

Waterway health and stormwater management at Jamison Creek, Blue Mountains

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Key Points

- Jamison Creek is a high-value waterway in the Blue Mountains that is threatened by urban runoff
- Crayfish and other macroinvertebrates recovered well from a deadly pesticide spill at the creek
- Long-term water quality and aquatic macroinvertebrate data suggests ongoing disturbance-recovery cycles
- Blue Mountains City Council and WaterNSW built twelve stormwater biofiltration systems to remove pollutants and increase groundwater recharge

Abstract

Blue Mountains City Council and WaterNSW rate Jamison Creek in Wentworth Falls as a high-priority subcatchment for stormwater management, recognising the waterway's many environmental, cultural and social values and the threats posed to the creek by urban runoff. This vulnerability was highlighted in 2012, when a stormwater-borne pesticide killed over a thousand Giant Spiny Crayfish and many thousands of other invertebrates.

Recovery of crayfish and the wider macroinvertebrate community has been remarkable, however many threats to the creek remain. Council's regular monitoring of water quality and aquatic macroinvertebrates from 2008 to 2020 produced variable results, with evidence of ongoing disturbance-recovery cycles at the three creek sites sampled. In addition to pollution during this period, a drought and a major flood have also impacted the creek.

The Jamison Catchment Streets to Creeks Project (2015-2019) worked to protect Wentworth Falls Lake and Jamison Creek from stormwater. With funding from WaterNSW, council constructed twelve stormwater biofiltration systems, to remove pollutants and increase groundwater recharge.

While the biofilters are achieving promising site-by-site results, on their own they don't constitute a whole-of-catchment solution. For genuine transformation, additional holistic approaches are needed, in line with council's Water Sensitive Blue Mountains Strategic Plan. A high priority is to harvest and use stormwater and rainwater on private and public properties, effectively reducing impervious area, while providing a suite of community benefits.

Keywords

Urban streams, stormwater biofiltration, aquatic macroinvertebrates, water quality, water sensitive catchments, freshwater crayfish, pesticides.

Introduction

Jamison Creek rises in a semi-urban catchment, feeding Wentworth Falls Lake, flowing through the town of Wentworth Falls, plunging hundreds of metres over the escarpment at the eponymous waterfall and running on into the Blue Mountains World Heritage Area and Sydney's drinking water supply at Lake Burragorang (Warragamba Dam).

The creek and associated swamps have helped sustain countless generations of Gundungurra and Dharug people, who in turn have cared for Ngurra (Country) and the myriad beings, elements, stories and ceremonies that are part of the Blue Mountains. The Jamison catchment supports an Endangered Ecological Community (Blue Mountains Swamps) and several endangered species including the Blue Mountains Water Skink, the Giant Dragonfly and the Dwarf Mountain Pine. The creek and lake provide for aquatic biodiversity, there are high levels of coordinated community involvement (including multiple Bushcare groups and the Jamison Creek Catchment Working Group) and the Charles Darwin Walk and Wentworth Falls waterfall serve as iconic Blue Mountains tourist destinations at the interface with the World Heritage Area.

However, urban stormwater threatens the values of Jamison Creek, with altered hydrology and pollution of particular concern. WaterNSW's Pollution Source Assessment Tool flagged Jamison Creek as a high risk drainage unit (within the urban stormwater module) for phosphorus, nitrogen and suspended solids (Scott and Chafer, 2018). Blue Mountains City Council's Catchment Classification Method identified Jamison Creek as one of eleven subcatchments across the Local Government Area (LGA) requiring 'active management' to mitigate high risks to waterway health (BMCC, 2019b). The International Union for the Conservation of Nature recognised urban runoff as a 'high threat' to the swamps and waterways of the Greater Blue Mountains World Heritage Area, which contributed to the recent upgrading of the area's conservation risk rating to 'significant concern' (IUCN, 2020).

