Multi-objective optimization in Water Systems

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A multi-objective optimization-based strategy is developed to determine the optimal releases from real-time controlled storages, with the aim of simultaneously minimising flood risk, augmenting water supply and protecting stream ecosystems that are home to platypuses and other aquatic species.

Background

Urbanization changes catchment hydrology and degrades urban waterways [1]. The expansion of urban impervious surfaces increases stormwater runoff, exacerbating flooding and channel erosion. Meanwhile, it reduces baseflow, decreasing habitat for aquatic species.

Real-time controlled rainwater storages can mitigate these problems by intercepting rainfall and releasing it slowly (more 'naturally') back to the streams (called 'environmental flows'), while also providing alternative water sources for household use. These benefits can be maximized when we manage a system of storages as an optimised network. In this research, an optimization-based strategy to control the entire network of storages is developed and tested through an experimental study in Monbulk Creek, which is a critical habitat for platypuses.

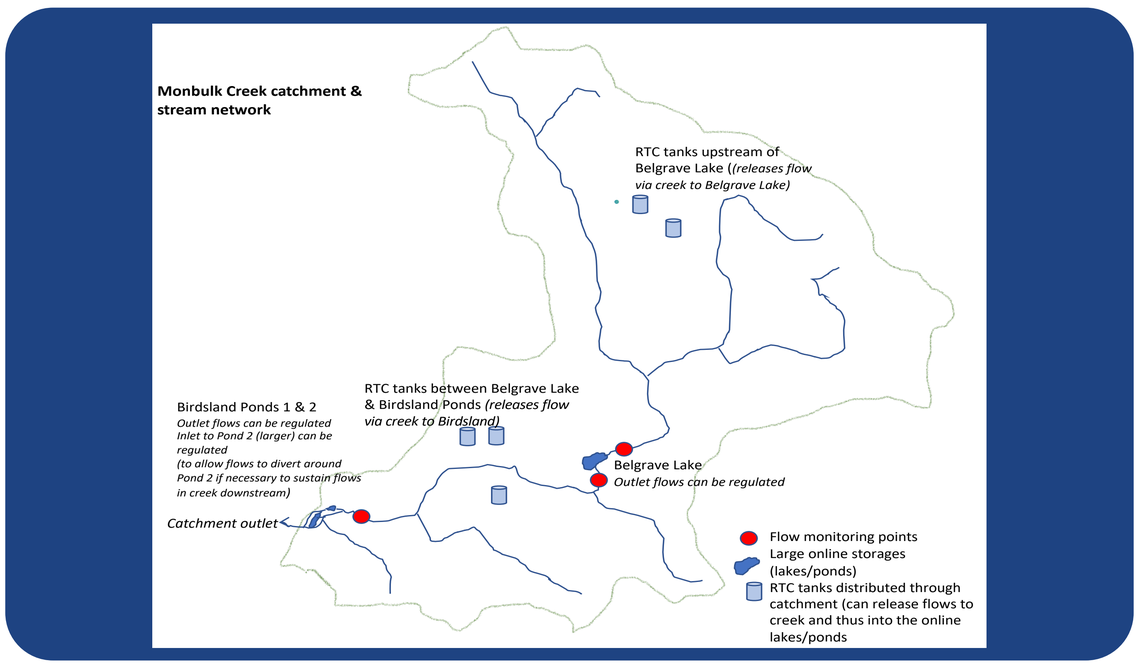

Figure 1: Schematic stream network of Monbulk [2].

Methodology

The network of Monbulk Creek is shown in Figure 1. Up to 100 rainwater tanks will be installed to on private and public land to collect and retain rainwater runoff. The lakes and ponds, receiving flows from upstream tanks and the creek, act as regulating storages to deliver targeted environmental flows. By remotely controlling the releases from all storages, excess runoff is transformed into a source of non-potable water supply for households and a more natural downstream flow regime.

In the optimization-based strategy, the three objectives (flood reduction, water supply and baseflow restoration) are incorporated into a mixed integer linear programming model, and the receding horizon control is utilized to account for future events. The optimal release plan is selected considering both specified priority rankings and trade-off among the objectives. To examine this strategy's performance, it is tested and compared with the existing conventional and rule-based strategies through computational experiments.

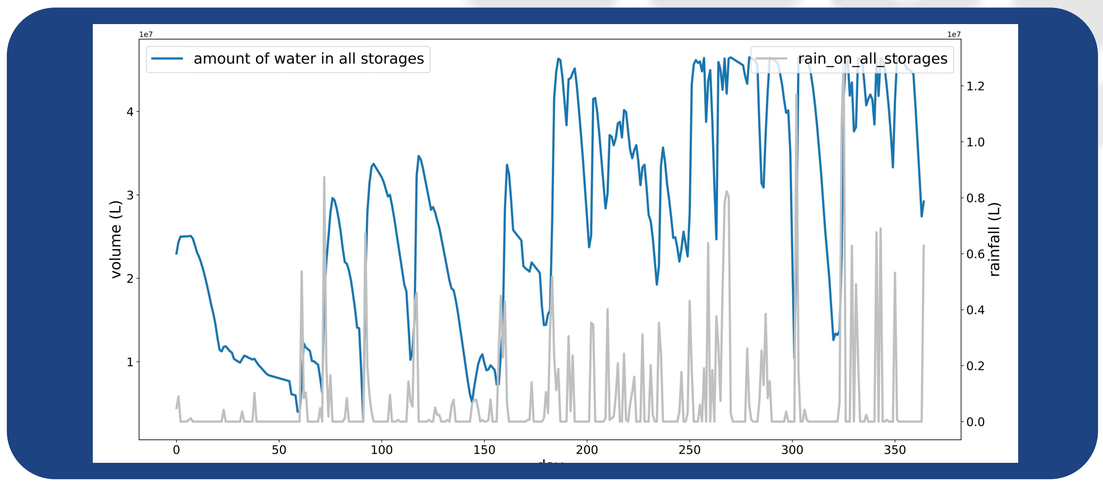

Figure 2: Amount of water in storages vs. rainfall for the optimization-based strategy.

Results and Discussion

The optimization-based strategy is tested across an annual cycle. As shown in Figure 2, it manages to release water before the storm to reduce overflow (e.g. before day 300, 325), and restore baseflow during dry weather (e.g. the first 60 days). It is observed to significantly outperform the existing conventional and rule-based strategies in overflow reduction and baseflow restoration (Table 1).

However, the strategy is tested based on perfect forecast, ignoring the reality of forecast errors. To improve this strategy's applicability, stochastic programming and robust optimization techniques can be incorporated to handle the uncertainties. In addition, the mixed integer linear programming problem is theoretically NP-hard and it is observed to take a long time to solve for some circumstances. Future work will tackle this.

strategies	overflow (L)	deviation from household supply (L)	deviation from target baseflow interval (L)
conventional	186403200	4060800	2020359300
rule	161551454	4060800	1579817540
optimization-based	67160432	8381814	1413850561

Table 1: Comparison of annual Performance of different strategies, with lower values more optimal.

Conclusion

A basic optimization-based strategy has been developed and achieves significant results theoretically, yet there is still room for improvement. We aim to develop an strategy that can act as a template for urban water management, and tackle the challenges in Monbulk Creek and beyond.

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FOR FURTHER INFORMATION

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REFERENCES

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[2] T. Fletcher, "Monbulk network simple schematic," (Unpublished), 2022.

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