17/08/15	535227	424808	21	47.62	8.61	82
19/08/15	1193070	1136125	5	61.6	9.12	85
4/09/15	402166	333474	17	188	9.73	95
11/09/15	364788	254822	30	18.67	7.3	61
18/10/15	239255	120522	50	33.85	8.54	75

Nutrient attenuation

DEFINE PERFORMANCE

- Do WSUD elements reduce nutrient concentrations to below ANZECC Guideline values?

  "**nutrient concentration reduction**"

- Do WSUD elements attenuate nutrient load (mass of nutrients)? By how much?

  "**nutrient load attenuation**"

Raingarden: nutrient concentration reduction

Event		TP [mg/L]	TN [mg/L]	FRP [mg/L]	NOx-N [mg/L]	NH_3-N [mg/L]	DOrgN [mg/L]	TSS [mg/L]
ANZECC		0.03	0.75	0.005	0.045	0.04*	n/a	n/a
17/5/15	Inflow	0.230	2.350	0.047	0.615	0.295	0.620	39
	Outflow	0.025	0.440	0.005	0.180	0.012	0.240	7
19/6/15	Inflow	0.096	0.525	0.018	0.020	0.025	0.138	335
	Outflow	0.019	0.320	0.011	0.110	0.017	0.190	2
20/7/15	Inflow	0.210	1.200	0.018	0.045	0.053	0.170	216
	Outflow	0.036	0.640	0.009	0.330	0.013	0.150	5
31/7/15	Inflow	0.430	2.400	0.025	0.030	0.018	0.420	451
	Outflow	0.028	0.400	0.002	0.240	0.005	0.086	4
17/8/15	Inflow	0.098	0.550	0.002	0.067	0.005	0.160	62
	Outflow	0.028	0.440	0.005	0.240	0.015	0.140	2
19/8/15	Inflow	0.190	0.930	0.007	0.014	0.005	0.085	190
	Outflow	0.027	0.280	0.006	0.170	0.005	0.110	3
20/8/15	Inflow	0.120	0.530	0.002	0.012	0.005	0.110	120
	Outflow	0.021	0.200	0.006	0.100	0.005	0.087	1
30/8/15	Inflow	0.042	0.310	0.002	0.019	0.017	0.110	28
	Outflow	0.019	0.420	0.002	0.250	0.017	0.140	1
10/9/15	Inflow	0.245	1.340	0.006	0.030	0.005	0.185	148
	Outflow	0.014	0.270	0.002	0.130	0.005	0.130	1

** Corresponds to un-ionised ammonia-N at 20°C.*

Outflow TP, FRP and TN, NH4 almost always below ANZECC

Outflow NOx and DON typically higher in outflow than inflow

Strong decrease in TSS

Bioretention basin: nutrient concentration reduction

Table 14: Mean concentrations for the bioretention basin (BF4) for individual events. ANZECC Guidelines (for estuarine protection) are given for nutrients. Numbers in red represent concentration values exceeding the guidelines.

Event		TP [mg/L]	TN [mg/L]	FRP [mg/L]	NOx-N [mg/L]	NH_3-N [mg/L]	DOrgN [mg/L]
ANZECC		0.03	0.75	0.005	0.045	0.04*	n/a
21/06/15	Inflow	0.023	0.585	0.014	0.360	0.023	0.150
	Outflow	0.032	0.497	0.017	0.309	0.009	0.170
6/07/15	Inflow	0.037	0.230	0.013	0.101	0.046	0.038
	Outflow	0.033	0.660	0.006	0.318	0.021	0.285
20/07/15	Inflow	0.025	0.510	0.009	0.380	0.011	N/A
	Outflow	0.024	0.240	0.010	0.140	0.005	N/A
31/07/15	Inflow	0.019	0.470	0.007	0.420	0.005	0.012
	Outflow	0.015	0.540	0.006	0.440	0.005	0.090
17/08/15	Inflow	0.016	0.863	0.009	0.556	0.013	0.131
	Outflow	0.017	0.746	0.006	0.493	0.005	0.245
19/08/15	Inflow	0.035	1.152	0.006	0.675	0.018	0.300
	Outflow	0.022	0.480	0.007	0.350	0.020	0.101
4/09/15	Inflow	0.018	**1.100**	0.002	0.870	0.005	0.220
	Outflow	0.007	**1.100**	0.002	0.830	0.039	0.180
11/09/15	Inflow	0.014	1.360	0.004	1.090	0.031	0.207
	Outflow	0.010	0.800	0.002	0.560	0.016	0.200
18/10/15	Inflow	0.010	0.520	0.005	0.380	0.005	0.130
	Outflow	0.015	**1.100**	0.002	0.700	0.005	0.370

