



Droughts and Floods: Towards a More Holistic Approach

Releasing the Full Value of UK Research

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UK Water Partnership Research and Innovation Group

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Launched in February 2015, the UK Water Partnership brings together policymakers, businesses and research funders to enhance coordination and direction of innovation in the water technology sector.

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For a full list of contributors, see Appendix B.

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Research Councils referred to:

AHRC: Arts and Humanities Research Council

BBSRC: Biotechnology and Biological Sciences Research Council

EPSRC: Engineering and Physical Sciences Research Council

ESRC: Economic and Social Research Council

NERC: Natural Environment Research Council

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Executive Summary

Water has to be at the heart of any debate about natural resources, their sustainability and the need to avoid serious economic, societal and environmental impacts resulting from a failure to value and manage them properly.

Droughts and floods are two particularly critical topics for the UK to address: in England alone, insured losses due to floods and severe weather events have cost an average of £1.1 billion per year over the past 20 years.

Despite the investment in research over the last decade – for example, through the UK Government and Research Councils, and at EU level – it remains vital to pinpoint new ways of ensuring security of water supply and effective drought and flood protection.

Achieving this will require a genuinely ‘joined up’ approach rooted in greater integration across scientific disciplines and whole-system thinking across the water cycle.

To date, key barriers impeding this have resulted from the separate arrangements in place for research and innovation focused on droughts and that focused on floods – even though droughts and floods both represent climate-driven pressures on the water cycle. Moreover, arrangements for prioritising and commissioning research differ between funders and are largely uncoordinated, while institutional interactions and interdependencies can create complexity and militate against joined-up thinking.

Adopting a more coherent, more holistic approach to water issues – and improving existing fragmentation across the UK water sector with greater integration – would not just make it easier to translate research and innovation into real-world impact and enable the UK to tackle water-related threats more effectively; it would also help the UK secure an increasing slice of the lucrative global water technology and services market.

In particular, adopting an ecosystems approach – recognising, for instance, how river flow regimes and recharge are affected by land use change and catchment management – can play a key role by providing an effective framework for looking at the environment and valuing the services it provides.

Crucially, taking a more holistic approach to water management would help open up a range of ecosystem-related markets – markets revolving, for example, around environmental technologies, products that sustain ecosystem services and schemes through which users pay providers of those services.

Opportunities are apparent in a range of specific sectors in terms of the potential for research and innovation to deliver solutions that can guarantee water supply for various uses while ensuring sustainable development of ecosystems alongside economic prosperity.

This report concludes by setting out a series of **Ten Key Findings** and **Five Key Recommendations** designed to help the UK take the next steps forward in releasing the full value of its world-leading research and innovation in the sphere of droughts and floods.

1. Introduction: The Remit of this Report

Aims and Audience

This publication sets out to:

- Summarise UK research and innovation in the sphere of droughts and floods.
- Assess how outputs are currently implemented and exploited, and how well they are integrated.
- Explore the potential benefits of establishing a more holistic approach to such research and innovation.
- Consider how this could help increase the UK's share of the global water market.

It especially targets those in the water domain with the leadership skills to form effective partnerships that can progress the recommendations and influence how UK research and innovation are funded and enabled.

Water: The Front Line of Environmental Change

The global environment is changing rapidly and human activity is the biggest cause. Yet both our wealth as a nation and our individual wellbeing depend critically on the environment and on improving understanding of the value of natural assets and the vital goods and services they provide. All too evidently, we are fast outliving our planet's resources and showing little regard for those available.

Water has to be at the heart of any debate about natural resources. In view of our water-intensive lifestyle, we need to find ways of using this precious resource more efficiently and sustainably:

- In its 2015 Global Risks report, the World Economic Forum identified water as a significant threat to the global economy, ranking water crises as the leading threat in terms of impact and eighth in terms of likelihood. Extreme events (including droughts and floods) are ranked second in terms of likelihood.
- The UK National Ecosystem Assessment (UK NEA 2011) and its follow-on phase (UK NEAFO 2014) provided the first-ever comprehensive account of the state of the UK's natural environment. Along with recent reports by the Natural Capital Committee (NCC), they show how we have undervalued our natural resources – leading to ongoing loss of biodiversity and degradation of ecosystems, with failure to value water for environmental needs playing a key role in this process.

Ultimately, the decline of natural assets puts at risk goods and services we all rely on. Moreover, recent events have underlined the UK's vulnerability to environmental extremes, including droughts and floods. Insured losses due to floods and severe weather events in England alone have cost, on average, £1.1 billion per year over the

past 20 years¹; in 2007, widespread flooding affected 55,000 homes, killing 13 people and costing an estimated £3.2 billion²; and a severe drought between 2010 and 2012 was followed by the wettest period in England and Wales for almost 250 years³. Extreme events are likely to become more frequent and severe as the climate changes.

Droughts and Floods: The Role of Research

There is a critical need to improve assessment of risks and impacts related to extreme events and obtain scientific evidence that can aid the difficult trade-off decisions needed if long-term sustainability is to prove compatible with economic growth. Failure to develop adequate mitigation strategies potentially carries a grave human cost, exacerbated by ever-increasing population densities. Similarly, valuing natural resources properly will enable better decision-making, more secure investments, wealth/job creation and enhanced wellbeing in changing times ahead.

All of this poses both a challenge and an opportunity for UK research and innovation. Over the last decade, significant investment in drought and flood research has advanced understanding and raised awareness of threats triggered by population growth and climate-driven events. But many uncertainties remain and it is vital to generate research outputs that aid discovery of new ways of ensuring sustainable security of water supply as well as effective drought and flood protection.

Achieving this will require the UK's research, innovation and exploitation capacity to become genuinely 'joined up'. In the UK and the rest of Europe, the water sector is fragmented and characterised by widely diverse stakeholder interests and multiple research funding arrangements and networks. This can present obstacles not only to strategic research and innovation but also to implementation and wider exploitation of the outputs.

To date, there has been neither overall coordination of water research in the UK nor a single, united voice. In particular, there is no holistic, system-level approach to water security. Adopting such an approach, however, has real potential to deliver benefits in terms of the economy, society and the environment, while preventing habitat degradation and reversing trends in biodiversity loss.

The UK Water Partnership's Response

Addressing these issues, this report considers the degree of integration between science and end-user communities and explores opportunities for further innovation, wider exploitation and better realisation of the market potential of UK research outputs. It also underlines how the UK can build on its leading position in global environmental research to secure a larger share of the lucrative worldwide water market⁴.

¹ Commons Library Standard Note, 2014.

² EA, 2007.

³ CEH, 2013.

⁴ See also the UKWRIP report 'Tapping the Potential' (UKWRIP, 2014a; weblink in footnote 16 on p.10).

2. The Research Landscape: Droughts

Current, Recent and Planned Research

In contrast to floods and coastal erosion (see Section 3), there have been few UK investments in research relating to droughts. Nevertheless, scientific evidence is emerging thanks to funding targeting water scarcity⁵ and climate-driven events. Key investments made through the Research Council mechanism include those summarised below.

