# The role of model complexity in assessing water supply system resilience

HR Wallingford
Working with water

Contact: Mason Durant
m.durant@hrwallingford.com
www.hrwallingford.com

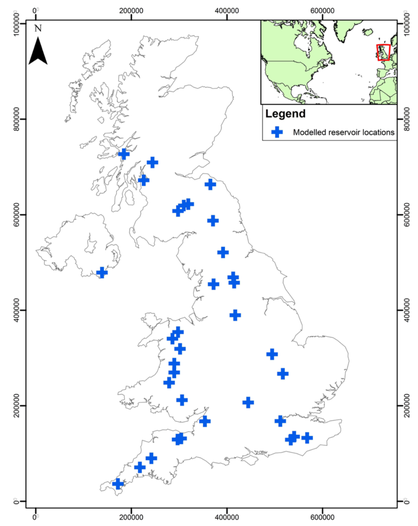
Durant, M., Counsell, C. & Simm, J.

## Water supply system modelling using statistical and deterministic approaches to highlight the role of each method in assessing system resilience at the regional and national scale.

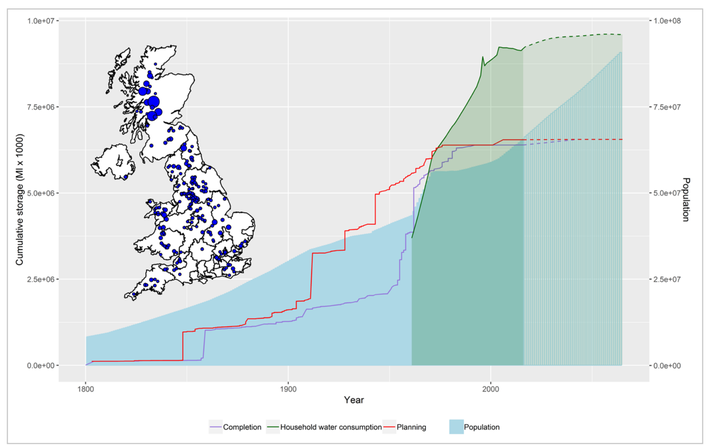
## Background

Assessing water supply system resilience from local to national scale is becoming increasingly important as system pressures, including climate change impacts and population, increase. The resilience of water supply systems in the United Kingdom (UK) to droughts of differing intensity and duration has traditionally been assessed through local scale simulation of a range of extreme droughts using detailed water supply system models. This process can be time consuming, data intensive and in some cases, the input effort is not proportionate to the impact of results. It is also challenging to coherently aggregate such outputs to regional and national scales.

This poster summarises work undertaken as part of the Historic Droughts project – a cross-disciplinary project funded by the UK Research Councils – to develop a national understanding of water supply system response. The inter-disciplinary nature of the project and the assessment of water supply at regional and national scales necessitated a simple modelling approach with rapid analysis times and minimal data input, in contrast to the more complex models increasingly being used in the industry. The role such a modelling framework has in assessing national scale water supply system resilience and its potential use as a near-term planning tool are also discussed.




