Energy and Environment Institute, University of Hull

submission to EFRA select committee inquiry

14th May 2020

Dr Kate Smith, Dr Rob Thomas, Dr Chris Skinner, Dr Giles Davidson, Prof Dan Parsons, Dr Stuart McLelland, Prof Tom Coulthard, Dr Krysia Mazik, Dr Lisa Harrison, Dr Sam Ramsden, Dr Jess Moloney, Dr Josh Ahmed, Chloe Carter, Josh Wolstenholme, Florence Halstead, Pip Betts

Summary

This submission presents the research conducted within the Energy and Environment Institute at the University of Hull. Our work demonstrates that hazards represented by flooding have multiple dimensions, and that solutions to them need to take these complex inter-relationships into account. The research described below covers both the physical and social impacts of flooding; the recommendations that follow from our work are based on our understanding that flood risk management needs to expand across land-water boundaries at the full range of spatial, temporal and societal scales. Responding to each of the terms of reference in turn, our data shows that the response to flooding needs to start changing now in order to ensure the resilience of our communities, businesses and infrastructure in the future.

About the Energy and Environment Institute

The interdisciplinary Energy and Environment Institute at the University of Hull, led by Professor Dan Parsons, brings together the skills and capabilities of leading researchers to tackle global challenges related to climate change and population growth and their consequences for society and livelihoods. We work within four themes at the interface between sustainable energy and environmental resilience: Global Change, Risk and Resilience; 'Energy Estuary' 2050; the Co-Evolution of Earth and Life; Energy and Resource Recovery and Waste. With a portfolio of active research and a strong community of dedicated academics, we lead on a range of interdisciplinary projects tackling some of the biggest challenges faced by humanity.

As a flood-focussed research institute located close to the Humber, we live and work in an area that faces significant flood risk. We present this submission to the inquiry because our lived experience, as well as our research, tells us how important it is that we do better at building flood resilience into our communities and landscapes. We believe that our research has important insights about how to make that happen.

Introduction

The past months of flooding across the UK confirm that despite major investment over recent decades, flooding continues to be a significant risk to communities, businesses and infrastructure. That risk is rising due to the combined hazards of more extreme weather, sea-level rise and land-use changes. This inquiry is therefore timely. Its terms of reference recognise that the hazards presented by flooding have multiple causes, solutions and impacts that extend well beyond the immediate threat posed by water out of place. The research into flooding at the Energy and Environment Institute (EEI) responds to that multi-factorial, multi-dimensional threat. This submission presents our research, responding to each of the terms of reference in turn.

1. Are the current national and local governance and co-ordination arrangements for flood and coastal risk management in England effective?

The 2007 Hull Flood report (Coulthard, Frostick et al. 2007) fed into the 2008 Pitt review. Both made recommendations for the provision of a robust national system for pluvial (i.e. rainfall-related) flood warnings. The creation of the national Flood Forecasting Centre and subsequent legislation mandating Surface Water Management Plans (SWMPs) were attempts to address this. Whilst SWMPs have done much – particularly in Hull – to create robust plans for regional flood risk and management, there is still no granular flood warning system to specifically alert local communities to pluvial flood hazards: although pluvial flood forecasts have improved, surface water flood warnings are only available at a relatively coarse spatial resolution. This is of limited use for affected communities.

The June 2018 Cross Report acknowledged the ongoing problem with the highly variable level of responsibility for (and responsivity to) surface water flooding. It also made recommendations for the provision of multi-agency training and response infrastructure. Based on the pressing need for safe, innovative and economically sustainable research into future flooding, the EEI has formed a partnership with Humberside Fire and Rescue Service to drive the development of Ark, the National Flood Resilience Centre (Hull 2019). The Ark project aims to enhance community flood resilience through research, innovation, education and multi-agency flood response training at a unique, purpose-built urban and swift water flood simulation facility.

The legacy of the UK's compartmentalised approach to flood and water management (Crouch and McDonagh 2016, Haughton, Bankoff et al. 2015) is an ongoing obstacle to improving national flood resilience. This has been addressed on a localised basis in Hull through the Living With Water partnership. This innovative project is part of the Rockefeller Foundation's

City Water Resilience Framework, and has pioneered a multi-agency, multi-disciplinary approach to building flood resilience within Hull. The University of Hull has invested significantly in the Living With Water project, and hosts a dedicated Living With Water PhD cluster. The EEI also hosts the Flood Innovation Centre, jointly funded by the European Research and Development Fund. The Flood Innovation Centre exists to support innovation in flood resilience products, processes and services amongst small and medium-sized enterprises in the Humber region. These projects offer a model for more coordinated flood hazard education that should be initiated nation-wide.

