Managing flood risks in a changing climate

The devastating 14–15 July flood events in Germany, Belgium and the Netherlands took place while the parts of Western North America were witnessing widespread wildfires triggered by the exceptional heat waves of late June with record-breaking temperatures. These two hydrologically opposite events, now seemingly caused by the same culprit, are the latest and among the most unambiguous warnings of what hazards the warmer Earth has to offer to both our and future generations. Early research has provided evidence of attribution of each extreme to human influence on the climate (see World Weather Attribution, 2021a, 2021b).

While these two examples are still extreme events, the year 2021 is not an exception. The World Meteorological Organization (WMO) in its State of the Global Climate 2020 described the year 2020 as ‘a year of widespread flooding’ (WMO, 2021), which is particularly the case in Asia and Africa with one of the wettest monsoon seasons of the recent decades in India and parts of SE Asia, and extensive flooding in several countries in Africa. The Storm Alex of October 2020 caused record-breaking 1-day precipitation in parts of Europe (Copernicus Climate Change Service, 2021). What is becoming increasingly clear is that such hydro-meteorological extremes are not going to be just an exceptional in 2020 or 2021, but more of a new normal. The sheer magnitude of the extreme heat wave, however, did shock climate scientists.

The occurrence of the heatwave was virtually impossible without human-caused climate change (World Weather Attribution, 2021a).

Flooding is one of many natural disasters that has been exacerbated by climate change, and this is set to continue. The warmer Earth undoubtedly adds more water vapour in the atmosphere and as a consequence leads to more precipitation on average globally (IPCC, 2021). More worrisome are the scenarios of more frequent high-intensity rainfall events resulting in floods that undermine the capacities of both natural and constructed drainage systems. For example, a recent study finds that increasing temperature can intensify hourly extreme precipitation at higher rates than expected (Ali et al., 2021). This brings into question standard design procedures that are primarily based on the assumption of statistical stationarity.

Climate scientists have warned that extreme events like the July 2021 in Europe may repeat more often should the present rate of global warming continue.

All available evidence taken together, including physical understanding, observations over a larger region and different regional climate models give high confidence that human-induced climate change has increased the likelihood and intensity of such an event to occur and these changes will continue in a rapidly warming climate (World Weather Attribution, 2021b).

Although we have highlighted the flooding in Northern Europe in July 2021, we are conscious that in July and August that fatalities from severe flash floods and lowland flooding have also occurred in China, Japan, North Korea, Turkey and the United States.

In August 2021, the contribution to the IPCC sixth assessment report (AR6) from Working Group 1 (WG1) was published, giving the most up-to-date physical understanding of the climate system and climate change. In launching the report, the UN Secretary-General António Guterres' stated:

... [the] IPCC Working Group 1 report is a code red for humanity. The alarm bells are deafening, and the evidence is irrefutable ... (UN, 2021).

The Summary for Policy Makers (IPCC, 2021) provides several important statements on the degree of certainty for past changes in the global hydrological cycle and global sea level, and the likelihood of change in projections under five future Shared Socio-economic Pathways (see, e.g., paragraphs A1.4, A1.7, A2.4, A3.2, A3.3,
B2.3, B2.4, B3.1 to B3.4, B5.3, B5.4, C2.2, C2.5 and C2.6). Limiting greenhouse gas emissions to net zero is the only sustainable choice for safer Earth; the actions needed to cut down on the current 50 billion tons of CO₂-equivalent emissions are daunting and are the challenge set for the international COP 26 in Glasgow in November 2021.

One line of action, however, is clear for flood risk management. The changes already being experienced from past global warming and those inevitable in the future – especially seal level rise – require adaptation measures to reduce increased flood risks now and for the foreseeable future. Moreover, there is a need to translate the clear messages on climate change at the global scale into actions based upon sound science and understanding at the scale of river catchments, urban drainage networks, coastal process cells and, the social scales of national and local governments that make and implement risk management decisions.

1 PAPERS IN THIS VIRTUAL SPECIAL ISSUE

Over the last decade, the Journal of Flood Risk Management (JFRM) has published many contributions that have addressed various challenges and emerging questions about flood risks in the context of climate change. To prepare this Virtual Special Issue (VSI), we considered all the papers published in the Journal since its inception, which referred to climate change either in the title or among the keywords. This search yielded 45 papers, and we have refined our consideration in this VSI to 11 papers, which have been well read (measured by downloads) and well cited.

The contribution by Whitfield (2012) is a review paper that discusses the state of knowledge at the time using the scenarios summarised in the IPCC fourth assessment report. It focuses on the complexities of moving from the global and regional scale implications of flood-generating processes linked to the atmosphere to interpretation at the catchment scales commonly required for flood risk management. The breadth of the issues discussed remains instructive and is illustrated in Table 5 of Whitfield’s review paper as potential questions for assessing floods in future climates.