** Corresponds to un-ionised ammonia-N at 20°C.*

Outflow TP, FRP only slightly lower than inflow.

Outflow TN, NOx and DON sometimes higher in outflow than inflow, especially toward end of season.

Outflow TN, NOx and DON generally higher than outflow from raingarden

Nutrient load attenuation - raingardens

Table 12: Load attenuation for each event at the raingarden (BF1).

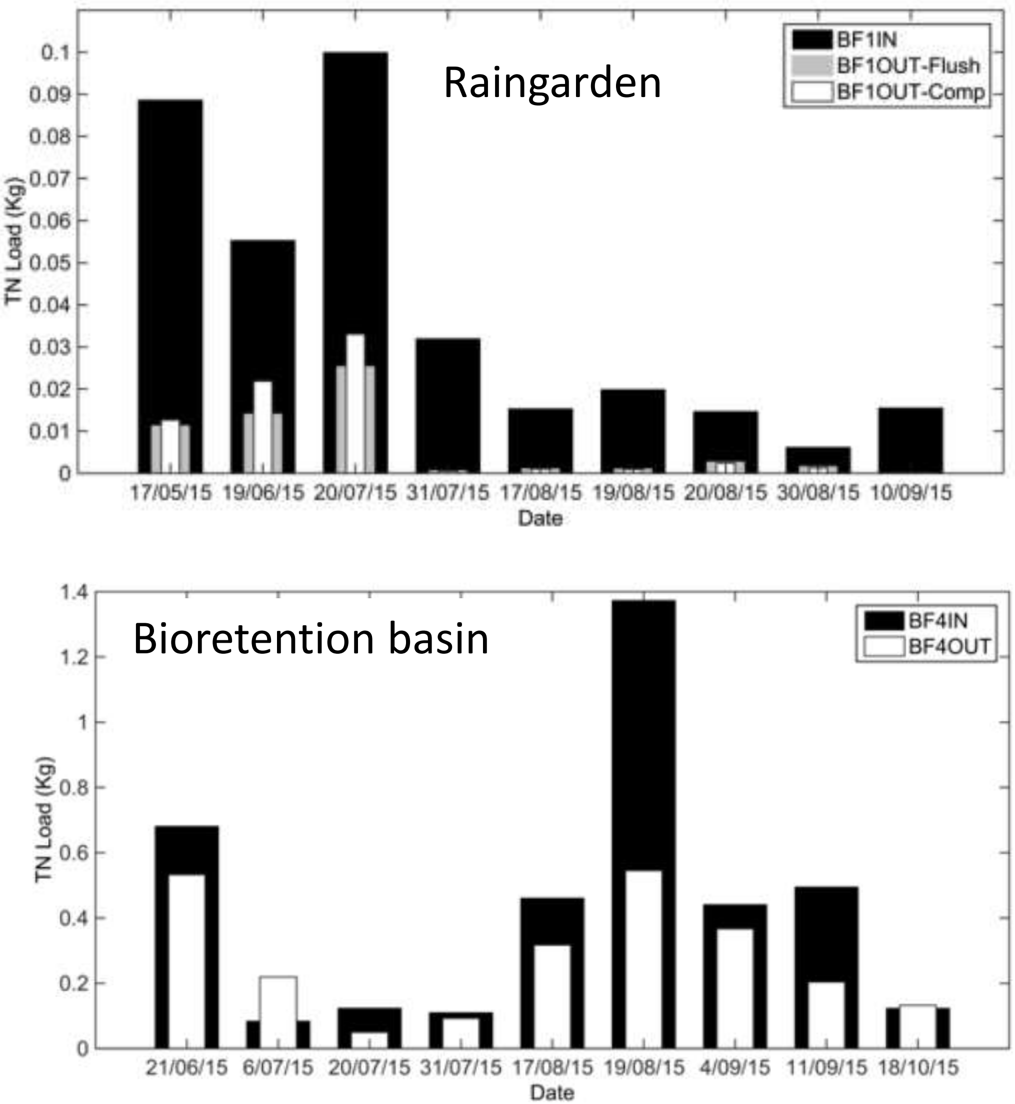
Event data	Inflow [L]	Outflow [L]	TP [%]	TN [%]	FRP [%]	NOx-N [%]	NH_3-N [%]	DOrgN [%]	TSS [%]
17/5/15	37758	28832	92	86	92	78	97	70	86
19/6/15	84775	43813	90	68	68	-184	65	29	100
20/7/15	83333	51658	89	67	69	-355	85	45	99
31/7/15	13349	1416	99	98	99	15	97	98	100
17/8/15	27992	2424	98	93	83	69	74	92	100
19/8/15	21461	3326	98	95	87	-88	85	80	100
20/8/15	27841	12045	92	84	-30	-261	57	66	100
30/8/15	20162	3051	93	79	85	-99	85	81	99
10/9/15	15772	182	100	100	100	95	99	99	100
		Average	**95**	**86**	**72**	**-81**	**83**	**73**	**98**

