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Understanding catchment hydrology approaches for flow estimation

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Abstract: Flood estimation remains a critical challenge in Australia, a country frequently exposed to severe and damaging flood events (Johnson et al., 2016). Nathan & Ladson (2019) suggests that in the Australian context, floods are primarily driven by the rainfall that generates large streamflows. For flood estimation, the transformation of rainfall into runoff is typically represented using hydrological models. These models simulate the underlying rainfall-runoff processes and provide the basis for estimating design floods.

A range of hydrological modelling approaches is applied across Australia, varying in complexity, data requirements, and the level of detail (Kemp & Daniell, 2020). The Australian Rainfall and Runoff (ARR) guidelines classify these approaches into three categories as lumped, semi-distributed, and distributed models, according to how they represent the spatial variability of hydrological processes (Nathan & Ladson, 2019).

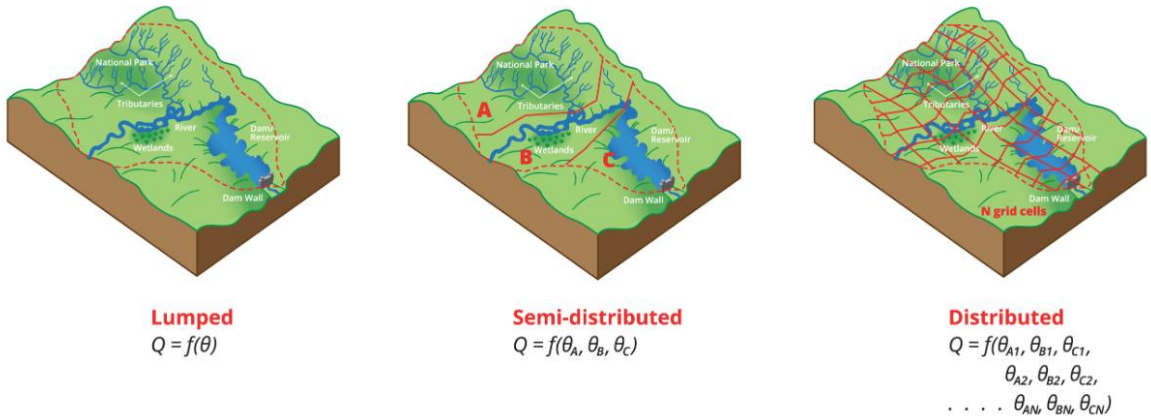

Figure-1 Spatial Representation of Hydrological Processes (ARR 2019, Book 4 Figure 4.2.5)

Lumped models treat the catchment as a single unit, using spatially averaged rainfall and simplified routing models, offering computational efficiency but limited spatial detail. Semi-distributed models divide the catchment into sub-areas to capture spatial variability in rainfall, losses, and routing, and are widely used in design flood assessments. Distributed models adopt a grid-based framework, requiring more detailed inputs and yielding highly resolved outputs, often coupled with two-dimensional hydraulic routing to better capture spatial flood behaviour (Ryan et al., 2022)

This study applies and compares these approaches for a small rural catchment in Finch Hatton in Queensland as a case study. The Probabilistic Rational Method and the GR4H model are used to represent lumped approach, RORB is applied as a semi-distributed model, and TUFLOW rain-on-grid is employed as a fully distributed model.

Models were calibrated against three recorded flood events at the downstream flow gauge on Finch Hatton Creek (Figure 2). Calibration performance was assessed using the Nash–Sutcliffe Efficiency (NSE) and/or peak ratio, with final parameter sets derived from weighted averages based on both performance metrics and event magnitudes.

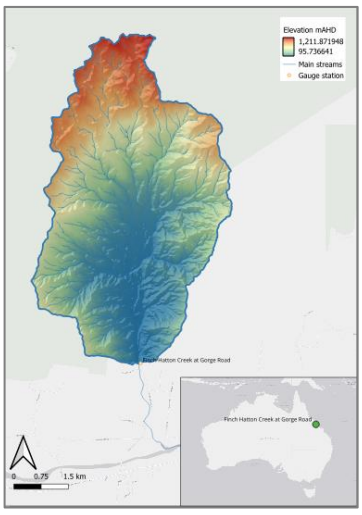

Figure-2 Finch Hatton catchment map

Using the calibrated models, design event flows were estimated for a range of Annual Exceedance Probabilities (AEPs) from 10% to 1%. The resulting peak flows from each approach were compared with Flood Frequency Analysis (FFA) and Regional Flood Frequency Estimation (RFFE) benchmarks.

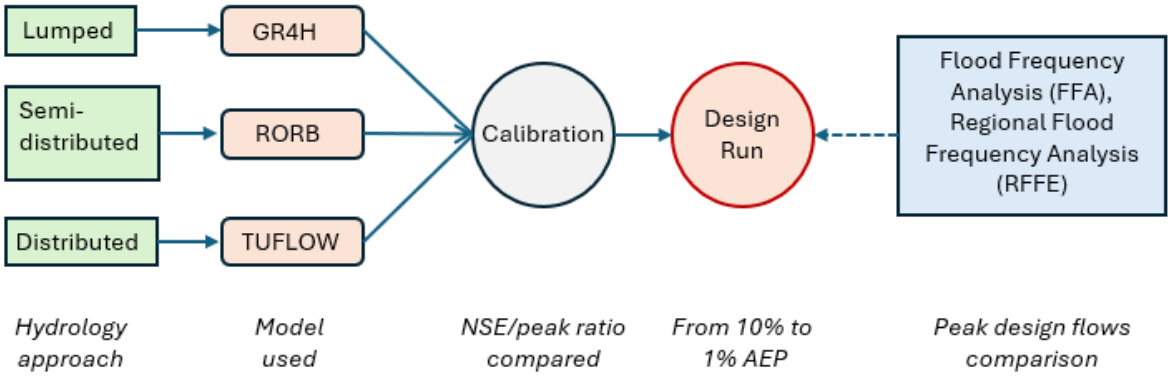

Figure-3 Methodology flow diagram

The study highlights the differences in outputs produced by each modelling approach and evaluates their relative strengths. Results show that while complexity, data demands, and computational effort increase from lumped to distributed methods, the outputs also become more informative and valuable for flood risk management. Moreover, the study highlights the potential of joint calibration of hydrological and hydraulic models, showing the inclusion of flood level observations or satellite-derived flood extents can improve confidence in flood estimates and enhance model reliability.

REFERENCES

Johnson, F., White, C. J., van Dijk, A., Ekstrom, M., Evans, J. P., Jakob, D., Kiem, A. S., Leonard, M., Rouillard, A., & Westra, S. (2016). *Natural hazards in Australia: floods, Climatic change*, *139*(1), 21-35.

Kemp, D., & Daniell, T. (2020). A review of flow estimation by runoff routing in Australia – and the way forward. *Australasian Journal of Water Resources*, *24*(2), 139–152.

Nathan, R., & Ladson, A. (2019). Book 4: Catchment Simulation, Chapter 2: Hydrologic Processes Contributing to Floods. In J. Ball, M. Babister, R. Nathan, W. Weeks, E. Weinmann, & I. Testoni (Eds.), *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia.

Ryan, P., Syme, B., Gao, S. and Collecutt, G., 2022. Direct rainfall hydraulic model validation. In: *Proceedings of the 40th Hydrology and Water Resources Symposium (HWRS 2022)*. Engineers Australia. ISBN 978-1-925627-64-0.

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