2. What lessons can be learned from the recent floods about the way Government and local authorities respond to flooding events?

The recent floods underscore the difficulty in using probabilistic models for predicting combination flooding hazards. A major proportion of the EEI's modelling and experimentation work is focussed on understanding these hazards. This research consistently demonstrates that the behaviour and impact of combination hazard events is both different to and greater than the sum of their various parts. For example, recent research into combinations of fluvial and surge-tide extremes has contributed new knowledge and methods for catchment-to-coast modelling (Robins, Harrison et al. 2020). The combination of fluvial and surge-tide hazards creates flood risks that have the potential to increase in future as the frequency, phasing and/or intensity of hazard drivers changes. Our research resolved intra-estuary sensitivities to fluvial and surge-tide extremes for the Dyfi and Humber estuaries. Each estuary responded differently to the various combinations of rainfall events, surge-tide and projected sea-level rise, showing that the interaction of combination hazards is complex and cannot be extrapolated from the impacts of singular hazards. Hydrodynamics vary considerably both between and within estuaries, which poses challenges for probabilistic or 1D modelling for assessing combination flooding hazards.

The Cross report made a specific recommendation about bringing surface (and groundwater) flooding into line with main river and coastal flooding responsibility, which is undertaken by the Environment Agency (EA). However, the highly localised and stochastic nature of pluvial flooding means that the current opt-in Flood Warning Service provided by the Environment Agency faces a significant challenge when integrating pluvial flood warnings into its current capability.

Legislation adopted by the EU in December 2018 mandates for the provision, by June 2022, of the implementation of national emergency alerting platforms in all member states. As the UK was still formally a member of EU when the legislation was adopted, the UK government is required to put such a system in place. The Environment Agency has been involved in previous trials of emergency messaging using localised SMS as part of their ongoing responsibility for disseminating flood warnings. Their expertise in this field led to the EA collaborating with Fujitsu, EE and the University of Hull to run a series of trials of emergency messaging technology using cell broadcasting.

Following several months of technical testing and exploration, field research took place on the Hull campus in November 2019 to test public reactions to receiving cell broadcast emergency flood warnings (Grant, Smith et al. 2020). Research participants experienced the receipt of cell broadcast messages on live handsets. The research team recorded the reactions and responses of participants, finding that the distinctive tone and delivery mode of the messages was particularly effective in focussing the attention of participants, leading to their subsequent engagement in protective, appropriate behaviours. This research has been reported and presented to the EA and Cabinet Office, and is currently under discussion as the government seeks to find more reliable ways of communicating with citizens during the present COVID-19 emergency.

3. Given the challenge posed by climate change, what should be the Government's aims and priorities in national flood risk policy, and what level of investment will be required in future in order to achieve this?

The £5.2bn recently allocated for flooding in the Budget is welcome and commendable but it needs to be able to be deployed creatively to support strategic and innovative approaches like Ark. The DEFRA Grant in Aid is currently constrained and may only be used for physical flood defences that protect identifiable (and quantifiable) properties. This is not consistent with emerging policy in the form of the 2019 draft Flood and Coastal Erosion Risk Management (FCERM) strategy. This marked a major shift in the Environment Agency's approach to future flood hazards. Based on the climate change that is already 'baked in' to the system and also taking into account a range of future climate scenarios, the strategy accepts that we cannot keep the water out everywhere, forever. We need to learn to live with water. This approach is typically associated with moving from 'flood protection' to 'flood resilience'.

National policy should encourage community-level resilience (in addition to infrastructure and property resilience). This can be achieved through intermediate-scale schemes (e.g. well-designed Natural Flood Management (NFM) and SUstainable Drainage Schemes (SUDS)) and enhanced multi-agency training facilities as well as through larger catchment-scale interventions. There is also a need, demonstrated by the Living With Water programme, for improving community flood resilience by raising awareness and understanding of flood risk, and by supporting households to be better prepared for floods.