Study area

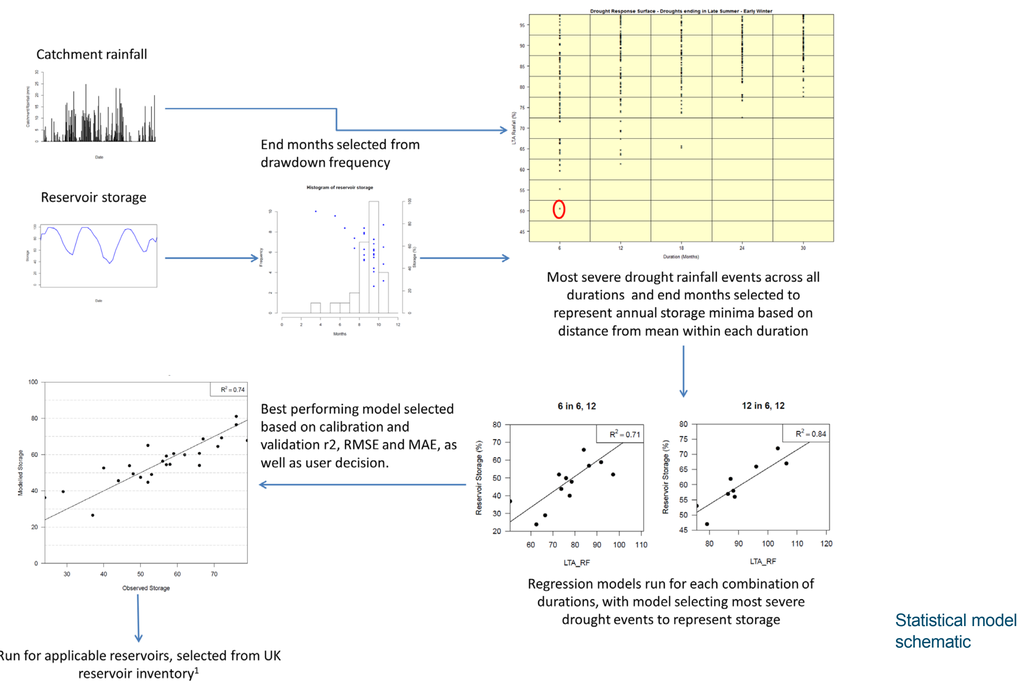



UK reservoir history and possible future

*Storage and planning data [1], Population data [2], Water demand data [3]*

## Method

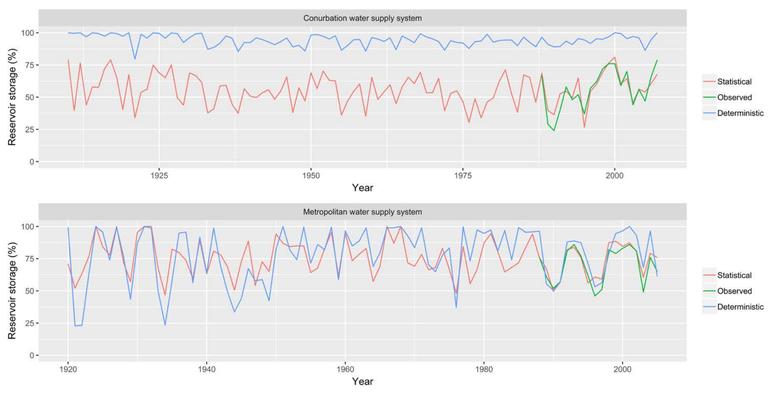
The UK has a long temporal and high density spatial rain gauge network, which allows estimates of rainfall at all locations in the UK [4]. Water supply reservoir storage levels have also been recorded for many important water supply systems from circa 1988 until the present day as part of the National Hydrological Monitoring Programme. These datasets facilitated a machine learning modelling approach, with statistical relationships between rainfall deficits and reservoir storage determined for system critical durations used to hind-cast historic reservoir storage back to 1890. The use of reconstructed streamflow as an explanatory variable was also explored, but a lack of suitable data reduced the impact of a machine learning approach using this method.




Statistical model schematic

## Comparison with deterministic modelling results

The results of the statistical modelling were compared against deterministic modelling for two water supply systems – Metropolitan and Conurbation. Deterministic modelling was undertaken using the traditional approach of hydrological modelling, followed by mass balance calculations using supply and demand on a daily timestep. The statistical approach has a better fit with the observed record for the Conurbation water supply system, however, the scenarios under which both approaches have been developed must be considered. Deterministic approaches have been run with the current system under a specified level of demand, whereas the statistical approach has been run taking into account system characteristics and demand over the near-recent past (1988-2015).

