Hydrologic performance of green infrastructure

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Highlights

- Green infrastructure including biofilters and green roofs can effectively reduce stormwater volume as demonstrated by numerous field studies.
- Performance varies widely with factors including climate, soil conditions, design configuration and sizing. Satisfactory performance outcomes are more challenging in adverse conditions (such as low infiltration soils) but can still potentially be achieved.
- Reductions in direct stormwater discharges from bioretention are usually achieved predominantly through infiltration while evapotranspiration is secondary, but still significant.

Introduction

Waterway health is adversely impacted by increased flow volumes, flow frequency and stormwater pollutant loads. There is a need for stormwater flow volumes to be reduced in addition to providing stormwater treatment for pollutants and management of flood events. Green infrastructure including biofilters, green roofs and passively irrigated tree pits offer potential means to reduce stormwater flow volumes.

The fundamental principles and processes by which green infrastructure reduce volumes are reasonably well understood. However, there remain significant gaps and uncertainties in our understanding and modelling approaches. Furthermore, there has been limited recent synthesis of learnings and detailed monitoring data from experimental studies of green infrastructure assets and in Australia there is no comprehensive database of such studies. Such a database is a necessary precursor to support the development of improved design methods and tools to design green infrastructure to achieve stormwater volume management objectives for flood mitigation, waterway protection and landscape enhancement.

A literature review was undertaken to identify monitoring studies of these types of green infrastructure with reported stormwater retention outcomes. A range of contextual and causal variables potentially influencing performance were identified and summarised. These then informed a discussion of the mechanisms by which stormwater is retained through these assets and potential learnings for consideration in their design, modelling and application. Target studies were identified and researchers were contacted to requested detailed data hydrologic sets to support future analysis and model calibration with a focus on Australian data. A number of data sets were obtained and collated.

Methodology

Literature review

A search of the literature was undertaken, searching for key words including biofilter, bioretention and green roof to identify relevant papers reporting monitoring studies and hydrologic performance. The literature review was substantial but focussed specifically on monitoring of field studies and hydrologic performance rather than an extensive research literature review.

Papers specifically relating to monitoring of field green infrastructure assets were sought and papers that did not contain monitoring data and reported hydrologic performance, or that related solely to laboratory studies were discarded.

A range of meta-studies and data-sets were identified and allowed additional monitoring papers to be located. Original sources were referenced where possible. Meta-studies included:

- International BMP Database
- Davis 2012 (Davis *et al.*, 2012)
- Hoban and Gambirazio (Hoban and Gambirazio, 2018)
- Mentens (Mentens, Raes and Hermy, 2006)

At the conclusion of the study, the extensive literature review by Spraakman (Spraakman *et al.*, 2020) was identified. This paper identified a broad range of bioretention papers including both hydrologic performance and other aspects of potential interest. Further papers drawing on this study may be incorporated into future work.

Detailed hydrologic data

From within the papers obtained, selected studies were identified and researchers were contacted to requested detailed data hydrologic sets to support future analysis and model calibration. Focus was placed on securing Australian data. This would likely now include the largest single collection of detailed hydrologic monitoring data for Australian green infrastructure assets. These data sets include inflows, outflows, rainfall and relevant data such as water levels, temperature and evapotranspiration as available.

Results and discussion

The data from the papers was summarised including the overall hydrologic performance of each asset for the period over which monitoring occurred. It is recognised performance is influenced by a variety of factors and a wide range of performance results may be anticipated.

The performance results for bioretention are shown by way of example in **Figure 1** with broader statistics summarised in **Table 1**. As foreshadowed above, the range of performance is essentially from 10-80% covering the range of possible outcomes. Average performance for bioretention and green roofs indicates 50% or better reductions in stormwater volume. Other factors and variability aside, this alone demonstrates the potential for these assets to significantly reduce stormwater volumes.