The challenges identified in Robins, Harrison et al (2020) are replicated across results from other research undertaken by the EEI's scientists. We know, for example, patterns of rainfall are set to change in the UK. These changes will impact when and how much rain we receive; climate change will also have more complex impacts on the structure, intensity and frequency of storms. Some of our research investigates the potential impact of these changes on and in the ground. Rainfall events may cause landslides and may also cause sediment to be washed off farmers' fields into our rivers: this influences the flood risk and potentially causes toxic nutrient levels where that sediment is deposited. In addition, floods often cause erosion of riverbanks and riverbeds (Lai, Thomas et al. 2015). This results in local land loss and exacerbates issues arising when sediment and absorbed nutrients are deposited downstream. Currently, there is no forecasting system that is rapid and reliable enough to understand these processes. This is in part because geomorphology is not currently represented within current forecasting systems. Based on our research, we recommend that increased amounts of geomorphic observations are incorporated into current and future forecasting systems (Flack, Skinner et al. 2019).

Coulthard, Ramirez et al. (2012) showed that predicted increases in rainfall volumes by UKCP09 would result in large increases of sediment run off from an upland UK catchment, as occurred in Glenridding, Cumbria, in 2015. An increase in rainfall across the catchment translated to increases in water discharge at the river mouth but also led to non-linear, cubic increases in sediment yields. When sediment moves from place to place, it impacts the scale and severity of flooding (as well as affecting water quality), so if sudden rainfall events result in large quantities of sediment shifting rapidly downstream, predictions of when and where flooding may occur will be unreliable. Milan (2012) showed how an extreme convective event shifted the behaviour of an upland UK catchment, potentially increasing downstream sediment delivery from the system for decades.

Numerical modelling using CAESAR-Lisflood (Coulthard and Skinner 2016) has also explored the impact on sediment yields of rainfall patterns observed during convective (thunder) storms, which typically move rapidly whilst depositing large amounts of rainfall. Our research showed that this kind of rainfall more than doubled the amount of sediment run-off, which is likely to change flooding patterns. Increasing temperatures (resulting from climate change, for example) increase the frequency and intensity of thunderstorms. They also change the structure of thunderstorms by altering the distribution of rainfall intensities across the storm cell. Recent research has shown that sediment run-off is also sensitive to these changes (Peleg, Skinner et al. 2020, Skinner, Peleg et al. 2020).

The EEI's facilities allow us to undertake large-scale physical modelling of geomorphological processes. We combine these with numerical modelling to develop our understanding of the long-term impact of changes in river systems. Our modelling helps us understand outcomes at a wide range of temporal scales; researchers at Hull have led studies using these models to enhance the understanding of intense rainfall and resulting runoff, both under present and future climate conditions (Thomas, Johnson et al. 2014, Baynes, van de Lageweg et al. 2018). This understanding could help mitigate the risks associated with the impact of climate change on our river systems.

The ability of the UK flood research community to continue modelling, testing and understanding the complex interactions between landscape, water, weather, built environment and modern society depends on having access to resources that are equal to the rising challenge of climate adaptation. The launch of this inquiry underlines the fact that flooding is a significant and growing local and global challenge. Our plans for Ark respond to this challenge by facilitating enhanced flood research, innovation and responder training. Firstly, the unique combination of features offered by Ark will drive research in hitherto neglected areas, including full-scale flood-plain simulation, upland catchment dynamics and street-scene experimentation. Secondly, it offers a full-scale testing facility for innovative flood solutions, like those developed within the EEI's Flood Innovation Centre. Thirdly, the Cross report (2018) identified the need for a clearly laid out and publicised annual programme of flood exercises for Category 1 and Category 2 responders plus government officials and the military. Despite this recommendation, response training remains haphazard. Training infrastructure is not consistent across the UK; existing facilities are limited to a number of recreational white-water centres. These are usually fed from natural water courses and so have inherent health and safety risks for those undertaking training in and on them.

There is, in particular, no facility in the UK nor the rest of Europe which simulates the flooded urban environment. Indeed, the only other such facility in the world was commissioned in New York State in May 2018. Construction of a National Flood Resilience Centre would address the need for safe, realistic, multi-scale flood training facilities by allowing responders to coordinate, exercise and train together in clean, safe, swift and still water.

The Cross report also noted the lack of affordable and accredited training programmes for local responders. Ark responds to that need by providing a facility for delivering professional qualifications and accredited training. The EEI has already launched taught postgraduate-level training in flooding, and is developing further accredited courses to equip a diverse range of stakeholders with skills, experience and confidence in flood processes, resilience and response.