- NERC programmes⁶:
 - **Changing Water Cycle**: developing an integrated, quantitative understanding of the changes taking place in the global water cycle, to help improve predictions of regional precipitation, evapotranspiration, soil moisture, hydrological storage and fluxes.
 - **The Joint Weather and Climate Research Programme (JWCRP)**: facilitating joint research between NERC and the Met Office, to ensure the UK maintains and strengthens its leading position in weather and climate science.
 - **Droughts and Water Scarcity**: led by NERC in collaboration with ESRC, EPSRC, BBSRC and AHRC and enabling users to identify, predict and respond to droughts and understand interrelationships between the many drivers and impacts of drought events.
- Other examples of research funded through RCUK:
 - **The ESRC Nexus Network**: fostering debate, innovative research and practical collaborations across the linked domains of food, energy, water and the environment⁷.
 - **BBSRC**: BBSRC funds a number of studies on drought tolerance and resistance in crops, including projects focusing on using wild ancestor plants to make rice more resilient to increasingly unpredictable water availability⁸ and on combining field phenotyping and next-generation genetics to uncover markers, genes and

⁵ Water scarcity and drought are interrelated but distinct concepts. Drought is a natural phenomenon – a temporary deviation from average rainfall values over a large region and significant time period. Water scarcity is manmade – a recurrent imbalance arising from overuse of water resources.

⁶ For more information on these programmes and individual grants, see www.nerc.ac.uk/research/funded/programmes; for additional information and an overview of drought-related research, see www.groundwateruk.org/Drought-how-resilient-are-we.aspx

⁷ <http://thenexusnetwork.org.uk>

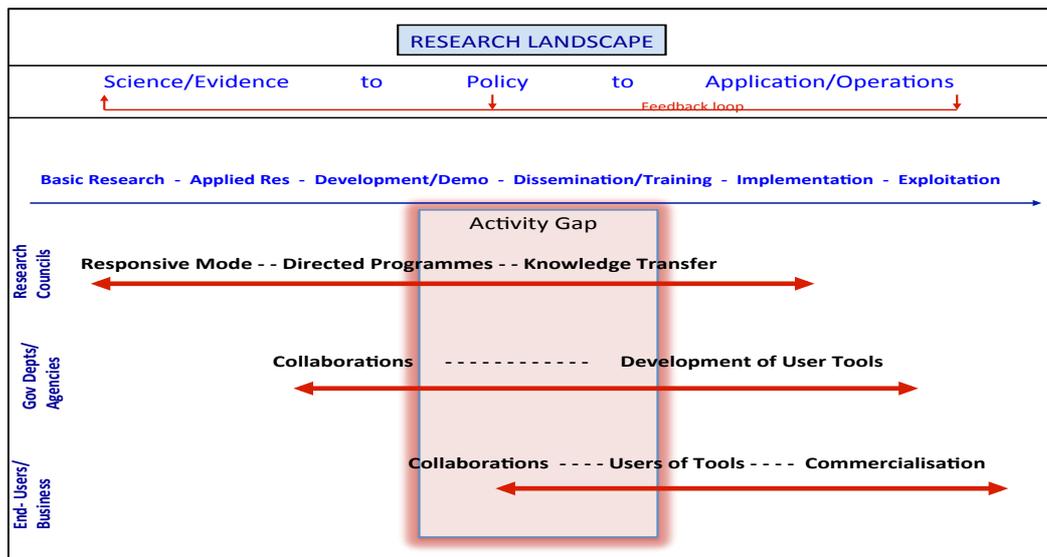
⁸ <http://gtr.rcuk.ac.uk/project/81088144-454D-4371-AC34-B080D2E7F554>

biology underlying drought tolerance in wheat⁹.

Research investments in Europe have been more extensive largely because droughts have hit it hard in recent decades. Every year between 2000 and 2006, an average of 15% of the EU's total area suffered from the impact of droughts. Key initiatives include:

- **The European Drought Centre (EDC):** a virtual centre for drought research and drought management organisations, promoting capacity building and collaboration between scientists and the user community¹⁰.
- **The European Drought Observatory (EDO):** providing timely, consistent information on droughts and compiling drought indicators based on meteorological and satellite data and hydrological simulation models¹¹.

Follow Through and Implementation



The figure¹² highlights the part of the UK research landscape where more activity is needed to help translate research outputs into real-world outcomes and aid pull-through to implementation and wider exploitation.

Against this backdrop, the Research Councils' primary role is to fund world-class science and provide training. They also strive for 'excellence with impact' and to facilitate knowledge exchange (KE). In recent years, there has been an increase in KE activities alongside greater focus on demonstrating impact from UK investments in environmental research. Mechanisms include:

⁹ <http://gtr.rcuk.ac.uk/project/DB2499E3-8A24-4068-9226-CD4112C415C9>

¹⁰ www.geo.uio.no/edc

¹¹ <https://ec.europa.eu/jrc/en/research-topic/desertification-and-drought>

¹² Adapted from Moores and Rees, 2012.

- Policy placement fellowships, enabling researchers to work closely with policymakers in government, public and third-sector organisations.
- Directed KE programmes, such as NERC's Water Security Knowledge Exchange Programme (WSKEP) which delivered the WSKE Portal¹³.

Translation is also supported by Innovate UK's Catapult initiatives. To date, there has not been any specific initiative targeting the water market – although the Future Cities Catapult considers new solutions to deliver a thriving economy and improved quality of life with a reduced environmental footprint¹⁴. Similarly, the Satellite Applications Catapult seeks to exploit UK space-related expertise, including innovative monitoring capability¹⁵.

Nevertheless, research often fails to deliver products and services that can increase the UK's share of the global water market. The UKWRIP report 'Tapping the Potential' identifies nine reasons for this, including funding that is focused on research rather than exploitation and the lack of an aligned vision¹⁶.

The process by which commissioned research is implemented and more widely exploited is not always easy to identify. WSKEP, however, produced case studies (still available via the WSKE Portal) showing how water-related challenges can be tackled, while positive examples of successful research implementation also include the following:

- Artificially recharging groundwater aquifers with water to provide storage for later abstraction, developed internationally since the 1980s and, in a few cases, adopted in the UK during the late 1990s.
- UK water companies working with estate owners and farmers to change land management to improve upstream water quality, avoiding treatment costs.
- South West Water's work with the Wildlife Trusts of Devon and Cornwall, the Westcountry Rivers Trust, Dartmoor and Exmoor National Parks, the EA, Natural England and English Heritage to restore water-rich landscapes and river basins.
- The UK's first water-sensitive partnership, recently launched to reduce the impacts of climate change and population growth in towns and cities in South West England.

Globally, the recognition of business risk posed by scarce water resources has resulted in opportunities for collaboration between city governments and business¹⁷. Examples of efforts to boost cities' climate resilience and economic competitiveness include:

- San Diego, US: water resource plans and urban water management to cut water

¹³ www.wskep.net

¹⁴ <https://futurecities.catapult.org.uk/>

¹⁵ <https://sa.catapult.org.uk>

¹⁶ http://www.theukwaterpartnership.org/wp-content/uploads/2015/04/ukwrip_tapping_potential_report_interactive.pdf

¹⁷ CDP, 2014a.

demand and conserve water resources.

- Escondida, Chile: investment in a desalination plant to ensure availability of adequate water.

