About Drought

Maximising the impact of UK research on drought & water scarcity

BRIEF

How to plan and manage water resources for public water supply: future directions

The UK is facing pressing water supply challenges. The impacts of a growing population and changing climate mean that the UK is increasingly vulnerable to water shortages, erratic weather events, and associated environmental, economic, and social disruption. To remain resilient in these uncertain conditions, the effective planning and management of public water resources is vital.

To determine how this can best be achieved, the UK Government set up the Drought & Water Scarcity Research Programme.[1] This brief aims to share relevant findings from the programme with water planners and managers, so that they can be put into practice moving forwards.

Main findings:

- The UK faces water supply shortages in the future, especially in London & the south-east. Increases in frequency & intensity of drought & high-precipitation events are projected in most regions.
- Uncertainty is 'the new normal' & conventional approaches to forecasting (based on past observed data) are less reliable than they were. Risk-based planning provides a more effective alternative framework.
- Decision support for risk-based water resource planning is already available.
- A 'blueprint' for the water industry has been proposed. It is based upon system simulation modelling, multi-objective optimisation tools, and sensitivity analysis.

Context: what are the issues with future water supply in the UK?

Public water companies in the UK are required to provide safe and wholesome supplies of water to the population. However, there are a number of pressing challenges facing the water industry, including the demands of population growth and the need to sustainably manage the nation's aquatic environment.

What is more, the impacts of climate change are leading to more erratic weather patterns. Modelling and data analysis tell us that, in the future, the UK is likely to experience:

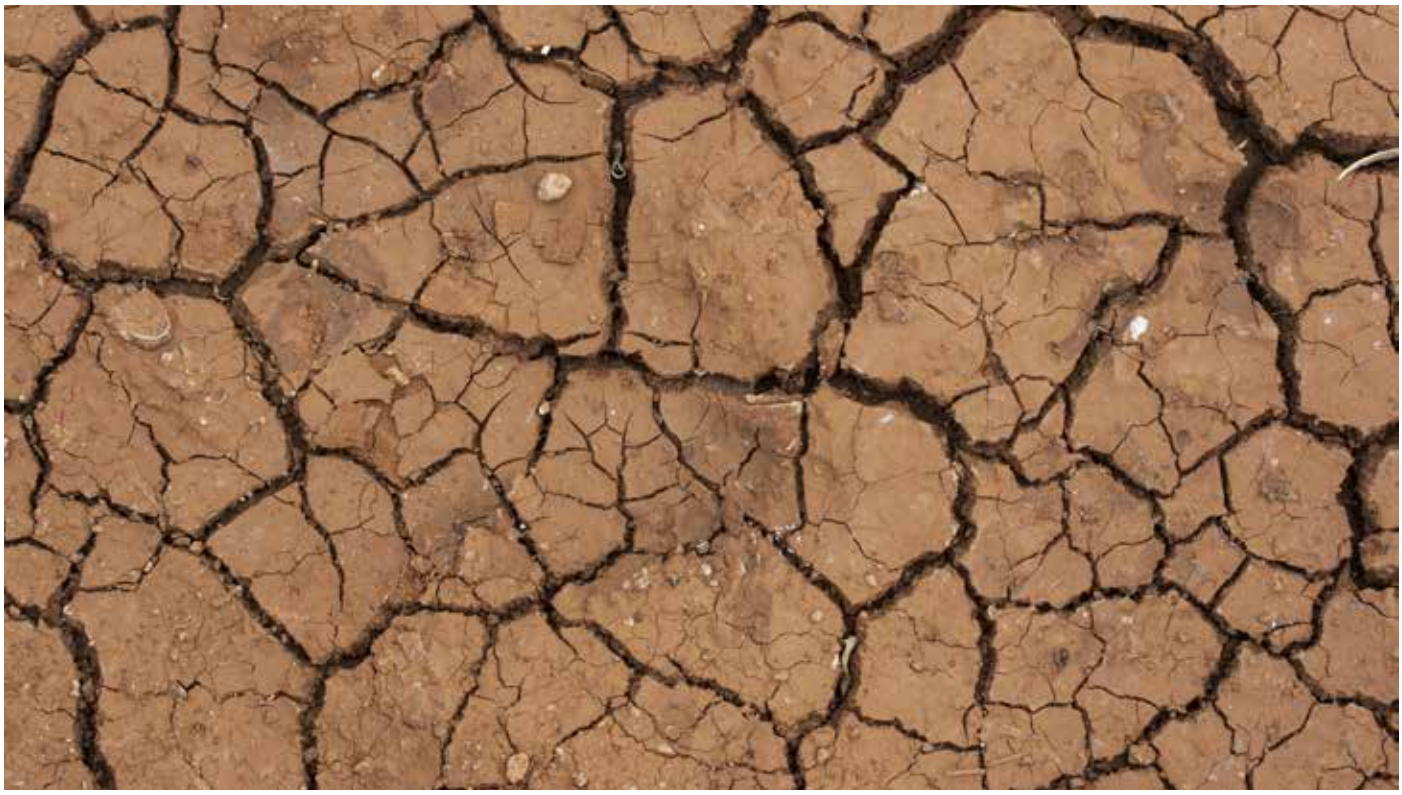
- Small precipitation increases in winter and larger precipitation decreases in summer (on average), leading to an overall drying effect.[2]
- Increases in frequency and intensity of drought and high-precipitation events in most regions.[2]
- More severe droughts, which will affect larger areas of the country.[3]
- Low river flows, particularly in the south of the UK.[4]