The estimated capital cost of Ark is £15m (inc VAT). Our project partners have committed significant investment; additional funding is being sought to enable the physical development to begin. Market research has demonstrated that the demand for Ark's services is such that it will be a self-sustaining, not-for-profit operation. The project has received emphatic support from a range of stakeholders including the Environment Agency, Local Authorities and MPs in our region and across the country. Arup, Aviva and Yorkshire Water are prominent private sector supporters. We will continue to strive to bring Ark to fruition to develop world-leading UK-based capability in community-focussed catastrophic flood management.

4. How can communities most effectively be involved, and supported, in the policies and decisions that affect them?

Effective participatory policy-making necessitates a culture of connectedness, openness and transparency. Ongoing issues of compartmentalisation and resource-scarcity within flood mitigation institutions work against the involvement of communities affected by flooding. University of Hull researchers have pioneered participatory projects such as #theHullWeWant (Hughes 2018), which provide a model for more effective engagement with communities affected by flood hazard. In order to embed resiliency behaviours, we need to build climate change education and flood hazard understanding into our culture by informing and educating beyond the boundaries of academia. To that end, we are working with the National Youth Theatre (2020) to develop a new immersive flood-themed performance work, MELT, the latest in a series of environmental epics responding to the climate emergency.

Our research with communities in Hull indicates that there is ongoing alienation of flood-prone communities from flood-management authorities (Ramsden 2018). Results from over 450 surveys indicate that there is appetite for more local involvement in water level monitoring by local communities, who are often aware of points within drainage systems that are most vulnerable. Our survey respondents also reported a clear need to be able to communicate directly with members of staff in the various flood prevention agencies. Our research suggests that establishing (and resourcing) Flood Action Groups more widely would have a positive impact on residents' engagement with resiliency behaviours, leading to greater uptake of flood warnings, property-level flood protection and community resilience.

Each Lead Local Flood Authority (LLFA) should have a dedicated flood line; LLFAs should lead in the provision of flood resilience information to flood-vulnerable households. As part of the community education work undertaken by Living With Water, Hull City Council and East Riding of Yorkshire Council have recently done exactly this – distributing information developed jointly by the University of Hull and Living With Water partners about household-level flood resilience measures to residents.

Research conducted both in the UK and overseas points to the long-term psycho-social impact on flooding across all age groups (Halstead 2018). Children are particularly vulnerable to the traumatic impact of flooding, and are often overlooked in the flood planning process. Children are experts in their own experience; this work underlines the importance of listening to them before, during and after flood events.

It can, however, be difficult to engage those who have not experienced flooding but who may be at risk. It is important to build trust with those researching flood-related issues and spark an interest so that people are willing to learn more. The SeriousGeoGames Lab in the EEI has been using innovative applications of environmental data and models, games, and virtual reality (VR) to reach new audiences (Seriousgeo.games 2020). The *Humber in a Box* application was a world-first merging of a research-grade hydraulic code (Lisflood-FP) with a gaming engine (UNITY-3D) and allowed the public to witness flooding in a gamified space using VR. Our *Flash Flood!* experience uses VR to place people in a river as it floods and undergoes rapid geomorphic change. Our impact research shows that engaging with these VR tools increases people's desire to find out more about flooding and geomorphology (Skinner 2020). Through the use of 360° videos on YouTube, the SeriousGeoGames Lab has shared flood risk messages with over half a million viewers worldwide. The applications have been used at many public events, including supporting the Environment Agency's Humber Strategy and the Living With Water Partnership. We believe these participatory approaches to flood hazard communication should be resourced more widely and available to all communities.

5. With increasing focus on natural flood management measures, how should future agricultural and environmental policies be focussed and integrated with the Government's wider approach to flood risk?

There is widespread interest in the use of various natural flood management (NFM) measures to attenuate the impact and slow the flow of flood water. This is, in part, because they are relatively simple and cheap to implement, with low ongoing maintenance costs. However, there has, to date, been no adequate critique or assessment of the different designs and construction of one of the most common forms of NFM, leaky wooden dams. Within the EEI, research teams (Wolstenholme 2018, Carter 2019) are investigating the functionality and impacts of leaky wooden dams as part of broader NFM schemes. The lack of research into their design and deployment means that they may cause detrimental changes to fluvial and riparian environments. Associated with this lack of understanding is a low legislative profile: anyone can install a leaky dam anywhere. Given that leaky dams disrupt not only the natural flow regime, but also sediment and geochemical transfer, developing better understanding of how these structures impact their environment is critical.