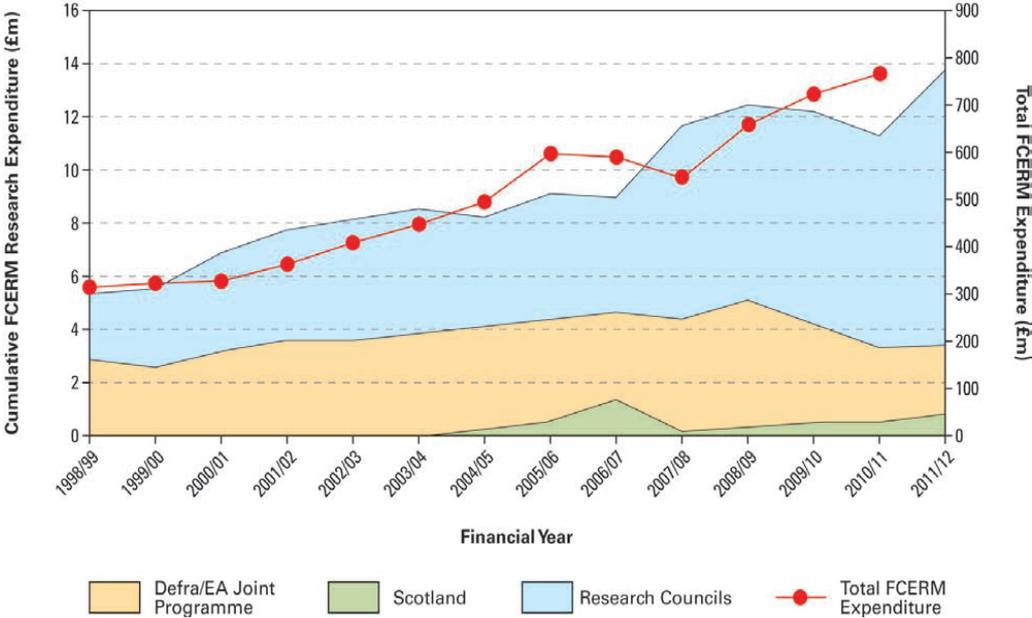
Finally, it is worth noting that long-term benefits from research investments are often difficult to track due to the complexity of the many factors determining outcomes. Research clearly contributes to the competitiveness of UK consultancies but this is impossible to quantify.

3. The Research Landscape: Floods

Current, Recent and Planned Research

Over more than a decade, the UK Government has allocated funding to manage the risk of flooding and coastal erosion, with the EA responsible for the strategic overview of all sources of flooding in England. In 2009, following the Government Foresight Study on Flooding (2004) and the Pitt Review (2007), the EA published a long-term strategy setting out evidence on the choices England faces regarding investment needed to manage the risk of flooding and coastal erosion between 2010 and 2035.

As the graph shows, the past decade has also seen substantial research investment in Flood and Coastal Erosion Risk Management (FCERM); however, the funding allocation is relatively modest when compared to the scale of flooding’s potential consequences.



FCERM Research Investment¹⁸

Following a 1999 review¹⁹, a Joint R&D Programme on FCERM was established, sponsored by the Department for Environment, Food and Rural Affairs (Defra) and the EA – and now also by Natural Resources Wales (NRW) and the Welsh Government (WG). Major investments subsequently included the Flood Risk Management Research Consortium (FRMRC) 2004-2008, which attracted wider funding (primarily from EPSRC and the EA), plus a subsequent multi-partner-funded phase designed to complement the Joint R&D Programme and receiving additional sponsorship from EPSRC, NERC, UKWIR, the Scottish Executive and the Northern Ireland Rivers Agency.

Flood events have had a big bearing on policy direction. Most notably, the Pitt Review that followed the summer 2007 floods was instrumental in producing the UK FCERM

¹⁸ Moores and Rees, 2012.
¹⁹ Ministry of Agriculture, Fisheries and Food (MAFF)/EA, 1999.

Research Strategy (2012). Developed through the Living With Environmental Change (LWEC) partnership, this sets out a coherent vision for future research and aims to place research and evidence at the heart of FCERM activities through:

- Effective translation of research findings into practical application.
- Promotion of better interactions between research community, business, public, policymakers and international partners.

RCUK investments enhance scientific excellence and recognition of the UK as a global leader in flood-related research. A key role is played by NERC's Centre for Ecology and Hydrology (CEH) and the British Geological Survey, which have conducted research over many years on both floods and droughts, while NERC's National Oceanographic Centre delivers excellence in marine and coastal studies. EPSRC's Centre for Earth Systems Engineering Research (CESER) provides analyses, tools and demonstrations enabling practical responses to the challenges of intensifying global change.

- NERC programmes include²⁰:
 - **Coastal Sediment Systems**: improving our ability to predict long-term and regional-scale change on coasts and in estuaries.
 - **Flooding from Intense Rainfall**: cutting the risk of damage and loss of life through improved identification, characterisation and prediction of interacting processes contributing to flooding associated with high-intensity rainfall events.
 - **Probability, Uncertainty and Risk in the Environment (PURE)**: improving assessment and quantification of uncertainty and risk in natural hazards.
 - **Storm Risk Mitigation through Improved Prediction and Impact Modelling**: improving forecasting of storms and their impacts on catchments and coasts.
 - **Flood Risk from Extreme Events (FREE)**: this built flood prediction models enabling flooding events to be identified minutes, weeks and decades in advance.
 - **Environmental Risks to Infrastructure Innovation**: aiming to provide sound evidence for the identification and assessment of environmental risks and their impacts, and to translate the latest research into industry-relevant outputs.
- ESRC research includes:
 - **The Orientation project**: this constructed 'timelines' of infrastructure protection policy and mass population response to examine how and why policy changes over time. Results were tested using case studies of actual disasters and expert groups of policymakers²¹.

²⁰ For more information on these programmes and individual grants, see

www.nerc.ac.uk/research/funded/programmes

²¹ <http://gtr.rcuk.ac.uk/project/2F553843-A076-4AEE-B91A-BB55438D5B5F>

- **Sustainable Flood Memories:** investigating the extent to which local communities with histories of extreme flooding are better equipped practically and psychologically to cope during and after new floods²².
- EPSRC research projects include:
 - **Blue-Green Cities:** an interdisciplinary initiative developing new strategies for managing urban flood risk as part of wider, integrated urban planning.²³.
 - **Organisational Operational Response and Strategic Decision Making for Long Term Flood Preparedness in Urban Areas:** researching the behaviours of organisations and developing a digital tool providing practical information in a format that engages users in an active learning process to make them more flood-resilient²⁴.
 - **Flood MEMORY (Multi-Event Monitoring Of Risk and recoverY):** considering the most critical flood scenarios caused by sequences or clusters of extreme events striking vulnerable flood defences, urban areas communities and businesses. Identifying worst-case scenarios could lead to enhanced flood resilience and better allocation of resources for protection²⁵.
 - **Sesame:** finding ways of helping Small and Medium-sized Enterprises (SMEs) adapt to flood risk by developing tools encouraging them to become more resilient and more aware of the ongoing risk²⁶.
- Other research funded through RCUK includes:
 - **Before the Flood:** supported by AHRC, this explored the scope to build flood resilience among hard-to-reach urban communities by staging performance events and developing narrative-based audio resources²⁷.
 - **The Summer after the Floods:** using UK flood events to study factors enabling or inhibiting flood recovery from the perspective of businesses, homeowners, local communities and the environment²⁸.