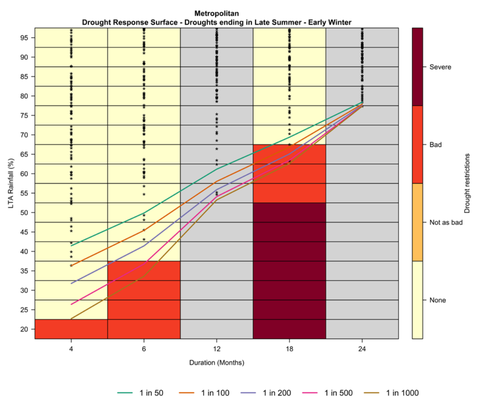



Model validation

## Discussion around resilience

The drought response surface [5] has become a useful tool in UK water supply system planning to quickly visualise modelled outputs, and therefore resilience, to droughts of differing intensity and duration. Statistical analysis was used to translate storage to customer impacts through levels of service for water use restrictions and drought permits. In the context of the statistical method, the Metropolitan system is least resilient to droughts of 4, 6 and 18 month durations, and that for these durations, system impacts would be worse during an 18 month drought of the same severity.

Understanding how droughts of different intensity, duration, timing and spatial extent impact system performance across a region or country requires rapid comparison for ensembles of climate data. This can be applied to the statistical model in the context of forecasting water supply system response to near-future rainfall scenarios, or as a diagnostic tool for assessing the capacity of climate models and weather generators in reproducing drought events.



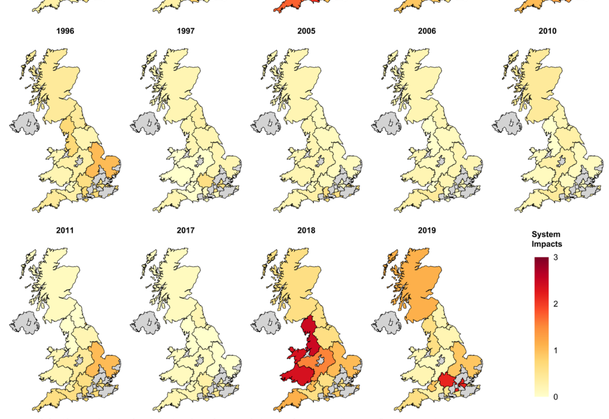

Metropolitan drought response surface

### System resilience information from statistical approach:

- Highlight system critical drought durations.
- Predict system response to meteorological droughts.
- Models can perform poorly due to an insufficient number of observed reservoir drawdowns, indicating that the system is resilient to droughts within the observed record.
- Includes measures of uncertainty around storage estimates.
- Can be applied quickly and for a large number of systems and underpin regional / national studies.

### Limitations to the statistical approach:

- System resilience is only accurate for meteorological events with similar characteristics to those within the observed historic record, based on the data used to train the model.
- Different demand scenarios cannot readily be simulated directly within the model. System characteristics can be accounted for through partitioning of the training data to derive different relationships, therefore allowing an assessment of the change in system resilience due to system changes.




National scale historic drought and near-term forecast

### Limitations of deterministic approach:

- Time consuming.
- Data intensive.
- Costly (resources and money).
- Input effort sometimes disproportionate to impact of results.

## Summary

The benefits and limitations of both the deterministic and statistical approaches demonstrate that there are roles for both within water supply planning at the regional and national scale. The deterministic approach will always be required where accurate local scale estimations of system behaviour under drought events, and testing of operational responses, are needed for decision making and detailed investment planning. However, the statistical approach could be used to rapidly develop national scale assessments and near term outlooks, comparing system behaviour and resilience in different areas under different weather forecasts or future climate scenario ensembles. Such approaches may also have particular applications in data and model poor regions. Similar methods could also be developed for other aspects of the water supply network, including groundwater systems.

## References

[1] Durant, M.J. & Counsell, C.J. (2018). Inventory of reservoirs amounting to 90% of total UK storage. NERC Environmental Information Data Centre.

[2] United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.

[3] Artesia Consulting (2018). The long term potential for deep reductions in household water demand (AR1206).

[4] Tanguy, M.; Dixon, H.; Prosdocimi, I.; Morris, D. G.; Keller, V. D. J. (2016). Gridded estimates of daily and monthly areal rainfall for the United Kingdom (1890-2015) [CEH-GEAR]. NERC Environmental Information Data Centre.

[5] Environment Agency (2015). Understanding the performance of water supply systems during mild to extreme droughts (SC120048/R).