Previous modelling of leaky dams has been limited to hydrological and hydraulic simulation, without the inclusion of sediment and geochemical transfer or morphological response. Our research includes those vital geomorphological processes. In doing so, it will better inform communities about the need to be aware that careful planning and placement of NFM is essential, since without proper deployment they may exacerbate flooding by synchronising flood peaks from different tributaries, as well as having longer-term impacts on sediment and geochemical transfer. A toolkit for the CAESAR-Lisflood model is in development to facilitate the assessment of both hydrological and geomorphological impacts of different types of NFM interventions. This will be supported by guidance materials for practitioners and will include methods of forecasting future maintenance costs.

Further applications of our work to better understand the impacts and efficacy of NFM led to the collaborative development, with Hull City Council, of an NFM matrix (Hull City Council, 2020). This project sought to understand the impact of implementing NFM measures in Hull's flood-prone catchments. A combination of modelling using CAESAR-Lisflood and field assessment led to the development of bespoke NFM maps, which identified the most effective NFM interventions for each area. The maps were then combined with a matrix of other impacts, including ecosystem services, to generate robust data about which would be the most beneficial NFM interventions overall. For example, leaky dams were found to reduce peak flows, but wet woodland and tree planting offered wider ecosystem services in addition to delaying the timing of peak flows. This multi-dimensional analysis could identify site-specific, impactful and cost-effective NFM in a range of contexts. More ambitious and creative planning and environmental policies are needed nationwide to encourage this kind of initiative.

The importance of capturing information at the broadest range of biological, hydrological and geomorphological scales cannot be underestimated. Careful consideration of the impacts of interventions such as NFM, managed realignment of coastlines and estuarine restoration needs to include awareness that the impact of our actions may not be benign: with increasing understanding of the profound interconnectivity of all life on earth, attempts to engineer our way out of anthropogenic problems run the risk of failure. Our research into ecoengineering and ecohydrology highlights the potential for both failure and success in these endeavours (Elliott, Mander et al. 2016). Any change we make by modifying the physical environment to create or try to restore natural processes relies on suitable physical hydrographic and sedimentological conditions before the natural successional process can allow birds and fish to reoccupy a rehabilitated area. Without a sound understanding of both the underlying processes and intervention impacts, such rehabilitation – and the benefits for water attenuation that they bring – cannot succeed.

The most recent large-scale flood impacts in Yorkshire and North Lincolnshire repeated the outcome of other recent major flood events: in 2007, approximately 200km^2 of farmland across Yorkshire and the Humber was affected by summer flooding. This led to costs of £50 million in food, animal and infrastructure losses in an area that is subject to intensive land management strategies that employ heavy machinery and regular deep cultivation. These processes damage the deep soil structures and reduce subsurface pore networks. This in turn reduces the soil's ability to retain water, and increases the sediment and nutrient run-off to nearby watercourses. Research at the EEI, under the umbrella of the collaborative THYME project (Ahmed 2020), is using a combination of in-situ soil moisture monitoring and ex-situ chemical and structural analytical techniques to assess how changes in land management strategy affect the physical structure of soil, and therefore impact its ability to retain water and nutrients.

Up to now, it has not been possible to assess how historic land-use patterns have impacted sediment run-off and hence flood patterns. Current research, based on previous work using acoustic Doppler current profilers (Simmons, Azpiroz-Zabala et al. 2020), is decoding historic Environment Agency datasets to see how changes in landscape use have affected sediment run-off over time. This is important for understanding both ecological and hydrological change, and inform the recommendations for changes in agricultural policy that follow from the THYME soils project.

6. How can housing and other development be made more resilient to flooding, and what role can be played by measures such as insurance, sustainable drainage and planning policy?

Our research into the long-term impact on residents who were flooded during the 2007 and 2013 in Hull indicates that major issues exist in what should be the 'recovery' phase of a flood event (Ramsden et al. 2020). From over 450 surveys, our research found that for many respondents the trauma, expense and uncertainty of the post-flood period was more distressing than the original event. Respondents reported many months of difficulties in dealing with insurance companies and loss adjusters. Many people in Hull do not have insurance, including 37% of our survey respondents. It is not possible for some households to obtain cover for flooding, while others cannot afford it. We found higher levels of insurance cover for residents in more affluent areas, and amongst home-owners. Our evidence suggests that FloodRe may not be working well enough to help people struggling to obtain or afford insurance after their property has been flooded.