Within Europe, the UK has actively participated in a considerable number of investments focusing on strategic integration of flood risk management (FRM). These include two recently completed European Research Area Networks (ERA-NETs):

- **CRUE** (Coordination of Research financed in the European Union), which delivered strategic integration of research with the goal of providing knowledge and

²² <http://www.esrc.ac.uk/my-esrc/grants/ES.I003576.2/read>

²³ www.bluegreencities.ac.uk/bluegreencities/index.aspx

²⁴ <http://gtr.rcuk.ac.uk./project/B75839B5-9C3E-430A-B86E-BF319CAFFB64>

²⁵ <http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/K013513/1>

²⁶ <http://sesame.uk.com/index.php>

²⁷ <http://gtr.rcuk.ac.uk/project/6A8A6B18-8B57-434F-9664-DA288B0F15AF>

²⁸ <http://gtr.rcuk.ac.uk/project/B2CE9642-5A7F-41C5-A206-B26C26190C4B>

understanding for the sustainable management of flood risks²⁹.

- **IWRM** (Integrated Water Resources Management), bridging the gap between national research programmes and establishing the online European Water Community³⁰ connecting science with policy and innovation.

In addition:

- The **FLOODsite** initiative works with authorities and agencies internationally to assist implementation of research³¹.
- The Joint Programming Initiative **Water Challenges for a Changing World** has aimed to tackle the challenge of achieving sustainable water systems for a sustainable economy in Europe and abroad. It will be a relevant structure for Horizon 2020, the next EU research and innovation strategy³².

To sum up, over the past decade, a thematic programme approach, together with Research Council-funded initiatives and European-sponsored programmes, has generated numerous research outputs whose details can be accessed via:

- RCUK's Gateway to Research³³.
- NERC's website³⁴.
- UKWIR's Research and Innovation Mapping Study³⁵.
- The EA's website³⁶.

The FCERM stakeholder group, meanwhile, has identified many remaining research challenges including: developing a better understanding of floods and our natural environment; working with natural processes; and setting up catchment laboratories³⁷.

Follow Through and Implementation

There are many examples of research outputs being implemented to boost capabilities in FCERM. One excellent example is the UK Government's Foresight Study on Flooding (2004), which used the best available science to provide a challenging vision for UK flood and coastal defence between 2030 and 2100. The more obvious examples of take-up tend to arise from initiatives that are more applied and supported financially by the

²⁹ <http://www.crue-eranet.net/>

³⁰ <http://www.iwrm-net.eu/>

³¹ <http://www.floodsite.net>

³² <http://www.waterjpi.eu>

³³ <http://gtr.rcuk.ac.uk/>

³⁴ www.nerc.ac.uk/research/funded/programmes/

³⁵ <http://www.theukwaterpartnership.org/#portfolio-page/publications/2>

³⁶ <https://www.gov.uk/government/organisations/environment-agency>

³⁷ <http://www.fcerm.net/resource/Environment-Agency-Challenges>

end-user community. Examples from the Defra/EA/NRW/WG joint research programme (see p.12) include:

- Policy on understanding and communicating flood risk, providing more consistent communication on flood risk assessment/management (reports FD2302, FD2007).
- Integrated management through mapping, modelling and probabilistic forecasting at different spatial scales (reports SC010017, SC080050, SC090008, SC050051, SC090032).
- An asset condition assessment manual on flood defences, enabling accurate and consistent inspection (report SC040018).
- Operational instructions, e.g. outlining methods and approaches to target communications at communities at risk (Defra's 'Making Space for Water' report and reports FD2321, SC070021).

More recently the Environmental Science to Services Partnership (ESSP), comprising six public sector bodies (the British Geological Survey, the CEH, the EA, the Met Office, NERC and Ordnance Survey), was established with the aim of developing ways to translate and apply environmental science to support delivery and improvement of UK services³⁸.

Examples also exist of wider exploitation of scientific understanding to the UK's economic benefit, although it is more difficult to identify the direct translation of floods and coastal erosion research into market-available products. Blue Pages is a web-based directory of flood products and services³⁹, while an internet trawl reveals many UK consultancies offering services from project management to full-scale civil engineering planning and design. With some notable exceptions, however, it is not clear how market experience feeds back to help shape UK research planning and investment.

³⁸ <http://www.bgs.ac.uk/essp/>

³⁹ <http://www.bluepages.org.uk/>

4. Towards a More Holistic Approach

Integration, not Fragmentation

Sections 2 and 3 revealed some good examples of take-up of research outputs by a range of end-users – a process enhanced in recent years by greater emphasis on multi-stakeholder working arrangements and targeted KE activities. However, while current UK Research Council water-related investment amounts to around £120 million⁴⁰, the overall evidence indicates relatively poor translation in terms of delivering products and services capable of increasing our share of the global water market.

It is clear that separate arrangements are in place for research focused on issues relating to too much water and research focused on issues relating to drought and water scarcity – although both droughts and floods represent climate-driven pressures on the water cycle and often affect similar economic, societal and environmental issues. Moreover, arrangements for prioritising and commissioning research differ between funders and remain largely uncoordinated. This is reflected in fragmented governance arrangements in the UK water sector and current legislation separating EU policies on FRM (the Floods Directive 2007) and the environment (the Water Framework Directive 2000).

Institutional interactions and interdependencies can also create complexity and unintended consequences that militate against joined-up thinking and drive reductionist approaches, resulting in bias towards a technical focus at the expense of ‘softer’ social processes and the tricky socio-technical interface. Anecdotal evidence also suggests that, despite greater stakeholder involvement and agreement in the preparation of long-term strategies, coordination and execution of research are often problematic.

More detailed, better resourced delivery plans for arrangements that are genuinely co-funded, co-designed and co-delivered would help orchestrate a portfolio of programmes to meet strategic goals. This is especially the case where central coordination and funding arrangements are absent and delivery relies heavily on individual funders making piecemeal contributions to the strategic effort.

Attempts to improve stakeholder engagement have seen a proliferation of networks and social media outlets in recent years. Examples include the:

- **FCERM Network:** providing experts with opportunities to collaborate, share research outcomes with diverse audiences and promote translation of research outcomes into policy and practice⁴¹.
- **Ecosystems Knowledge Network:** aiming to share knowledge and learning about the practical benefits of adopting an ecosystem approach⁴².

⁴⁰ UKWRIP, 2014a. http://www.theukwaterpartnership.org/wp-content/uploads/2015/04/ukwrip_tapping_potential_report_interactive.pdf

⁴¹ <http://www.fcERM.net>

⁴² <http://ecosystemsknowledge.net>

- **Valuing Nature Network:** bringing together natural scientists, economists and decision-makers in business and policymaking with an interest in valuing nature⁴³.
- **ESRC Nexus Network:** fostering collaborative projects and encouraging a more holistic approach to research funding and decision-making across the linked challenges of food, energy, water and the environment⁴⁴.
- **Knowledge Transfer Network:** bringing together businesses, entrepreneurs, academics and funders to develop new products, processes and services⁴⁵.
- **LWEC Ecosystem Task Force:** facilitating use of LWEC knowledge in decision-making, helping to create the tools needed to realise nature's value⁴⁶.
- **Joint Water and Evidence Group:** bringing together 'land & water' evidence teams from Defra, the EA, Natural England and the Forestry Commission (England) to work on topics of common interest and make better use of available evidence⁴⁷.