These uncertain conditions are expected to place further pressure on public water supplies, increasing the UK's vulnerability to water shortages and associated social, economic and environmental disruption.

Appropriate adaptation measures are needed. If no action is taken and business continues as usual, the Environment Agency warns that England faces water supply shortages by 2030.[5] All regions of the UK are likely to be affected, with London and the south-east region at particular risk.[6] According to the Greater London Authority, the UK capital is likely to face supply problems by 2025 and serious shortages by 2040.[6] For this reason, the BBC has placed London on a list of 11 cities that, like Cape Town, are at risk of running out of water.[7]

Action must be taken to safeguard the UK's public water supplies. Conventional approaches to managing water shortage risk continue to hold promise. For example, it is estimated that one-third of water taken from the natural environment in the UK is wasted, and efforts to reduce this wastage

How can we understand the risks?



(e.g. through water efficiency measures and leakage reduction) have significant potential.[6] However, it is unlikely that such actions will be sufficient, on their own, to meet future challenges. For this reason, innovative approaches to water resource planning and management are required.

People often think of the UK as a "wet" country.[8] This, combined with a number of large-scale flooding events in recent years, means many members of the public are more concerned about floods than droughts.[3] Nonetheless, drought events are projected to become more severe and affect larger areas of the country over the coming century.[3] Further, the rainfall received over the UK is not always close to large centres of population which mean that some areas, such as the south east, have less water per person than countries acknowledged to be water scarce, such as Morocco. Efforts should therefore be made to engage the public in awareness of drought risk and in initiatives to use water more efficiently.

Uncertainty is the 'new normal'

In addition to engaging with water users, water resource planners and managers should take steps to prepare for the erratic droughts of the future. This is challenging as climate change mean that the UK is facing a 'new normal' that is marked by uncertainty. Until now, investments in new pipes or reservoirs have been based on estimates of future water availability and needs, which are made using past observations.[6] In these rapidly changing and uncertain times, however, past observations can no longer function as effective predictors of future conditions. This means that public utilities and their regulators will frequently find themselves in situations where they have to make decisions in conditions of uncertainty, where it can be difficult to confidently assign probabilities to possible future states.[9] Moreover, whatever approaches are implemented to manage these risks, it is essential that a balance between resilience and affordability is achieved.

A risk-based approach

This is where risk-based planning comes in. According to researchers:

> *"A risk-based approach enables the development of management measures whose costs and impacts are in proportion to the probability and consequences of water scarcity, informed by a mature understanding of droughts from the perspectives of a range of communities and stakeholders. Improved understanding of uncertainties provides the basis for identification of management responses that are robust to uncertainty, reflect society's attitude to risk, and help to make the case for adaptive management approaches informed by targeted data acquisition."*[10]

The 2016 Environment Agency's Water Resources Planning Guideline goes some way towards adopting this approach, in that it requires water companies to assess comprehensively the effects of uncertainty and conduct scenario analysis to test the robustness of proposed plans.[11] However, in order to move to a more explicitly risk-based framework, researchers advise that explicit analysis of risk become a standard requirement for reporting and comparing alternative plans.[11] Specifically, this would require water companies to report the level of risk (in terms of the expected frequency, duration, severity and impacts of restrictions on water use) of their proposed plans.[11]

Simulating the uncertain

The application of risk-based approaches often requires large data sets of extreme events, which are not commonly available. However, hydrological models can be used to simulate past, present and future data sets, and so fill these gaps.