Our survey data also indicated potential problems with sharing information about flood events and flood prevention. Our respondents favoured local television and radio as their primary source of information about flooding and flood prevention. Not all households have access to the internet; relying on websites as the primary route for sharing flood information will exacerbate social inequality by overlooking the accessibility issues faced by more elderly, economically insecure communities.

A substantial sum was allocated in this year's budget for improving flood defences, yet the Environment Agency's recent draft Flood and Coastal Erosion Management Strategy indicated a reducing emphasis on physical flood protection in favour of more innovative, adaptive, resiliency-based interventions. There is an urgent need for more policy-level support for flood innovation, both as a driver of growth in less economically active regions such as the Humber, and as a way of finding better long-term solutions to the dynamically evolving flood risks that the UK currently faces. Put simply, we cannot simply keep building ever higher flood barriers, which are costly to build and maintain, have a limited lifespan, and inevitably have consequential impacts on other parts of the hydrological system in which they are placed.

Recognising this, the University of Hull established the Flood Innovation Centre, co-funded by the European Research and Development Fund (ERDF). The Flood Innovation Centre supports small and medium-sized businesses to develop new products and services to enhance flood resilience. It was established in April 2019 in response to climate change and a desire to drive forward innovative and commercial thinking in the flood resilience sector through collaborations with the University's expertise in climate change, flooding, engineering, logistics, materials and computer science.

As optimistic as we are about the opportunities for the development of robust, innovative flood solutions, these will be of little use without government-level support. A combination of strong regulatory powers to enforce and extend existing limits of flood plain development, mandating for new build properties to have meaningful flood resilience fitted as standard, and using regulatory powers to improve the provision of insurance services are all needed if we are to live in flood resilient communities in the future.

Conclusion

The understanding of flood risk management needs to expand across land-water boundaries at the full range of spatial scales. Without such expansion, it will not be adequate to take on the multi-factorial hazards of growing population size, changing land use, increasing extraction of water and other resources, climate change and sea-level rise. Achieving the very best in terms of resiliency outcomes necessarily involves taking an interdisciplinary, interspatial, transboundary perspective from the outset. The inter- and transdisciplinary approaches such as those taken by researchers at the Energy and Environment Institute at the University of Hull yield better understanding about floods at the full range of spatial, temporal and societal scales. This understanding is critical for developing sustainable and adaptive strategies for long-term flood resilience. There is no doubt that there is the ambition and will to support new ways of working towards a more flood-resilient future. What is lacking at this point is the top-down institutional resource, confidence and determination to break out of the historic compartmentalisation of the UK's flood management programme. This should include deploying government resources intelligently and creatively to optimise their impact. We need to embrace more connected, synergistic and adaptive ways of responding to the changing hazards around us.

Bibliography

Ahmed, J. (2020). Strengthening environmental resilience through sustainable soil management strategies; Improving soil quality to enhance environmental and societal resilience to climate change. University of Hull.

Baynes, E. R. C., W. I. van de Lageweg, S. J. McLelland, D. R. Parsons, J. Aberle, J. Dijkstra, P.-Y. Henry, S. P. Rice, M. Thom and F. Moulin (2018). "Beyond equilibrium: Re-evaluating physical modelling of fluvial systems to represent climate changes." Earth-Science Reviews 181: 82-97.

Carter, C. (2019). PhD: Natural Flood Management: Optimising design to reduce geomorphic impact. Living With Water PhD Cluster. Supervisors: Prof Tom Coulthard, Dr Stuart McLelland, Dr Rob Thomas. Energy and Environment Institute, University of Hull.

Coulthard, T. J., J. Ramirez, H. J. Fowler and V. Glenis (2012). "Using the UKCP09 probabilistic scenarios to model the amplified impact of climate change on drainage basin sediment yield." Hydrol. Earth Syst. Sci. 16(11): 4401-4416.

Coulthard, T. J. and C. J. Skinner (2016). "The sensitivity of landscape evolution models to spatial and temporal rainfall resolution." Earth Surf. Dynam. 4(3): 757-771.

Elliott, M., L. Mander, K. Mazik, C. Simenstad, F. Valesini, A. Whitfield and E. Wolanski (2016). "Ecoengineering with ecohydrology: successes and failures in estuarine restoration." Estuarine, Coastal and Shelf Science 176: 12-35.

EnvironmentAgency (2019). Draft national flood and coastal erosion risk management strategy for England, UK Government.