Jamison Creek's vulnerability to urban runoff was highlighted in 2012, when a stormwater-borne pesticide (bifenthrin) killed over a thousand of the creek's Giant Spiny Crayfish (*Euastacus spinifer*) and many thousands of other aquatic macroinvertebrates (St Lawrence *et al*, 2014). Recovery of crayfish and the wider macroinvertebrate community has been remarkable, however many threats to the creek remain. A 2017 study of creek sediments by council and Melbourne University found elevated levels of pesticides, metals and hydrocarbons in Jamison Creek due to ongoing stormwater pollution (Sharp, Myers and Sharley, 2018).

Council's regular monitoring of water quality and aquatic macroinvertebrates from 2008 to 2020 produced variable results, with evidence of ongoing disturbance-recovery cycles at the three creek sites sampled. In addition to pollution during this period, a drought and a major flood have also impacted the creek.

Water sensitive retrofitting of an already developed catchment is challenging, yet council and partners have made substantial progress since the last Australian Stream Management Conference paper on Jamison Creek (St Lawrence *et al*, 2014). Twelve stormwater biofilters were built as part of the Jamison Catchment Streets to Creeks Project (2015-2019), a joint council and WaterNSW initiative to remove pollutants and increase groundwater recharge (BMCC, 2020). At a broader level, council has adopted the Water Sensitive Blue Mountains Strategic Plan, which aims to integrate water management across the Local Government Area (BMCC, 2019b).

This paper summarises waterway health monitoring results for Jamison Creek, outlines the stormwater management actions taken to date and touches on future management priorities.

Waterway health at Jamison Creek

Blue Mountains City Council and partners conduct regular aquatic monitoring at Jamison Creek, including water quality and aquatic macroinvertebrate sampling and freshwater crayfish surveys. Figure 1 maps monitoring sites and stormwater treatment sites discussed in this paper.