Researchers within the UK Droughts & Water Scarcity programme have been working to develop models capable of simulating data that provide some insight into potential future scenarios. For example, using these models, researchers are now able to simulate:

- Low flow in natural and human-impacted catchments.[12,13] Catchment models can be useful for drought risk management as they are capable of modelling hydrological extremes.
- Extreme weather events using an improved global-regional climate modelling system supported by volunteer distributed computing.[14] Potential uses include impact assessment, and the model has already been used to assess drought-related risks.[14]
- Historic droughts at the national scale.[9,13,15,16] Understanding the characteristics of historic droughts and how these have changed over time may help build future resilience. For example, simulations of drought events from 1891 to 2015 tell us that groundwater-dependent areas typically experience more severe droughts.[9]
- The movement and growth of multiple phytoplankton groups in rivers and reservoirs.[17] This is important, since phytoplankton play a vital role in fluvial ecosystems, are important indicators of river water quality and can prevent the use of water from reservoirs for potable supplies. These models could be applied in climate-change and land-use-change impact analysis, treatment plant design, and for the reconstruction of phytoplankton series.

Decision support for water resource planning

Within a risk-based framework, accounting for uncertainty and robustness is key. How best should public utilities and their regulators go about this? And which factors should guide decision-making?

Choosing a decision-tool

In a risk-based approach, the goal is to identify optimal actions that yield the biggest benefits for a smaller number of states, and robust actions that are resilient to a wide range of different states.[18]

To achieve this, choice of decision-making tool should be calibrated on the basis of various factors. These include:[18]

- The **level of uncertainty** confronting the utility and the regulator.
- The **risk tolerance** of stakeholders, particularly consumers.
- **Institutional capacities**, including resources and skills.

A new approach to cost-benefit analysis

In addition, cost-benefit analysis of water resources investments should be expanded to include concepts of robustness to uncertainty. Researchers have developed a framework that enables difficult decisions to be made and different levels of robustness to be attained under different risk attitudes.[19] The framework involves the following four steps (summarised in Figure 1):

1. Problem framing – including definition of objectives, inputs, decision alternatives, and system model construction.
2. Risk analysis – synthetic climatic sequences are used to estimate a risk metric comprising the three dimensions of duration, severity, and intensity. A classical cost-benefit analysis is carried out to explore the trade-off between risk and cost and inform the identification of a tolerable level of risk.
3. Robustness analysis – robustness to a wide range of futures is integrated into the analysis to explore trade-offs between robustness and cost for a given level of tolerable risk.
4. Option selection – decision-makers select an option that robustly meets their risk attitude and monitor outcomes against their objectives to inform future decisions.

By adopting this framework, stakeholders can trade off costs, risk reduction, and robustness requirements of water investments.

