MID-TERM REVIEW

Restoring the health of urban streams through stormwater management

Strategic alignment

Regional Performance Objectives (RPOs):

- RPO-14: Standards, tools and guidelines are in place and implemented to enable re-use and infiltration of excess storm- water, and protect and/or restore urban waterways.

Key Research Areas:

- Stormwater management and flooding: Improving stormwater treatment performance and determining the optimal maintenance of WSUD systems
- Stormwater management and flooding: Developing decision support tools to inform the most effective stormwater treatment systems and locations to protect waterway biodiversity, amenity and recreation

*This fact sheet is a summary of the Technical Report: Restoring the health of urban streams through stormwater management: A synthesis of the Little Stringybark and Dobsons Creek research projects (Technical Report No. 23.2, Melbourne Waterway Research-Practice Partnership). A **Glossary** of terms is provided at the end of the fact sheet.*

Background

The primary cause of urban stream degradation is uncontrolled runoff from impervious surfaces through hydraulically efficient stormwater drainage networks. The resulting disturbances are both hydraulic, arising from larger, more frequent high-flow event and lower dry weather flows, and chemical, arising from the complex cocktails of pollutants associated with impervious runoff. In response to this, alternative drainage approaches have been advocated, that attempt to restore the natural hydrology of a catchment, through the installation of stormwater control measures (SCMs). This use of SCMs has been subject to expensive research and successfully trialed at the site scale. However, although shown to be theoretically sound at the catchment scale, this approach had remained largely untested. Despite this, this approach to managing stormwater is being adopted as policy (e.g. Melbourne Water's Healthy Waterway Strategy) on the assumption that stream protection, and potentially restoration is possible through catchment scale application of dispersed stormwater control measures. This project has sought to test this assumption by asking if stormwater runoff from urban developments can be adequately retained, used and treated to protect or restore stream ecosystem structure and function, which is degraded by urban development with conventional stormwater drainage.

What did we do?

Over eight years beginning in 2009, we constructed 620 dispersed SCMs projects across our two peri-urban catchments, thereby treating runoff from 4 km^2 of urban development across the intervention catchments. SCMs were designed to improve both water quality and restore important elements of the natural flow regime, being designed to reduce contaminated stormflows via infiltration, harvesting and evapotranspiration.

SCM's were dispersed across two peri-urban catchments (Little Stringybark and Dobsons Creek) on private and public land. Public land works were installed in collaboration with local council (Yarra Ranges & Knox City Councils), and ranged in scale from dispersed small infiltrating nature strip systems (treating < 100m^2) to large complex systems (treating >20,000m^2) that combine harvesting, re-use and infiltration. Private land systems, comprising mostly rainwater tanks connected to internal water demands, where installed through incentivized community engagements programs. In addition to funded installations, the project partners collaborated in the development of planning controls to minimse the impact of new impervious surfaces.

To assess the impact of our works, we established a Before-After-Control-Reference-Impact study framework, in multiple catchments across the Dandenong Ranges. We continuously monitored stream hydrology (2009-2021) and intermittently monitored water quality (monthly and event; 2001-2003, 2004-2006, 2009-2019), macroinvertebrate community composition (Spring/Autumn; 2001-2003, 2004-2006, 2008-2020), diatom community composition, benthic algal biomass and leaf litter decomposition (Spring/Autumn; 2011-2018). All monitoring ceased at the start of 2022, except macroinvertebrates, which is ongoing as part of Melbourne Water's macroinvertebrate monitoring program.

We also undertook a number of complimentary investigations to further our understanding of the delivery and value of this type of project. To enable an objective assessment of the value of competing SCMs, we developed an Index of Environmental Benefit. We also examined the participation of the project's stakeholders, namely Yarra Ranges Council and local residents. Additionally, we also explored the long-term performance of residential rainwater tanks. Finally, building on the environmental benefit index, we developed improved catchment metrics to allow prediction of the effects of catchment urban stormwater runoff and works aimed at stormwater control on receiving streams.

What did we find?

The experiment has demonstrated that important aspects of stream ecosystem structure and function degraded by urban

Key findings from the Little Stringybark & Dobsons Creek Projects

Water Quality

- Reduced phosphorus concentrations and summer temperatures to reference levels in dry weather and after small events, with smaller reductions following less frequent, larger rain events.
- Reduced nitrogen concentrations (which were influenced by septic tank seepage).
- No effect on suspended solids concentrations, which was lower in urban than in reference streams.
- Marginally increased electrical conductivity (already high in LSC), suggesting that (along with reduced temperature) SCMs increased the contribution of groundwater to baseflow.

