Editorial

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One of the defining challenges for humanity in the twenty-first century is to respond to a problem of our own making: climate change. Carbon dioxide levels have risen over the past 150 years to stand at a level not seen for at least 400 000 years (NASA, 2017) and global surface temperatures have risen 0.85°C above pre-industrial levels (IPCC, 2014).

Mitigation of climate change requires rapid action to ‘decarbonise’ our buildings, transport and energy systems. However, mitigation alone will not be sufficient. We are already committed to at least ~0.5°C of further global warming due to lags in the climate system, against the aspiration of the Paris Agreement to limit the total rise to well below 2°C, beyond which ‘dangerous’ levels of climate change may occur. Current commitments of mitigation fall well short of the 2°C target.

In addition we are poorly adapted to the current climate. I write this as the UK and much of Western Europe tries to cope with a significant heatwave. Adaptation to climate change is a process which requires long-term planning, cross-sector action and active stakeholder participation. Short-term, narrowly defined and top-down implementation is unlikely to be sustainable. Maladaptation would require further, unplanned adaptation at greater cost and which would be harder to implement. However, we should not be afraid to innovate, as well as use adaptive management – for example, flexible solutions that can be adjusted through time.

Water is both highly sensitive to climate and the medium through which many climate change impacts will be experienced. In the opening paper of this themed issue on sustainable adaptation, Mike Muller (2017) considers what sustainable water management should look like in this period of time, which some term the Anthropocene. Counter to traditional conservation management, Mike argues that we should aim for ‘hydrosupportive’, rather than purely ‘hydrocentric’, water resource management, balancing our water needs with those of the environment; however, to be sustainable this requires activity beyond current practice.

Seeking sustainable adaptation is likely to require new modelling techniques, in particular those which can rapidly test large numbers of future scenarios and the performance of many possible portfolios of adaptation measures. Simulation models provide the ability to do

this and Lan Hoang and Suraje Dessai compare these with traditional optimisation models that seek a single best portfolio (Hoang and Dessai, 2017). These models reveal different vulnerabilities and a combined approach may represent the best way forward.

The relationship between water and agriculture and the sensitivity of these systems to climate change is explored by David Evans (2017). He demonstrates that changes to rainfall and especially evaporation will lead to significant desiccation in eastern England and a much greater need for irrigation than has been the case or has been previously forecast. Storage of water, both on-farm but particularly in larger reservoirs, is seen as the best adaptation measure, with some potential for water transfer. More integrated planning is called for and is underway, for example in the Water Resources East project (WRE, 2017).

There is a perception by some that adaptation should wait for more accurate and precise projections, or to see what happens in future. Both approaches are flawed. In the latter case, unless adaptation is quick and easy, it will be too late, especially considering that severe events, which are often the events of most concern, typically occur infrequently. In the former case there is no guarantee that greater accuracy or precision will be available and in any case validation would also require some waiting. Where science can assist in particular is in identifying uncertainties and, if possible, reducing significant ambiguities.

One such recent case has been the use of operational weather forecasting models for climate change experiments, which has enabled convective storms to be modelled. This has concluded that summer thunderstorms are likely to be more intense in future (Kendon *et al.*, 2014). This is relevant for a number of systems, including sustainable drainage of our urban areas. Murray Dale and colleagues combine these new findings with spatial analogues to provide new estimates of changes to rainfall intensities (Dale *et al.*, 2017). The use of these in sewer models demonstrates an increase in sewer flooding and combined sewer overflows.

In the final paper of the first part of this themed issue we turn our attention to railways. British railways are renowned for their relationship with the weather, notably the seasonal effect on the railway of leaves on the line, although as I write trains

are operating at reduced speed due to the risk of rail buckling. John Armstrong and colleagues focus on the winter 2013–2014 floods using a systems perspective (Armstrong *et al.*, 2017). They then propose a framework for assessing and improving network resilience that prioritises elements of the network with the highest probable costs of disruption, and measures with the highest benefit–cost ratio.

Adapting water, agriculture and transport is vital for these systems, but also ensures that the critical infrastructure and services they provide for a well-functioning society and economy are sustainable for the long term.

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