MID-TERM REVIEW

How can retention, use and treatment of urban stormwater protect or provide natural flow regimes for waterway health?

Strategic alignment

Regional Performance Objectives (RPOs):

- RPO14: Standards, tools and guidelines are in place and implemented to enable re-use and infiltration of excess stormwater, and protect and/or restore urban waterways.
- RPO 11: Understanding of groundwater dependent ecosystems is improved and opportunities to maintain or improve these continue to be investigated.
- RPO-16: Protection mechanisms are in place for headwaters to ensure that they are retained as features in the landscape for environmental, social, cultural and economic benefits.

Key Research Areas:

- Hydrology and environmental flows: Investigating opportunities for managing stream flows in urban catchments to protect and improve aquatic biodiversity, amenity, recreation and reduce flooding
- Stormwater management and flooding: Understanding the costs and benefits of various stormwater management interventions for biodiversity, amenity and recreational outcomes

Summary

Melbourne Water's Healthy Waterway Strategy proposes that stream protection, and potentially restoration may be possible through catchment-based Stormwater Control Measures (SCMs). This project aims 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.

The major component of this research, investigating the potential to protect urban stream structure and function in the face of urbanisation, has been undertaken in association with the Sunbury Integrated Water Management (IWM) project. Melbourne Water and the City of Hume is planning to apply IWM to the eastern region of Sunbury, while other parts of Sunbury and Diggers Rest to the south are likely to be developed with conventional stormwater management, as a Business As Usual (BAU) case study. Depending on the option implemented, IWM is expected to result in as much as 80 % of urban stormwater runoff harvested and prevented from running to the large receiving streams, with complete control of water quality and flow delivered to small tributaries, while BAU will achieve current practice involving partial treatment and very little volume reduction of stormwater flows. If successfully implemented, IWM should be sufficient to protect (and likely restore) both the small tributaries and the larger receiving waters downstream, as it will achieve the primary principles of stormwater management for stream protection (Walsh et al. 2016).

Overall, the contrasting stormwater management approaches around this growth area permit a replicated comparison of trajectories of ecological response to IWM development and to BAU development. This project seeks to establish a monitoring program to permit effective assessment of contrasting development approaches and further understand the role and ecosystem structure and function of small ephemeral tributaries around Sunbury which remain poorly understood.

This project, which commenced in 2019, is currently recording baseline (or 'before') data. While the full findings of this research project are dependent on completion of the IWM program, some valuable insights are being provided via the preliminary research, especially the comparison between rural and forested (reference) streams.

Recommendations:

- That this project be continued, including additional measures of ecosystem structure and health (e.g. benthic algal biomass, microbial DNA) to ensure a robust assessment of the stream health benefits of the Sunbury IWM project to inform the design and implementation of future regional stormwater harvesting and use projects across Greater Melbourne.
- Although we are only beginning to fully understand the ecosystem structure, function and value of the small ephemeral headwater streams, our preliminary research points to the importance of subsurface connectivity and interactions in the near-stream region and the broader headwater catchment for healthy ecosystem structure. As such, consistent with RPO 16, we recommend that every effort be made to protect headwater streams from urban development, and where this is not possible, appropriately designed SCMs are adopted that mimic the natural flow and water quality regimes observed in this study.

What are we doing?

This research is being undertaken in the eastern part of the Sunbury growth area for which a large IWM project is proposed. This project is planning on maximising large demands for harvested stormwater, which provide potential for restoration of flow- and water-quality-regimes that are predicted to be adequate for the protection of the small intermittant tributaries draining the development, and its main receiving water, Emu Creek. Presently, the project is continuing to collect data on stream structure and function to permit robust assessment of the effects of the development and its IWM systems.

This monitoring and investigation is being undertaken across 11 intermittant tributaries in and around Sunbury and 21 river monitoring sites (on Emu, Deep, Bolinda, Riddells and Jacksons Creeks) using sampling methods piloted in the first three years of the project.

Intermittant stream monitoring includes the following: bi-monthly water quality quality (incl. total and dissolved N and P, total suspended solids, del 18O, del 2H, pH, electrical conductivity, dissolved oxygen and temperature), event water quality (6 events/annum; analytes as above), stygofauna (fauna that live in groundwater systems or aquifers, annual spring sampling), carbon decomposition (annual spring sampling), microbial community diversity (annual spring sampling), benthic algal biomass (annual spring sampling), and continuous surface and sub-surface hydrological monitoring.

Monitoring station, Goonawarra Creek in Sunbury

River monitoring includes the following: bi-monthly water quality (incl. total and dissolved N and P, total suspended solids, pH, electrical conductivity, dissolved oxygen, and temperature) , event water quality (6 events/annum; analytes as above) and macroinvertebrates (annual spring sampling).

What are the expected outputs and outcomes?