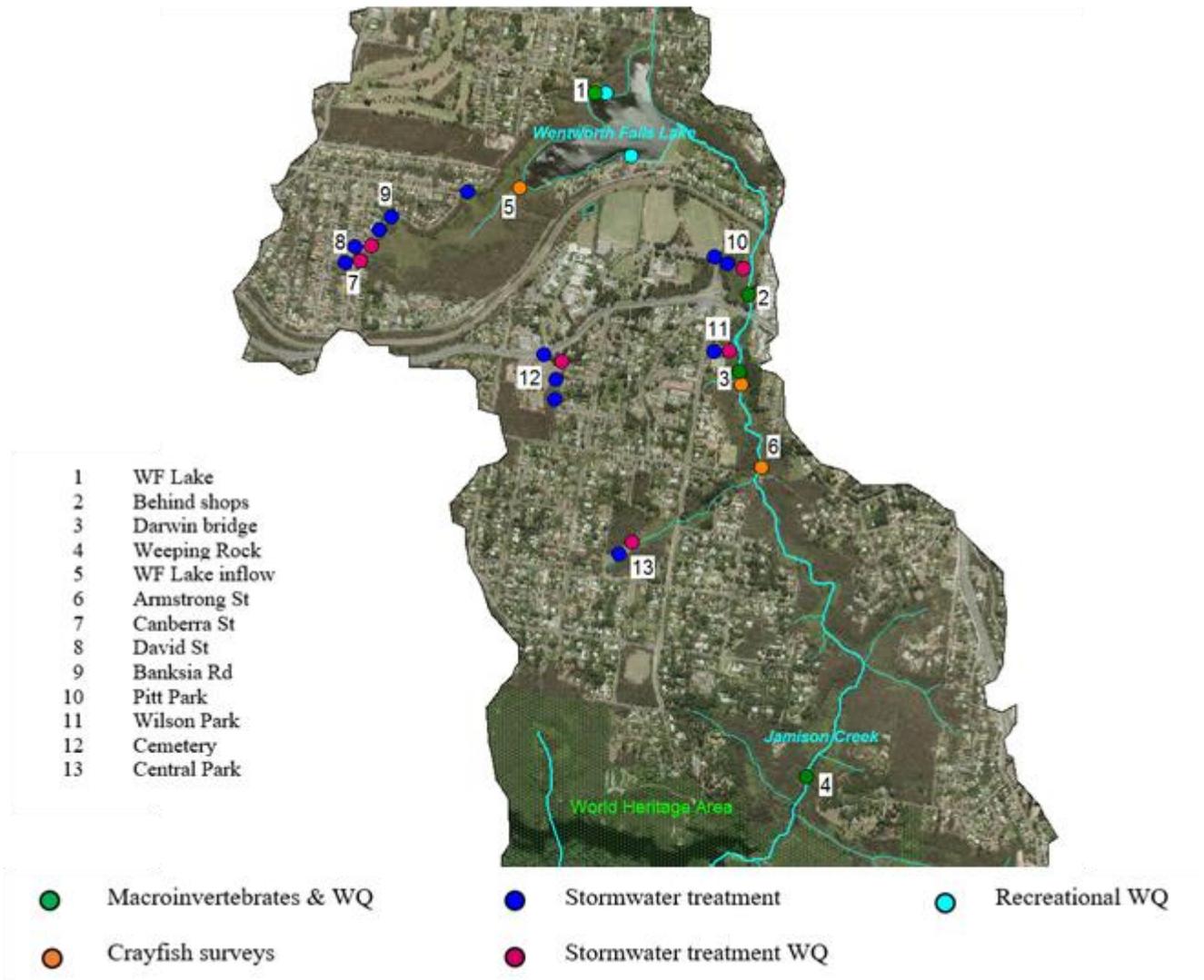


Figure 1: aquatic monitoring and stormwater treatment sites in the Jamison Creek catchment

Water quality

Council staff sampled water quality at three Jamison Creek sites and one Wentworth Falls Lake site during macroinvertebrate surveys (2008-2020), using a portable multiparameter water quality probe and a range of test kits (for full methods see BMCC, 2018; BMCC, 2019a).

Summary results are presented along with local desirable ranges in table 1. Water quality at each site was variable, with means generally representing good to fair water quality, notwithstanding some exceedances of local trigger values for electrical conductivity, alkalinity, faecal coliforms, dissolved oxygen and nitrate-nitrogen (BMCC, 2018; ANZECC, 2000).

Council’s weekly summer recreational water quality monitoring at two Wentworth Falls Lake sites indicates that microbial water quality is suitable for swimming most of the time (Beachwatch, 2019).

Table 1: Summary of water quality at Jamison Creek and Wentworth Falls Lake

Parameter*	WF Lake Mean (n) Min-Max	Behind Shops Mean (n) Min-Max	Darwin Bridge Mean (n) Min-Max	Weeping Rock Mean (n) Min-Max	Local desirable range [#]
Temperature (°C)	18.2 (54) 11.1-28.7	13.4 (36) 8.9-18.6	13.2 (36) 8.5-18.8	11.7 (38) 6.8-19.6	n/a**
pH	6.8 (55) 6.0-8.0	6.5 (36) 5.9-7.8	6.5 (35) 6.0-7.0	6.8 (35) 5.7-7.7	4.4-7.2
Turbidity (NTU)	3.9 (43) 0.0-19.0	7.6 (30) 0.0-28.9	6.5 (30) 0.0-26.8	3.3 (31) 0.0-8.6	<12.3
Dissolved oxygen (% sat)	85.9 (52) 64.8-114.5	61.1 ^{##} (33) 46.5-105.6	85.2 (33) 54.5-101.8	96.3 (34) 84.9-107.1	63.3-100.4
Electrical conductivity (us/cm)	54.2 (53) 36.0-178.0	81.3 (36) 49.0-121.0	88.5 (36) 57.0-121.0	72.3 (37) 51.0-194.0	<65
Alkalinity (mg/L)	9.3 (21) 4.0-20.0	23.8 (10) 9.0-38.0	18.6 (13) 8.0-36.0	13.4 (13) 6.0-33.0	<10.9
Available phosphate (mg/L)	0.08 (18) 0.0-0.41	0.0 (11) 0.0-0.0	0.02 (10) 0.0-0.05	0.06 (13) 0.0-0.44	n/a
Nitrate-N (mg/L)	0.08 (18) 0.0-0.22	0.19 (11) 0.0-1.46	0.18 (10) 0.11-0.32	0.43 (13) 0.3-0.76	<0.22
Faecal coliforms (CFU/100ml)	228.8 (17) 0-3600	45.5 (11) 0-180	50.7 (14) 0-150	206.7 (15) 0-2600	<20
* water quality measurements taken during aquatic macroinvertebrate surveys, 2008-2020					
[#] Local desirable range values derived from Blue Mts reference site 95 th /5 th percentile values (2010-2015).					
** n/a = not available; ^{##} highlighted figures represent mean exceedances of local trigger values.					