The challenge is to harness opportunities and knowledge in order to generate productive outcomes. Without whole-system understanding, high-level coordination, effective partnership working and more integrated collaborative efforts, the risk is that optimal benefit from UK investment in water research will disappoint expectations.

The Importance of Whole-System Thinking

It is perhaps unsurprising that a number of recent initiatives point to the need for greater integration across scientific disciplines and for more whole-system thinking. For example, Defra's 2008 water strategy for England looked ahead to 2030 from the perspective of the water cycle as a whole (from rainfall and drainage to discharge and treatment).

There are many reasons why, at a whole-system level, we need better understanding of the impacts of extreme events and of interventions designed to manage associated risks. Increased food production during the latter 20th century was largely achieved by making more land available for agriculture; but removing hedges, wetlands and woodlands and applying nitrogenous fertiliser resulted in unintended loss of landscape resilience and a reduction in its ability to hold and move water⁴⁸. This has been exacerbated by infrastructure such as weirs, dams and reservoirs which, while aiding control of water, can result in hydromorphological changes with adverse ecological results.

River flow regimes and recharge are affected by land use change and the way a catchment is managed. For instance:

⁴³ <http://www.valuing-nature.net>

⁴⁴ <http://thenexusnetwork.org.uk>

⁴⁵ <http://www.ktn-uk.co.uk>

⁴⁶ <http://www.lwec.org.uk/our-work/ecosystems>

⁴⁷ <https://www.h2020uk.org/web/jweg/overview>

⁴⁸ <http://ecosystemsknowledge.net>

- Excessive groundwater abstraction can result in salt intrusion in some coastal areas.
- Field run-off of agrochemicals and sediment erosion have resulted in many water bodies failing to achieve their Water Framework Directive status.
- The presence of emerging pollutants and the spread of pathogens reduce water quality and put at risk both human health and ecosystem conservation.
- Environmental change can increase susceptibility to invasive species⁴⁹.

One consequence can be increased levels of contaminants in water abstracted for potable supply, leading to increased treatment costs. Yet an expanding population will demand more potable abstraction and will increase discharges of sewage effluent. Future pressures on the environment due to uneven distribution of seasonal rainfall, higher incidence of extreme events and increasing urban development are all likely to exacerbate water scarcity and to require changes in water usage patterns.

Reflecting the requirement for whole-system thinking, the 2004 Foresight Study on Flooding identified the need to manage the layout and functioning of cities so they can adapt to future changes in rainfall patterns. It identified green corridors and the maintenance of existing undeveloped spaces as ways of providing ‘safety valves’ for storage and passage of floodwaters and delivering substantial sustainability benefits. Above all, decisions on where to build new houses, factories and infrastructure – avoiding areas at flood risk – must be balanced against other needs.

More holistic understanding is required at global scale too. In wet years the Amazon rainforest takes more carbon out of the atmosphere, but recent evidence shows it has the potential to become a source of carbon emissions in drought years⁵⁰. Moisture plays an important role in determining the Amazonian carbon balance, so focusing solely on stopping deforestation may not lead to carbon reductions and siloed understanding could have serious repercussions.

The Value of an Ecosystems Approach

The Millennium Ecosystem Assessment popularised the term ‘ecosystem services’ and detailed the benefits we derive from our environment. The UK NEA and its follow-on phase provided a UK-specific assessment and, together with NCC reports in 2013 and 2014, highlighted how ongoing loss of biodiversity, ecosystem degradation and likely impacts of demographic and climate change put at risk goods and services we all depend on.

Looking ahead, the Intergovernmental Panel on Climate Change predicts that by 2100 the planet will warm by 1.8-7.1°C above pre-industrial levels⁵¹. This presents many risks as shown below⁵²:

⁴⁹ Arnell et al., 2014.

⁵⁰ Gatti, et al., 2014.

⁵¹ The Climate Change Committee website (<http://www.theccc.org.uk/tackling-climate-change/the-science-of-climate-change/>) provides more information on these risks.

⁵² Adapted from <http://www.theccc.org.uk>

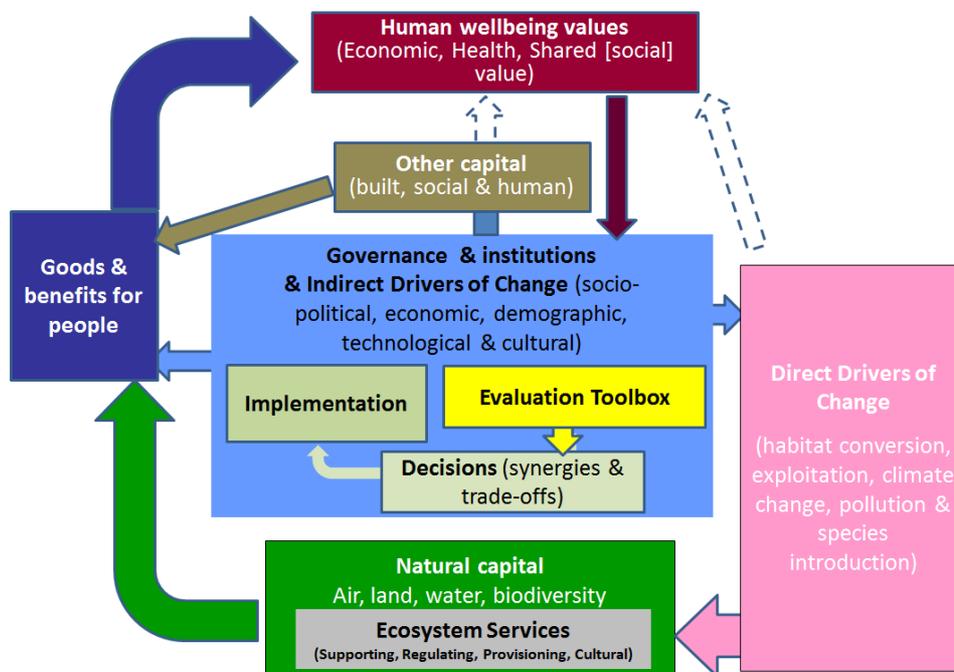
WATER	Hundreds of millions exposed to water stress			
ECOSYSTEMS	Increasing risk of global species extinctions			
FOOD	Yields fall in tropics		Yields fall in most areas	
COASTS	Millions exposed to more flooding			
HEALTH	Increasing burden from disease and extreme weather			
Temp. rise	1	2	3	4°C

These risks illustrate the need for more holistic thinking and specifically an ecosystems approach that provides a framework for looking at whole ecosystems and valuing the services they provide. Fundamentally, such an approach provides a way of looking at the environment throughout the decision-making process, helping one consider:

- The way the natural environment works as a whole system, as well as the risks and impacts of natural and human-induced pressures.
- The spatial scale of interactions with this environment, constraints, limitations and the people involved in supplying/receiving ecosystem services and benefits.

Carrying out an economic valuation of ecosystem services will also help incorporate the value of the natural environment into planning and management actions.