Flack, D. L. A., C. J. Skinner, L. Hawkness-Smith, G. O'Donnell, R. J. Thompson, J. A. Waller, A. S. Chen, J. Moloney, C. Largeron, X. Xia, S. Blenkinsop, A. J. Champion, M. T. Perks, N. Quinn and L. J. Speight (2019). "Recommendations for improving integration in national end-to-end flood forecasting systems: an overview of the FFIR (Flooding From Intense Rainfall) programme." Water 11(4): 725.

Grant, S., K. R. Smith and R. E. Thomas (2020). "Emergency alerting using cell broadcast: public reaction to emergency flood warnings " in prep.

Halstead, F. (2018). PhD: Children's perceptions of flooding and climate change in the Mekong delta, Vietnam. Supervisors : Prof Dan Parsons, Dr Chris Hackney, Dr Lisa Jones. Energy and Environment Institute, University of Hull.

Hughes, G. (2018). "Desperately seeking the good society." Local Economy 33(6): 636-654.

Hull City Council, March 2020. River Hull Natural Flood Management Study Synthesis Report.

Hull, U. o. (2019). "Ark: National Flood Resilience Centre." Retrieved 12/05/2020, 2020, from https://arkfloodcentre.co.uk/.

Milan, D. J. (2012). "Geomorphic impact and system recovery following an extreme flood in an upland stream: Thinhope Burn, northern England, UK." Geomorphology 138(1): 319-328.

Peleg, N., C. Skinner, S. Fatichi and P. Molnar (2020). "Temperature effects on the spatial structure of heavy rainfall modify catchment hydro-morphological response." Earth Surf. Dynam. 8(1): 17-36.

Ramsden, S. (2018). Living With Water baseline survey. https://universityofhull.box.com/s/5kgxlpbg539at3khsgluhef2vkisp12g

Ramsden, S., R.E. Thomas, L. Jones, D. R. Parsons, J. Affolderbach (2020). "Flooding in Hull and a 'resilience gap'? Exploring how vulnerability and previous experience of being flooded create a disconnect between flood agencies and local residents." in prep.

Robins, P., L. Harrison, M. Elnahrawi, M. Lewis, T. Coulthard and G. Coxon (2020). Interactions of extreme river flows and sea levels for coastal flooding. EGU General Assembly 2020.

Seriousgeo.games. (2020). "The Serious GeoGames Lab." Retrieved 13/05/2020, from https://seriousgeo.games/.

Simmons, S. M., M. Azpiroz-Zabala, M. J. B. Cartigny, M. A. Clare, C. Cooper, D. R. Parsons, E. L. Pope, E. J. Sumner and P. J. Talling (2020). "Novel acoustic method provides first detailed measurements of sediment concentration structure within submarine turbidity currents." Journal of Geophysical Research: Oceans n/an/a): e2019JC015904.

Skinner, C. (2020). "Flash Flood!: a SeriousGeoGames activity combining science festivals, video games, and virtual reality with research data for communicating flood risk and geomorphology." Geoscience Communication 3: 1-17.

Skinner, C. J., N. Peleg, N. Quinn, T. Coulthard, P. Molnar and J. Freer (2020). "The impact of different rainfall products on landscale modelling simulations." Earth Surface Processes and Landforms in press.

Theatre, N. Y. (2020). National Youth Theatre NYT and the University of Hull announces Melt. https://www.londontheatre1.com/theatre-news/national-youth-theatre-nyt-and-the-university-of-hull-announces-melt/.

Thomas, R. E., M. F. Johnson, L. E. Frostick, D. R. Parsons, T. J. Bouma, J. T. Dijkstra, O. Eiff, S. Gobert, P.-Y. Henry, P. Kemp, S. J. McLelland, F. Y. Moulin, D. Myrhaug, A. Neyts, M. Paul, W. E. Penning, S. Puijalon, S. P. Rice, A. Stanica, D. Tagliapietra, M. Tal, A. Tørum and M. I. Vousdoukas (2014). "Physical modelling of water, fauna and flora: knowledge gaps, avenues for future research and infrastructural needs." Journal of Hydraulic Research 52(3): 311-325.

Wolstenholme, J. M. (2018). PhD: Modelling the geomorphology impacts of Natural Flood Management interventions using a novel coupling of physical and computational experiment. Supervisors: Dr Chris Skinner, Dr David Milan. Energy and Environment Institute, University of Hull.