Nutrient load attenuation – bioretention basin

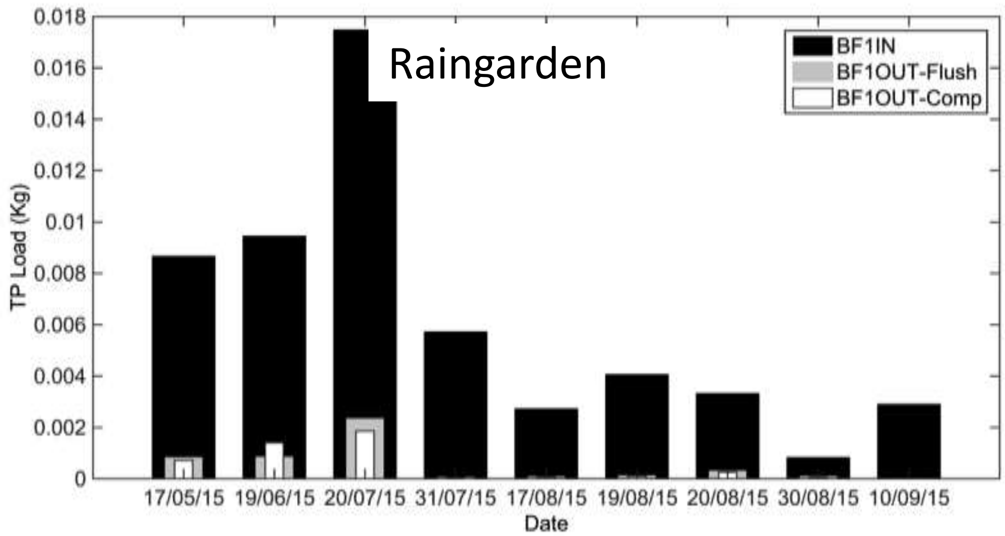
Table 15: Load attenuation for each event at the bioretention basin (BF4).