A decision-making framework specifically designed for use with regard to natural capital is set out below⁵³:



⁵³ Source: UK NEAFO, 2014.

Importantly, in the flood domain, some essential elements of an ecosystems approach are already being explored:

- A recent Ecosystems Knowledge Network Newsletter reports new research from the University of Leeds, where studies on a headwater of the Calder Valley have identified how an environmentally beneficial reduction in peak flow of up to 5% can be achieved by modifying vegetation close to streams and watercourses⁵⁴.
- A research proposal recently initiated under the EA/Defra Joint R&D Programme (see p.12) reviews a number of schemes in catchment laboratories across the UK (report SC130004). The project will build on current catchment studies, including the Defra-led Demonstration Test Catchments⁵⁵ looking at farming practices aiming to reduce diffuse pollution from agriculture.
- Examples from the Joint R&D Programme that consider the wider environmental benefits of flood relief schemes include reports on Landscape and Environmental Design Guidance (2006), the River Restoration Manual (2013), the Pontbren Project⁵⁶, the Ripon Multi-Objective Project⁵⁷ and the Water Framework Directive Mitigation Manual (2013).

Additionally, a Forum for the Future⁵⁸ initiative on sustainable water movement has developed a systems map to help shape funding, collaboration and KE across diverse stakeholders working with natural processes.

Further details on catchment-based approaches are included in a Parliamentary Office of Science and Technology Note (POSTNOTE 2014), which describes a range of natural flood management (NFM) measures across river catchments to reduce the probability of flooding. For example, it looks at interventions to reduce the likelihood or severity of flooding by gradually lowering or spreading out the flood peak as it passes along a river. This expands a river's drainage network during periods of high flow and purposely floods some areas, while reducing water flow to areas more vulnerable to flood damage.

Despite the success of several UK pilot schemes, catchment-wide FRM has yet to be widely implemented. Lack of empirical evidence that such measures result in reduced flood risk can create difficulties in proposing integrated schemes, as resources are prioritised to achieve the greatest possible flood risk reduction.

Tackling Institutional Barriers

To facilitate more flexible outcomes, institutional barriers to embedding ecosystem services into government policies and decision-making need to be recognised and addressed. Recent initiatives to promote holistic thinking include:

⁵⁴ <http://www.pennineprospects.co.uk/local/naturalflood+management>

⁵⁵ <http://www.lwec.org.uk/activities/demonstration-test-catchments>

⁵⁶ <http://www.waterco.co.uk/pdf/pontbren-report.pdf>

⁵⁷

<http://webarchive.nationalarchives.gov.uk/20130402151656/http://archive.defra.gov.uk/environment/flooding/documents/manage/riponlessons.pdf>

⁵⁸ www.forumforthefuture.org

- **The Natural Hazard Partnership**⁵⁹: providing information, research and analysis on natural hazards (including floods and droughts) for the development of more effective policies, communications and services for civil contingencies, governments and the responder community across the UK. The challenge is to broaden the focus from predominantly an early warning system towards a more integrated approach emphasising risk reduction and prevention.
- **The Climate Change Adaptation Sub-Committee**⁶⁰: established by the 2008 Climate Change Act to provide independent advice to the UK Government and Parliament, this has collated evidence and identified indicators to help assess preparedness for priority risks and opportunities. In 2012, it reported on flood risk to people and property and potential risks to water availability for public supply. In 2013, it reported on the ability of England's natural capital to continue to provide food, timber, clean water, carbon storage and coastal protection, and to support wildlife, in a changing climate. In 2014, it reported on climate risks to health and wellbeing and the current state of resilience of England's emergency services, infrastructure and businesses.

Given that many ecosystems – and the services they deliver – are in long-term decline, there is also an urgent need to illustrate the threat to wellbeing posed by further environmental deterioration:

- The NEAFO aims, through an Adaptive Management Strategy, to assist decision-makers in making and exercising informed choices. This flexible 'learning-by-doing' process is central to the Ecosystem Services Conceptual Framework and can be implemented through a Decision Support System Toolbox (see figure on p.20).

The NEAFO offers a powerful mix of methods to incorporate non-monetary values into decision-making, illustrated through case studies at local and national scales. Bateman et al. (2013) show that significant increases in value can be obtained from targeted planning by incorporating all potential services and their values.

- The UK is at the forefront of scientific research on the ecosystem approach and modelling, mapping and valuing flows of ecosystem services. Current research includes the NERC programmes Biodiversity and Ecosystem Services Sustainability⁶¹ and Valuing Nature⁶². This unique position opens up the potential to increase the UK's share of global water markets.

⁵⁹ <http://www.metoffice.gov.uk/nhp/about-us>

⁶⁰ <http://www.theccc.org.uk/wp-content/uploads/2014/09/2014-08-27-ASC-submission-to-EAC-v2.pdf>

⁶¹ <http://www.nerc-bess.net>

⁶² <http://www.nerc.ac.uk/research/funded/programmes/valuingnature/>

5. Optimising Exploitation, Maximising Market Opportunities

Pinpointing Potential

The 2014 UKWRIP report ‘Tapping the Potential’ highlights the UK’s low share of the global water market. It also sets ambitious yet achievable goals to extend that share from 3% to 10% by 2030 and to increase employment in the sector from 15,000 to 71,000 by the same date. Complementing this, the report analyses UK strengths and weaknesses and pinpoints potential target markets for growth.

In this context – and assessing the scope for growth from the perspective of a more holistic approach to water management – this Section considers potential areas for exploitation, as well as some of the constraints. Underpinning this discussion is the recognition that different sectors of the economy rely on the natural environment to sustain their business and provide opportunities for jobs and growth. Above all, there is a clear need for better understanding of these dependencies and of difficult trade-off decisions to maintain growth without further environmental damage⁶³.

Ecosystem-related Markets

A more holistic approach to water management can open up a range of ecosystem-related markets. Commissioned by the Valuing Nature Network on behalf of the Ecosystem Market Task Force, a scoping study has identified eight main types of business opportunity – with many directly relevant to water markets⁶⁴:

1. **Product markets:** derived from and/or sustaining ecosystem services and potentially incorporating certification schemes.
2. **Biodiversity offsets:** helping companies manage their impacts on ecosystems, these compensate for impacts in one place by creating equivalent benefits elsewhere.
3. **Payment for ecosystem services (PES):** embracing schemes through which beneficiaries or users of ecosystem services provide payment to stewards or providers of those services.
4. **Environmental technologies:** preventing or treating pollution, enhancing management of ecosystems and enabling more efficient use of resources. Such solutions include direct interventions (e.g. river restoration) and systemic changes (e.g. less resource-intensive production processes).
5. **Markets for cultural services:** derived from environmental settings that give rise to cultural goods and benefits (e.g. tourism) and including gardens, informal and formal green and blue spaces, the countryside and national landscapes/seascapes.
6. **Financial and legal services:** categorised as enabling activities relevant to ecosystem service business opportunities, in the same way as they relate to the

⁶³ The third NCC report (2015) takes an in-depth look at how natural capital benefits the economy.

⁶⁴ Duke et al., 2012.

wider economy.