Aquatic macroinvertebrates

Between 2008 and 2020, council staff sampled aquatic macroinvertebrates at a total of three Jamison creek sites and one Wentworth Falls Lake site (initially at one creek and one lake site). Sampling intensified following the bifenthrin contamination incident in 2012, then settled into routine spring and autumn sampling at the four sites from 2016-2020. Sampling of macroinvertebrates was performed using the AUSRIVAS protocol for collecting and processing samples in New South Wales (NSW) (DEC, 2004). Two staff “live picked” samples on site for 40-60 minutes per sample per site, identifying to family level, recording and releasing where possible and preserving in ethanol those specimens requiring laboratory (binocular stereoscope) identification with the aid of family level scientific keys (Gooderham and Tsyrlin, 2002; The Waterbug Company, 2016; Murray-Darling Freshwater Research Centre, 2020). For more detailed methods see BMCC, 2018.

Council used four biotic indices to score waterway health (BMCC, 2018): SIGNAL-SF (a ‘sensitivity’ score, see Chessman 2001); number of aquatic macroinvertebrate families present; number of mayfly/stonefly/caddisfly families present (# EPT families); and percentage of individual macroinvertebrates recorded that were mayflies, stoneflies or caddisflies (% EPT). Descriptive statistics for macroinvertebrate results are presented in table 2. Two of these sites (Darwin Bridge and Weeping Rock) were impacted by the 2012 bifenthrin incident, while the other two were upstream of the point of impact.

Overall waterway health ratings indicated degraded macroinvertebrate assemblages at the two most ‘urban’ sites, ‘Behind Shops’ and ‘Darwin Bridge’, with both sites generally scoring in the low-mid range of the waterway health scale. The ‘fair’ mean waterway health rating for the Weeping Rock site was due mainly to the influence of samples recorded in the year following bifenthrin contamination, with 85% of 2014-2020 samples recording ‘good’ to ‘excellent’ waterway health ratings. Wentworth Falls Lake consistently scored in the ‘good’ to ‘excellent’ wetland health categories, thought to be aided by the substantial buffer and groundwater inputs provided by the lake’s fringing Upland Swamps (note the lake is scored using a system specific to Blue Mountains wetlands rather than the general Blue Mountains scoring system for flowing streams – BMCC, 2018).

Table 2: summary descriptive statistics for Jamison Creek macroinvertebrate results 2008-2020

Site*	# families	# EPT families	% EPT	SIGNAL-SF	Waterway health score
WF Lake					
Mean (n=27)	10.4	3.3	51.8	6.1	Excellent [#]
Min-max	5.0-15.0	1.0-5.0	5.6-85.3	5.3-6.9	Fair-Excellent
Behind shops					
Mean (n=19)	13.0	2.4	21.3	6.4	Poor
Min-max	7.0-18.0	1.0-5.0	1.6-54.9	5.7-7.1	Poor - Fair
Darwin bridge**					
Mean (n=19)	8.5	1.1	6.4	6.3	Poor
Min-max	1.0-20.0	0.0-2.0	0.0-23.5	5.0-7.8	Very Poor - Fair
Weeping Rock**					
Mean (n=24)	15.0	4.7	39.0	6.9	Fair
Min-max	3.0-24.0	0.0-8.0	0.0-80.7	6.0-7.6	Very Poor - Excellent
*WF Lake sampled 2008-2020; Behind Shops 2012-2020; Darwin Bridge 2012-2020; Weeping Rock 2008-2020.					
**sites affected by bifenthrin pesticide contamination in July 2012 (St Lawrence et al, 2014).					
[#] Wentworth Falls Lake was scored using a separate wetland health rating system (see BMCC, 2018).					