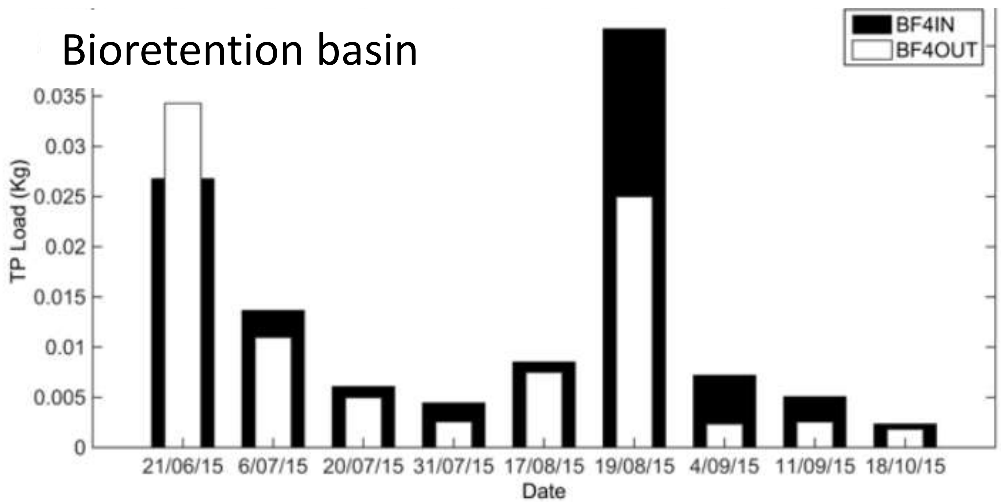
Event data	Inflow [L]	Outflow [L]	Load attenuation [%] TP [%]	FRP [%]	TN [%]	NOx-N [%]	NH_3-N [%]	DOrgN [%]
21/06/15	1166424	1071508	-28	-6	22	21	63	-4
6/07/15	370491	332293	20	57	-157	-181	59	-573
20/07/15	244773	206990	19	6	60	69	62	N/A
31/07/15	236370	171200	43	38	17	24	28	-421
17/08/15	535227	424808	14	43	31	30	69	-48
19/08/15	1193070	1136125	47	-1	66	58	9	73
4/09/15	402166	333474	47	17	17	21	-547	32
11/09/15	364788	254822	50	58	59	64	64	33
18/10/15	239255	120522	24	75	-7	7	50	-43
Average			**33**	**42**	**39**	**37**	**50**	**46**

