Long-term streamflow projections: A summary of recent results from the Millennium Drought

M.C. Peel [a], M. Saft [a,b], K.J.A. Fowler [a], A.W. Western [a], L. Zhang [b], N.J. Potter [b], T.J. Peterson [a], J.-M. Perraud [b]

[a] *Infrastructure Engineering, The University of Melbourne, Victoria*
[b] *CSIRO Land and Water, Canberra, ACT*
Email: mpeel@unimelb.edu.au

Abstract: The recent Millennium Drought in South-Eastern Australia (1997 – 2009) was a 13-year extended dry period during which unusual catchment responses with significant implications for long-term streamflow projections were observed. Here I present a summary of recent results using the Millennium Drought as an observed case study of a prolonged dry period to investigate actual catchment response and hydrologic model performance during the drought. I draw conclusions from these results relevant to future long-term streamflow projections.

Saft et al (2015a) observed a statistically significant downward shift in the long-term annual rainfall-runoff relationship in just over half of the catchments investigated. During the drought all catchments experienced rainfall at the lower end of their historical annual rainfall-runoff relationship. However, in catchments that experienced a downward shift in rainfall-runoff relationship, during the drought a given amount of low rainfall resulted in an even smaller than usual amount of runoff. Drought severity was not a strong predictor of whether a catchment experienced a downward shift in annual rainfall-runoff relationship. Rather, drier, flatter and less forested catchments were more susceptible to a shift in relationship. The internal catchment processes responsible for the shift remain unclear, but connectivity between surface water and groundwater is strongly suspected.

The implications of this downward shift in annual rainfall-runoff relationship for runoff modelling during prolonged dry periods, like a climate change impact assessment, was investigated by Saft et al (2015b) using observed runoff during the Millennium Drought. Calibrating six conceptual rainfall-runoff models prior to the Millennium Drought and evaluating their performance during the drought, Saft et al (2015b) found model performance was acceptable for catchments without a shift in annual rainfall-runoff relationship, but significantly degraded in catchments with a shift in relationship. In catchments where model performance was degraded all six models over-estimated runoff, with average model over-estimation ranging from ~35–140%, with a model ensemble average overestimation of 93%. Developing an understanding of which catchments are likely to experience a change in annual rainfall-runoff relationship during prolonged dry conditions is therefore vital for providing realistic long-term streamflow projections into the future.

Finally, Fowler et al (2015) investigated whether poor conceptual rainfall-runoff model predictive performance during the Millennium Drought was due to poor model structure or selection of model parameters that are non-robust to changing conditions. Using a Pareto approach, Fowler et al (2015) searched for parameter sets within five conceptual rainfall-runoff models that could successfully model pre-drought and drought conditions using the same parameter set. In a comparison with parameter sets identified through calibration on the pre-drought period and evaluated over the drought (a traditional Differential Split Sample Test, DSST), about half the cases where the DSST indicated the model was incapable of successfully modelling both pre-drought and drought conditions, the Pareto approach had identified a parameter set capable of modelling both successfully. Thus, in these cases the model structure contained a robust parameter set, but the calibration procedure had failed to find it. The implications of this study are that poor conceptual rainfall-runoff model performance in predicting dry conditions is not entirely due to poor model structure, but is also due to not finding the model parameters that are robust to changing conditions during calibration.

References

Fowler KJA, Peel MC, Western AW, Zhang L, & Peterson TJ (2015), Predicting runoff under changing climatic conditions: revisiting an apparent deficiency of conceptual rainfall-runoff models. *Water Resources Research*, under review.

Saft M, Peel MC, Western AW, Perraud J-M & Zhang L (2015b), Bias in streamflow projections due to climate-induced shifts in catchment response. *Geophysical Research Letters*, under review.

Saft M, Western AW, Zhang L, Peel MC & Potter NJ (2015a), The influence of multiyear drought on the annual rainfall-runoff relationship: an Australian perspective. *Water Resources Research*, 51, 2444–2463.