One site, Weeping Rock, has data both pre-and-post bifenthrin contamination. This site is over two kilometres downstream from the point of impact of the pesticide ‘spill’, and yet effects on the macroinvertebrate community following the incident were severe (St Lawrence et al, 2014). To assess ongoing recovery at this site, multivariate analysis (PRIMER software) was used to compare macroinvertebrate assemblages over time. Non-metric multidimensional scaling (nMDS) was performed on a similarity matrix calculated with square-root transformed macroinvertebrate data, using the Bray-Curtis dissimilarity measure. Three categories (‘pre-spill’, ‘spill’ and ‘recovery’) were used to test for macroinvertebrate assemblage differences by one-way analysis of similarity (ANOSIM).

The five samples collected at Weeping Rock in the 7 months following bifenthrin contamination had a modified macroinvertebrate community structure compared to samples from the same site prior to contamination (5 samples Apr2008-Mar2012) and following recovery (14 samples Jul2013-Oct2020). The nMDS plot (figure 2) shows that ‘spill’ samples were distinctly different from ‘pre-spill’ and ‘recovery’ samples, which cluster together, suggesting the macroinvertebrate community has recovered from the incident, with families lost to the pesticide recolonising the site. ANOSIM results (table 3) confirm that ‘spill’ samples are statistically different from both ‘pre-spill’ (R=0.62, significance 0.8%) and ‘recovery’ (R=0.91, significance 0.1%) samples, while no significant difference is apparent between ‘pre-spill’ and ‘recovery’ samples (R=0.23, significance 6.3%).

Table 3. Extent and significance of ecological differences in Weeping Rock macroinvertebrate samples (ANOSIM R statistics and p-values) for pairwise comparisons of pre-spill, spill and recovery samples

Pairwise comparison	R Statistic	Significance level (%)
‘Pre-spill*’ samples vs ‘Spill*’ samples	0.62	0.8
‘Spill’ samples vs ‘Recovery*’ samples	0.91	0.1
‘Pre-spill’ samples vs ‘Recovery’ samples	0.23	6.3
* All samples are from the Weeping Rock site. ‘Pre-spill’ samples were collected Apr2008-Mar2012; ‘Spill’ samples were collected Jul2012-Mar2013; ‘Recovery’ samples were collected Jul2013-Oct2020.		

Similarity Percentages (SIMPER) were calculated to assess the changes in type and abundance of macroinvertebrates contributing to the degraded ecological condition observed in ‘spill’ samples. Gripopterygidae (stonefly) was the most numerically influential family in this analysis, all but disappearing in the five samples following contamination, but just as abundant in recovery samples as it was prior to the bifenthrin incident.

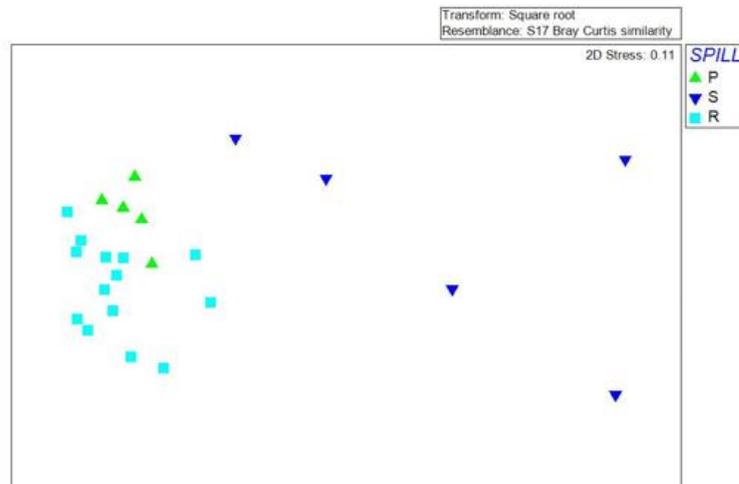


Figure 2: nMDS ordination of Weeping Rock site (Jamison Creek) macroinvertebrate data 2008-2020. Stress = 0.11. Pre-bifenthrin contamination samples are upward green triangles, 'spill' samples from Jul 2012 - Mar 2013 are downward blue triangles and 'recovery' samples from Jul 2013 - Oct 2020 are light blue squares.