Hydrology

- Reduced quickflow* volume and peak flow for small-to-moderate storm events (2-8 mm)
- Changes to the flow regime diminished for large storm events (> 20 mm)

Catchment Scale Experiments

- Stream protection requires large stormwater harvesting demand and adequate space in appropriate parts of the catchment for stormwater control measures.
- A weighted measure of effective imperviousness can be used to **predict** stream ecosystem response to catchment stormwater control measures.
- Can not rely solely on the capacity of infiltration system's to minimize the frequency of uncontrolled runoff.
- Should not rely entirely on large, centralized end-of-pipe SCMs to protect streams.
- A comprehensive, integrated and dispersed approach is needed, so that upstream systems reduce the hydraulic loading on downstream systems, and downstream systems act as insurance for upstream SCMs that fail.

Ecology

- Increased abundance of some moderately sensitive macroinvertebrate taxa.
- An increase in the similarity of the diatom abundance across the community.
- Little or no observed changes in biotic indices, such as SIGNAL or LUMaR for macroinvertebrate assemblages or DSIAR for diatom assemblages.

Stakeholders

- Economic incentives were an effective means of securing public engagement
- Willingness and capacity of *local government* for adopting SCMs was increased
- Tank owners valued their tank and made reasonable efforts to keep them functioning.

In summary....the important aspects of stream ecosystem structure and function degraded by urban stormwater drainage can be restored.

*****The 'flashy' component of the flow, or more specifically, the flow that makes its way to the stream as runoff or as interflow, being flow that moves laterally within the upper soil horizon.*

***Figure 1.**Summary of reserach findings.*

stormwater drainage can be restored (see Figure 1). Moreover, the project has informed how SCMs should be designed for stream protection/restoration and demonstrated the challenges in implementing SCMs across catchments for stream protection, highlighting the need for large stormwater harvesting demand, and adequate space in appropriate parts of the catchment for stormwater control measures (low land that can intercept runoff from stormwater pipes).

For water quality, our catchment interventions reduced phosphorus concentrations and summer temperature to reference levels where effective imperviousness (EI) was sufficiently reduced in dry weather and after small rain events, but reductions were smaller following less frequent, larger rain events. SCMs also reduced nitrogen concentrations which were influenced by septic tank seepage in all sites. SCMs had no effect on suspended solids concentrations, which were lower in urban than in reference streams. SCMs marginally increased electrical conductivity, which was already high in LSC and its tributaries: along with reduced temperature this is evidence that SCMs increased the contribution of groundwater to baseflows.

The stormflow hydrology of the catchment was also positively influence by catchment interventions. We found that SCMs reduced quickflow volume and peak flow for small-to-moderate storm events (2-8 mm). SCM-induced changes to the flow regime diminished for large storm events (> 20 mm). The reductions in storm event quickflow volume observed are commensurate with the likely runoff retention capacity afforded by the SCMs implemented. Decreased storm event peak flows are likely a result of both the detention and retention behaviour of the SCMs. The changes to the flow regime observed are likely biologically meaningful, given that small-to-moderate storm events dominate wet-weather conditions.

Analysis of the ecological effects of catchment interventions remain in progress, but we offer the following preliminary observations (as of October 2022). The catchment interventions resulted in little or no change in biotic indices, such as SIGNAL or LUMaR for macroinvertebrate assemblages or DSIAR for diatom assemblages. There was a positive trend in macroinvertebrate assemblage composition (as measured by SIGNAL and LUMaR) in Dobsons Creek since 2013, but not in LSC or its tributaries. This difference may have resulted from the greater pool of colonizing species from the forested headwaters of Dobsons compared to LSC, whose headwaters are primarily urbanized. Despite little change in summary indicators of taxonomic presence or absence, abundances of taxa changed in response to the catchment interventions, with numbers of some moderately sensitive macroinvertebrate taxa increasing. A single common diatom species, *Achnanthes oblongella*, which tends to be more common in less urban streams, became more dominant after SCM implementation, associated with the reduced relative abundance of a dozen species of varying sensitivity to urban impacts. The effect of the reduced nutrient concentrations and reduced flow disturbance was thus to increase the evenness of the diatom assemblage, which was unexpected. We are yet to determine if this change in the diatom assemblage was associated with reduced algal biomass.

Using a weighted measure of effective imperviousness (EIS), allows prediction of stream ecosystem response to catchment stormwater control measures (by linking catchment-scale effective imperviousness with the 'environmental benefit index' applied at the scale of individual SCMs). EIS predicts both degradation responses (resulting from conventional stormwater drainage increasing effective imperviousness) and restoration responses (resulting from SCMs reducing effective imperviousness) in receiving stream water quality and hydrology.

Community participation in the LSC Project was influenced by a range of internal and external factors. Overall, the community was generally supportive of the project's objective to improve the health of the creek. Still, the primary motivating factor for participating was the financial assistance for rainwater tanks, demonstrating that economic incentives are an effective means of securing public engagement in such projects. While the barriers to participation were financial and time constraints, other disincentives included: bureaucratic and conceptual complexity of the auction process; distrust of the offer of subsidized tanks; and dislike of the aims, ethos and institutional identity of the project. The project was found to be an effective avenue for increasing the willingness and capacity of local government (Yarra Ranges Council) to trial new approaches to urban stormwater management, leading to a long-term commitment essential for the development of trust and a culture of learning among the collaborators in the project. Examination of private tank management found that that tank owners generally placed a high value on their tank, desired to have them fully operational, and made a reasonable effort to keep them functioning. However, the frequency and extent of maintenance action and effort was variable, and in the context of a private residence, rainwater tanks were typically afforded a low relative priority for repair when compared with other residential assets. This low relative priority could be a primary driver for the reported delay between when a fault occurs with the tank and when it is repaired. This 'repair lag' means that a proportion of domestic rainwater tanks are likely to be non-operational at any one time and thus offer no retention benefits.