TN load attenuation

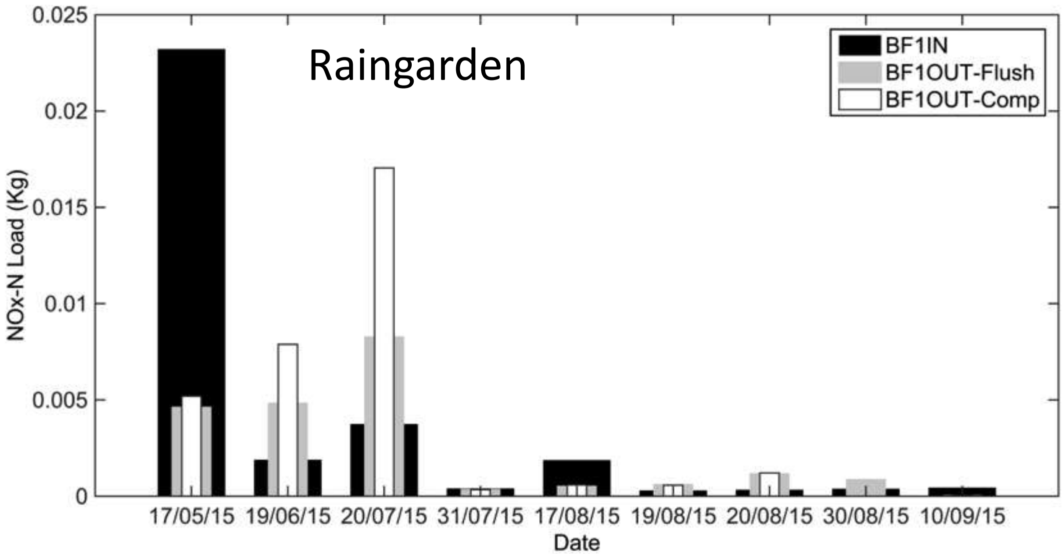


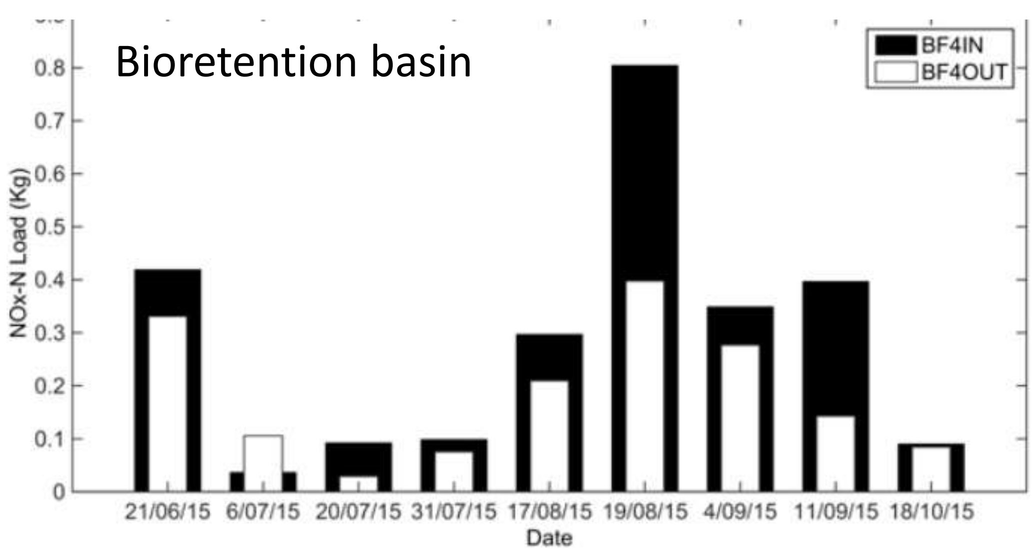
TP load attenuation





NOx load attenuation





The raingarden

- The raingarden was very effective at attenuating stormflows.

- The raingarden attenuated TP and TN concentrations to below ANZECC guidelines. Dissolved fractions were more variable with storms events

- The raingarden attenuated TP and TN loads: up to 90% reduction in TP, 85% reduction in TN, NOx not being attenuated (probably due to unsaturated and oxic media).

The bioretention basin

- Strong seasonality related to the interception of the groundwater around August - contributed up to 20% of the outflows.

- Overall TN and TP nutrient load attenuation was reasonable, but 30-40% lower than the raingarden.
- DON concentrations were higher at the outflow than the inflow, and at times the basin was discharging significant loads of DON.

N versus P attenuation

- The raingarden attenuated P loads more consistently than N loads.

- Both systems were well oxygenated and the filter media attenuated FRP loads.

- While TN loads were on average attenuated, there was variability across the year with periods of poor attenuation of NOx-N
  - likely due to the oxic conditions that were maintained in the filter media.
  - maintained by the short travel times of subsurface drain inflows.

Conclusions

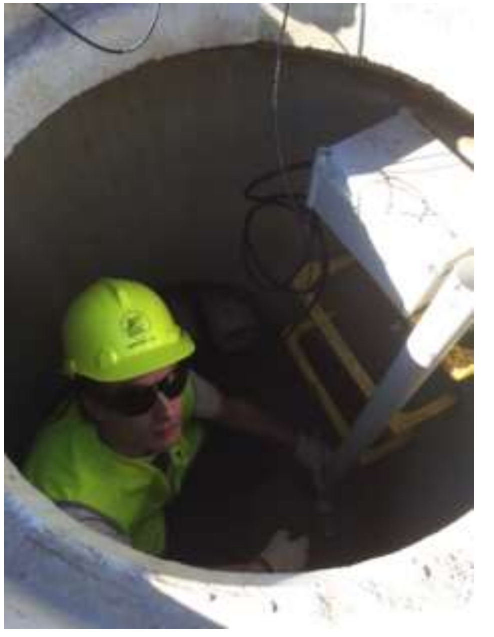
- Oxic conditions in media during the summer season.

- Winter rains and higher groundwater may increase soil saturation, however the high soil permeability, rapid subsurface travel times (subsurface drainage) inject oxygen into the system.

- Redox conditions have a profound impact on P and N attenuation
  - P is attenuated effectively under oxic conditons while N is not.

- There will always be challenges to maintain the optimal redox conditions for N and P attenuation.

Recommendations



- Adopt a treatment train approach to provide a range of redox conditions for nutrient attenuation.
- Design to maximize the travel time of subsurface flows
  - across the catchment,
  - through the filter media.
- Smaller biofilters throughout the catchment
  - enhance infiltration,
  - increase subsurface travel times
  - increase the likelihood of nutrient attenuation.
- Alternate surface and subsurface flowpaths across the catchment => range of redox conditions.

watersensitivecities.org.au/content/project-b2-4-3/

=> Technical Reports