Freshwater crayfish surveys

Following the mass crayfish kill caused by bifenthrin contamination at Jamison Creek in 2012 (St Lawrence et al, 2014), council and expert Rob McCormack conducted crayfish surveys at the creek in 2013, 2016, 2017, 2018, 2019 and 2020. Baited traps were used in combination with hand-capture, with all specimens weighed, measured and sexed, eggs counted if present, pit tags implanted in larger individuals and pre-existing tags scanned to track growth, movement and breeding success (see McCormack, 2020 for detailed methods).

Three freshwater crayfish species were recorded during the surveys: two endemic spiny crayfish species (*Euastacus spinifer* and *Euastacus australasiensis*) as well as the invasive yabby *Cherax destructor*. The main trunk of the creek was dominated by *E. spinifer*, while the lake site was dominated by *E. australasiensis* and *C. destructor*.

E. spinifer rapidly recolonised the creek in the year following the pesticide incident; likely this was due to animals migrating to the main trunk of the creek from unaffected tributaries, and it may be that some animals also survived the incident. As the graph in figure 3 illustrates, the spiny crayfish population at Jamison Creek has continued to recover, with a general upward trend in numbers recorded during surveys. Note that the Darwin Bridge and Armstrong St sites were affected by the pesticide, while the lake inflow site was well upstream of the point of impact.

Recapture of tagged crayfish (10 *E. spinifer* recaptured in 2020; first tags deployed 2017) revealed a slow growth rate of 17.7g/year on average (mean recaptured crayfish weight was 170g, a mere 17% of the maximum size for the species - McCormack, 2012). The slow growth and limited sizes observed are thought to be largely due to low water temperatures at the sites, suggesting that the largest crayfish at Jamison Creek may be older than previously thought. Lifespan for *E. spinifer* is not known definitively, but is believed to be up to 40 years (Turvey and Merrick, 1997) and potentially much longer, with the current study intending to contribute to a better understanding of lifespan in the species (McCormack, 2021). Recapture data showed the crayfish had a limited range, moving location very little if at all year to year (McCormack, 2020).

Some potentially concerning factors to monitor (identified by McCormack, 2020) include:

- presence of mature females that have not bred – this could indicate that the creek is already at capacity or may be due to the scarcity of mature males;
- scarcity/absence of large males – this could indicate poaching of the largest crayfish;

- presence of *Cherax destructor* – so far recorded only at Wentworth Falls Lake in diminishing numbers as well as during macroinvertebrate surveys at the Behind Shops and Darwin Bridge sites. The fast growth and rapid breeding capacity of this species make it a threat to the two slow growing spiny crayfish species that are native to Jamison Creek;
- ongoing threat of stormwater pollution by toxic contaminants such as pesticides.

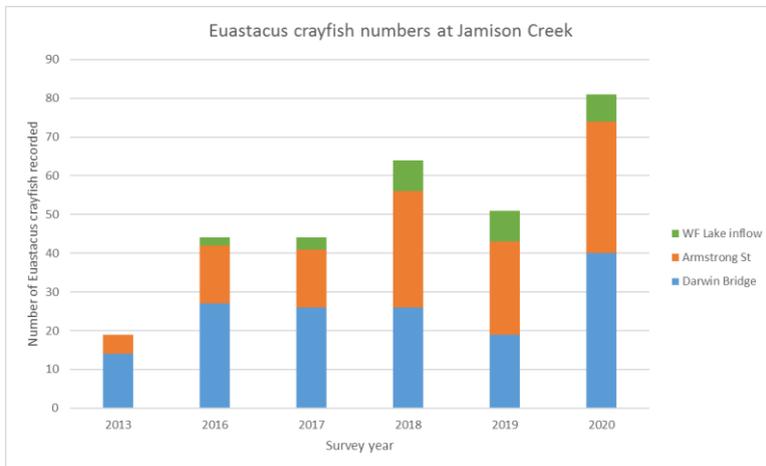


Figure 3. numbers of freshwater spiny crayfish recorded during Jamison Ck surveys (WF Lake inflow not surveyed in 2013). WF Lake inflow numbers are predominantly *E australasiensis*; while Armstrong St and Darwin Bridge are *E. spinifer*.