Post implementation of IWM

- Improved understanding of the pre-development condition (pre-IWM approach) of stream function.
- More accurate waterway protection targets and intervention standards/objectives for urbanising catchments
- Inform the policy and standards for stormwater treatment in new urban developments.
- Clarification of the critical assumptions in the HWS Monitoring, Evaluation, Reporting and Improvement (MERI) Framework on the benefits of higher levels of stormwater treatment during/for urban development.
- Informing the evaluation of the benefits of the Sunbury IWM for protecting stream health during and after urban development

Preliminary findings

The preliminary analysis of two ephemeral headwater streams: 1) a reference stream (Tributary of Barringo Creek) and 2) a stream impacted by agricultural and urban development in the Sunbury region (Gellies Creek) showed contrasting results, which are detailed below.

Our reference stream, Tributary of Barringo Creek, is an ephemeral system with a fully forested catchment, located in the Macedon Regional Park. Stream flow data from this site showed little to no surface flows despite numerous small to large rainfall events. Subsurface water levels displayed high seasonality with levels remaining very low (below 600mm) for the duration of summer. During this time, we also observed minimal changes in subsurface water levels in response to small-medium rain events, indicating high buffering capacities (i.e. catchment soils infiltrating most rainfall, meaning very little makes its way to the stream in the short-term). Significant and rapid changes in subsurface water levels only occurred during large rainfall events, defined as in excess of 30mm/day. Del 18O and 2H (used to partition water sources; i.e. groundwater versus surface runoff) suggested that subsurface water was derived from well mixed groundwater and levels were most often influenced by broader scale groundwater levels. During very large rain events (i.e. March 2020), however, both surface and subsurface water was less well mixed, containing groundwater, recent rainfall and surface runoff. This pattern was also reflected in nutrient levels; where nitrate concentrations at the surface and subsurface remained consistently low; with increased concentrations in shallow subsurface flows only observed following very large rain events. Overall, these findings suggest our forested headwater stream was efficiently buffering the delivery of water, sediment and nutrients to the lower stream network. While water and nutrients were rapidly transported downstream during large rainfall events, these were infrequent. For the majority of time, this stream catchment was infiltrating water and rapidly processing dissolved nitrogen. These findings are similar to those of Alexander et al. (2007) and many others which have shown headwater streams to be important for nutrient processing and retention. While some research indicates headwater streams often lack surface and subsurface water storage and hyporheic zones (e.g. McGlynn et al. 2004, Wohl 2017), our data highlighted the significant role of subsurface and water infiltration and retention.

Our second site, Gellies Creek, was a rural ephemeral headwater stream subject to agricultural and urban development. Stream flow data from this site showed frequent surface flows in response to small rainfall events; with a hydrograph more similar to those seen in flashy urban streams to Melbourne's East. During wetter periods (June-September), even when the stream surface was dry, subsurface water levels remained high indicating elevated subsurface water levels and reduced flow buffering capacities. Del 18O and 2H values indicated that during moderate to large rain events surface flows were dominated by water derived from recent rain and surface runoff. Nutrient levels told a similar story, with nitrate concentrations greater at the surface than the subsurface and rising rapidly as a function of surface runoff following moderate to large rain events. Even during periods of seasonal flow and smaller rainfall events, however, water in Gellies Creek generally displayed elevated nutrient concentrations and a wider variety of less well mixed water sources.

Comparing our two catchments indicates that the combination of agriculture and urbanisation increases the frequency of surface flows, reducing the duration and timing of cease-to-flow periods and thus overall seasonality and intermittency. Surface flows during large rainfall events were also more likely to originate directly from surface runoff. These differences indicate that urban and agricultural development of intermittent headwater streams reduces their capacity to infiltrate and buffer the export of water and nutrients to downstream reaches; with subsurface environments remaining wetter year-round and smaller rain events producing surface flows from a wider variety of water sources (cf. reference stream). This loss of buffering capacity reduces surface sediment-water contact time for nutrient removal and results in both greater moisture and nutrients, driving significant shifts in the composition of fungal and bacterial communities and ultimately elevating rates of organic matter decomposition in both surface and subsurface environments. While microbial community richness was not significantly impacted by landuse, bacterial community composition was. Bacterial communities were strongly influenced by nutrient concentrations, redox conditions and temperature, and one of the major drivers of elevated decomposition rates in our mixed agricultural urban and agricultural site.

In summary, our research indicates that agricultural and urban development of headwater streams increases the transport of water and nutrients (incl. dissolved nitrogen and carbon) to the lower parts of the stream network; increasing the frequency and magnitude of high flows and reducing the frequency and duration of surface cease-to-flows. Changes in hydrology, nutrients and residence time also alter microbial community composition and rates of organic matter decomposition. Ultimately our data suggests that headwater stream ecosystem structure and function may be even more sensitive to the effects of agriculture and urbanisation that larger streams studied to the east of Melbourne.

How are we sharing findings?

Publications

- Imberger, M., B. Hatt, S. Brown, R. Burrows, M. J. Burns, C.J. Walsh (2023) Headwater streams in an urbanizing world. Freshwater Science, 42:3, 323-336, DOI: 10.1086/726682

For more details on the research outcomes of this project, or other projects of the MWRPP, please contact:

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