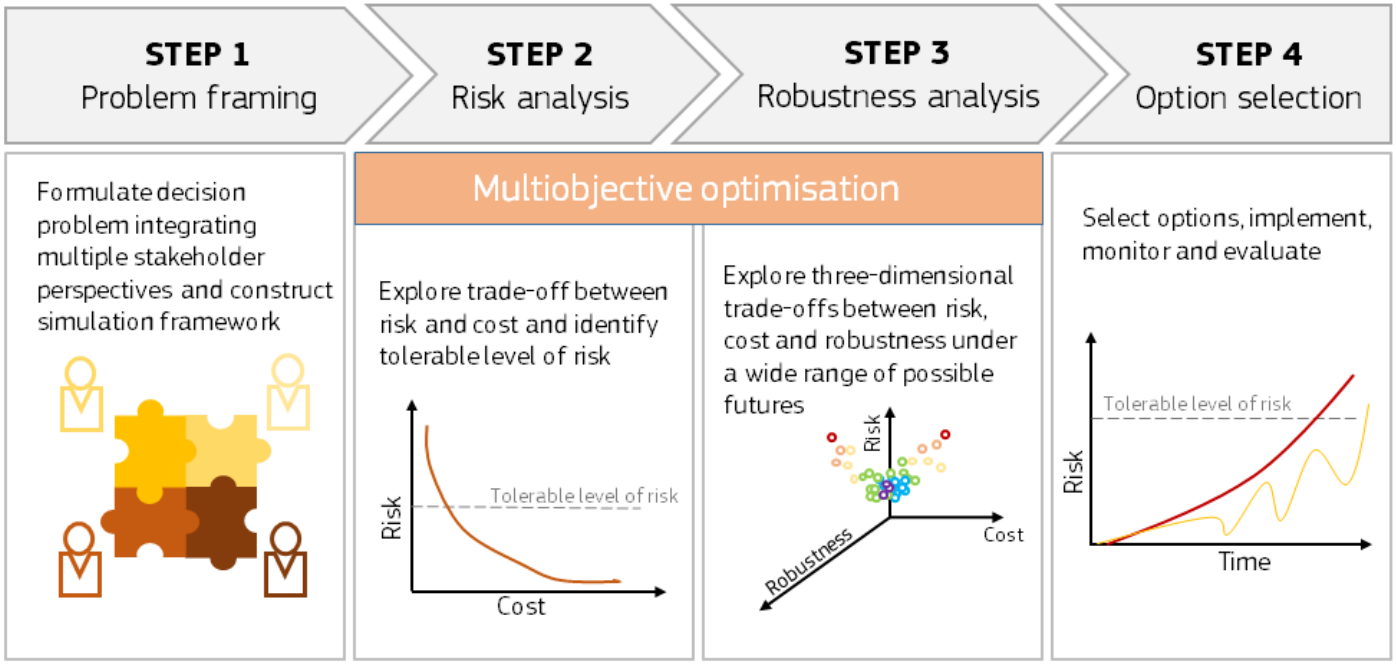


Figure 1. Framework to identify a water resources investment that robustly meets a tolerable level of risk.[19]

Novel data sets and resources

Using a variety of models, researchers within the UK Droughts & Water Scarcity programme have generated a large collection of data sets that can be used to support future water resource planning and management. These include:

- Historic hydro-meteorological data.
- Near real-time drought-related metrics.
- Climate change projection data.
- New social and socio-economic datasets.
- A cross-sectoral inventory of past droughts.
- A database of reservoir construction.

Many of these data sets, together with interfaces for accessing and visualising data over the web and guidance for use of the data, can now be accessed at: http://aboutdrought.info/drought-research/data-and-information/. For more information on these data sets, please email Matt Fry (mfry@ceh.ac.uk).

Future pathways for planning and managing water resources

Investing in uncertain conditions

There is a clear need to shift investment to focus on the "new normal" of a variable climate. A transformation in investment appraisal is therefore needed, with increased focus on the risks, trade-offs, and uncertainties associated with alternative investment pathways.[20]

In practice, this will likely require: [20]

- Accounting for what is known about variability and taking proportionate risk-based decisions.
- Extensive sensitivity testing of residual uncertainties to identify key vulnerabilities and select robust options.
- Promotion of adaptive approaches and system resilience that can cope with unexpected change.

Embracing innovation

To safeguard the UK's water supply, it will also be necessary to invest in new and innovative solutions. For example, researchers at Oxford's Environmental Change Institute have examined various options for meeting London's water supply needs moving into the future. Their investigations show that, compared to conventional approaches such as building new reservoirs or transferring water into the region, recycling treated wastewater back into the Thames would also make sense from an economic and risk reduction standpoint.[6] Such an approach is already in use in Singapore – but implementing this solution in the UK would require a significant change in thinking, and customer acceptance.

Improved forecasting

Moving forward, it is also essential to avoid making assumptions based on past predictions. Researchers working on the IMPETUS project, part of the UK Droughts & Water Scarcity Programme, have been working to improve the skill of UK drought forecasts on monthly to seasonal timescales.[21] Improved forecasts would be valuable for effective drought management and for minimising the negative impacts of droughts.

A blueprint for the water industry

So what could risk-based planning look like in practice? Researchers have put forward a blueprint for the water industry.[11] In this proposal, risk-based water resource planning is based upon:

- System simulation modelling – to estimate the frequency, duration and severity of water shortages at present and in the context of future plans and scenarios.
- Multi-objective optimisation tools – to explore trade-offs between the risk metrics and costs of alternative plans.
- Sensitivity analysis – to identify plans that robustly achieve targets for tolerable risk alongside other performance objectives.

The proposed methodology has been successfully applied in a case study in the Thames basin.[11] This suggests that risk-based planning is ready to be put into practice using available datasets and models.

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About this Brief

This Brief is part of a series aiming to support improved decision-making in relation to droughts and water scarcity by providing research that identifies, predicts and responds to the interrelationships between their multiple drivers and impacts.

About Drought communicates about the UK Droughts & Water Scarcity Research Programme, a five-year, interdisciplinary, £12 million+ NERC programme in collaboration with ESRC, EPSRC, BBSRC and AHRC. It is supporting improved decision-making in relation to droughts and water scarcity by providing research that identifies, predicts and responds to the interrelationships between their multiple drivers and impacts.

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