Ecologically-informed stormwater control to protect peri-urban platypus habitat

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Key points

- Stormwater management now considers multiple objectives including downstream ecosystem protection.
- Hydraulic habitat modelling can support stormwater management decisions and real-time control operations to protect certain organisms or communities, in a similar way to environmental flow studies for regulated and flow-stressed rivers.
- This paper presents a four-step approach to integrating habitat requirements into stormwater management: objective setting, habitat survey, hydraulic modelling to develop flow-habitat relations, and integration into design and control systems.

Abstract

Over the past three decades, stormwater management has evolved beyond just flood control to also consider ecosystem protection. Real-time control technology now enables adaptive systems that can potentially maintain stream flows and habitat, but their operation requires ecologically relevant flow objectives based on habitat requirements. We developed a four-step method for integrating flow-habitat relationships into stormwater control: defining habitat requirements, conducting high-resolution surveys, undertaking hydrodynamic modelling to create flow-habitat curves, and embedding these into control algorithms. We applied this to the Monbulk Creek Smart Water Network, which aims to protect vulnerable platypus populations alongside other stream health, flood protection and household water use benefits. We identified five key habitat metrics for platypus (wetted area, swimmable area, pool habitat, large wood, and avoidance of overbank flooding during nesting season). Then, flow-habitat curves based on feature survey and 2D TUFLOW modelling across eight reaches were developed to show how habitat availability changes with flow. Flow-habitat curves were then used to define objectives for control of rainwater tanks and stormwater storages. This approach provides a pathway for adaptive, multi-objective stormwater systems that support instream biodiversity alongside other benefits.

Keywords

Environmental flow requirements, real-time control, stormwater management, hydraulic habitat, physical habitat, platypus

Introduction

Platypus are found across Melbourne's waterways, but are threatened by, among other things, ongoing urbanisation and climate change (Coleman et al. 2022). They are particularly sensitive to changes in flow regimes, including reduced flow permanence and reduced baseflow, but also increased flooding during the nesting season (Serena et al 2014; Serena and Grant 2017). Therefore, under a drying climate, further reductions in baseflow driven by urban imperviousness reducing subsurface flow will reduce foraging and refuge areas and food availability for platypus, while increased frequency of summer bankfull flow due to flashy urban runoff threatens to drown juveniles in their nesting burrows.

New 'smart' stormwater systems (based on real-time control; RTC) offer a potential solution: capturing rainwater in tanks, reservoirs and other storages during rainfall events, and discharging it slowly to streams during dry periods. In theory, application of such technology should mean that flood risk can be reduced and more natural levels of baseflow restored. In practice, however, incomplete application and competing demands mirror classic environmental flow problems: the complete natural flow regime likely cannot be recreated, so objectives need to be defined for the most ecologically important aspects of the flow regime to be delivered.

This paper presents a method to define environmental flow requirements for a keystone species in urban and peri-urban streams and integrate them into stormwater management systems. The method adopts a hydraulic habitat modelling approach, surveying the stream in fine detail then using hydraulic modelling to relate instream habitat availability to flow. Flow-habitat curves can then be used to guide stormwater management operations.

Monbulk Creek Smart Water network

Monbulk Creek in Belgrave, Victoria (Figure 1A illustrates the typical stream character), supports the last remaining platypus population in the Dandenong Creek catchment. The platypus population is threatened by urban stormwater impacts, such as reduced baseflow and increased frequency of bankfull flooding, among other pressures (Coleman et al, 2022). The catchment has around 7% total and 3% effective (i.e., directly connected) impervious cover, meaning that while stormwater impacts are already substantial, there is an opportunity to meaningfully lower them through smart stormwater management. This opportunity is even more important under a drying climate, which further threatens low flow habitat.