Managing stormwater in the Jamison catchment

The Jamison Catchment Streets to Creeks project aimed to protect Wentworth Falls Lake and Jamison Creek from stormwater pollution and other threats posed by urban runoff, to improve the health of swamps and waterways in Wentworth Falls as well as downstream in the World Heritage Area and drinking water supplies. With funding from WaterNSW (two grants totalling \$329,502 ex GST), council constructed twelve stormwater biofiltration systems to remove pollutants such as litter, sediment, nutrients and pathogens and increase groundwater recharge. Biofilters improve water quality by slowing, filtering and infiltrating stormwater through beds of sand and gravel planted with native sedges and shrubs (CRC for Water Sensitive Cities, 2015).

Total biofilter size across the twelve sites was approximately 423m². All treatment systems were designed and built by council staff and local contractors. Table 4 summarises the attributes of systems at each site, and photographs of three systems are shown in figure 4. Figure 1 maps stormwater treatment sites, along with monitoring sites in the catchment.



Figure 4. Photographs from 3 of the 12 stormwater treatment systems constructed at Jamison Creek. Top left is one biofilter cell at Canberra St, bottom left is one biofilter cell at Pitt Park, middle is an aerial view of the Central Park system (drone photo by Greg Findlay), right is one biofilter cell at Central Park.

Table 4. Attributes of biofilters constructed at each site

Site	Catchment size (ha)	Catchment impervious %	Flows (ML/yr)	Pre-treatment	Biofilter size	Other system features
Canberra St	14.9	50	116	GPT	4 offline cells totalling 94m ² (0.13% of imp catchment)	High flow bypass Groundwater recharge pit
David St	5.6	50	39	GPT	Offline cell 16m ² (0.06% of imp catchment)	High flow bypass
Banksia Rd (3 separate systems)	11	60	Not modelled	A = GPT; B = stilling pit; C = trash rack	Total of separate systems (in-line cells) = 30m ² (0.05% of imp catchment)	Rock-lined channel (system A)
Central Park	30	40	225	Stilling basins	5 offline cells totalling 132m ² (0.09% of imp catchment)	High flow bypass Groundwater recharge pits
Cemetery (3 separate systems)	5.3	40	41	Stilling pits/ponds	3 separate systems with in-line cells totalling 60m ² (0.3% of imp catchment)	Rock-lined channel (system A)
Wilson Park	3	40	23	Stilling pit	Inline cell 6m ² (0.05% of imp catchment)	Rock-lined channel; rock ramp
Pitt Park (2 separate systems)	11	40	Not modelled	Stilling ponds	2 separate systems (one in-line; one offline) totalling 85m ² (0.19% of imp catchment)	Grass swale; rock-lined channel; groundwater recharge pits; rock ramp; highflow bypass (lower system)
For all biofilters listed above: media (sand & gravel) depth = 700mm; extended detention depth = 200mm; saturated zone depth = 100mm. Catchments for treatment systems are predominantly residential, with some highway, cemetery and/or school campus runoff.						

As shown in table 4, the biofilters constructed were sized at an average of 0.12% of their impervious subcatchment areas (when we include impervious subcatchments with no biofilters, combined biofilter size across the whole catchment represents around 0.02% of impervious area). This is well below the 2% recommended as a general guide by the CRC for Water Sensitive Cities (CRCWSC, 2015), however in an already developed catchment with limited suitable land, it is difficult to find the space for larger biofilters.