The remaining 10 of the 11 papers selected for this VSI cover three broad categories, which also reflect the topics of all the papers we identified from the keyword search:

1. Novel methodologies and tools: Faulkner et al. (2020), Güçlü et al. (2018) and Burch et al. (2010),
2. Assessment of impacts: Mishra et al. (2018) and Wobus et al. (2014), and
3. Design and evaluation of adaptation options: Dittrich et al. (2019), Velasco et al. (2018), Van Alphen (2016), Nye et al. (2011) and Woodward et al. (2011).

The three papers in this VSI that discuss novel methodologies and tools tackle two distinct topics – analysis of hydrometric records (Faulkner et al. (2020) and Güçlü et al. (2018)), and the use of visualisations as decision-support tools for spatial planning (Burch et al. (2010)).

Both Faulkner et al. (2020) and Güçlü et al. (2018) look for trend over time in observations with Güçlü et al. (2018) considering precipitation records at a single site near Istanbul and Faulkner et al. (2020) considering over 500 river flow gauging stations in Great Britain. The outcome of these two papers illustrates one of the points made by Whitfield (2012), that it is important to understand the variability in local processes and conditions when assessing the evidence for climate change impacts on flood management.

Güçlü et al. (2018) propose the use of frequency–intensity–duration (FID) curves for storm design for urban water management rather than the traditional ordering of intensity–duration–frequency (IDF). By analysis of 46 years of record in two equal parts (1964–86 and 1987–2009), they demonstrate a clear reduction in the rainfall intensities for the shortest durations in the more recent period, but no change for storm durations of 30 minutes or more.

The motivation of the investigation by Faulkner et al. (2020) is repeated severe flooding in north-west England. Flood defences constructed after the severe floods of 2005 and 2009 were overtopped again in 2015, which raises the question of whether something has changed that increases the probability of such events. The standard UK hydrological design procedure is based upon the assumption of statistical stationarity. Initially, trend tests and non-stationary flood frequency analysis techniques were applied in the NW region, and the resulting estimates of flow, for the present day, were up to 55% higher than using stationary estimates. Following this, data from 509 sites across Great Britain, each with over 40 years of gauged flows, were analysed, producing evidence of upward trends in peak flows at nearly a quarter of flow gauges.

The paper by Burch et al. (2010) addresses a different aspect of flood risk management in response to climate change and illustrates an advance in best practice for flood risk management and climate change planning. It explores key institutional barriers to effective decision-making on flood risk management at a municipal level.
and suggests possible ways to overcome such barriers. The Local Climate Change Visioning Project in British Columbia, Canada, is one unique approach aimed to assist local decision-making. The Visioning Project incorporates novel 3D visualisation techniques with a participatory approach to explore visions of the future under climate change. It enables more effective and equitable modes of public participation with innovative tools for the communication of complexity and uncertainty.

In terms of assessments of impacts, the two papers highlighted in the VSI that deal with the assessment of evidence of change demonstrate different approaches. Wobus et al. (2014) consider potential changes in flood damage values at the scale of the whole United States (excluding Alaska and Hawaii) in the long-term to the year 2100. The land area is divided into 18 water resource regions (WRR) and statistical relationships developed between observed precipitation and flood damages over the course of the observational record. These relationships then provide estimates of future damages under a changing climate from general circulation model (GCM) projections to 2100. By working with damage data directly, the problems associated with the preparation and validation of a chain of hydrological and hydraulic models are avoided. Their results indicate that monetary damages from flooding will increase in 14 of the 18 WRRs under a ‘business as usual’ scenario, with statistically significant increases in damages in four regions.

Mishra et al. (2018), however, consider changes in the near term (2020–2039) for a specific 428 km² catchment in Jakarta region of Indonesia. They analyse likely impacts of climate and land use change on flood inundation for the purpose of crafting sustainable strategies for urban water environment design. The approach is to bias-correct climate projections from three different GCMs and two Representative Concentration Pathways, and consequently use them with standard hydrological and hydraulic models for future flooding simulation, including projected changes in land use. The increase in simulated flood inundation areas and depths (6%–31% for different GCMs) in the future showed the importance of improving flood management tools for the sustainable development of urban water environments.

The remaining five papers collated in this VSI cover aspects of the design and evaluation of adaptation options and associated decision-making. They illustrate different approaches for mitigating the impacts of climate change on flood risk and the associated uncertainty in future scenarios. As indicated by Burch et al. (2010), path-dependent governance and decision structures that have evolved historically can limit the options within municipal institutions and influence fundamentally the context for the design and implementation of responses to climate change impacts such as flooding. Given the deep uncertainty in the future physical, economic and social conditions under which decisions on flood management will need to be taken, it is important as far as possible not to restrict choices available to future generations.