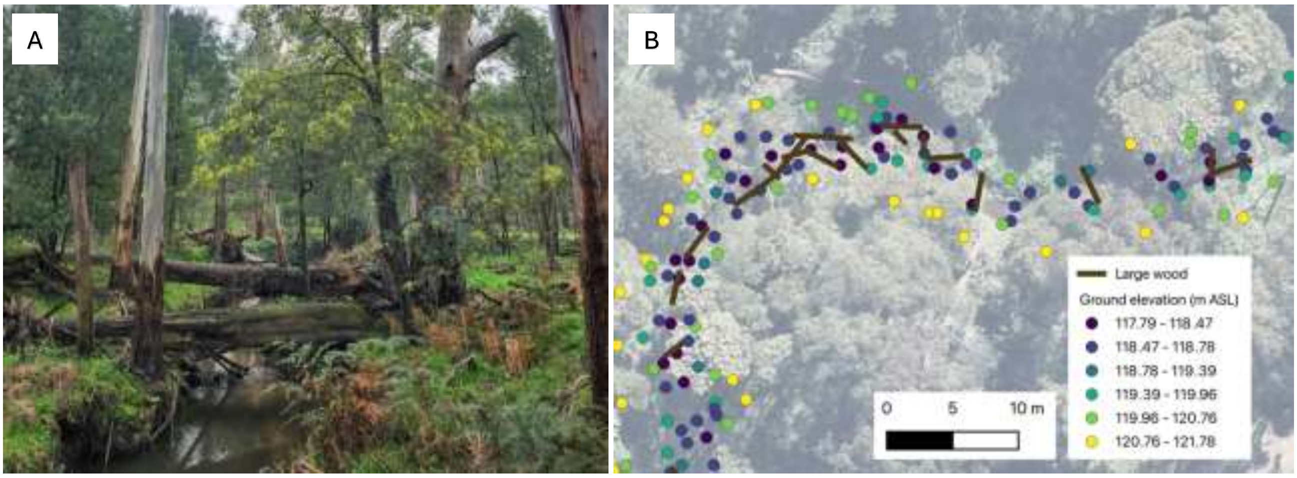

Figure 1 (A) typical instream habitat, Monbulk Creek; (B) Example of survey data

The Monbulk Creek Smart Water network consists of interconnected rainwater tanks and stormwater storages (urban lakes), operated by a real-time control platform (hosted at https://smartraingrid.org.au) to deliver targeted flows to Monbulk Creek. The tanks are fitted with remotely operated actuator valves which can be closed to retain water or opened to release water into the stormwater drainage network and thus ultimately into the stream. The lakes also have smart outlets which can release or store water at different rates. The network is controlled by a central algorithm that determines when additional water is needed in the stream and allocates releases across the distributed storages. Based on 7-day weather forecast information, the algorithm can also release water from the tanks prior to storms, to increase stormwater harvesting and reduce overflows to the drainage network – both decreasing the impact of stormwater on the health of the creek and decreasing localised flood risks. During periods when flows fall below specified minimum requirements (Jacobs, 2017), releases are initiated from both the lakes and tanks, until the flow level returns to the minimum specified threshold (Figure 2).

To ensure that the flow releases meet the aquatic habitat requirements of platypus, the algorithm requires clear definition of these needs, a problem mirroring environmental flow studies in regulated streams (e.g., Acreman and Dunbar 2024). The logic follows a series of questions: *what do platypus need in their habitat in terms of flow depth, velocity, inundation of features? What physical habitat exists in the studied stream? What is the relationship between flow and the provision of these habitat aspects?* Using high-resolution surveys and hydraulic models to answer these questions results in evidence-based flow objectives that can be integrated into stormwater management systems including real-time control algorithms.