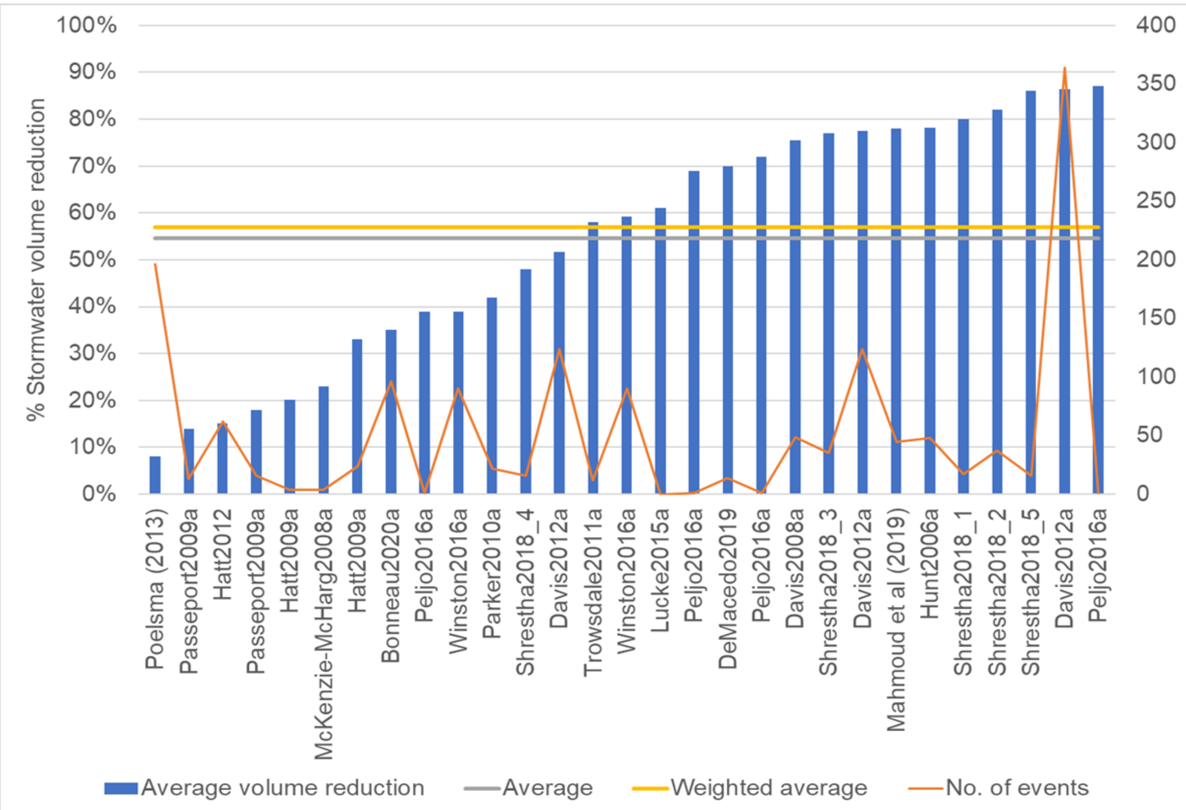

Figure 1. Percentage of stormwater volume retained by bioretention assets

Table 1. Stormwater volume reduction performance summary

Paper ID	n	Min	Mean	Median	Max
Biofilters	29 assets 1522 events	8%	55%	59%	87%
Green roofs	55 assets 782 months*	11%	50%	56%	77%
Tree pits	28 assets (only 2 studies) 18 months	5%	18%	-	44%

*Due to differences in the common reporting, number of events was less readily available for green roofs.

Conclusions and future work

The key findings can be briefly summarised as follows:

- Bioretention assets and green roofs are generally effective for reducing stormwater volumes as demonstrated by a wide range of field studies across many different climates and conditions.
- Performance varies widely and depends on climate, soils, design, size and other factors. The design and sizing of assets is important.
- Bioretention assets and tree pits are typically small relative to catchment. As a result, infiltration is usually the dominant pathway. Where possible, it is desirable bioretention and tree pits are unlined to enable infiltration. This reduces direct surface discharges and supports groundwater recharge.
- Satisfactory outcomes may still be achieved in slow draining soils or even lined assets. This is subject to context, design and usually larger sizing than may otherwise be required for stormwater quality purposes.

- Future work in the second stage of the project (to be reported on at the conference if possible) will include:
- Statistical analysis of hydrologic performance and influencing factors
- Calibration of continuous simulation stormwater models (MUSIC) to selected detailed data sets
- Guidance for industry on design and likely performance of green infrastructure assets

References

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