Biofilter sampling (inflows and outflows) was conducted by BMCC, with NATA accredited lab analysis funded by WaterNSW. Despite system sizing limitations, preliminary monitoring of biofilters showed promising pollutant reductions (table 5), particularly for faecal coliforms and suspended solids, which both displayed statistically significant reductions. Joint BMCC-WaterNSW monitoring was also conducted at four Jamison Creek sites, however insufficient post-construction data has been collected to date and results are not included in this paper. Continued monitoring is required to collate sufficient data for analysis.

Table 5. Mean water quality variables at biofilter inflows and outflows

Parameter	Biofilter inflow* (n=32)	Biofilter outflow* (n=30)	% Reduction	t-test Significance
Faecal coliforms (CFU/100ml)	2696	992	63	Significant (p=0.042)
Suspended solids (mg/L)	12.62	5.13	59.34	Significant (p=0.0046)
Total nitrogen (mg/L)	0.48	0.32	32.74	Not significant
Total phosphorus (mg/L)	0.044	0.036	19.86	Not significant
* combined averages from Canberra St, David St, Wilson Pk, Central Pk, WF Cemetery and Pitt Pk systems				

Conclusions

Jamison Creek is a high-value waterway under pressure from urban runoff. Long-term health of the creek depends upon continued improvements in catchment and integrated water management: though there is obvious resilience in the ecosystem, capacity for recovery is finite and will be aided by more water sensitive approaches in urban areas. Retrofitting an already developed catchment is challenging, yet council, WaterNSW and partners have made substantial progress with the Jamison Catchment Streets to Creeks

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project, significantly improving stormwater quality at individual sites, increasing habitat value at formerly weed-infested locations, engaging community, reducing localised flooding of properties and advancing the integration of water management across traditionally siloed disciplines.

While the biofilters constructed within this project are achieving promising site-by-site results, on their own they don't constitute a whole-of-catchment solution. Combined biofilter size is around 0.02% of the impervious catchment area, a proportion difficult to increase in an already developed catchment. For genuine transformation, additional holistic approaches are needed, in line with council's Water Sensitive Blue Mountains Strategic Plan. A high priority is to harvest and use stormwater and rainwater on private and public properties, effectively reducing impervious area, while providing a suite of community benefits. Continued monitoring is recommended to assess longer-term changes in waterway health.

Acknowledgments

This work was conducted within the Country of the Dharug and Gundungurra peoples. The authors recognise that Dharug and Gundungurra Traditional Owners have a continuous and deep connection to their Country (Ngurra) and that this is of great cultural significance to Aboriginal people, both locally and in the region. For Dharug and Gundungurra People, Ngurra takes in everything within the physical, cultural and spiritual landscape—landforms, waters, air, trees, rocks, plants, animals, foods, medicines, minerals, stories and special places. It includes cultural practice, kinship, knowledge, songs, stories and art, as well as spiritual beings, and people: past, present and future. The authors pay respect to Elders past and present, while recognising the strength, capacity and resilience of past and present Aboriginal and Torres Strait Islander people in the Blue Mountains region.

The Jamison Catchment Streets to Creeks Stormwater Project was brought to life by the expertise of several local contractors involved with designing and constructing the stormwater treatment systems, including The Bush Doctor, Bones Excavation, the Corneys and Baramy Engineering. Local residents, schools and Bushcare groups contributed to the project by taking part in Waterways Festivals, catchment crawls, planting and weeding days and citizen science events. The project was managed by Blue Mountains City Council's Natural Area Management, Healthy Waterways and Civil Assets teams, with joint funding from WaterNSW and BMCC. In addition to funding on-ground works, WaterNSW continues to support BMCC's transition to a Water Sensitive City, including professional development for staff, funding lab analysis for joint projects and other supportive measures.

We thank the editors and acknowledge the work of past and present staff and volunteers who have contributed to the Waterway Health Monitoring Program, including Christina Day and Cecil Ellis, as well as contractors including Chris Madden and Sydney Water who have identified some of the macroinvertebrate samples reported here. BMCC is grateful to Ian Wright, Rob McCormack and John Gooderham for generously sharing their expertise.

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