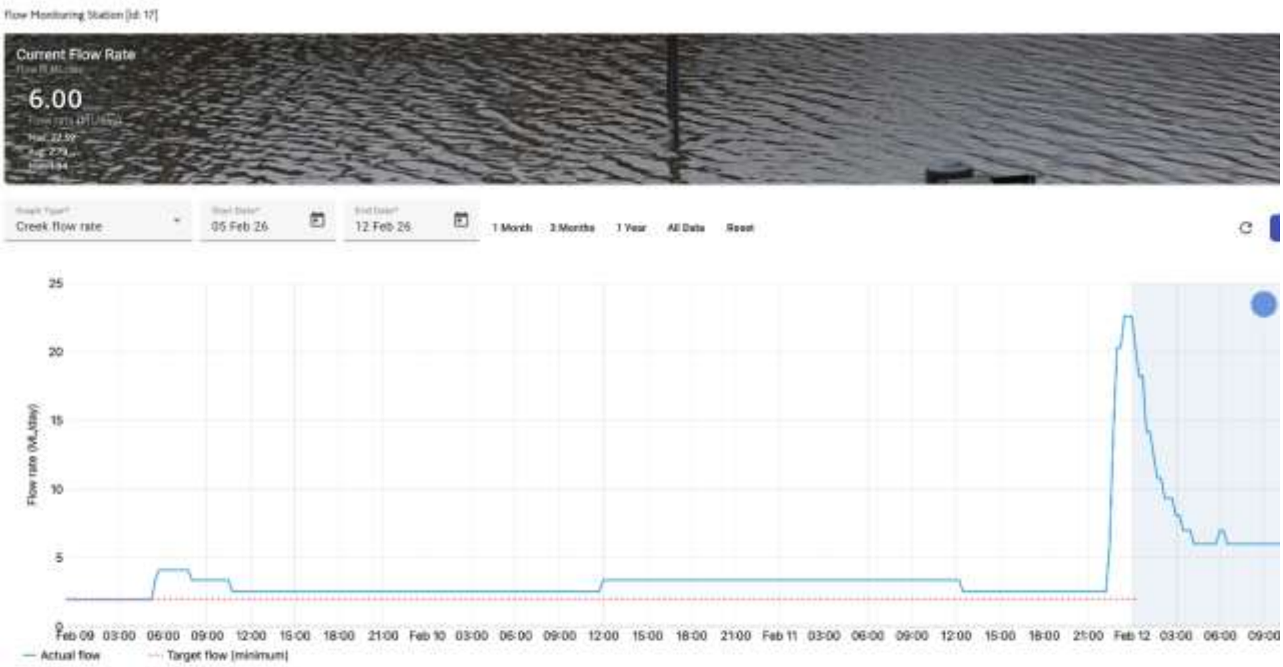

Figure 2 Example of release initiated by Monbulk Smart Water Network in February 2026 to meet a minimum summer flow requirement of 2 ML/d

Implementing instream habitat protection objectives for stormwater management

Step 1: Define habitat requirements: what does the target organism need?

Firstly, the habitat preferences and requirements of the target species need to be defined, through expert input, literature review and targeted research. For Monbulk Creek, platypus requirements were defined through a series of workshops that outlined firstly what general habitat attributes were required and then what hydraulic and physical conditions those attributes corresponded to. Five habitat objectives were defined (Table 1), covering foraging and refuge habitat, along with the avoidance of high flows that could be harmful to juveniles during nesting season. Ongoing original research on platypus behaviour and creek ecological conditions may be used to adjust these objectives in future.

Table 1 Platypus habitat preferences and hydraulic criteria adopted for Monbulk Creek

Habitat type	Habitat attributes	Hydraulic conditions
Wetted habitat	Total area of stream inundated, influencing food availability and foraging area.	Depth > 0
Swimmable (body-cover) habitat	Area of stream with depth great enough to fully submerge a platypus body, allowing diving and hiding behaviours.	Depth > 0.15 m
Pool habitat	Area of pool habitat, an important foraging zone for platypus (e.g. McLachlan-Troup et al. 2010).	Velocity < 0.2 m/s and depth > 0.3 m (Rosenfeld et al. 2011)
Large wood habitat	Surface of large wood under water with potential to be colonised by waterbugs, which make up platypus diet (Coleman 2006).	Wetted large wood surface area under water surface
Overbank flooding	Overbank flooding is avoided during nesting season when juveniles are in burrows (Serena et al. 2014).	Depth < bankfull depth (October to April)

Step 2: High resolution instream survey: what physical habitat exists?