Recommendations

Catchment scale interventions

- EIS, by integrating measures of SCM performance in its formulation, can be used to assess the effects of a wide range of potential SCM types, designs, and implementation strategies, to predict in-stream water quality and hydrologic responses. We recommend that it be used to prioritize management actions for stream protection and restoration. While broadly consistent with the intention of the Victorian EPA urban stormwater management guidance for volume reduction and filtered-flow volume, EIS, includes explicit measurement of direct in-stream stressors (frequency of uncontrolled flow disturbance and ambient water quality concentrations)
- Stream protection requires changing standard drainage practice so that conventional drainage is no longer the default. It will require near all impervious surfaces draining to SCMs with high performance standards.
- Stormwater control is likely to require control measures at multiple scales, including at the scale of individual properties, on streetscapes and at the end of pipes as a final treatment before receiving streams. As a result, the reservation of (at least) small areas along flow lines as public open space for stormwater interception at the planning stage is required.
- Stormwater control measures will provide greater protection to stream ecosystems if they mimic the predevelopment water balance, requiring substantial demand for stormwater.
- The selection of future catchments for such restoration efforts should investigate and consider community interest in the creek in question.
- • The legacy effects of past agricultural land use and septic tank seepage can be mitigated by SCMs, but long-term mitigation requires ongoing monitoring. Yarra Valley Water's sewerage backlog program is reducing the prevalence of septic tanks in several of the study's catchments. We recommend that YVW and MW resume water quality monitoring in the study streams to assess the longer-term effects of this complementary management action.

Community participation

- No single approach to community engagement provides a "silver-bullet", meaning an integrated suite of mechanisms will be required. In the case of a problem such as stormwater retention, which needs maximum participation to ensure the required environmental outcomes, a combination of incentive- and regulation-based systems will be required.
- Programs should allow sufficient time to build recognition and understanding of the problem and solutions, alongside trust.
- The requirement of an upfront payment by the householder should be avoided, to reduce the perception of risk.
- Having a single point of contact was also identified as a positive factor for householder participation. Sustained engagement of project staff also permits growth in understanding of the primary drivers of participation.

Design of SCMs

- While interception of runoff from all catchment impervious surfaces is likely a requirement for stream protection, the intercepting SCMs need to have high performance in terms of their reduction in the frequency and volume of runoff, and the provision of filtered baseflows.

- Relying solely on infiltration systems capacity to minimize the frequency of uncontrolled runoff is likely to result in unnaturally high groundwater flows, with concomitant pollution risks.
- Strategies that rely entirely on large, centralized end-of-pipe SCMs will likely fail, as they will (i) likely be unable to ensure effective treatment with the large hydraulic loading they receive, (ii) likely be distant from demands for their water, thus reducing their effectiveness in load reduction, (iii) potentially cause perverse effects (e.g. higher water temperature) and (iv) fail to protect upland stream length.
- A comprehensive, integrated and dispersed approach is needed, so that upstream systems reduce the hydraulic loading on downstream systems, and downstream systems act as insurance for upstream SCMs that fail, or for runoff from untreated impervious areas.

SCM Maintenance

- One strategy to guarantee the ongoing maintenance of SCMs managed by local government could be to include (and set aside for later use) the cost of maintenance as part of the total project cost.
- Relying solely on the good intentions and the existing capacity of homeowners to manage their SCMs is risky, given issues such as repair lag and the potential complacency, ignorance and inexperience of asset owners.
- An essential pillar of support for private land owners to manage their SCMs would be increased education on maintenance, to build awareness, confidence and the capacity of private asset owners.
- The use of new 'real-time monitoring and control' technologies is a potential solution to private asset maintenance, with the potential to enhance the owner's awareness about when and what maintenance is required, or facilitate remote monitoring, that will allow for a centralised support program.

How are we sharing Findings?

Publications

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- Prosser, T., Morison, P.J. & Coleman, R.A. (2015). Integrating stormwater management to restore a stream: perspectives from a waterway management authority. Freshwater Science, 34, 1186–1194.
- Walsh C.J., Burns M.J., Fletcher T.D., Bos D.G., Kunapo J., Poelsma P., & Imberger, M.J. (2022) Linking stormwater control performance to stream ecosystem outcomes: incorporating a performance metric into effective imperviousness. PLOS Water
- Walsh, C.J. & Fletcher, T.D. (2015). Stream experiments at the catchment scale: the challenges and rewards of collab-

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