Woodward et al. (2011) explore the use of real options in the selection of strategies for flood risk management. Real options analysis is a widely recognised approach for encouraging appropriate climate change adaptation and mitigation investment decisions. The methodology has the capability to value the flexibility associated with intervention options for flood risk management across a range of future climate change and socio-economic scenarios. They illustrate the methodology for a real-life case study situated in the Thames Estuary (UK) and show the potential for substantial cost savings under future uncertainties when the real options, as opposed to more traditional approaches, are used.

Van Alphen (2016) describes the Delta Programme in the Netherlands, which has been established to protect the country against flooding and to safeguard freshwater supply while anticipating climate change. The programme is aimed at avoiding a flood disaster rather than responding to it after the event. A farsighted countrywide programme such as this is only possible with strong collaboration between multigovernmental agencies and adequate institutional arrangements to guarantee ‘future-proof’ implementation. Uncertainties about the future climate, population, economy and society are tackled through four so-called delta scenarios giving the ‘corner flags of the playing field of plausible futures’. This enables an adaptive way of planning, maximising flexibility, keeping options open and avoiding lock-in. The multifunctional design of these measures increases societal added-value and enhances acceptance.

Nye et al. (2011) explore the evolution of a more socio-technical variety of flood and coastal risk management (FCRM) in the United Kingdom since the 1990s. This they call the ‘social turn’, which emphasises community engagement and personal- or community-level responsibility for flood risk planning, awareness and resilience. This is seen as a shift in emphasis not only in research but also within the Environment Agency’s FCRM programme. Risk management measures and practice now incorporate social aspects alongside more traditional, centrally managed structural and technical measures. This more collaborative form of public engagement aims at empowering flood risk ‘citizenship’ as both a natural outcome of the different drivers for change and a necessary tool for tackling the complexity of sustainable FCRM.

Velasco et al. (2018) discuss the potential impact of climate change on flooding in a critical urban area of
Barcelona and the assessment of the effectiveness of structural and non-structural measures to cope with such impacts of the medium term to 2050. They argue that the development of updated methods to assess climate change impacts is as important as the provision of improved climate change data. Using a coupled surface and storm sewerage model, they investigate the influence of two scenarios for climate change impact on extreme precipitation in Barcelona. Alongside the business as usual scenario, the paper explores several scenarios of adaptation measures based upon property-level protection, flood warning, implementation ‘green roofs’ as a sustainable drainage measure, and traditional increases in capacity of the drainage system. The paper discusses the implications on several aspects of risk and assesses the sensitivity of the selected best option from benefit–cost analysis to the assumed discount rate.

There is significant interest in nature-based solutions (NBSs) as a means for mitigation and adaptation to climate change (see, e.g., Seddon et al., 2020). In terms of flood risk management, NBSs include natural flood management measures (NFMs), and these are the subject of the paper in this VSI by Dittrich et al. (2019). This paper considers NFM, notably re-afforestation on hillslope and floodplain, to provide a better understanding of the costs and benefits of afforestation as a climate change adaptation measure for flooding. Dittrich et al. (2019) describe a case study of a small rural catchment in Scotland with an analysis of the costs and benefits not only for flood management but also more broadly including ecosystem services and changed agricultural yield. For the ecosystem services, Dittrich et al monetise explicitly climate regulation (including carbon sequestration), recreational and aesthetic values, water quality, as well as educational and biodiversity benefits. The hydrological response was calculated in 2016 (current) and for nationally set climate scenarios in 2040 and 2080. Significant positive net present values (NPV) were found for all alternatives considered; however, benefits are dominated by ecosystem services other than flood regulation. Thus, the case study suggests that afforestation as a sole NFM measure provides a positive NPV only in some cases but highlights the importance of identifying and quantifying additional ecosystem co-benefits.

2  |  CONCLUDING REMARKS

Preparing this VSI has emphasised to us the complexity of dealing with the consequence of climate change on flood risk in practice. However, some important themes emerge:

- the need to move away from judging future risk on the assumption of stationarity when using a statistical appraisal of data;
- the importance of understanding the impacts of the large-scale changes from GCM simulations at the scale of the catchments and coastlines where management actions are taken;
- the need to explore a credible range of climatic conditions, particularly in planning beyond the short-term (i.e., >20 years ahead) combined with more scientifically based scenarios for land use, population and socio-economic changes;
- the need to avoid constraining future measures by making choices now, which offer maximum flexibility, opting for adaptive planning;
- the need to fully account for all benefits and costs, particularly when implementing NBSs to manage flood risks.

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It will be evident to readers of this editorial that we have relied extensively upon the wording (particularly in the abstracts and conclusions) of the authors of papers we have included in the VSI. In places, we have used this verbatim, but we have also edited, shortened and re-ordered as we considered best illustrated the contribution to the VSI. We trust that we have not misrepresented the intentions of the original authors and we fully acknowledge their original contributions to the Journal.

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