Next, high-resolution survey allows the spatial distribution of instream habitat to be characterised accurately. Possible survey methods that can characterise underwater habitat include green lidar (which penetrates water), sonar bathymetry, or manual feature survey using instruments such as a total station. For Monbulk Creek, aerial survey methods were prevented by dense canopy, and sonar methods were prevented by shallow water and wood prevalence. Therefore, survey was undertaken using a total station.

A full census of streambed bathymetry over an entire stream is usually not feasible if manual methods are used, in which case a reasonable sampling scheme needs to be designed. The number of sites needs to be great enough to capture the longitudinal variability of the stream, the length of each site needs to capture the within-reach heterogeneity, and the detail at each site needs to be tuned to the scale of the stream and its habitat features. For Monbulk Creek, eight reaches, each around 180 m in length, were surveyed, across a total study stream length of around 4 km (the length of stream segment to which controlled releases will be discharged). The survey picked up the channel centreline, top and toe of each bank, other defined edges and breaks of slope, and additional points to infill details as required (Figure 1B). The stream averaged around 5 m wide at bankfull stage, and surveyed point spacing was around 1.8 m on average, with greater point density in the low-flow channel. Every piece of large wood greater than 0.1 m in diameter and 1 m in length was also surveyed, to allow large wood habitat to be quantified as a metric of interest.

Step 3: Hydraulic modelling and habitat-flow curves: what is the relationship between flow and hydraulic habitat?

Survey data from Step 2 is then processed to create hydrodynamic models (using software such as TUFLOW, MIKE by DHI, River2D) that preserve their level of detail. These models use a numerical representation of the bed bathymetry and roughness, and solve fluid dynamics equations to simulate flow patterns (i.e., flow depth and velocity) across the bed. Usually, two-dimensional (2D) models are most appropriate to simulate instream habitat because 2D flow patterns across the stream bed are important but simulating vertical flow movements (i.e., three-dimensional modelling, which is very computationally intensive) is usually not required.

For Monbulk Creek, a 2D TUFLOW model was constructed for each reach. A grid-based model was used with a resolution of 0.5 m, including sub-grid-sampling, to capture the fine detail of the survey data. The models were calibrated to observed flow and water level conditions, then a range of steady-state flows was simulated in each reach, ranging from very low baseflows (0.5 ML/d) up to overbank flows (500 ML/d). A custom script in the data-analysis software R was used to calculate each habitat metric for each flow rate, from the simulated water level and velocity grids outputted by TUFLOW (Figure 3A and 3B). The habitat-flow curves were then normalised by reach length to make them comparable between reaches and aggregated over all the reaches downstream of the stormwater interventions to give an overall flow-habitat relationship for the study area (Figure 3C). Bankfull flow was also determined for each reach by determining the flow which first started to spill onto the floodplain.

Step 4: Integration with stormwater control systems

Flow-habitat curves can be used to set design and operation objectives for stormwater management systems. Once initial surveys and modelling are developed (Steps 2-3), the results can be embedded into simple workflows in spreadsheets or code, meaning that specialised modelling expertise, software and computational power are only needed at the outset.

Ecological objectives defined in this way can be managed or optimised alongside more typical objectives related to water quality and flood protection. They can be applied to passive or actively managed systems, but are particularly well suited to RTC systems such as the Monbulk Creek Smart Water Network. RTC systems provide the flexibility to apply different objectives depending on shifting conditions and priorities (e.g. adapting to climate change, applying different rules for different seasons, integrating new research on habitat needs).