7. **Ecosystem knowledge economy:** providing opportunities to develop knowledge-based businesses, high-quality employment and growth opportunities.
8. **Corporate ecosystem initiatives:** voluntary actions by companies driven by factors such as the need to enhance/protect brands, meet consumer demand and manage supply chain issues, or simply by the desire to 'do the right thing'.

The Differing Needs of Specific Sectors

Key to boosting the UK's global market share is (i) a better sector-level understanding of business risks and opportunities associated with more frequent extremes of climate and (ii) identification of solutions that can tackle existing and emerging challenges in the water domain. Further research and innovation are needed to deliver solutions guaranteeing water supply for various uses while ensuring sustainable development of ecosystems alongside economic prosperity. The following examples provide a flavour of the challenges and opportunities facing specific sectors:

- **Corporates, Investors and Insurance**

A growing number of corporations are seeking to understand how resource constraints and natural capital depletion will impact them⁶⁵. Although there is still no agreed protocol for National Capital Accounting, a general approach does exist and companies at the cutting-edge are implementing methods to measure/value their impacts and factor these into their decision-making.

A significant end-user of risk research and catastrophe modelling, the insurance sector occupies a key position in terms of its contribution to the UK economy and its role as a risk transfer mechanism for droughts and floods. Recent developments include the Flood Reinsurance Scheme, which will ensure domestic property insurance continues to be widely available and affordable in areas of flood risk.

- **Landowners, Policymakers and Agriculture**

The way we exploit land and water resources is critical to the challenge of improving food security worldwide. In some places, agricultural water management has caused wide-scale ecosystem changes and undermined a range of ecosystem services.

The UK offers many excellent examples of research on land management interventions that can improve water flow and water quality at catchment scale and deliver wider societal and cultural benefits. For instance, an increasing number of PES schemes have arisen where downstream users pay for catchment management upstream that sustains the required supply and quality of water⁶⁶.

⁶⁵ Winstanley and Brownlee, 2014.

⁶⁶ <http://www.southwestwater.co.uk>

However, there remain many challenges in terms of working with landowners and farmers in fragmented arrangements at catchment scale. These are of global importance and a 2011 Food and Agriculture Organization (FAO) report identifies the need for commitments and investments to produce more nutritious food with less water, with innovative technologies required to ensure greener, more sustainable food production. A UKWRIP Agriculture Action Group synthesis report published in 2015 explores the linkage between water and food production, plus the challenges of delivering both food and water to society in a sustainable way⁶⁷.

- **Energy Providers**

Realisation is growing that future development of the UK's energy system has profound implications for natural capital and for ecosystem service provision. Increased use of electricity, nuclear generation, renewable energy production, fossil fuel imports, onshore extraction of unconventional fossil fuels and carbon capture and storage (CCS) could cause new conflicts but could provide opportunities for synergies between energy and a range of ecosystem services.

A key consideration is interdependency between future energy needs and water availability and use. The proportion of water abstraction used for power generation varies significantly across the UK, so competition with other abstraction uses also varies. Water availability varies at different times too, potentially leading to shut-down of power stations during drought conditions when supply needs to be sustained for other purposes. Such trade-offs are likely to be exacerbated by population growth and climate change⁶⁸.

This opens up research and innovation opportunities to develop and integrate the practices of the currently separate UK energy and valuing nature communities and bring together natural, economic and social science disciplines. To help address this, NERC is funding a five-year UK Energy Research Centre challenge, 'Valuing Natural Capital in Low Carbon Energy Pathways'. This aims to understand the implications for natural capital and ecosystem service provision of future energy scenarios, including those compatible with the policy goals of maintaining energy security, keeping energy affordable and cutting greenhouse gas emissions by 80% by 2050.

- **Water Utilities**

Discharges to watercourses are inextricably linked with water abstraction and need to be considered holistically. Water utilities are the largest of all dischargers, accounting for over 50% of releases to rivers in England and Wales and, in some places, up to 60% of volume during periods of low flow.

Statutory 25-year water company resource management plans consider long-term planning for supply and inform Ofwat reviews of water price limits. They examine supply options and take into account the best available information on changes in climate, population and water demand. Water companies are also charged with

⁶⁷ UKWRIP, 2015a. <http://www.theukwaterpartnership.org/wp-content/uploads/2015/04/water-synthesis-report.pdf>

⁶⁸ Rance et al., 2012.

preparation and execution of drought plans. The Government is seeking to inform actions to meet water security challenges through its consultations on Water Abstraction Reform and Drought⁶⁹ and Water Abstraction Reform and Water Company Discharges⁷⁰.

The economic impact of growing global demand in terms of water quantity and quality is becoming better understood. The CDP's Global Water Report found that over two-thirds of Global 500 companies reporting to the CDP face substantive water risks and that investing to conserve, manage or obtain water has become crucial⁷¹. Companies increasingly recognise that 'business as usual' approaches to water management are no longer sufficient and a shift is needed if they are to realise the true benefits of water stewardship and achieve competitive advantage. Partnership arrangements present opportunities to innovate and to fund sustainable initiatives that have multiple long-term benefits.

At the technology level, major breakthroughs are needed to cope with emergent challenges – for instance, deployment of capital-intensive water infrastructure and the need to reduce energy use by water processes.

- **Urban Development and Future Cities**

Ecosystems have suffered more human-induced fragmentation in Europe than in any other continent. In the last 20 years alone, built-up areas have increased by 20% and, as a result, almost half of European wildlife is in serious decline and valuable ecosystems have become degraded and fragmented.

Recent estimates indicate that, by 2050, 800 million people worldwide will be living in cities of 5 million-plus inhabitants, creating unprecedented demand for innovations suited to densely populated areas. Urbanisation, a growing population, climate change and pressures on resources make water and cities a particularly challenging multidisciplinary issue to tackle⁷².

Future cities and the way people live there are likely to become more dependent on local supply of many goods and services that our environment provides. A more holistic, integrated planning approach will need to consider the availability and sustained management of water, energy and food, as well as natural regulation embracing water quality, flood protection and waste management, plus risks and opportunities in terms of health and wellbeing.

Water and cities would benefit from a joined-up national strategy integrating the whole water cycle and its relationships with other systems. The indirect benefits of water, in terms of leisure, recreation, urban ecosystems, biodiversity, health and

⁶⁹ <http://defra.dialogue-app.com/water-abstraction-reform-and-drought>

⁷⁰ <http://www.water.org.uk/abstraction-reform-response-defra-consultation>

⁷¹ CDP, 2014b.

⁷² UKWRIP, 2014b. http://www.theukwaterpartnership.org/wp-content/uploads/2015/06/ukwrip_final_city_report.png

wellbeing, should also be considered more holistically and recognising the need to protect natural assets.

Some key issues and research requirements were assessed in a 2015 UKWRIP Thought Piece highlighting innovative approaches to better city planning⁷³. Options could include green space, roof gardens, raised buildings, porous surfaces, catchment controls and better use of grey water.

- **General Public, Health and Wellbeing**

Department of Health figures estimate that poor mental health costs the UK economy £145 billion per year. Currently, we lack sound understanding of the role our environment plays in determining health and wellbeing outcomes but, if improved ecosystem management eliminated just a fraction of these costs, the economic benefits of further research could be substantial.