The flow-habitat curves developed in Step 3 were integrated into algorithms for stormwater control in Monbulk Creek. The control system specifies release rates from real-time controlled stormwater storages to optimise for the physical habitat metrics, within the limits of the water (during low-flow periods) or retention capacity (during high-flow periods) available within the network. The release algorithm has a lookup function to calculate the four habitat metrics (from Table 1) for each of the surveyed reaches, for a given flow rate. For ease of computation, polynomial and power functions were fitted to the modelled curves in a piecewise fashion (see Eq. 1 for example).

$$A_{pool} = \begin{cases} -1{,}11 \times 10^{-4}Q^3 - 4.43 \times 10^{-3}Q^2 + 1.12 \times 10^{-1}Q + 1.35 \quad for \; 0.5 \leq Q < 10 \\ 6.86 \times 10^{-5}Q^3 - 3.64 \times 10^{-3}Q^2 - 2.09 \times 10^{-2}Q + 2.42 \quad for \; 10 \leq Q < 30 \\ 3.02 \times 10^{-4}Q^{-3.33} \quad for \; 30 \leq Q < 100 \\ 3.09 \times 10^{-7}Q^2 - 6.66 \times 10^{-5}Q + 6.65 \times 10^{-3} \quad for \; 100 \leq Q < 500 \end{cases} \qquad [1]$$

where A is pool area in m^2 per m of reach length and Q is Flow in ML/d. Building in these equations allows the control algorithm to deliver the optimal hydraulic environment (based on the habitat metrics and seasonal rules) for each reach along the creek, by choosing from which storages to release water, based on the location at which they discharge to the stream.

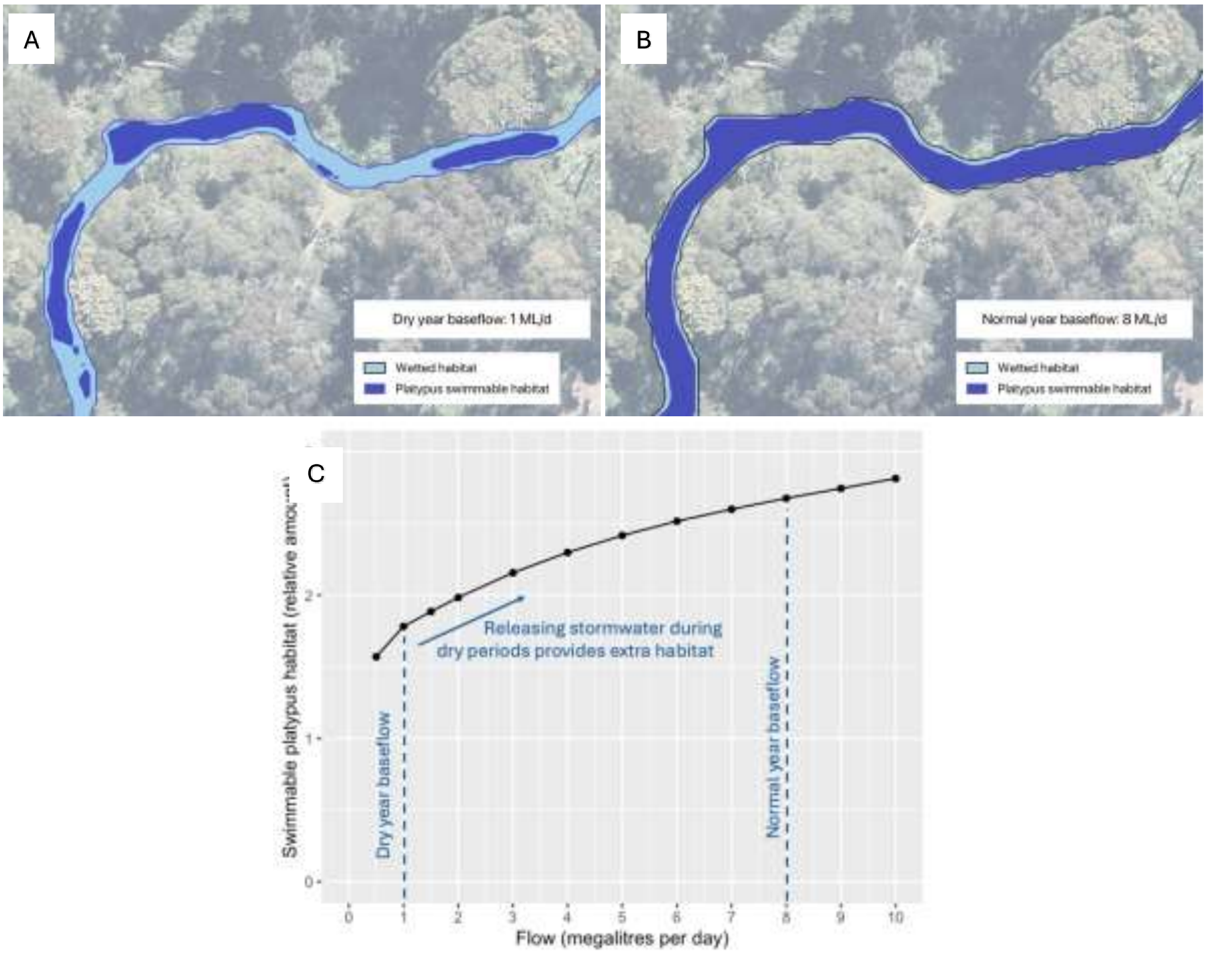

Figure 3 Example of (A) platypus swimmable habitat map for 0.5 ML/d and (B) 8 ML/d; (C) overall habitat-flow relation for platypus swimmable habitat showing the effect of releasing stormwater during very low baseflow. The y axis represents the area of available habitat per reach length (in m^2/m), such that an increase from 1 to 2 m^2/m corresponds to a doubling of the habitat area

Future prospects and challenges

The method presented here is highly suited to environmental flow problems where hydraulic habitat conditions for species or values of interest can be defined (e.g., an iconic or endangered species known to be sensitive to flow conditions). The approach can be used for design, planning, and operation in a variety of settings. For example, similar approaches are commonly used for defining environmental flow objectives and setting rules in regulated rivers. In urban settings, hydraulic habitat approaches can be used to design passive stormwater control systems, as well as to design and operate actively controlled (i.e. RTC) stormwater control measures. Coupling habitat-flow curves with forecast-based storage releases offers a path to more proactive habitat protection under a drying climate.

The approach could extend to other flow-sensitive taxa (e.g. fish, crayfish, riparian vegetation) in urban streams. A key challenge still to be resolved is how best to manage complex sets of rules and optimisation problems when integrating multiple objectives into stormwater RTC algorithms, a challenge which will only grow as the number of taxa and flow requirements increases. Approaches for combining flow objectives for multiple species will likely be required. Such methods, whereby complexity is accounted for and then collapsed into simplified objectives, still need to be tested against simpler methods of defining integrative flow objectives for stream ecosystem health.

Additionally, beyond flow requirements, other habitat factors, such as cover and predation, may exert strong controls on target species. Protecting iconic and endangered species in urban waterways will likely require a suite of interventions alongside stormwater management. Ongoing monitoring of ecological outcomes (e.g., platypus populations, breeding success) is needed to confirm the effectiveness of flow manipulations, alongside further research into how platypus behaviour responds to specific flow interventions. Mechanisms to evaluate and adjust models and algorithms as knowledge evolves and conditions (e.g. channel form, climate) change will also be required, and will need to extend beyond typical project implementation timelines.

Conclusions

The method presented here offers a pathway to greater ecological relevance in stormwater management. Real-time control enables more adaptive, multi-objective systems with greater environmental and societal benefit. Defining sound ecological objectives for smart stormwater networks requires understanding target organism requirements, modelling flow-habitat conditions, and aggregating habitat metrics through clear conceptual models, from which ecologically appropriate management objectives and operating rules can be derived. Applying this method to Monbulk Creek enables a smart stormwater management approach with a clear, evidence-based connection to platypus protection. Realising this potential at scale will require resolving how multiple species and objectives are integrated within stormwater control algorithms, and pairing model-based flow objectives with ongoing ecological monitoring to confirm real-world outcomes.

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