Awareness is gradually growing that higher average temperatures and an increase in the frequency and severity of extreme weather events (e.g. floods, droughts and heatwaves) could have a range of impacts on human health. For example, evidence is emerging that flooding can have a substantial effect on mental health, causing anxiety and depression⁷⁴, and that this can be long-lasting⁷⁵. However, there are still significant research gaps on the health effects of flooding.

An expanding population, meanwhile, will demand more potable water abstraction and will increase discharges of waste effluent. These trends will require both technology and behavioural solutions.

While this brief analysis illustrates how risks and opportunities in the water domain differ by sector, it also highlights many overlapping issues and interdependencies. An obvious example is the energy, food and water nexus. Although a holistic approach is clearly needed⁷⁶, energy, water and food resource systems have mostly been organised and studied independently.

There is little evidence that the UK flood or drought research communities have embraced a more systematic evaluation of sectors to help direct research and innovation from a business perspective. However, the UKWRIP report 'Tapping the Potential' found that, in some countries, coordination between government, academia, utilities and business has acted as an engine of growth, providing a robust basis for developing competitive, innovative companies capable of impressive export performance.

⁷³ UKWRIP, 2015b. <https://www.gov.uk/government/publications/future-of-cities-water-and-cities>

⁷⁴ Alderman, K. et al., 2012.

⁷⁵ UK 2012 Climate Change Risk Assessment for the Health Sector:

<http://www.defra.gov.uk/environment/climate/government/>

⁷⁶ Halstead et al., 2014.

The Challenge for Research and Innovation

The UK's position as a world leader in environmental research provides opportunities to innovate and to improve translation of UK research into global market share. Closer links between business and academia are needed to ensure we capitalise on our capabilities. A whole-system approach will allow interdependencies to be pinpointed and research efforts to be better targeted.

Realising the benefits will require different skill-sets and effort across disciplines not previously familiar with each other. Effective engagement between researchers and end-users is essential in problem construction, co-production of knowledge and development of clear strategies for knowledge application and exploitation.

Research works best when participants are regularly informed about priorities and timings. UKWRIP's 'Tapping the Potential' highlights the fractured nature of the UK's water technology sector and the significant market potential available if this can be eliminated – a goal that would be aided significantly by better aligning basic and applied research with longer-term commercial opportunities.

6. Key Findings and Recommendations

Water scarcity is already a reality for almost a third of the world's population. Projections indicate that an expanding, wealthier global population will need as much as 70% more food by 2050 – with obvious implications for water demand. Moreover, across Europe, droughts and floods are already the most important environmental hazards in terms of economic loss.

Current evidence indicates that, in the UK, rivers will become warmer, summer stream flows lower and winter stream flows higher⁷⁷. It is not so much the amount of water that is lacking but good governance and management of water and land resources. These challenges require partnership arrangements in co-designed, co-delivered programmes that generate innovative solutions and more holistic, whole-system thinking.

A number of issues raised in this report therefore warrant more detailed consideration – particularly those concerned with design, delivery, implementation and exploitation of research. Indeed, some findings challenge current funding models and governance arrangements. The new UK Water Partnership is an appropriate vehicle to generate debate and pursue some of the necessary actions.

Ten Key Findings:

1. **The global environment is changing rapidly and human activity is the biggest cause.** Increased pressures on the environment in years to come are likely to exacerbate water scarcity and pose a threat to human health and wellbeing.
2. **The past decade has seen substantial research investment in Flood and Coastal Erosion Risk Management (FCERM).** However, funding is still relatively modest and there is clearly a case for increased research effort.
3. **There have been few UK investments in research relating to droughts and water scarcity,** although investments in Europe have been more extensive.
4. **There are many examples of research outputs being implemented,** although the most obvious tend to relate to initiatives that are more applied and supported financially by the end-user community.
5. **UK research on flood-related issues is generally commissioned independently of research on droughts and water scarcity,** even though droughts and floods both represent climate-driven pressures on the water cycle and often impact similar issues.
6. **Fragmented research/governance arrangements in the UK water sector and absence of a more holistic approach can impede translation and implementation of research deliverables.** To date, the research and end-user

⁷⁷ Arnell et al., 2014.

communities for flooding and coastal erosion and for droughts and water scarcity have largely operated independently.

7. **Anecdotal evidence suggests coordination and execution of research are often problematic**, despite greater stakeholder involvement and agreement in preparing long-term strategies. More detailed and well-resourced delivery plans for arrangements that are genuinely co-funded, co-designed and co-delivered would help orchestrate a portfolio of programmes to meet strategic goals.
8. **The impact of extreme events on property, infrastructure and people's welfare are well reported in the media, but impacts on our environment and economy reach far wider than that.** An ecosystems approach provides a framework for looking at whole ecosystems and valuing the services they provide, ensuring a healthy, resilient environment now and for future generations.
9. **Different sectors of the UK economy rely on the natural environment to sustain their business and provide opportunities for jobs and growth.** Adopting a more holistic approach would open up a number of ecosystem-related markets, although to date there is little evidence of cross-sector integration.
10. **A growing number of corporations are seeking to understand how resource constraints and natural capital depletion will impact them.** There is a key need for better sector-level understanding of business risks and opportunities associated with more frequent extremes of climate.

Five Key Recommendations:

1. **The UK Water Partnership should consider the potential for wider research exploitation and global trade, promoting the benefits of UK expertise in floods and droughts.** UK research on floods, droughts and ecosystem services is recognised worldwide. There are many good examples of outputs implemented in policy, of UK consultancies exploiting this knowledge base and of market-related products. This expertise has potential for wide transfer to enhance the UK's share of the global water market. *UK Water Partnership led action.*
2. **The UK's research, innovation and exploitation capacity needs to become 'joined up'.** The fractured nature of the UK's water sector hampers exploitation of the significant market potential worldwide. The UK Water Partnership should facilitate discussions with research funders and business sectors on partnership arrangements and better alignment of basic and applied research with longer-term commercial opportunities. *UK Water Partnership led action.*
3. **Led by RCUK, research funders should consider the case for cross-Council multidisciplinary research and innovation, including capacity building,** towards a more holistic understanding of (i) threats posed to natural capital and ecosystem services by more frequent extreme weather events and (ii) the need for resilience to meet future water demands and deliver health and wellbeing benefits. *UK Research Councils led action.*

4. **Led by Defra, Government departments should provide a steer to research funders and environmental regulatory agencies on the need for more holistic thinking in the water domain**, with institutional, cultural and policy barriers considered in order to provide practical guidance on how to embed an ecosystems approach. *UK Government led action.*

5. **The UK Water Partnership should facilitate discussions with business sector representatives to promote development of sector-based plans** for water security and risk management associated with extreme climate-driven events, population growth and associated demographics, including an evaluation of sector interdependencies and investment opportunities. *UK Water Partnership led action.*

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European Drought Centre: www.geo.uio.no/edc

European Drought Observatory: <https://ec.europa.eu/jrc/en/research-topic/desertification-and-drought>

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LWEC Ecosystem Task Force: <http://www.lwec.org.uk/our-work/ecosystems>

Met Office: <http://www.metoffice.gov.uk/education>

Natural Capital Accounting: www.naturalcapitalcoalition.org

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This report would not have been possible without the contributions of many experts and the participation of the following members of the Action Group:

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